IS SOLAR POWER TO GAS (P2G) READY FOR PRIME TIME ON THE US GRID?

A Guide for Bankers and Their Engineers

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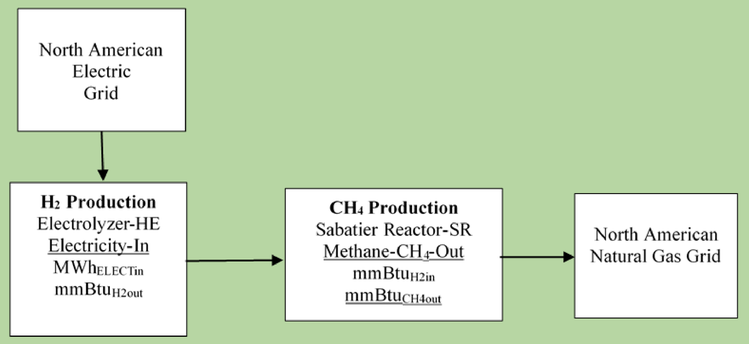
P2G Plant (P2GP) Basics

- *To the right is the Schematic of a P2G Plant (P2GP)*
- *In a P2GP, first a hydrogen (H_2) electrolyzer (HE) converts solar power into green H_2. Second, a Sabatier reactor (SR) converts green H_2 into green methane (GCH_4).*
- *The LCOG Algorithm is presented on an Excel Workbook with HE and SR Worksheets*
- *Below the schematic is the HE Worksheet*
- *Solar power is measured in MW_{ELECT}*
- *HE capacity is measured in MW_{ELECT} that power the HE*
- *Solar electricity is energy and is measured in MWh_{ELECT}*
- *The technology is called Power (MW_{ELECT}) to Gas (P2G) but it is actually solar electric energy (MWh_{ELECT}) converted to first H_2 gas ($mmBtu_{H2}$) and then to green CH_4 gas ($mmBtu_{CH4}$)*
- *The green goal is to replace fossil natural gas (NG) with green CH_4*
- *NG is mostly CH_4 but it is not green CH_4 (GNG)*
- *The North American (NA) NG grid cannot accept significant quantities (>20%) of even green H_2. The green H_2 must, therefore, be converted in green CH_4 (GNG)*
- *The solar energy that powers the HE is first measured in MWh_{ELECT}*
- *The LCOG algorithm converts MWh_{ELECT} of solar electricity into $mmBtu_{ELECT}$ H_2 is measured in $mmBtu_{H2}$ because the LCOG algorithm must measure green CH_4 in $mmBtu_{CH4}$ to compare its LC to the Henry Hub NG Market Price which is priced in US$/$mmBtu_{NG}$*
- *In the US, both NG production and gas flows ($mmBtu_{NG}$/day) and the Henry Hub NG price (US$/$mmBtu_{NG}$) are measured in $mmBtu_{NG}$*
- *The paper's energy conversion factors are listed below*
- *1 MWh_{ELECT} = 1 MWh_{H2} = 3.4120 $mmBtu_{ELECT}$ = 3.4120 $mmBtu_{H2}$*
- *This does not mean that the HE or the SR are 100% efficient (η)*
- *In the € zone, NG production and flows are measured kWh_{NG}/day (or in GJ/day) and the price is measured in €/kWh_{NG} (or in €/GJ_{NG})*
- *In HE H_2 production, $MWh_{ELECTin}$ from the NA electric grid go into the HE and $mmBtu_{H2out}$ come out of the HE and then go into SR*
- *HE are in serial production but no HE technology is "financially mature"*
- *In SR CH_4 production, $mmBtu_{H2in}$ go into the SR and $mmBtu_{CH4out}$ come out of the SR and into the NA NG grid*
- *Unlike HE, wind turbines and PV panels, SR are not yet in serial production. SR are not yet "financially mature"*
- *The SR equation is: $CO_2 + 4H_2 \rightarrow CH_4 + 2O_2$*
- *For the SR CH_4 to be green, the CO_2 must also come from a green source. Atmospheric CO_2 would be a green source*



Schematic of a P2G Plant (P2GP)

line		HE Worksheet--$LCOG_{H2}$	H_2 Production		
Foreign Exchange			a	m/d/y	
FX	Enter	US$/€ exchange rate	$1.14610	05/22/20	COLOR CODE
P2G Plant HE Specifications					Entry
1	Enter	P2G Plant HE Efficiency-η-%	70%	Capacity Factor	Result
2	Enter	P2G Plant-hrs/day Operating	20	83%	Side Column Result
3	Enter	P2G Plant-HE Power Input-MW_{ELECT}	300.0		Transfer Result
A	Computed	Daily MWh_{ELECT} of Solar Electricity to be converted into H_2-MWh_{ELECT}/day	6,000		Check Value
B	Enter	Daily P2G Plant HE H_2 Produced-MWh_{H2}/day	4,200		In €
CF	Enter	Conversion factor-mmBtu/MWh	3.4120		Conversion Factor
C	convert MWh to mmBtu	Daily P2G Plant HE H_2 Produced-$mmBtu_{H2}$/day	14,330		
D	Computed	Yearly P2G Plant HE H_2 Energy Produced-$mmBtu_{H2}$/year	5,230,596	€/kW ↓	
4	Enter	P2G Plant HE CapEx-US$/$MW_{ELECT}$	$573,000	500 €	
E	Computed	Total P2G Plant HE CapEx-US$/P2G Plant HE	$171,900,000	€ 149,986,912	
Cost of the Solar Power to be Converted into $mmBtu_{H1}$				€/MWh↓	€/kWh↓
5	Enter	Cost of the Solar Power to be converted into H_2-COE_{ELECT}-US$/$MWh_{ELECT}$	$40.00	€ 34.90	€ 0.03490
F	converted to mmBtu	Cost of the Solar Power to be converted into H_2-COE_{ELECT}-US$/$mmBtu_{ELECT}$	$11.7233	€ 0.03490	
				€/kWh ↑	
After Efficiency η Lost Cost of the Solar Power to be Converted into $mmBtu_{H1}$				€/kWh ↓	
G	computed	After η Loss Cost of the Solar Power to be converted into H_2-$AELCOE_{ELECT}$-US$/$mmBtu_{ELECT}$	$16.75	€ 0.04986	
H	computed	Extra Cost ($AELCOE_{ELECT}$-COE_{ELECT}) of the Solar Power-US$/$mmBtu_{ELECT}$	$5.02	€ 0.01496	
I	computed	% Increase in the Cost of the Solar Power when converted into H_2	43%	43%	
P2G Plant HE CapEx and OpEx					
6	Enter	Annual Fixed O&M Cost-% Total HE CapEx, Line E	3.00%	€/yr↓	
J	Computed	Annual Fixed O&M Cost-US$/yr	$5,157,000	€ 4,499,607	
7	Enter	Variable O & M Cost-US$/$mmBtu_{H2}$	$1.00	€ 0.00298	←€/kWh
8	Enter	Physical Life of the P2G Plant-Years	20		
9	Enter	Interest/ROE Rate-%	6.0%		
K	Computed	Capital Amortization Factor-CAF	0.0872	€/yr↓	
L	Computed	Annual Capital Amortization-ACA-US$/yr	$14,987,025	€ 13,076,542	
Computation of the LC of the H_2 gas used as a feedstock to Produce CH_4 (GNG) in the SR-US$/$mmBtu_{H2}$-$LCOG_{H2}$			US$/mmBtu↓	€/kWh ↓	%
M	Computed	Annual Capital Amortization-ACA-US$/$mmBtu_{H2}$	$2.87	€ 0.00853	13.3%
N	Computed	Fixed O&M Cost-US$/$mmBtu_{H2}$	$0.99	€ 0.00294	4.6%
O	Transferred from Line 7	Variable O&M Cost-from Line 7 above-US$/$mmBtu_{H2}$	$1.00	€ 0.00298	4.6%
P	Transferred from Line F	After η Loss Cost of the Solar Electricity to be converted into H_2-$AELCOE_{ELECT}$-US$/$mmBtu_{ELECT}$	$16.75	€ 0.04986	77.5%
Q	Computed	LC of the H_2 gas to be used as a feed stock to produce CH_4 in the SR-$LCOG_{H2}$-US$/$mmBtu_{H2}$	$21.60	€ 0.06430	100.0%
Difference between the HE $LCOG_{H2}$ and the Current Market Price of NG at the US Henry Hub-US$/$mmBtu_{NG}$				€/kWh ↓	
R	Transferred from Line Q	LC of the H_2 gas to be used as a feed stock to produce CH_4 in the SR-$LCOG_{H2}$-US$/$mmBtu_{H2}$	$21.60	€ 0.06430	
10	Enter	US Henry Hub Market Price-US$/$mmBtu_{NG}$	$1.85	€ 0.00551	
S	Computed	The HE $LCOG_{H2}$ is greater (less) the Henry Hub NG Market Price-US$/$mmBtu_{NG}$	$19.75	€ 0.05879	
T	Computed	% that the HE $LCOG_{H2}$ is greater (-%) then US Henry Hub NG Market Price	91%	91%	

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Download the Paper and its Excel P2GP LCOG Algorithm Workbook @ https://tinyurl.com/StavyPapers2020

Conclusion

Power to Gas plants (P2GP) are not currently ready for prime time on the North American (NA) electric and NG girds. Bankers and their engineers should be skeptical of any developers' claims that they are.

On this paper's P2G HE $LCOG_{H2}$ Algorithm Worksheet, the LC of the Green H_2 (GH_2) was computed to be US$21.60/$mmBtu_{H2}$ (€0.00551/kWh_{NG}).

On 05/19/20, the US IEA reported that the Henry Hub NG spot price wasUS$1.85/mmBtu (€0.0643/$kWh_{NG}$).

Currently, P2G GH_2 can not compete with the price of Henry Hub NG. The price of GH_2 from solar power is 91% higher than the Henry Hub NG spot price before this GH_2 is converted, at an extra cost in the SR, to green CH_4. Therefore the paper does not present the P2G SR $LCOG_{CH4}$ Algorithm Worksheet.

Currently, P2G GH_2 can not compete with the Eurostat NG price. Eurostat reported (04/28/20) that for the 27 EU countries, the average NG price (2019S2) was €0.0276/kWh_{NG} The P2G price of GH_2 from solar power is 51% higher than the Eurostat NG price.