Is Power to Gas (P2G) Ready Prime Time on the US Grid?

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PAPER'S PURPOSE

The purpose of this paper is to exam if wind power to gas (P2G) technology is ready for prime time (is currently commercially viable) on the North American (NA) electric and natural gas (NG) grids. The paper discusses the two phases of a model wind power to gas plant (P2GP). In the first phase, wind power (electricity) from the grid is converted into hydrogen (H_2) gas using a H_2 electrolyzer (HE). In the second phase, a Sabatier reactor (SR) is used to convert the H_2 into synthetic or green (GNG) [methane (CH_4)]. The GNG is then injected into the grid. The HE H_2 has to be converted into CH_4 by the SR because the NA NG grid cannot accept significant quantities of even green H_2.

The paper discusses both the HE and SR technologies. To exam the topic, the author developed a levelized cost of gas (LCOG) financial algorithm for a model P2GP. The LC financial principles are discussed. The LCOG Algorithm uses "project accounting" to compute a partial LCOG for each P2GP operating phase (HE; SR). This LCOG algorithm is used for sensitivity analysis and to confirm "published" P2GP specifications (specs).

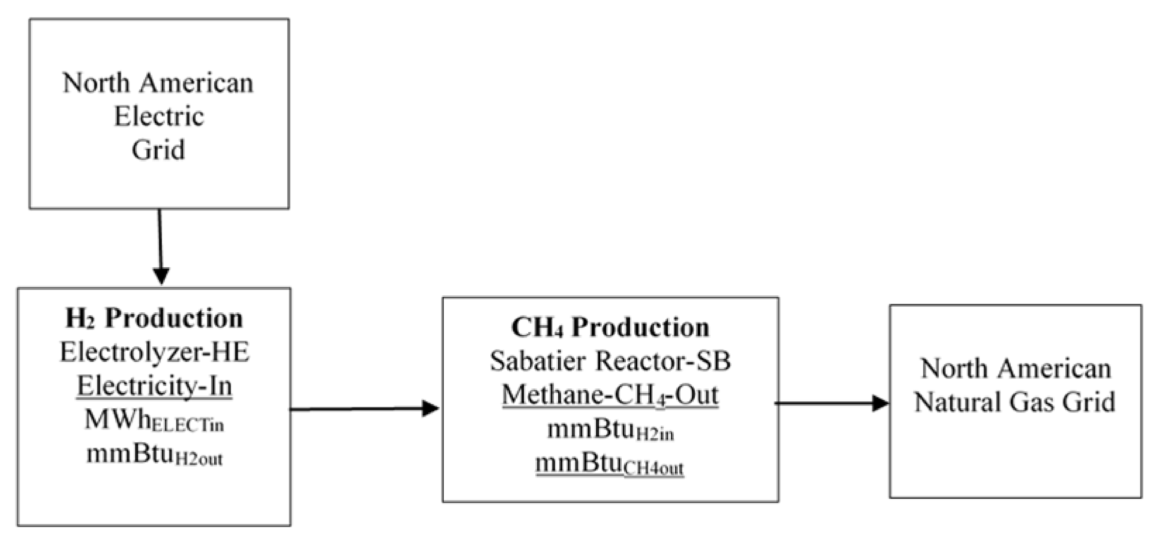
WRITTEN WHILE "SHELTERED-IN-PLACE"

This paper was prepared while the author was unexpectedly "sheltered in place" in Georgetown, CO. The author did not have his office files which are in Chicago, IL. The paper's Excel P2GP LCOG Financial Algorithm Workbook currently only has the HE Phase Worksheet. Because the $LCOG_{H2}$ was so high, the author found that this HE worksheet was sufficient.

METHOD

This paper discusses the finances of P2G technology using a levelized cost of gas LCOG financial algorithm. This algorithm is presented to the reader on an Excel P2GP LCOG Financial Algorithm Workbook. The P2GP LCOG Algorithm uses "project accounting" to compute a partial "LCOG" for both P2G plant phases: the HE production of H_2 and the SR production of GCH_4.

To the right, the algorithm's P2GP HE Phase worksheet requires 10 HE specifications (specs) and 20 dependent variables to compute the $LCOG_{H2}$. Both the HE and the SR specs (metrics) and dependent variables are defined using a standard set of SI and US "English" energy units. At the end of the HE Phase, the algorithm compares the $LCOG_{H2}$ with the Henry Hub NG spot market price. The $LCOG_{H2}$ was so much higher then the NG price that the SR phase was not required to determine that P2G technology is not yet ready for prime time.



Schematic of a Power to Gas (P2G) Plant

LCOG HE Workbook

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

P2G Plant HE and SR FACTS

- *To the left is the a Schematic of a P2G Plant*
- *Below the schematic is the algorithm's HE $LCOG_{H2}$ Worksheet*
- *Wind power is measured in MW_{ELECT}*
- *HE capacity is measured in MW_{ELECT} used to power the HE*
- *Wind electricity is energy and is measured in MWh_{ELECT}*
- *The technology is called Power (MW_{ELECT}) to Gas (P2G) but it is actually wind electric energy (MWh_{ELECT}) to first H_2 gas ($mmBtu_{H2}$) and then to green CH_4 gas ($mmBtu_{CH4}$)*
- *The green goal is to replace fossil NG with green CH_4*
- *NG is mostly CH_4 but it is not GREEN CH_4*
- *The NA NG grid cannot accept significant quantities of even green H_2.*
- *When solar energy is used to power a P2GP, the CH_4 will also be green*
- *The wind energy that powers the HE is first measured MWh_{ELECT}*
- *The LCOG algorithm converts MWh_{ELECT} intro $mmBtu_{ELECT}$ H_2 is measured in $mmBtu_{H2}$ because the LCOG algorithm must measure GCH_4 in $mmBtu_{CH4}$ to compare its LC to the Henry Hub NG 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 either the HE or the SR are 100% efficient (η)*
- *In the € zone, NG production and flows are measured (kWh_{NG}/day; in some countries in GJ/day) and the price is measured in €/kWh_{NG} (in some countries in €/GJ_{NG})*
- *In the HE H_2 production, $MWh_{ELECTin}$ from the NA electric grid goes 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 the SR GCH_4 Production-- $mmBtu_{H2in}$ go into the SR and $mmBtu_{CH4}$ 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: $CO_2 + 4H_2 \rightarrow CH_4 + 2O$*
- *For the SR CH_4 to be green, the CO_2 must also come from a green source*
- *Taking CO_2 from the atmosphere would be one such green source.*

CONCLUSION

Power to Gas technology is not ready for prime time on the North American (NA) electric and NG girds. Bankers and investors should be skeptical of any claims that it is.

- On this poster's HE $LCOG_{H2}$ Algorithm Worksheet, the LC of the green H_2 was computed to be US$21.60/$mmBtu_{H2}$
- On 05/19/20, the US IEA reported that the Henry Hub NG spot price was US$1.85/mmBtu (€0.00551/$kWh_{NG}$).
- The price of green H_2 from wind 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. Currently, NA green H_2 can not compete with Henry Hub NG.
- Eurostat reported (updated on 04/28/20) that for the 27 EU countries, the average NG price during 2019S2 was €0.0276/kWh_{NG}
- There are no commercial P2G plants on the NA grids
- Specs (metrics) for commercial NA P2G plants were not found in the authoritative literature.
- Because the € price of EU NG is five times the € price of US NG, the author is currently working on his next paper, *Is Power to Gas (GH_2) Ready for Prime Time on the European Grid?*

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The author took (1961) the Physical Science Study Committee (PSSC) Course (Niles TWP High School, Skokie, IL) where he learned how to do the unit analysis used in this paper. https://tinyurl.com/y8lgyzxw

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