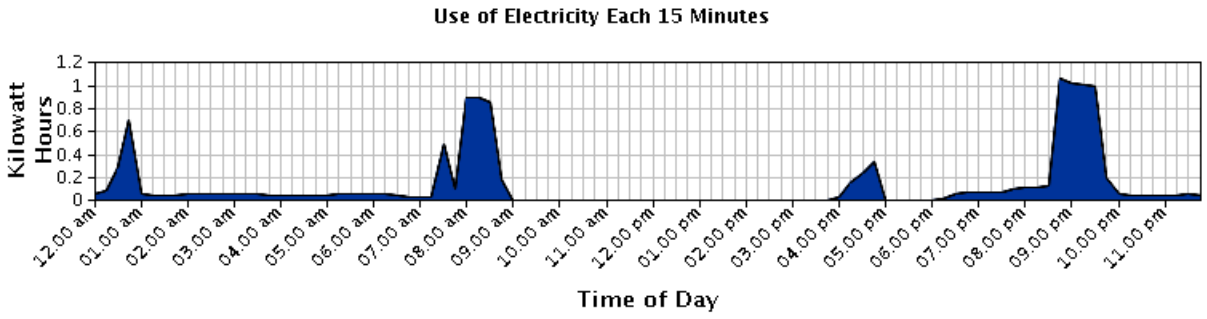
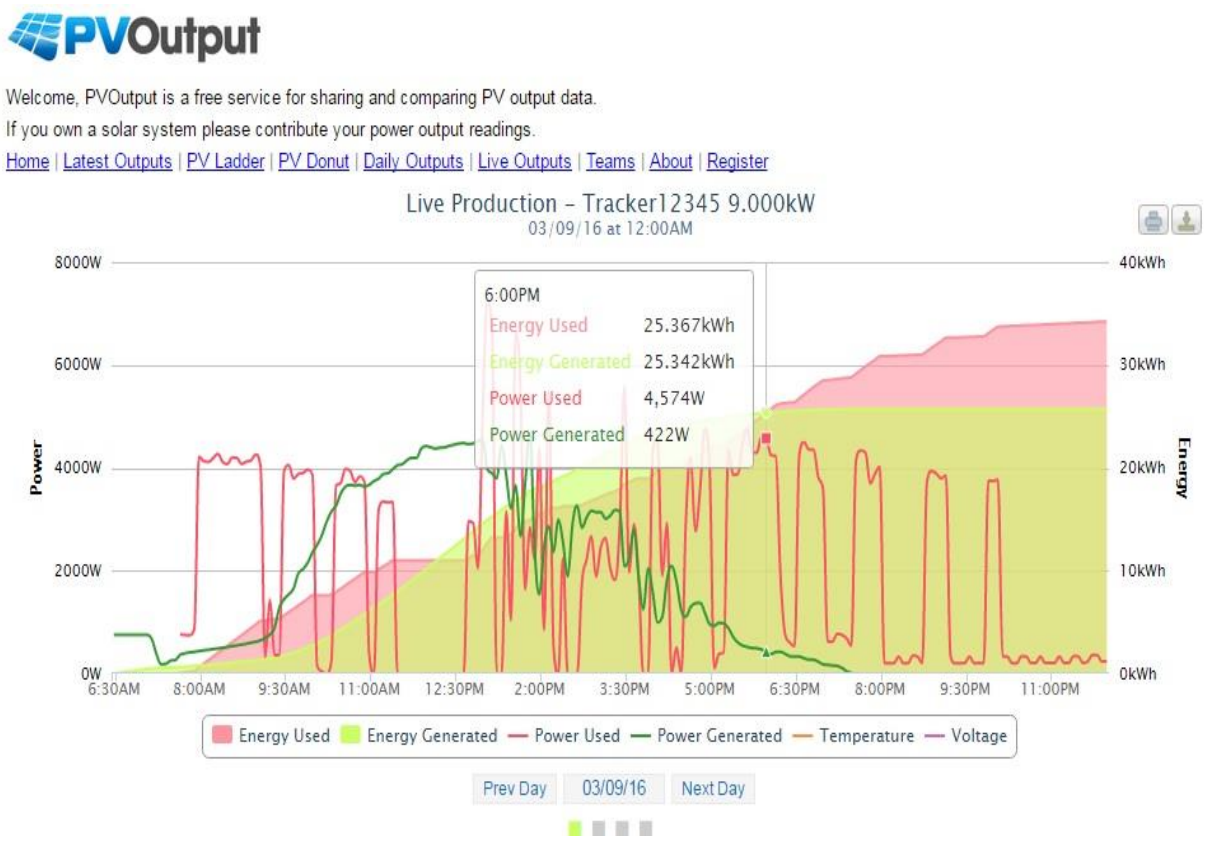
Solar Resource

Daily Usage (each 15 minutes) - Kilowatt Hours for 07/01/2016





Topics:

1. Array 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**

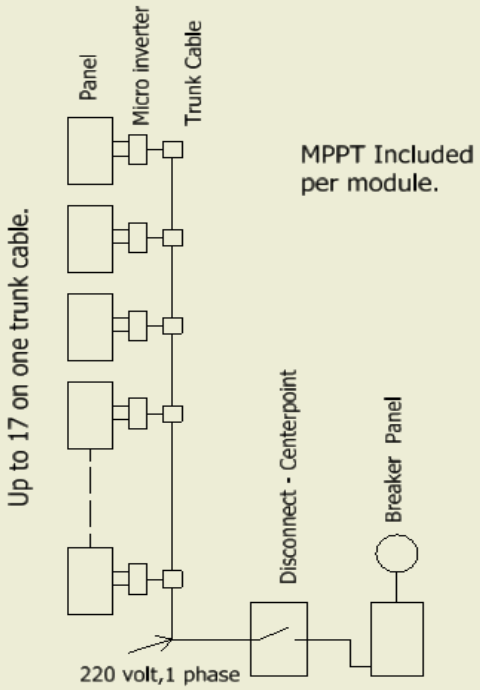
14. **Voltage Drop Calculations**

15. **Entry Cost**

16. **Texas based organizations promoting renewables**

Three basic types of PV Arrays

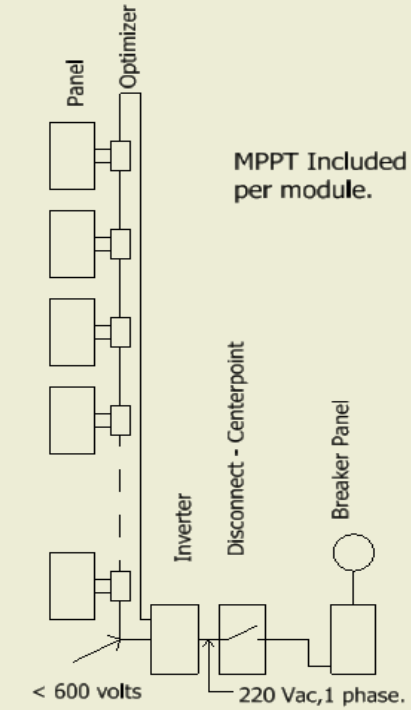
1. Microinverter based



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.

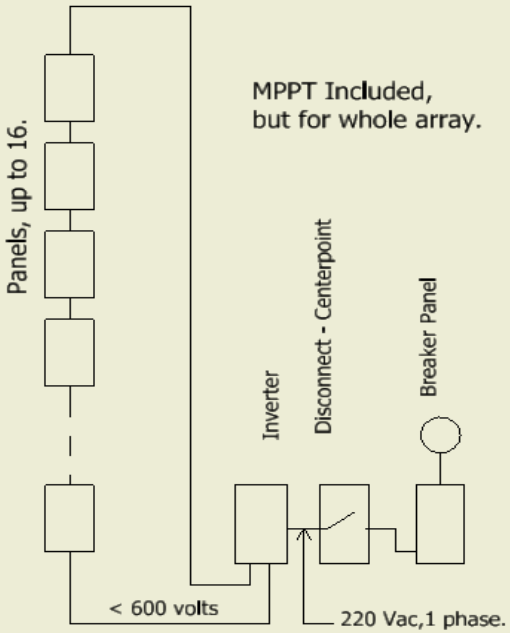
2. Solar Edge



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



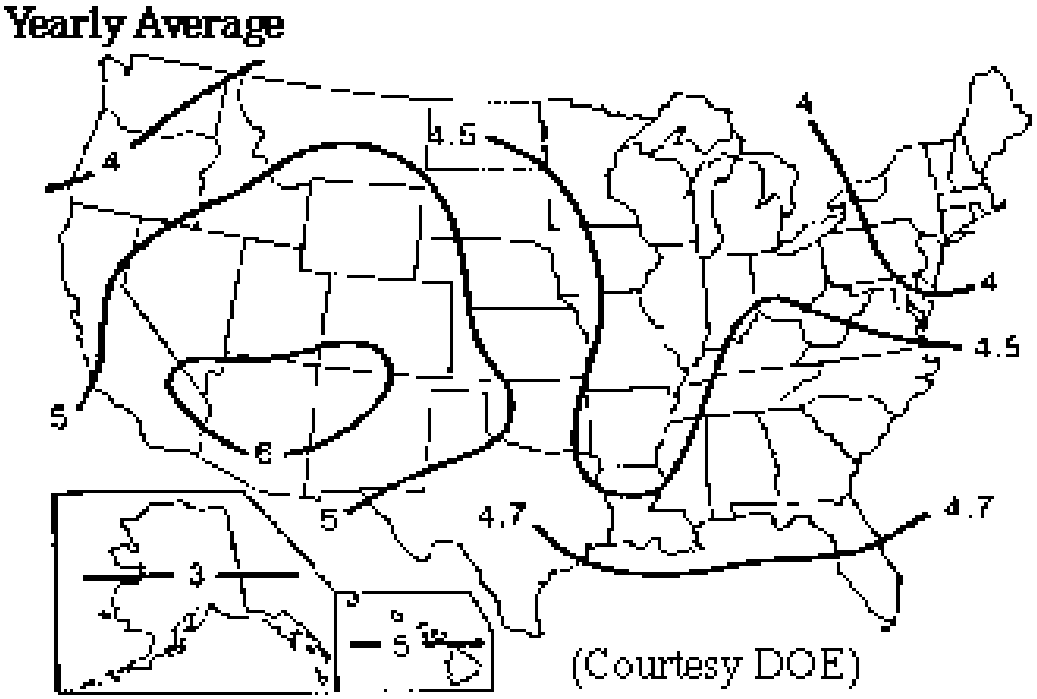
Pros:
1. No module level monitoring.
2. Warranty - 15 years
3. Sapid shutdown requires extra component.

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'.

3. Permitting in Houston

1. COH: www.solarhoustontx.org

2. Centerpoint: http://www.centerpointelectric.com/cehe/bus/windandsolar

4. Local source for components:

1. Houston Renewable Energy Group – For a current list of Houston based installers see http://houstonrenewableenergy.org/resources/business-directory/

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

5. Solar Resource by City:

1. Advanced version: By zip code - http://pvwatts.nrel.gov/

Key is Zip or address at the top. Press the rightmost arrow, Go to System info….. Have fun.

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

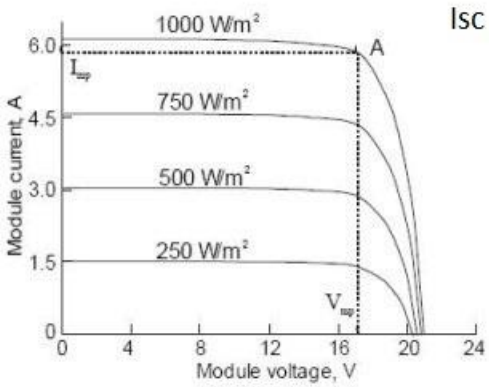


Figure 1. Dependence of current and voltage on incident sunlight levels.

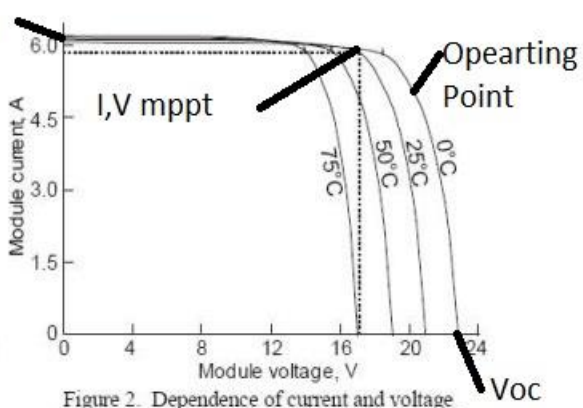


Figure 2. Dependence of current and voltage on temperature for sunlight level of 1000 W/m².

I_{sc} = Current when the panel leads are <u>short circuited.</u>

V_{oc} = Voltage measured at the panel leads – <u>open circuit</u>.

V_{mp}, I_{mp} = Voltage or current at <u>maximum power.</u>

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

<u>7. Local Solar Costs:</u>

1. Panels and Micro inverters – 1.20 $/Watt (4/25/2014). Before federal rebate.

2. Panels - $0.69 / watt

3. Racking – 0.33 $ / 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.

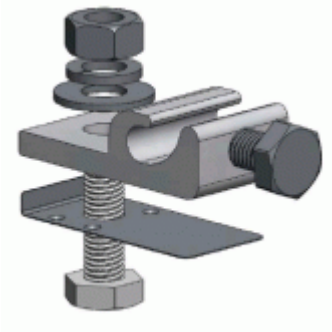
5. Watts of Sun- shows daily production with Enphase inverters.

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

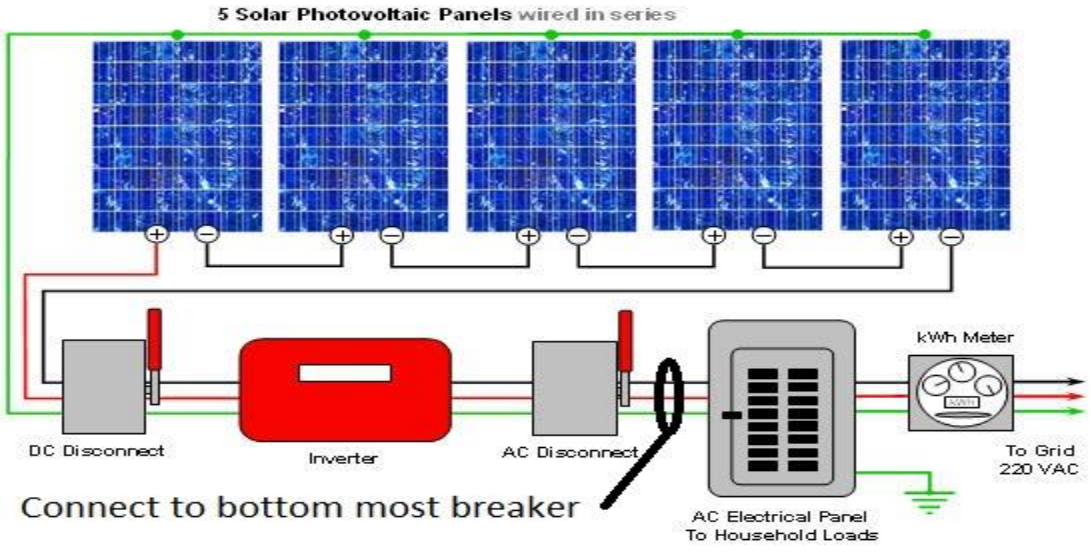
13. Grounding: All components are grounded with #6 bare copper. Panels are anodized aluminum, a surface treatment that makes the surface be a non-conductor. Because of the possibility of electrolytic action between dis-similar metals, stainless steel fasteners are recommended. Avoid the use of plain 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 3000TL-us costs $1600 (Ebay6/2016), and the minimum input voltage is 150 volts. Maybe 5 panels make 150 volts. At $0.65 per watt, panels cost $780. So, the cost of entry is $1600 + $780 = $2380. $/watt = $2380/(240*5) = $1.98.

If, on the other hand, a panel and micro-inverter were chosen, the entry cost is 240 x $1.20 = $288. $/watt = 288/240 = 1.20. The federal rebate has not been included. And the cost of racking and installation is not included.

16. **Statewide organizations promoting renewables**

a. Texas Solar Energy Society

b. Texas Renewable Energy Industries Association - $

c. HARC – Houston Area Research Center

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 is installing 400 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. Local classes for NABCEP certification. www.Ontility.com

and www.ImagineSolar.com have classes.

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

7. COH Permit requirements - http://www.solarhoustontx.org/LinkClick.aspx?fileticket=AG%2fTKH%2fgbzQ%3d&tabid=2666&mid=6494

8. Enphase M250 - http://enphase.com/m250/

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

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