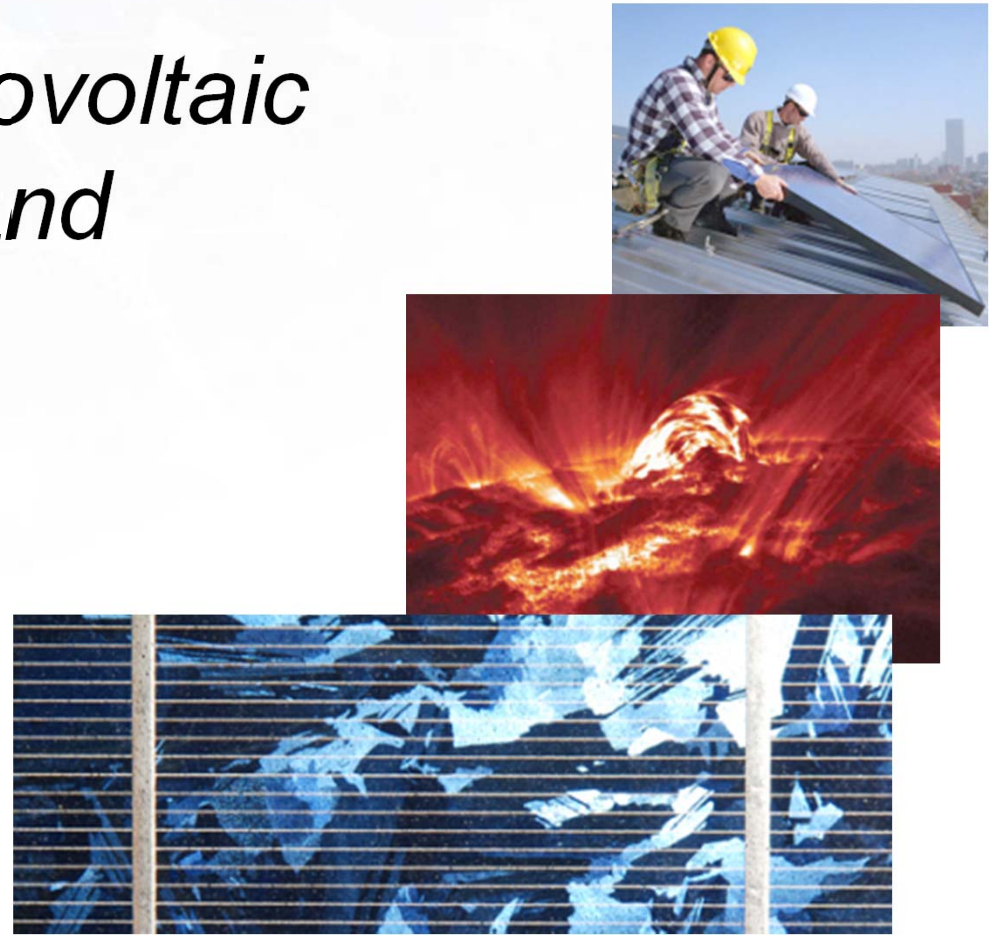
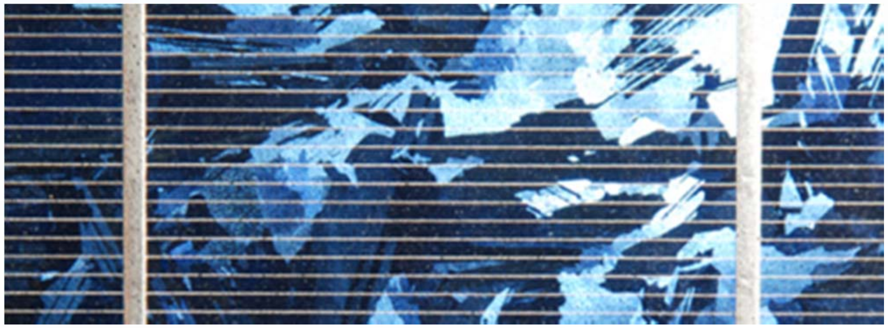
Residential Photovoltaic Solar - Options and Expectations



Randy Dunton
March 2012

outline



- Historic market drivers and costs of solar photovoltaic energy
- Our energy needs and future outlook (yikes!)
- Solar policies and the role of industry and government
- Solar power system examples
- The effects of aging, shading, and temperature
- Options for PV systems for suburban living – design & cost benefits

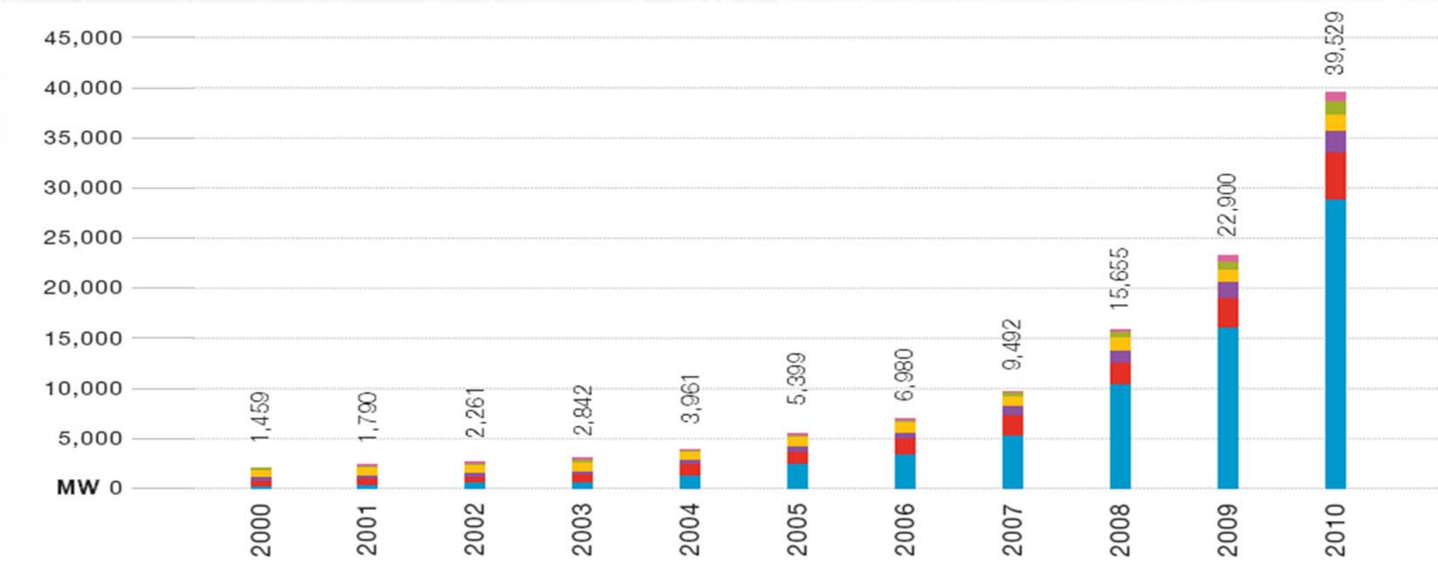
Brief overview of the Solar PV market drivers

- In 1960 PV modules were approximately $1000 per watt, PV remained dormant – the world ran on cheap & abundant fossil fuels
- The oil crisis in the late 70's, the nuclear disaster in Chernobyl, and global warming sparked a renewed interest in alternatives
- With proper government incentives in Japan and Germany, the industry fueled the exponential ramp in automated manufacturing capability, production grew exponentially for over a decade, reducing costs dramatically
- With today's recent Chinese competition - the retail price in 2012 has dropped to ~ $1 per watt for a module: a *1000 x* reduction in 50 years


Early PV cells


Chernobyl


Automated manufacturing



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China	19	30	45	55	64	68	80	100	145	373	893
APEC	38	43	49	57	66	80	112	170	466	718	1,191
Rest of the world	758	814	894	971	1,000	1,010	1,128	1,190	1,303	1,427	1,844
North America	146	177	222	287	379	496	645	856	1,205	1,744	2,727
Japan	318	452	637	860	1,132	1,422	1,708	1,919	2,149	2,632	3,622
EU	181	275	414	613	1,319	2,324	3,307	5,257	10,387	16,006	29,252
Total	1,459	1,790	2,261	2,842	3,961	5,399	6,980	9,492	15,655	22,900	39,529

Figure 1 - Evolution of global cumulative installed capacity - 2000-2010

Fukushima

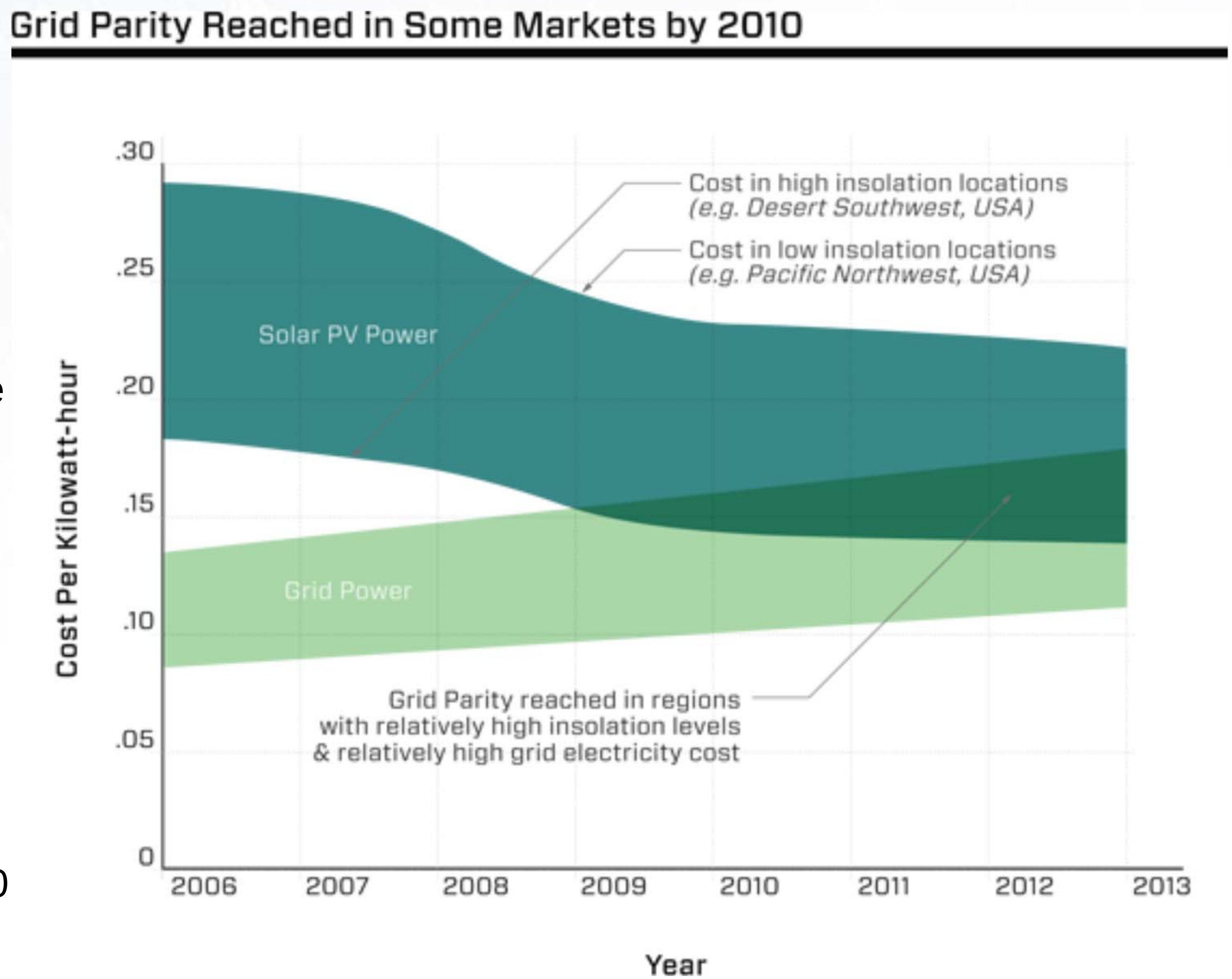
- PV market growth is rapid, prolonged, and world-wide; 2011 = 67MW (recession-proof; 01, 08)
- The United States and China, the largest consumers of energy, have yet to face the inevitable fact that traditional energy resources are unsustainable
- After the Fukushima disaster most of Japan's nuclear power plants are now offline, we should expect to see even greater growth worldwide

Graph courtesy of European Photovoltaic Industry Association (EPIA)

- There is a magic cross-over point called *grid-parity* where the economics are in favor of PV

- Depending on where one lives (solar radiation) and also depending on how much one pays for energy - this cross-over point has been achieved (e.g. Hawaii, California)

- Hawaiians pay 30-40 cents/ kWh
- Arizonans pay 10-15 cents/kWh
- Washington State pays ~6 cents/kWh



- We are just starting - renewables are in their infancy (~1%) as contributors to the utility energy mix
- Utility-scale PV power plants consisting of 100's of thousands of modules are becoming more common, especially in the south-western USA (e.g. Mesquite Solar 150MW)
- Utility PV power plants are built in very short time as compared to nuclear (10 years), however upfront costs are high as compared to gas or coal - and power output varies with the weather, making it intermittent – storage is the next challenge

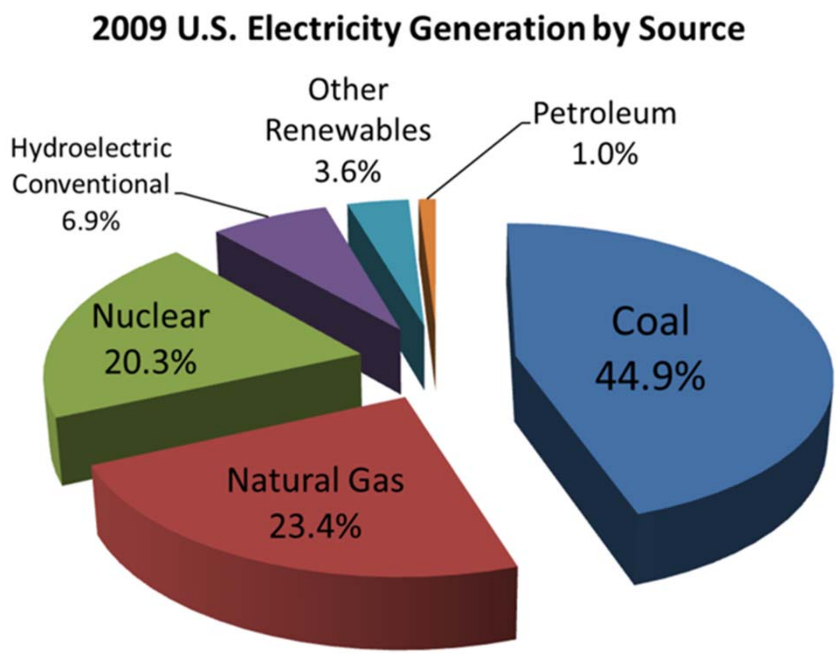


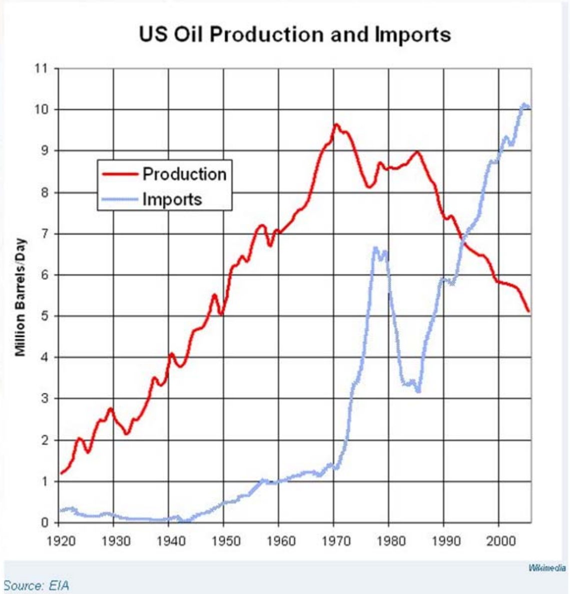
Image source: NREL/DOE (SunPower), Graph: D. Cardenas (EIA/DOE)

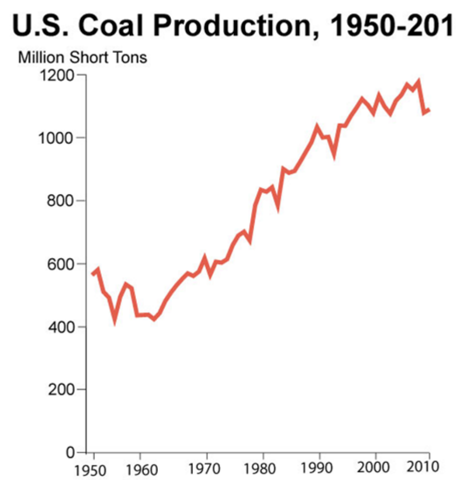
Our energy needs

“It is not necessary to change. Survival is not mandatory."

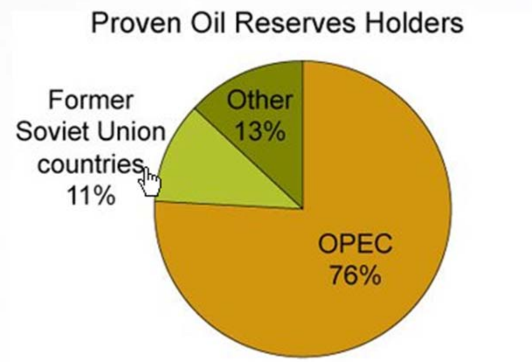
--W. Edwards Deming,
American statistician, professor

Fossil Fuels – especially oil - is wreaking havoc with life on earth

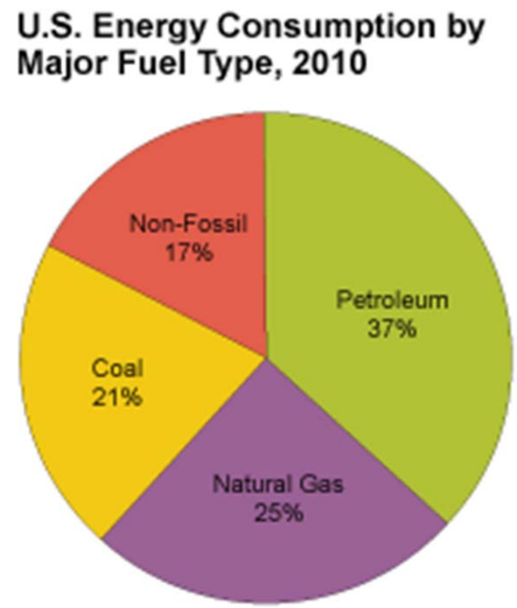




Source: U.S. Energy Information Administration, *Annual Energy Review 2008* (June 2009), *Quarterly Coal Report 2010 Q4* (May 2011), preliminary 2010 data.



Source: BP Statistical Review of World Energy (2007)

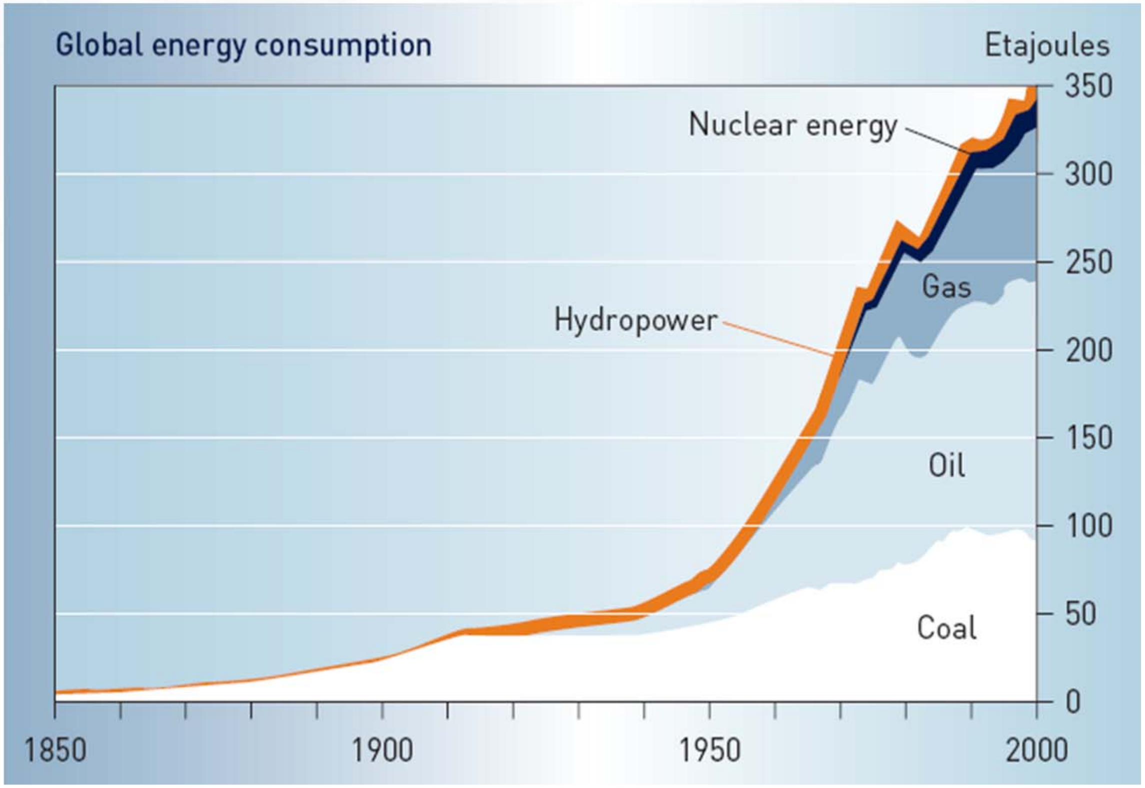


Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 (March 2011), preliminary data.

- The long term trends are all very alarming
- Peak production has occurred twice now (USA, global)
- Replacing oil and coal will be monumental undertakings and will take decades of *concerted* effort
- The longer we wait the more difficult, risky, and expensive it will become
- The USA has 2% of the world's reserves - we require 25% of the oil produced - no amount of drilling will fix this

Energy Challenge and solutions

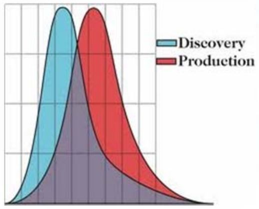
The exponential, unsustainable rate of energy use *will* be reversed



1) source: Novatlantis
http://www.novatlantis.ch/fileadmin/downloads/2000watt/leichterleben_eng.pdf
2) World Energy Council

- *The choice of current energy sources is unsustainable, economically and environmentally*
- The world's population has grown by a factor of 3 in the last 6 years and our energy demand by a factor of 7
- China and India joining industrialized life results in explosive new demand
- Each year energy demand grows by ~2% - and is expected to grow by 30-50% by 2020, almost doubling by 2050 from 2010 [2)]
- Per capita the USA uses 6x the energy of1950 levels 1)

Why is solar PV so exciting and important right now? Is it not too expensive?



PV is an expensive energy form - it would seem

- However solar and wind are the only known viable energy options worldwide to replace the majority of oil for transportation and coal/gas for electricity
- The USA spent ~ $4 trillion on Iraq alone attempting to "secure" the oil pipeline
- The world is addicted to cheap oil, addicts must have what they need at almost any cost…
- *Over 100'000 people* perished in the war on Iraq – over oil…
- Extracting the last ½ of the oil reserves is proving to be very costly from a human, monetary, moral, and environmental point of view
- Coal , the other big dependency the world has, creates the worst forms of pollution: CO_2, SO_x, NO_x, heavy metals

Incentives for solar and wind?

- *Worldwide the PV industry, as well as the other renewable energies require financial incentives to be viable ($46B [1)])*
- *However - all energy production has a form of direct subsidy, even oil, coal, and gas ($557B [2)]), it just much less apparent*
- *The indirect cost of oil - considering pollution and war ? (we spend ~65$/barrel on the middle east oil for US troops [3)])*

1) Bloomberg New Energy Finance
2) International Energy Agency (EIA)
3) "oil panic and the global crisis" (S. Gorelick)

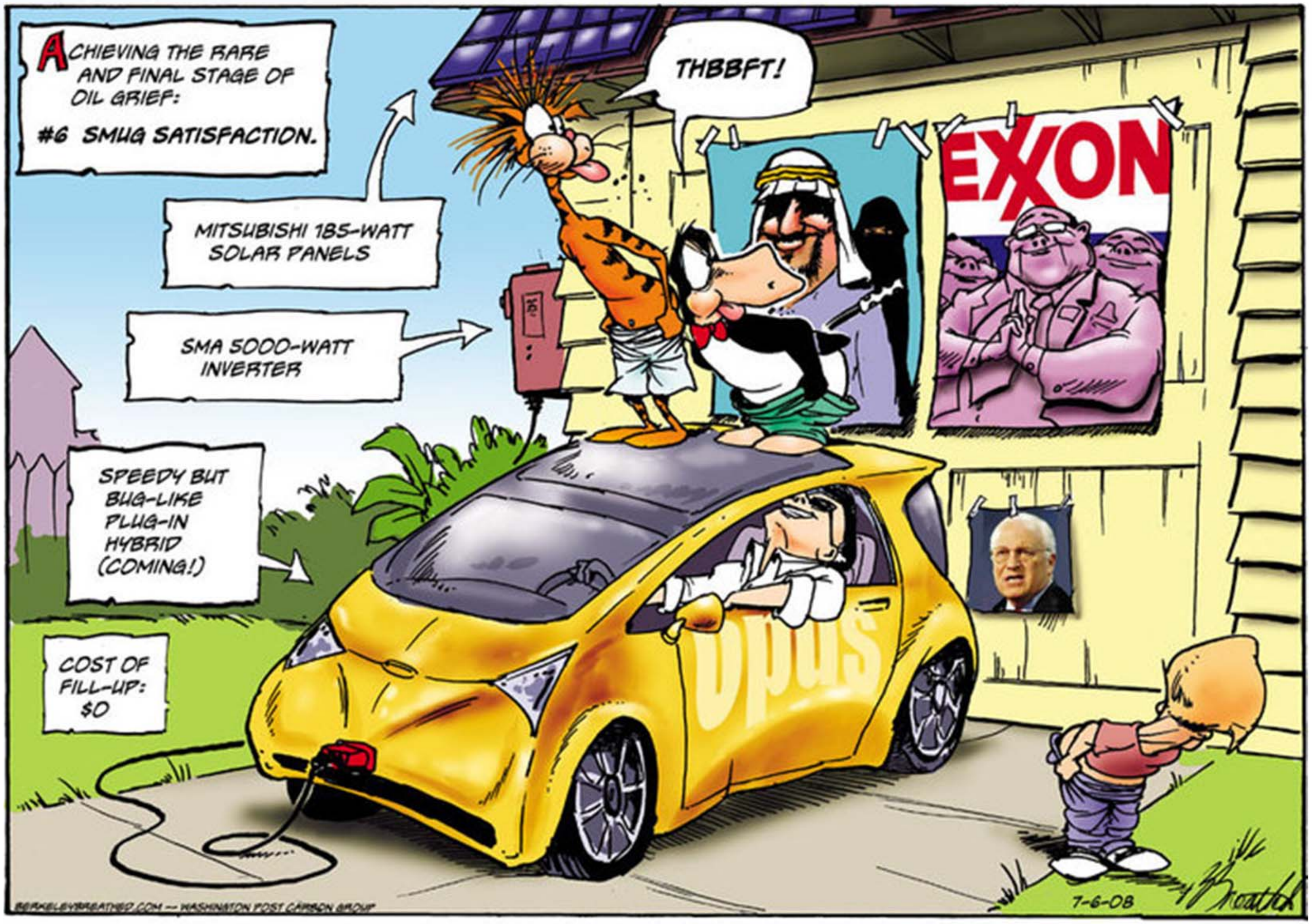
Why is solar PV so exciting and important right now?

Suburban PV has two unique advantages over all forms of energy; solar modules fit on rooftops, close to the load

- By bringing energy production and consumption together - something fossil fuel power plants and other renewable energy can't do – suburban PV is *distributed generation* (DG) without the transmission losses incurred with grid power
- Being *distributed*, PV actually competes with <u>retail</u> power delivered by the utility – not wholesale (enforced by law: *net metering*)

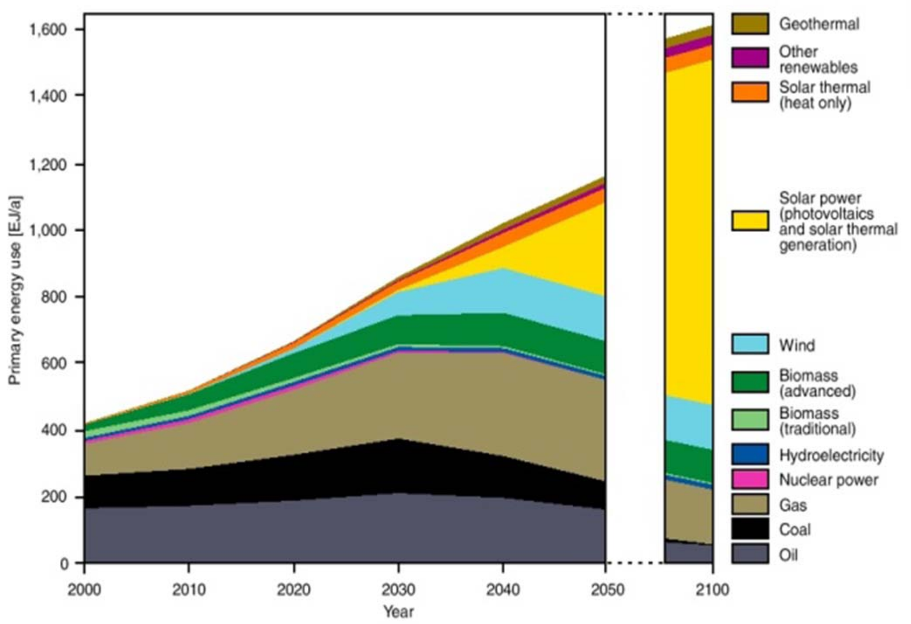
Imagine a world with solar on every possible rooftop - and electric vehicles in every garage

- Every person becomes an energy entrepreneur
- The sun never sends a bill
- No wars over energy, no environmental disasters


ACHIEVING THE RARE AND FINAL STAGE OF OIL GRIEF:
#6 SMUG SATISFACTION.
THBBFT!
MITSUBISHI 185-WATT SOLAR PANELS
SMA 5000-WATT INVERTER
SPEEDY BUT BUG-LIKE PLUG-IN HYBRID (COMING!)
COST OF FILL-UP: $0
EXXON
Opus
7-6-08
BERKELEYBREATHED.COM — WASHINGTON POST CARBON GROUP

Role of Government and Industry

- Physics & technology dictates where energy can be harvested, however energy is politically driven
- Most people agree that the government's role is to *protect its citizens – long and short term*
- One wise way is to set *policies* – through which industry will react: with solutions for the benefit of the citizens
- Industry's role is to become profitable (short term mindset)
- "the market" cannot plan or execute far reaching goals – energy transition will take decades; oil, hydro, and nuclear were all government driven initially



- *How it works - state level: Renewable portfolio standards (RPS)* set goals: AZ 15% by 2025, CA 33% 2020, etc. – driven in AZ by the Arizona Corp. Commission (ACC)
  - AZ Utilities required by law to comply – renewable energy credits (REC) purchased from homeowners by the utility – *net metering* is a law
  - AZ: No sales tax and no property tax increase for PV systems
- Federal level: Emergency Economic Stabilization Act of 2008 and the American Recovery and Reinvestment Act of 2009 continue to enable a 30% Federal Investment Tax Credit (ITC) (through 2016) on the purchase of PV systems

Picture: Data: (graph) Used by permission of the World Energy Council, London, www.worldenergy.org

Predictions of the future of PV

- Hard to predict the future, here is one insider's viewpoint:
- Suntech's founder & CEO Dr. Zhengrong Shi runs the largest PV manufacturing operation in the world. 2011 sales were $3.1 B.
- Suntech has manufacturing in Goodyear AZ
- Q: How big can solar get?
- A: "Today it's only about 1% of the global energy market. In many markets we already are price competitive. I think in five years' time solar won't need subsidies and that will help accelerate growth. By 2050, 25% of our electricity will come from solar."

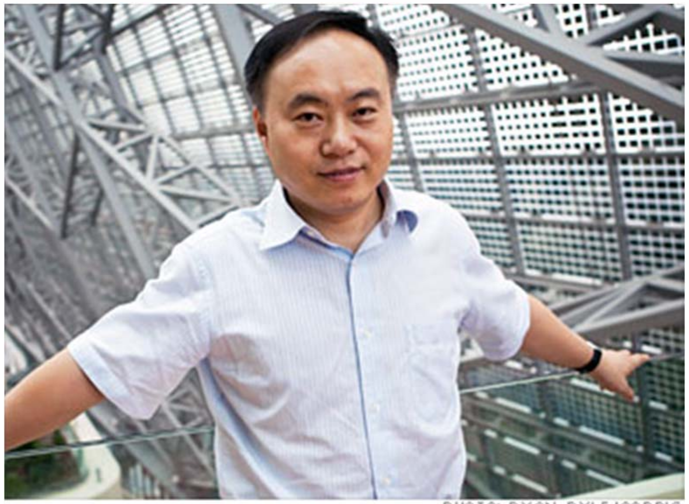


PHOTO: RYAN PYLE/CORBIS

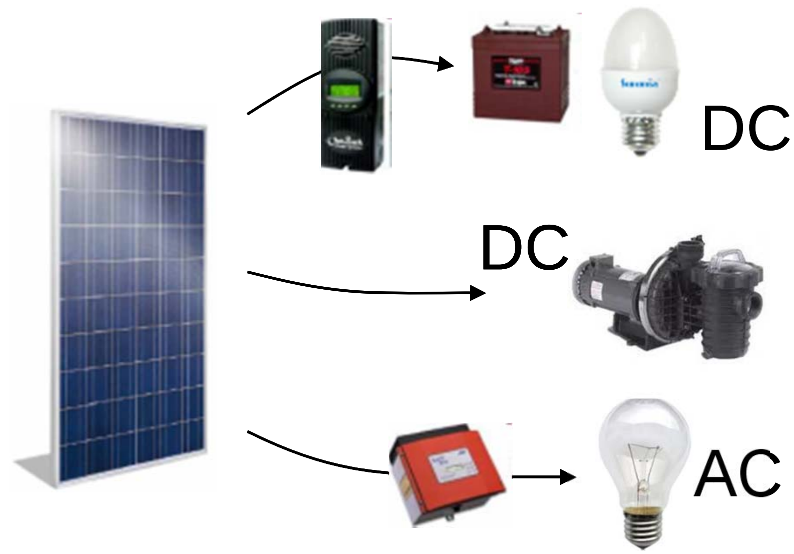
Picture and article: Fortune (Feb27, 2012), Suntech

Brief tour of the various types of solar power plants

Image: Courtesy of DOE/NREL

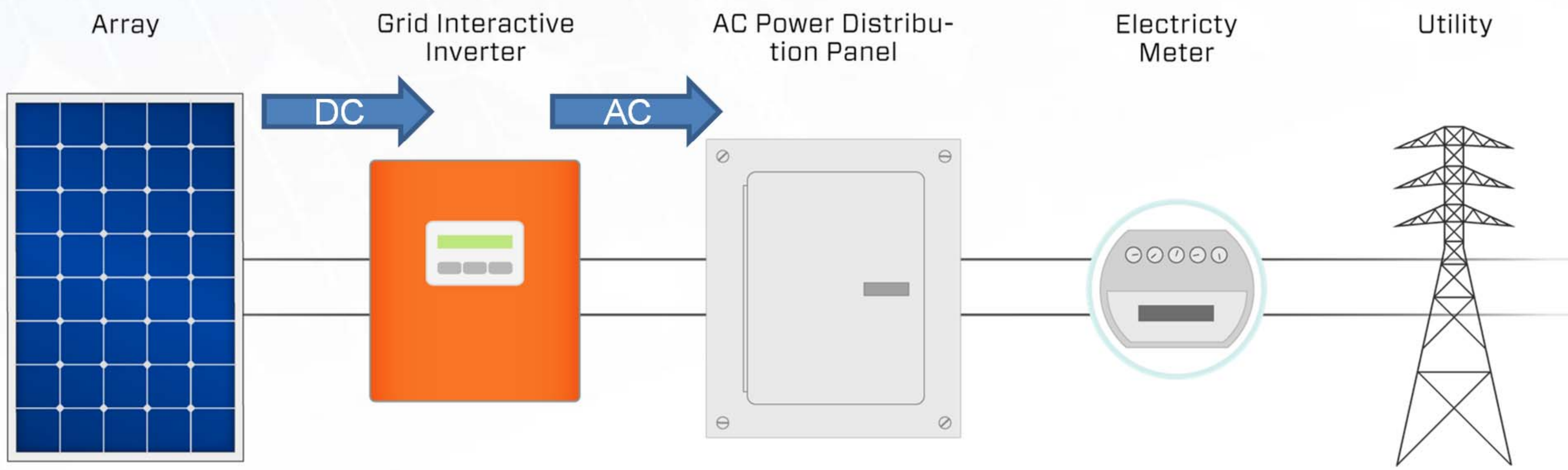
Photovoltaic (PV) systems

- The most visible and costly system component, common to all *Photovoltaic* (PV) systems, is the PV array
- *Arrays* consist of *modules*, which are electrically connected to produce a calculated voltage, current, and power output
- PV cells produce DC power, and in most cases *modules* produce DC power as well
- DC energy can be stored in batteries, directly power DC loads, or be converted to AC power by *inverters* to power AC loads with the excess energy sold back to the electric utility



Images courtesy of American Solar Electric, Solon, Outback Power, SMA, Sunmia

Utility Interactive Systems



- One very popular system in suburban neighborhoods is the *grid-tied* system sometimes known as *grid-connected* or *utility-interactive system*

- It operates as one of many power *generators* in parallel feeding the utility grid, modular in nature a number of these may be connected in parallel even on one premise

- they will not operate without the presence of a grid; a common misconception is to assume that somehow the PV will supply power to a home when the grid is down – there is no storage

Details of the grid-tied system

- Grid tied systems consist of a "flat-plate" array and an "inverter" that feeds the utility grid (and loads)
- Other than some safety disconnect equipment, conduit, and racking, the system is not much more than the inverter and the array
- This system requires very little maintenance and lasts 25 or more years

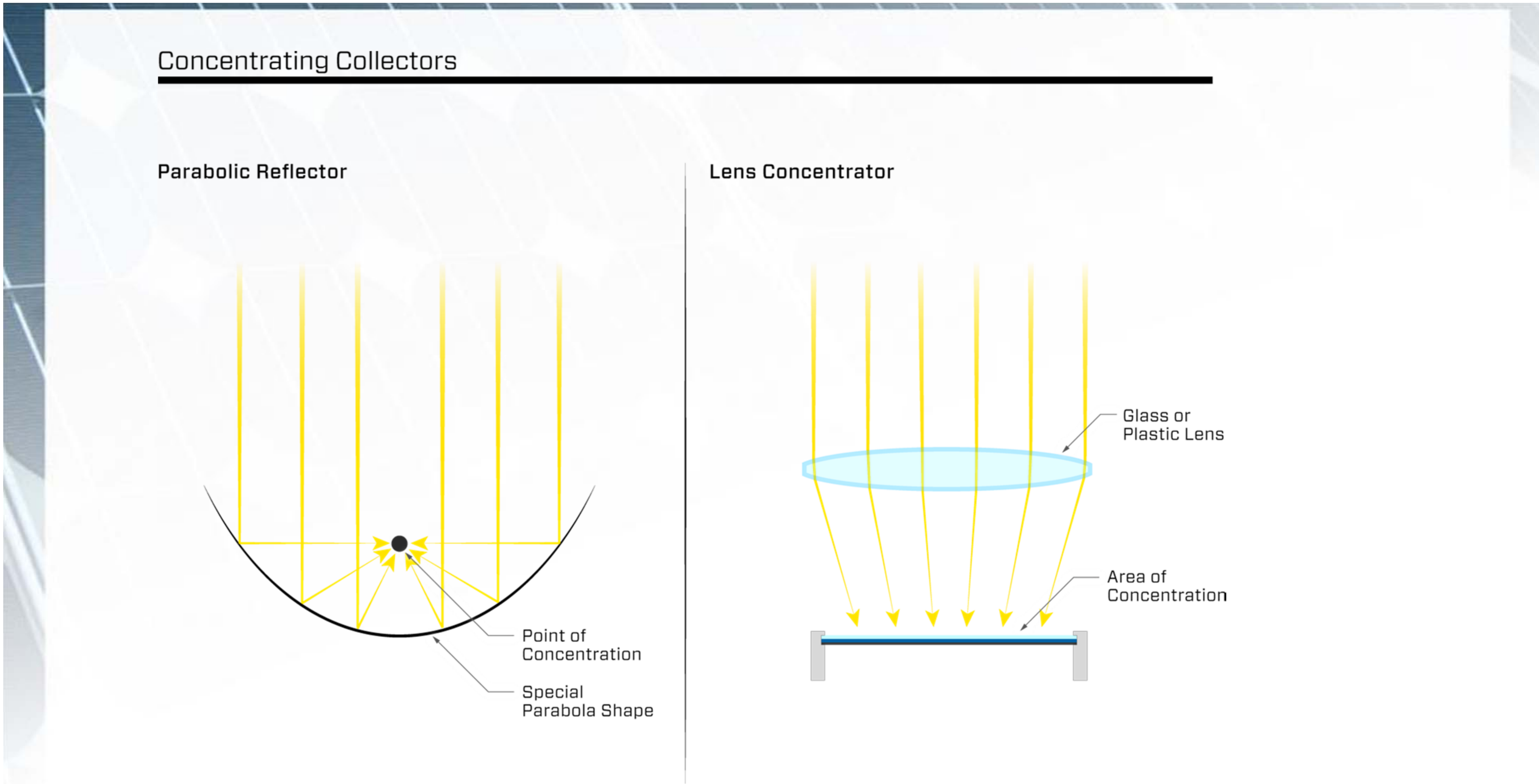
- System costs are ~$4/W (2012), and after rebates and incentives close to 1/2 to 2/3 of that
- Residential Systems range in size from 3KW to 15KW (DC)
- Commercial systems are generally 100KW to 1000KW, e.g. schools and stores
- Utility scale are 100's of MW

module

disconnect

Inverter

Photo courtesy of Solar City, SolarWorld, SMA, Eaton

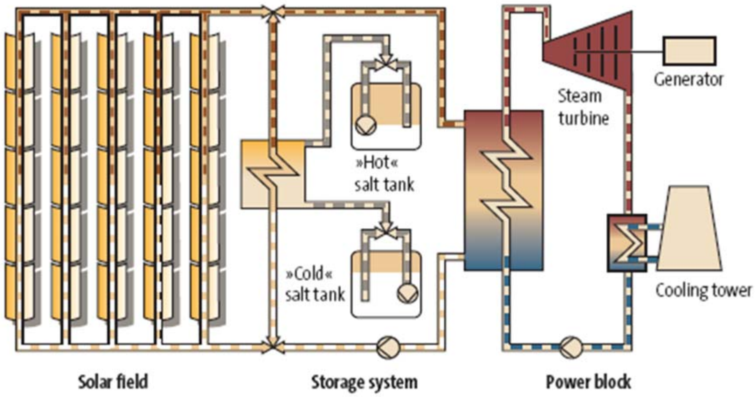


- Concentrating collectors focus the sun’s energy into an intense radiation through reflective surfaces or lenses – and must track the sun
- high-efficiency solar cells: concentrating PV (CPV)
- working fluids: concentrating solar thermal (CST) that transfer thermal energy (a.k.a. Concentrating Solar Power CSP)

A concentrating collector can take many forms, the two popular ones:

- Heliostats
- Mirrored lens (trough)
- In both cases steam is generated to run a turbine and a generator

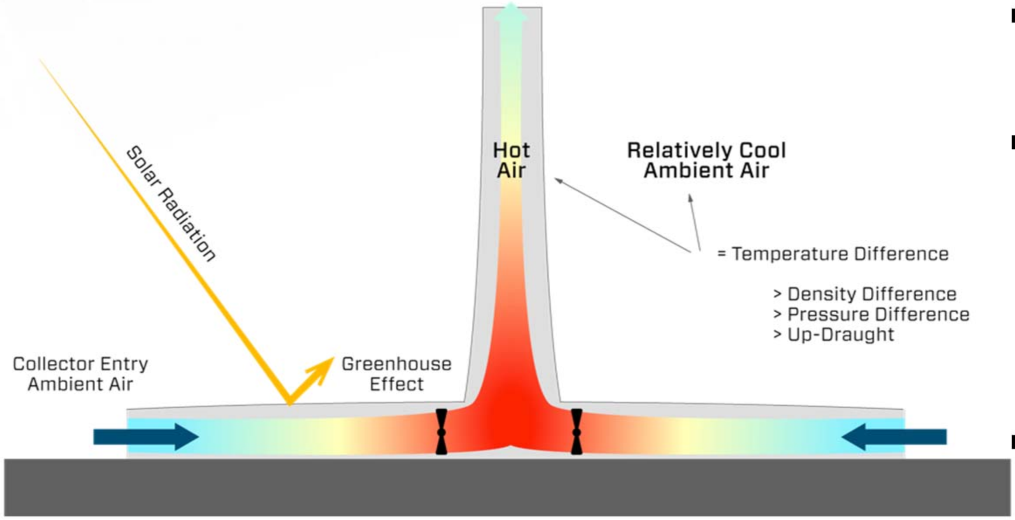
Large arrays of mirror troughs heat a working fluid to very high temperatures



Large sets of Heliostats can work together as a lens and reflector

Image: Courtesy of DOE/NREL

Thermal Solar (solar chimney)



Images courtesy of EnviroMission

- The sun's radiation is used to heat a large body of air under an expansive collector zone, which is then forced by the laws of physics (hot air rises) to move upward through large turbines generating electricity
- In the 1980s, a solar chimney power plant was demonstrated to work in a pilot project in Spain
- Able to generate power day and night
- *EnviroMission* is planning a 200MW plant in Arizona; 1000m high and 7000m diameter, $750M (est.) ($3.25/W)
- No water !

Effects of shade, heat, aging on PV systems

Images courtesy of American Solar Electric

Shade and heat

Courtesy of Solmetric

- Modules perform less than nominally rated at higher temperatures: -0.5% / degree Celsius
- E.g. a 200W module will produce ~160W in the summer heat – this part of normal system design
- Keeping the array well ventilated is good practice (>4” off the roof)

- Shade is the performance killer
- 50% to 90% power loss if module is partially shaded
- A *proper* system design starts with sun-path analysis and shading considerations (site survey)

Module aging

- PV systems age very well in AZ – 15 year old power plant from SRP is running reliably without issues
- Long-term aging is ~ 0.4% to 0.7% [2] per year
- studies shows that module power drop ~4% [1] over 11 years

- What causes aging?: there is no conclusive data yet, it seems UV causes cell p-n junction degradation, additionally internal hot-spots and internal module electrical resistance reduces the power

15 year old 200KW SRP Power plant Tempe AZ

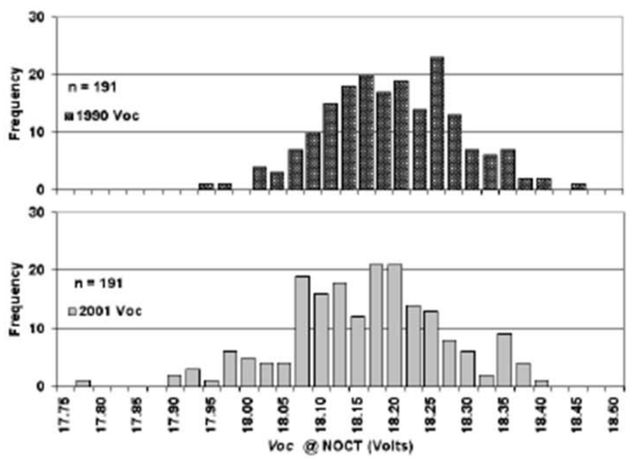


Figure 4. Comparison of V_{oc} distribution between 1990 and 2001.

'able 2. Comparison of mean value ($\bar{x}$) and standard leviation (s_x) of module parameters from 1990 and 2001 t NOCT.

Parameter	1990		2001		% Change
	$\bar{x}$	S_x	$\bar{x}$	S_x	
P_{max} (W)	39.88	0.849	38.13	1.67	-4.39
V_{oc} (V)	18.19	0.131	18.15	0.108	-0.22
I_{sc} (A)	3.29	0.044	3.08	0.120	-6.38
R_s (Ohms)	0.347	0.115	0.384	0.184	10.66
R_p (Ohms)	171	39.2	115	48.7	-32.75
ekt (V^{-1})	0.709	0.125	0.896	0.26	26.38
V_{mp} (V)	13.9	0.20	14.2	0.33	2.16
I_{mp} (A)	2.88	0.033	2.69	0.111	-6.60

Notes: 1) Source "COMPARISON OF PV MODULE PERFORMANCE BEFORE AND AFTER 11-YEARS OF FIELD EXPOSURE" (A.M. Reis et. al.)
2) "DEGRADATION ANALYSIS OF WEATHERED CRYSTALLINE-SILICON PV MODULES" (C.R. Osterwald et. Al.)

Example Systems:

- Off-grid 1.5HP pool pump with 1.3KW array
- 3.9KW grid-tied generator

Off-grid pool pump (1.3KW)

- Running a load directly from the array is simple and the most efficient type of system
- DC motor efficiency (~90%) is greater than common 1-phase AC motors (56%)
- 1.3KW of PV power can run the 1.5HP pool pump to filter the pool (30’000G) 1.5x to 2x per day
- Pool is filtered during the day; best time to run pump to avoid algae growth, less chemicals and longer running times in the summer, automatically runs less during winter with shorter days
- Pump is very quite and manufactured in Safford Arizona (*Sun Pumps*)
- Smaller pools use 1 to1.5 HP motors and 2-4 modules

Off-grid pool pump (1.3KW)

	options cost/year		cumulative cost		breakeven
year	utility $	solar $	utility $	solar $	
1	$ 742	879	$ 742	$ 879	n
2	$ 772	879	$ 1,514	$ 1,757	n
3	$ 803	879	$ 2,316	$ 2,636	n
4	$ 835	879	$ 3,151	$ 3,515	n
5	$ 868	879	$ 4,019	$ 4,393	n
6	$ 903	0	$ 4,921	$ 4,393	y
7	$ 939	0	$ 5,860	$ 4,393	y
8	$ 976	0	$ 6,837	$ 4,393	y
9	$ 1,015	0	$ 7,852	$ 4,393	y
10	$ 1,056	0	$ 8,908	$ 4,393	y
total	$ 8,908	$ 4,393			

Cost & benefit breakdown :

- Pump ~$1100, PV array ~$1300, other electrical equipment ~$300
- Hardware for roof (rails) ~$600
- Labor (est.) ~$2500
- Total costs: ~$5700 (less for smaller systems)
- 30% ITC (federal) = $1800, price of system ~$4000 (not including financing)
- Saves $60-70 per month
- 6 year simple payback compared to existing AC pool pump

(4% interest, 4% inflation of energy)

Grid-tied 3.9KW generator - design

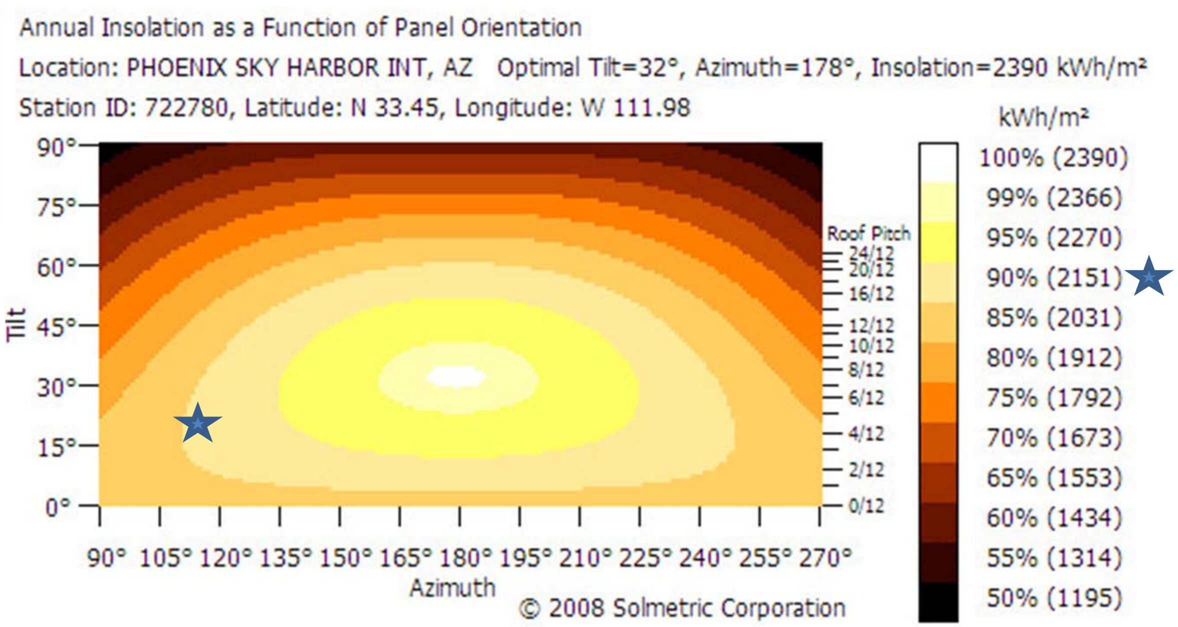





Array, sensors, support equipment, rails and standoffs with flashing, tie into grid via breaker

- The array performance depends on tilt and azimuth – if the array is not pointed in the ideal way a loss of performance will occur

- E.g. if the roof resulted in an array tilted at 20 deg. and the array azimuth is 115 degrees from north one would experience a ~10% loss in energy production



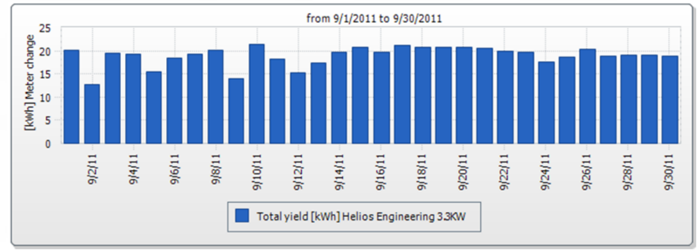
Graphic and toolc Courtesy of Solmetric

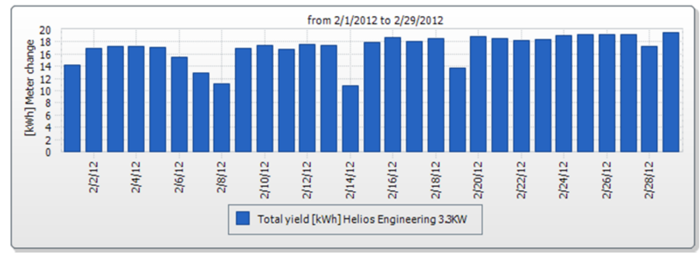
Grid-tied 3.9KW performance: PVWatts

Station Identification	
City:	Phoenix
State:	Arizona
Latitude:	33.43° N
Longitude:	112.02° W
Elevation:	339 m
PV System Specifications	
DC Rating:	3.8 kW
DC to AC Derate Factor:	0.850
AC Rating:	3.2 kW
Array Type:	Fixed Tilt
Array Tilt:	20.0°
Array Azimuth:	115.0°
Energy Specifications	
Cost of Electricity:	12.0 ¢/kWh

Results			
Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.79	353	42.36
2	4.81	406	48.72
3	5.76	521	62.52
4	7.39	634	76.08
5	7.97	689	82.68
6	8.05	650	78.00
7	7.54	631	75.72
8	7.14	602	72.24
9	6.51	536	64.32
10	5.42	479	57.48
11	4.13	366	43.92
12	3.44	321	38.52
Year	6.00	6187	742.44

Actual data





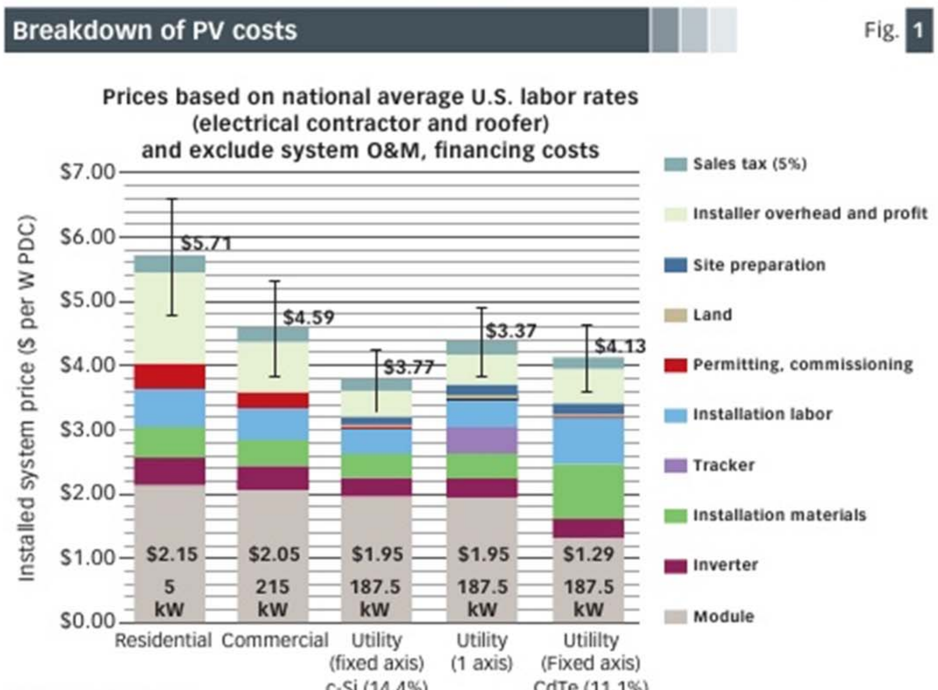
- NREL's PVWatts (V1.0) is a simple and accurate tool that provides a good estimate of energy and value with a few system inputs
- (e.g. tilt and azimuth of array, system efficiency (~85%), location)

Compared with actual data (3.8KW, 20 tilt,115 azimuth, 85%)

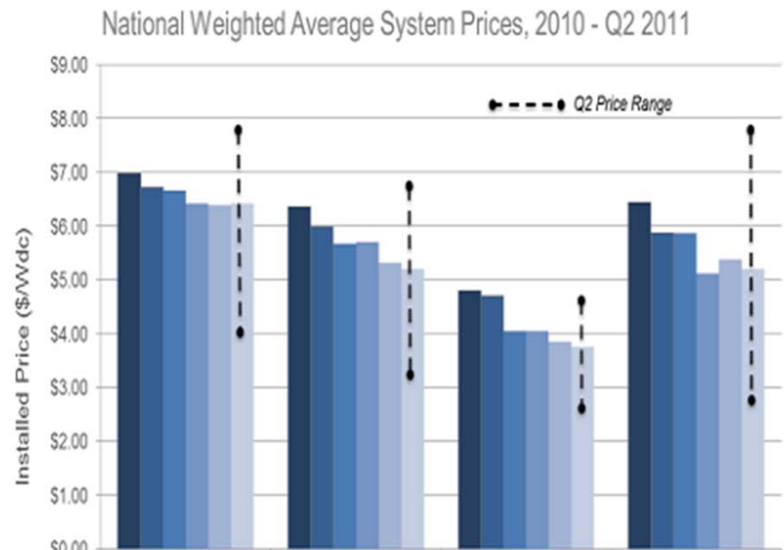
- Feb 2012: ~17kWh/day = 29 days x 17kWh/day = 493kWh
- Sept 2011: ~19 kWh/day = 30 days x 19kWh/day = 570kWh

http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/

Grid-tied 3.9KW generator – costs



Source: eere.energy.gov



	Residential	Non-Residential	Utility	Blended
Q1 2010	$6.98	$6.36	$4.80	$6.45
Q2 2010	$6.72	$6.00	$4.70	$5.88
Q3 2010	$6.66	$5.68	$4.05	$5.87
Q4 2010	$6.42	$5.71	$4.05	$5.13
Q1 2011	$6.39	$5.32	$3.85	$5.37
Q2 2011	$6.42	$5.20	$3.75	$5.20

Source: GTM Research - ***Q2 U.S. Solar Market Insight Report***

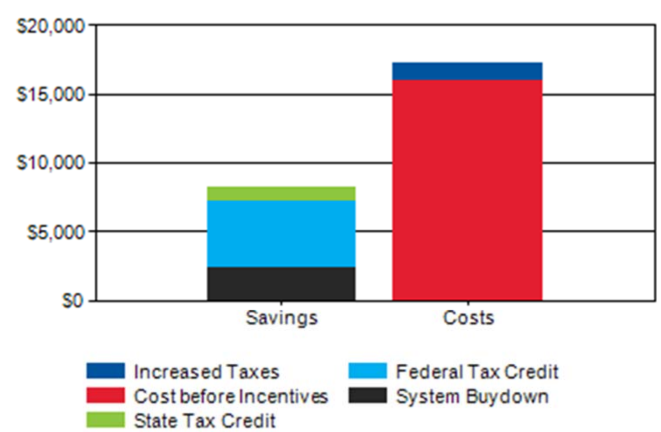
- Cost trends continue down; with $1/W modules, and lower margins than 2011, expect to pay around $4/W in 2012
- Leasing is popular, and *prepaid lease* is near $2/W

Grid-tied 3.9KW generator – cost / benefit

KYOCERA

Cost Breakdown

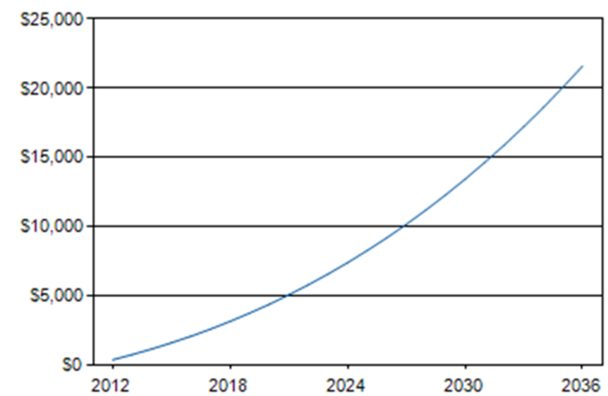
Your net cost for this Kyocera Solar PV system is $8,990



System Cost			$16,000
Incentives			
	APS PV UFI (Res.) (Feb. 2012), 100% DF	$2,400	
	Federal PV Tax Credit (Res.) (Jan. 2009)	$4,800	
	AZ PV Tax Credit (Res.)	$1,000	
	less **Total Incentives**		$8,200
Increased Taxes			
	APS PV UFI (Res.) (Feb. 2012), 100% DF	$860	
	AZ PV Tax Credit (Res.)	$330	
	plus **Total Tax Increase**		$1,190
NET COST			$8,990

Details | **Cumulative**

Your Kyocera Solar system saves an estimated $21,570 over 25 years



	Net Cash Flow	Cumulative
2012	$340	$340
2013	$373	$712
2014	$407	$1,119
2015	$443	$1,562
2016	$479	$2,041
2017	$517	$2,559
2018	$557	$3,115
2019	$597	$3,713
2020	$640	$4,352
2021	$683	$5,036
2022	$728	$5,764
2023	$775	$6,538
2024	$823	$7,361

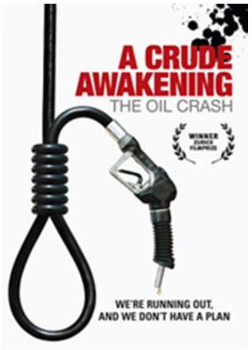
	Net Cash Flow	Cumulative
2025	$872	$8,233
2026	$923	$9,156
2027	$976	$10,132
2028	$1,030	$11,162
2029	$1,086	$12,249
2030	$1,144	$13,393
2031	$1,204	$14,597
2032	$1,265	$15,862
2033	$1,328	$17,190
2034	$1,393	$18,583
2035	$1,459	$20,042
2036	$1,528	$21,570

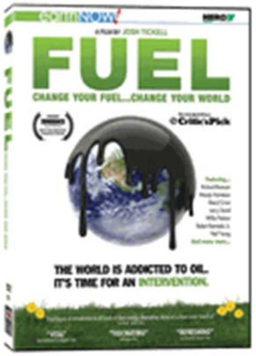
- Payback is complex; long timeframes, large upfront costs, cost of money, opportunity cost of money, inflationary cost of energy - e.g. simple payback: $9K in 14 years
- Choose variable you are comfortable with, try this great tool from Kyocera: http://www.kyocerasolar.com/calculate-your-savings.php

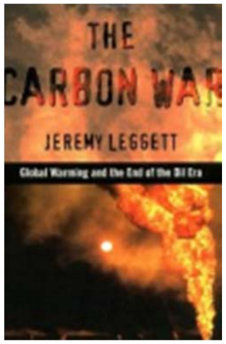
Reference materials

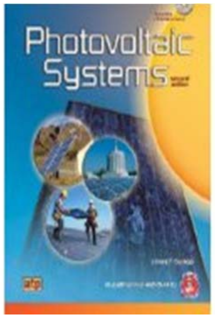
- Energy: “Crude the incredible journey of oil”
  - http://www.abc.net.au/science/crude/
- Energy “Fuel”
  - http://thefuelfilm.com/
- Energy “Crude Awakening”
  - http://www.oilcrashmovie.com/
- Role of government & renewable energy policy
  - Carbon War: Global Warming and the End of the Oil Era (Jeremy Leggett)
- PV system design
  - Photovoltaic Systems (James P. Dunlop)

ABC Science

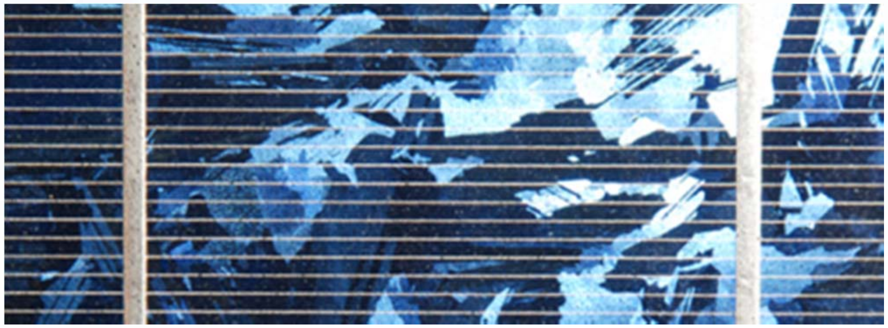








outline



- Historic market drivers and costs of solar photovoltaic energy
- Our energy needs and future outlook (yikes!)
- Solar policies and the role of industry and government
- Solar power system examples
- The effects of aging, shading, and temperature
- Options for PV systems for suburban living – design & cost benefits

Backup information

Calculating PV performance by hand

Roof Area Needed in Square Feet (shown in **Bold Type**)							
PV Module Efficiency (%)	PV Capacity Rating (Watts)						
	100	250	500	1,000	2,000	4,000	10,000
4	**30**	**75**	**150**	**300**	**600**	**1,200**	**3,000**
8	**15**	**38**	**75**	**150**	**300**	**600**	**1,500**
12	**10**	**25**	**50**	**100**	**200**	**400**	**1,000**
16	**8**	**20**	**40**	**80**	**160**	**320**	**800**

For example, to generate 2,000 watts from a 12%-efficient system, you need 200 square feet of roof area.

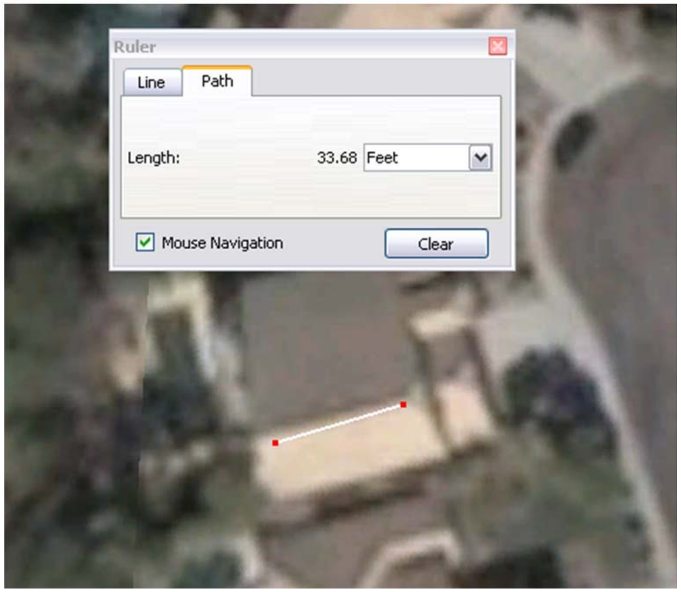
To answer the question: "how much energy will a PV system produce on my house?"

- We can examine the following items:
  - Roof area pointing generally south (~20 degree pitch)
  - Use Rule of thumb to calculate power: *10W/ft² generated AC* power (at noon) for silicon PV (assume array is 12% efficient)

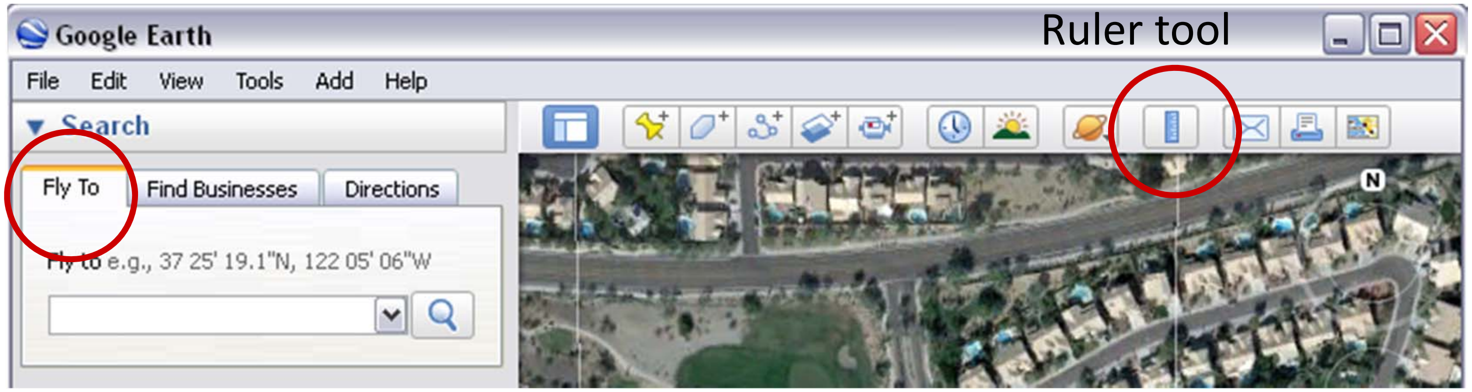
Image: courtesy of American Solar Electric
Table courtesy DOE/NREL

1) Calculate roof area and power

- Using Google Earth you measure the size of area on roof for the array
- E.g. ~30 feet x ~15 feet leaving some area around the array to walk = 450 square feet
- 450 square feet of array x 10 Watts per square foot = 4500 Watts AC

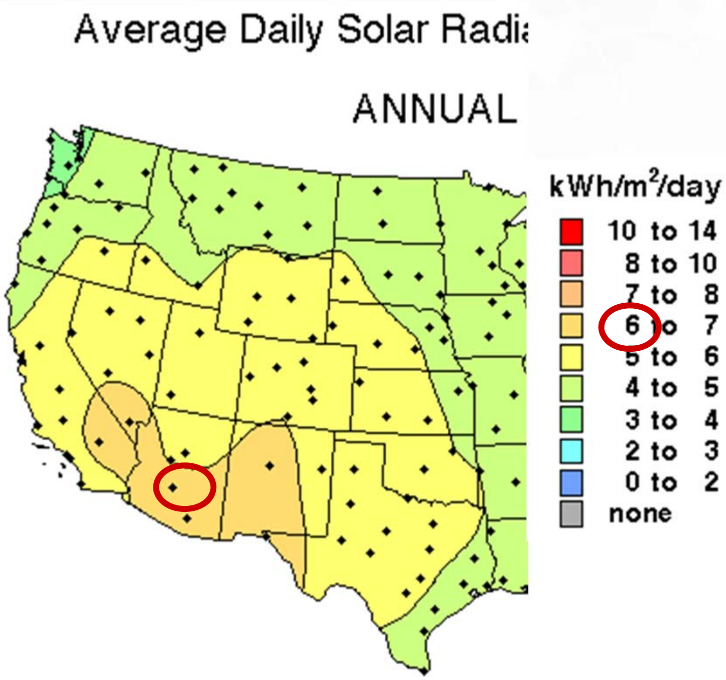


Courtesy of ©2010 Google and ©2010 Europa Technologies



2) energy per day

U.S. Solar Radiation Resource Maps:



Flat Plate Tilted South at Latitude - 15 Degrees

- Flat Plate Tilted South at Latitude
- Flat Plate Tilted South at Latitude - 15 Degrees
- Flat Plate Tilted South at Latitude + 15 Degrees
- Horizontal Flat Plate

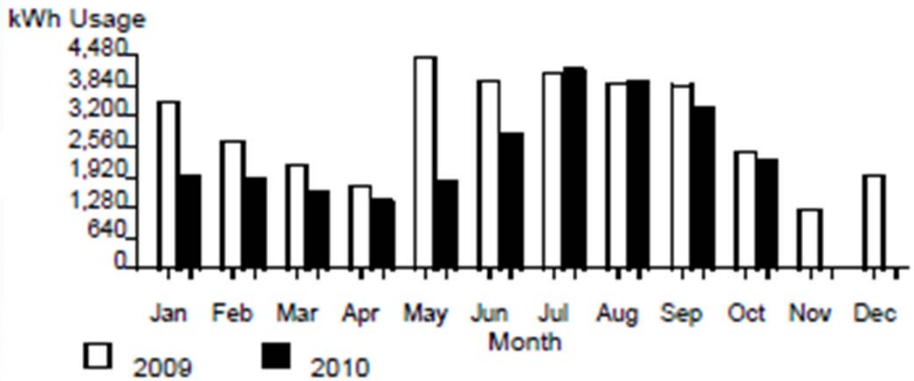
- Google search: “NREL insolation” NREL’s radiation resource maps show that a “Flat Plate tilted at latitude” has an annual average daily irradiation level or *peak sun* hours of <u>6-7 hours</u>

- Using 6 peak sun hours we multiply this by 4500 W to get average daily energy production of <u>27 KWh</u>

- Power (kW) x Time (h) = Energy (kWh)

Graphics: Courtesy of NREL link: http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/redbook/atlas/

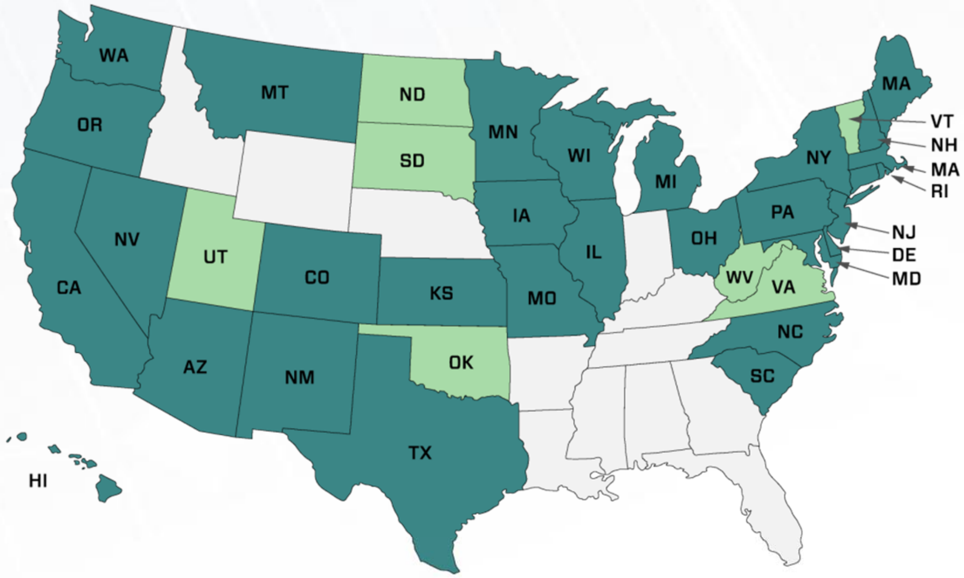
3) energy per month and value



- 27 KWh per day with and average of 30 days per month = 810 KWh of energy delivered per month

- At an average of $0.12 per KWh
  - 810 KWh/month x $0.12/KWh = <u>$97.2/month</u>

Renewables Portfolio Standards (RPS) and Goals



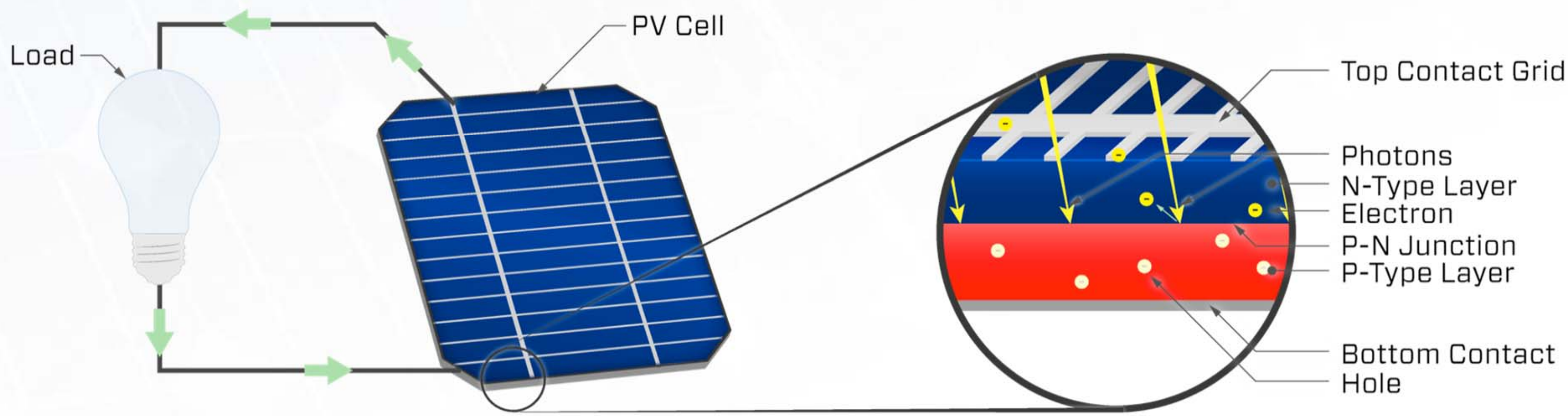
AZ: 15% x 2025
CA: 33% x 2020
CO: 30% by 2020 (IOUs)
10% by 2020 (co-ops & large munis)*
CT: 23% x 2020
DE: 25% x 2026*
HI: 40% x 2030
IA: 105 MW
IL: 25% x 2025
KS: 20% x 2020
MA: 22.1% x 2020 New RE: 15% x 2020 (+1% annually thereafter)
MD: 20% x 2022
ME: 30% x 2000
New RE: 10% x 2017
MI: 10% + 1,100 MW x 2015*
MO: 15% x 2021
MN: 25% x 2025
(Xcel: 30% x 2020)
MT: 15% x 2015
NC: 12.5% x 2021 (IOUs)
10% x 2018 (co-ops & munis)
NH: 23.8% x 2025
NJ: 22.5% x 2021
NM: 20% x 2020 (IOUs)
10% x 2020 (co-ops)
NV: 25% x 2025*
NY: 29% x 2015
OH: 25% x 2025†
OR: 25% x 2025 (large utilities)*
5% - 10% x 2025 (smaller utilities)
PA: ~18% x 2021†
RI: 16% x 2020
TX: 5,880 MW x 2015
WA: 15% x 2020*
WI: Varies by utility
10% x 2015 statewide

Pro-solar policy and tools

The RPS (renewable portfolio standards) varies from state to state

- For example, California has committed to producing 20% of its electricity needs with renewable energy by 2010, Arizona 15% by 2025
- RPS is one tool for a government to direct industry and consumers towards a sustainable future, Hawaii is in a hurry since their electric grid is oil based

Photovoltaic Effect



- A *photon* is a unit of electromagnetic radiation from the sun
- Photons contain various amounts of energy depending on their wavelength
- Certain wavelengths can be absorbed by the semiconductor material
- Photons transfer their energy to electrons in the semiconductor material, forcing electrons to move to the "N-layer" in the semiconductor
- Given that electrons are negative in charge, this creates a voltage potential
- The *photovoltaic effect* produces *free electrons* that must travel through conductors in order to recombine with *electron voids*, or "holes", this is the electric current which produces power

Micro-grid – small communities

http://islandsgoinggreen.org/about/eigg-electric/

Photos courtesy of islandsgoinggreen.org

- Eigg Electric (Scotland) is a community owned company which provides electricity for all island residents from the renewable sources of water, sun, and wind
- PV array: 10KW
- Four wind turbines: 24KW
- Hydro: 100KW
- Diesel generators: 140KW
- A number of AC-coupled SMA Sunny Island battery inverters create a 3-phase AC mains for the island
- 11KM of AC grid wiring

- Power is capped, 5KW residence, 10KW for businesses
- Currently adding more solar PV for the mild dryer summers

Video: (9:54) Eigg Electric

http://www.youtube.com/watch?v=l3n-6YHquno&hl=en&fs=1&]

Installation and geographies

- Germany is the world leader so far – it is time for China and the USA to step up to the adoption as top world energy consumers

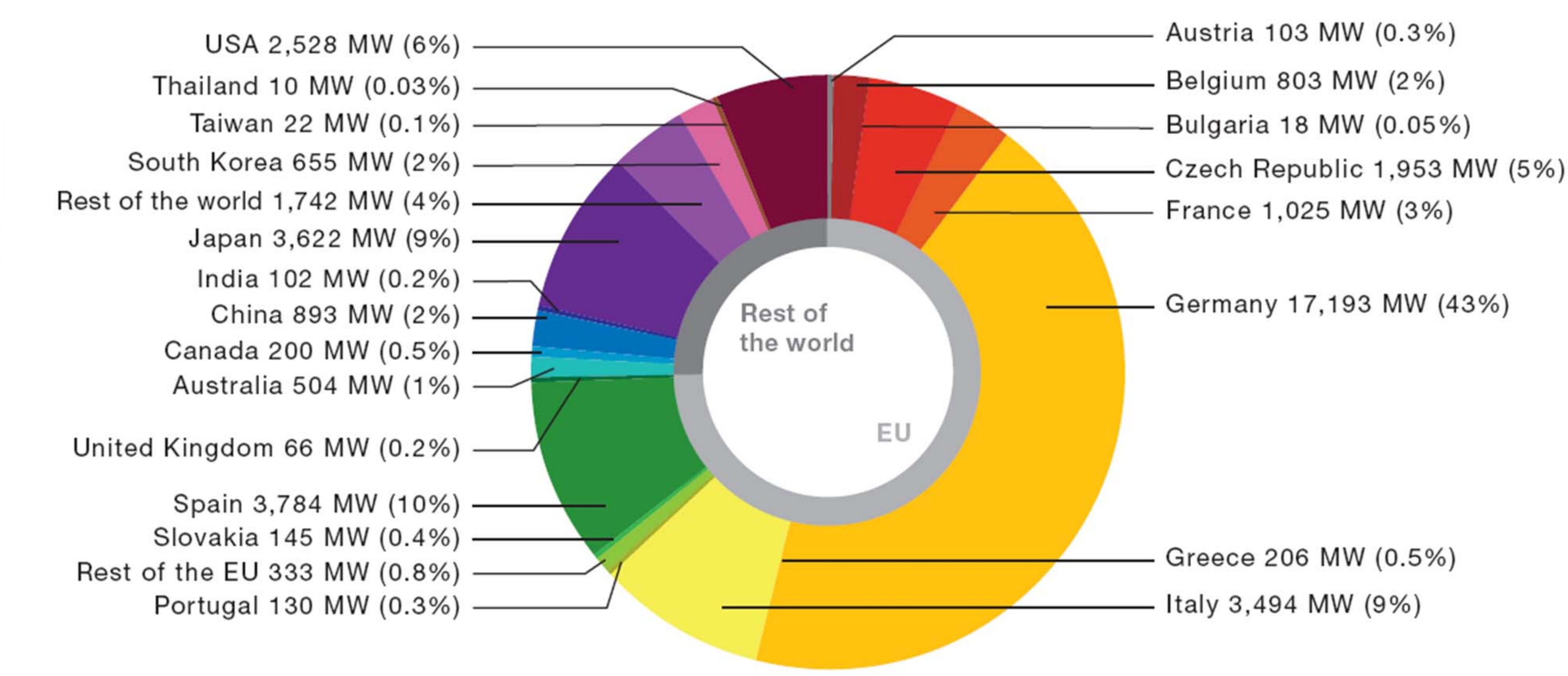


Figure 22 - 2010 global cumulative installed capacity share (MW, %)

Source: data and graph courtesy of European PhotoVoltaic Industry Association