Solar Resource

My solar trackers

Home for which wind load is important.

5 kw Solar, - 450$ annual energy cost

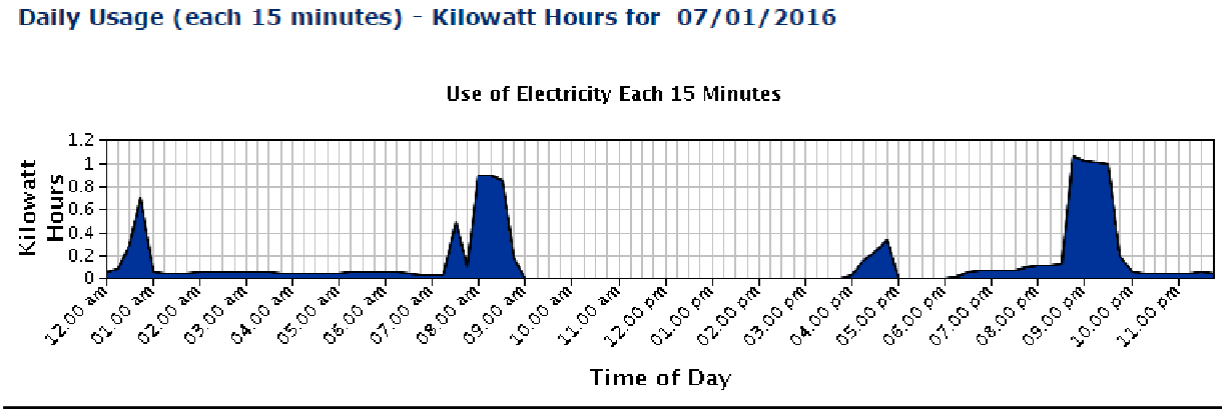
A DIY Solar – with ill-advised practices

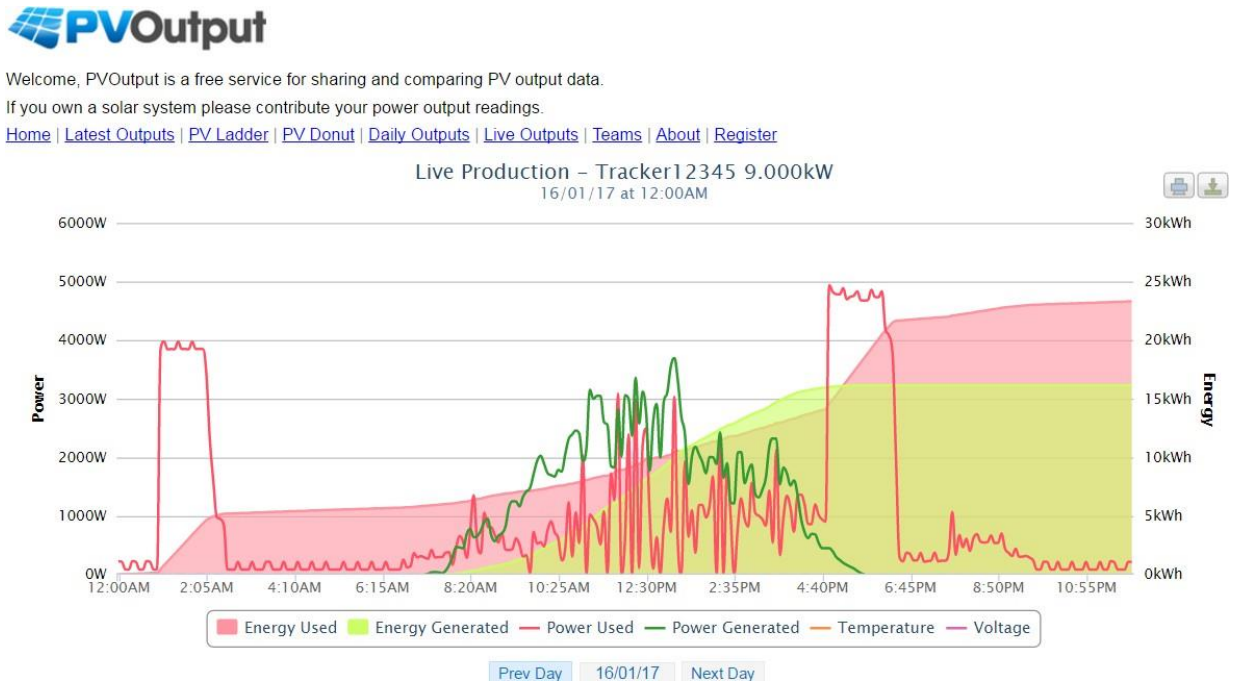
This Handout for Solar Workshop – Brouse to

"HoustonRenewableEnergy.org"

See Events tab. See Solar

Workshop. RSVP There.





Topics:

1. Inverter Types

2. **First Steps**

    A. What would it cost to harvest base load energy?

B. How much area would I need for this?

3. Permitting in Houston

4. Local Source for Components

5. Solar Resource by City

6. Solar IV Curve

7. Local Solar Costs

8. Labor Costs

9. Value of Solar calculator

10. Life of PV panels and Inverters

11. Online Video Discussions

12. Smart-Phone Applications

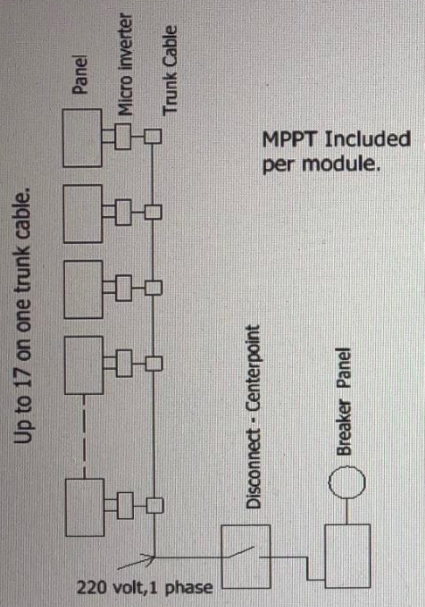
13. Grounding

14. Voltage Drop Calculations

15. Entry Cost

Three basic types of PV Arrays

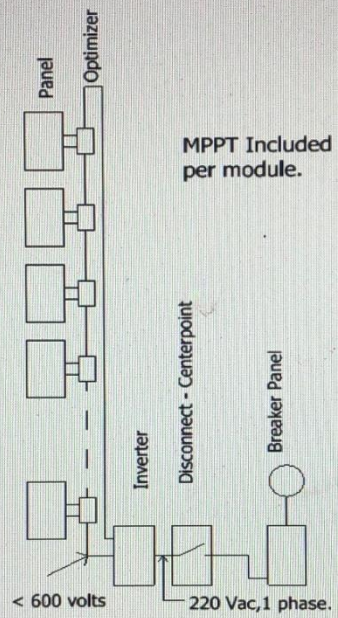
1. Microinverter based



Pros:
1. Can start with one panel ($210) plus racking for expected array size
2. Module level tracking / health.
3. Shading takes out just panel shaded.
4. 25 year warranty
5. Rapid shutdown easy for firefighters.
6. No high voltage wiring. 240 Vac off the roof.

Cons:
1. More expensive than #2
2. Ease of installation
3. Trunk cable is extra expense.

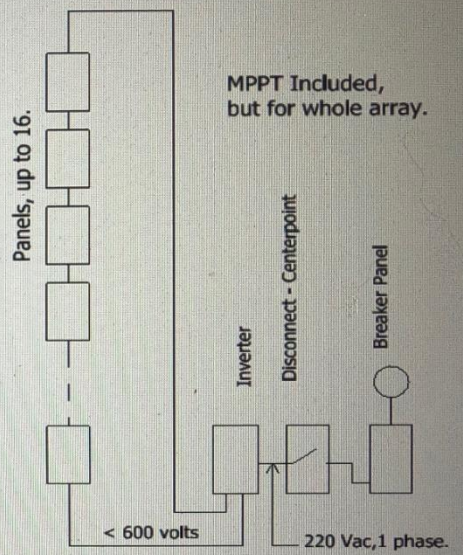
2. Solar Edge



Pros:
1. 3000 watt min Inverter size.
2. Module level tracking / health.
3. Shading just takes out panel shaded.
4. Warranty - 25 yr on optimizer,12 yr on Inverter.
5. Rapid shutdown easy for firefighters.

Cons:
1. Last expensive - they say.
2. More complicated installation than #1.
3. High voltage wiring to inverter <600 volts.

3. String inverter



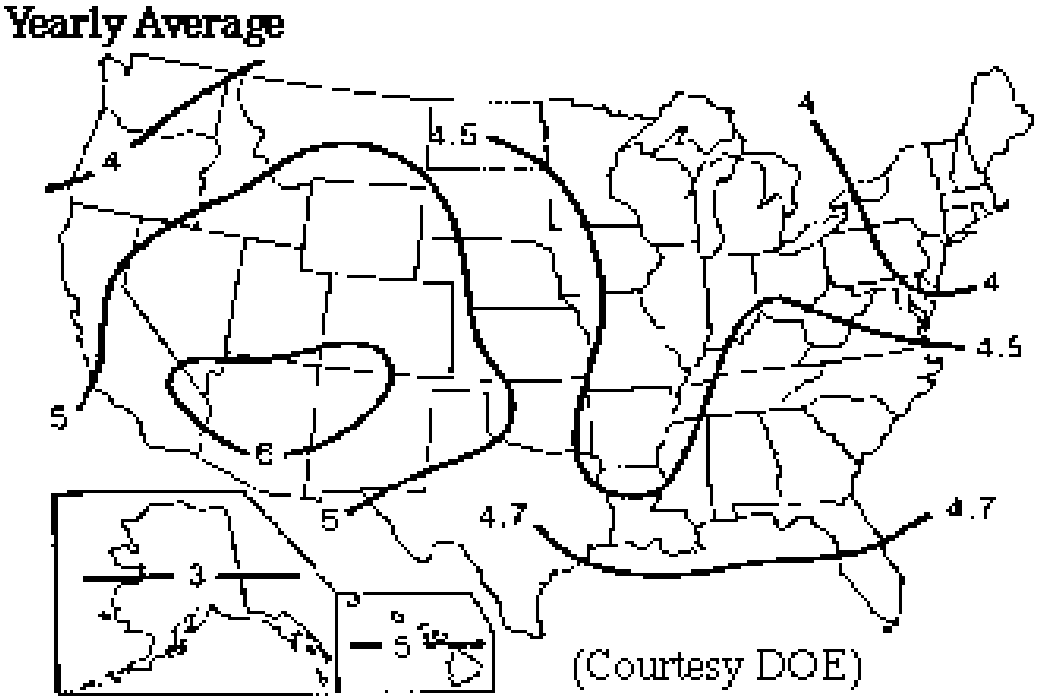
Pros:
1. No module level monitoring.
2. Warranty - 15 years
3. Sapid shutdown requires extra component.

Cons:
1. Shading takes out whole array.
2. More complicated installation than #1.
3. High voltage wiring to inverter <600 volts.

2. First steps

What is the size of the array?

Look at your utility bill. Say you want to provide 750 kWatt-Hr per month. That is 25,000 watt- hours per day. (750*1000/30).



Google “NREL Data Tables”. In Houston, we receive 4.7 hours per day of full sunshine, yearly average. (Ranges from 3.6 in January to 5.5 in August)

Divide 25,000 watt-hours / 4.7 hours = 5319 Watts. The conversion process is not perfect. Assume we get 80% of the power coming in. So we need 5318 watts / 0.8 = 6648 watts. **A rule of thumb**: **Multiply the KW-hr per month by 9 to get the array size.**

How large of an array can I place on the roof?

Measure the roof or ground area for panels, in square feet. If on a roof, avoid vent pipes and shadows from adjacent roof sections. If in doubt, use a Solar Pathfinder to evaluate shading. **Rule of thumb: Divide the watts by 15 to obtain the array size in square feet.** Example: 6648 watts (above) requires an array size of 6648 / 15 = 443 ft^2, or 21' x 21'.

What about the Years to pay for the array, or the return on investment (ROI)?

1. The value of energy harvested is what you pay per kilowatt hour. Go to PowerToChoose.org to see this. It ranges from 8.7 to 17 cents / kwh. (2019) Also look at <https://www.TexasPowerGuide.com>.

2. The annual energy produced is obtained from PVWATTS. Key in your address, and in advanced parameters, what you pay for energy. The result is production in kwh/year and $/year.

3. The going rate for an installation in Houston is $3 / watt. This includes everything, and is negotiable. If a DIY, the components cost $0.75 / Watt, and falling.

4. Assume you have 4000 watts. The cost is 4000 watts (3$/watt)(0.7) = $8400. The 0.7 is the federal tax credit. You have to owe tax in order to take this credit. (DIY – 4000watts x 0.75$/watt x 0.7 = $2100)

5. Years to pay for system ranges from 5600/242 = 23 years to 8400/630 = 13.3 years. (DIY – 3.3 Years)The reciprocal of the numbers (ROI) is 1/13.3 = 7.5% to 1/3.3 = 30 %.

You do the system layout, get the building permits and provide the labor of installation.

3. Permitting in Houston

1. COH: See notes below.

2. Centerpoint: https://www.centerpointenergy.com/en-us/Services/Pages/wind-solar-application-guidelines.aspx?sa=HO&au=res

3. Houston adopted the 2015 IRC unanimously. It requires that all new residential construction be solar ready. This means 600 ft^2 of clear space on the west or south roof for solar PV.

4. Local source for components:

1. Racking – Ironridge.com. Try the Design Assistant, which will give a racking cost, in $/watt for your array.

5. Solar Resource by City:

By zip code - http://pvwatts.nrel.gov/

Key is Zip or address at the top. Go to advanved parameters and key in the cost of your energy. Press the rightmost arrow, Go to System info….. Have fun.

6. **Solar IV Curve –** Parameters are listed on solar panel label.

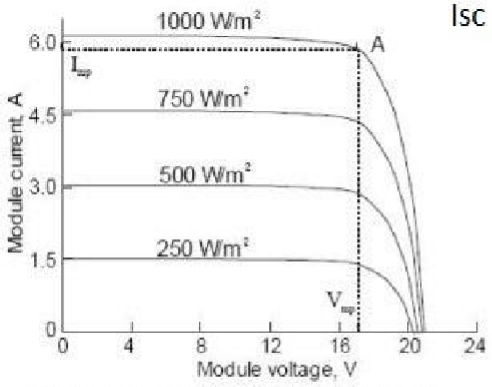


Figure 1. Dependence of current and voltage on incident sunlight levels.

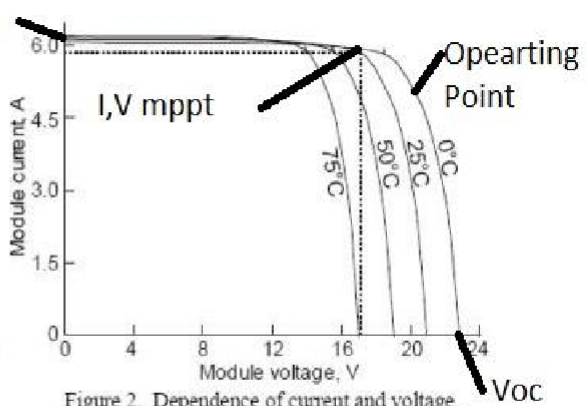


Figure 2. Dependence of current and voltage on temperature for sunlight level of 1000 W/m².

I_{sc} = Current when the panel leads are short circuited.

V_{oc} = Voltage measured at the panel leads – open circuit.

V_{mp}, I_{mp} = Voltage or current at maximum power.

Most inverters and some charge controllers are have MPPT = Maximum Power Point Trackers.

7. Local Solar Costs:

1. Panels and Micro inverters – 0.75 $/Watt (3/10/17). Before federal rebate.

2. Panels - $0.50 / watt

3. Racking – 0.37 $ / watt.

4. Other costs – Permit fee, conduit and lockable disconnect, Fee to Centerpoint. Labor and engineering costs.

8. Labor Costs:

1. Racking installation –Ironridge.com is a good resource –If you use Ironridge, for instance, the certification by a PE requirement (City of Houston permit requirement) may be waved, because the racking has been pre-certified by UL.

2. Running Conduit – Someone has to do it. If an outdoor run is installed, use watertight connections. Also might use conduit grounding bushings.

3. If ground mount is used, the buried home run is necessary. Use rigid PVC conduit. Often, digging an 18" deep trench is a difficult part of an install.

9. **Value of Solar calculator:** The value of the income stream by installing solar can be found with different metrics.

1. Payback Time = initial investment / value of power generated.

For 5 kW, with a DIY cost of install of 1.25$/watt, the cost is $6250 and the value of the energy is $633 / year. Payback time is 6250/633 = 9.8 years. This omits the 4% inflation in the cost of energy.

2. Return on Investment – Compute (1 / payback time). In the above example – 1/9.8 = 10.2 Percent

3. LCOE http://en.wikipedia.org/wiki/Cost_of_electricity_by_source

4. NREL program "SAM" https://sam.nrel.gov/ advanced financial modeling software.

10. Life of PV panels and Inverters.

1. Panels degrade at < 0.5%/year. Performing in 20 years at $(.995)^{20} = 0.904 = 90\%$. In 40 years, it is $(.995)^{40} = 0.81 = 81\%$. I might add that when you purchase panels, you should get 3 rd. party insurance in case the panel manufacturer goes out of business.

2. Micro Inverters – Enphase – M250 – Warranted for 25 years

3. String Inverters – SMA – pay extra for a warranty greater than 15 years. http://www.sma-america.com

11. **Online video discussions** – For free 1 hour presentations, see http://solpowerpeople.com/solarmooc-newsletter-archive/

Subject matter from off-grid to grid connected systems, including the NEC code and system grounding... the list goes on and on.

12. Smart-Phone Applications

1. Unirac ToolBelt – Tools for field angle measurements.

2. Sun Seeker – Evaluate the sun path – 3-D

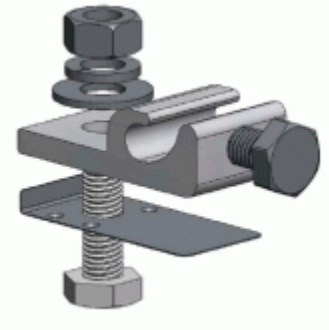
3. Mr. Sun – Solar position Utility

4. Solar PV Estimator – PV Cost estimator, based on location and load and % covered by solar.

5. HM Tracker – An i-Phone app for visualizing a solar tracker, and to evaluate wind forces.

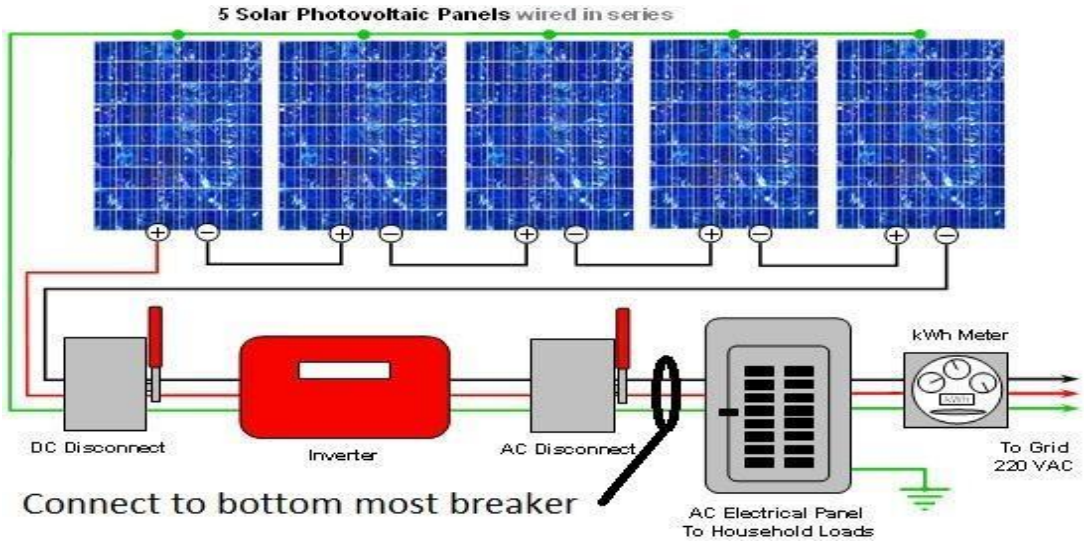
13. **Grounding:** All components are grounded with #6 bare copper. Panels are anodized aluminum, a surface treatment that makes the surface be a non-conductor. Because of the possibility of electrolytic action between dis-similar metals, stainless steel fasteners are recommended. Avoid the use of plain steel connectors. Also, a special washer – called a weeb washer is used because it has sharp, surface penetrating edges. It takes many forms.

Weebs should be used between the inverter and the panel frame. Components as shown below should be used. View this video on YouTube <https://www.youtube.com/watch?v=RafNjMV-49k>



14. **Voltage Drop Calculations:** The panel wiring is type USE-2 or PV wiring. It is sunlight resistant, and can carry the rated amps. The steps necessary to determine the wire gauge size are as follows: A panel has a rating I_{cs}(Current short circuit). You can short circuit panels, but NOT batteries. The I_{sc} value is multiplied by 1.25 to find the highest current that will ever occur. The circumstance for this is maybe a cold day, at

noon, with an atmospheric condition where additional radiation occurs because of cloud lensing. For wire sizing and fusing, the latter value is multiplied by another 1.25, making 1.56 x I_{SC}. Additional factors are applied for wire in conduit that is exposed to sunshine. For example, a PV string has current X to the combiner box. You may have to make up a lead for the home run (See PV schematic). Use the same ampacities as the PV wiring. At the combiner box, amperes increase by the number of strings. The design amps here is (X) times (1.56) times (# strings) times I_{SC}. To size the wire, factors will then be applied to keep the voltage drop below 1-3%. For instance, wires in conduit may heat up if exposed to sunlight. The factors are summarized in the NEC Code.



15. **Entry Cost –** Microinverters versus String Inverter.

The Sunny boy 6000TL-us costs $800 (Ebay4/2019), and the minimum input voltage is 150 volts. Maybe 5 panels make 150 volts. At $0.55 per watt, panels cost $687. So, the cost of entry is $800 + $687 = $1487. $/watt = $1487/(250*5) = $1.19. After fed rebate = 0.83$/watt. But there is the racking cost @0.37$/watt.

16. Organizations promoting renewables and sustainability

a. Texas Solar Energy Society

b. Texas Renewable Energy Industries Association - $

c. HARC – Houston Area Research Center

d. HREG-Houston Renewable Energy Group

e. HREN-Houston Renewable Energy Network- good networking breakfasts / socials with people working in renewables.

f. Solar United Neighbors – (google this) Group promoting group purchases of solar systems. 15% discounts are typical.

350.org – Group promoting the idea that parts per million of Carbon needs to be lowered from 410 to 350. Also view the Facebook page.

17. Miscellaneous links:

1. Bill Brooks, a solar expert. http://www.pge.com/includes/docs/pdfs/shared/solar/solareducation/inspecting_pv_systems_for_code_compliance.pdf

2. Webinars: http://www.solarabcs.com/

3. San Antonio has installed 500 megawatts of trackers. See - <https://www.youtube.com/watch?v=B_B3Q2lwrr4>

4. If you want to become NABCEP certified as an installer, look at http://www.nabcep.org/

5. Centerpoint requirements - http://www.centerpointelectric.com/cehe/bus/windandsolar

6. Typical string inverter layout - http://www.altestore.com/store/descfiles/kits2go/kitongrid/grid_tie_360w.jpg

7. Permitting, CoH –

https://edocs.publicworks.houstontx.gov/documents/divisions/planning/enforcement/1198_residential_solarpanel_pemit_and_inspection_guide.pdf

Amount of Solar Currently Installed in the U.S.

42.3 GV

State Ranking by Cumulative Solar Capacity

1 California - 18,304 MW
2 North Carolina - 3,013 MW
3 Arizona - 2,682 MW
4 Nevada - 2,365 MW
5 New Jersey - 1,982 MW
6 Utah - 1,489 MW
7 Massachusetts - 1,487 M W
8 Georgia - 1,409 MW
9 Texas - 1,215 MW
10 New York - 927 MW

Number of Solar Businesses in the U.S.*

9,000

In 2016, a new solar project was installed every

8*(seconds

Solar PV prices have fallen by n% over the last year, and by

53%

over the last 5 years

Number of Peopte **Employed by** the Solar Industry*: more than

260,000

Largest Solar Power Plants in Operation

SolarStar, CA-579MW
Topaz Solar Farm, CA-550MW
Desert Suntght, CA-550MW
Ivanpah. CA-392MW
Statetne Solar, NV-300 M\/V

Number of Solar Energy Systems Installed in the U.S.

1,346,000

Carbon emissions reduced:

52.3 million

metric tons annually, equivalent to:
-taking T1 million vehicles off the road
-5.9 billion gallons of gas not used
-planting Over 1.4 billion trees
shuttering 15 coal-fired **power plants**

For the first time ever, solar was the top source of new capacity, representing

39%

of installed electric capacity in 2016

Value of the U.S. Solar Market in2016

.8 BILLioN

In 2016, the U.S. installed

e6 G

of solar capacity, an increase of

95%

over2ol5

Top Corporate Solar Users*

1. Target - 147.5 MW
2. Walmart - 145 MW
3. Protogis - 107.8 MW
4. Apple - 93.9 MW
5. Costco - 50.7 MW
6. Kohl's - 50.2 IvlW
7. IKEA - 44 MW
8. Macy's - 38.9 MW
9. General Growth Properties - 30.2 M\N
10. Hartz Mountain - 22.7 MW

Since 2006, the solar market has grown an average of

68%

every year

There is enough solar energy installed in the U.S. to power

8.3 million

households°

SEIA Solar Energy Industries Association®

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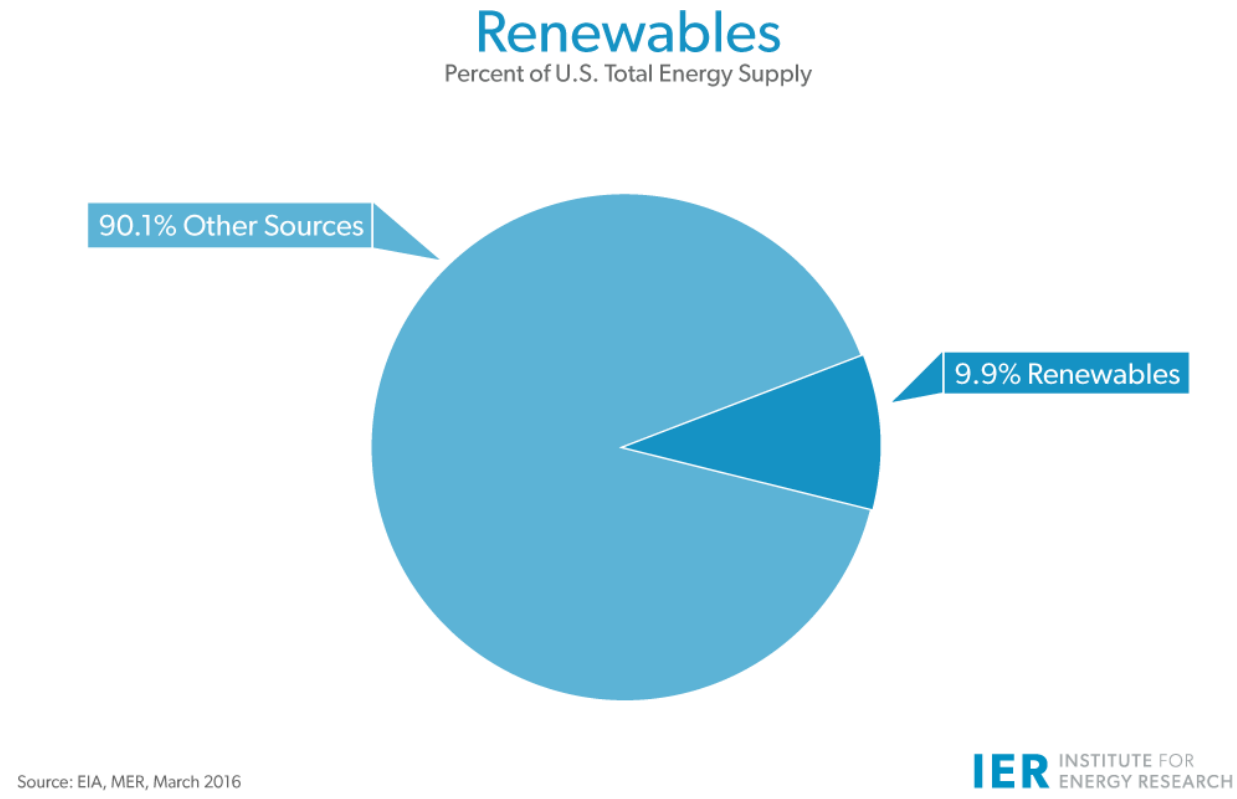

Prepared by Bill Swann-Ph:832-338-3080

e- Mail:William.swann2@gmail.com