Solar PV Overview

(TEMA: Virtual Energy Basics 101)

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ENERGY STAR PARTNER

Overview

- Presentation originally part of the SECO webinars series (2022)
  - *SECO Technical Assistance*
- Solar PV Payback vs Typical Measures
- PV System Components
- Solar Project Feasibility Process Overview
  - Facility Selection
  - Identifying Potential
  - Site Visits & Measurements
  - Selecting Components and System Sizing
  - PV Watts Modeling Tool
  - Project Cost & Savings
  - Incentives and Funding Options
  - Calculating Payback
- Case Study
- Construction Considerations
- Q & A Session

SECO Technical Assistance Programs

- Engineering Services
  - ***Schools and Local Gov't Technical Assistance***
    - ***Solar PV feasibility evaluation***
  - Energy efficiency design guide for new construction and renovations
  - Renewable energy application

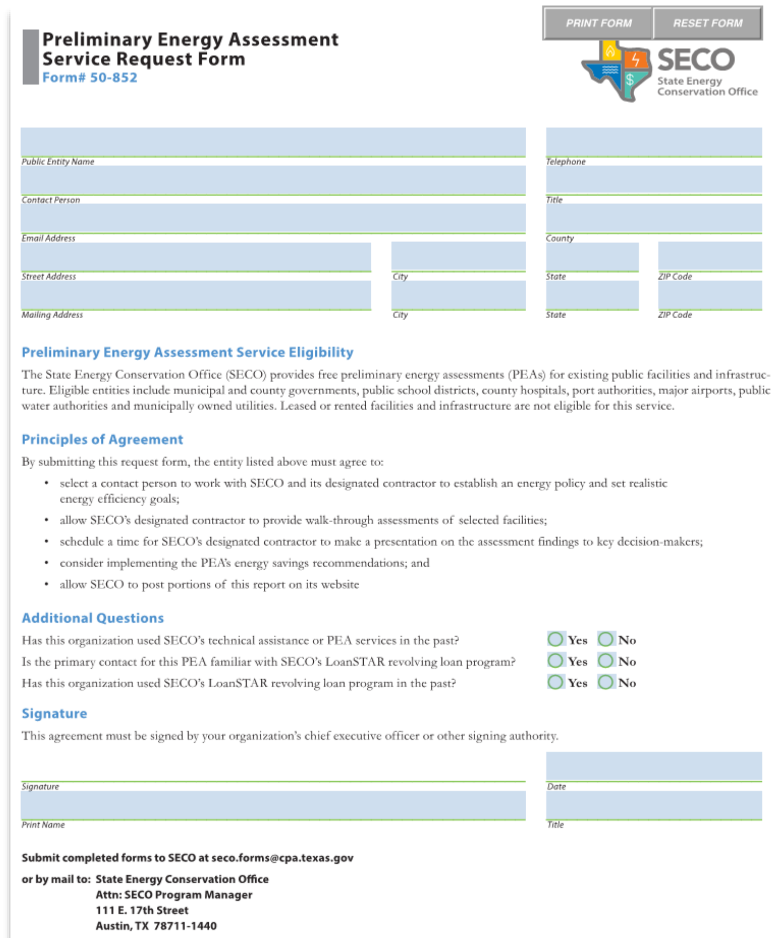
Eligibility

Available at *no cost* to the following entities:

- Municipal and County Governments (Cities & Counties)
- Independent School Districts
- County Hospitals
- Port Authorities
- Major Airports
- Public Water Authorities
- and Municipally-Owned Utilities

How do I participate?

- Visit SECO website & fill out Service Request Form
  - For Local Government Entities: https://comptroller.texas.gov/programs/seco/programs/local/pea.php
  - For School Districts: https://comptroller.texas.gov/programs/seco/programs/schools/pea.php
  - Contact LeShawn Manus or John Kyere if you have any questions



PRINT FORM RESET FORM

Preliminary Energy Assessment Service Request Form
Form# 50-852

SECO State Energy Conservation Office

Public Entity Name / Telephone
Contact Person / Title
Email Address / County
Street Address / City / State / ZIP Code
Mailing Address / City / State / ZIP Code

Preliminary Energy Assessment Service Eligibility

The State Energy Conservation Office (SECO) provides free preliminary energy assessments (PEAs) for existing public facilities and infrastructure. Eligible entities include municipal and county governments, public school districts, county hospitals, port authorities, major airports, public water authorities and municipally owned utilities. Leased or rented facilities and infrastructure are not eligible for this service.

Principles of Agreement

By submitting this request form, the entity listed above must agree to:

- select a contact person to work with SECO and its designated contractor to establish an energy policy and set realistic energy efficiency goals;
- allow SECO's designated contractor to provide walk-through assessments of selected facilities;
- schedule a time for SECO's designated contractor to make a presentation on the assessment findings to key decision-makers;
- consider implementing the PEA's energy savings recommendations; and
- allow SECO to post portions of this report on its website

Additional Questions

Has this organization used SECO's technical assistance or PEA services in the past? Yes No
Is the primary contact for this PEA familiar with SECO's LoanSTAR revolving loan program? Yes No
Has this organization used SECO's LoanSTAR revolving loan program in the past? Yes No

Signature

This agreement must be signed by your organization's chief executive officer or other signing authority.

Signature / Date
Print Name / Title

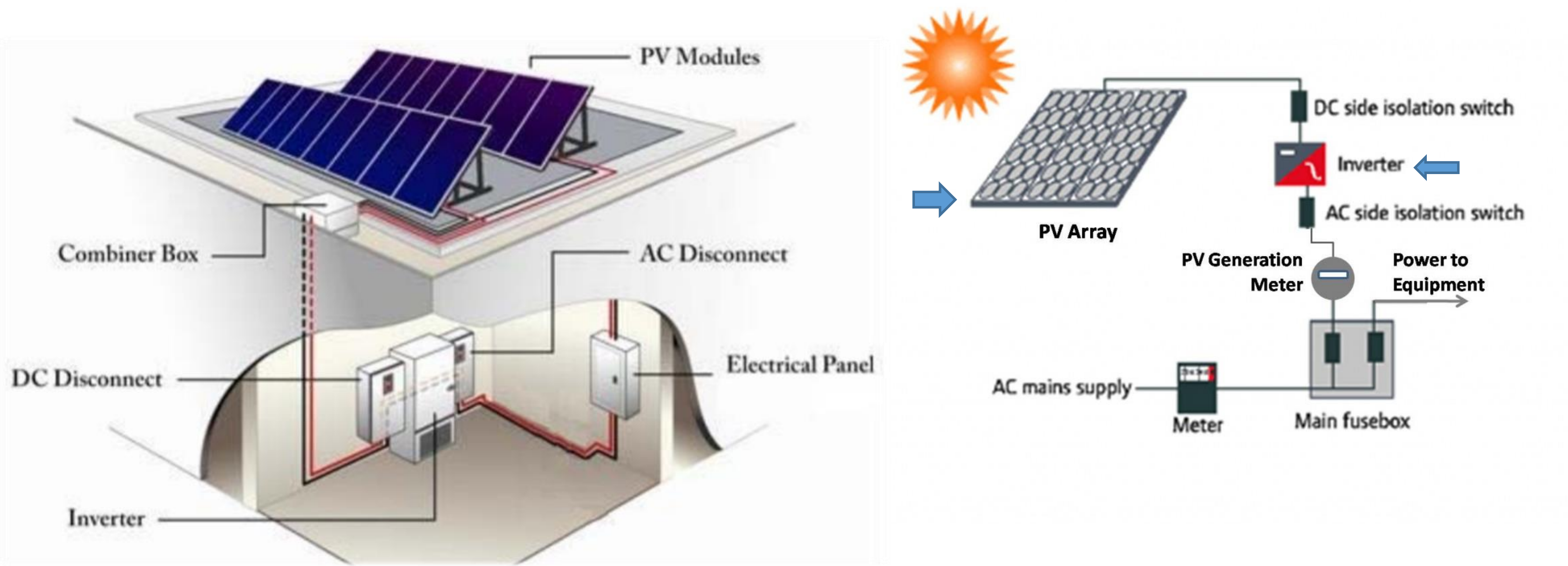
Submit completed forms to SECO at seco.forms@cpa.texas.gov

or by mail to: State Energy Conservation Office
Attn: SECO Program Manager
111 E. 17th Street
Austin, TX 78711-1440

Solar Compared to Typical UCRMs

UCRM	Payback Range (Yrs)
T8 Linear Fluorescent to LED	4 - 8
Exterior LED Retrofit	6 - 10
Motion Sensors & Day-lighting Controls	2 - 8
Solar Window Film	5 - 15
Existing Building HVAC Retro-Commissioning	1 - 6
Water Conservation	4 - 9
Solar Thermal Pool Heating	12 - 20
Cooling Tower Replacement	8 - 15
Thermal Storage	12 - 25
HVAC Unit Replacement	15 - 25
Chiller Replacement	15 - 25
Boiler Replacement	15 - 25
Solar PV Installation	***12 - 20***

PV System Components

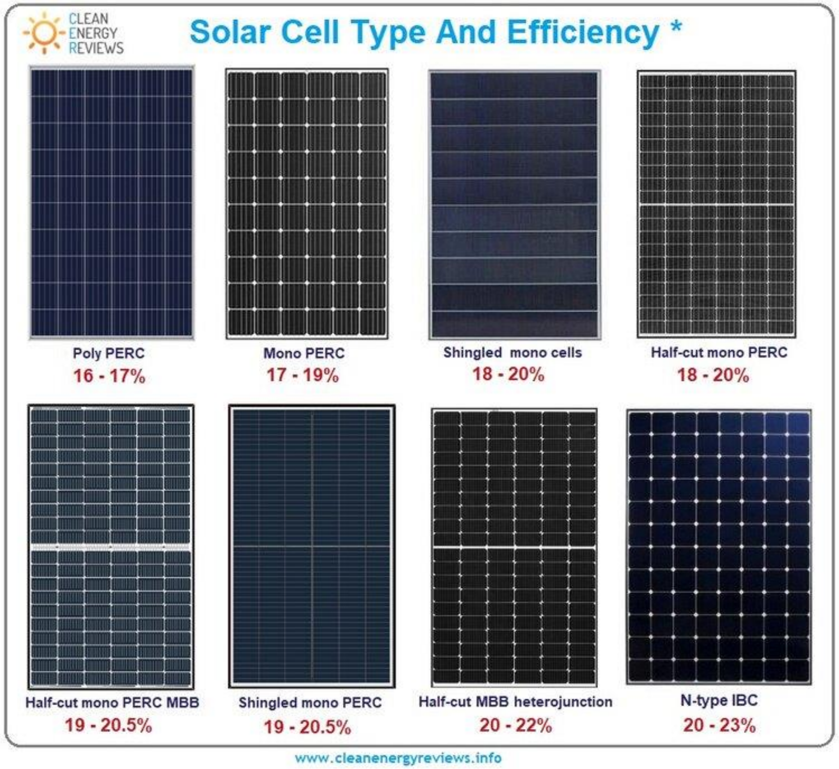


Typical Solar Array System

(source: National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy10osti/46078.pdf)

PV Module (Panel) Types

- Module Type
  - Cell material
    - Monocrystalline, polycrystalline, thin-film
  - Nominal efficiency
  - Module Cover
- Temperature Coefficient of Power
  - 25°C (77 °F) standard test condition for nominal wattage
  - -0.2% / °C to -0.5% / °C
- Advantages & Drawbacks
  - Cost vs Performance & Efficiency



(source: Clean Energy Reviews, https://www.cleanenergyreviews.info/blog/most-efficient-solar-panels)

Examples of Racking Systems

Ballasted

Anchored

Static / Fixed Mount

Tracking Mount

(source: PV-magazine-usa.com, https://pv-magazine-usa.com/2020/09/21/quiet-world-of-us-solar-racking-is-innovating-and-consolidating/)

Texas Energy Managers Association

Ballasted Racking Systems

- Static system using ballast (weighted objects to secure)
- Flat (leveled) roof
- Used for wind loading on roofs

Advantages:

- No roof membrane penetrations
- Simple system construction
- PV array components can be easily removed if access to roof is required for repair.

Drawbacks:

- Structural limitations due to weight
- May void roof warranty in some cases

Anchored Racking Systems

- Static System using fasteners
- Used for wind loading on roofs
  - Flat or sloped roof

Advantages:

- Generally lighter than ballasted design
- May be used on car ports or similar structures

Drawbacks:

- May require roof membrane penetrations
  - Potential leaks
  - May void roof warranty

Tracking Type Rack Systems

- Tracks the movement of the sun to maximize electric generation
- 1-axis, 1-axis with backtracking, and 2-axis

Drawbacks:

- System complexity
  - Software, moving parts, motors & actuators
- High upfront cost
- Requires more maintenance
  - Fine tuning and calibration required
- Expensive repair cost

(source: PV-magazine-usa.com, https://pv-magazine-usa.com/2020/09/21/quiet-world-of-us-solar-racking-is-innovating-and-consolidating/)

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Examples of Inverter Types

source: Solarreviews.com, https://www.solarreviews.com/blog/pros-and-cons-of-string-inverter-vs-microinverter

Inverters Compared (String Inverter)

Advantages:

- Easy to troubleshoot
- Lower cost – can serve multiple strings of modules

Drawbacks:

- Series circuit & shading effects
  - Limits entire string to lowest performer
- Difficult system expansion
- Shorter lifespan (8-12 years warranty)
- System monitoring limitations
  - No panel level performance data
- Replacement cost much greater than replacing 1 microinverter

String inverter

source: Solarreviews.com, https://www.solarreviews.com/blog/pros-and-cons-of-string-inverter-vs-microinverter

Inverters Compared (Microinverter)

Advantages:

- Parallel circuit
    - Not limited by lowest producing panel
    - Each panel will produce as much as it can (based on conditions)
    - More electricity yield
- Flexibility for site conditions
- Longer lifespan (25-year warranty)
- No single point of failure
    - If one microinverter fails, the rest of the system will continue to generate electricity
- Ease of system expansion

Drawbacks:

- Overall Cost
    - More expensive than string inverters
- Maintenance difficulty
- "Clipping"
    - Panel output limited to the inverter's output

Micro inverter

source: Solarreviews.com, https://www.solarreviews.com/blog/pros-and-cons-of-string-inverter-vs-microinverter

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Feasibility Overview

1. Facility Selection
2. Identify Available Space at each Facility
3. Site Visits (Spot Check)
4. Estimate PV Array Size at each Facility
5. Use PV Watts to Estimate Power Generation
6. Account for Efficiency Degradation over Time
7. Project Costs, Savings, Rebates
8. Calculate Payback

1 Facility Selection

2 Identifying Potential

- Identify available areas for solar array:
  - Building roof
  - Covered parking structures
  - Open unshaded areas (fields) adjacent to buildings

  - Spot check measurements at the site
  - Use PV generation calculator to estimate annual kWh based on available area and local TMY data.

3 Site Measurements

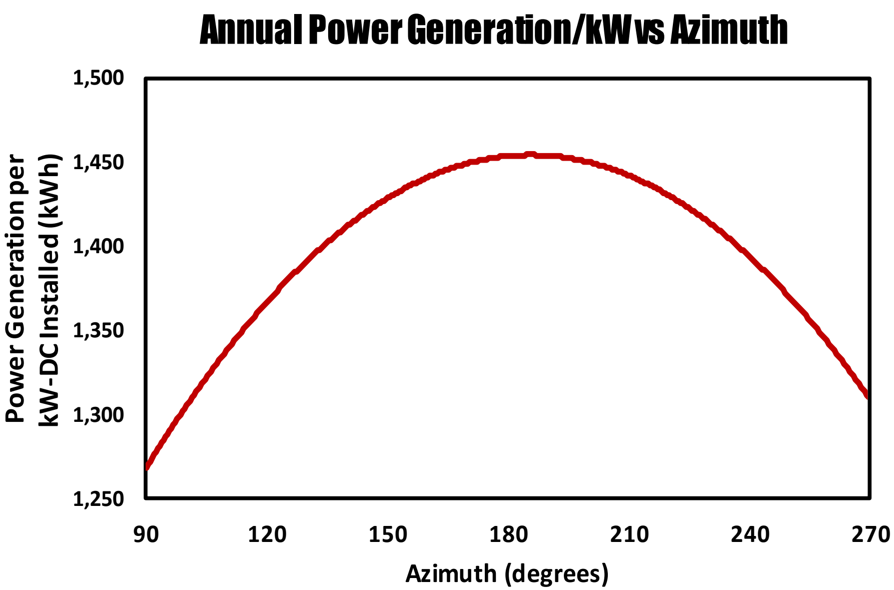
- Area available
- Tilt Angle
- Azimuth Angle
- Note obstructions from tall buildings, trees, & shading factors from HVAC equipment, and parapets

Potential Roof space for solar installation

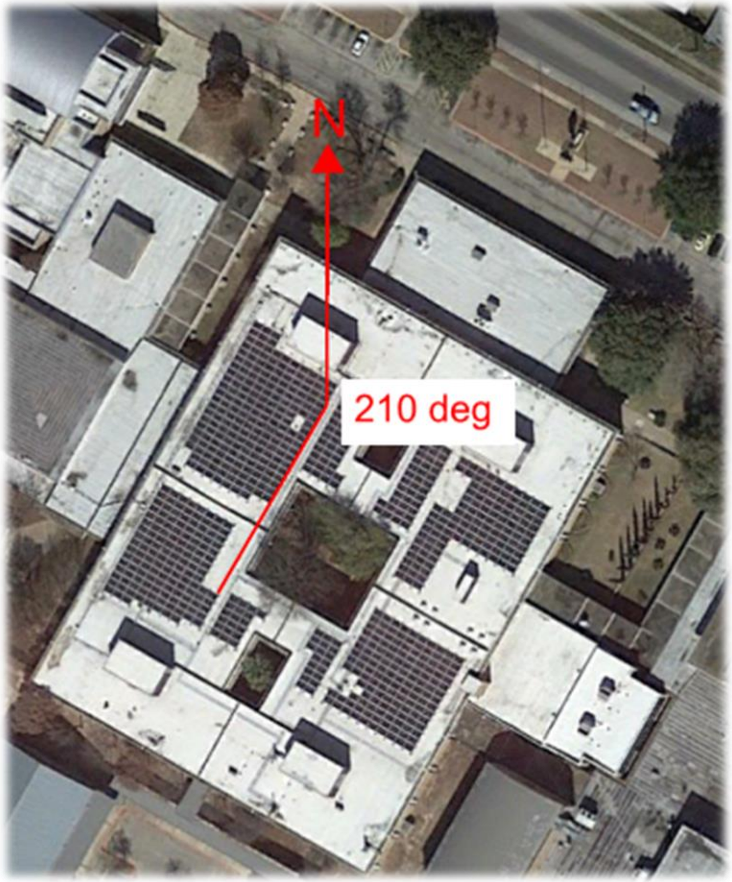
Shading from RTU

3 General Guidelines for Array Configuration

- Azimuth - Clockwise angle from true north
- Ideally, 180° or south facing
- Array facing east or west: 87-90% of "ideal" condition

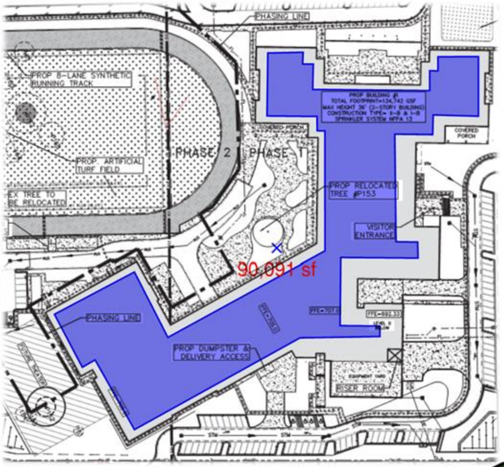


Power generation vs azimuth (on a per kW basis & 20-degree tilt)
Source: PV Watts output data summarized



4 Selecting Components and System Sizing

- PV Modules/ Panels
- Racking Type
- Inverter Type
- Battery/ Storage (optional)



- Sizing Considerations
  - What application?
  - Benchmarking
  - Available area/ structural loading
  - $/W installed cost

Picture Source: Solar Builder Magazine, https://solarbuildermag.com/energy-storage/hiding-in-plain-sight-will-rooftop-batteries-lead-the-next-era-of-solar-storage/

5 PV Watts Modeling Tool

- Developed by National Renewable Energy Laboratory (NREL)
- Free web app
- Estimate electric generation
  - User specified system design, configuration, location
  - Solar and TMY weather data

5 PV Watts Modeling Tool

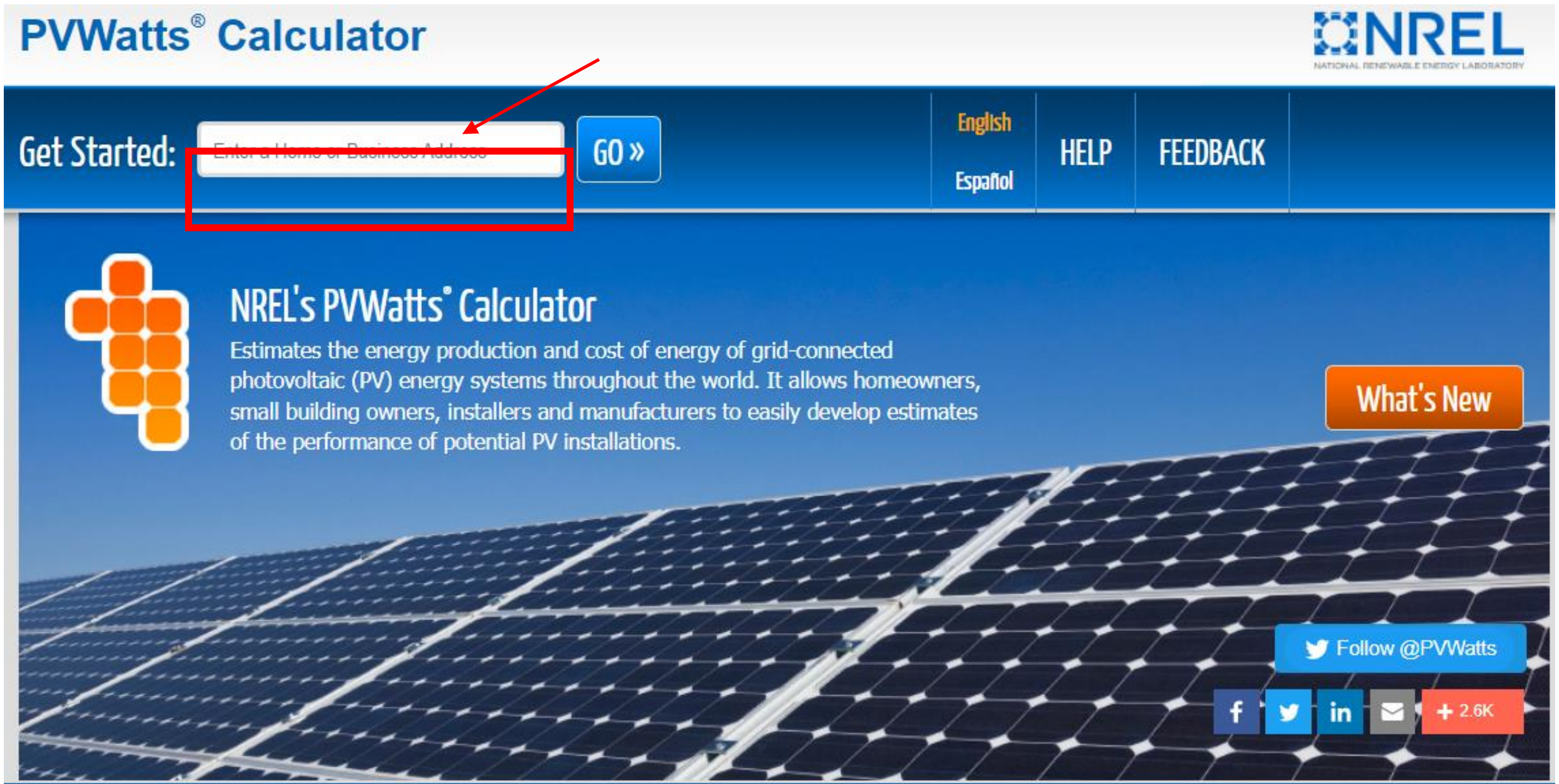
- **Required Inputs:**
  - DC System Size
  - Module Type – Standard, premium, thin-film
  - Array Type – Fixed (open rack or roof mount), 1, or 2-axis tracking
  - System losses – soiling, shading, line losses, degradation, etc.
  - Array Tilt Angle
  - Array Azimuth Angle (orientation)

Module Type Options

PVWatts® Module Type	Cell Material	Approximate Nominal Efficiency	Module Cover	Temperature Coefficient of Power
Standard	Crystalline Silicon	15%	Glass	-0.47 %/°C
Premium	Crystalline Silicon	19%	Glass with anti-reflective coating	-0.35 %/°C
Thin Film	Thin film	10%	Glass	-0.20 %/°C

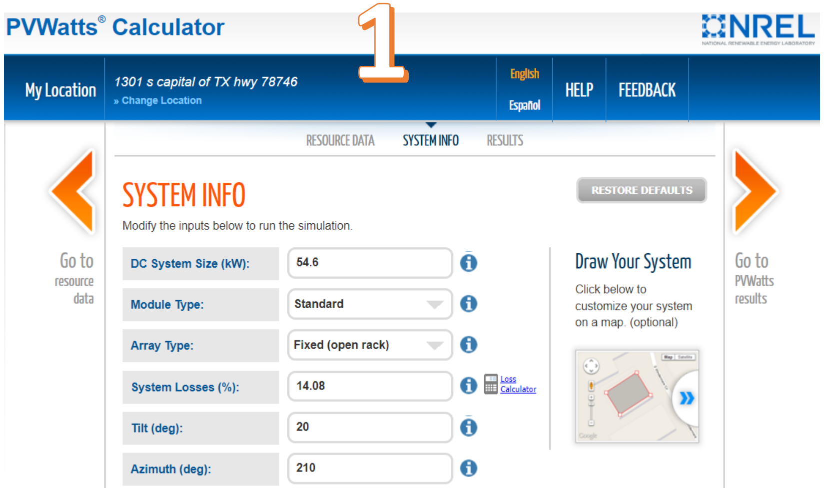
- **Optional Inputs:**
  - DC to AC Size Ratio
  - Inverter efficiency
  - Ground coverage ratio (GCR)

PVWatts® Calculator



PVWatts® Calculator

1



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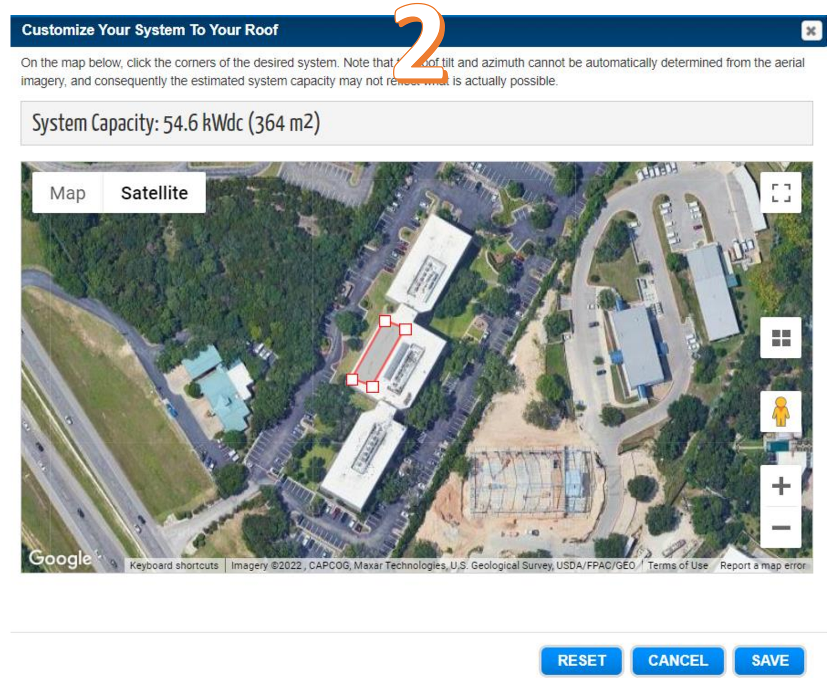


3

RESOURCE DATA | SYSTEM INFO | RESULTS

Go to system info

RESULTS

Print Results

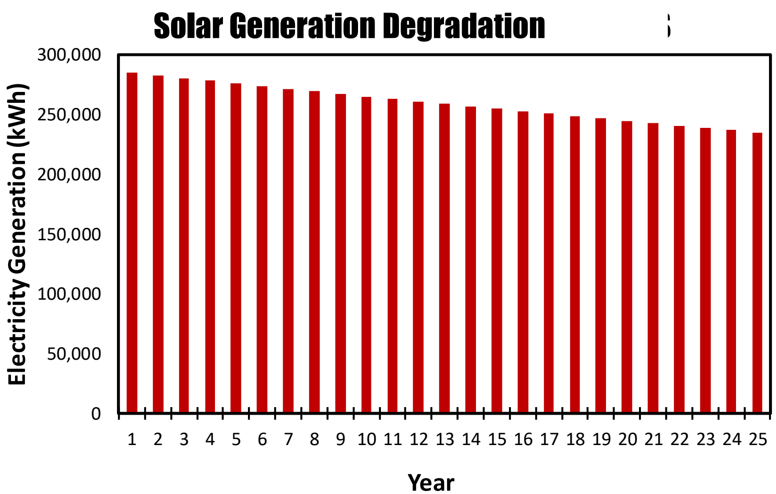
80,662 kWh/Year*

System output may range from 78,726 to 82,453 kWh per year near this location. Click HERE for more information.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	4.04	5,405
February	4.82	5,657
March	5.22	6,817
April	5.92	7,301
May	6.03	7,596
June	6.40	7,634
July	6.74	8,118
August	6.71	7,976
September	5.82	6,892
October	5.22	6,563
November	4.55	5,661
December	3.75	5,042
Annual	5.44	80,662

6 Degradation Over Time

- Usual range observed: 0.2-1.0% / year
- Average 0.5–0.8% /year*
- 20% degradation is considered the end of useful life
- Panel will continue to generate power beyond this point.



Estimated solar generation degradation

7 Incentives and Funding

- Utility Rebate Programs
- SECO LoanSTAR
- Qualified Energy Conservation Bonds (QECB)
- Energy Efficiency and Conservation Block Grant (EECBG)
- New Clean Renewable Energy Bonds
- Power Purchase Agreement (PPA)
- ESPC funded
- Advantages and Disadvantages must be evaluated on an individual basis.

8 PV System Cost/ Payback

- Average Solar PV System Cost $1,790/kW (rooftop >200-kW)
- Average Solar PV System Size 55 SF/kW
- Average annual electric output 1,300 kWh per kW
- Therefore a 200 kW Solar PV System will
  - require 11,000 SF
  - cost $358,000
  - produce 260,000 kWh/yr
  - at $0.10/kWh will save $26,000/yr
  - simple payback of 13.8 years

Table ES-2. Q1 2021 PV and Energy Storage Cost Benchmarks

Cost Benchmarks[a]	PV System
Residential Systems	
$2.65/W$_{DC}$ (or $3.05/W$_{AC}$)	7.15-kW$_{DC}$ rooftop PV
$4.26/W$_{DC}$ –$4.72/W$_{DC}$	7.15-kW$_{DC}$ rooftop PV with 5 kW$_{DC}$/12.5 kWh[b] $_{nameplate}$ of storage
Commercial Systems	
$1.56/W$_{DC}$ (or $1.79/W$_{AC}$)	200-kW$_{DC}$ rooftop PV
$1.64/W$_{DC}$ (or $1.88/W$_{AC}$)	500-kW$_{DC}$ ground-mounted PV
$1.97/W$_{DC}$ – $2.06/W$_{DC}$	1-MW$_{DC}$ ground-mounted PV colocated with 600 kW$_{DC}$/2.4 MWh$_{usable}$ of storage

Source: NREL - PV Watts, www.pvwatts.org
U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks: Q1 2021

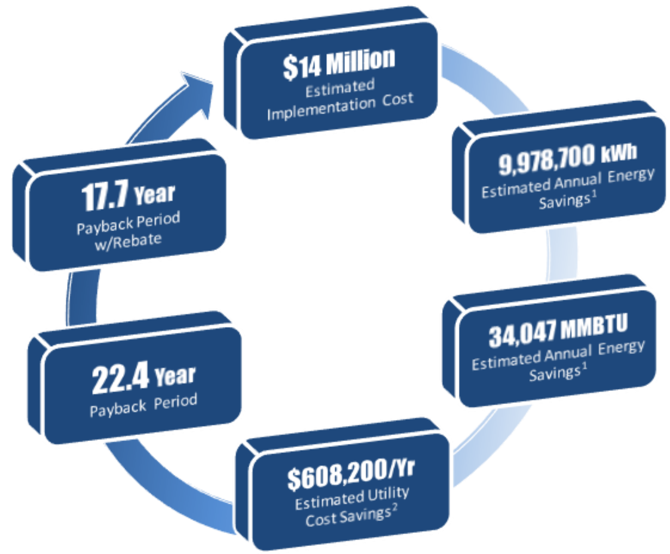
Assumed PV System located in Austin, TX.

No incentive, rebate, tax credit or utility rate escalation assumed.

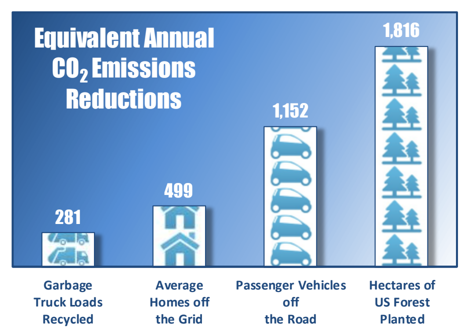
Case Study: Austin ISD (2019 SECO TA Rpt.)

Facility	PV Array Size (kW-DC)	Cost ($)	Year 1 Generation (kWh)	Avg. Generation[1] (kWh)	Payback (Yrs)	Payback w/PBI (Yrs)
Anderson HS	522	$955,700	734,500	668,100	19.4	14.8
Crockett HS	371	$716,000	522,400	475,200	20.5	15.9
Eastside HS	394	$754,000	554,400	504,300	20.4	15.7
LBJ HS	739	$1,249,600	1,040,600	946,600	17.8	13.3
Travis HS	398	$761,400	560,700	510,000	20.3	15.7
Ann Richards MS	605	$1,075,200	851,400	774,500	18.8	14.2
Blazier Relief MS	147	$316,700	207,200	188,500	23.1	18.4
Fulmore MS	297	$587,700	418,400	380,600	21.1	16.4
Lamar MS	117	$260,000	160,000	145,500	24.7	19.9
Mendez MS	131	$286,000	178,100	162,000	24.4	19.6
Murchison MS	226	$457,200	317,600	288,900	21.7	17.0
Small MS	119	$263,200	155,900	141,800	25.7	20.9
Webb MS	345	$671,200	471,300	428,700	21.4	16.7
Baranoff ES	185	$382,900	260,000	236,500	22.2	17.5
Brown ES	97	$218,600	136,200	123,900	24.4	19.6
Cook ES	194	$398,900	273,600	248,900	22.0	17.3
Cowan ES	119	$263,000	160,900	146,400	24.8	20.1
Doss ES	200	$407,700	281,200	255,800	21.8	17.2
Govalle ES	204	$416,400	287,600	261,600	21.8	17.1
Guerrero-Thompson ES	168	$354,300	236,600	215,200	22.6	17.9
Houston ES	201	$409,300	282,400	256,900	21.8	17.1
Menchaca	315	$618,700	443,100	403,100	21.0	16.3
New SW ES	199	$406,400	280,000	254,700	21.9	17.2
Odom ES	181	$376,900	255,000	232,000	22.3	17.6
Palm ES	98	$221,300	128,800	117,200	26.2	21.4
Pillow ES	135	$294,700	190,600	173,400	23.4	18.7
Reilly ES	89	$202,500	125,300	114,000	24.6	19.8
Ridgetop ES	63	$147,500	89,200	81,100	25.2	20.4
Walnut Creek ES	202	$411,100	283,700	258,100	21.8	17.1
Wooten ES	65	$152,100	92,000	83,700	25.2	20.4
PROJECT TOTAL SUMMARY	*7,128 Total kW-DC*	*$14,036,200 Est. Cost*	*9,978,700 kWh Total Generation*	*9,077,200 kWh Avg. Generation*	*22.4 Year Payback*	*17.7 Year Payback*

1) Average generation was taken over a 25 year lifetime of PV arrays.



(1) Based on Year 1 generation of identified Solar PV potential
(2) Based on revenue from average PV generation over 25-year lifetime of PV arrays (not including rebates)



Design & Construction Considerations

- Permitting and inspection
- Structural
  - “Dead load”
  - “Live loads”
  - Wind Loading
  - Seismic forces
  - Snow accumulation
- Roof warranties
- Fire Classification/ Rating
- Maintenance & monitoring
- Warranties
  - System, components & labor
- Available area
  - Module spacing
  - Servicing pathways
- Roof height
- Monitoring systems and software
- NEC (Electrical Code)
- Rapid shutdown capabilities

Questions?

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