Solar Photovoltaic Costs for Life of System

Spreadsheet by Russell Lowes, www.SafeEnergyAnalyst.org, 3/5/09 DRAFT

Energy Production Assumptions

Residential	**Residential**	**Residential**	**Utility Industrial**	
Based on Construction Cost Given By Solon at 2/12 Tour	Based on Typical Construction Cost Locally	Based on 50% rebate from Gov't & Utilities	Based on Lower Cost Industrial w/ Higher 12% Charge Rate	
1	1	1	1	kilowatt
8766	8766	8766	8766	hours per year
30.0%	30.0%	30.0%	30.0%	capacity factor (percentage of maximum nameplate rating realized in kilowatt-hours)
25	25	25	25	Lifespan; years of production of electricity
65745	65745	65745	65745	Subtotal
10.0%	10.0%	10.0%	10.0%	average degradation over 25 year lifespan, based on Solon guarantee of
59170.5	59170.5	59170.5	59170.5	kilowatt-hours production for lifespan

Cost Assumptions

$4,000.00	$12,000.00	$6,000.00	$4,000.00	Dollars per kilowatt of e capacity, A/C
$1,000.00	$1,000.00	$1,000.00	$1,000.00	Repairs and Maintenance over 25 year lifespan (GENERAL ESTIMATE)
$5,000.00	$13,000.00	$7,000.00	$5,000.00	Total investment over lifespan

Simple cost per Kilowatt-hour, without finance charges

$0.085	$0.220	$0.118	$0.085	dollars per kilowatt-hour

To calculate the finance charges:

$4,000.00	$12,000.00	$6,000.00	$4,000.00	Capital investment, construction cost
25	25	25	25	Years of loan
8.25%	8.25%	8.25%	12.00%	Interest rate of loan / FIXED CHARGE RATE FOR INDUSTRIAL OPTION
$386.52	$1,159.56	$579.78	$480.00	Mortgage payment for loan per year (hand-entered from loan amortization program for Residential, Calc'd for Industrial)
$9,663.00	$28,989.00	$14,494.50	$12,000.00	Total repayment for loan over lifespan (line above times lifespan years)

Total lifespan costs with mortgage payments

$9,663.00	$28,989.00	$14,494.50	$12,000.00	Capital costs (mortgage) over lifespan
$5,000.00	$5,000.00	$5,000.00	$5,000.00	Repairs and maintenance over lifespan
$14,663.00	$33,989.00	$19,494.50	$17,000.00	Total cost over lifespan
$0.25	$0.57	$0.33	$0.29	Final cost per kilowatt-hour with interest
			$0.06	For Utilities, add 6 cents for Transmission and Distribution
			$0.35	End cost for average retail price.

Note that profit for investors, insurance & property taxes are included in the 12% levelized fixed charge rate, in the Industrial example. 12% is used by Standard and Poor's for utilities (non-nuclear).

Other factors:
For residential non-utility examples, insurance and property costs are not included.
The maintenance costs need to be better grounded in experience, for all examples.

Deterioration Rate of Solar PV at 0.5% per year

1	1	Initial kilowatt of capacity
2	0.995	
3	0.990025	
4	0.985075	
5	0.98015	
6	0.975249	
7	0.970373	
8	0.965521	
9	0.960693	
10	0.95589	
11	0.95111	
12	0.946355	
13	0.941623	
14	0.936915	
15	0.93223	
16	0.927569	
17	0.922931	
18	0.918316	
19	0.913725	
20	0.909156	
21	0.90461	
22	0.900087	
23	0.895587	
24	0.891109	
25	0.886654	
	0.942238	Average delivery of electricity per initial kilowatt of capacity

Electricity Costs for Pima County Residents
Now and in the Future

Spreadsheet by Russell Lowes, www.SafeEnergyAnalyst.org, 3/17/09 DRAFT

Typical Residential Consumption KWH/Mo	**Reduction In Electricity With Different Mix of Consumption KWH/Mo**	**Prior Column over 25 years**	
750	750	225000	Current consumption for a typical residence
$ 0.105	$ 0.105		Cost per kilowatt-hour of electricity
$ 78.75	$ 78.75		TOTAL ROUGH CURRENT COST
0.00%	25.00%		Asssumed % reduction in consumption of KWH
750	563	168,750	New consumption level after energy efficiency program
0	188	56,250	Energy saved per month in KWH

Projected Blend of Energy in %

0.00%	10.00%	New Solar PV
70.00%	50.00%	Old Coal
30.00%	25.00%	Old natural gas plants
0.00%	5.00%	New natural gas plants
0.00%	0.00%	New Nuclear
0.00%	10.00%	Wind
0.00%	0.00%	Hydro
100.00%	100.00%	

Energy efficiency with new mix of solar/coal/natural gas

			Cost for Electricity for Each Source
$ -	$ 13.50	$ 4,050.00	New Solar PV
$ 52.50	$ 28.13	$ 8,437.50	Old Coal
$ 26.25	$ 16.41	$ 4,922.44	Old natural gas plants
$ -	$ 4.22	$ 1,265.63	New natural gas plants
$ -	$ -	$ -	New Nuclear
$ -	$ 8.44	$ 2,531.25	Wind
$ -	$ -	$ -	Hydro
$ 0.03	**$ 0.03**	**$ 0.03**	**Energy efficiency cost per KWH**
$ -	$ 5.63	$ 1,687.50	Energy efficiency cost per month
$ 78.75	**$ 67.88**	**$ 20,363.06**	Total new cost of electricity
$ (0.00)	**$ 10.87**	**$ 3,261.94**	**Savings/total bill**
0.0%	1.4%	1.4%	Savings as % of original bill **Savings in Total CO2:**
			Average CO2 per Kilowatt-Hour
			Savings per KWH CO2:

Cost per Kilowatt-Hour Resulting KWH Used

$0.240	$0.240		New Solar PV
$0.100	$0.100		Old Coal
$0.117	$0.117		Old natural gas plants
$0.150	$0.150		New natural gas plants
$0.240	$0.240		New Nuclear
$0.150	$0.150		Wind
$0.100	$0.100		Old Hydro
$0.035	$0.035		Energy Efficiency

KWH Consumption breakdown by source

0	56	16,875	New Solar PV
525	281	84,375	Old Coal
225	141	42,188	Old natural gas plants
0	28	8,438	New natural gas plants
0	0		New Nuclear
0	56		Wind
0	0		Hydro
750	563	168,750	Total KWH/Mo
$ 0.105	$ 0.121		Total Cost Per KWH

CO2 Output. . .	. . .See Below

Initial CO2 Output grams/KWH	New Mix CO2 Output Output
0	1,800
504,000	270,000
112,500	70,313
0	12,459
0	0
0	506
0	0
616,500	354,572

	42%
822	630
	23%

Initial CO2 Output grams/KWH	New Mix CO2 Output Output

32	32
960	960
500	500
443	443
400	400
9	9
10	10
5	5

Cost for a Nuclear Reactor and Cost Per Person for Nuclear Energy, Capital Portion Only

A Worksheet by Russell J. Lowes, updated 3/5/09

I have seen nuclear industry estimates have run from $1,000-2,000 per kilowatt of installed electrical capacity to $4,000, over the 2000-2006 period. When 2006 arrived, cost estimates increased dramatically.

Recently, some spokespersons for the industry have begun to face reality and have increased their projections dramatically, two estimates as high as $8,200 and $10,000 per kilowatt.

However, reactors in the late 1980s were finishing at just over $3000, in 1980s dollars. (See Brice Smith, Insurmountable Risks: The Dangers of Using Nuclear Power to Combat Global Climate Change at www.ieer.org/)

This $3000 does not count all the reactors that were canceled due to cost overruns, so this figure is low. Running a $3000 price out from 1988 to 2008 with simple inflation yields (at the http://data.bls.gov/cgi-bin/cpicalc.pl) $5500, rounded to the nearest $100.
This $5500 figure is low due to construction costs outpacing general inflation, particularly with the price of copper, steel and cement going up with increased world demand.
On top of the $5500 in 2008, projecting out to 2020 as a completion year for a reactor at a 4% annual cost escalation rate yields $8500.

However, more robust reactor designs with two decades worth of lessons of safety improvements has its costs. The industry is going to be required to build structures capable of withstanding large jet impacts, per post-911 rules. This will substantially increase the cost of building nukes. Additionally, "passive" cooling systems will require substantial cost increases, as massive reservoirs will be built to hold water for ECCS backup.

What will the nuclear program cost per person in the U.S. if the industry builds 1000 reactors, each averaging 1000 megawatts, in this nation?

The following table assumes that the 100 reactors are built the same year, and run for 30 or 40 years. However, no reactor has run for this long of a period at an average 85% capacity factor, so this 40-year estimate is giving the nuclear industry the benefit of the doubt.

1,350	average size reactor, megawatts
$9,000	average cost per kilowatt of electrical capacity installed (for 2020 completion)
$12,150,000,000	cost per plant
100	number of plants under the Bush and McCain plans
$1,215,000,000,000	total construction cost
14.0%	levelized fixed charge rate for 30 year payback schedule
$170,100,000,000	annual rate paid per year
$5,103,000,000,000	total capital payback over 30 years
350,000,000	people in the U.S. on average over the 30-year payback peroiod
486	costs per person per year for loan payback

If the above scenario is realized, what will the cost of nuclear power be per kilowatt-hour, for just the capital portion?

Keystone Report/Nuclear Power Joint Fact-Finding

		Low Cost 40Yr90%	High Cost 30Yr75%
$9,000	Cost per kWe installed	**$2,950**	**$2,950**
14.0%	Capital payback per year/Fixed Charge Rate	12.3%	13.8%
$1,260	Annual payback per KW, first 30 years	$363	$408
30	**Reactor Life in years**	**40**	**30**

	30	**Capital Payback Period**	**30**	**30**
			10,887	12,229
	$37,800	Capital payback over 30 years Capital Payback per kW installed	$14,516	$12,229
	85.0%	Capacity factor	**90.0%**	**75.0%**
	223,533	kWhe generated per kWe installed, for years in Reactor Life	315,576	197,235
$	**0.1691**	$/kWhe	**0.046**	**0.062**
		compared with the calculations on the left:	**0.127**	**0.169**
	40	**Extended 40-year reactor life in years**		
	298,044	kWhe generated per kWe installed		
$	**0.1268**	Capital cost/kWhe		

If the reactors ran at the fanatasy industry figure of $2000 per kWhe, lasted 40 years and had a 85% capacity factor:

	280	Annual Payback per KW, first 30 years
	$8,400	Capital payback over Reactor Life per kilowatt installed
$	**0.0376**	Capital cost/kWhe

Fuel, and Operation and Maintenance Costs are Projected Differently by the Following Sc

		From the Keystone Report/"Nuclear Power Joint Fact-Finding," page 42.
	0.015	Fuel
	0.023	Fixed Operating and Maintenance Cost
	0.005	Variable O&M
$	**0.0430**	Total Fuel and O&M
$	**0.1698**	Total All Costs/kWhe

		From IEER January 2008 Science for Democratic Action newsletter:
$	**0.0430**	per kilowatt-hour, average projection by the Keystone Report, 2007 $
$	**0.0230**	PacifiCorp, a Western states utility company 2007 $

		From Report submitted to the California Public Utilities Commission,
		Energy & Environmental Economics, Inc.
		www.ethree.com/cpuc_ghg_model.html
		Fixed O&M is estimated at $83/kW-yr, this would be
$	**0.0111**	Fixed O&M
$	**0.0012**	Variable O&M
		Fuel is listed as $.78/MMBtu, with Heat Rate @10,400 btu/kwh
$	0.7800	/MMBtu (million btu)
	293	kilowatts = 1 MMBtu At 3413 btu/kWh 1MMBtu
$	**0.0027**	Cost of fuel
$	**0.0150**	Cost of Fuel and O&M

		From Standard & Poor's "Which Power Generation Technologies Will Take the Lead In Response to Carbon Controls," May 11, 2007
$	**0.0134**	per kW/yr
		$/kWhe @ 85% Capacity factor

*The Keystone report is considered the most accurate and up-to-date for future reactors, and will be used in the cost of calculating nuclear energy. It should be noted that there is a predicted shortage of uranium for fueling reactors, starting around 2018, with resource depletion problems getting worse over the subsequent years. Keystone does not take into account the more dire projections. Keystone was an interdisciplinary process involving teams of researchers and writers from the nuclear industry, NGOs, etc.

Nuclear and Other Energy Options
Cost Recap

		Projected Nuclear Costs per Kilowatt-Hour of Electricity Delivered
$	0.1268	Capital costs
$	0.0150	Fuel Costs
$	0.0230	Fixed Operation and Maintenance
$	0.0050	Variable Operation and Maintenance
$	0.1698	Total Generating Cost for Nuclear Electricity Per Kilowatt-Hour
$	0.0700	Transmission and Distribution
$	0.2398	Total Cost of Electricity for Delivered Nuclear Electricity
$	0.1000	**Current Coal Technology Electricity Generation Cost**
$	0.0700	Transmission and Distribution
$	0.1700	Total Cost of Electricity for Delivered Coal Electricity
$	0.0800	**Current Natural Gas Technology Electricity Generation Cost**
$	0.0700	Transmission and Distribution
$	0.1500	Total Cost of Electricity for Delivered Gas Electricity
$	0.1200	**Solar Thermal Electricity Generation Cost**
$	0.0700	Transmission and Distribution
$	0.1900	Total Cost of Electricity for Delivered Solar Thermal Electricity
$	0.15-0.40	**Solar Photovoltaic Electricity Generation, including On-Site T&D**
$	0.0800	**Wind Generation Cost of Electricity**
$	0.0700	Transmission and Distribution
$	0.1500	Total Cost of Electricity for Delivered Wind Electricity
$	0.0350	**Cost of Energy Efficiency Per Kilowatt-Hour Saved, if Implemented On Large Scale**

ources

KWH/Household for nukes and coal	2	2
capacity factor for nukes and coal	75	75
capacity factor for wind and PV	35	30
Renewable CF fraction of Nuke/Coal CF	0.466667	0.4
KWH/Household for wind and PV solar	4.285714	5
Households per kilowatt of nukes & coal	0.5	0.5
Households per kilowatt of wind & solar	0.233333	0.2

Decommissioning and Waste Cost of Surveillance System Over One Million and Ten Thousand Years

	The total number of megawatt-hours put out by a 1000 1000-MW nuclear plants over 40 years at 85% capacity factor
1000	number of reactors
1000	Megawatts of electricity per reactor, Design Electrical Rating
40	Number of years
8766	Hours per year
85.0%	Capacity Factor/Load Factor
298,044,000,000	Megawatt-hours of electricity for reactors
298,044,000,000,000	Kilowatt-hours of electricity for reactors

The federal court system has ruled that the Environmental Protection Agency can no longer use 10,000 years as a guideline for nuclear waste planning – they must now use 1 million years.
See: U.S. News & World Report, "Mired in Yucca Muck, Nuclear power is trendy again, but what about the waste?" by Bret Schulte, at http://www.usnews.com/usnews/news/articles/061022/30nukes.htm

Under the old 10,000 year guidline, the amount of kilowatt-hours the plants produce divided by 10,000 would equal what?

298,044,000,000,000	Kilowatt-hours of electricity for reactors
10,000	years of waste management
29,804,400,000	Kilowatt-hours of electricity for waste management.
30.0%	Reduced by the 30%, for example of energy input at the front end: mining, milling, conversion, enrichment, re-conversion, fabrication, building the plant, running the plant, short-term waste storeage
30.0%	Reduced by say another 30%, with the goal of having a 40% net energy gain.
11,921,760,000	Hours per year to devote to waste management.

If the new 1,000,000 year guideline is used, the amount of kilowatt-hours for waste storeage per year:

298,044,000,000,000	Kilowatt-hours of electricity for waste management.
1,000,000	years of waste management
298,044,000	Kilowatt-hours of electricity for waste management.
30.0%	Reduced by the 30%, for example of energy input at the front end: mining, milling, conversion, enrichment, re-conversion, fabrication, building the plant, running the plant, short-term waste storeage
30.0%	Reduced by say another 30%, with the goal of having a 40% net energy gain.
119,217,600	Kilowatt-hours per year to devote to waste management.

How does this waste cost compare to other industrial management processes?
If the waste is kept at the reactor sites, as may be the case in the future, then there will be 104 reactor sites (if you count each reactor as a site – many reactors are at multiple-reactor sites).
10,000-Year Plan:

11,921,760,000	Kilowatt-hours per year to devote to waste management.
1,000	reactors
11,921,760	Kilowatt-hours per year to devote to waste management.

Million-Year Plan:

119,217,600	Kilowatt-hours per year to devote to waste management.
1,000	reactors
119,218	Kilowatt-hours per year to devote to waste management.

What would this value be in today's dollars at, for example, 10 cents per kWhe?

10,000-Year Plan:

11,921,760	Kilowatt-hours per year to devote to waste management.
$0.10	
$1,192,176	Electricty cost per year in today's dollars.

Million-Year Plan:

119,218	Kilowatt-hours per year to devote to waste management.
$0.10	
$11,922	Electricty cost per year in today's dollars.