444 Castro Street, Suite 710
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September 16, 2022

Dr. Cheryl Laskowski,
Branch Chief, Transportation
California Air Resources Board
Sacramento, CA 95814
Submitted via LCFS Comments Upload Link

RE: Comments on LCFS Program Staff Presentation on August 18, 2022

Dear Dr. Laskowski:

H Cycle, LLC ("H Cycle") appreciates the California Air Resources Board ("CARB") moving forward with the informal rulemaking of the Low Carbon Fuel Standard Program ("LCFS Program"), the staff presentation regarding potential changes to the LCFS Program, as well as the opportunity to provide comments to this process. Below you will find our comments regarding LCFS Program changes proposed at the workshop, as well as our comments and recommendations pertaining to issues of primary importance to H Cycle, a leading company in the waste-to-hydrogen sector. We believe the following recommendations will benefit both the LCFS Program and California's emerging low-carbon hydrogen sector.

About H Cycle

H Cycle is a developer of low-cost, low-carbon hydrogen production facilities that deploy a proven waste-to-hydrogen thermal conversion technology. H Cycle is currently developing multiple projects in California. Our solution can utilize a diverse composition of waste feedstocks (post-separated municipal solid waste, agricultural residues, woody biomass from wildfire risk reduction projects) to produce a renewable hydrogen product, thereby reducing methane emissions from landfill and other disposal methods and helping achieve California's waste diversion targets under Senate Bill 1383. The H Cycle process delivers low-carbon hydrogen that can be used as an energy source for decarbonizing hard-to-abate sectors such as low-carbon fuel refining, heavy-duty trucking, and sustainable aviation. We are excited to work with CARB and local communities to deploy our solution and support the State in meeting its climate, sustainability and air quality goals.

Comments Summary

H Cycle appreciates the opportunity to provide recommendations regarding the following proposed LCFS Program changes. We hope that CARB will consider all of these issues as the

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agency moves forward with the LCFS rulemaking and will provide specific sub-workshops to focus on these issues with input from stakeholders.

To summarize, H Cycle:

1. Supports CARB's proposal to introduce a Tier 1 ("T1") Calculator for Hydrogen;
2. Recommends that CARB include thermal conversion of biomass and organics as a production pathway in the T1 Calculator for Hydrogen;
3. Recommends that CARB extends the existing authorization of electricity indirect accounting ("book-and-claim") for hydrogen production beyond electrolysis to include renewable hydrogen produced using non-fossil-based pathways; and
4. Recommends that CARB updates emission factors utilized to determine avoided landfill emissions for organic diversion pathways.

Comments Detail and Background

H Cycle supports CARB's proposal to introduce a Tier 1 ("T1") Calculator for Hydrogen, however we request that CARB include thermal conversion of biomass and other specified organics as a production pathway in the T1 Calculator

In the Staff Presentation, CARB proposed introducing a new T1 Calculator for Hydrogen, specifically covering Steam Methane Reforming ("SMR") and electrolysis production pathways. H Cycle supports the development of a T1 Calculator as a key enabler of the hydrogen economy. By establishing a Tier 1 Calculator for Hydrogen, CARB expedites the process for obtaining an LCFS pathway designation for hydrogen pathways and provides an opportunity to gain the program efficiencies that are a priority objective in this rulemaking. Similarly, the exportability of the LCFS program structure to other jurisdictions is benefited by the efficient review that a Tier 1 Calculator provides for hydrogen pathways.

However, the presentation omits a key branch of hydrogen production technology that is of vital importance to achieving California policy as enunciated by the Draft 2022 Scoping Plan Update. To unlock the deployment of these vital feedstocks, H Cycle requests that CARB extend the production pathways to include thermal conversion of biomass and organics. H Cycle's technology is a conversion solution for biogenic materials (organics and biomass) that produces low-carbon hydrogen but does not fit within the SMR or electrolysis categories.

Including thermal conversion of biomass and organics is consistent with existing regulatory definitions for renewable hydrogen, as showcased below. H Cycle believes that the omission of renewable hydrogen pathways from the new T1 Calculator is a missed opportunity to align CARB's tools with the wider envisioned hydrogen pathways.

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(1) CARB LCFS Regulation[1]: "Renewable Hydrogen" means hydrogen derived from (1) electrolysis of water or aqueous solutions using renewable electricity; (2) catalytic cracking or steam methane reforming of biomethane; or (3) thermochemical conversion of biomass, including the organic portion of municipal solid waste (MSW)."

(2) CARB's Draft 2022 Scoping Plan Update: The draft Scoping Plan notes that for its purposes, "'green hydrogen' is not limited to only electrolytic hydrogen produced from renewables."[2]

(3) California Energy Commission's ("CEC") Integrated Energy Policy Report ("IEPR")[3,4]: The 2017 IEPR report defines renewable gas as gas generated "from organic waste or from renewable electricity and […] includes renewable hydrogen" (pg. 245). The 2021 IEPR report states "Renewable hydrogen can also be produced using renewables feedstocks and organic waste, including from RPS-eligible sources."

(4) Senate Bill 1075[5]: States the intent of California to develop a leading green hydrogen industry to support a number of clean air, climate, and energy priorities, including supporting "forest management, short-lived climate pollutant and waste management goals." SB1075 defines renewable hydrogen as hydrogen generated from Renewable Portfolio Standard ("RPS") feedstocks and energy. The RPS in turn includes biomass as an eligible resource, where biomass is defined (in page 79 of the CEC RPS Guidebook) as "any organic material not derived from fossil fuels" and includes a variety of MSW organic components (e.g. food waste, non-recyclable paper). Similar definitions are also found in Budget Trailer Bills AB209 and AB211.

Additionally, by supporting thermal conversion pathways in the LCFS Program through inclusion in the T1 Calculators, CARB in turn supports and accelerates the much-needed progress across a variety of California goals:

(1) Senate Bill 1383: Thermal conversion of organics provides a needed option for landfill diversion that supplements conventional methods such as anaerobic digestion ("AD") and composting. Climate science is now very clear that reducing short-lived climate pollutants ("SLCP") emissions is by far the most impactful step we can take to address climate change as it is one of very few measures that begins to cool the climate in the near term. As CARB's Short-Lived Climate Pollutant Reduction Strategy states, "The science unequivocally underscores the need to immediately reduce emissions of short-lived climate pollutants (SLCPs)." The importance of harnessing organic waste is clearly

[1] (CARB, Low Carbon Fuel Standard Regulation, 2020)
[2] (CARB, Draft 2022 Scoping Plan Update, 2022)
[3] (CEC, Final 2021 Integrated Energy Policy Report Volume III Decarbonizing the State's Gas System, 2021)
[4] (CEC, Final 2017 Integrated Energy Policy Report, 2017)
[5] (SB-1075 Hydrogen: green hydrogen: emissions of greenhouse gases, 2022)

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recognized by CalRecycle's recent report "*Analysis of the Progress Toward the SB 1383 Organic Waste Reduction Goals*"[6] which:

- Highlights the scale of the challenge ahead of us (27 million tonnes per annum of organic waste must be diverted in a beneficial and cost-effective manner);
- Showcases the importance of novel approaches complimentary to conventional organic diversion methods (namely anaerobic digestion and composting); and
- Points to the promise of technologies like H Cycle's that can handle a wide range of difficult waste streams in an environmentally friendly process.

H Cycle's numerous commercial interactions with waste haulers across the state confirm the value proposition of thermal conversion pathways - namely the ability to handle a wide range of mixed organic material that are difficult to purify further (e.g. contain glass, textiles, metals) or that are not suitable conventional biological treatment (e.g. compost or anaerobic digestion). Such materials often have limited cost-competitive options besides landfilling, but can still offer significant energy and climate benefits if converted to hydrogen through thermal conversion pathways.

(2) Senate Bill 1440: SB 1440, following on SB 1383, specifically highlights biomethane as an important strategy to addressing state climate goals and reducing SLCP emissions. In implementing SB 1440, the California Public Utilities Commission ("CPUC") includes pilots for biomass gasification in its adopted Renewable Gas Standard and hydrogen blending standards and biomethane procurement in the scope of the Rulemaking (R.13-02-008). The Rulemaking specifically calls out Synthetic Natural Gas ("SNG") produced from thermal conversion of biomass and organics as a pathway to gas network decarbonization. From the work done in Lawrence Livermore National Laboratories ("LLNL") "*Getting to Neutral*", the authors conclude that a significant fraction of the State's renewable gas potential is found in cellulosic and lignocellulosic waste. These wastes are not suitable for anaerobic digestion and are ideally suited for thermal conversion processes; it is estimated that 85% of the state's bio-energy potential lies in such wastes, as shown in the following table from the Getting to Neutral (pg. 31) report.[7]

[6] (CalRecycle: Analysis of the Progress Toward the SB 1383 Organic Waste Reduction Goals, 2020)

[7] Sarah E. Baker, Joshuah K. Stolaroff, George Peridas, Simon H. Pang, Hannah M. Goldstein, Felicia R. Lucci, Wenqin Li, Eric W. Slessarev, Jennifer Pett-Ridge, Frederick J. Ryerson, Jeff L. Wagoner, Whitney Kirkendall, Roger D. Aines, Daniel L. Sanchez, Bodie Cabiyo, Joffre Baker, Sean McCoy, Sam Uden, Ron Runnebaum, Jennifer Wilcox, Peter C. Psarras, Hélène Pilorgé, Noah McQueen, Daniel Maynard, Colin McCormick, Getting to Neutral: Options for Negative Carbon Emissions in California, January, 2020, Lawrence Livermore National Laboratory, LLNL-TR-796100, at p. 5, available at https://www gs.llnl.gov/content/assets/docs/energy/ Getting_to_Neutral.pdf .

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Category	2025 Amount	2045 Amount
Agriculture Residue	10.4 M BDT/yr	12.7 M BDT/yr
Municipal Solid Waste	12.3 M BDT/yr	13 M BDT/yr
Landfill and Anaerobic Digester Gas (Gaseous Waste)	7.1 M tons/yr	6.1 M tons/yr
Forest Biomass	24 M BDT/yr	24 M BDT/yr
Total	54 M tons/yr	56 M tons/yr

(3) California's Goals for Carbon Neutrality by 2045: Thermal conversion of biogenic feedstocks is a critical strategy for California to deploy at scale due to the imperative of carbon removal. The "*Getting to Neutral*" report discusses the role thermal conversion plays to support California's carbon neutrality goals. The report concluded that "gasifying biomass to make hydrogen fuel and CO_2 has the largest promise for CO2 removal at the lowest cost and aligns with the State's goals on renewable hydrogen." Based on the LLNL analysis, renewable hydrogen from biomass and organics is one of the three pillars of carbon neutrality for California and might represent the single most promising climate strategy in California. Indeed, the state has already taken initial steps to study and promote the use of biogenic feedstocks in the production of renewable hydrogen. Senate Bill 155 (2021) made available $50 million of state funding to the Department of Conservation to, in collaboration with CARB, invest in pilot projects in the Sierra Nevada region to produce carbon-negative fuels from thinnings and residues, including hydrogen. These and other similar state legislative efforts (e.g. Assembly Bill 2878) will rely on CARB's continuing support for biomass utilization in the production of renewable hydrogen.

Additionally, thermal conversion is a net generator of energy, multiplying the impact renewable power can have on decarbonization goals. Thermal conversion takes advantage of the inherent energetic value of organic materials, extracting their energy as low carbon molecules (such as hydrogen). The process energy input to operate the process are a small fraction of the final product's energy. For instance, thermal conversion can utilize 1 KWh of clean power to produce 2 KWh of hydrogen energy. On the other hand, Electrolysis utilizes 1 KWh of clean power to produce 0.6 KWh of hydrogen energy. The benefits from an energy efficiency standpoint will ultimately help the state achieve its SB 100 goals by lessening the need for over-building renewable energy production and transmission in order to produce the renewable hydrogen that the decarbonized economy of the future will require.

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(4) Jobs in CA / Transition Justice: Thermal conversion will entail the build out of new infrastructure, resulting in capital expenditure and high-road job creation in California. The feedstock for thermal conversion is particularly well-suited to waste feedstocks that California has in abundance, be it agricultural residues, forest biomass, and MSW organic-fractions. Unlike the approach of Steam Methane Reforming of RNG, Thermal Conversion will entail building of a new facility as opposed to maintain existing fossil-based infrastructure, and will utilize California-native energy sources as opposed to outsourcing the production of the RNG to out-of-state facilities . Local jobs, local waste diversion, and local utilization of the final renewable hydrogen for fleets or industrial uses are all key components of this approach to the generation of renewable hydrogen. It is difficult to imagine another process for the production of renewable hydrogen that can perform better on these issues.

Therefore, we recommend that CARB incorporates in the T1 Calculator for Hydrogen a thermal conversion module, which includes calculator steps that allow users to input waste organics and biomass as feedstocks. For instance, waste organic crediting can be based off the T1 Organic Waste ("OW") Calculator approach, whereas biomass has precedence in the CA-GREET model.

To support CARB's review of this request, we have provided an illustrative set of calculation steps for the thermal conversion of post-processed MSW organics. We believe a workshop would help facilitate the process of integrating thermal conversion into the T1 Hydrogen Calculator.

- Feedstock GHG credit from landfill avoidance could be applied directly from the T1 OW calculator. An illustrative value of 125 kg CO_2,eq/wet ton of waste is assumed.
    - H Cycle would like to note that expanding the applicability of landfill GHG avoidance credits to thermal conversion (beyond AD as per T1 OW Calculator) enhances the fairness and consistency of the LCFS Program while providing a critically needed economic driver to develop landfill diversion technologies and projects beyond AD.
- Yield of hydrogen product per wet ton of waste is a key input assumption that varies based on technology choice and feedstock. Generally, thermal conversion has an energy conversion factor of approximately 50% (accounting for syngas conversion to hydrogen and hydrogen purification), i.e. 50% of energy in the waste is converted to energy in the hydrogen product. Given that waste energy content varies from 9 MJ/kg to 18 MJ/kg, a hydrogen yield of 45 to 75 kg is expected per wet ton of waste.
- Therefore, the Feedstock GHG credit from landfill avoidance can be translated to a CI credit of approximately is 7.5 kg CO_2,eq / kg H_2 or 62.5 g CO_2,eq / MJ H_2 (calculation approach: 125 kg CO_2,eq / wet ton waste x 60 kg hydrogen / wet ton waste)
- Thermal conversion processes will also utilize external energy in the processing facility, such as natural gas and electric power. The total consumption and source of energy differ

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by technology utilized, site or local considerations, and feedstock type. Based analysis conducted by H Cycle, the CI range resulting from external energy use can range from 2.5 kg CO_2,eq / kg H_2 or 21 g CO_2,eq / MJ H_2 (if electric power is sourced renewable) to 10 kg CO_2,eq / kg H_2 or 83 g CO_2,eq / MJ H_2

- Therefore, the resulting CI of this illustrative pathway can be determined by subtracting the GHG credit of the feedstock from the process energy utilized, resulting in a CI range as low as -41.5 g CO_2,eq / MJ H_2 to as high as +20.5 g CO_2,eq / MJ H_2.

Ultimately, H Cycle is supportive of the T1 Calculator approach for hydrogen as a key enabler of the hydrogen economy. H Cycle believes expanding the pool of production options is highly beneficial for the sector and for the achievement of the multiple California policy objectives referenced in this comment. It is our experience that hydrogen off-takers are seeking a diverse portfolio of options, as they trade off priorities such as price, scale, proximity, variability, and CI score.

<u>H Cycle recommends extending book-and-claim accounting for low-carbon intensity electricity for hydrogen production beyond electrolysis to include other non-fossil technologies</u>

H Cycle strongly recommends that CARB extend the existing system of indirect accounting ("book-and-claim" accounting) beyond electrolysis, particularly to recognized conversion pathways for biogenic/non-fossil feedstocks.

Under existing regulations for hydrogen as a transportation fuel or used in the production of transportation fuel (e.g. in refining), indirect accounting (i.e. renewable energy power purchase agreements, renewable energy certificate purchases) for low-carbon electricity is only allowed for the production of hydrogen through electrolysis. In scenarios where such indirect accounting is not allowed, the environmental attributes of low-carbon electricity can only be captured by a non-electrolysis hydrogen facility if there is a direct connection from the generation source to the facility (i.e., behind-the-meter). For low-CI hydrogen facilities, just like for electrolysis facilities, there are many considerations that will affect where to site a hydrogen production facility. Site selection criteria often necessitate separating the hydrogen production facility from a renewable electricity generation site. Hydrogen production may require closer proximity to biogenic feedstocks and/or hydrogen offtakers, rather than a source of renewable electricity, in order to minimize costs, transportation emissions and other potential impacts.

H Cycle believes that this is an artificial distinction that is inconsistent with California's GHG policy objectives and hydrogen's potential. Given that California has an abundance of waste feedstocks including biomass from forest treatment, agriculture residues, and the organic fraction of municipal solid waste that can be used to produce transportation fuels using advanced technologies, it is essential for the LCFS Program to enable low-carbon hydrogen production

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solutions beyond electrolysis that can benefit from flexibly contracted low-carbon electricity supply. This imperative is strengthened by Governor Newsom's recent letter to Chair Randolph emphasizing that "state agencies plan for an energy transition that avoids the need for any new natural gas plants to meet our long-term energy goals while ensuring reliability and meeting growing demand for electricity."[8]

The Governor's letter also noted the importance of zero-carbon, clean energy sources including hydrogen to achieve this future and requested that "CARB evaluate and consider an increase in the stringency of the Low Carbon Fuel Standard and to work with relevant agencies to accelerate refinery transitions away from petroleum to the production of clean fuels.[9] For the LCFS Program to play its optimal role in decarbonizing and phasing out fossil fuels, it must include pathways for biogenic feedstocks that can achieve similar or better (i.e., negative carbon) emission outcomes than electrolysis. Such an approach simultaneously advances state goals to dramatically reduce short-lived climate pollutants, enable waste and forest management, minimize agricultural field burning and achieve other climate priorities.

We strongly believe thermal conversion pathways to hydrogen should be considered a low-CI solution in the same light as electrolysis in the eyes of the Program given that both can achieve greater levels of decarbonization through low-carbon electricity procurement. Furthermore, lifting the existing book-and-claim restriction will help grow not only the clean hydrogen industry but also the suppliers of zero-carbon power. As the levelized cost of renewable technologies such as wind and solar continues to fall, the LCFS Program should not limit the benefits of sourcing renewable electricity to any one specific renewable hydrogen production technology.

H Cycle recommends that CARB updates the emission factors utilized to determine avoided landfill emissions for organic diversion pathways

In the Staff Presentation, CARB requested feedback on emission factors as applicable for lifecycle analyses. H Cycle recommends that the LCFS Program considers updating factors associated with Landfill emissions – namely landfill leakage rates and methane Global Warming Potential ("GWP").

Due to SB1383, cities and counties (and their waste haulers) are developing projects to convert their organic wastes to transportation fuels. Accurately assessing the carbon intensity of these fuels is essential and that depends on an accurate assessment of avoided landfill emissions. H Cycle requests CARB use actual real-world monitoring data, which NASA's jet Propulsion

[8] Governor Gavin Newsom Letter of July 22, 2022, to CARB Chair Liane Randolph, at page 3, available at https://www.gov.ca.gov/wp-content/uploads/2022/07/07.22.2022-Governors-Letter-to-CARB.pdf?emrc=1054d6
[9] Id. at p. 3, 4.

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Laboratory and other highly credible data sources can provide, rather than outdated estimates of landfill methane emissions. NASA's monitoring data makes clear that landfill emissions are higher – in some case, significantly higher – than previously believed.[10] Furthermore, similar work is being conducted by CalRecycle and CARB, showcasing the large range in leakage rates, leakage of non-CH4 emissions such as Volatile Organic Compounds and Nitrous Oxide, and highlighting the discrepancy with the modeling approaches utilized.[11] CARB has clearly indicated its intention to better track fugitive emissions from the fossil fuels sector and should similarly utilize the best available scientific data for landfill gas emissions.

The carbon intensity of LCFS fuels generated from diverted organic waste should include actual avoided emissions from landfills where that data exists and updated estimates where landfill-specific data is not available. This will make the carbon intensity analysis more accurate, by basing it on actual data rather than decades-old estimates, and will accelerate the diversion of organic waste from landfills, which is critical to meet the requirements of SB 1383.

Furthermore, H Cycle recommends that the GWP of methane utilized in lifecycle calculations be reassessed for organic waste landfill diversion pathways. CARB utilizes an outdated figure for GWP-100 years of 25x based on Intergovernmental Panel on Climate Change ("IPCC") AR4. The latest IPCC report AR6 showcases a GWP value of 30x. While seemingly small, the underestimation of benefits provided by organic waste diversion can adversely impact project economics and therefore slows down the diversion rates of organics from landfills.

Conclusion

H Cycle thanks the California Air Resources Board for its consideration of our input regarding the Staff Presentation on the potential changes to the LCFS Program. Please do not hesitate to contact us if any further input or clarification would be helpful. We look forward to continuing to support the Program and providing input towards its success.

Sincerely,

Karim Ibrik
Chief Technology Officer

[10] (NASA. A third of California methane traced to a few super-emitters. NASA. Retrieved September 8, 2022, from https://www.jpl.nasa.gov/news/a-third-of-california-methane-traced-to-a-few-super-emitters)
[11] (California Polytechnic State University Prepared for CARB, Estimation and Comparison of Methane, Nitrous Oxide, and Trace Volatile Organic Compound Emissions and Gas Collection System Efficiencies in California Landfills, 2020, from https://ww2.arb.ca.gov/sites/default/files/2020-12/CalPoly_LFG_Study_03-30-20.pdf)