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	<p>Narration Script for Expo Hall Speaker Presentation-Solar Track North America Smart Energy Week Michael STAVY, Speaker Wednesday, October 21, 2020 2:40-3:00pm EDT In Slide Order</p>
Slide #	<p><i>Are P2G Plants Ready for Prime Time on the North American Electric and Natural Gas Grids? A Guide for Bankers and Their Engineers</i></p>
1	<p>Hello, my name is Michael Stavy. I am going answer on this question.</p> <p>Is power to gas (P2G) ready for prime time on the NA electric and NG grids?</p> <p>This gas is either green H₂ or green CH₄</p> <p>By “ready for prime time”, I mean are P2G Plants ready for commercial development today, not in 5, 10 or 15 years from now.</p> <p>Since 1990, I have been an advisor on the finances of renewable energy projects.</p> <p>I earned my MBA in 1969 at Kellogg, Northwestern’s Graduate School of Management</p> <p>I was a registered Illinois CPA, but my certificate is now inactive.</p> <p>My email address is listed right on this slide.</p> <p>At the end of each slide, there may be a phase in my oral comments before the next slide starts.</p> <p>This will give you some time to study the current slide.</p>



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2	<p>Slide # 2 This presentation is for Bankers and their Engineers but everybody can listen.</p> <p>In a P2G Plant, a hydrogen (H₂) electrolyzer (HE) first converts solar (PV) electricity from the electric grid into green H₂.</p> <p>Then a Sabatier Reactor converts the green H₂ into green CH₄ which is then injected into the North American NG grid.</p> <p>The green H₂ has to be converted into green CH₄ because the NG grid cannot accept significant quantities (that is >20%) of even green H₂.</p> <p>This is because H₂ in a NG pipe makes the pipe brittle.</p> <p>Fossil NG is over 90% CH₄, but it is not green NG.</p> <p style="text-align: center;">NG ≡ CH₄</p>



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<p>3</p>	<p>Slide # 3, This slide shows a P2G Plant Schematic</p> <p>As you can see, MWh of PV electricity enter the E. The PV electric MWh electric energy unit is mathematically converted into the mmBtu electric energy unit.</p> <p>The HE produces mmBtu of green H₂ which leave the electrolyzer and enter the Sabatier R. The R produces mmBtu of green CH₄ which are then injected into the NG grid.</p> <p>The GREEN Goal of P2G Plants is to replace fossil NG with green CH₄.</p> <p style="text-align: center;">Green CH₄ is the equivalent of Green NG</p>



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4	<p>Slide # 4, On this slide, I will go over some P2G Plant Basics</p> <p>The technology is called power (that is MW of electric power) to gas (either H₂ or CH₄ gas) but it is actually PV electric energy (that is MWh of electric energy) that are first converted into H₂ gas and then in to CH₄ gas</p> <p>PV electric power is measured in MW</p> <p>HE capacity is measured in MW of power input</p> <p>PV electricity is energy and is measured in MWh</p> <p>PV electricity is kinetic energy while the H₂ and CH₄ gases are potential energy</p>



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5	<p>Slide #5 This presentation is based on my paper, <i>Is P2G Ready for Prime Time on the NA Grid? A Guide for Bankers and their Engineers.</i></p> <p>A key feature of my paper is a P2G Plant LCOG Financial Algorithm.</p> <p>I developed my LCOG algorithm to first compute the cost of the green H₂ gas and then the cost of green CH₄ gas produced in a model P2G Plant</p> <p>The MWh energy unit is mathematically converted into the mmBtu energy unit so that the LC of the green H₂ produced in the E is priced in \$/mmBtu</p> <p>My LCOG algorithm compares the LC of the green H₂ to the Henry Hub NG market price which is priced in \$/mmBtu</p>



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<p>6</p>	<p>You can download my paper and its functioning Excel LCOG Financial Algorithm Workbook at my website. My website is listed on this slide.</p> <p>My paper and its Excel Workbook have financial values in both US\$ for North American readers and in € for readers in the € zone.</p> <p>Once you download my Excel Workbook, you can enter your P2GP specification (spec) values and view the results.</p> <p>I discuss P2G plant specs and their compilation in my paper.</p> <p>The LC of the green H₂ produced in the HE is priced in \$/mmBtu_{H2} This is because the Henry Hub NG price is priced in \$/mmBtu_{NG}</p> <p>Not using the relevant H₂ energy unit is still common in articles on the H₂ economy.</p> <p>For example, in the Sept 29, 2020 WSJ article, <i>Hurdles Await Nikola on Technology and Cost</i>, the cost of producing H₂ is priced in \$/kg. \$/kg is H₂ priced as an industrial gas; not priced as a motor vehicle fuel.</p>



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6	<p>Since this WSJ article discussed the cost of H₂ when it is used as a motor vehicle fuel, the H₂ price should have be in \$ per gasoline gallon equivalent (gge)</p>
7	<p>Slide # 7 P2G Plant LCOG Financial Algorithm Basics</p> <p>The algorithm is presented on an Excel Workbook with the E phase and the R phase each having separate worksheets</p> <p>The algorithm uses “project accounting” to compute a separate “LCOG” for each P2G plant phase: the LC of H₂ for the E phase; the LC of CH₄ for the Sabatier R phase</p> <p>Both the E and the R specs and dependent variables are defined using a standard set of SI (Système International) and US “English” power and energy units</p>



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8	<p>Slide # 8 Here are my paper's Energy Conversion Factors</p> <p>$1 \text{ MWh}_{\text{ELECT}} = 1 \text{ MWh}_{\text{H}_2} = 3.4120 \text{ mmBtu}_{\text{ELECT}} = 3.4120 \text{ mmBtu}_{\text{H}_2}$</p> <p>This does not mean that either the E or the Sabatier R are 100% efficient</p> <p>H₂ as an industrial gas is measured in Kg or in Nm³</p> <p>Green H₂ and green CH₄ as green substitutes for fossil NG should be priced in the same energy units as fossil NG</p> <p>These fossil NG energy units are \$/mmBtu in the US and in €/kWh in most countries in the € zone.</p> <p>Yes, in most European countries, residential NG is priced in €/kWh while industrial NG is priced in €/MWh</p>



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9	<p>Slide # 9, The HE Basics</p> <p>The E equation is that two molecules of:</p> $2\text{H}_2\text{O} + \text{PV electricity} = 2\text{H}_2 + \text{O}_2$ <p>In the E production of H₂, MWh of PV energy from the grid, force water to separate into H₂ and O₂. The H₂ comes out of the E and go into the R</p> <p>E are in serial production but no E technology is “financially mature”</p> <p>To compute the LC of H₂ gas, my algorithm’s E phase WS requires 10 HE specs. [the algorithm’s independent variables]</p> <p>My paper discusses, in detail, each spec and its value</p> <p>The E Worksheet computes 20 dependent variables including the LC of H₂ and the difference between the LC of H₂ and the Henry Hub NG price.</p> <p>My paper discusses, in detail, each dependent value and its mathematical calculation</p>



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10	<p>My paper does not present a database of P2G Plant Specs I present</p> <ol style="list-style-type: none"> 1. a recognized standard LC methodology 2. a model P2G Plant 3. 10 realistically compiled "base case" specs 4. an accurate "back of the envelope" P2G Plant financial algorithm LCOG <p>My paper discusses, in detail, each spec and its value. My paper discusses, in detail, each dependent value and its mathematical calculation</p> <p>My paper explains how to compile a set of P2G Plant specs</p>



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11	<p>Slide #11 The Sabatier Reactor Basics</p> <ul style="list-style-type: none"> In the Reactor’s production of green CH₄, mmBtu of green H₂ go into the reactor and mmBtu of green CH₄ come out of the reactor Unlike HE, wind turbines, and PV panels, Sabatier R are not yet in serial production. The R is also not yet “financially mature” The R equation is one molecule of $\text{CO}_2 + 4\text{H}_2 + \text{PV electricity} = \text{CH}_4 + 2\text{H}_2\text{O}$ For the R CH₄ to be green, the CO₂ must also come from a green source. Atmospheric CO₂ would be one such green source



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12	<p>Slide # 12 The Excel Hydrogen Electrolyzer Worksheet</p> <ul style="list-style-type: none"> • The next two slides show the actual Excel Electrolyzer Worksheet with the 10 E specs in BOLD. • The 10 specs are numbered; the 20 dependent variables are numbered using letters. • The LC algorithm is based on a financial annuity with one constant (or level) payment. • This is why it is called the LC method • My paper discusses the LC method in more detail. • I will start to discuss the E specs on this slide. I will continue my discussion of the E worksheet on my two E worksheet slides. • Spec 1 is E efficiency. I set it at 70%.



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12	<ul style="list-style-type: none"> On your copy of my Excel E Worksheet, you can enter your own 10 spec values including efficiency Spec 2 is the hours per day that the Electrolyzer operates. I set it at 20 hours Spec 3 is the Electrolyzer power input. I set it at 300 MW
13	<p>Slide # 13, The First Excel Electrolyzer Worksheet Slide</p> <ul style="list-style-type: none"> Spec 4 is the Electrolyzer CapEx. I set it at \$573,000/MW which is about €500/kW Line E, Total E CapEx is US\$171,900,000. This is computed by multiplying Spec 3 times Spec 4 Spec 5 is the Cost of the PV Electricity to be converted into green H₂. I set it at \$40/MWh (4¢/kWh) On Line F, a dependent variable, the \$40/MWh is converted into \$11.72/mmBtu



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13	<ul style="list-style-type: none"> • I will now start to discuss the E specs that are on the second E Worksheet Slide. • Specs 6 & 7 are the E fixed and variable O&M costs. • You can study the math in my paper • Spec 8 is the Electrolyzer life. I set it at 20 years. • Spec 9 is the WACC to finance the E. I set it at 6%. • Spec 10 is the Henry Hub NG Spot Price. I set it at \$1.85/mmBtu



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14	<p>Slide # 14, The Second Excel Electrolyzer Worksheet Slide</p> <p>My LC algorithm is based on a financial annuity</p> <p>Line K is the Capital Amortization Factor. It is computed to be 8.72 cents.</p> <p>This 8.72 cents is the end of year annual payment computed for a financial annuity having \$1.00 as the principal borrowed, a loan period of 20 years; which is Spec 8 and an interest rate of 6%; which is Spec 9.</p> <p>Line E, the Total E CapEx, is the principal amount borrowed.</p> <p>Line E is multiplied by Line K, the Capital Amortization Factor, to compute Line L, the Annual Capital Amortization, which is \$14,987,000 per yr</p> <p>The compilation of Line Q, the LC of green H₂, is done on a per mmBtu basis.</p> <p>Line M, the Annual Capital Amortization per mmBtu is Line L, \$14,987,000 per yr, divided by Line D, the mmBtu of H₂ produced by the E each year.</p> <p>The math involved in the LC of H₂ calculation is explained in my paper.</p>



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15	<p>I will now answer the question, Are P2G Plants ready prime time?</p> <p>My answer is NO.</p> <p>This is based the fact that my HE Worksheet computes the LC of green H₂ to be \$21.60/mmBtu</p> <p>One May 15, 2020, the US EIA reported that the Henry Hub NG spot price was only \$1.85/mmBtu</p> <p>Currently P2G Plant green H₂ cannot compete with the price of Henry Hub NG. The LC of H₂ is 91% higher than the Henry Hub NG price even before the green H₂ is converted, at an extra cost, by the Sabatier Reactor into green CH₄.</p> <p>For this reason, there is no need to present the R worksheet</p>



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16	<p>Slide # 16 Suggestions for Improving the E</p> <p>To make the LC of Green H₂ competitive with the Henry Hub NG price requires that:</p> <ol style="list-style-type: none"> 1. The E efficiency (η) must be increased <p>On the HE worksheet, the η was set at 70% but this is a very optimistically high value</p> <ol style="list-style-type: none"> 2. The E CapEx must be reduced <p>On the HE worksheet, it is set at \$573,000/MW but this a very optimistically low value</p> <ol style="list-style-type: none"> 3. The cost of the PV electricity used to fuel the E must be reduced. <p>On the HE worksheet, it is set at \$40/MWh</p> <p>This is a realistic PV electricity price for 2020, but for green H₂ to compete with the Henry Hub NG price, the PV electric price must still be lower.</p>



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16	<p>The Henry Hub NG price could be increased by a carbon tax</p> <p>A carbon tax is beyond the scope of my paper</p>
17	<p>Slide # 17 P2G Plant Proforma Financial Statements</p> <p>With my “back of the envelope” LCOG calculation, bankers can develop their P2G Plant proforma income, balance sheet and cash flow statements after their engineers confirm the P2G Plant specs and verify the P2G technology</p> <p>Note that I am assigning the engineers to confirm the P2G Plant specs and the P2G technology</p> <p>I am working on a paper to reconcile the LCOG calculation with GAAP income, balance sheet and cash flow statements</p> <p>In the future, I hope to publish these results</p>



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18	<p>Slide 18 The Last Slide</p> <p>Thank you for your attention.</p> <p>Your questions and comments are welcome.</p> <p>Contact me at my email address that is listed on this last slide</p> <p>Again, my name is Michael Stavy and I have been an advisor on the finances of renewable energy projects since 1990</p> <p>P2G is not currently ready for prime time, but in 2025, that is in 5 years, in 2030, (in 10 years) or in 2035 (in 15 years), who knows.</p> <p>For a Greener Planet, I hope so!</p>

