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Subject: August 7, 2017 Presentation: Public Workshop to Discuss Potential Low Carbon Fuel Standard Rulemaking Items and H2 Renewable's Proposed H2 Plant

In response to the rulemaking discussions in CARB's recent August 7th Workshop and position paper, and as a follow-up to our past discussions with various members of CARB regarding the proposed changes to the LCFS program to incorporate hydrogen into the program and address the requirements of SB1505, **H2 Renewables** would like to clarify its position regarding the economics and rationale for producing renewable hydrogen. Our paper will concentrate on the distinct differences between feedstock and process energy inputs and the resulting carbon impact of producing renewable hydrogen via Steam Methane Reforming (SMR) using electric boilers. With regard to carbon intensity reduction, especially as it relates to the potential to generate (and potentially sell) LCFS credits through the production of hydrogen at our facility is a contributing factor, our primary focus will be on the definition of renewable hydrogen as it relates to our production process. In our particular production process, natural gas is our only feedstock and it is not used as an energy source since it is not combusted in any phase of the production. Unlike traditional SMR units that use natural gas as both a feedstock and process energy (through combustion); we propose using electric boilers in combination with renewable electricity to generate renewable hydrogen. Through the use of electric boilers, the methane reacts alone with steam (energy source) that provides the thermal energy for the chemical reactions to occur. If you look at the SMR that we propose, our only source of energy is renewable electricity for the machinery and for the steam, which comes from electrical boilers. Again, natural gas is not an energy source in our process.

Feedstock (Methane/CH4)

Natural gas is our only feedstock and is not used as an energy source since it is not combusted. The methane reacts with steam (energy source) that provides the thermal energy for the chemical reactions to occur. If you look at the SMR proposed, our only source of energy is electricity for the machinery and for the steam which comes from electrical boilers. Again, natural gas is not an energy source in our process and remains the feedstock along with renewable contracted electricity directly from named renewable sources.

Process Energy - Renewable Electricity (Steam-Electric boiler)

Steam is a feedstock since 50% of the actual hydrogen produced chemically comes from the water/steam (H2O).

The steam reforming of methane consists of three reversible reactions: the strongly endothermic reforming reactions (1) and (3), and the moderately exothermic water-gas shift reaction (2):

$$CH_4 + H_2O \leftrightarrows CO + 3H_2 \qquad \Delta H^\circ_{298} = +206 \text{ kJ/mol} \qquad (1)$$
$$CO + H_2O \leftrightarrows CO_2 + H_2 \qquad \Delta H^\circ_{298} = -41 \text{ kJ/mol} \qquad (2)$$
$$CH_4 + 2H_2O \leftrightarrows CO_2 + 4H_2 \qquad \Delta H^\circ_{298} = +165 \text{ kJ/mol} \qquad (3)$$

It should be emphasized that CO_2 is not only produced via the shift reaction (2), but also directly via the steam reforming reaction (3). This implies that reaction (3) is not just the 'overall reaction', despite the fact that in literature steam-methane reforming is often considered to be a combination of reactions (1) and (2) only. (**See Attached Paper "On The Catalytic Aspects of Steam-Methane Reforming**")

If you determine the "renewable" content based on energy input for the hydrogen, we believe that the H2 renewable content is 100% is due to the only energy input, being renewable electricity. Electricity creates the steam, which gives the SMR its energy to produce H2.

If you determine "renewable" content based on feedstock, the renewable content for H2 produced will be 50% directly from the water (natural resource) that is turned into steam by renewable electricity. Water provides 50% of the hydrogen molecules in the SMR.

Current Issue:

Under LCFS staff's current thinking, the renewable content of hydrogen produced by SMR would be calculated based on the portion of feedstock energy that is renewably sourced in the production of hydrogen. This calculation should be based on the renewable energy input on the basis of energy content, rather than mass. Note also that under the LCFS, renewable process electricity only counts towards a reduction in CI if is directly supplied (behind the meter).

LCFS' Goal:

As we understand it, the LCFS group is very much interested in gauging industry response to this requirement and would like to understand **H2 Renewables'** evaluation of the tradeoffs between evaluating renewable content on the basis of the smaller amounts associated with feedstock energy vs. the larger amounts associated with total (process + feedstock) energy input

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Our Metrics:

We estimate the following:

- 18.62 kWh/kg of energy are provided to the system as process energy in the form of renewable electricity to produce steam
- 90% of the process electricity is utilized in the boilers (roughly 16.75 kWh/kg) (6,000 kW/358 kg/hr of H2)
- 18.61 kWh of electricity is used to produce and process 1 kilo of H2. (6,000 kW/358 kg/hr of H2)/.90
- All energy will be accounted and purchased directly by contract with regulated authorities. There will be no purchase of RECs to offset carbon reduction requirement.

Assuming renewable implementation was calculated on the basis of total energy input, and assuming that the source of renewable process electricity for our proposed facility meets the LCFS requirements, we see **two possible alternatives** for evaluation of the implementation of renewable energy in our process:

1. If only the electricity to the boilers is considered renewable, hydrogen produced at the facility could be at most 38.8% renewable (16.75/[24.5+18.61]).

2. If electricity for all process electricity at the facility is renewable, hydrogen produced at the facility could be at most **43%** renewable (18.61/[24.5+18.61]).

Economics of Co-Locating plant with renewable source (behind-the-meter)

As we understand it, the option exists to take power behind-the-meter or from a regulated utility source. It is illegal to take power from both behind-the-meter and "in front of" or a metered regulated utility at the same time. Regulated utilities have the exclusive right to sell their electricity exclusively to the grid per PUC regulations. Due to the intermittent nature and availability of renewable power energy in the State of California (around 27% of the time) and the constraints of available power options, there needs to be other determining factors to guaranty the economically viability of a renewably produced product for investors, producers, and distributors alike.

From a producers and investors standpoint, the LCFS is not a guaranteed structured payment and is not "bankable" in the sense that neither producer nor distributor has the sole rights to the credits, which fluctuate greatly in today's market. According to "matching principles" and most investor's requirements, incentives need to match the terms contracted backed by the revenue projected over the term of the project. The LCFS is neither a guaranty nor a known factor allowing investors to have the full faith that the incentive will be in place over the course of their investment.

In addition, the time and costs associated with interconnection costs and logistics today (3 years on average) weigh on investor's returns and expectations. The option to either co-Locate at the renewable power source or connect directly to the regulated grid in California has known limitations. We believe that having access to an approved 100% approved and qualified renewable sourced power from the regulated utility is a necessary and a viable option for both investors and renewable hydrogen producers

alike as long as the renewable power contracted is outside the RPS (Renewable Portfolio Standard) and the amount contracted matches the power drawn from the grid and used by the hydrogen plant.

Carbon Capture/CO2 (Carbon Intensity Score)

- No combustion = no emissions in production (only transport – "Well-to-Wheels")
- Only 60% of standard CO2 SMR plant emissions (if vented)
- Can capture 100% of CO2 resulting in near zero CO2 emissions (if CO2 sold)
- LCFS Well-to-Wheels CI value s/b under 30 according to our preliminary calculations

LCFS pathway

Out of the existing paths, we anticipate that path HYGN005 is the closest to our actual production of H2 since it is based on a SMR using natural gas with a 33% renewable input into the plant that will produce compressed gaseous H2. The CI value is 88.33 at the plant with a value of 35.33 delivered to LCFS as a car fuel. Since our process has no combustion and assuming that we apply for our own CI pathway, we know that our CO2 output is 60% less than a conventional SMR. Hence, our estimate CI value if we create a new path, would be 88.33 * 40% = 35.32 which is divided by the EER of 2.5 to get a CI value for a car of only 14.13.

Conclusion

We look forward to discussing potential paths forward for incorporating hydrogen fuels into the LCFS program and determination of renewable energy implementation in accordance with Senate Bill 1505. We are of the opinion that the renewable content for hydrogen should be determined by both its energy content and it's feedstock input and leave it up to the project developer to determine which methodology best meets the renewable content and financial returns for the hydrogen project, which also accomplishes the objective for increasing the supply of renewable hydrogen in California. When one uses electricity in the process, renewable electricity should be available via the electric grid so that enough renewable electricity can be contracted to provide the highest capacity factor for the hydrogen plant.

Sincerely,

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