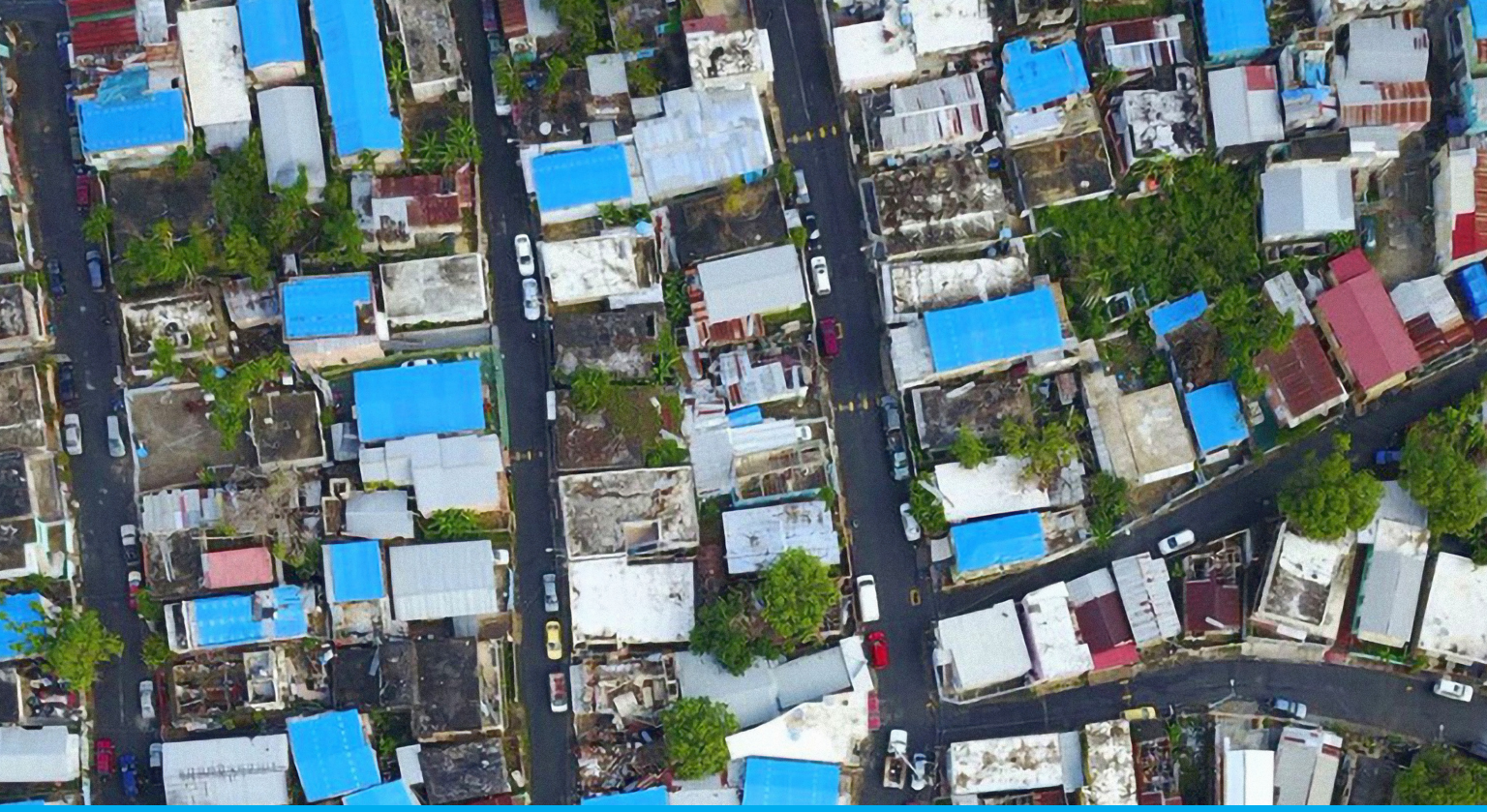


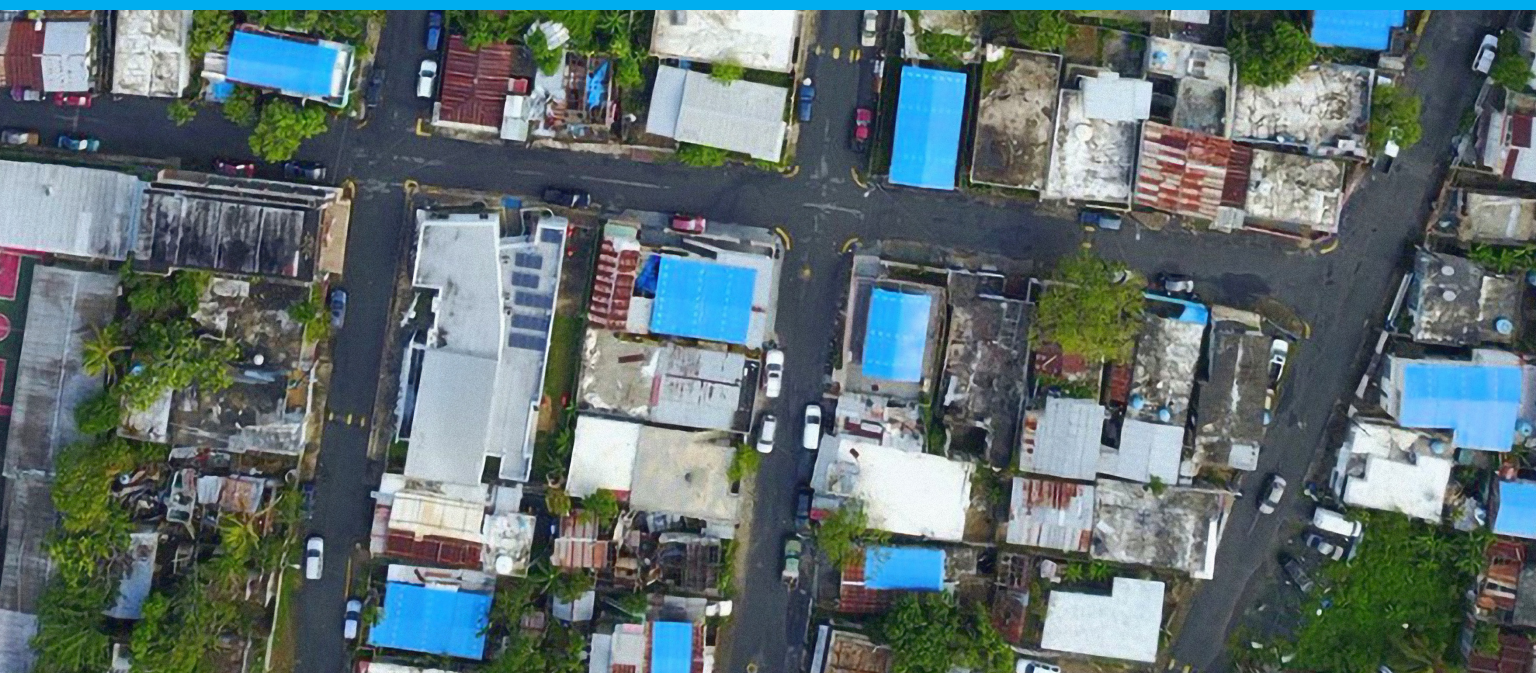
KEEP SAFE

A GUIDE FOR RESILIENT HOUSING DESIGN IN ISLAND COMMUNITIES

Enterprise®

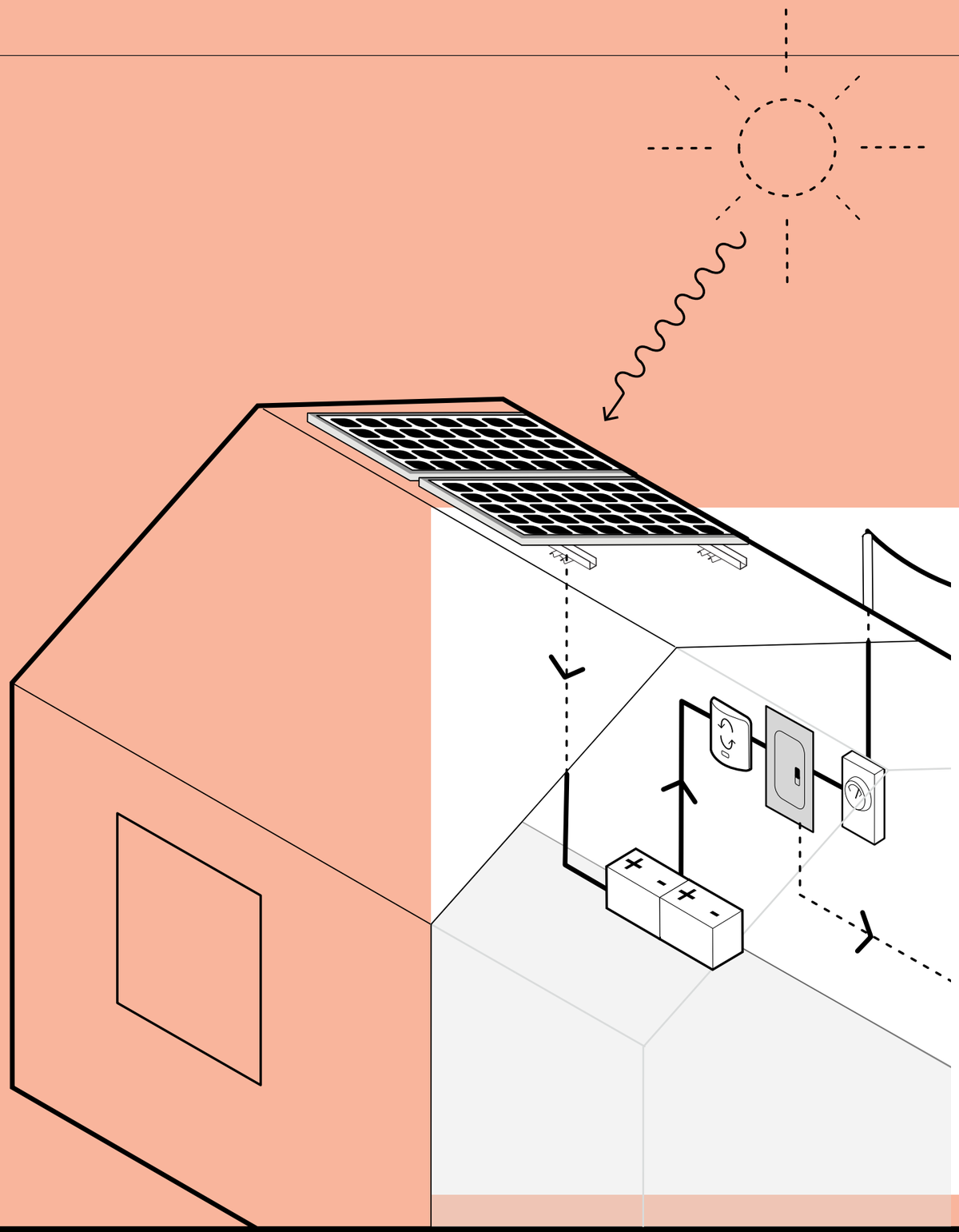
UNIVERSIDAD DE PUERTO RICO 1903

ASOCIACIÓN DE CONSTRUCTORES DE PUERTO RICO



CHAPTER

4



ENERGY GENERATION + BACKUP

Strategies that provide critical needs for power when a facility loses power or other services

TYPES OF STRATEGIES LISTED IN THIS SECTION

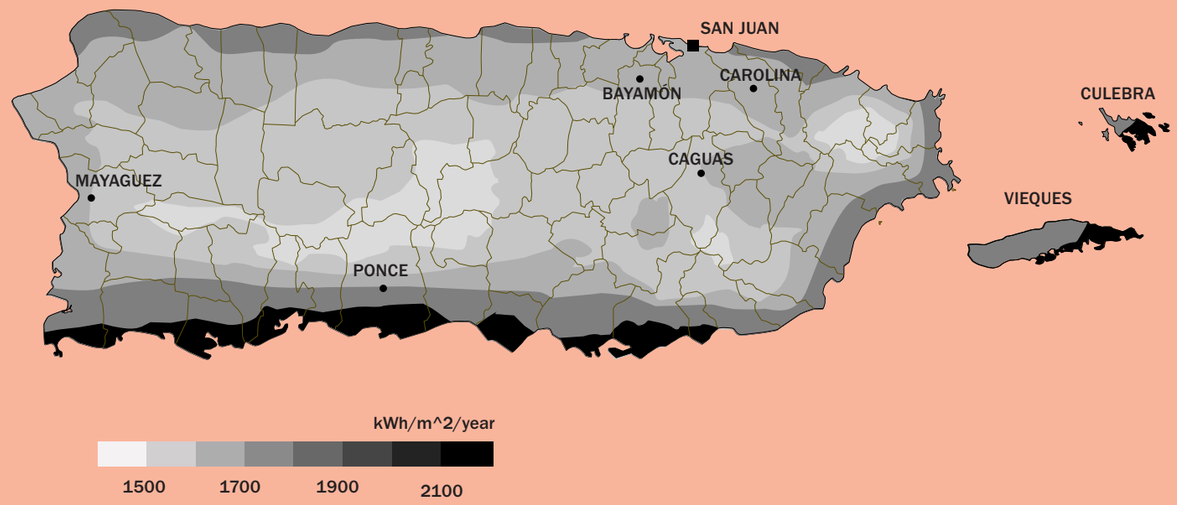
STRATEGY #	15	16	17	18
STRATEGY NAME/TITLE	REDUCE YOUR ENERGY USE	INTEGRATE SOLAR ELECTRICITY	INTEGRATE SOLAR THERMAL ENERGY	INSTALL ENERGY BACKUP
DESCRIPTION	The first step to reduce energy consumption is to know how much we are consuming, and think through which uses are critical. Installing energy-efficient fixtures and complementing your electric systems with passive strategies will further help reducing your energy consumption while making sure to supply your most important needs during an emergency.	This strategy focuses on explaining the basics of how to evaluate a home's potential for solar energy use as well as, and the basics of how to harness its possibilities.	Solar thermal systems use the heat from the sun to heat water as opposed to solar photovoltaic (PV) which uses solar energy to energize a home. This system allows it to depend less on electric water heating and reduce costs. This strategy focuses on explaining how the system works, how to purchase it, and how to install it.	Backup energy systems offer homes the ability to power essential equipment when the electrical grid is not available. This strategy focuses on explaining how to choose a generator and how to install it.
	$-$$	$-$$$	$-$$$$	$$-$$$

The majority of electrical power in Puerto Rico is produced, transmitted, distributed, and sold by a single source: the Puerto Rico Electric Power Authority (PREPA)/Autoridad de Energía Eléctrica Puerto Rico (AEEPR, by its Spanish acronym). When PREPA's power plants (largely fueled by natural gas and imported oil) and power lines were completely disabled by Hurricane Maria, millions of people suddenly went without the conveniences of modern life (electricity, refrigeration, and Internet service). Water distribution became impossible when pumps lost power. The situation became life-threatening for people whose medical care depended on electrical devices. Seniors and others who needed air-conditioned spaces suffered from heat-related illnesses. Best estimates indicate that the death toll in Puerto Rico grew by a factor of approximately 1700% in the three months following Maria's landfall, partly because of the lack of electricity, potable water, and limited access to medical facilities and healthcare.

For years, it has been common knowledge that both equipment and purchasing sources of electricity need to be diversified. Hurricane Maria accelerated the development of new options for homes and communities that are both greener (not dependent on fossil fuels) and more resilient. A growing, alternative energy industry is making renewable technology, such as solar panels and solar thermal systems, available to more people, and is working towards localizing distribution through micro-grids. While emergency generators remain a good support for short-term power loss, new energy systems can provide long-term value.

Along with these technological solutions, the way to scale down dependence on electrical suppliers is to reduce daily energy consumption patterns in your home. This chapter explains how to live using less power, how to evaluate alternative energy systems for year-round use, and how to manage a backup system to get through an emergency.

HORIZONTAL SOLAR IRRADIATION IN PUERTO RICO



STRATEGY

15 REDUCE YOUR ENERGY USE

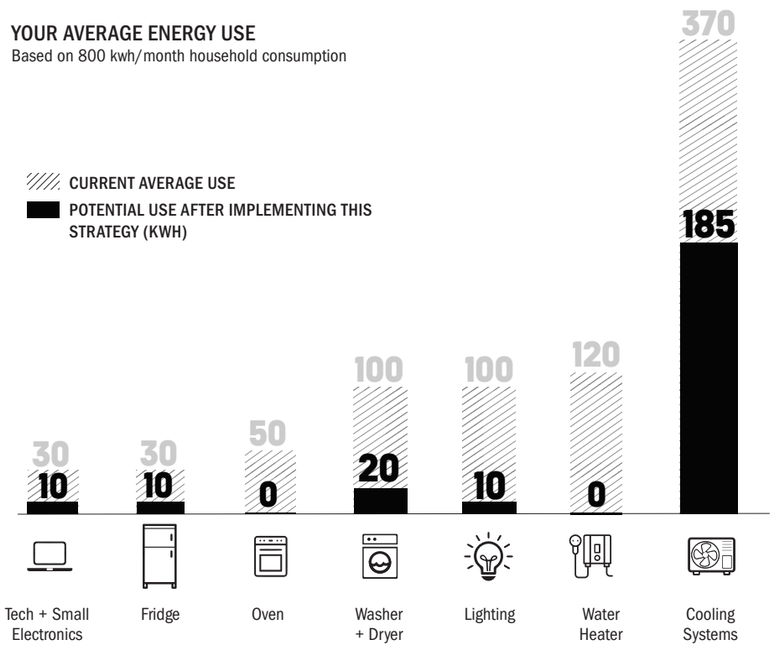
$-$$

Many homes depend on generators on a frequent basis. Energy efficiency is of critical importance if you need backup power, if limited grid power exists, or if you decide to have the home solar energy powered. In addition to surviving power loss, reducing energy consumption will also save households money. This strategy focuses on identifying easy ways to conserve and use energy efficiently to save on home energy bills and reduce the cost of any renewables, battery, or generators.

WHAT YOU NEED TO KNOW

- A typical home in Puerto Rico consumes between 500 and 1,000 kWh per month.
- This strategy will allow you to reduce your energy consumption by more than 70%.
- Once your energy consumption is lowered, the next step is estimating total home energy use as well as critical power energy use. This information is important for determining energy budgets and making decisions regarding renewable energy systems, batteries, or generators.

YOUR AVERAGE ENERGY USE
Based on 800 kwh/month household consumption



STEP 1 - IDENTIFY YOUR ELECTRIC ENERGY CONSUMPTION

Use your electric energy bill to understand your monthly consumption. Plug the result in the equation below to know your yearly consumption.

UNITS	POWER (W)	KILOWATT-HOUR (KWH)	VOLTAGE (V)
DESCRIPTION	The amount of energy used over a period of time. It is measured in watts.	A unit that equals 1000 watts in one hour. The AEE charges you per kWh.	Voltage is the pressure from an electrical circuit's power source that pushes charged electrons (current) through a conducting loop or circuit, enabling them to do work such as illuminating a light. In brief, voltage = pressure, and it is measured in volts (V).

SUPPORTING STRATEGIES

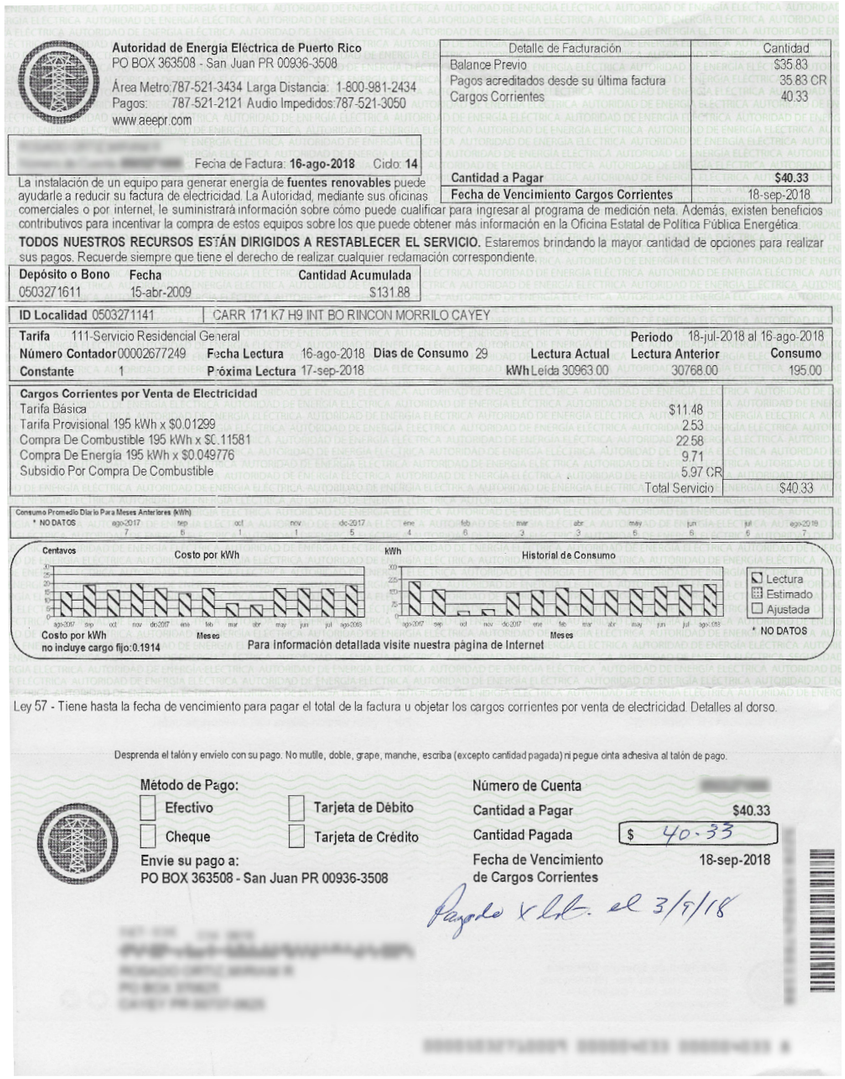
10	11	12
Reduce Heat Transfer	Increase Ventilation	Benefit from Natural Light

STRATEGY 15

REDUCE YOUR ENERGY USE

STEP 1 - IDENTIFY YOUR ELECTRIC ENERGY CONSUMPTION

PAPER BILL



Autoridad de Energía Eléctrica de Puerto Rico
PO BOX 363508 - San Juan PR 00936-3508
Área Metro:787-521-3434 Larga Distancia: 1-800-981-2434
Pagos: 787-521-2121 Audio Impedidos:787-521-3050
www.aeepr.com

[redacted] Fecha de Factura: **16-ago-2018** Ciclo: **14**

Detalle de Facturación	Cantidad
Balance Previo	$35.83
Pagos acreditados desde su última factura	35.83 CR
Cargos Corrientes	40.33
Cantidad a Pagar	**$40.33**
Fecha de Vencimiento Cargos Corrientes	18-sep-2018

La instalación de un equipo para generar energía de **fuentes renovables** puede ayudarle a reducir su factura de electricidad. La Autoridad, mediante sus oficinas comerciales o por internet, le suministrará información sobre cómo puede cualificar para ingresar al programa de medición neta. Además, existen beneficios contributivos para incentivar la compra de estos equipos sobre los que puede obtener más información en la Oficina Estatal de Política Pública Energética.

TODOS NUESTROS RECURSOS ESTÁN DIRIGIDOS A RESTABLECER EL SERVICIO. Estaremos brindando la mayor cantidad de opciones para realizar sus pagos. Recuerde siempre que tiene el derecho de realizar cualquier reclamación correspondiente.

Depósito o Bono	Fecha	Cantidad Acumulada
0503271611	15-abr-2009	$131.88

ID Localidad 0503271141 CARR 171 K7 H9 INT BO RINCON MORRILO CAYEY

Tarifa 111-Servicio Residencial General
Número Contador 00002677249 **Fecha Lectura** 16-ago-2018 **Días de Consumo** 29 **Lectura Actual** kWh Leída 30963.00 **Periodo** 18-jul-2018 al 16-ago-2018
Constante 1 **Próxima Lectura** 17-sep-2018 **Lectura Anterior** 30768.00 **Consumo** 195.00

Cargos Corrientes por Venta de Electricidad

Tarifa Básica	$11.48
Tarifa Provisional 195 kWh x $0.01299	2.53
Compra De Combustible 195 kWh x $0.11581	22.58
Compra De Energía 195 kWh x $0.049776	9.71
Subsidio Por Compra De Combustible	5.97 CR
Total Servicio	$40.33

Consumo Promedio Diario Para Meses Anteriores (kWh)
* NO DATOS ago-2017 7 sep 6 oct 1 nov 1 dic-2017 5 ene 4 feb 6 mar 3 abr 3 may 5 jun 6 jul 6 ago-2018 7

Centavos — Costo por kWh — Meses
kWh — Historial de Consumo — Meses
Lectura / Estimado / Ajustada
* NO DATOS

Costo por kWh no incluye cargo fijo:0.1914

Para información detallada visite nuestra página de Internet

Ley 57 - Tiene hasta la fecha de vencimiento para pagar el total de la factura u objetar los cargos corrientes por venta de electricidad. Detalles al dorso.

Desprenda el talón y envíelo con su pago. No mutile, doble, grape, manche, escriba (excepto cantidad pagada) ni pegue cinta adhesiva al talón de pago.

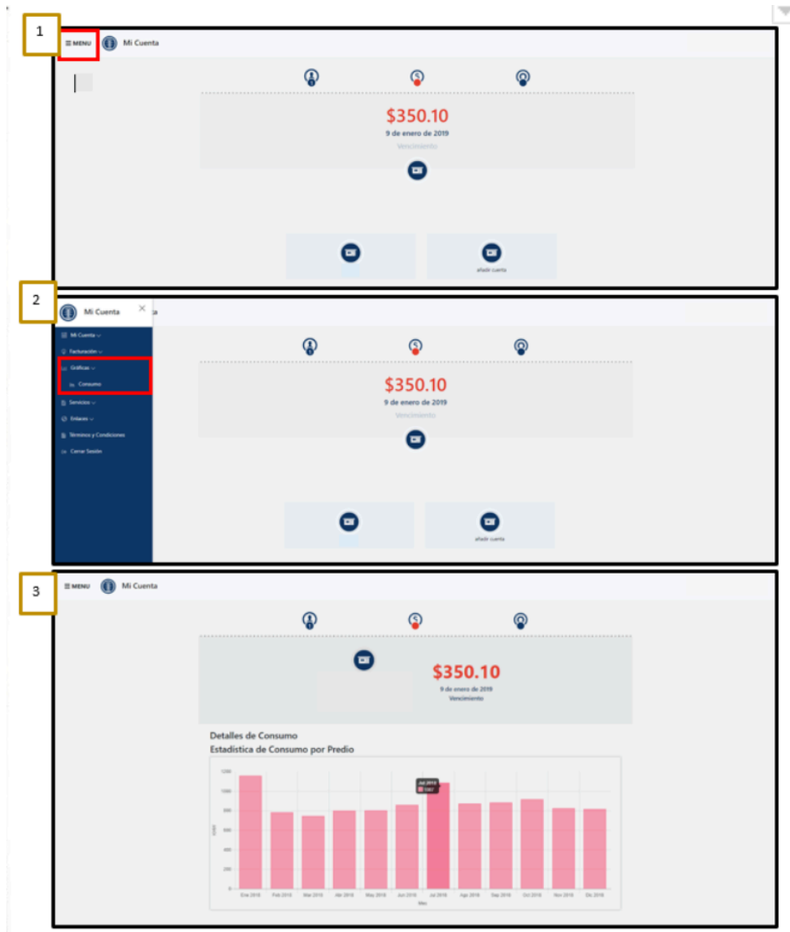
Método de Pago:
☐ Efectivo ☐ Tarjeta de Débito
☐ Cheque ☐ Tarjeta de Crédito

Envíe su pago a:
PO BOX 363508 - San Juan PR 00936-3508

Número de Cuenta [redacted]
Cantidad a Pagar $40.33
Cantidad Pagada $ 40.33
Fecha de Vencimiento de Cargos Corrientes 18-sep-2018

Pagado x Int. el 3/9/18

E-BILL



UNITS	POWER (W)	KILOWATT-HOUR (KWH)	VOLTAGE (V)
DESCRIPTION	The amount of energy used over a period of time. It is measured in watts.	A unit that equals 1000 watts in one hour. The AEE charges you per kWh.	The amount of energy stored and available for use. Most appliances use 110/120V lines, but others need 220V. These typically have a double breaker (fusibles guaretos).

STRATEGY 15

REDUCE YOUR ENERGY USE

STEP 2 - INSTALL ENERGY EFFICIENT EQUIPMENT AND FIXTURES

- Replace old standard fixtures and appliances for more efficient new models.
- Use products that have an Energy Star label. These use up to 70-90% less energy than the regular models, while producing up to 70% less heat, which indirectly reduces the cooling system energy consumption. For more information, visit https://www.energystar.gov/.
- Properly install fixtures and appliances to avoid short circuits. When necessary, hire a professional.

LIGHTING

- Choose task-specific lighting to reduce lighting excess.
- Energy Star certified LED bulbs are the most cost-effective. They use 10% of the energy regular bulbs use, and last 25 times longer.
- In a multi-family building, consider automatic lighting controls, like occupancy sensors, to significantly reduce energy use.

WATER HEATER

- Insulate hot water pipes and storage tanks to lower heat loss and use 10-20% less energy in heating.
- Tankless and/or solar water heaters use 10% of the energy electric water heaters use.
- Design new plumbing layout to minimize water loss through hot water delivery.
- Consider a solar water heater and refer to Strategy 17 for more information on solar thermal systems.

COOLING SYSTEM – FAN

- Ceiling fans help cool a space.
- Use counter-clockwise spin during the summer to drive the warm air upwards, and counter-clockwise spin during the winter to drive the warm air downwards.
- Size equipment in accordance with the Air Conditioning Contractors of America Manuals J, S, or ASHRAE.

COOLING SYSTEM – AC

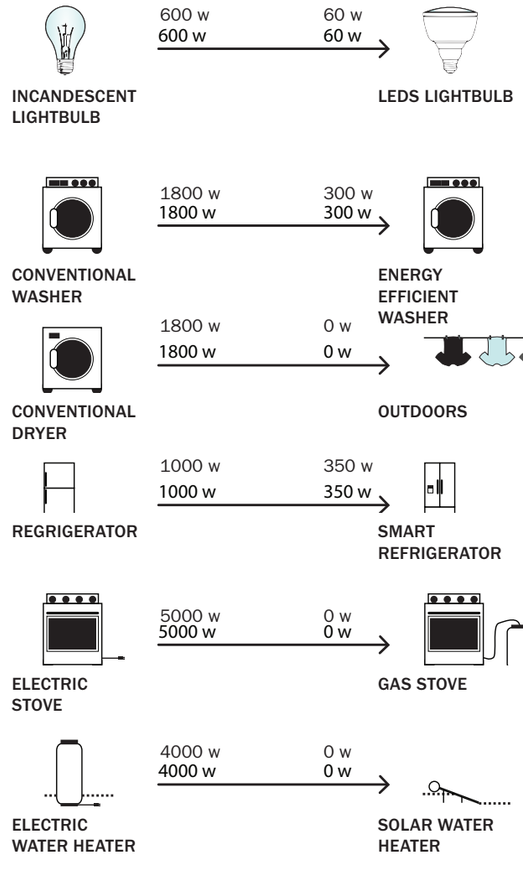
- Locate AC within the building envelope to reduce thermal loss.
- Replace AC filters once a month.
- Replace system with an energy efficient one.

DETERMINE YOUR POTENTIAL ANNUAL ENERGY CONSUMPTION

- Identify which fixtures you can exchange and your current fixtures, and determine their wattage.
- Estimate the number of hours used daily. Some items, like the refrigerator, are used 24 hours a day.

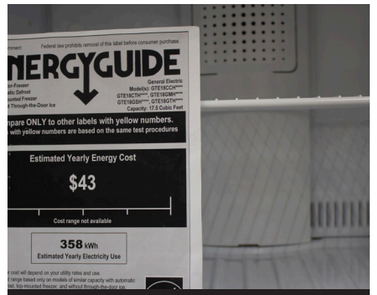
  _____ (w) x _____/ hours per day 1000 = _____ kw per hour for 1 appliance

- _____ (kwh for 1 appliance) x _____ days used in a month = _____ kw consumed per month
- Add the results from the above formulas to calculate your monthly energy consumption.
- Calculate your annual energy consumption.
  _____ (kw per month) x 12 = _____ Potential Annual energy consumption



ENERGY EFFICIENT LIGHTBULBS


ENERGY EFFICIENT WASHER



ENERGY EFFICIENT REFRIGERATOR


GAS STOVE

STRATEGY

15 REDUCE YOUR ENERGY USE

REMEMBER

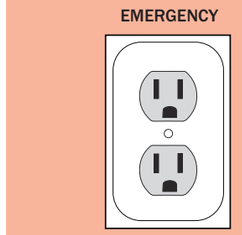
Take advantage of sunlight hours to complete tasks that will need a light during the night.

STEP 3 - ESTABLISH CRITICAL LOADS

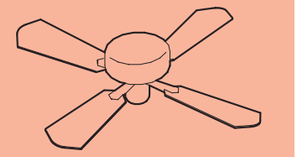
- Critical load refers to the collective load of home equipment that should remain on consistently in order to safely inhabit the space (e.g., refrigerators and medical devices.)
- Produce at least the critical load needed to withstand an emergency.
- Use Chart 2 to determine the critical load that you need to produce using an alternative energy system.

CRITICAL LOADS SINGLE FAMILY

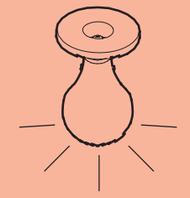
CRITICAL LOADS MULTI FAMILY



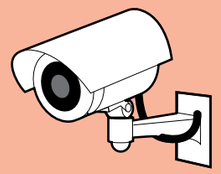
EMERGENCY OUTLETS



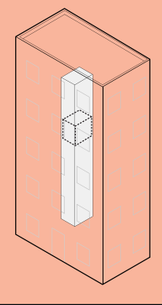
COOLING (FANS)



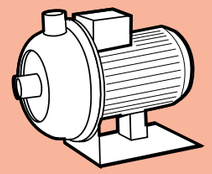
ESSENTIAL LIGHTING



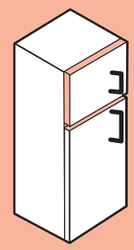
SECURITY SYSTEMS



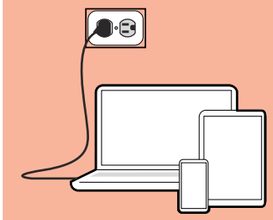
ELEVATOR



WATER PUMPS



REFRIGERATION FOR MEDICAL SUPPLIES



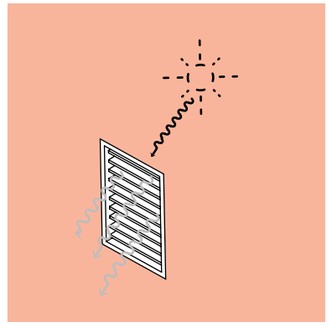
TECH HUB

STRATEGY

15 REDUCE YOUR ENERGY USE

STEP 4 - IMPLEMENT PASSIVE STRATEGIES THAT DON'T NEED ELECTRICITY

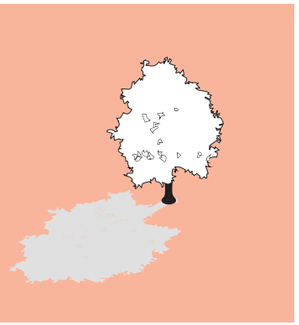
Design and operation choices can help reduce energy use. See Strategies on Passive Habitability for more information.



CREATING MORE DAYLIGHT

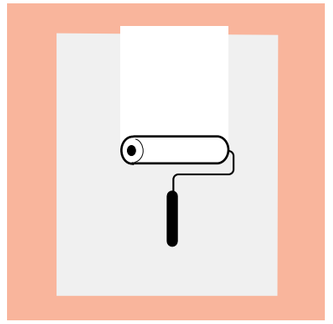
SEE STRATEGY: 12 - Benefit from Natural Light

IMAGE



NAME: PLANTING VEGETATION

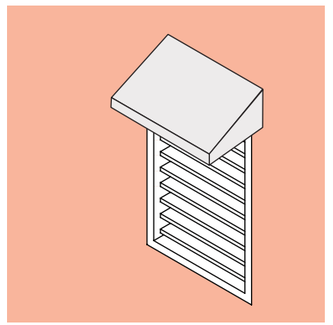
SEE STRATEGY: 02 | Reinforce Site with Vegetation



USING LIGHT INTERIOR COLORS

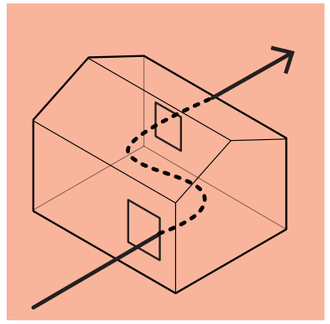
SEE STRATEGY: 10 - Reduce Heat Transfer

IMAGE



NAME: SHADE

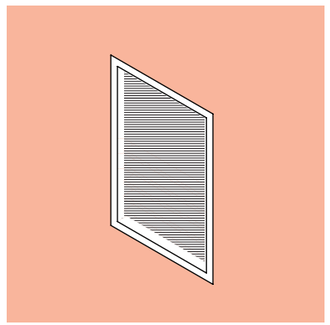
SEE STRATEGY: Strategy 10: Reduce Thermal Height Gain



USING NATURAL VENTILATION

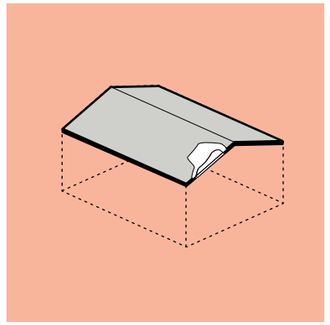
SEE STRATEGY: 11 - Increase Ventilation

IMAGE



NAME: WINDOW FILMS

SEE STRATEGY: Strategy 10: Reduce Thermal Heat Gain

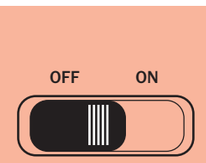


ROOF

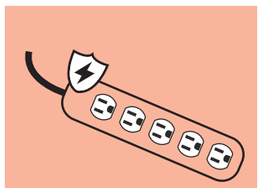
10 | Reduce Heat Transfer

STEP 5 - CONSERVE ENERGY

Look for the Energy Star label on new devices. Products tagged with this logo use half the energy of standard models.



Turn off electronic equipment when not in use.



Invest in advanced power strips. These will prevent electronics from drawing excessive energy and protect them from surge damages.

Unplug devices when fully charged or not in use. Just by being plugged-in, these become "vampire charges," adding up to 10% of your home energy use! Leaving devices unplugged will reduce energy use and prolong the device's battery life.

OPERATIONS AND MAINTENANCE TIPS

- Clean or replace air-conditioning (AC) unit filters once a month.
- If your cooling system has been in use for more than 15 years, replace it with an energy efficient system.

STRATEGY

16 INTEGRATE SOLAR ELECTRICITY

$-$$$

Successful installations of photovoltaic (PV) panels across Puerto Rico are increasing. PV panels provide some portion, if not all, of a home's energy needs, while making it less dependent on the system. This strategy focuses on explaining the basics of how to evaluate a home's potential for solar energy use as well as the basics of how to harness its possibilities.

WHAT YOU NEED TO KNOW

- A photovoltaic module (PV), also known as a "solar panel," is a technology that converts sunlight into electrical energy. There are three different PV modules available, which vary in material composition, internal structure as well as cost. Photovoltaic modules vary in size mainly due to the number of solar cells connected in series. Generally, 60-cell and 72-cell modules are commonly found in residential and larger commercial installations.
- Monocrystalline: these are cells made out of silicon that are formed into bars and cut into wafers. Typically, they are of a dark black hue color with even texture (high efficiency, leads PV market).
- Polycrystalline: cells that are made out of silicone fragments and are melted together to form the wafers. They are slightly less efficient but can be cost effective. This is the recommended and most common type in Puerto Rico.
- Thin layer or thin film: cells made out of a translucent material that maximizes light and visibility but is not as efficient. It is also more expensive.
- PV arrays are composed of multiple modules made up of two layers of semiconductor material with opposite charges. When sunlight hits their surface, it knocks electrons loose, makes them move through the layers, and creates a current (see below).
- PV arrays are connected in series referred to as "strings."
- For autonomous systems, some PV systems inverters include charge controllers which redirects power from the PV or power authority to charge the batteries.

SUPPORTING STRATEGIES

10 Reduce Thermal Heat Transfer

11 Increase Ventilation

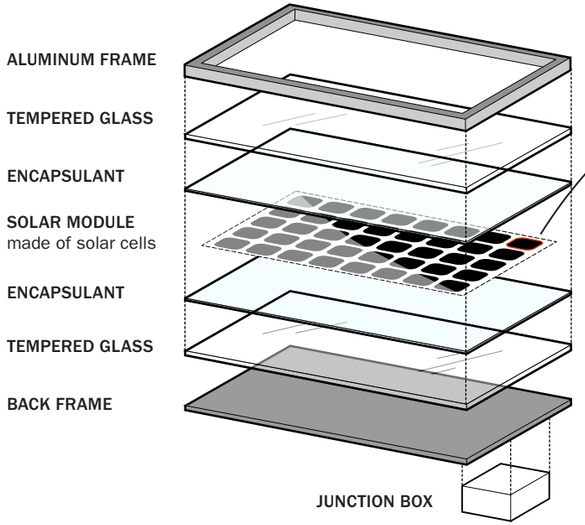
12 Benefit from Natural Light

15 Reduce Your Energy Use

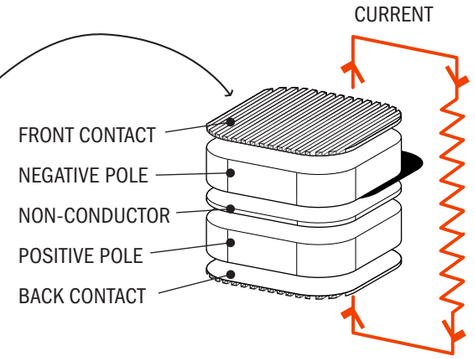
18 Install Energy Backup

- An inverter is a device that takes stored energy and converts it from direct current (DC) to alternating current (AC), which is the type of frequency used by most fixtures and appliances.
- Arrays can be connected to a battery pack to store energy if the grid is not available.
- If switching completely to solar energy is not an option, at least use solar modules as backup power by installing a small array only to power critical loads.
- A grid-tie inverter converts direct current (DC) from PV modules to alternating current (AC) and voltage levels compatible to the utility grid (synchronized to 60 hertz).
- A stand-alone inverter converts stored energy in batteries, electrically transforming direct current (DC) to alternating current (AC).
- Power conditioning units are intelligent units that monitor charge, usage, and supplement difference with stored energy while simultaneously charging from the grid. These can be used in interconnected and bimodal systems.

PHOTOVOLTAIC PANEL



SOLAR CELL



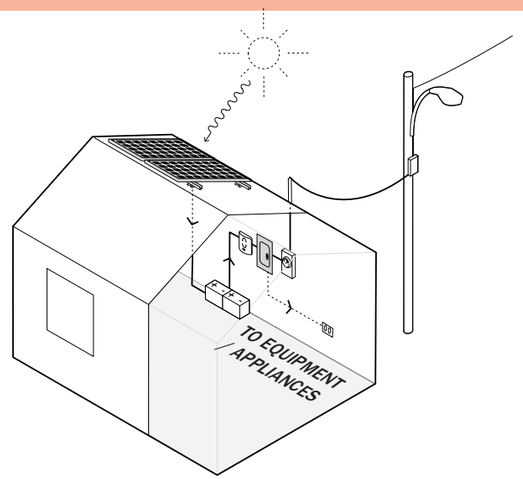
Solar cells are composed of two layers of semi-conductor material with opposite charges. Sunlight hitting the surface of a cell knocks electrons loose, which then travel through a circuit from one layer to the other, providing a flow of electricity.

STRATEGY 16

INTEGRATE SOLAR ELECTRICITY

STEP 1 - IDENTIFY POWER NEEDS

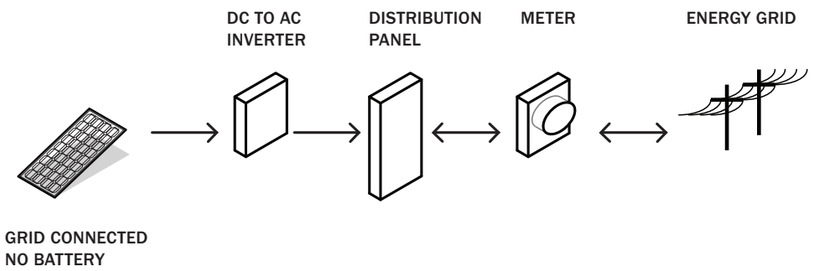
- Refer to Strategy 15 to determine your home's power needs and calculate how many panels are necessary.
- What percentage of power do you want to draw from solar PV?
- By how much do you want to reduce your electricity bill?
- How much do you need backup electricity?
- Are there many power outages because of grid failure?
- What is your budget for the PV system?



STEP 2 - IDENTIFY THE APPROPRIATE PV SYSTEM CONFIGURATION

- Panels are typically 3' x 5' in size and each one produces about a maximum of 250 watts. There are 3.5' x 7.5' panels that go up to 370 watts, but these are heavier and more difficult to install, maintain, and replace.
- A typical residential array produces about 3.5-5 kWh of direct current (DC) electricity. Critical loads require around 50% of that energy.
- Ensure the system complies with both local and national electrical codes and regulations (National Electric Code or NEC).
- Verify neighborhood regulations to comply with aesthetics.
- Note: The homeowner should be aware of the configuration, but a professional should install the system.

GRID CONNECTED NET METERING



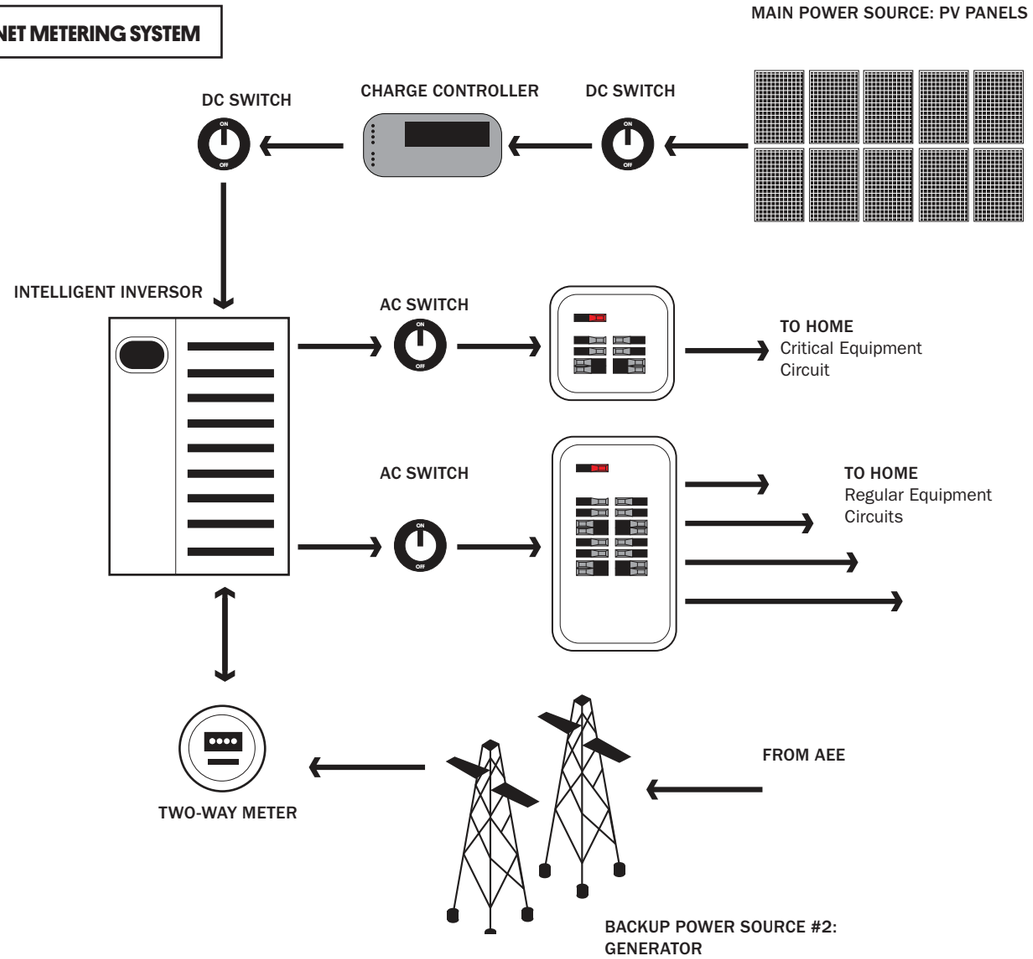
GRID CONNECTED-NET METERING

- Provides energy to running appliances (the house load). The energy contribution percentage depends on size of array and solar radiation available.
- Surplus energy generated beyond the load consumption is sent back to the power authority (PA) which is referred to as "net metering."
- Excess energy sent back to the grid is credited at a discounted service rate.
- Provides some stability to the grid.
- Reduces dependence on the PA.

✓
- Reduces dependence on PA
- Provides PA with renewable energy

✗
- If the PA fails, the user receives no energy, unless the fixture and appliances can work off direct current (DC) energy.
- Higher installation costs and longer return on investment.
- Complexity of automated or manual switch transfer during power outage.

NET METERING SYSTEM



STRATEGY 16

INTEGRATE SOLAR ELECTRICITY

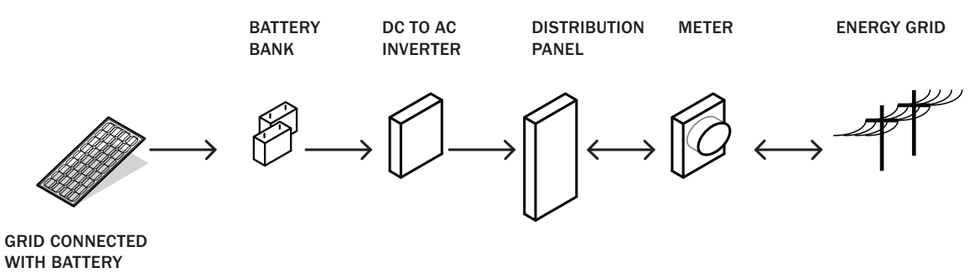
STEP 2 - IDENTIFY THE APPROPRIATE PV SYSTEM CONFIGURATION

GRID CONNECTED / HYBRID SYSTEM WITH BATTERY

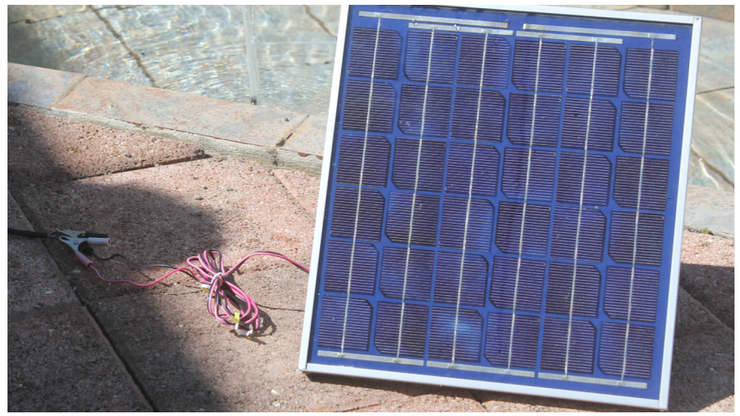
- ► Recommended system.
- ► Can provide backup during grid outages.
- ► Surplus energy produced by the PV panels is stored in a battery bank and excess power is sent back to the PA.
- ► When excess energy is produced, the user can sell or “net meter” energy to the PA at a discounted rate.
- ► Provides backup power to critical equipment until storage is depleted.

✔
- Reduces dependence on PA.
- Battery provides uninterrupted reliability if the grid fails.

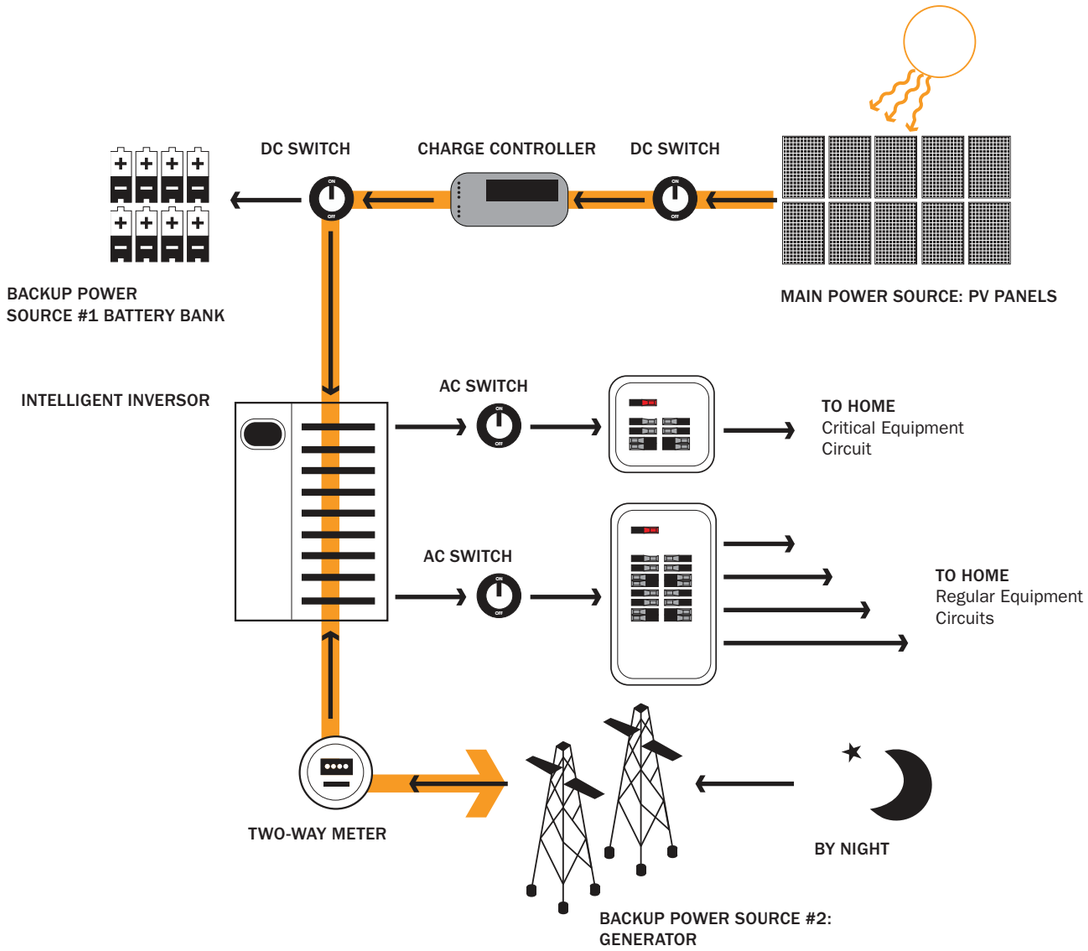
✖
- Higher installation costs and longer return on investment.
- Flooded type batteries require maintenance.



GRID CONNECTED WITH BATTERY



HYBRID/INTERCONNECTED SYSTEM



STRATEGY

16 INTEGRATE SOLAR ELECTRICITY

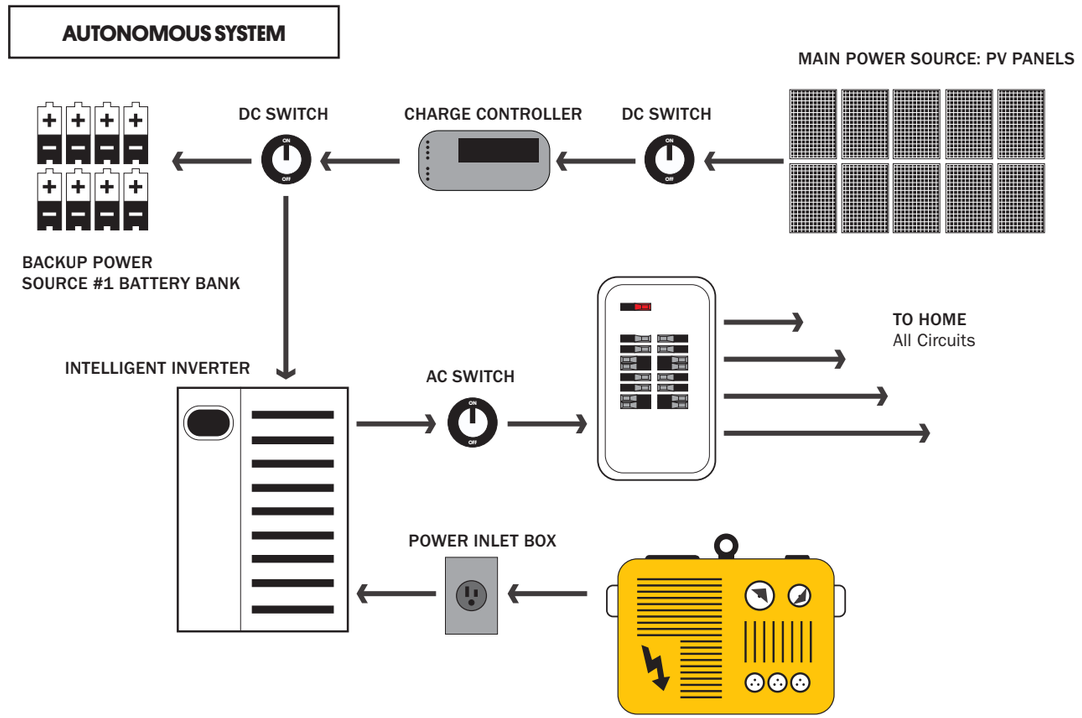
STEP 2 - IDENTIFY THE APPROPRIATE PV SYSTEM CONFIGURATION

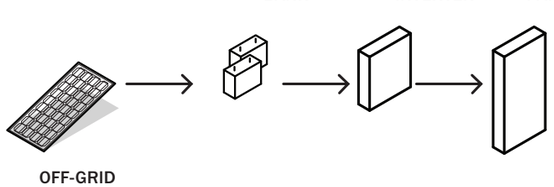
OFF GRID / AUTONOMOUS SYSTEM

- Completely disconnected from grid.
- Home relies on PV and on-site battery backup for all power needs.
- Recommended at remote locations or regions that are far away from existing public infrastructure.
- Complete independence from central grid.
- Safely runs appliances without damaging voltage spikes.
- For autonomous systems, some PV systems' inverters include charge controllers which redirect power from the PV or PA to charge the batteries. Charge controllers are needed for charging

✔
- Not affected by price and power fluctuations.

✖
- If battery depth of discharge or capacity is exceeded, the system will shut down and there will be no power during the night.





OFF-GRID

Laurie Schoeman Ecocenter at Herons Head Park

FERNANDO ABRUNA

SCALE YOUR SYSTEM TO FIT YOUR NEEDS!

Installing solar panels can seem daunting and unattainable if you think of covering 100% of your electrical needs right from the start. Consider using solar panels with battery as backup power! Begin with a smaller array and battery backup exclusively to power up critical equipment or as backup during power interruptions. This will give your home a head start toward resilience. Plan this system to accommodate future home expansion.

Generally, smaller, autonomous 120VAC inverters, say 400W to 2000W (12V to 48V battery), need about triple the rated wattage to start-up a reactive/inductive electrical equipment (a compressor, electric chainsaw, motors in general, etc.). So, you won't be able to start a 380-watt small refrigerator with a 400-watt inverter. Consequently, the inverter will shut down, trip, or won't even start before damaging the equipment, although it is entirely possible that damage could happen. Consult the manufacturer listing of appliances the inverter can run on a specific wattage. On larger inverters (240VAC) for autonomous systems, there is a peripheral called an autoformer. This "transformer," usually a separate box attached to the main inverter, can play various roles. One of them is to be able to deal with the above mentioned inductive reactance startup. Another could be to balance the load across a 240VAC home electrical system.

STRATEGY

16 INTEGRATE SOLAR ELECTRICITY

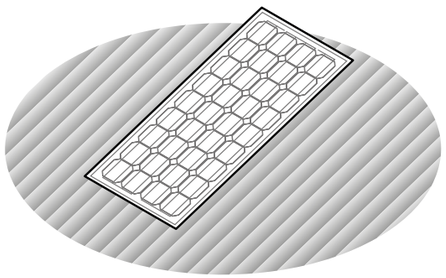
STEP 3 - INSTALL THE SYSTEM

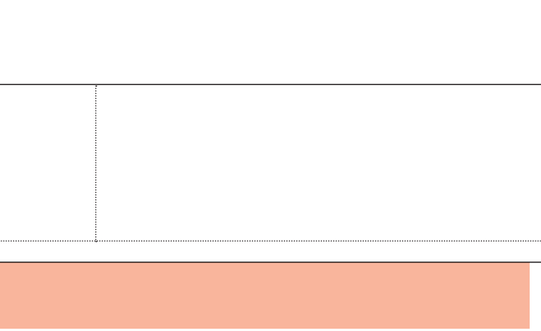
- Identify approved vendors and certified equipment for PV system at: http://www.prgef.com/resources and forms.
- Each PV panel weighs about 3-40 pounds. Anchor a panel properly so it does not blow away during strong winds. For more information, see FEMA's guide titled Rooftop Solar Panel Attachment: Design, Installation, and Maintenance.
- A PV system can last up to 30 years without replacement.
- Hire a professional to ensure installation complies with both local and national electrical codes and regulations.
- Do not connect the system to electric circuits by yourself. Hire an electric technician/engineer.
- A transfer switch should be installed. Refer to Strategy 18 for additional information.

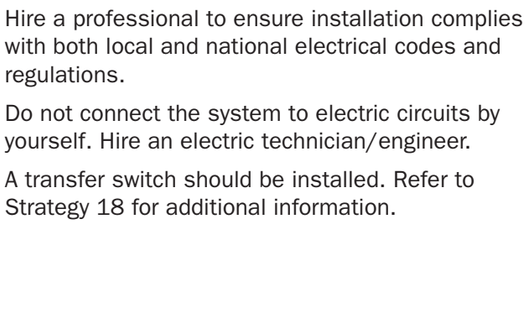
A. LOCATION: ROOF

- Can be installed in any roof, regardless of material or inclination.
- Can be installed in innovative ways, such as over carports or awnings.
- May reduce shading from trees or neighbors' buildings.

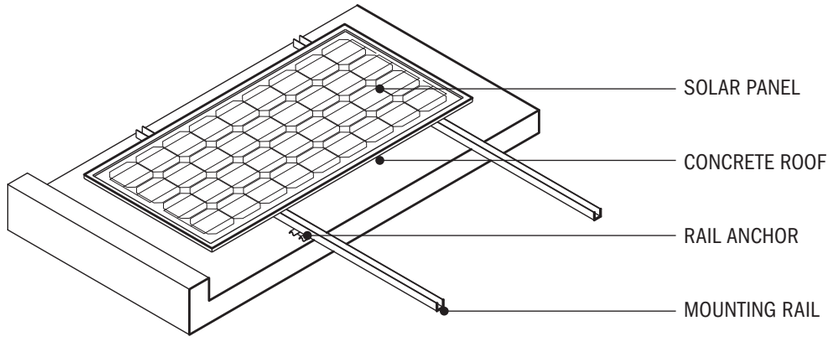
ROOFTOP MOUNTING







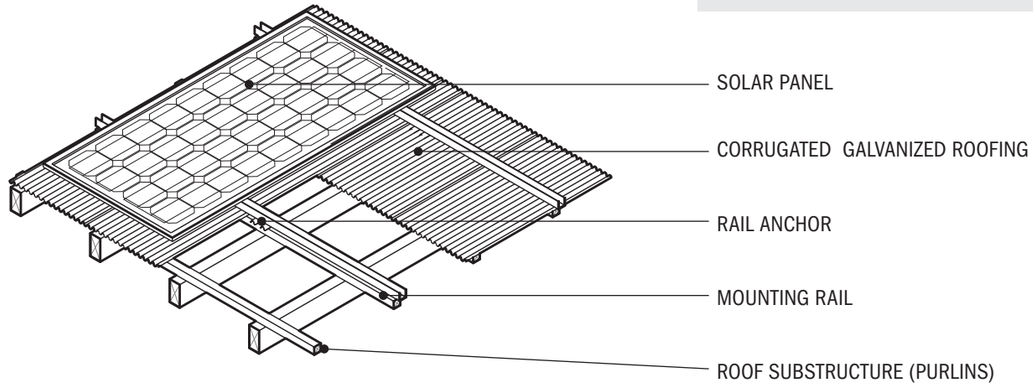
ROOF ANCHORAGE FOR CONCRETE ROOFS



- CAN BE INSTALLED IN ANY ROOF, REGARDLESS OF MATERIAL OR INCLINATION.
- CAN BE INSTALLED IN INNOVATIVE WAYS, SUCH AS OVER CARPORTS OR AWNINGS.
- MAY REDUCE SHADING FROM TREES OR NEIGHBORS BUILDINGS.

ROOF ANCHORAGE FOR WOODEN ROOFS

- EXPOSED TO UPLIFTING CAUSED BY STRONG WINDS. ANCHOR PROPERLY.



Mounting rails and anchors are to be installed following the supplier's specifications for warranty.

STRATEGY 16

INTEGRATE SOLAR ELECTRICITY

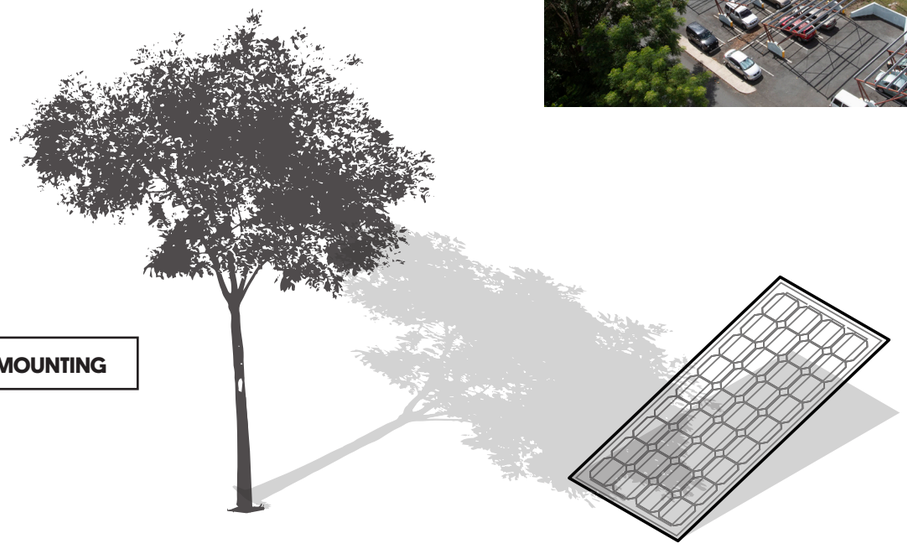
STEP 3 - INSTALL THE SYSTEM

A. LOCATION: GROUND

Ground mounting is the cheapest and easiest option for installation. As with the rooftop, it provides good airflow in the back. However, horizontal space and shading may be an issue. These are highly susceptible to theft.

- CHEAPEST OPTION
- NO NEED TO FORTIFY ROOF OR NO POTENTIAL DAMAGE TO ROOF MEMBRANE.
- CAN DISASSEMBLE BEFORE HIGH WINDS.
- CONVENIENT FOR HOMES THAT SIT ON A BIG LAND PLOT.

- TAKES UP A LOT OF SPACE IN SMALL LOTS.
- SUSCEPTIBLE TO THEFT.
- MAY BE MORE SUSCEPTIBLE TO SHADE BY NEIGHBORS' TREES OR BUILDINGS.
- EXPOSED TO UPLIFTING CAUSED BY STRONG WINDS. ANCHOR PROPERLY.



GROUND MOUNTING

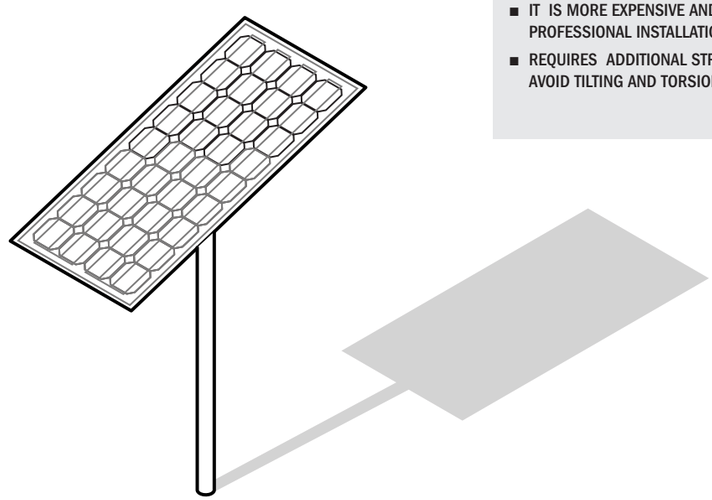
A. LOCATION: POLE

Pole mounting absorbs the benefit of sun exposure from rooftops as well as above-ground location freedom. However, these are the most difficult to install and will require additional structural support to avoid tilting and torsion due to storm winds.

- FLEXIBLE IN TERMS OF INSTALLATION AND PLACEMENT.
- CAN INCLUDE PASSIVE SOLAR TRACKING DEVICES THAT DETECT THE SUN'S PATH TO MAXIMIZE ENERGY COLLECTION.

- DEMANDS SPECIAL INSTALLATION BECAUSE OF STRUCTURAL LOADING SPECIFICATION NEEDS.
- IT IS MORE EXPENSIVE AND REQUIRES PROFESSIONAL INSTALLATION.
- REQUIRES ADDITIONAL STRUCTURAL SUPPORT TO AVOID TILTING AND TORSION.

POLE MOUNTING



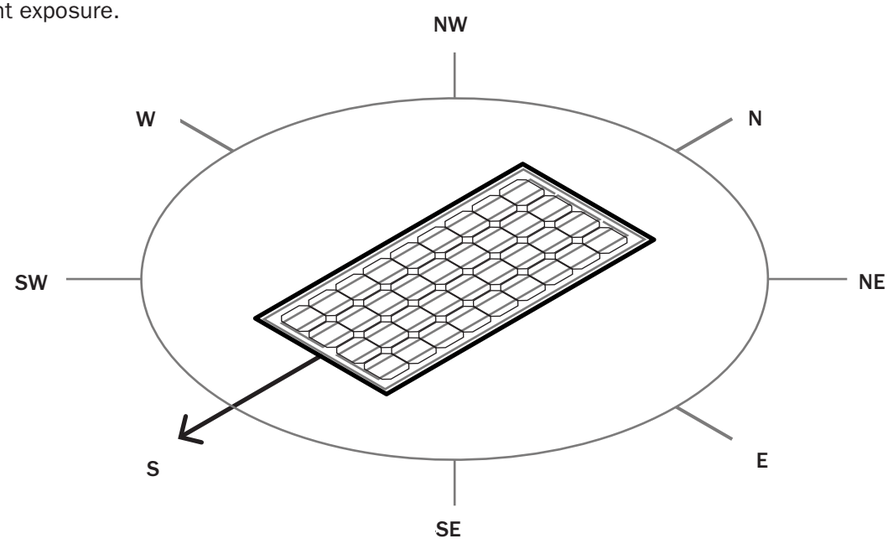
STRATEGY 16

INTEGRATE SOLAR ELECTRICITY

STEP 3 - INSTALL THE SYSTEM

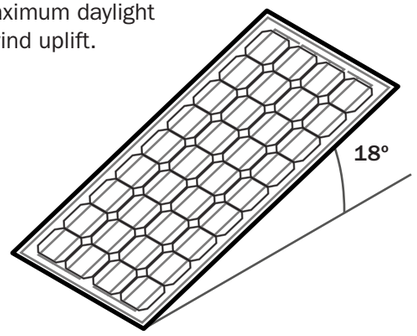
B. PLACEMENT: ROTATION

- Rotate panels so they face south, for maximum daylight exposure.



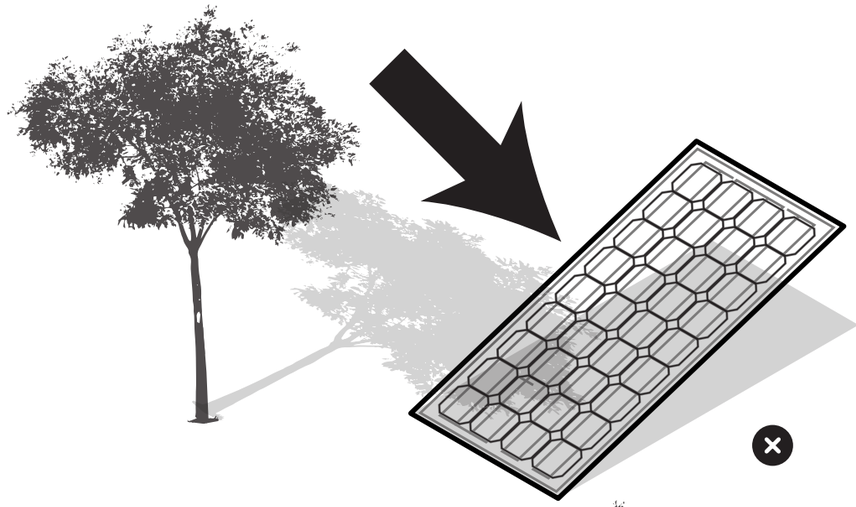
B. PLACEMENT: INCLINATION

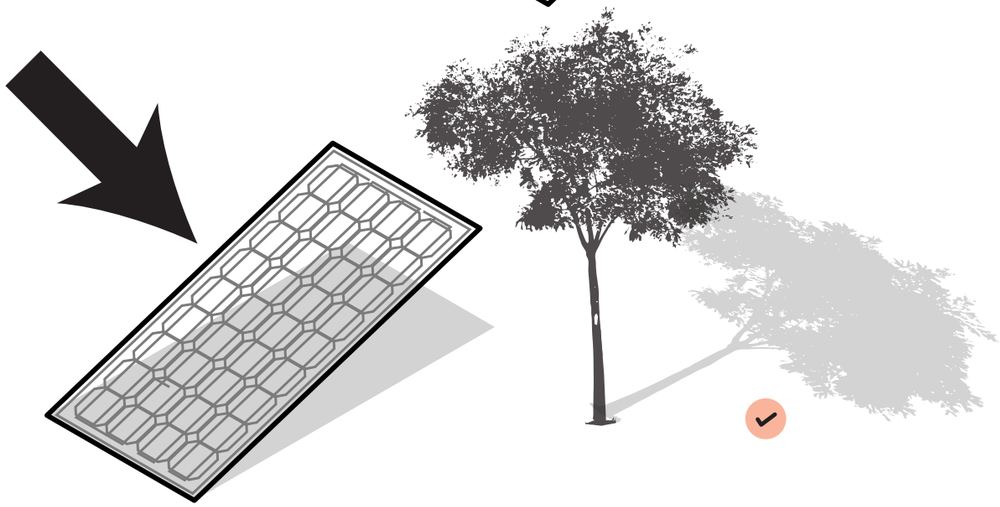
- The location latitude degrees should equal degrees of PV panel inclination.
- In Puerto Rico, incline each panel by 18 degrees facing south for maximum daylight exposure and to minimize wind uplift.



B. PLACEMENT: VEGETATION

- Avoid placing panels near trees as shade will affect the system's efficiency.





STRATEGY 16

INTEGRATE SOLAR ELECTRICITY

STEP 4 - CONNECT THE RESIDENTIAL SYSTEM TO AN INVERTER

- Most inverters are made to provide excess energy to the grid.
- If you are considering a solar panel system for your home, the key decision you should make is the type of inverter you want to install. Inverters are devices that convert direct current (DC) to alternating current (AC) to power up fixtures and appliances. Most household appliances and fixtures use AC power.
- Inverters come in two phases: split-phase 240VAC and single-phase 120VAC inverters.
- A grid-tie inverter converts direct current (DC) from PV modules to alternating current (AC) and voltage levels compatible to the utility grid (synchronized to 60 hertz).

STRING INVERTER (GRID-TIED)

PV modules are connected in strings, providing interactive operation with the house load and grid. SMA Sunny Boy and Sunny Island have Secure Power Supply feature that runs appliances without grid and battery systems.

**SMA Sunny Boy and Sunny Island have the Secure Power System (SPS) feature that runs appliances without grid and battery systems.

PROS

- The most commonly used inverter and can be used with grid-tied or stand-alone.
- The secure power system (SPS) feature of the SMA module allows owner to manually power appliances in the home through a dedicated outlet to run appliances without batteries or grid.

CONS

- It does not typically operate as stand-alone.

MICRO-INVERTER (GRID-TIED)

PV modules are connected individually, eliminating the need for a central inverter while providing interactive operation with the house load and grid.

PROS

- Prevents system from failing due to panel malfunction.
- Equalizes the system for optimum performance.

CONS

- Shorter lifespan
- Will not work without the grid

STAND-ALONE INVERTER

PV modules are connected in strings, providing interactive operation with the house load, inverter, and battery backup. Recommended inverters: SMA Sunny Boy and Sunny Island, Schneider, Tesla, Outback and Matcha Sine Magnum are leading stand-alone inverters

PROS

- Operates as a stand alone system.

CONS

- Need to provide backup power to provide redundancy and power during the evening or times of low power.

- Stand-alone inverter converts stored energy in batteries, electrically transforming direct current (DC) to alternating current (AC).

- A hybrid inverter is primarily used for grid-tie (selling back to the utility company) purposes but also has the added feature that they provide backup power to your home when the electric utility fails.

HYBRID INVERTER/CHARGER 3KW 48VDC - NEEDS BATTERY BANK

A hybrid inverter is primarily used for grid-tie (selling back to the utility company) purposes but also has the added feature that they provide backup power to your home when the electric utility fails.

PROS

- Inverter inside the unit
- Storage space
- Battery is configurable if upgrade is desired.
- Better with extreme temperatures

CONS

- Capacity could be bigger

MICRO-INVERTER (GRID-TIED)

A hybrid inverter is primarily used for grid-tie (selling back to the utility company) purposes but also has the added feature that they provide backup power to your home when the electric utility fails.

PROS

- Inverter inside the unit
- Storage space
- Battery is configurable if upgrade is desired.

CONS

- Capacity could be bigger

HYBRID INVERTER 7.5 KW WITH BACKUP BATTERY CAPABILITY (400VDC NOM.)

A hybrid inverter is primarily used for grid-tie (selling back to the utility company) purposes but also has the added feature that they provide backup power to your home when the electric utility fails.

PROS

- It is compact and has the charge controller inside.
- Scaleable

CONS

- Premium cost
- Tesla requires Tesla battery brand

STRATEGY 16

INTEGRATE SOLAR ELECTRICITY

STEP 5 - CONNECT THE SYSTEMS TO BATTERIES

- ► Batteries store surplus energy for future use.
- ► Preferred; if connecting to batteries, a charge controller is needed to charge batteries.
- ► Battery chemistry is generally divided into two main categories: lead and lithium.

LEAD-ACID BATTERIES

- ► **Flooded Lead-Acid batteries** - they produce hydrogen outgas when charging and can be dangerous in poorly ventilated spaces.
- ► **Deep Cycle Lead-Acid Batteries** - [recommended] can discharge below 50% depth of discharge (DOD) without damaging the battery.
  - Produce hydrogen when charging
- ► **Valve-Regulated Lead-Acid (VRLA)** – it re-combines outgassing when charging with minimum emissions.
  - Sealed VR Wet
  - Absorbent Glass Matt (AGM)
  - Gel Type
- ► **Lead Nano-Carbon** – can discharge up to 70% depth of discharge, which is a way to identify how deeply the battery is discharged.

✓ ■ DISCHARGE BELOW 50% WITHOUT DAMAGING THE BATTERY

✗ ■ DANGEROUS IN POORLY VENTILATED SPACES

OPERATIONS AND MAINTENANCE TIPS

- ■ Register your system with your insurance company in case of natural disasters or theft.
- ■ Monitor PV array output monthly to detect any anomaly. Some PV installers or manufacturers offer real-time monitoring of system performance and maintenance plans.
- ■ Inspect your PV system to check for:
  - Dirt on array
  - Storm damages
  - Loose cables
  - Inspect and protect your system by dismounting your panels before a storm event, whether it is a pole-mounted system or a ground-mounted system.
- ■ For off-grid and bimodal systems, be sure to inspect your battery bank regularly and look out for:
  - Battery voltage inconsistencies
  -
  - Metal corrosion
  - If you have lead batteries, check depleted electrolyte levels by verifying water levels in the lead batteries.
- ■ Preparations prior to hurricane landfall:
  - Property owners or operators should have a maintenance staff or a contractor that adequately prepares their PV systems prior to landfalling hurricanes or forecasted severe windstorms by performing the following:
    - Debris removal from roof drains, scuppers, and gutters.
    - Removal of loose objects such as buckets, lumber, and sheet metal from the roof and surrounding areas.
    - If there is enough time, check tightness of the PV array's bolted connections with a torque wrench.
- ■ After a severe wind storm[1]:
  - Property owners or operators should have a maintenance staff or a contractor perform post severe windstorm damage assessments and take any actions needed for repairs or improvements to their system, including the following:
  - Check the PV array for damage.
  - Remove, replace, or temporarily secure loose panels.
    - Check the roof covering for damage caused by wind-borne PV panels or other debris.
    - Check tightness of the PV array's bolted connections.

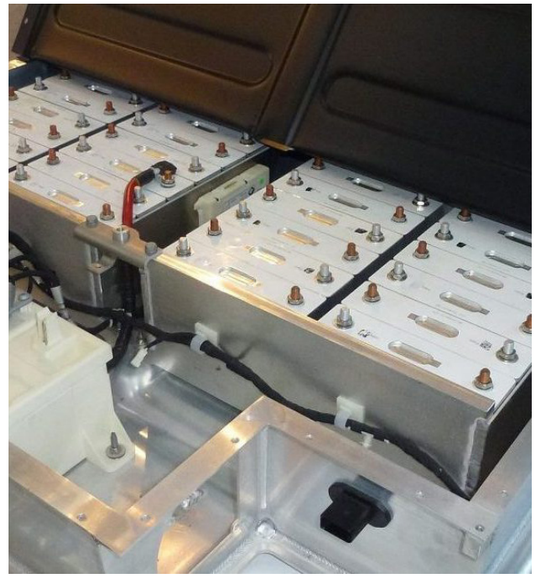
1 Rooftop Solar Panel Attachment: Design, Installation, and Maintenance https://www.fema.gov/media-library-data/1535554011182-e061c2804fab7556ec848ffc091d6487/USVI-RA5RooftopSolarPanelAttachment_finalv3_508.pdf

LITHIUM ION BATTERIES

- ► **Lithium Batteries** - (Longer Life: higher charge/discharge cycles) – higher initial cost ($)
- ► **Lithium-Ion** - can be discharged to 90% of its capacity. Typically, it can endure three times the number of cycles compared to lead-acid.
- ► **Lithium Ferro Phosphate** – usually found in nominal 24V and 48V packages.

✓ ■ DISCHARGE 90% OF ITS CHARGE

✗ ■ MORE EXPENSIVE



DISCLAIMER

DO hire a professional to ensure that installation complies with local codes and regulations. Code or NEC).

DO verify neighborhood regulations or talk with your neighbor to comply with aesthetic concerns.

DO NOT connect the system to electric circuits by yourself. Hire an electric technician/engineer for this purpose.

STRATEGY

17 INTEGRATE SOLAR THERMAL ENERGY

$-$$$$

Solar thermal systems use the heat from the sun to heat water as opposed to solar photovoltaic (PV) which uses solar energy to energize a home. This system allows it to depend less on electric water heating and reduce costs. This strategy focuses on explaining how the system works, how to purchase it, and how to install it.

Strategy in Action

1. Identify Home Hot Water Needs

2. Choose the System

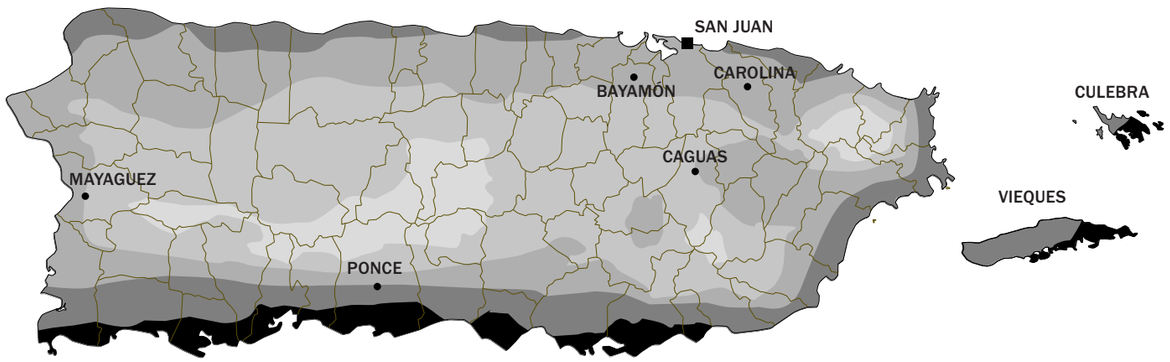
3. Install the System

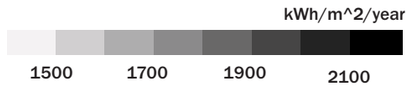
4. Connect the System

WHAT YOU NEED TO KNOW

- A solar thermal collector is a device that transfers radiation from the sun to heat water for household use. It is typically located on the roof and must have access to the plumbing system.
- There are two types of solar thermal systems:
  - **Thermosiphon**: passive; does not require energy from the grid
  - **Flat Plate**: active; does require energy from the grid
- Water is pumped to the roof and then stored in a home water storage tank for household use.
- Consult a structural or civil engineering to verify that the home's roof can hold the weight.
- Solar systems with higher solar energy factor (SEF) and solar fraction (SF) perform better.
- Identify the system's warranty with your contractor or vender to ensure you are protected should it fail due to possible defects.
- Identify distance between the solar system on the roof and electric tank location.
- When the system is installed, check that the hot water delivery temperature valve is correctly set and not exceeding 130 degrees Fahrenheit.

HORIZONTAL SOLAR IRRADIATION IN PUERTO RICO





SUPPORTING STRATEGIES

10 Reduce Thermal Heat Gain

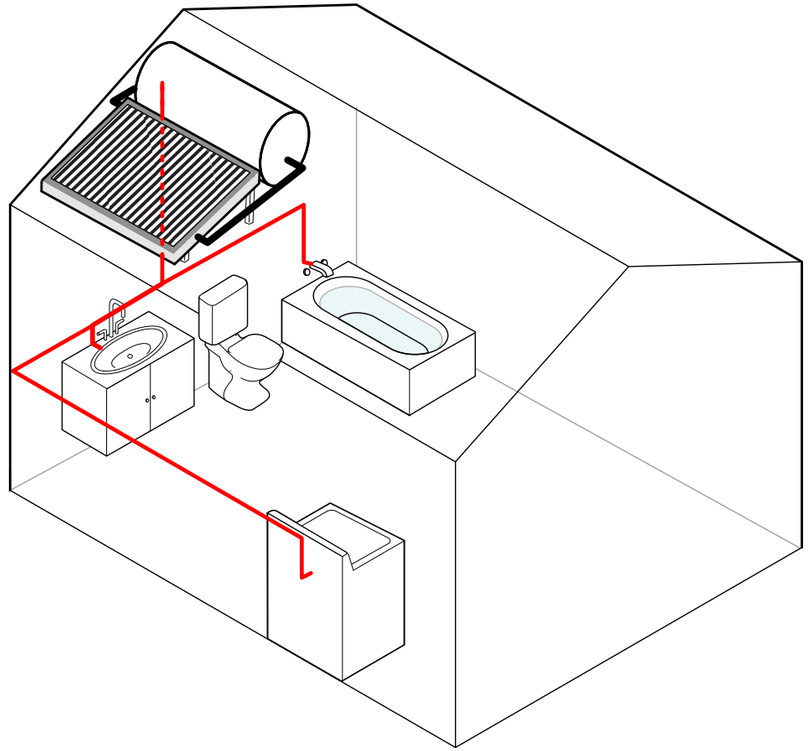
11 Increase Ventilation

12 Benefit from Natural Light

15 Reduce Your Energy Use

18 Install Energy Backup

SOLAR THERMAL PANEL



STRATEGY

17 INTEGRATE SOLAR THERMAL ENERGY

DISCLAIMER

- The system and its components should be certified by an accredited testing institution following international code and standards.
- Use a programmable 24-hour timer with battery backup clock to prevent the use of electric resistance heating. Program it according to your weekly occupancy. schedule.

STEP 1 - IDENTIFY HOUSEHOLD HOT WATER NEED

- A family of four using 52 gallons of hot water (125 Fahrenheit) would consume about 5.2 kilowatt-hours (kWh) per day.
- The appliances that are used for heating water (sinks, bathtubs, washing machines) determine how much hot water you will need. Using a flow meter is the most accurate way of identifying how much hot water you are using. in absence of a flow meter, collecting (weighing) a sample (timed in seconds) of hot water out of each faucet or shower is the most accurate way to identify how much water per person you are using.
- The more water conservation practices you have in place, the smaller your appliance and the less water you will need to heat with your solar thermal system.

STEP 2 - CHOOSE THE SYSTEM

THERMOSIPHON

- Used by itself with integrated storage, connected, or added to an existing tank to backup electric storage water heater and increase hot water capacity.
- Unlike an active system, the thermosiphon does not use an active pump.
- A thermosiphon collector heats water within the collector where hot water rises by convection into the top of the storage tank. Cold water flows down from tank to the collector therefore establishing a slow, natural flow without the use of a pump.
- Solar systems with higher solar energy factor (SEF) and solar fraction (SF) perform better. Look for an efficient system, with a SEF between 1.2 and 1.9 and a SF between 26% to 52% (.26 to .52).

FLAT PLATE

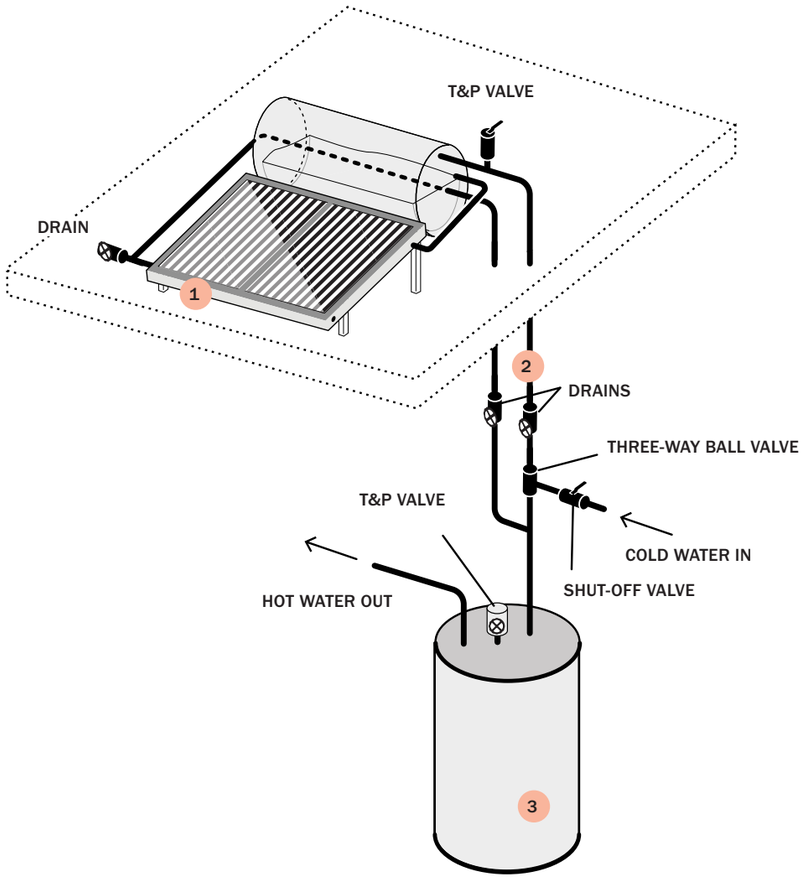
- Utilizes hot water circulation pump to provide higher level of efficiency.
- Utilizes a single larger storage tank (usually 50-120 gallons) depending on collector size or number of multiple collectors.
- Alternating current (AC) pumps provide higher pumping capacity, compared to direct current (DC) ones.
- Recommended for:
  - Homes with an integrated renewable energy system in place
  - Works for residential or commercial applications
  - When little power is needed for the pump to circulate water
- Solar systems with higher solar energy factor (SEF) and solar fraction (SF) to perform better. Look for an efficient system, with a SEF between 2.0 and 4.5 and a SF between 50% to 75% (.50 to .75).

STRATEGY 17

INTEGRATE SOLAR THERMAL ENERGY

STEP 2 - CHOOSE THE SYSTEM

1. SOLAR COLLECTOR
2. CIRCULATION PIPES & DRAIN
   The solar thermal panel heats waterflowing through the collector which transfers its heat to the holding tank.
3. HOLDING TANK
   Insulated tank hold the water.



THERMOSIPHON

SOLAR COLLECTOR

- Consists of an insulation, absorber plate and flow tubes.
- Absorbs the sun's light energy and transfers heat to water via pumped fluid circulating through the collector tubes.
- Can Use up to 3 collectors connected to a integrated 120 or 80 gallon tank size

INTEGRATED SOLAR STORAGE TANK

- Stores heated potable water in a separate tank with backup electric resistance element.

DRAIN VALVE

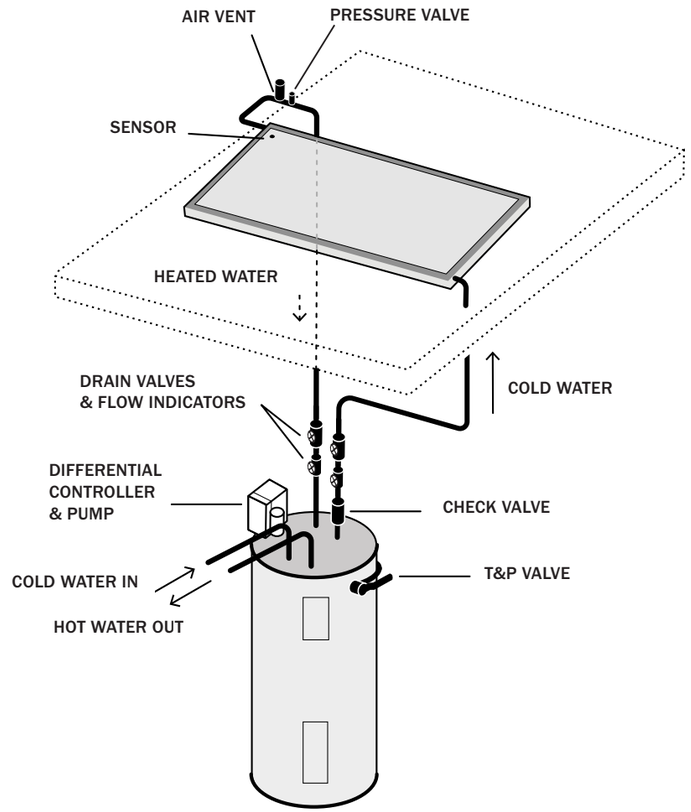
- Allows draining, filling, and servicing of the system.

ANTI-SCALD / MIXING VALVE

- Tempers hot water from the solar storage tank with cold water to maintain an adequate temperature of the hot water delivered to its end use.

COLD WATER CUT-OFF VALVE

- Isolates the system from incoming water supply.



FLAT PLATE

SOLAR COLLECTOR

- Absorbs the sun's light energy and transfers heat to water via pumped fluid circulating through the collector tubes.
- Can Use up to 3 collectors connected to a integrated 120 or 80 gallon tank size

AUXILIARY/MAIN STORAGE TANK

- Stores heated potable water as it circulates in a separate tank with backup electric resistance element.

SOLAR LOOP EXPANSION TANK

- Allows for the expansion and contraction of heat transfer. Outdoor solar systems should be equipped with temperature and pressure relief valves. The expansion tank will absorb thermal expansion of hot water from the solar system and prevent hammer shock when opening fixtures.

SERVICE DRAIN VALVES

- Pumps air out of circulation lines to allow proper water circulation.

ANTI-SCALD / MIXING VALVE

- Tempers hot water from the solar storage tank with cold water to maintain an adequate temperature of the hot water delivered to its end use.

AIR VENT

- Purges air from the collector.

DIFFERENTIAL CONTROLLER

- Controls alternating current (AC) over a timer, sensing the temperature at the bottom of the tank and outlet of the collector. It activates the pump when temperature is prime and prevents activation in case of overheating, overuse, or when the home is empty (so no water is used).

SOLAR PUMP/CONTROLLER

- Controls the operation of hot water circulation to the collector.water circulation.

STRATEGY 17

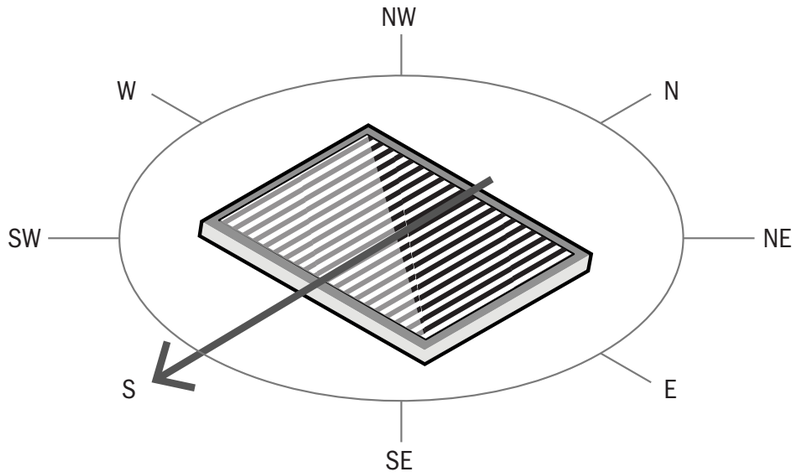
INTEGRATE SOLAR THERMAL ENERGY

STEP 3 - INSTALL THE SYSTEM

- Install in accordance with local regulations and through a certified PV contractor as determined by Puerto Rico's regulations.
- Install a heavy-duty commercial grade 240VAC (30-amp) toggle switch that is easily accessible to cut-off power to the backup water heater. This is in addition to the existing 240VAC circuit panel breaker (20-amp for 120VAC small capacity water heaters).
- Utilize a tank wrap to prevent heat loss from storage tank.
- Install a mixing valve to prevent excessive hot water delivery to the use point. Note: most anti-scald mixing valves prevent hot water flow during pressure loss of city water mains; a thermostatic mixing valve is an alternative.

ORIENTATION

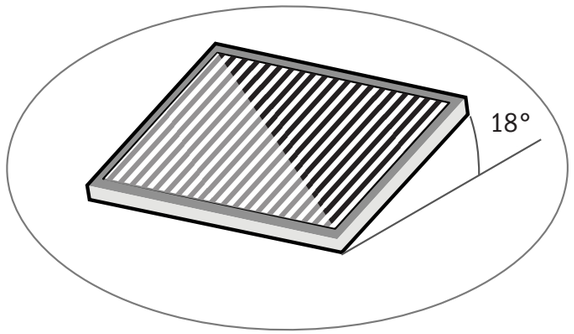
- The optimal angle for installation is usually pre-set by the rack support system supplied by the installer/manufacturer providing the optimum performance.
- Collector should face south and be free of shading.
- Incline 18 degrees, close to Puerto Rico's latitude. On the thermosiphon system, an inclination of less than 8 degrees or more than 30 degrees is unacceptable.
- Orient portrait facing south to reduce air bubbles.



LOCATION

- Place on a concrete slab, heavy-duty platform, or concrete roof.
- Ensure roof can hold the load of the equipment. The system can be more than 800 pounds.
- Proximity between tanks and equipment reduces piping losses.

- Aplique aislante de tubería (pared de ½", mín. R-3) a las líneas de conducción solar y de agua caliente. En los tramos exteriores, tape el aislante con una cubierta protectora para resguardarla de los elementos (rayos UV y humedad).
- Tape o recubra (con pintura) el aislante en los lugares donde esté expuesto a la luz del sol.
- Es posible que el código local requiera un vaso de expansión.
- Por lo general, un sistema solar por termosifón se añade en serie a un calentador eléctrico ya existente, así aumentando la capacidad de almacenamiento de agua caliente. Por ejemplo, se puede tener una cisterna solar de 80 galones en el techo y un calentador eléctrico de 40 galones ubicado en el cuarto de lavandería, para un total de 120 galones. La cisterna solar suministra agua caliente al tanque de 40 galones del calentador eléctrico en el hogar.
- En algunos casos, es posible utilizar solo un almacenamiento solar por termosifón, así evitando la necesidad de un calentador eléctrico primario de 40 galones.
- También es posible conectar una toma de termosifón a un calentador eléctrico pequeño sin tanque.
- Se puede utilizar una sola cisterna (de mayor capacidad) con dos puertos solares adicionales para canalizar el agua por bombeo desde la cisterna hacia el colector y viceversa.



STRATEGY

18 INSTALL ENERGY BACKUP

$$-$$$

Backup energy systems offer homes the ability to power essential equipment when the electrical grid is not available. This strategy focuses on explaining how to choose a generator and how to install it.

WHAT YOU NEED TO KNOW

- Choose a generator based on:
  - Wattage (800W for portable generators – 130 kW for commercial generators)
  - Fuel (gasoline, propane, natural gas, diesel)
  - Size/Weight (portable or stationary)
  - Budget ($120 portable to $30,000 stationary)
  - Level of atmospheric pollution
  - Level of noise pollution
  - The more energy efficient your home is, the less backup power you need. Refer to Strategy 15 to know more about how to save energy.
  - A generator's capacity depends on the critical load. See Strategy 15.
  - Check local code requirements for generator equipment and fuel storage.
  - Consider methods of securing the generator to the site to prevent theft.

Old San Juan in the dark at night after Hurricane Maria

SUPPORTING STRATEGIES

10 Reduce Thermal Heat Gain

11 Increase Ventilation

12 Benefit from Natural Light

15 Reduce Your Energy Use

17 Integrate Solar Thermal Energy

STEP 1 - CHOOSE A GENERATOR

- Refer to Strategy 15 to determine power needs for household and calculate how many watts are necessary.
- What percentage % of power do you want to draw from solar (PV) or generator?
- By how much do you want to reduce electric bill?
- How much do you need backup electricity – are there many power outages because of grid failure.
- What is your budget for the generator?

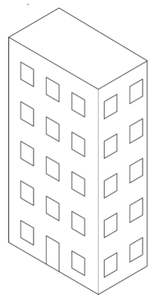
A. IDENTIFY YOUR CRITICAL LOAD

- Sizing your generator will be informed by how much "electrical load" you need to provide for sustaining your household when grid power is down. Critical load refers to the collective load of equipment in the home that should remain on consistently in order to safely inhabit the space.
- Refer to Strategy 15 to assist in identifying what load is necessary to provide power for so you can size your appropriate generator.

B. IDENTIFY WATTAGE REQUIRED

- Generators have a starting wattage and a running wattage.
- Starting wattage, also known as maximum surge wattage, is the amount of energy it requires to start up. This one is more critical when choosing.
- Running wattage is the amount of energy it requires to operate continuously.
- Use the critical load result from Strategy 15 to decide which capacity you need.
- For multi-family buildings, include emergency exit signs and emergency lighting.

GENERATOR POWER CAPACITY: MULTI FAMILY HOME



WATTAGE

CAN POWER

___ WATTS

- 1 to ___ Housing Units/per floor 2000 to 7000 Watts
- 1 to 3 Housing Units/per floor, limited to one small AC window unit or mini split (preferrably) and small refrigerator, few led lights and small tablet/compouter

UP TO 150,000 WATTS

- Common Load of Building
- Common area lighting
- Utility pumps
- Lighting in common areas
- Alarms
- Life safety equipment
- Elevator

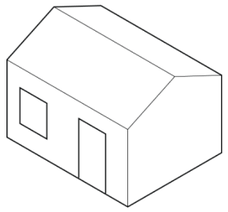
STRATEGY

18 INSTALL ENERGY BACKUP

STEP 1 - CHOOSE A GENERATOR

B. IDENTIFY WATTAGE REQUIRED, CONTINUED

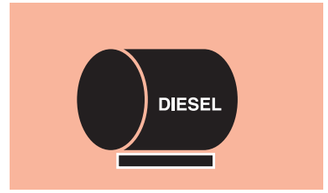
GENERATOR POWER CAPACITY: SINGLE FAMILY HOME



WATTAGE

2,500 WATTS	5,000 WATTS	7,500 WATTS
CAN POWER		
■ 1 refrigerator ■ 1 fan ■ 2 phone chargers ■ 4 LED 60-watt bulbs	■ 1 refrigerator ■ 5 LED 60-watt bulbs ■ 2 fans ■ 2 phone chargers ■ 1 sump pump ■ 1 well pump ■ 1 security system	■ 1 refrigerator ■ 9 LED 60-watt bulbs ■ 5 fans ■ 4 phone chargers ■ 1 well pump ■ 1 sump pump ■ 1 security system ■ 1 washing machine ■ 1 computer ■ 1 radio

C. FUEL



FUEL TYPE	GASOLINE	PROPANE	DIESEL
DESCRIPTION	■ **Type:** Single family home ■ **Emissions:** medium ■ **Flammability:** High	■ **Type:** Medium Size Home ■ **Emissions:** low ■ **Flammability:** Lowest	■ **Type:** Medium Size Home ■ **Emissions:** medium ■ **Flammability:** Medium
PROS	■ Easy to store on site ■ Fuel is easiest to find ■ Easy to store on site	■ Lighter weight and easy to store ■ Longer shelf life ■ Quieter	■ Most fuel efficient ■ Can be converted to biodiesel which can reuse oil. ■ Fuel easy to obtain
CONS	■ Limited storage life. Add fuel stabilizer for long storage time. ■ Requires plan for cycling. ■ Expensive ■ Highly flammable	■ Availability may be limited	■ Diesel fueled generators are large, bulky, and can be loud. Highly flammable

REMEMBER

After an emergency or natural disaster, fuels may be in limited supply. Consider a smaller generator, therefore consuming the least amount of fuel to provide energy to essential needs

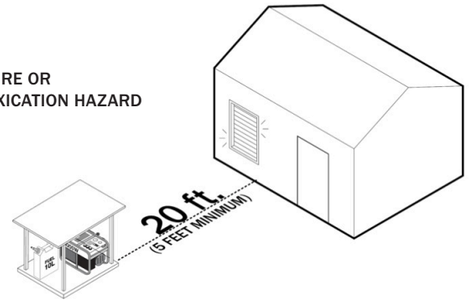
STRATEGY

18 INSTALL ENERGY BACKUP

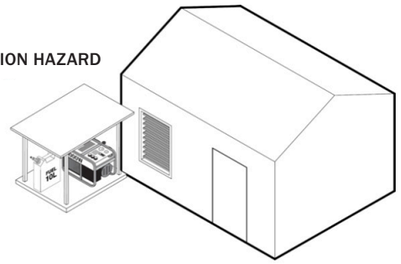
STEP 1 - CHOOSE A GENERATOR

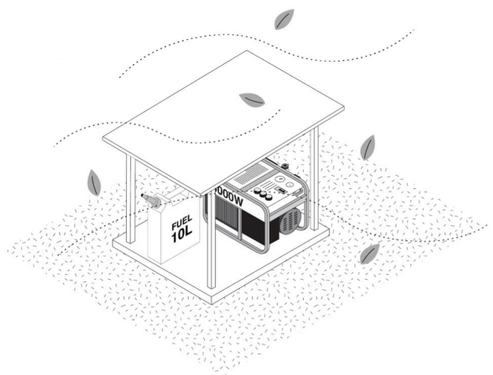
D. SITE

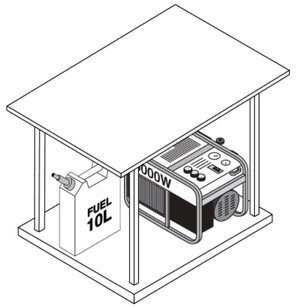
NO FIRE OR
INTOXICATION HAZARD

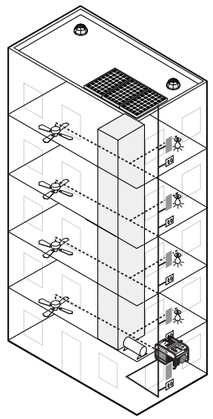


FIRE +
INTOXICATION HAZARD





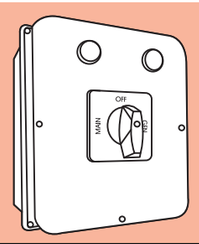




STEP 2 - CONNECT THE SYSTEM

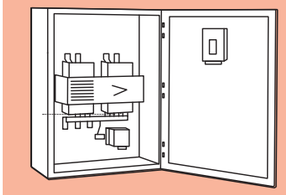
- The generator powers up an emergency circuit dedicated to critical loads, as established in Strategy 15.
- Install a transfer switch to switch from the regular system to emergency power.
- Locate the switch between the main distribution panel and the emergency circuits.
- Ensure the emergency distribution panel (or critical load panel) is isolated from the grid via the transfer switch for easier control when operating a generator.

TYPES OF SWITCHES



MANUAL TRANSFER SWITCH

Activate manually when the main power supply fails and deactivate when power is restored. This switch is less expensive, and it allows for a closer management of available energy, yet requires more effort to operate.



AUTOMATIC TRANSFER SWITCH

Continuously monitors electric power. It automatically switches to emergency power when the main power supply fails, and switches back when power is restored. The switch is more expensive but requires less effort to operate.

OPERATIONS AND MAINTENANCE TIPS

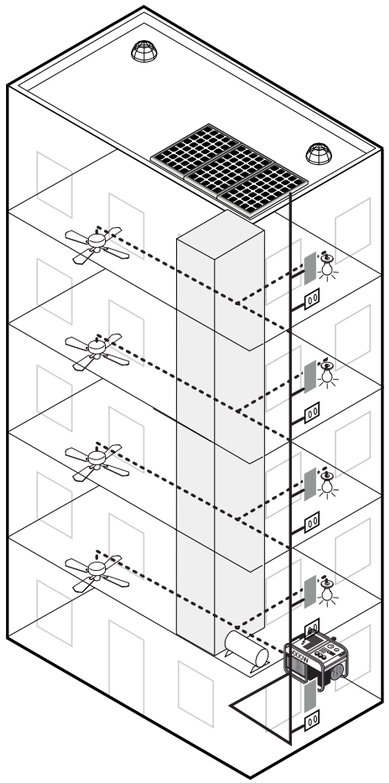
- All fuels must be appropriately stored and anchored to prevent fires!
- Exercise the generator at least once a month. Many modern models perform test runs automatically while some are manual.
- Perform exercise drills every month for a 2-hour period at 50% load capacity. This allows enough time for the unit to lubricate while allowing all moisture to evaporate.
- For portable generators, generator manufacturers recommend draining the fuel from the tank and running the carburetor dry prior to storing or if it has been stored for more than 6 months.
- Stock up on oils and filters. Most generators require their first oil change after 25 hours and then every 50 to 60 hours of use.
- Keep the tank full and remove all loads before shutting down the generator. Failure to do so will damage it.
- Contact a professional electrician upon the installation of the generator and schedule regular check-ups various times in a year.
- Have on hand the telephone/email of a professional electrician or manufacturer in case of an emergency.

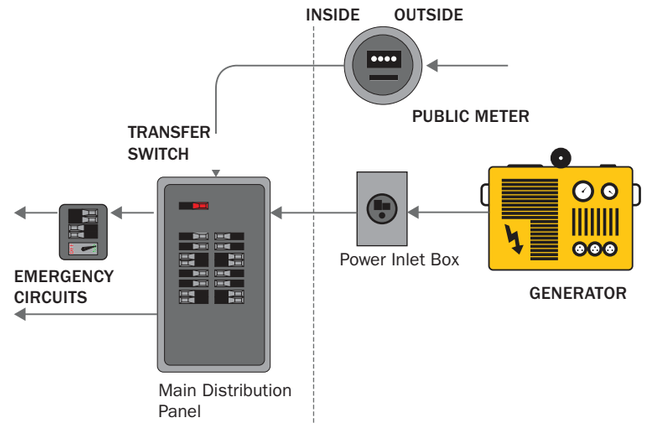
STRATEGY

18 INSTALL ENERGY BACKUP

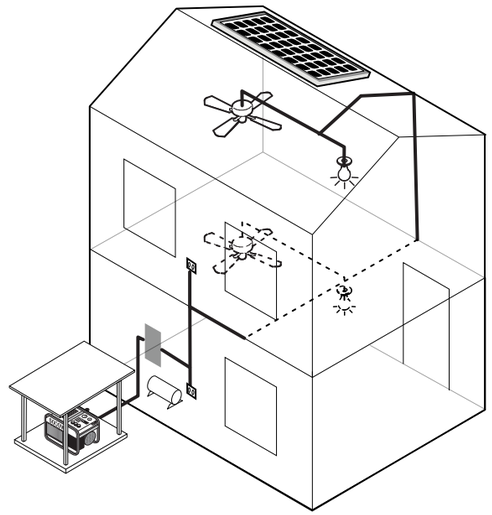
STEP 2 - CONNECT THE SYSTEM

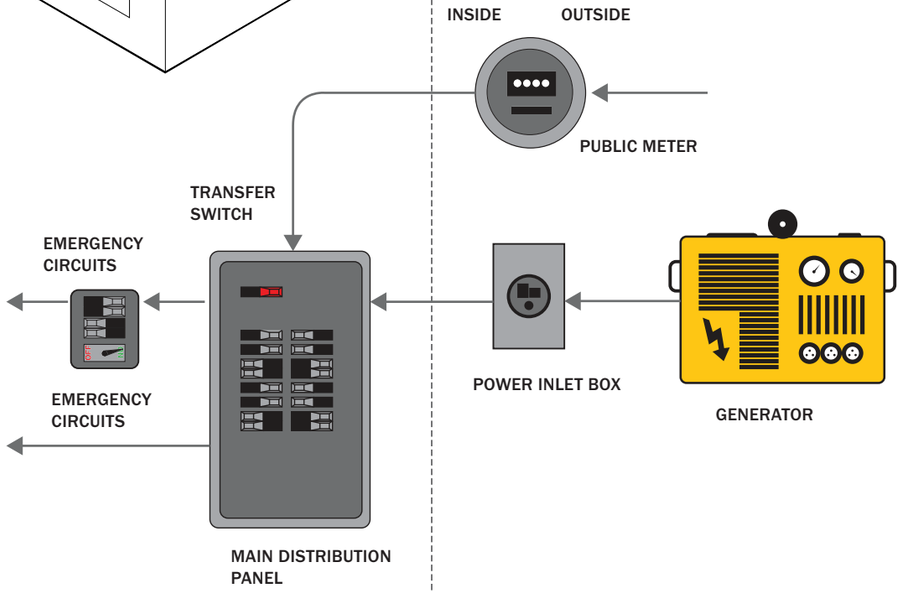
MULTI FAMILY HOME





SINGLE FAMILY HOME



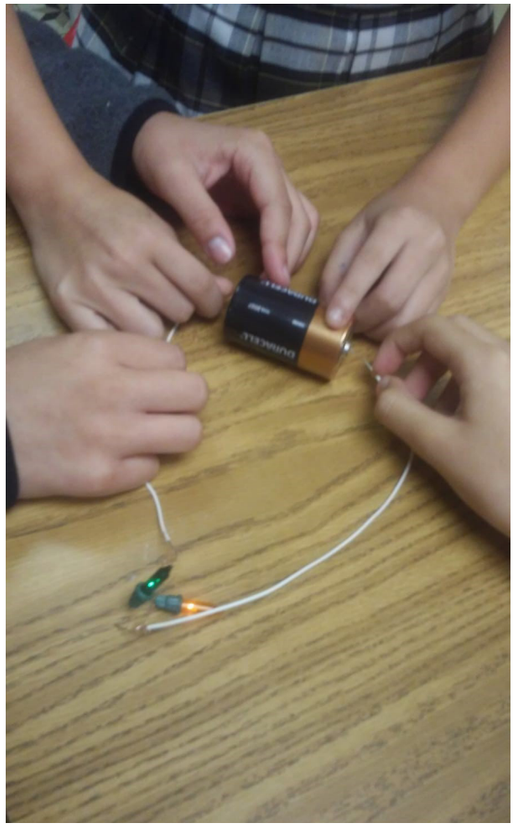


STRATEGY

18 INSTALL ENERGY BACKUP

TROUBLESHOOTING GUIDE

APPARENT PROBLEM	Generator running but no AC output available	Generator runs good but bogs down when loads are connected	Switches are not working with generator power	Appliances do not operate after utility power is restored	Only some loads work on generator power
PROBABLE CAUSE	☐ generator circuit breaker has tripped ☐ poor connection ☐ connected device is bad ☐ fault in generator	☐ short circuit in a connected load ☐ generator is overloaded ☐ try appliance startup one at a time	☐ switches are in OFF or LINE position ☐ generator circuit breaker has tripped ☐ poor connection or defective cord set ☐ connected device is bad ☐ fault in generator	☐ switches are in GEN or OFF position ☐ Circuit breaker tripped	☐ circuit breaker tripped ☐ poor connection or defective cord set
PROBABLE SOLUTION	☐ reset circuit breaker ☐ check and repair ☐ select a different load or appliance that is in good condition ☐ contact a qualified professional	☐ disconnect shorted electrical load ☐ review load power requirements and rearrange	☐ move switches to GEN position ☐ reset circuit breaker ☐ check and repair ☐ select a different load or appliance that is in good condition ☐ contact a qualified professional	☐ move switches to LINE position ☐ Reset circuit breaker	☐ reset circuit breaker ☐ check and repair



COMUNIDAD TORO NEGRO, INC., CIALES

Description: Comunidad de Toro Negro is located in Ciales, a municipality in Puerto Rico's inner mountains. This community is comprised of close to 60 families and has become renowned over the years for the numerous projects they have developed to improve the quality of life of its residents. Their developed projects include the construction of two concrete slabs to provide motor vehicle access across the Toro Negro River, and the development of hanging bridges [puentes hamaca] to provide access for residents if the river overflows, among other projects. Recently, the Puerto Rico Community Foundation (FCPR, by its Spanish acronym) and the non-profit organization SOMOS Solar, in partnership with Maximo Solar Industries, joined forces to develop an efficient solar system for the region. This is the first time that the system is run by a community-based organization whose members are the residents themselves.

JONATHAN MARVEL
FOUNDER, RESILIENT POWER PUERTO RICO

Founded in the wake of hurricane Maria, Resilient Power Puerto Rico is led by Jonathan Marvel and Puerto Rico-born New York attorney, Cristina Roig. Resilient Power Puerto Rico's long-term mission is to address the vulnerabilities of the island's existing, fossil-fueled electrical infrastructure by supporting initiatives that promote renewable, clean energy. Our vision is a Puerto Rico with redundant, reflexive, adaptable, and inclusive built and social infrastructures, where communities across our islands autonomously adapt and build a sustainable and equitable society.

As an architect, urban designer, and civilian who wants to help his hometown, the biggest lesson I've learned after Maria is to not wait for help. Set your goal, make your plan, and call it into action through execution. Always observe what people need first as the starting point. I have had a great deal of access to many communities across Puerto Rico through the work of my mother, Lucilla Marvel, who has worked with and documented the needs of informal communities for over 40 years. Members of these communities have taught me so much about putting ideas into action.

The donations we have received (from around the world and especially the Puerto Rican Diaspora) have gone straight to supporting communities throughout Puerto Rico. We have already solarized 25 communities, and after stepping back and observing what happened we have a plan to solarize an additional 75 communities. We are leveraging support to build systems that can be self-sustaining so that communities are empowered to control their own energy.

The basic installation of hardware package consists of 20 solar panels at 350 watts per panel, which enables us to power up a community center, which in turn allows households to power their lives. Our installations are designed to be off-grid and autonomous if necessary, with no need for fossil fuel–burning generators.

My recommendation for the federal agencies working towards rebuilding Puerto Rico is to seize this opportunity and utilize Puerto Rico's vast reserves of renewable energy as a key part of the recovery process as well as support Puerto Rico's energy resilient future. Future considerations should be to build decentralized systems (where deemed possible and appropriate) and create community scale solar hubs and microgrids to power up entire communities, working in partnership with each municipality, community by community.

I believe that housing, commercial industry, universities, and hospitals can all achieve 100% renewable energy source systems, if they are designed properly using rooftops and parking lots which can have a co-benefit of providing shading from the hot sun. We don't need to mount large scale solar systems on arable agriculture land and displace farms and economies. We must work to ensure a resilient and renewable future for Puerto Rico so that the heavy, old fossil-fuel energy plants that traditionally powered Puerto Rico can be a thing of the past.

13,800

9,200

Gumersindo Torres
Executive Director of Rio Chiquito