



City of Palo Alto

Solar Power 101: Solar Electric Basics

Lucie Stern Community Center • May 17, 2014

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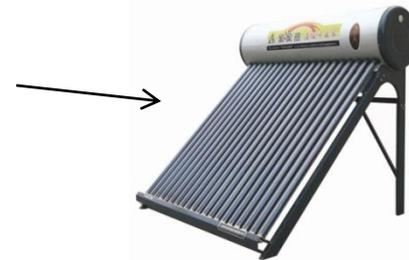
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Agenda

- What is Solar Power?
- Solar Today
- Solar Economics
- Steps to Making Informed Choices

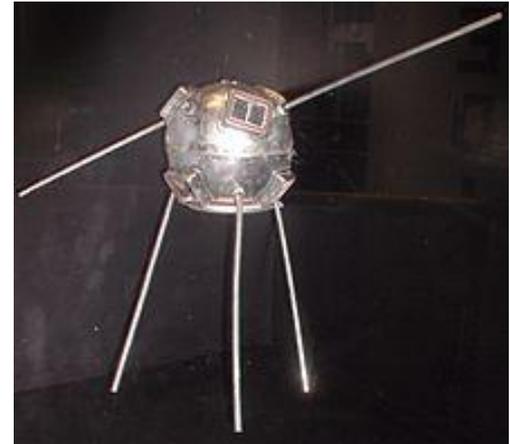
Types of Solar Power

- Solar Electric Power (Photovoltaic or PV)
 - Sunlight produces electricity →
 - The focus of this presentation
- Solar Thermal
 - Heat water for home or business use.
Check out www.cityofpaloalto.org/SWH
 - Concentrate heat to generate electricity.
Brightsource's Ivanpah project:
4,000 acres of mirrors →
- Many other forms
 - Desalinization, Photosynthesis
Passive solar ("green-houses"),
Pre-heating of ventilating air for
large buildings, ...



Short history of PV

- Edmond Becquerel discovered the photo-voltaic effect in 1839
- First practical solar cell: Bell Labs in 1954
- The Space Race in the 1950s/60s and the 1970's oil crisis propelled PV. Vanguard I was partly solar powered (1958). Exxon lowered PV costs using solar to help power offshore oil rigs
- Solar's booms and busts ("Solar Coaster"). On & off & on subsidies, shortages and oversupplies, industry volatility & uncertainty
- The present federal subsidy, running through 2016:
Tax credit of 30% of the full cost of the solar system



Presidential history of PV

- Pres. Carter put solar (hot water) on the White House in 1979
- Pres. Reagan, in 1981 in one of his first acts, ordered them removed
- Pres. GW Bush installed solar hot water and PV on a White House maintenance building in 2003
- Pres. Obama said in 2010 he would install solar on the White House roof by Spring 2011.

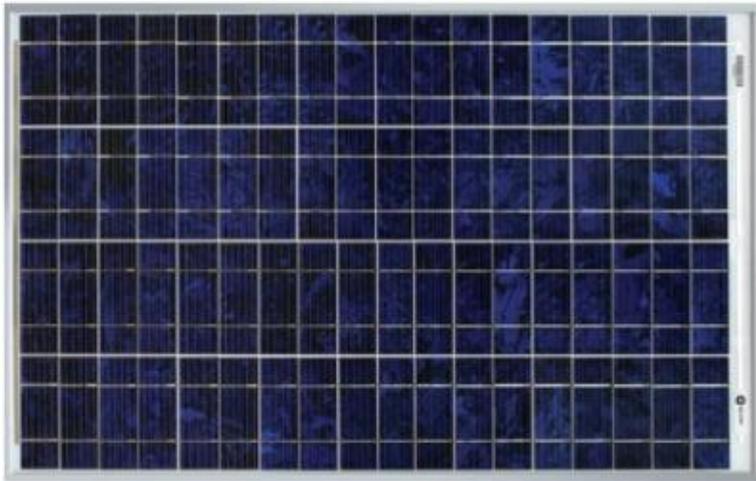
May 2014 – Done!



Most common PV panels

Mono-crystalline silicon

- Most expensive, most efficient, needs the least space



Poly-crystalline silicon

- Less expensive, less efficient, needs more space



Thin Film

- Least expensive, least efficient, needs the most space

Inverters get the electricity to the grid

String Inverter

Usually one per residential solar system



Micro-inverter

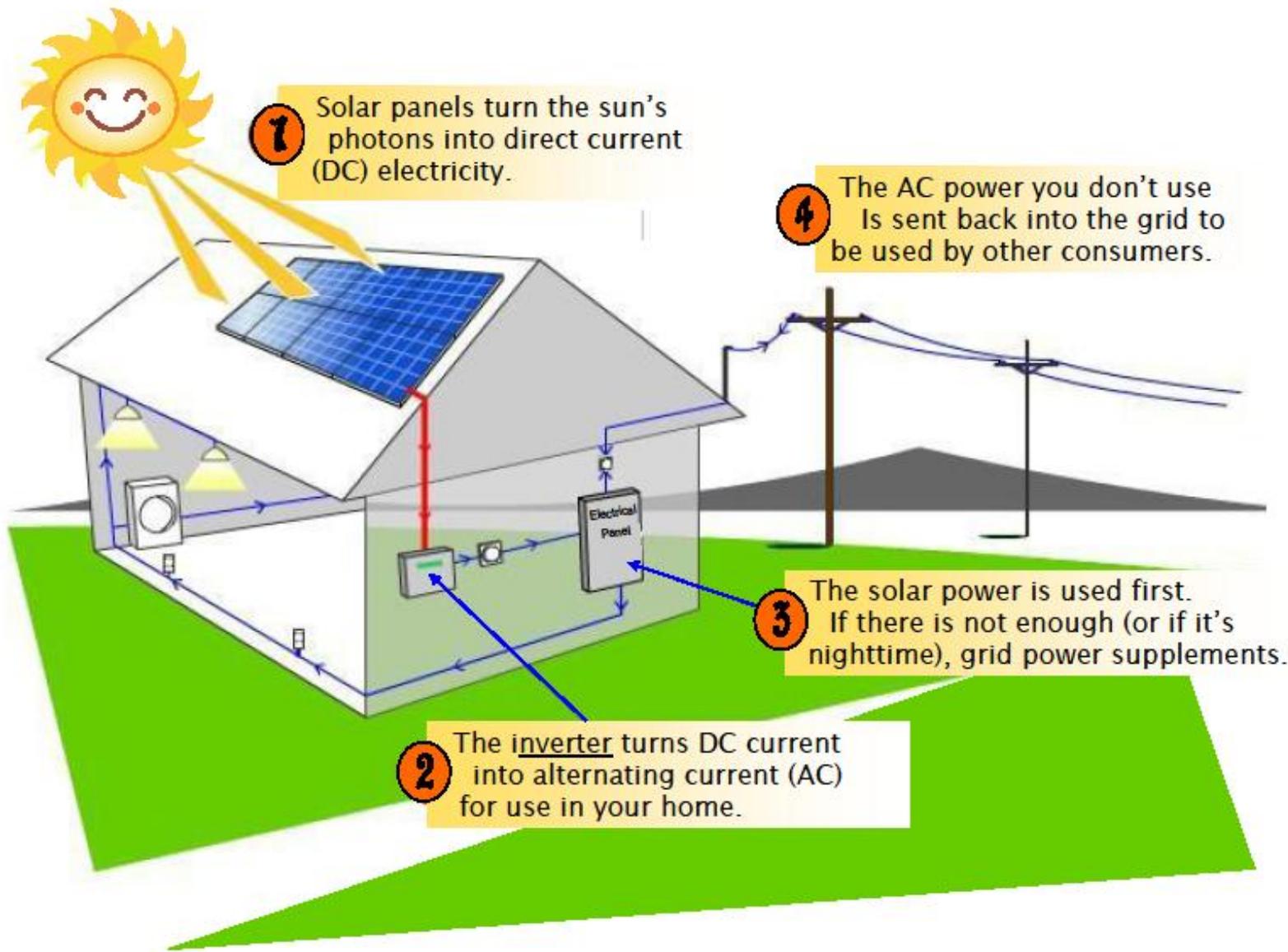
Usually one per solar panel



DC Optimizer

Usually one per solar panel;
still need a string inverter



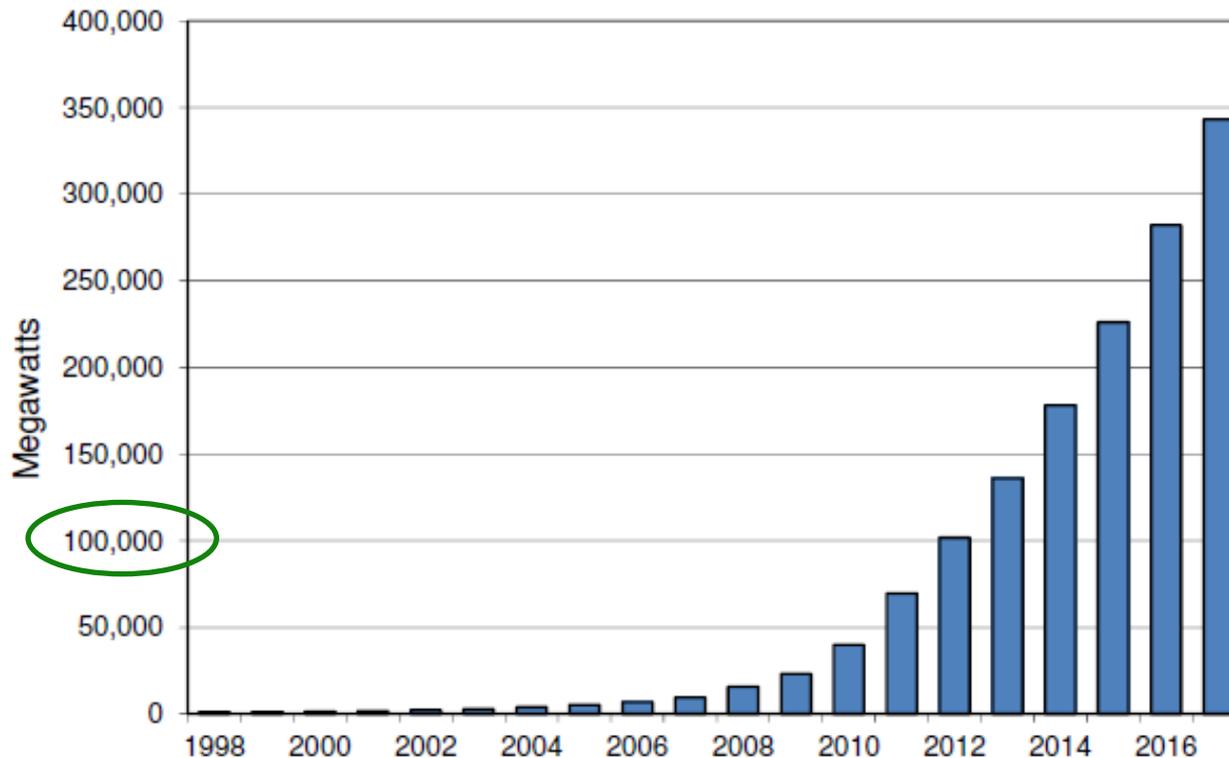


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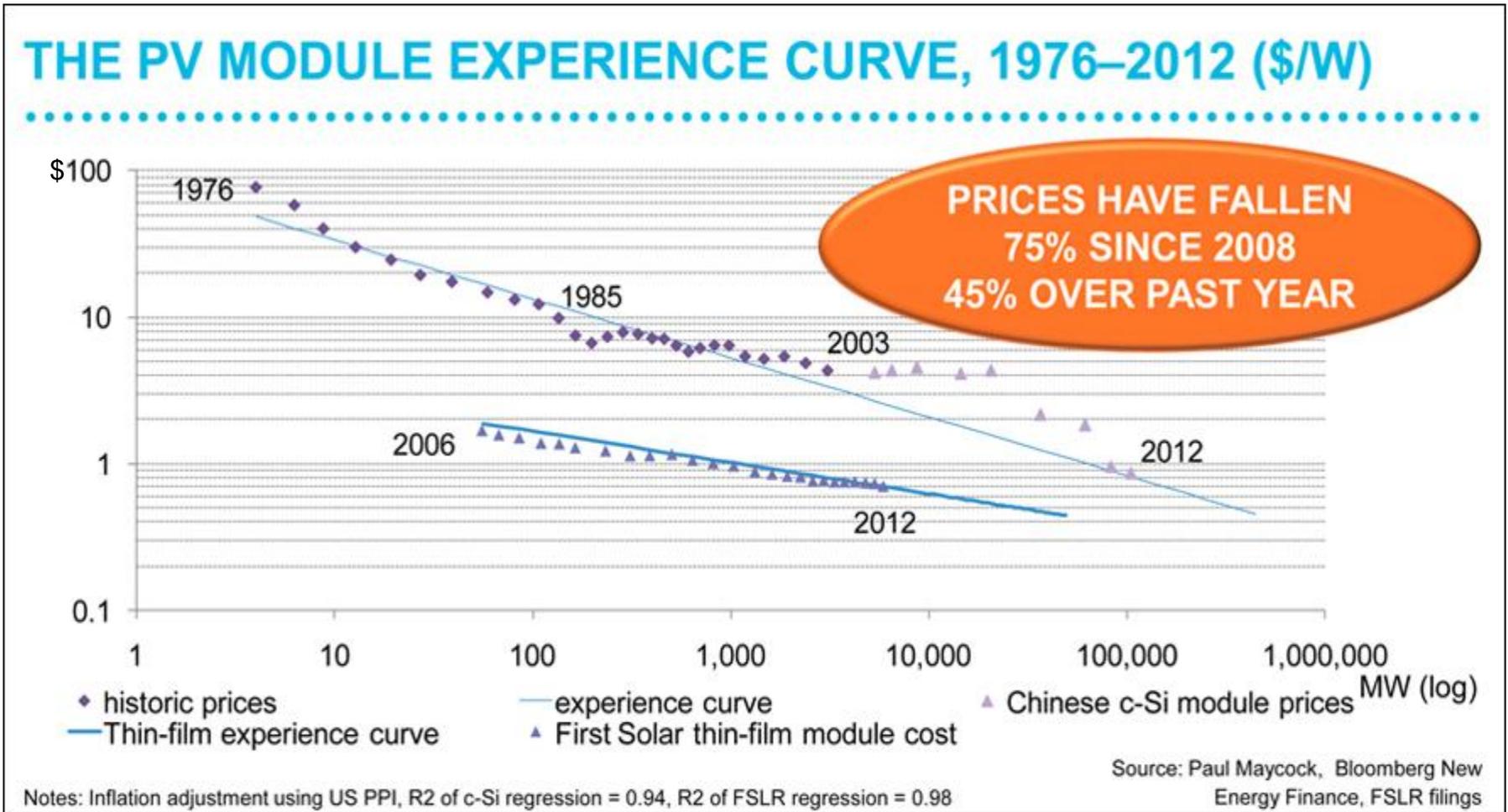
Many decades to install the first 100 GigaWatts (GW)
3 years to install the second 100 GW

World Cumulative Solar PV Installations,
1998-2012 (actual), 2013-2017 (estimate)



Sources: Europe PV Industry Association; Earth Policy Institute; Information Handling Services

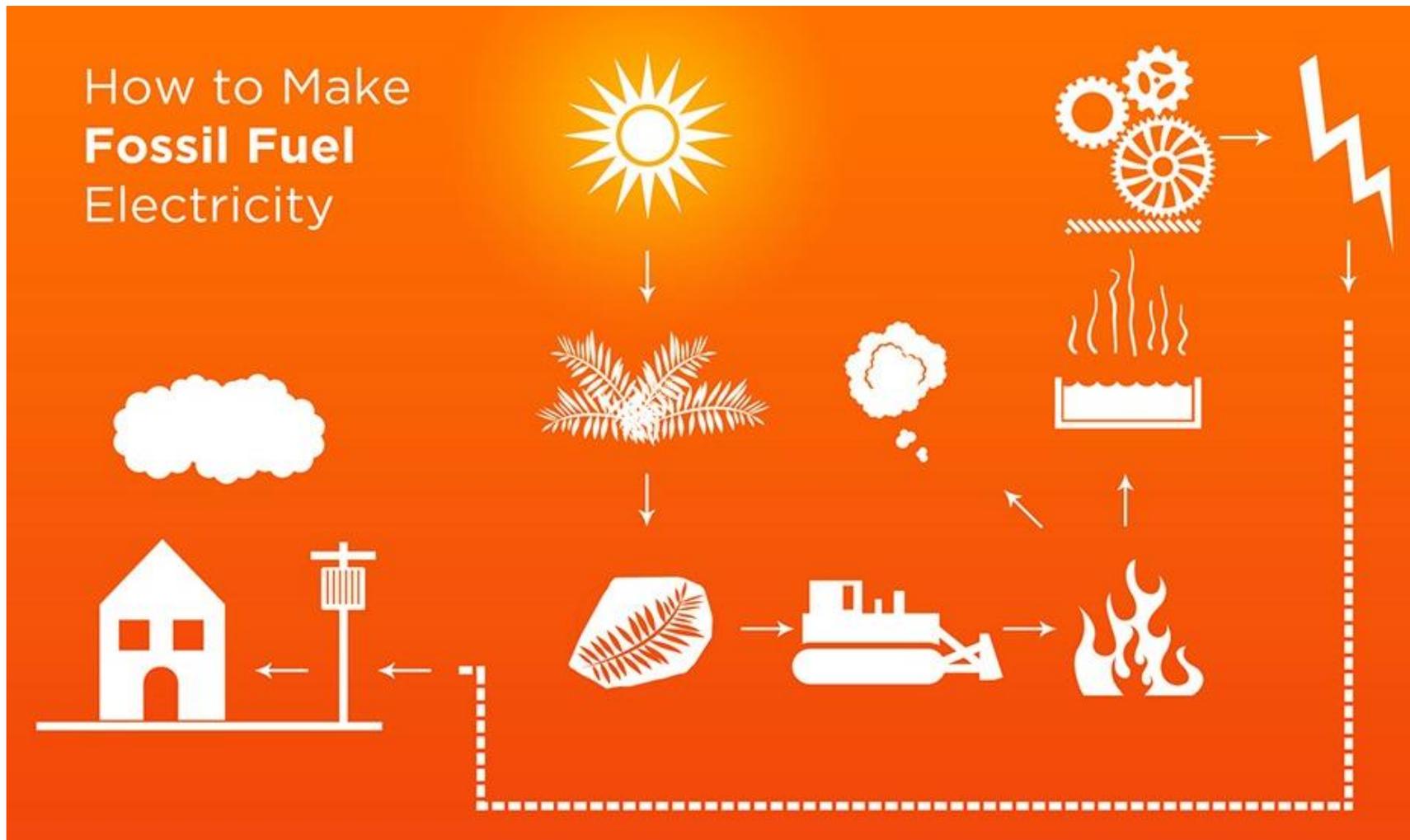
“Swanson Effect” - the cost of PV panels falls by 20% for each doubling of global shipped volume



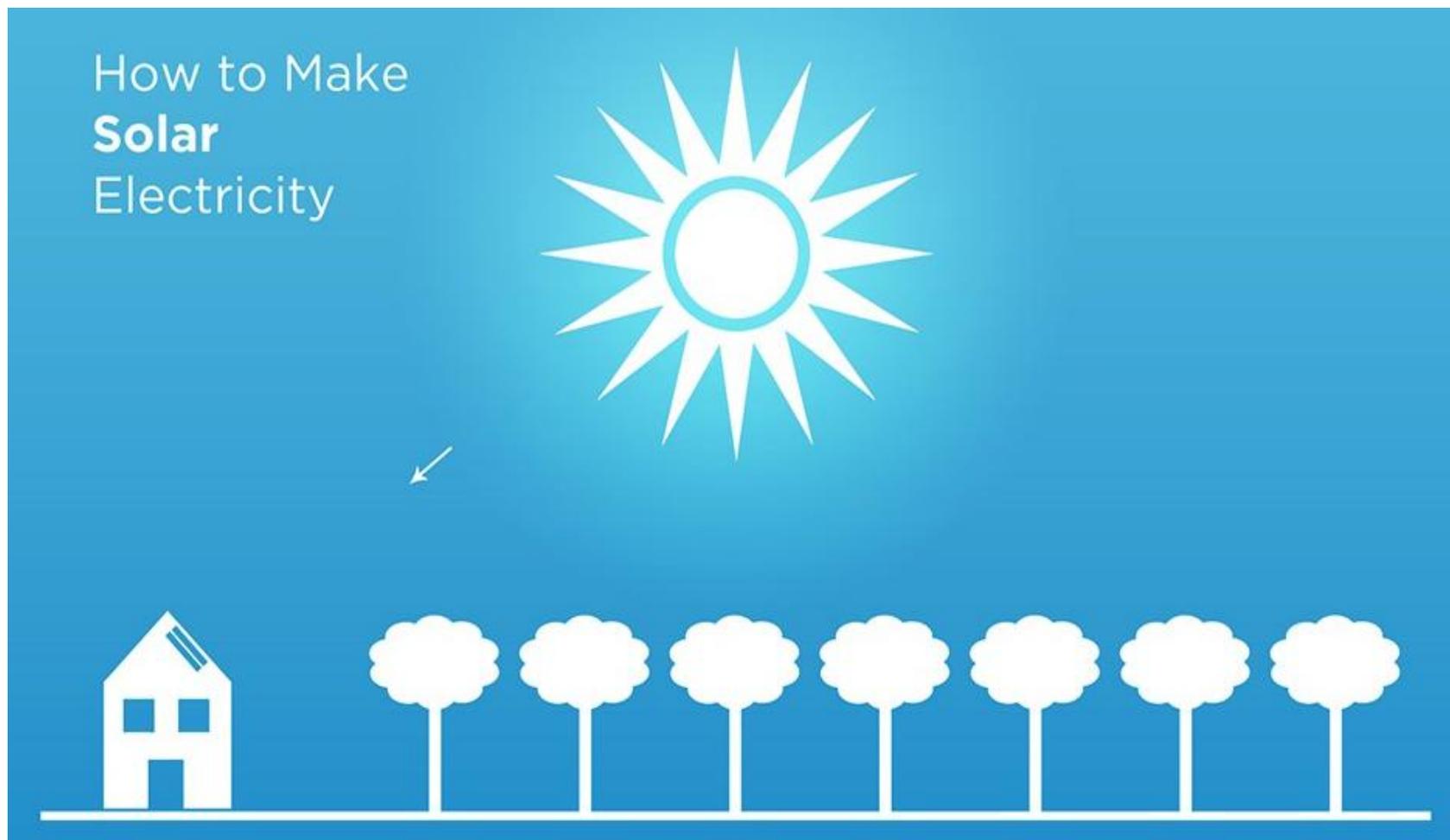
Benefits of Solar

- **Minimal pollution from fossil fuel combustion**
- **Reduces dependence on foreign oil**
- **Minimal greenhouse gas emissions**
- **Minimal negative health impacts**
- **Minimal environmental damage from drilling/mining/spills/combustion**
- **Reliable and safe**
- **Reduces need for utility transmission lines**
- **Reduces need to build expensive peak-power plants**
 - **Produces power during peak demand**
- **Solar industry is labor intensive (creates jobs)**
- **Rooftop generation increases awareness of energy use**
- **Protects against rising electricity rates**
- **Scales well (homes to businesses to utility power plants)**
- **Enables clean transportation (solar powered electric vehicles)**

From THIS



To THIS



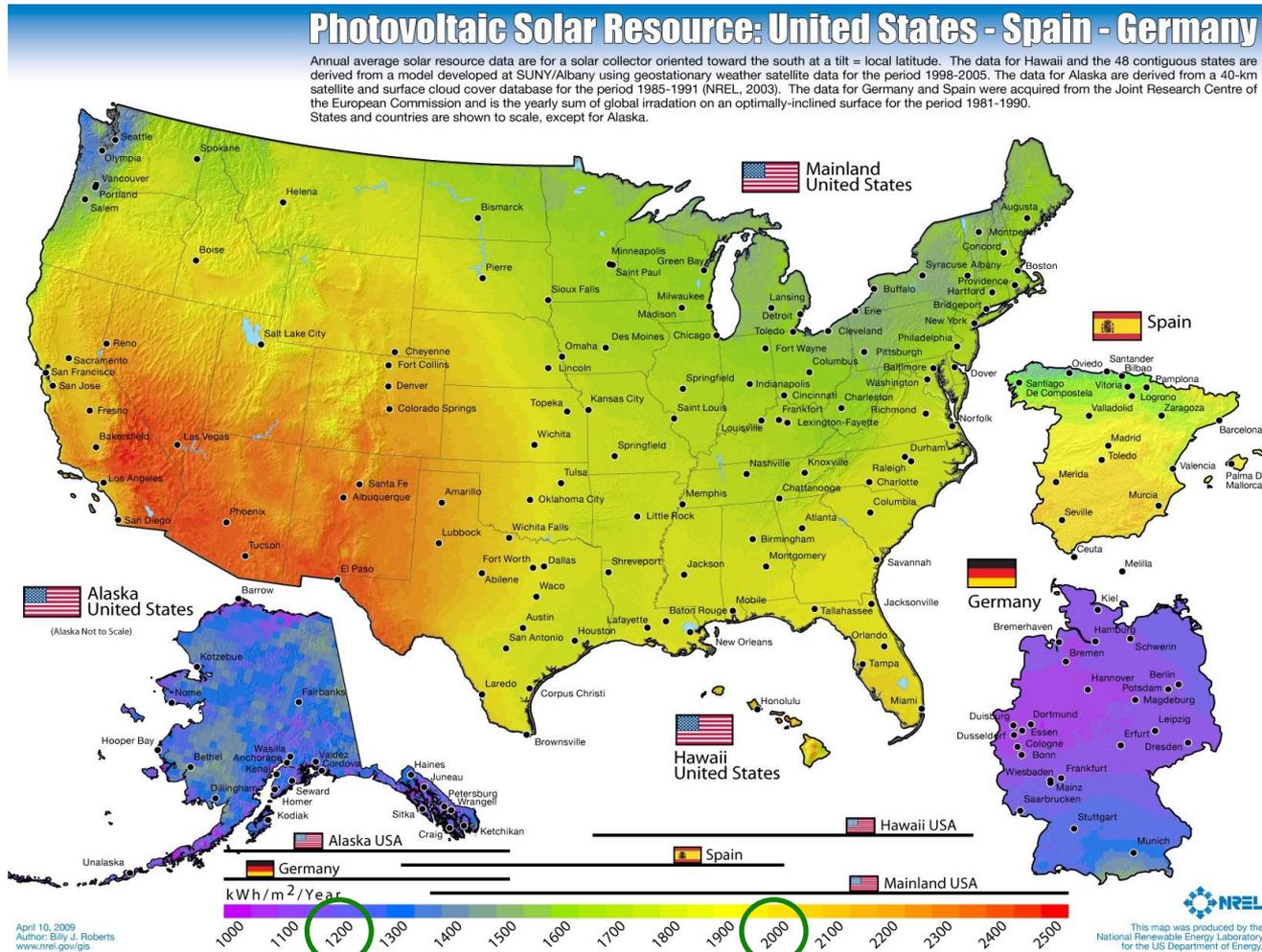
Solar is beautiful... to more and more beholders



Myth: Solar is better in Germany because “they’ve got a lot more sun than we do” Fox News reporter Shibani Joshi in Feb 2013

<https://www.youtube.com/watch?v=jJNOB2RIIMI>

Truth



Myth: Solar requires a huge amount of land

French journalist, author, economic advisor Guy Sorman in 2011: *“If California were to rely on solar power for its electricity consumption, the entire state would have to be covered with photovoltaic cells.”*

<http://www.project-syndicate.org/commentary/the-end-of-green-ideology>

Truth

- CA is 163,696 square miles
 - CA 2011 total electricity consumption: 272,645 GWh
 - A standard 345 watt panel is 17.3 ft² and will generate ~520 kWh per year
 - Calculating ... *
- 0.2%** (not 100%) of CA would need to be covered with solar panels to generate 100% of energy demand.
Sorman is wrong by 50,000% !



* Details: <http://www.lightsonsolar.com/solar-basics-kw-and-kwh>

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- Solar Today
- **Solar Economics**
- Steps to Making Informed Choices

First → An *energetic* digression

- Power & Energy are often confused
 - Rep. Dana Rohrabacher (R-CA), of the House Committee on Science, Space, and Technology said in Feb 2012: “I’m not educated enough to know the difference between the terms that we were talking about, energy and power” *
- **Power** is the rate that energy is generated or consumed
 - Measured in Watts, KiloWatts (KW), MegaWatts (MW), Horsepower, ...
 - Examples: A 100-Watt light bulb, a 4 KiloWatt rooftop solar PV system, a one GigaWatt nuclear power plant, a 400 horsepower car (1 hp \approx 745 watts)
- **Energy** is power generated or consumed over time
 - Measured in KiloWatt-hours (kWh), MegaWatt-hours (MWh), BTUs, Calories, ...
 - A 100-watt bulb on for 1 hour uses 100 Watt-hours of energy
Your utility bill shows how many kWh you used during the month, and you’re billed at a rate such as 10¢/kWh or 30¢/kWh
 - An average home uses not quite 1000 kWh/month, or about 10,000 kWh /year

* http://www.slate.com/blogs/future_tense/2012/01/24/dana_rohrabacher_should_know_the_difference_between_energy_and_power.html

Definitions

- ***Grid Parity*** means many different things and is often confused and abused. For today
Grid Parity for solar on *your* home means it will be *economically* beneficial to you during the lifetime of your solar system



OR



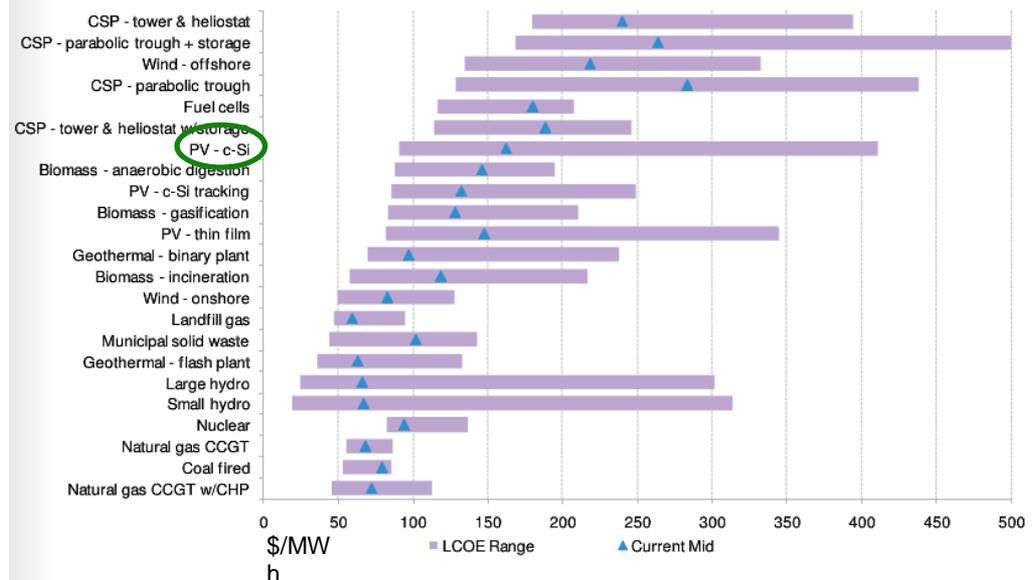
Definitions

- **Levelized Cost of Energy (LCOE)** is a complicated calculation but a simple concept: How much you pay for the solar over its entire life, divided by how much energy will it produce over its entire life

$$\text{LCOE} = \text{Total dollars spent} \div \text{total energy produced}$$

- LCOE uses ¢/kWh just like your utility bill.
If your solar LCOE is less than your average electricity rate over the same period, your solar beats grid parity

Q4 2012 LEVELIZED COST OF ENERGY FOR SELECT TECHNOLOGIES

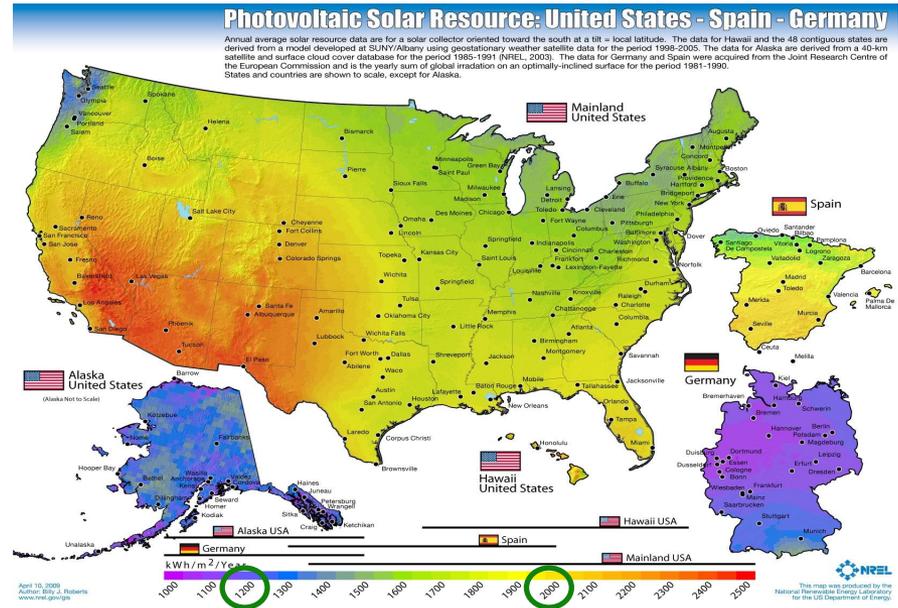


Source: Bloomberg New Energy Finance, EIA

Shortcuts – simplify to get started

- Skip the time value of money (Net Present Value, Discount Rate, Internal Rate of Return)

- Use the National Renewable Energy Lab (NREL) numbers to estimate electricity production



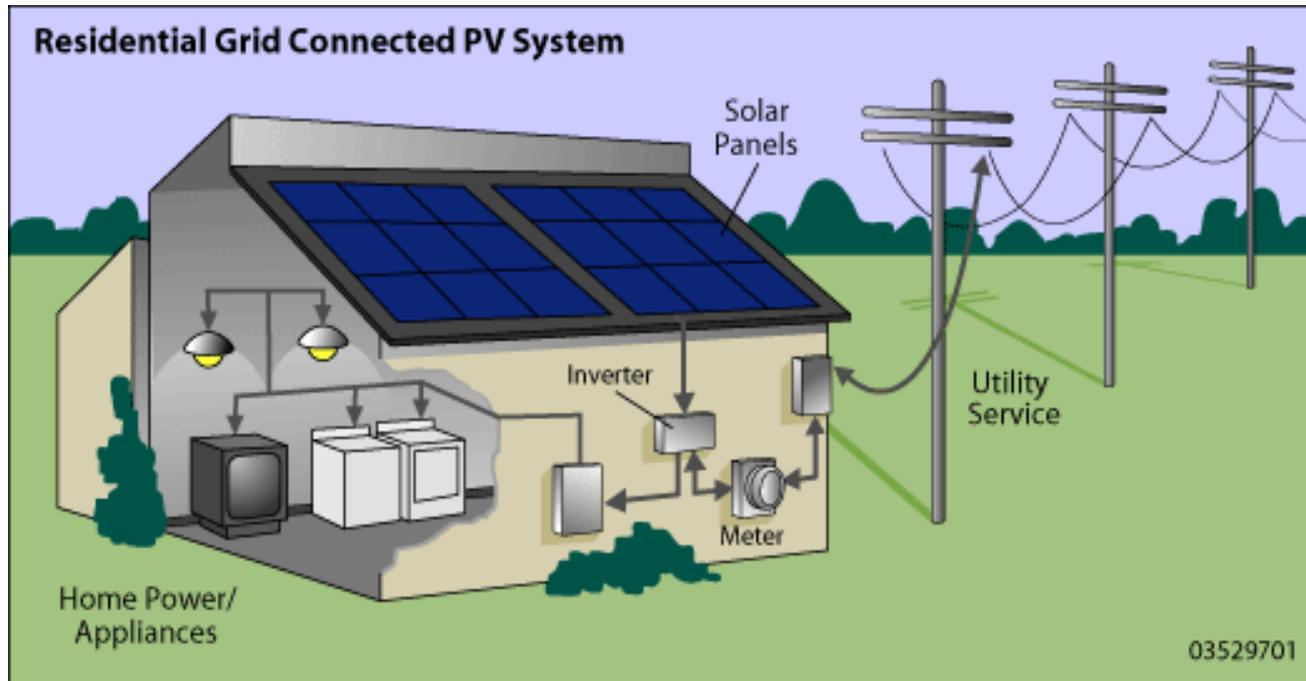
- Ignore the likelihood that grid electricity prices will increase

Step 1, estimate total cost of the system

Common-sized 5KW system may cost about \$5.50/Watt or \$27,500

Add \$3000 to replace the inverter once over the 25 year life of the system

Example home - solar total cost: \$30,500 *



* Average cost of residential solar in Palo Alto in the last 12 months: \$5.83/Watt (before all incentives)

Step 2, Estimate total production of the system

- NREL shows the amount of sun energy available at a location throughout the year. Divide by 365 for the daily amount. Palo Alto is 5.4 “sun-hours” per day, meaning “solar insolation” each day on average totals 5.4 times the energy from one hour of the sun directly above the panels
- Our 5KW DC system will produce about 4 KW AC, because of “de-rate” factors including where the panels are aimed, imperfect efficiency of the inverter, etc. Multiplying 4 KW by 5.4 “sun-hours” gives 21.6 kWh per day, which is 7884 kWh per year, or over 25 years *:

Example home total solar production: 197,100 kWh

* Solar panels are guaranteed for 25 years, but should last much longer

Step 3, Calculate LCOE

Total lifetime dollars divided by total lifetime kWh:

$$\$30,500 / 197,100 \approx 15.5\text{¢/kWh}$$

Example home LCOE: 15.5¢/kWh

Average price of electricity in PA is roughly 11.3¢/kWh *

Not grid parity

But this is *before* subsidies...

* Assumes 10,000 kWh/year

Step 4, Calculate subsidies

- Palo Alto rebate: \$800 per KW AC so for our 4 KW AC system, subtract \$3200 *
Total initial cost is now $\$30500 - \$3200 = \$27,300$
- Federal subsidy: 30% tax credit on the total initial cost of the system
Subtract 30% of \$27,300 or \$8190. $\$27,300 - \$8190 = \$19,110$
- Total initial cost is now \$19,110
Total lifetime system cost is $\$19,110 + \$3000 = \$22,110$
- LCOE after subsidies:
 $\$22,110 / 197,100 \text{ kWh} = \$0.094/\text{kWh} = 9.4\text{¢}/\text{kWh}$

Example home LCOE: 9.4¢/kWh
Grid Parity!



* Only 140KW remains in PA's rebate program. Funds may run out by Oct. 2014 if not sooner.

More about PA's residential electricity rates *

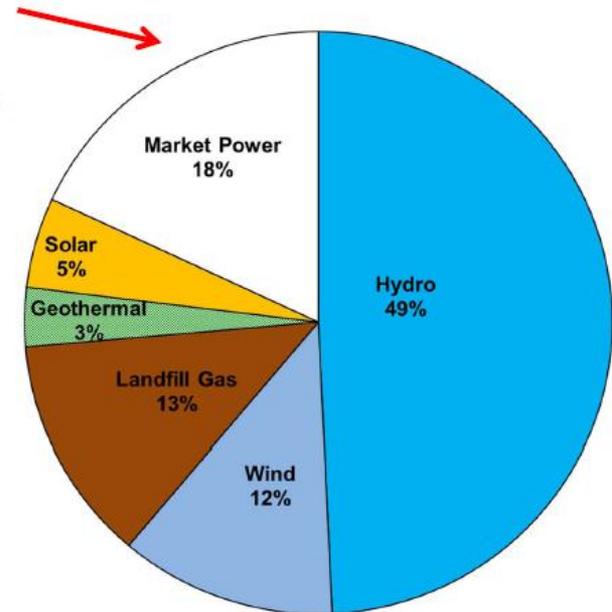
- **Tier 1** (up to 300 kWh/month): **9.5¢/kWh**
- **Tier 2** (300-600 kWh/month): **13¢/kWh**
- **Tier 3** (over 600 kWh/month): **17.4¢/kWh**

- Palo Alto Green rates have ended. But...
- The PA City Council approved our Local Solar Plan on 4/21/2014, which will raise PA PV from 5MW to 23MW by 2023! 20% compound annual growth!

Palo Alto Power Supply Carbon Neutral since January 2013!

2013: Renewable Energy Credits will displace market power.

>2013: More solar



* <http://www.cityofpaloalto.org/gov/depts/utl/residents/rates.asp>

Check out your consumption on your bill

<https://myutilitiesaccount.cityofpaloalto.org>

Consumption History Data (Meter number xxxx)

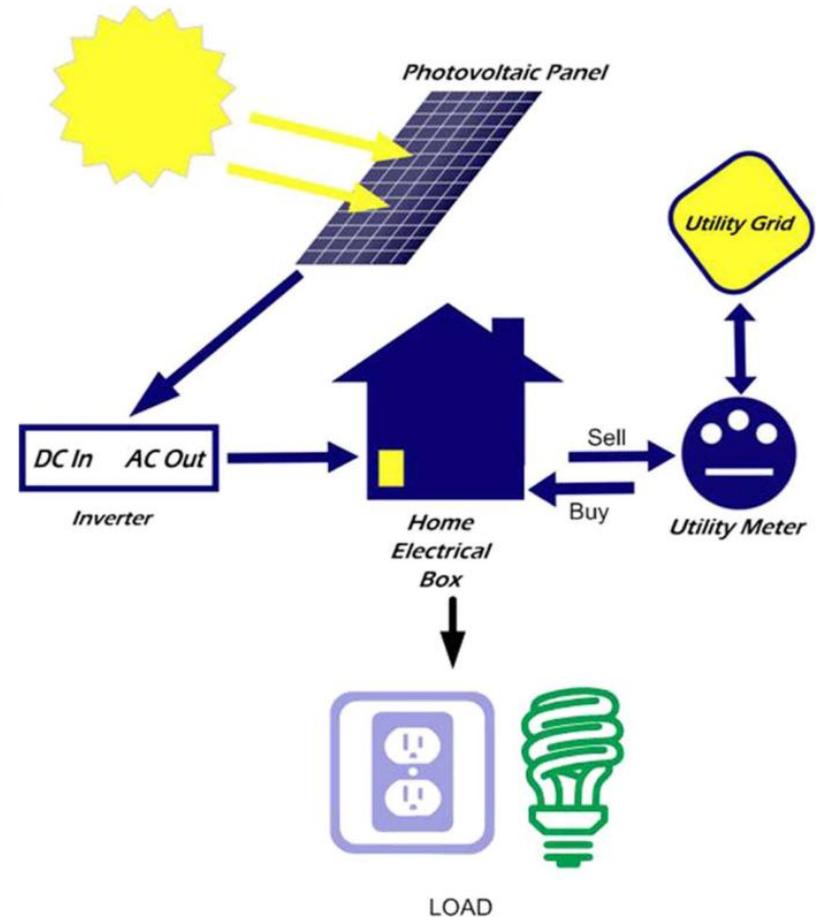
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	980	600	520	948	0	0	0	0	0	0	0	0
2013	954	422	380	505	680	609	735	749	690	696	626	650
2012	770	601	531	655	452	514	584	508	473	498	509	585
2011	977	637	747	664	590	676	661	620	581	542	558	822

MONTH	SERVICE DAYS	ELECTRIC	
		KWHS PER DAY	DOLLARS PER DAY
03/2014	29	17.9	1.99
02/2014	29	20.7	2.38
01/2014	33	29.7	3.95
12/2013	29	22.4	2.68
11/2013	30	20.9	2.41
10/2013	32	21.8	2.57
09/2013	30	23.0	3.01
08/2013	33	22.7	3.07
07/2013	28	26.3	3.74
06/2013	30	20.3	2.62
05/2013	29	23.4	3.21
04/2013	33	15.3	1.88
04/2014	33	28.7	3.78

How does Palo Alto pay you for your solar electricity? ...

Net Energy Metering – PA charges only for your net energy consumed (12 month period)

- Your meter reads the difference between generation and consumption
- When your monthly energy consumption
 - **EXCEEDS** the amount generated by solar, you pay for the energy at retail rates (9.5-17.4¢/kWh)
 - Is **LESS THAN** the amount generated, you receive a credit based on retail rates (9.5 to 17.4¢/kWh)
- Net Metering Credit is only used to offset future electricity charges



Annual “True Up” ...

Annual True Up

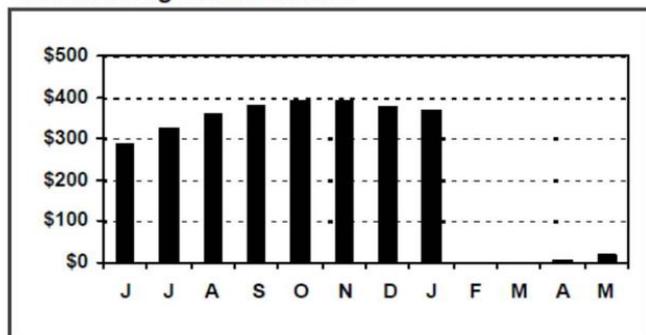
- If annual kWh generation is \leq annual kWh consumption, no action needed
- If generation is greater than consumption:
 - Every 12 months you have a settlement option
 - **Option A: cash out last 12 months of net surplus kWh**
Value is based on wholesale net surplus rate (5.841¢/kWh)
 - **Option B: continue to carry net metering credits forward**
Value is based on full retail rates (9.5-17.4¢/kWh)
- Change your election once a year, but can only cash out last 12 months

Option A *

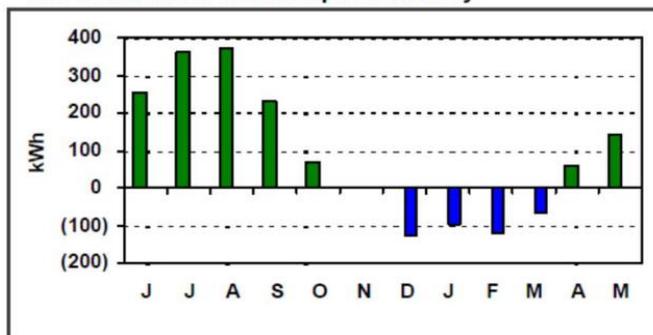
Customer elected option A: Cash Out
 Settlement period ended February 2012
 Customer's net metering credit balance went to zero
 Customer received \$68.05 payment for the 1,165 kWh Annual net surplus electricity

Month	Net Generation or Net Consumption	Net Metering Credit Balance	Annual Net Surplus (To-Date)	Net Surplus Compensation Rate	Net Surplus Cash Value
May-12	143 kWh	\$19.24	133 kWh	5.841 ¢/kWh	\$7.77
Apr-12	59 kWh	\$5.62	-10 kWh	5.841 ¢/kWh	\$0.00
Mar-12	-69 kWh	\$0.00	-69 kWh	5.841 ¢/kWh	\$0.00
Feb-12	-120 kWh	\$0.00	1,165 kWh	5.841 ¢/kWh	\$68.05
Jan-12	-96 kWh	\$367.45	1,285 kWh	5.841 ¢/kWh	\$75.06
Dec-11	-127 kWh	\$376.59	1,381 kWh	5.841 ¢/kWh	\$80.66
Nov-11	-1 kWh	\$388.69	1,508 kWh	5.841 ¢/kWh	\$88.08
Oct-11	67 kWh	\$388.78	1,509 kWh	5.841 ¢/kWh	\$88.14
Sep-11	229 kWh	\$382.39	1,442 kWh	5.841 ¢/kWh	\$84.23
Aug-11	371 kWh	\$360.57	1,213 kWh	5.841 ¢/kWh	\$70.85
Jul-11	362 kWh	\$323.46	842 kWh	5.841 ¢/kWh	\$49.18
Jun-11	252 kWh	\$286.81	480 kWh	5.841 ¢/kWh	\$28.04

Net Metering Credit Balance



Net Generation/ Consumption History



* This is mailed only to Palo Alto's Net Metering customers who have a net metering credit balance

Option B *

Customer elected option B: Carry Net Metering Credits Forward
 Settlement period ended February 2012
 Net metering credit balance of \$255.68 carried forward on to future bills
 Will not be eligible to receive a cash payment in exchange for this credit in the future

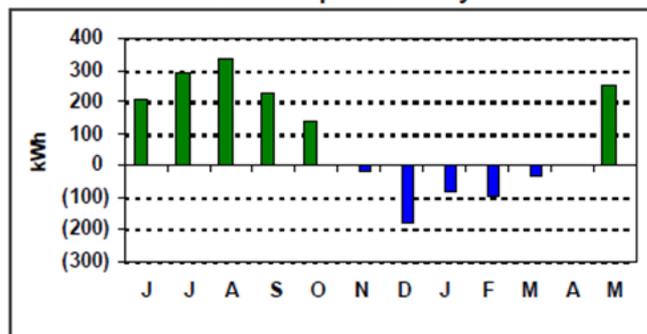
Your next settlement month is February, 2013. Your current election is B

Month	Net Generation or Net Consumption	Election B		Election A	
		Net Metering Credit Balance	Annual Net Surplus (To-Date)	Net Surplus Compensation Rate	Net Surplus Cash Value
May-12	254 kWh	\$280.06	221 kWh	5.841 ¢/kWh	\$12.91
Apr-12	2 kWh	\$252.05	-33 kWh	5.841 ¢/kWh	\$0.00
Mar-12	-35 kWh	\$251.82	-35 kWh	5.841 ¢/kWh	\$0.00
Feb-12	-93 kWh	\$255.68	1,044 kWh	5.841 ¢/kWh	\$60.98
Jan-12	-80 kWh	\$265.94	1,137 kWh	5.841 ¢/kWh	\$66.41
Dec-11	-181 kWh	\$274.76	1,217 kWh	5.841 ¢/kWh	\$71.08
Nov-11	-16 kWh	\$294.72	1,398 kWh	5.841 ¢/kWh	\$81.66
Oct-11	140 kWh	\$296.48	1,414 kWh	5.841 ¢/kWh	\$82.59
Sep-11	227 kWh	\$281.04	1,274 kWh	5.841 ¢/kWh	\$74.41
Aug-11	340 kWh	\$256.01	1,047 kWh	5.841 ¢/kWh	\$61.16
Jul-11	292 kWh	\$218.18	707 kWh	5.841 ¢/kWh	\$41.30
Jun-11	206 kWh	\$185.99	415 kWh	5.841 ¢/kWh	\$24.24

Net Metering Credit Balance



Net Generation/ Consumption History



* This is mailed only to Palo Alto's Net Metering customers who have a net metering credit balance

Agenda

- What is Solar Power?
- Solar Today
- Solar Economics
- **Steps to Making Informed Choices**

Making Choices

- How's your roof?
- Consider your future electricity consumption
 - Energy efficiency improvements?
 - Electric vehicle?
- The future price of electricity?
- Solar financing alternatives

Do you have a suitable roof?

- Shade (trees, chimneys, power poles) is hard on solar PV. Our 5KW DC system would need 20 250-watt, 65" x 39" panels or about 350 square feet of sunny roof
- Solar lasts for over 25 years. If your roof won't, you may want to get a new one before installing solar
- If you have a south- or southwest-facing roof, perfect. Southeast, east or west is OK. If only north-facing is unshaded, forget it. Most Palo Alto streets are 45° off from due north/south/east/west
- Solar can be installed on flat, shallow- or steep-pitched roofs. It will cost more if the roof is difficult or unusual mounting/racking equipment is needed
- Some contractors avoid certain roofs (such as wood shake or ceramic tiles)

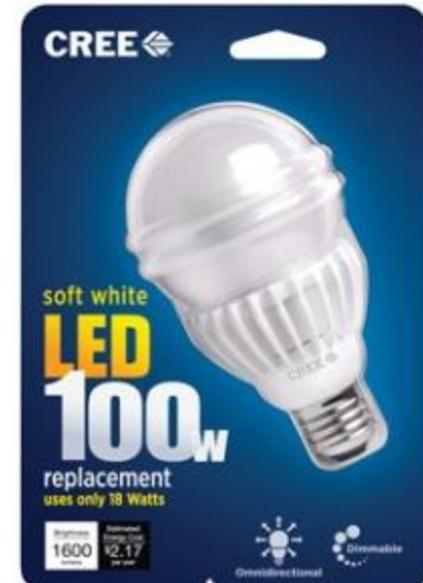


If you have a garage roof or carport or gazebo or shed, or even some available ground, solar may work out great

Your present and future electricity consumption

Energy efficiency improvements?

- Lowering your energy consumption often brings a faster return on investment than adding solar, and helps clarify your future energy need
 - Replace lights with Compact Fluorescents (CFLs) or LEDs (Cree 100 watt equivalent is now \$20). Replace inefficient appliances. Insulate attic and/or install an attic fan. Seal furnace ducts. Install double-pane windows. Measure electrical appliance energy usage and look for waste
- Some of these are cheap and easy
- Get a home energy audit from Acterra
<http://www.acterra.org/programs/greenathome>
 - Palo Alto will help. Just one example: PA will give you a \$75 rebate if you buy an Energy Star refrigerator, and will pay you \$35 to let them remove (and recycle) your old one:
<http://www.cityofpaloalto.org/smartenergy>



Your present and future electricity consumption

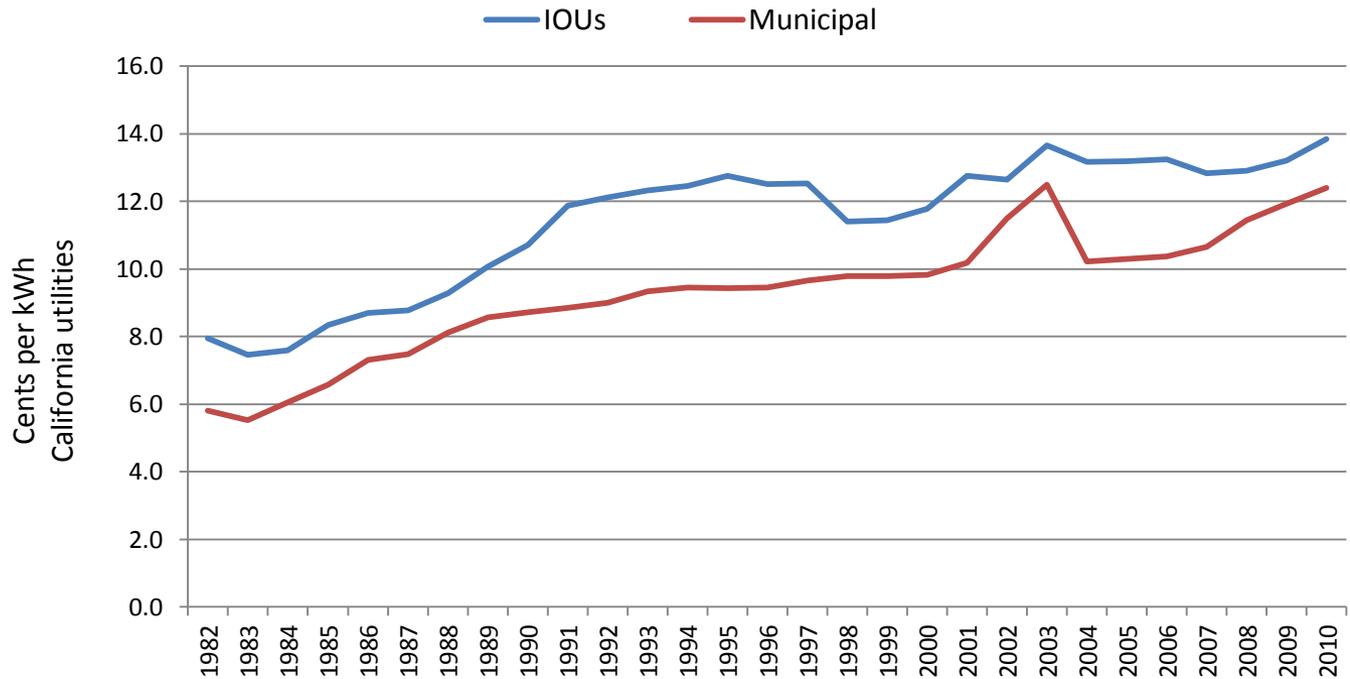
Electric vehicle?

- EVs cost about **4¢/mile** to drive (3 miles per kWh at 12¢/kWh)
- A Gas car costs **20¢/mile** to drive (20 MPG @ \$4/gallon)
Even a 40 mpg car costs **10¢/mile**
- At 12,000 miles/year:
 - \$480/year for Electric
 - \$2400/year 20 MPG gasor **\$2360/year in fuel savings**, not counting lower maintenance, no CO2, no pollution, no oil drilling damage and spills, no money for foreign oil, ...
- At 12,000 miles/year and 3 miles/kWh, an EV increases electricity consumption by about 4000 kWh per year. For reference, our 5KW DC example solar system produces 7884 kWh per year... so almost 50% more solar may be appropriate
- **After your solar is paid for, drive clean and free!**
- **EVs are really fun to drive!**



The future price of electricity

Electricity rates doubled in California from 1982 - 2010, and they'll probably continue rising. Natural gas produces half of California's electricity. NG bottomed at about \$2 per million BTU in 2012, and is now over \$4



Palo Alto's electricity is 100% carbon neutral, with the help of some great solar power plants in California

Financing Alternatives – Purchase

- **Outright purchase**
 - The Lawrence Berkeley Lab found the sale price of homes with solar was higher by about the cost of the solar system
 - In effect, purchase of solar costs nothing. Installing solar will not increase property taxes in California
- **Financing purchase with a Loan**
 - All the same benefits as with outright purchase apply, except you have to find a funding source and pay for the capital. Interest on the loan is tax deductible
 - Home Equity Loan
 - FHA-backed “PowerSaver” Solar Loan
- **Property Assessed Clean Energy (PACE)**
 - Minimal upfront cash, no FICO issues, minimal property-sale obstacles
 - Stay tuned. Promising CA program is just getting re-started...
- **Own the system, receive all incentives, handle all maintenance and repairs, work with manufacturers’ for warranty issues**

Financing Alternatives – Third Party Ownership

- **Lease**

- Pay a set amount for energy generated by the system each month. Vendors may have several offerings: \$0 down, partial down-payment or fully pre-paid lease (\$0 monthly payments). Lease guarantees generation of at least a certain number of kWh's per month. The lease holder does not benefit directly from system performance above guaranteed minimum

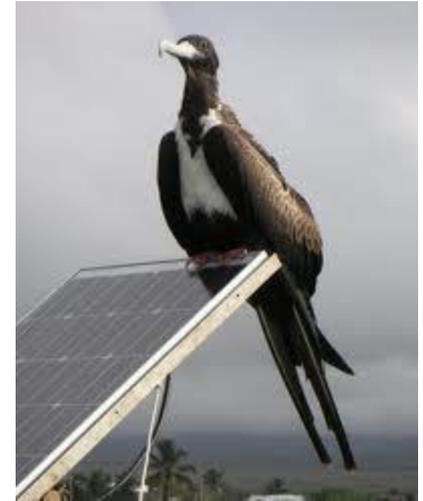
- **PPA (Power Purchase Agreement)**

- Pay a set amount per kWh generated by the system. There may be \$0 down up to fully-prepaid alternatives. The owner guarantees at least a certain number of kWh's per month. The PPA holder is paid for each kWh so benefits directly from maximum system performance

Financing Alternatives – Third Party Ownership

Advantages

- It's easy to go solar. Dollar outlay can be \$0, lower electricity bills begin the first month, payback time can be immediate
- No maintenance worries, no repairs, no worries if the solar is working well. System production (kWh per month) is guaranteed
- Homeowner may be able to buy the system at a reduced cost at a future time (often 5 years)
- Financial return is usually less than with an outright purchase. But a lease can benefit the (third-party) owner via federal and state subsidies as well as depreciation incentives unavailable to homeowners, and these can be passed on, making a pre-paid lease especially an attractive alternative



Financing Alternatives – Third Party Ownership

Disadvantages

- The third-party owner receives all incentives (reduces your return)
- There is often an “escalator” clause of ~3% per year
- The system encumbers the property. Some action must be taken to sell the property, such as buying the system or negotiating with the property buyer to take over the lease
- Contracts can be complex, and there may be significant variations across installers.
- You may need a credit score of 700 or above

Third party ownership is very popular, and accounts for the majority (70%+) of residential solar systems being installed in CA

Financing Alternatives – Third Party Ownership

Things to check in the lease or PPA contract:

- Is the amount of energy to be delivered per period and over the life of the contract, guaranteed?
- What is the term of the lease/PPA?
- Is the owner or installer responsible for all operation and maintenance responsibilities?
What if your roof begins to leak?
- Is it clear what you are paying per kWh? (It should be clear for a PPA, not necessarily so for a lease). Does this change over time?
- Is it clear how net metering (at your current consumption) will be valued?
- What rights do the system owners have to inspect and repair the system? How must they notify you?
- Is it clear how to handle the sale of the property?
- What will it cost if you choose to have the system removed?



Financing Alternatives – Third Party Ownership

More about leases and PPAs

From the Solar Energy Industries Association (SEIA)

<http://www.seia.org/policy/finance-tax/third-party-financing>

- From 1 Block off the Grid (1BoG)

<http://solarfinancing.1bog.org/solar-lease/>

- Most solar installers offer leases and/or PPAs

They are very common and popular, but they are all different

- SolarCity published its residential PPA and Lease contracts

– PPA

http://www.solarcity.com/downloads/SolarCity_Residential-Solar-PPA-Contract_sample.pdf

– Lease

http://www.solarcity.com/downloads/SolarCity_Res_Solar_Lease_Contract_sample2-2013.pdf

You are ready, so...

Select a great solar contractor

- Get referrals from friends, neighbors, ...
- Get bids from several licensed contractors
Ask if they're familiar with Palo Alto Permitting. PA recently streamlined its process
- Ask for (and check) their references
- Check California's database of solar contractors
<http://www.gosolarcalifornia.ca.gov/database/search-new.php>
- Verify the contractor's license with www.cslb.ca.gov or 1-800-321-2752
- Check online reviews (SolarReviews.com, Yelp.com, etc)
- Understand equipment choices, especially panels and inverters
- Understand panel placement and system size alternatives
- Understand financing choices offered
- Understand timelines
- Few construction projects of any kind go perfectly. A great contractor knows not only how to build, but how to resolve all problems to your satisfaction



Then, after a little while....

Watch your meter run backwards!





Solar Power 101: Solar Electric Basics

Thank you

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