



# A Financial Algorithm for Computing the Levelized Cost (US\$/MWh) of the Bulk Storage of Solar Electricity (LCOS)

## A Guide for Bankers and their Engineers

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**ABSTRACT ---** This paper discusses the financial and technical principles underlying the levelized cost (LC) method of computing the cost (US\$/MWh) of the bulk storage of solar electricity (LCOS). The paper presents a LC algorithm. For rapid computation, an Excel LC Algorithm Workbook is presented. The financial algorithm uses nine recognized energy storage plant (ESP) specifications (specs) to compute the LC of the stored solar electricity. “Published” (complied) specs for the proposed Highview/Encore Liquid Air Energy Storage (LAES) Plant (Vermont), for the upcoming Tesla Moss Landing Li-ion Battery ESP (California) and the actual Cabin Creek Pumped Hydro ESP (Colorado) are used as case studies to demonstrate the algorithm. The goal of this paper is to present a standard computational algorithm for bankers and their engineers to use. Readers can do a LC computation based on the paper’s LCOS algorithm and on their own complied ESP specs. The paper’s LCOS algorithm gives the reader who has the nine ESP spec values, a quick “back of the envelope” verification of the developer’s LCOS. A complication arises in using this paper’s LC algorithm. The complication is that “published” ESP specs are limited and that an ESP developer’s specs must be confirmed by the reader. The paper discusses how to compile the nine ESP specs when good specs are not publicly available. In finance, having good numbers is always a challenge. **RESULTS:** The LCOS in the three cases below are 2 to 2.5 times (Line  $\sqrt{-2}$ ) the cost of the solar electricity being stored (Line 5). The three ESP must be in markets that support these LCOS.

### ENERGY STORAGE FACTS

- Bulk solar electricity is energy and is measured in  $MWh_{ELECT}$
- Bulk solar power is measured in  $MW_{ELECT}$
- Bulk energy storage power is measured in  $MW_{ELECT}$  of power output
- Bulk energy storage is measured in  $MWh_{ELECT}$



Table I Poster Excel LCOS Algorithm Worksheet with Three Cases				Vermont Highview/Encore LAES Plant	California Tesla Moss Landing ESP	Colorado Cabin Creek Pumped Storage Plant	
<b>ES Plant CapEx</b>							
1	Enter	ESP-Power Output-MW		50	182.5	324	
2	Enter	ESP Daily Energy Storage Capacity-MWh/day		400	730	1,296	
A	Computed	ESP Yearly Energy Storage Capacity-MWh/yr		146,000	266,450	473,040	
3	Enter	ESP Plant CapEx-US\$/kWh		\$135	\$200	\$160	
$\sqrt{-1}$	Computed	ESP Plant CapEx-US\$/MWh		\$135,000	\$200,000	\$160,000	COLOR CODE
B	Computed	Total ESP Plant CapEx-US\$/EPS		\$54,000,000	\$146,000,000	\$207,360,000	
<b>Cost of the Stored Solar (Wind) Electricity</b>							Specification
4	Enter	ESS Plant Round Trip Efficiency- $\eta$ -%		70%	88%	86%	Computed Value
5	Enter	Cost of the Solar (Wind) Electricity to be Stored-COE-US\$/MWh		\$40.00	\$40.00	\$40.00	$\sqrt$ Check Value
C	Computed	Cost of the Stored Solar(Wind) Electricity-COSE-US\$/MWh		\$57.14	\$45.45	\$46.51	Transferred Value
D	Computed	Extra Cost (COSE-COE) of the Stored Solar (Wind) Electricity-US\$/MWh		\$17.14	\$5.45	\$6.51	
E	Computed	% Increase in the Cost of the Stored Solar (Wind) Electricity		43%	14%	16%	
<b>Energy Storage Costs</b>							
6	Enter	Annual Fixed O&M Cost-% Total ESP CapEx-Line B		1.00%	0.50%	1.00%	
F	Computed	Annual Fixed O&M Cost-US\$/yr		\$540,000	\$730,000	\$2,073,600	
7	Enter	Variable O&M Cost-US\$/MWh		\$1.00	\$1.00	\$1.00	
8	Enter	Physical Life of the ESP-Years		20	20	50	
9	Enter	Interest/ROE Rate-WACC-%		8%	8%	6%	
G	Computed	Capital Amortization Factor-CAF		0.1019	0.1019	0.0634	
H	Computed	Annual Capital Amortization-ACA-US\$/yr		\$5,500,019	\$14,870,422	\$13,155,807	
<b>Computation of the Levelized Cost of the Stored Solar (Wind) Electricity-US\$/MWh</b>							
I	Computed	Annual Capital Amortization-ACA-US\$/MWh		\$37.67	\$55.81	\$27.81	
J	Computed	Fixed O&M Cost-US\$/MWh		\$3.70	\$2.74	\$4.38	
K	Transferred	Variable O&M Cost-from Line 7 above-US\$/MWh		\$1.00	\$1.00	\$1.00	
L	Transferred	Cost of the Stored Solar (Wind) Electricity-COSE- from Line C above-US\$/MWh		\$57.14	\$45.45	\$46.51	
M	Computed	Levelized Cost of the Stored Solar (Wind) Electricity-LCOS-US\$/MWh		\$99.51	\$105.00	\$79.71	
N	Computed	Levelized Extra Cost of the Stored Solar (Wind) Electricity-LECOS-US\$/MWh		\$59.51	\$65.00	\$39.71	
O	Computed	% Increase in the Levelized Cost of the Stored Solar (Wind) Electricity		148.8%	162.5%	99.3%	
$\sqrt{-2}$	Computed	LCOS/COE		2.5	2.6	2.0	