



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

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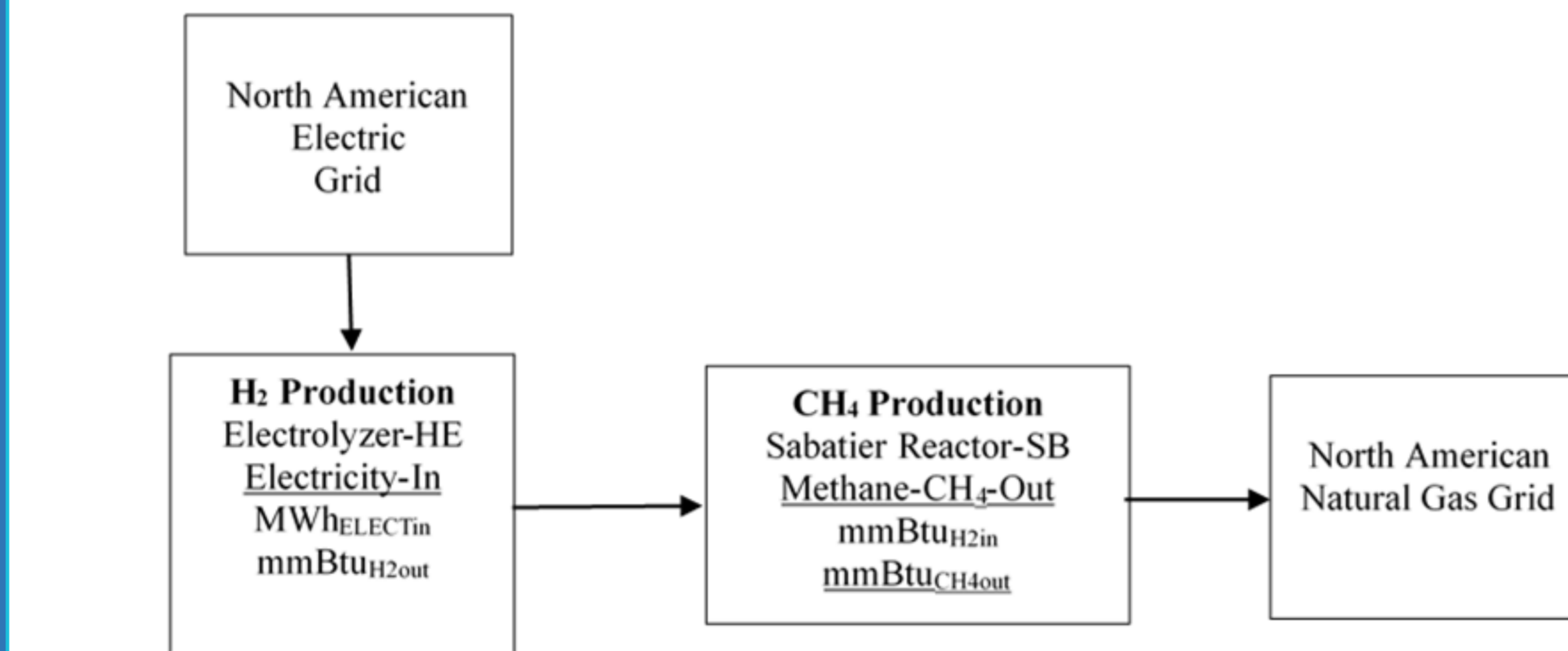
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## PAPER'S PURPOSE

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<sub>2</sub>) gas using a H<sub>2</sub> electrolyzer (HE). In the second phase, a Sabatier reactor (SR) is used to convert the H<sub>2</sub> into synthetic or green (GNG) [methane (CH<sub>4</sub>)]. The GNG is then injected into the grid. The HE H<sub>2</sub> has to be converted into CH<sub>4</sub> by the SR because the NA NG grid cannot accept significant quantities of even green H<sub>2</sub>.

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).



Schematic of a Power to Gas (P2G) Plant

LCOG HE Worksheet		H <sub>2</sub> Production		
dep spec	line	a	m/d/y	
<b>Foreign Exchange</b>				
FX	Enter US\$/€ exchange rate	\$1.14610	05/22/20	COLOR CODE
<b>P2G Plant HE Specifications</b>				
1	Enter P2G Plant HE Efficiency-%	70%	Capacity Factor	Result
2	Enter P2G Plant-Ins/day Operating	20	83%	Side Column Result
3	Enter P2G Plant-HE Power Input-MW <sub>ELECT</sub>	300.0		Transfer Result
1	A	Computed Daily MWh <sub>ELECT</sub> of Wind Electricity to be converted into H <sub>2</sub> -MWh <sub>ELECT</sub> /day	6.000	Check Value
2	B	Enter Daily P2G Plant HE H <sub>2</sub> Produced-mmBtu <sub>H2</sub> /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 <sub>2</sub> Produced-mmBtu <sub>H2</sub> /day	14.330	
4	D	Computed Yearly P2G Plant HE H <sub>2</sub> Energy Produced-mmBtu <sub>H2</sub> /year	5,230,596	€/kW ↓
4	4	Enter P2G Plant HE CapEx-US\$/MW <sub>ELECT</sub>	\$575,000	\$/000
5	E	Computed Total P2G Plant HE CapEx-US\$/P2G Plant HE	\$171,900,000	€ 149,986,912
<b>Cost of the Wind Power to be Converted into mmBtu<sub>H2</sub></b>				
5	5	Enter Cost of the Wind Power to be converted into H <sub>2</sub> -CO <sub>2</sub> ELECT-US\$/MWh <sub>ELECT</sub>	\$40.00	€/34.90 € 0.03490
6	F	converted to mmBtu Cost of the Wind Power to be converted into H <sub>2</sub> -CO <sub>2</sub> ELECT-US\$/mmBtu <sub>H2</sub>	\$11.7253	€/0.03490
<b>After Efficiency a Lost Cost of the Wind Power to be Converted into mmBtu<sub>H2</sub></b>				
7	F	computed After η Loss Cost of the Wind Power to be converted into H <sub>2</sub> -AELECT-US\$/mmBtu <sub>H2</sub>	\$16.75	€/0.04986
8	G	computed Extra Cost (AELECT-CO <sub>2</sub> ELECT) of the Wind Power-US\$/mmBtu <sub>H2</sub>	\$5.02	€/0.01496
9	H	computed % Increase in the Cost of the Wind Power when converted into H <sub>2</sub>	43%	43%
<b>P2G Plant HE CapEx and OpEx</b>				
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	\$3,427,000	€ 4,499,607
7	7	Enter Variable O & M Cost-US\$/mmBtu <sub>H2</sub>	\$1.00	€/0.00298
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	0.9872	€/yr ↓
12	K	Computed Annual Capital Amortization-ACA-US\$/yr	\$14,987,925	€ 13,076,542
<b>Computation of the LC of the H<sub>2</sub> gas used as a feedstock to Produce CH<sub>4</sub> (GNG) in the SR-US\$/mmBtu<sub>CH4</sub>-LCOG<sub>CH4</sub></b>				
13	L	Computed Annual Capital Amortization-ACA-US\$/mmBtu <sub>CH4</sub>	\$2.87	€/0.00853
14	M	Computed Fixed O&M Cost-US\$/mmBtu <sub>CH4</sub>	\$0.99	€/0.00294
15	N	Transferred from Line 7 Variable O&M Cost-from Line 7 above-US\$/mmBtu <sub>CH4</sub>	\$1.00	€/0.00298
16	O	Transferred from Line F After η Loss Cost of the Wind Electricity to be converted into H <sub>2</sub> -AELECT-US\$/mmBtu <sub>H2</sub>	\$16.75	€/0.04986
17	P	Computed LC of the H <sub>2</sub> gas to be used as a feed stock to produce CH <sub>4</sub> in the SR-LCOG <sub>CH4</sub> -US\$/mmBtu <sub>CH4</sub>	\$21.60	€/0.06430
<b>Difference between the HE LCOG<sub>H2</sub> and the Current Market Price Spot (Future) of NG at the US Henry Hub-US\$/mmBtu<sub>CH4</sub></b>				
18	Q	Transferred from Line P LC of the H <sub>2</sub> gas to be used as a feed stock to produce CH <sub>4</sub> in the SR-LCOG <sub>CH4</sub> -US\$/mmBtu <sub>CH4</sub>	\$21.60	€/0.06430
10	10	Enter US Henry Hub Spot (Future) Price-US\$/mmBtu <sub>CH4</sub>	\$1.85	€/0.00551
19	R	Computed The HE LCOG <sub>H2</sub> is greater (less) the Henry Hub NG Price-US\$/mmBtu <sub>CH4</sub>	\$19.75	€/0.05879
20	S	Computed % that the HE LCOG <sub>H2</sub> is greater (-%) than 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<sub>H2</sub> Worksheet
- Wind power is measured in MW<sub>ELECT</sub>
- HE capacity is measured in MW<sub>ELECT</sub> used to power the HE
- Wind electricity is energy and is measured in MWh<sub>ELECT</sub>
- The technology is called Power (MW<sub>ELECT</sub>) to Gas (P2G) but it is actually wind electric energy (MWh<sub>ELECT</sub>) to first H<sub>2</sub> gas (mmBtu<sub>H2</sub>) and then to green CH<sub>4</sub> gas (mmBtu<sub>CH4</sub>)
- The green goal is to replace fossil NG with green CH<sub>4</sub>
- NG is mostly CH<sub>4</sub>, but it is not GREEN CH<sub>4</sub>
- The NA NG grid cannot accept significant quantities of even green H<sub>2</sub>.
- When solar energy is used to power a P2GP, the CH<sub>4</sub> will also be green
- The wind energy that powers the HE is first measured MWh<sub>ELECT</sub>
- The LCOG algorithm converts MWh<sub>ELECT</sub> into mmBtu<sub>ELECT</sub> H<sub>2</sub> is measured in mmBtu<sub>H2</sub> because the LCOG algorithm must measure GCH<sub>4</sub> in mmBtu<sub>CH4</sub> to compare its LC to the Henry Hub NG Price which is priced in US\$/mmBtu<sub>NG</sub>
- In the US, both NG production and gas flows (mmBtu<sub>NG</sub>/day) and the Henry Hub NG price (US\$/mmBtu<sub>NG</sub>) are measured in mmBtu<sub>NG</sub>
- The paper's energy conversion factors are listed below
- 1 MWh<sub>ELECT</sub> = 1 MWh<sub>H2</sub> = 3.4120 mmBtu<sub>ELECT</sub> = 3.4120 mmBtu<sub>H2</sub>
- 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<sub>NG</sub>/day; in some countries in GJ/day) and the price is measured in €/kWh<sub>NG</sub> (in some countries in €/GJ<sub>NG</sub>)
- In the HE H<sub>2</sub> production, MWh<sub>ELECTin</sub> from the NA electric grid goes into the HE and mmBtu<sub>H2out</sub> 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<sub>4</sub> Production-- mmBtu<sub>H2in</sub> go into the SR and mmBtu<sub>CH4</sub> 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<sub>2</sub> + 4H<sub>2</sub> → CH<sub>4</sub> + 2O
- For the SR CH<sub>4</sub> to be green, the CO<sub>2</sub> must also come from a green source
- Taking CO<sub>2</sub> 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 grids. Bankers and investors should be skeptical of any claims that it is.

- On this poster's HE LCOG<sub>H2</sub> Algorithm Worksheet, the LC of the green H<sub>2</sub> was computed to be US\$21.60/mmBtu<sub>H2</sub>
- On 05/19/20, the US IEA reported that the Henry Hub NG spot price was US\$1.85/mmBtu (€0.00551/kWh<sub>NG</sub>).
- The price of green H<sub>2</sub> from wind power is 91% higher than the Henry Hub NG spot price before this G<sub>H2</sub> is converted, at an extra cost in the SR, to green CH<sub>4</sub>. Currently, NA green H<sub>2</sub> 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<sub>NG</sub>
- 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 (G<sub>H2</sub>) Ready for Prime Time on the European Grid?*

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## DOWNLOAD THE PAPER AND THE EXCEL P2G LCOG WORKBOOK

<https://tinyurl.com/StavyPapers2020>

## 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<sub>H2</sub> 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<sub>2</sub> and the SR production of GCH<sub>4</sub>.

To the right, the algorithm's P2GP HE Phase worksheet requires 10 HE specifications (specs) and 20 dependent variables to compute the LCOG<sub>H2</sub>. 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<sub>H2</sub> with the Henry Hub NG spot market price. The LCOG<sub>H2</sub> was so much higher than the NG price that the SR phase was not required to determine that P2G technology is not yet ready for prime time.