April 20, 2018

Clerk of the Board
California Air Resources Board
1001 I Street
Sacramento, CA 95812

Dear Chair Nichols and Board Members;

We are pleased to submit for consideration by the California Air Resources Board (ARB) a proposal for a ***Hydrogen Infrastructure Pathway*** to generate credits under the Low Carbon Fuel Standard (LCFS). We are proposing this to accelerate the build out of hydrogen refueling stations and reducing carbon intensity of hydrogen supply by providing LCFS credits based on installed fuel dispensing capacity.

We believe this Hydrogen Infrastructure Pathway can provide an effective incentive for expanding zero-emission vehicle infrastructure while remaining consistent with the LCFS policy intent by accomplishing the following during the early years of Fuel Cell Electric Vehicle (FCEV) deployment:

- partially offset the initial lower utilization of hydrogen refueling stations, thereby supporting refueling network development to increase the availability of hydrogen;
- enable efficient development of hydrogen refueling stations at a sustained pace and scale to achieve significant cost reduction, for efficient use of public and private funds and reducing the cost of low-carbon fuels for Californians;
- enable the incentive structure already in place in the LCFS to reduce the carbon intensity of hydrogen through increasing renewable content;
- become self-balancing and sun-setting, with credit generation through the Hydrogen Infrastructure Pathway decreasing over time as hydrogen sales and station utilization increase;
- ensure best-in-class carbon intensity and infrastructure quality through eligibility conditions;
- ensure no material or unintended impacts to the overall LCFS policy and stakeholders through fixed limits on duration, infrastructure capacity, and credit generation.

This is a revision to the proposal originally introduced at the ARB workshop on 6 November 2017, and submitted in writing to the ARB on 28 November 2017. This revision is intended to align with the objectives and direction in Executive Order B-48-18 and to build upon the original proposal to ensure it is effective for increasing the supply of hydrogen refueling stations and decreasing the carbon intensity of this Zero

Emission Vehicle (ZEV) fuel without having material or unintended impact to the overall LCFS policy and stakeholders.

A detailed description of the proposal as well as proposed regulatory language is attached.

Thank you for your consideration.

For further information on this proposal, please contact the company representatives listed below.

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Attachment 1 – Detailed Discussion of the Hydrogen Infrastructure Pathway

1. Introduction: expanding zero-emission vehicle infrastructure through the LCFS program

The Low Carbon Fuel Standard (LCFS) was established by Executive Order S-01-07, pursuant to AB32, to reduce the carbon intensity of California's transportation fuels. With Executive Order B-48-18, California announced a target of 5 million ZEV by 2030 and an eight-year $2.5 billion investment initiative to continue the state's clean vehicle rebates and spur more infrastructure investments. The Executive Order also specifically calls for state entities to collaborate with stakeholders to implement this order, including "expand zero-emission vehicle infrastructure through the Low Carbon Fuel Standard Program."

Reaching California's goals for greenhouse gas and criteria pollutant emission reductions necessitate the acceleration and scaling up of very low-emission options in the transportation sector. This will require consumer choice across all vehicle segments and refueling/recharging modes of use, and will require growth in California's energy infrastructure to accommodate demand from the transportation sector as well as increasing supply from renewable sources. To be successful, a portfolio of Zero Emission Vehicles (ZEV) including Fuel Cell Electric Vehicles (FCEV), Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV) will be needed. Of these, FCEVs have the benefit of long range, fast refuel time and scalability; and is a very good ZEV option for those without the ability to charge at home. The refueling model for FCEVs is similar to that of conventional internal combustion engine vehicles in that it is done at a refueling station. As such, hydrogen refueling station capacity, coverage, and cost are prerequisites for a successful FCEV market. The initial low utilization of new refueling infrastructure during early stages of the market limits the pace of development and availability of this fuel, and increases the cost relative to traditional transportation fuels, all of which inhibit customer adoption. However, with modest scale in sustained development of hydrogen refueling infrastructure, it has been shown that the cost of hydrogen refueling stations can be reduced by 50% or more. A significant portion of cost reduction in hydrogen refueling stations serving light-duty vehicles can transfer to stations serving heavy-duty vehicles.

2. Hydrogen Infrastructure Pathway Proposal

The Hydrogen Infrastructure Pathway would generate LCFS credits based on installed hydrogen station fuel dispensing capacity. The number of credits generated by a hydrogen refueling station would be equal to the credits generated through hydrogen sales (current policy) plus credits for the remaining capacity of the station (new Hydrogen Infrastructure Pathway).

This proposal has two objectives: 1) supporting hydrogen fueling stations during low utilization for station network expansion, and 2) incentivizing the selection of lower-CI hydrogen production pathways.

The Hydrogen Infrastructure Pathway would be subject to eligibility criteria and boundaries on credit generation, pathway duration, and administration including documentation and reporting to protect against unintended impact to the LCFS policy and stakeholders.

1) ***Support for hydrogen fueling station network expansion***

This policy can incentivize a significant increase in the rate of hydrogen refueling station buildout, which supports the ability of automakers to deploy FCEVs into the market at higher volumes, and is an important step towards both commercialization and customer adoption of this best-in-class low-carbon fuel for FCEVs. Such acceleration can create both a positive cycle with cost reduction for further expansion, and will be important to realizing Executive Order B-48-18 target of 200 hydrogen refueling stations by 2025 which will require doubling of the historical pace to achieve approximately 2 stations opening per month or 24 stations per year.[1] In particular:

- For commercialization and further expansion of the hydrogen refueling network, cost reduction in the refueling station capital and operating costs are key. A pace of approximately 30 stations per year leading to a network density of approximately 60 stations in a service territory has been shown to reduce station capital and operating costs by 50% from current benchmarks.
- For customer adoption, both the availability of hydrogen fuel through expansion of refueling network coverage and retail price reduction are needed, both of which can be accomplished through acceleration and scale as cost reduction translates to retail prices in a competitive market.

Adopting the proposed Hydrogen Infrastructure Pathway may impact business decisions for the buildout of hydrogen refueling stations. The following example is intended to show this potential impact.

- In the case of a station with 400 kg/d capacity and initial utilization of 15% increasing to 80% in its 10th year of operation, the cumulative number of LCFS credits generated over 15 years under the existing fuel pathways would range from 4,950 with the HYFL pathway (liquefied hydrogen produced by reforming natural gas) to 29,000 with the HYER pathway (compressed hydrogen produced by solar- or wind- electrolysis). Assuming $100/credit market price and 10% discount rate, the present value of these credits supporting investment in the hydrogen refueling station ranges from $230,000 to $1,250,000.
- With adoption of the proposed Hydrogen Infrastructure Pathway, the incremental infrastructure investment credits generated under this example would range from 5,000 with the HYFL pathway to 24,000 with the HYER pathway, and yield an incremental present value supporting infrastructure investment of $330,000 to $1,480,000.

[1] As of December 2017, a total of 65 hydrogen refueling stations were funded through the ARFVTP program and 31 were open for retail. The pace of station openings from Q3 2015 through Q4 2017 has averaged approximately 3 stations per quarter or 1 station per month, although only six stations became open retail in 2017. The average station development time has decreased to approximately 25 months (excluding outliers). Source: California Energy Commission and California Air Resources Board, Joint Agency Staff Report on Assembly Bill 8: 2017 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California. To deliver the remaining 135 stations to achieve a total of 200 open retail by 2025 would require an average pace of approximately 24 per year or 2 stations per month even if begun immediately and with an average development time of 24 months.

The Hydrogen Infrastructure Pathway in this example more than doubles the support from LCFS credit generation to investments in expanding the refueling station network by partially offsetting the low initial utilization. In fact, the combination of fuel and infrastructure pathways in this example sum to the total incentive the existing LCFS fuel pathway alone would provide to hydrogen refueling in a mature market with 100% station utilization: from 10,000 to 53,000 cumulative credits with the HYFL and HYER pathways, providing $560,000 to $2,740,000 present value of credits to support investment in the hydrogen refueling station.

Furthermore, the support for infrastructure investment provided by LCFS credit revenue is scalable, meaning efficient programs of infrastructure development may be possible, and the nature of infrastructure investment credits being inversely proportional to station utilization can partially reduce the risk on initial station utilization. The impact to support infrastructure investment from the proposed hydrogen infrastructure pathway may be multiplied by the significant cost reduction enabled.

2) <u>Incentive for reducing the carbon intensity of hydrogen production pathways</u>

The proposal can also provide incentive for a significant acceleration in the decrease of carbon intensity in the production of hydrogen fuel, which in conjunction with increasing customer adoption of FCEV, can make a material contribution to achieving the LCFS goals for decreasing carbon intensity and emissions.

The contribution to emission reduction of 200 hydrogen refueling stations in 2025 will depend on the number of vehicles supported (thus volume of hydrogen displacing gasoline) and the carbon intensity of the hydrogen fuel. The following example is meant to illustrate the potential impact of policy to encourage scale and acceleration with fuel decarbonization such as the Hydrogen Infrastructure Pathway we are proposing.

- With relatively small stations developed to ensure adequate initial utilization (e.g., 200 kg/d capacity), supplied with conventional hydrogen produced from reformation of natural gas to keep cost as low as possible (e.g., HYGN001 pathway with 151 gCO2e/MJ), it might be that 200 vehicles per station are supported at 70% station utilization each using an average of 0.7 kg/d. In this example, the total number of FCEV supported by 200 hydrogen refueling stations would be 40,000 – just 2.7% of the target for 1.5 million ZEV on-road in 2025 – and the hydrogen displacing gasoline would be 28 metric tons per day, 10,220 metric tons per year, and approximately 90,000 MT CO2/year emission reduction.
- With somewhat larger stations developed to support market growth despite low initial utilization (e.g., 400 kg/d), supplied with renewable source hydrogen produced from renewable natural gas and/or renewable source electricity (e.g., HYGE200L pathway with 0 gCO2e/MJ or HYGLF200L pathway with -5 gCO2e/MJ), it might be that 400 vehicles per station are supported at 70% station utilization each using an average of 0.7 kg/d. In this example, the total number of FCEV supported by 200 hydrogen refueling stations would be 80,000 – contributing 5.3% to the target for 1.5 million ZEV on-road – and the hydrogen displacing

gasoline would be 56 metric tons per day, 20,440 metric tons per year, and more than 550,000 MT CO_2/year emission reduction.

Adopting the proposed Hydrogen Infrastructure Pathway may impact business decisions for decarbonizing hydrogen production pathways. As the LCFS policy is intended, the revenue from LCFS credit generation can support the selection of higher-cost lower-carbon production pathways if the difference in revenue from credit generation more than offsets the incremental cost of the lower-carbon production pathway. The following example is intended to show this potential impact.

- Again, in the case of a station with 400 kg/d capacity and initial utilization of 15% increasing to 80% in its 10th year of operation, the present value of fuel pathway credits received over 15 years assuming $100/credit and 10% discount rate is equal to $0.23/kg for the HYFL pathway (liquefied hydrogen produced by reforming natural gas) and $1.25/kg for the HYER pathway (compressed hydrogen produced by solar- or wind-electrolysis). Thus, the existing fuel pathway could support selection of low-carbon renewable-source hydrogen production if the incremental cost is less than approximately $1/kg in this example.
- With adoption of the proposed Hydrogen Infrastructure Pathway, the incremental present value of cumulative infrastructure investment credits received over this period is equal to $0.33/kg with the HYFL pathway and $1.48/kg with the HYER pathway. Thus, adoption of the proposed Hydrogen Infrastructure Pathway could increase support for selection of low-carbon renewable-source hydrogen production with incremental cost of as much as $2.17/kg in this example.

Once again, the Hydrogen Infrastructure Pathway in this example more than doubles the support from LCFS credit generation to selection of low-carbon hydrogen production pathways by partially offsetting the low initial utilization. In fact, the combination of fuel and infrastructure pathways in this example sum to the total incentive the existing LCFS fuel pathway alone would provide to hydrogen refueling in a mature market with 100% station utilization: from $0.56/kg to $2.74/kg credit value with the HYFL and HYER pathways.

3. Pathway structure aligning incentives and ensuring intended results: effective sideboards

Even as the proposed Hydrogen Infrastructure Pathway encourages hydrogen refueling infrastructure development, it is self-balancing and sun-setting with the quantity of LCFS credits generated through the Hydrogen Infrastructure Pathway decreasing as sales of hydrogen fuel increase, and naturally within the LCFS construct as the CI reduction target increases.

The Hydrogen Infrastructure Pathway as proposed also has several elements to ensure it aligns incentives for progress toward LCFS goals.

To ensure reduction in the carbon intensity of the hydrogen fuel supplied to refueling facilities receiving hydrogen investment credits, an eligibility threshold of either 40% renewable content per the current CEC GFO definitions for feedstocks or 75 gCO_2e/MJ carbon intensity ensures crediting only for “best in class fuel” going beyond requirements for hydrogen under SB 1505 for 33% renewable content and 30% reduction in carbon intensity compared to gasoline. Furthermore, it ensures a “no regrets” policy for LCFS goals by ensuring hydrogen credited under the proposed pathway is also best in class across other low-carbon fuels.[2]

The natural sunset to Hydrogen Infrastructure Pathway credit generation as station utilization and fuel sales increase is also limited within fixed caps to ensure the pathway provides incentive for early infrastructure development for a defined maximum scale that will not unduly impact the LCFS policy objectives, credit market, or other LCFS stakeholders.

- The time period for qualification for a hydrogen refueling facility into the hydrogen infrastructure pathway is limited to 10 years, approximately through year-end 2028, which is generally aligned with the expected period of pre-commercialization for hydrogen fuel during which increasing utilization and decreasing cost are improving viable market conditions.
- The maximum limit on the percentage of nameplate capacity eligible to receive hydrogen infrastructure investment credits – the “Maximum Capacity Fraction Cap” – declines from 100% to 40% over the 15 years of eligibility for each hydrogen refueling facility, which is generally aligned with the expected increase in hydrogen refueling facility utilization as more FCEV enter the market.

To ensure the Hydrogen Infrastructure Pathway does not have material or unintended impact to the overall LCFS policy and stakeholders, the total number of hydrogen refueling facilities that can be qualified into the Hydrogen Infrastructure Pathway is limited to 500 stations, which is generally aligned with the pace of development required to meet targets for ZEV and associated infrastructure established in Executive Order B-48-18. Furthermore, the maximum refueling capacity eligible to receive hydrogen infrastructure investment credits is capped at 1,200 kg/d (the “Maximum Capacity Cap”).

The Hydrogen Infrastructure Pathway as proposed also addresses the following potential unintended consequences to ensure a robust policy that will not create perverse incentives or unintended consequences. In particular, the following provisions protect against over-building hydrogen refueling facilities with poor quality and/or location in pursuit of hydrogen infrastructure investment credits.

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[2] For example, using the median CI of existing LCFS pathways for renewable source hydrogen of approximately 6 gCO2e/MJ and the CI of 121.43 gCO2e/MJ for the HYF pathway (central reforming of natural gas with gaseous delivery), the requirement for 40% renewable source hydrogen production would deliver 75.26 gCO2e/MJ CI or 30.10 EER-adjusted CI (68% reduction from the current reference gasoline). This carbon intensity would be “best in class” for hydrogen and also amongst other low-carbon fuels:

- Electricity: ca. 105 gCO2e/MJ CI or 30.9 EER-adjusted CI from California Grid electricity.
- Ethanol: ca. 40 – 80 gCO2e/MJ and EER-adjusted CI (except outliers)
- CNG: ca. 60 – 100 gCO2e/MJ CI and EER-adjusted CI
- RNG: ca. 40 – 75 gCO2e/MJ and EER-adjusted CI (except outliers)
- Renewable Diesel: ca. 20 – 40 gCO2e/MJ and EER-adjusted CI (except outliers)
- Biodiesel: ca. 15 – 60 gCO2e/MJ and EER-adjusted CI

- Station Design Quality: eligibility requires compliance with codes and standards as well as current station performance requirements to ensure stations deliver the fueling performance expected at the time of certification.[3]
- Station Operation Quality: eligibility requires a minimum of 90% availability to ensure customer satisfaction with the dependability of hydrogen refueling; stations not able to maintain this requirement would temporarily stop receiving hydrogen investment credits until such time as the requirement is met.
- Hydrogen Fuel Quality: hydrogen purity and quality is tested periodically and audited by DMS, as with all other fuels. A station closed to service by a regulatory authority for any reason will cease to generate Hydrogen Investment Credits until such time as the situation has been remedied and the station is allowed to re-open.
- Over-building Capacity: excessive capacity is limited by the Maximum Capacity Cap and Maximum Capacity Fraction Cap as discussed above.
- Refueling Network Coverage: continuation of grant funding for hydrogen refueling station development through the ARFVTP program can complement the proposed LCFS Hydrogen Infrastructure Pathway by ensuring refueling network coverage continues to grow in an efficient manner through combination of the CHIT model and OEM priority areas.

4. <u>Potential effect on the overall LCFS policy and stakeholders</u>

The potential impact of the proposed Hydrogen Infrastructure Pathway on the overall LCFS policy and stakeholders will depend on its success in creating an effective incentive to expand hydrogen refueling infrastructure and decarbonize hydrogen production, and the transition time for industry to respond with investments. The pace and number of hydrogen refueling stations remains largely determined by government policy.

For example, with the pace of station development suggested by Executive Order B-48-18 of approximately 20 stations per year, current average station size of approximately 190 kg/d and 22% average utilization, supplied with 33% renewable hydrogen, the 200 stations by 2025 and implied 260 stations through 2028 (10 years of the proposed policy) could generate an additional 1% above current LCFS credit generation for this period.[4] If, for example, station size were to double over this period to an average of 400 kg/d, average utilization were to increase to 70%, and the hydrogen supply

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[3] The California Air Resources Board may adopt a third-party engineering analytic model to certify station capacity in much the way the CI for proposed pathways is certified today: the applicant is required to submit requisite data for modeling, including documentation; the ARB uses the data supplied once verified with the third party model to simulate, verify, and certify the station capacity and fueling performance.

[4] As of December, 2017 there were 31 hydrogen refueling stations open retail with combined total capacity of 5,950 kg/d, and dispensing approximately 1,300 k/d in total. Source: California Energy Commission and California Air Resources Board, Joint Agency Staff Report on Assembly Bill 8: 2017 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California.

were to become 100% renewable, the increase over current LCFS credit generation would still be only 4 percent.

Two cases are defined here as illustrative for a pace of development achieving 450 hydrogen refueling stations in 2030 and continuing the previous examples for increase in station utilization:

- High Case: with successful incentive, hydrogen supply may come from renewable sources (e.g., the HYER pathway for solar- and wind-electrolysis) and station capacity may increase rapidly over time to support a growing demand from FCEV, from the current average of 230 kg/d to 1,000 kg/d for new stations in 2030. In this case, the cumulative hydrogen infrastructure investment credits generated over 15 years from 2019 – 2033 is less than 4 percent of the total LCFS credits the ARB expects to be generated under the "Project/LD/Low ZEV/20%" scenario.
- Low Case: with unsuccessful incentive, hydrogen supply may continue to come from reformation of natural gas (e.g., the HFL pathway) and station capacity may increase slowly over time, from the current average of 230 kg/d to 400 kg/d for new stations in 2030. In this case, the cumulative hydrogen infrastructure investment credits generated over 15 years from 2019 – 2033 is less than 1 percent of the total LCFS credits the ARB expects to be generated under the "Project/LD/Low ZEV/20%" scenario.

5. Conclusion

In summary and as discussed above, the Hydrogen Infrastructure Pathway accomplishes the following during early years of FCEV deployment:

- partially offsets the initial low utilization of hydrogen refueling stations, thereby supporting refueling network development to increase the availability of this fuel;
- enables efficient development of hydrogen refueling stations at a sustained pace and scale to achieve significant cost reduction, for efficient use of public and private funds and reducing the cost of low-carbon fuels for Californians;
- enables the incentive structure already in place in the LCFS to reduce the carbon intensity of hydrogen through increasing renewable content;
- becomes self-balancing and sun-setting, with credit generation through the Hydrogen Infrastructure Pathway decreasing over time as hydrogen sales and station utilization increase;
- ensures best-in-class carbon intensity and infrastructure quality through eligibility conditions;
- ensures no material or unintended impacts to the overall LCFS policy and stakeholders through fixed limits on duration, infrastructure capacity, and credit generation.

This pathway would create a durable and scalable mechanism to partially offset low utilization during early commercialization of hydrogen fuel.