Tables - LCOE Paper

TABLES

Table 1: Summary of LCOE estimated from various sources in North America

Estimated LCOE $/kWh	Technology	Year	Plant specifications	Life	Financing and incentives	Location and solar resource	Ref.
0.28-0.46	Solar PV (including tracking - 0.5%/yr degr.)	2008	residential ($7.5/W, CF 14%-33%)	30	no subsidies (30 yr mortgage, 100% financed, 6% IR, 6% DR, 35% TR)	various cities in USA (1000- 2500 kWh/m2/yr)	[11]
0.20-0.32	Solar PV (including tracking - 0.5%/yr degr.)	2008	residential ($7.5/W, CF 14%-33%)	30	with subsidies covering 30% initial cost (30 yr mortgage, 100% financed, 6% IR, 6% DR, 35% TR)	various cities in USA (1000- 2500 kWh/m2/yr)	[11]
0.15-0.80	Solar PV single axis	2009	25 MW (CF 27%,$4.55/Wp)	20	with and without tax benefits, and other incentives (merchant, IOU, POU)	California, USA [California Energy Commission]	[14]
0.15-0.20	Solar PV-crystalline	2009	10 MW (CF 20-27%,$5/Wp)	20	lower price include incentives	USA	[58]
0.12-0.18	Solar PV-thin film	2009	10 MW (CF 20-23%,$4/Wp)	20	lower price include incentives	USA	[58]
0.16 (year 1)	Solar PV	2010	large scale ($3.00/W, CF 21%)	20/ 100	20 yr, 6% IR, no incentives or tax	USA Southwest	[49]
0.316-0.696	Solar PV	Jan, 2011	2kW ($7.51/W)	20	5% cost of capital (tax and incentives excluded)	Global [used 5.5 sun-hours and 2.5 sun-hours as high and low sites]	[64]
0.169-0.372	Solar PV	Jan, 2011	500 kW ($3.98/ W)	20	5% cost of capital (tax and incentives excluded)	Global [used 5.5 sun-hours and 2.5 sun-hours as high and low sites]	[64]
0.319-0.702	Solar PV	Dec,2010	2 kW ($7.61/W)	20	5% cost of capital (tax and incentives excluded)	Global [used 5.5 sun-hours and 2.5 sun-hours as high and low sites]	[31]
0.171-0.376	Solar PV	Dec,2010	500 kW ($4.07/W)	20	5% cost of capital (tax and incentives excluded)	Global [used 5.5 sun-hours and 2.5 sun-hours as high and low sites]	[31]
0.15	Solar PV (1%/yr degr.)	2011	4.5 kW residential ($5/W, 10 yr inverter life)	35	not considered (SAM used)	Phoenix, USA	[19]
0.10	Solar PV (1%/yr degr.)	2011	150 kW commercial ($4/W, 15 yr inverter life)	35	not considered (SAM used)	Phoenix, USA	[19]
0.12	Solar PV (1%/yr degr.)	2011	12 MW single axis at tilt ($3.9/W, 15 yr inverter life)	35	not considered (SAM used)	Phoenix, USA	[19]

0.12	Solar PV (1%/yr degr.)	2011	12 MW two-axis conc. ($4.3/W, 15 yr inverter life)	35	not considered (SAM used)	Phoenix, USA	[19]
0.32	Solar PV (1%/yr degr.)	2005	4 kW (residential)($8.47/ W,	30	SAM (low values if unfinanced) effects of incentives, financing and tax considered	Phoenix, USA	[55]
0.18	Solar PV (1%/yr degr.)	2005	150 kW (commercial)($6.29 /W)	30	SAM (low values if unfinanced)	Phoenix, USA	[55]
0.15 - 0.22	Solar PV (1%/yr degr.)	2005	10 MW (utility scale) ($5.55/W)	30	SAM (low values if unfinanced)	Phoenix, USA	[55]
0.30	Solar PV (no degr.)	2007	Residential ($8.5/Wp)	30	home equity loan/mortgage, 90% debt, 6% IR, 28% TR, 30 yr loan with government incentives	USA (average - maps with state values given) (SAM used)	[56]
0.062	Solar PV	2006	3.51 MW, Utility Scale Pv fixed flat plate ($5.40/Wp, CF 19.5%)	30	no financing cost due to pay-as-go equity (IOU), includes tax credits	Springerville, Tucson, Arizona, USA (1707 kWh/kW/yr)	[59]
0.166	Solar PV	2003	5 MW ($4.16/W, CF 24%)	40	5% DR, no financing	USA	[26]
0.269	Solar PV	2003	5 MW ($4.16/W, CF 24%)	40	10% DR, no financing	USA	[26]
0.248	Solar PV	2010	roof top PV (projected)	25	weighted average cost of capital (6.4%)	Arizona, USA (1700 kWh/kWp)	[18]
0.294	Solar PV	2008	roof top PV ($5.2/W)	25	weighted average cost of capital (6.4%)	Arizona, USA (1700 kWh/kWp)	[18]
0.40	Solar PV (1%/yr degr.)	2009	commerical ($6.7/W, CF 18%)	30	7 % DR, no incentives (financing unclear)	USA	[38]; [10]
0.402-0.613	Solar PV (1%/yr degr.)	2009	rooftop ($7.20/Wp, CF 17%)	25	5 %-10% DR, no incentives (financing unclear)	Arizona, USA	[10]
0.309-0.499	Solar PV (1%/yr degr.)	2009	80 MW ($6.7/ Wp, CF 19%)	30	5 %-10% DR, no incentives (financing unclear)	Arizona, USA	[10]
0.561-0.860	Solar PV (1%/yr degr.)	2009	rooftop ($7.20/Wp, CF 12%)	25	5 %-10% DR, no incentives (financing unclear)	New Jersey, USA	[10]
0.198	Concentrated solar PV (CSP)	2007	65 MW ($3.7/W, CF 22%)	30	7% DR, no subsidies (higher O&M than Roof top) (financing unclear)	Nevada, USA	[10]
0.17-0.249	Concentrated solar PV (CSP)	2009	80 MW ($4.4/W, CF 29%)	30	5 %-10% DR, no incentives (financing unclear)	USA	[10]
0.122-0.192	Concentrated solar PV (CSP)	2009	500 MW ($3.9/W, CF 23%)	30	5 %-10% DR, no incentives (financing unclear)	USA	[10]

0.25 - 0.40	Solar PV (1-2%/yr degr.)	2003	Utility Scale PV or residential ($6.20-9.50/W)	20	with and without subsidies, taxes etc (financing uncertain)	California, USA (2000 kWh/m2/yr)	[61]- other projections made
0.49	Solar PV	2010	1 kW (CF 20%, $8.73/Wp)	25	residential amortization	USA	[15]
0.138-0.206	Solar PV thin-film	2009	large scale ≥ 20MW (CF 18-27%, $3.7-4.0/W)	20?	with and without incentives, financing?	California, USA	[25]
0.135-0.219	Solar PV crystalline single axis tracking	2009	large scale ≥ 20MW (CF 23-28%, $7.04-7.15/W)	20?	with and without incentives, financing?	California, USA* done for different project zones	[25]
0.456	Solar PV (fixed flat plate)	2008	20 MW ($7.98/W, CF 26%)	30?	weighted cost of captial after tax 5.9%, 15 yr accelerated Depr?	USA	[41]
0.20-0.80	Solar PV	2007	rooftop PV (2-5kW)	20?	no subsidies	worldwide range for 2,500 - 1,000 kWh/ m2 solar insolation -quoted from range of reports	[33]
0.20-0.50	Solar PV	2009	rooftop (2-5 kW)	?	no subsidies/ incentives	world average - quoted from range of reports	[3]
0.15-0.40	Solar PV	2008	different applications (?)	?	variable including taxes for USA (?)	different locations, USA (?) see [58]	[4]
0.19	Solar PV	2007	large scale	20	independent power producer financing (no incentives)	pacific north west, USA	[60]
0.22- 0.24	Solar PV	2007	small scale	20	independent power producer financing (no incentives)	pacific north west, USA	[60]
0.255	solar PV (solar cell)	2008	5MW ($5.782/W, CF 21%)	?	no incentives,financing for IPP	USA	[57]
0.20-0.50	Solar PV	2006	varies at consumer level	20?	no incentives	Canada	[36]
0.20,0.31	Solar PV	2004	2003 prices	?	DR 10% and 15% (Sandia Model, GenSim)	Chicago, USA	[62]
0.337-0.526	Solar PV - crystalline	2008 (2005 price)	5 MW ($6.31-%7.81/ W, CF 15-25%)	20	?	?	[34]
0.392	Solar PV	2008	5 MW ($7/W, CF 20%)	?	?	Minera Escondida Limitada copper mine (off-grid) - South America	[34]
0.25	Solar PV	2010	2006 prices, includes storage	?	?	USA	[54]
0.15 - 0.78	Solar PV	2003	?	?	?	Canada, Taken from US studies and converted to Canadian $	[37]

Legend: degr.: Degradation rate, CF: Capacity Factor, DR: Discount rate, IR: Interest Rate, TR: tax rate, Depr: Depreciation, IPP: Independant power producer , IOU: investor-owned utilities, POU: publicly owned utilities. W=Wp assumed as meaning the rated system power (units displayed as refered to in the sources). SAM: Solar Advisor Model (NREL)

Table 2: LCOE Calculation Nomenclature

Nomenclature	
T	life of the project [years]
t	Year t
C_t	Net cost of project for t [$]
E_t	Energy produced for t [$]
I_t	Initial investment/ cost of the system including construction, installation etc. [$]
M_t	Maintenance costs for t [$]
O_t	Operation costs for t [$]
F_t	Interest expenditures for t [$]
r	Discount rate for t [%]
S_t	Yearly rated energy output for t [kWh/yr]
d	Degradation rate [%]

Table 3: Summary of recent Solar PV installed system costs

Solar PV technology	Installed Cost [$/Wp]	Project Scale
Crystalline (Europe)[a]	5.00	Utility
Crystalline (China) [a]	4.42	Utility
Crystalline (Japan) [a]	5.02	Utility
Thin-Film CdS/CdTe[a]	4.28	Utility
Thin-Film a-Si/ μ-Si[a]	3.52	Utility
Crystalline and thin film (USA)[b]	7.50	Capacity weighted average (2009)
Crystalline and thin film (Germany)[c]	7.70	Residential (2-5 kW) (2009)
Crystalline and thin film (Japan)[c]	4.70	Residential (2-5 kW) (2009)
Crystalline and thin film (USA)[c]	5.90	Residential (2-5 kW) (2009)
Crystalline and thin film (CA,USA) [b]	7.30	Residential ≤10 kW (2010)
Crystalline and thin film (CA,USA) [b]	6.10	> 100 kW (2010)

NOTES: [a] estimate based on module prices [68] ; [b] average of installed systems [67]; [c] average of installed systems excluding sales taxes[67]

Table 4: Effect of degradation rate and performance requirement on system life

Degradation rate	Lifetime to 80% Pmax [years]	Lifetime to 50% Pmax [years]
0.2%	100	250
0.5%	40	100
0.6%	33	83
0.7%	29	71
0.8%	25	63
1.0%	20	50

Table 5: Summary of Power loss results for 204 modules installed in 1982-1986 with 19-23 years [77]

	Average losses (%)	Std dev (%)	Reasons
Power loss	17.3	23.5	Combination of losses in V_{OC}, I_{SC} and FF (see below)
Loss in V_{OC} (Open circuit voltage potential across terminal)	10.6	18.5	Loss of substrings in module in 6 series modules
Loss in I_{SC} (Short circuit current – maximum current delivered)	5.8	20	Module aging processes (gradual degradation of semiconductor properties, cell interconnections, encapsulant browning), optical properties degradation
Loss in Fill Factor, FF (ratio of maximum actual power to maximum theoretical power)	9.1	22	Module aging processes (gradual degradation of semiconductor properties, cell interconnections, encapsulant browning), microscopic cracks and degradation of interconnections increase resistance