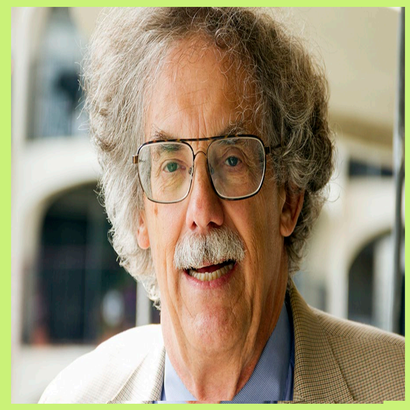
A Financial Algorithm for Computing the Levelized Cost (US$/kg; €/kg) of Producing Green Hydrogen (LCOH): A Quantitative Tool



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Description of Green Hydrogen (H_2) Production and the Explanation of the LCOH Algorithm

- There are no hydrogen (H_2) wells.. Green H_2 must be produced using a water electrolyzer powered by solar electricity to split water into green H_2 and O_2
- This white paper discusses the technology, operation and finances of a model utility scale water electrolyzer. The paper explains the levelized cost (LC) method
- The author has developed a LCOH algorithm for a model water electrolyzer.
- The paper explains the LCOH algorithm. The LCOH algorithm requires values for the nine electrolyzer specs [independent variables] to then compute the 17 dependent variables including Line Q, the LCOH itself.
- The LCOH algorithm is presented on the paper's Excel LCOH Worksheet. The LCOH worksheet, with the model electrolyzer's nine specs (Lines 1→9) and the 17 dependent variables (Lines A→W) is in the column to the right.
- The paper discusses the basis for the nine spec values as well as the sources for the price of gray (blue) H_2.
- Readers can enter their own nine spec values on their copy of the paper's Excel LCOH algorithm worksheet
- The goal of this paper is first, the computation of the LCOH of green H_2 produced at the model electrolyzer and second, the comparison of the LC of green H_2 with the cost of gray H_2 (blue H_2) **[**blue H_2 = gray H_2 + carbon capture**]**
- Gray H_2 is currently produced using natural gas in the carbon intensive steam methane reformation (SMR) process. It is used as an industrial gas and as a feedstock for the production of other industrial gases [i.e. ammonia (NH_3) methane (CH_4); methyl alcohol (CH_3OH)].
- The first use for green H_2 will be as a substitute for gray H_2 as an industrial gas
- The current H_2 industry price unit for gray H_2 is the US$/kg (€/kg). This paper also uses the kg, the SI unit for mass, not volume (Nm^3), as its price unit. The ton_m is also used.
- Line FX is used to convert US$ values into € values. One £ value is also converted in a US$ value
- Line CF--There are 39.41 kWh (0.03941 MWh) (HHV) in each kg of H_2 This converts solar electric energy measured in kWh into solar energy measured in kg of H_2
- Line 1-Efficiency (η) is 70%. A 100% η electrolyzer will only use 39.41 kWh of solar electricity to produce 1 kg of green H_2
- Line 2, the Capacity factor is 83.3% (20 hrs/day) which is very high
- Line 3, Electrolyzer capacity is 300 MW. Capacity is measured in MW_{ELEC} of solar electricity that power the electrolyzer
- Line 4, Electrolyzer CapEx is US$1,082,152/MW (£800,000). One British water electrolyzer manufacturer stated that its 2022 Electrolyzer CapEx is £800,000/MW while next year it would be £500,000/MW. A 37.5% reduction.
- Line E, Total Model Electrolyzer Invested Capital is US$364,645,600. This is the 300 MW on Line 3 times the US$1,082,152/MW on Line 4
- Line 5, Cost of Solar Electricity is US$35.00/MWh which is a good price for US solar electricity
- Line K, annual capitalization factor, US$0.0872, is the annual payment for an annuity have US$1.00 as the amount borrowed, a life of 20 years (Line 8) and a cost of capital of 6% (Line 9).
- 20 years is a very long life for an electrolyzer; 6% is a very low cost of capital.
- With the nine spec values entered on the worksheet, the LC of green H_2 is US$3.18/kg which is US$2.18 or 69% greater than the US$1/kg, current price of gray H_2
- The cost of the solar electricity is 62% of the LCOH while the annual electrolyzer CapEx amortization is 22.9%.

The White Paper's Excel LCOH Algorithm Worksheet

Line		07/09/22	A ↓	B ↓
1. Foreign Exchange-FX			US$/€ ↓	m/d/y
FX	Enter	US$/€ exchange rate	$1.14509	02/07/22
2. Water Electrolyzer Specifications				
1	Enter	Electrolyzer Efficiency-η-%	70%	hrs/day ↓
2	Enter	Electrolyzer Capacity Factor-%	83.3%	20.0
3	Enter	Electrolyzer Power Input-MW	300.0	
A	Computed	Max Daily MWh of Solar Electricity to be converted into H_2-MWh_{ELECT}/day	6,000	
B	Enter	Daily H_2 Produced-MWh_{H2}/day	4,200	
CF	Enter	Conversion factor-MWh_{ELECT}/kg_{H2}	0.03941	ton_m/day ↓
C	convert MWh to kg	Daily H_2 Produced-kg_{H2}/day	106,572	107
D	Computed	Yearly H_2 Produced-kg_{H2}/year	38,898,601	€/MW ↓
4	Enter	Electrolyzer CapEx-US$/MW	$1,082,152	€ 945,037
E	Computed	Total Invested Capital-US$/Electrolyzer	$324,645,600	€ 283,510,990
3. Cost of the Solar Electricity Converted into H_2				€/MWh ↓
5	Enter	Cost of the Solar Electricity converted into H_2-COE_{ELECT}-US$/$MWh_{ELECT}$	$35.00	€ 30.57
F	MWh converted to kg	Cost of the Solar Electricity converted into H_2-COE_{ELECT}-US$/$kg_{ELECT}$	$1.38	€ 1.20
				€/kg ↑
4. After Efficiency (η) Lost Cost of the Solar Electricity Converted into H_2				€/kg ↓
G	computed	After η Loss Cost of the Solar Electricity converted into H_2-$AELCOE_{ELECT}$-US$/$kg_{ELECT}$	$1.97	€ 1.72
H	computed	Extra Cost ($AELCOE_{ELECT}$-COE_{ELECT}) of the Solar Electricity-US$/$kg_{ELECT}$	$0.59	€ 0.52
I	computed	% Increase in the Cost of the Solar Electricity when converted into H_2	43%	43%
5. Water Electrolyzer CapEx and OpEx				
6	Enter	Annual Fixed O&M Cost-% Line E, Total Electrolyzer CapEx	3.00%	€/yr↓
J	Computed	Annual Fixed O&M Cost-US$/yr	$9,739,368	€ 8,505,330
7	Enter	Variable O & M Cost-US$/$kg_{H2}$	$0.23	€ 0.20
8	Enter	Physical Life of the Electrolyzer-Years	20	145,999
9	Enter	Cost of Capital-%	6.0%	€/yr ↓
K	Computed	Capital Amortization Factor-CAF	$0.0872	€ 0.0761
L	Computed	Annual Capital Amortization-ACA-US$/yr	$28,304,083	€ 24,717,780
6. Computation of the LCOH-US$/kg			US$/kg ↓	€/kg ↓
M	Computed	Annual Capital Amortization-ACA-US$/kg	$0.73	€ 0.64
N	Computed	Fixed O&M Cost-US$/kg	$0.25	€ 0.22
O	Transferred from Line 7	Variable O&M Cost-from Line 7 above-US$/kg	$0.23	€ 0.20
P	Transferred from Line F	After η Loss Cost of the Solar Electricity converted into H_2-$AELCOE_{ELECT}$-US$/kg	$1.97	€ 1.72
Q	Computed	Green LCOH-US$/kg	$3.18	€ 2.78
7. Difference between the LCOH and the Current Market Price of Gray H_2-US$/kg			US$/kg ↓	€/kg ↓
R	Transferred from Line Q	Green LCOH-US/kg	$3.18	€ 2.78
10	Enter	Gray H_2 Market Price-US$/kg	$1.00	€ 0.87
S	Computed	The Green LCOH is greater (less) the Gray H_2 Market Price-US$/kg	$2.18	€ 1.90
T	Computed	% that the Green LCOH is greater (-%) then Gray H_2 Market Price	69%	69%
8. Difference between the LCOH and the Current Market Price of Blue H_2-US$/kg			US$/kg ↓	€/kg_{H2} ↓
U	Transferred from Line Q	Green LCOH-US$/kg	$3.18	€ 2.78
11	Enter	Blue H_2 Market Price-U$/kg	$2.50	€ 2.18
V	Computed	The Green LCOH is greater (less) the Blue H_2 Market Price-US$/kg	$0.68	€ 0.59
W	Computed	% that the Green LCOH is greater (-%) then Blue H_2 Market Price	21%	21%

Download my RE+ 2022 White Paper and its Excel LCOH Algorithm Worksheet from my website
www.michaelstavy.com