8 Aug, 2022

State of California, Air Resources Board
Regarding: Low Carbon Fuel Standard

Dear Low Carbon Fuel Standard team:

Thank you for the opportunity to comment on the ideas and materials related to the Low Carbon Fuel Standard in California. The University of California, Davis Institute of Transportation Studies, along with the Policy Institute for Energy, Environment, and the Economy has been engaged in research, policy analysis, and technical assistance relating to alternative fuel policy for well over a decade. We commend CARB and the LCFS program staff for holding robust, collaborative workshops like the one on July 7th, which allow stakeholder engagement and focused discussion on a variety of topics. Most of these comments relate to topics identified by staff at that workshop as being of particular interest. We emphasize that neither UC Davis, nor the Policy Institute for Energy, Environment, and the Economy takes any formal positions regarding regulatory action and we are not requesting any specific actions or outcomes. We provide these suggestions as guidance, based on our long history of research and engagement on these topics. Please find several comments below, in no particular order.

Target Setting Through 2030

At the July 7th workshop, staff indicated an interest in hearing feedback from stakeholders regarding increased LCFS targets through 2030. Staff indicated three scenarios of interest: Maintaining the current 20% carbon intensity (CI) reduction target for 2030, or increasing it to 25% or 30% (Scenario A and B, respectively).

The Policy Institute has several ongoing research and modeling projects related to projections of California's fuel portfolio and the LCFS market. Notably, our researchers led the Fuels section research published in the Driving California's Transportation Emissions to Zero (abbreviated as "DtZ") report, published last year. Modeling done in that report predicted that by the end of this decade the LCFS would be likely to develop a structural imbalance between credit supply and deficit generation, leading to a significant accumulation of banked credits. This conclusion was strongly dependent on EV rollout achieving state goals, notably having at least 5 million EVs in the fleet by 2030. While the modeling done for this report did not attempt to quantify impacts on the LCFS credit price, rapid increases in banked credits like the one predicted in DtZ would be expected to result in significant downward pressure on credit prices. The DtZ modeling was conducted before the impacts of COVID-19 had been reflected in fuel consumption data. Those effects generated more downward pressure on LCFS credit prices, due to a significant and unexpected decline in gasoline consumption coupled with a much smaller decline in diesel consumption. Since the majority of deficits generated under the LCFS come from gasoline consumption, and diesel alternatives supply a majority of credits at present, this led to a significant shift in the net credit/deficit balance and a further accumulation of banked credits during a period that previous modeling had expected to be characterized by a net shortage of credits compared to deficits and a drawing-down of the existing bank of credits.[1] This significant shift in credit balance, combined with other market factors, notably the growth of credits from greater use of renewable diesel and livestock-derived biogas, has put downward pressure on the LCFS credit price and contributed to its recent decline.

Increasing the 2030 CI target from its current level would help address the imbalance between credit and deficit generation expected in the latter half of this decade. Quantifying this reduction requires an extensive set of modeling tools and a deep discussion of underlying analytical assumptions that is beyond the scope of this letter. The Policy Institute is currently working on this issue by updating the model used in the Fuels section of DtZ to incorporate recent data, notably including the COVID-19-induced decline in fuel consumption, as well as updated projections of ZEV deployment based on the anticipated adoption of the Advanced Clean Cars II rule.[2] We emphasize that this work is still ongoing and results are, at this point, preliminary and subject to change. This preliminary work, however, indicates that a 25% CI reduction target in 2030 (with smaller increases 2025-2029) would still yield a significant excess of credits relative to deficits, indicating continued downward pressure on LCFS credit prices. A 30% CI reduction target, in this modeling, would likely yield a market with an approximate balance between credits and deficits. It is important to note that this projection is based on the assumption of successful acceleration of the ZEV, particularly EV, market to match the trajectory modeled in the ZEV scenario of DtZ. In addition, the DtZ model assumes the availability of approximately 500 million gallons/year of a low-carbon (approximately 30-35 gCO_2e/MJ CI) drop-in gasoline substitute by 2030, aligning with recommendations made in the DtZ report, and state projections of transportation fuel demand. If any or all of these assumptions fail to materialize, the ratio of credits to deficits would change substantially.

Taken together, this preliminary modeling suggests that the 25% CI reduction target proposed by staff in Scenario A is achievable and would reduce, but not eliminate the significant excess of credits relative to deficits currently anticipated by 2030. The 30% CI reduction target proposed in Scenario B is plausibly achievable, though doing so may depend on the state meeting other decarbonization targets within the transportation sector.

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[1] See: California's Clean Fuel Future as well as the 20% CI target scenarios reported by CARB's 2018 Illustrative Compliance Scenario Calculator, https://www.arb.ca.gov/fuels/lcfs/2018-0815_illustrative_compliance_scenario_calc.xlsx

[2] We use the "ZEV" scenario from the DtZ model as an approximation of the impacts of ACCII within the light-duty space, with the understanding that details may change before final adoption of the regulation. Medium and heavy duty ZEV penetration rates are based off the "LC1" scenario, which included the expected impacts of the Advanced Clean Trucks rule.

The Policy Institute is committed to continuing the work of updating the DtZ model to improve its capacity to help inform this critical policy decision. We welcome collaboration or feedback from CARB staff on the modeling effort and anticipate publication of a working paper describing the revisions to the model and scenario outputs by Fall, 2022.

Target Setting Post-2030

Staff indicated an interest in feedback on post-2030 targets, specifically inquiring about whether such targets should be set, at what increments should they be set and how far in advance should they be announced. The subject of post-2030 targets received a significant amount of discussion in the Fuels section of the Driving California's Transportation Emissions to Zero report; we refer staff and interested stakeholders to those.

In general, the long timeframes involved in alternative fuel production capacity development necessitate the announcement of targets well in advance, in order to allow fuel providers to ensure sufficient supplies of low-carbon fuels to meet LCFS obligations. It can take in excess of five years for a commercial-scale alternative fuel production facility to go from concept to operation, given the complexity of permitting, financing, and construction that they entail. Project developers need certainty that facilities will be able to take advantage of the incentives offered by LCFS for several years post-commissioning, in order to recoup the significant investment in such facilities. In DtZ we recommended setting a 2035 LCFS target at the earliest possible opportunity to ensure that project developers have at least a decade of predictable policy incentives to underpin financing and capital requirements needed to complete projects.

Conceptually, setting post-2035 targets would maximize the predictability of policy incentives and help support robust continued investment in this space. We caution against setting specific quantitative LCFS targets beyond 2035 due to current limitations in modeling tools and our understanding of how markets respond to policy incentives in the later stages of a transition to zero or near-zero carbon operation. Specifically, the modeling done in DtZ predicts that, with the caveats outlined above, by the mid-2030's more than half of the total energy supplying California's transportation system will come from low-carbon alternative sources. At the same time, LCFS targets will need to rapidly accelerate to maintain balance between credit and deficit supply as the light-duty vehicle fleet rapidly transitions to EVs. Taken together, this presents a picture of a transportation energy system, and associated markets, that are radically different than those today. Current estimates of low carbon fuel supply and price-responsiveness are derived from historical data; the markets from which such data were obtained will bear little resemblance to the market of 2035. In particular, there is no historical precedent for predicting the behavior of producers of first-generation alternative fuels like corn-based ethanol or soybean oil-based renewable diesel as their fuels switch from being LCFS credit generators to deficit generators, as will likely happen during the 2030's.

Given the close coupling between future CI targets and both near-term and long-term market behavior, it is important that such targets be based on strong empirical evidence and robust modeling. While we have reasonable confidence that our understanding of future fuel technologies and markets is sufficient to support such modeling through 2035, we are less confident in the capacity of models to provide sufficient quantitative precision acceptable levels of uncertainty for target-setting in 2040 and beyond.

While precise post-2035 target setting may exceed the capabilities of current models, it may be possible to identify key milestones or targets within the alternative fuel space and signal CARB's intent to meet such milestones, using the LCFS as a key element in the policy portfolio to do so. Several examples of relevant milestones are suggested in the DtZ report, including the development of a supply of low-carbon drop-in gasoline substitutes, setting a target for the average CI of aviation fuels for intra-state flights, or the deployment of specified amounts of net-negative carbon capture and sequestration capacity. Alternatively, CARB could announce minimum or intended ranges of targets, to indicate long-run commitment to the program without needing to precisely quantify future targets.

Medium and Heavy Duty Infrastructure Capacity Crediting Proposals

At the July 7th workshop, staff outlined proposals under consideration for the development of Hydrogen Refueling Infrastructure (HRI) and Fast Charging Infrastructure (FCI) provisions targeted at medium and heavy-duty (MHD) vehicles. These provisions would largely mirror those in the existing HRI and FCI provisions, which are currently aimed at light-duty vehicles.

The development of public charging infrastructure will help support the smooth and rapid transition to a ZEV-dominated fleet; as such the HRI and FCI proposals work towards a laudable goal. Providing credits for the presence of such capacity, rather than the actual dispensing of fuel, does not align with the core relationship between real-world GHG reduction and incentive level that underpins the LCFS. Such credit provisions distort LCFS markets, and can contribute to the long-run oversupply of credits relative to deficits, like the one we addressed in the previous section of this comment letter. Increasing future LCFS targets to adjust for the expected infrastructure capacity credits can restore balance between credit supply and demand, but the increased targets ultimately result in higher costs to deficit-generating fuels, which would be passed on to consumers, primarily via higher gasoline prices. We also note that to date, credit generation from the existing HRI and FCI pathways has significantly underperformed projections.[3] Very little cost or utilization data from such stations is publicly available, which has

[3] Based on data from the July 31 Quarterly data summary as compared to projections from California's Clean Fuel Future and Driving California's Transportation Emissions to Zero.

prevented researchers, including those at the Policy Institute, from evaluating the cost-effectiveness of these provisions, as well as how best to use these policy-directed funds for the best social outcomes (e.g., in terms of infrastructure location, accessibility, and separate or joint treatment of LD and HD sectores). More research is needed before many of these critical questions can be answered.

Treatment of Crop-based Biofuels

CARB staff have identified crop-based biofuels as an area of potential concern and have asked the stakeholder community for input. At present, crop-based fuels like corn ethanol or biomass-based diesel substitutes made from vegetable oil represent the vast majority of liquid alternative fuels consumed in California. They have generated the majority of LCFS credits to date and generally contributed to improved air quality. While they have had a generally positive impact to date, there is significant uncertainty around some impacts, which has led to concern that continued expansion in this space could be counterproductive towards California’s long-run goal of climate neutrality. The crop-based biofuels supported by California’s LCFS generally produce fewer GHG emissions over their full life cycle than current petroleum fuels, however their assessed CI is still significant, due to the need for fertilizer and other emission-intensive inputs during feedstock production and subsequent conversion to fuels. Existing models and analytical tools are generally able to assess the emissions impact of inputs to production, such as fertilizer, fuels and chemicals with reasonable certainty. Models of soil biogeochemistry - such as those that predict soil carbon changes or emissions of high-GWP gasses like methane or nitrous oxide from the soil - are subject to more uncertainty, as are those related to market-mediated indirect effects like indirect land use change (ILUC). ILUC has been identified as a significant risk arising from the production of crop-based biofuels, occurring when the diversion of crops or arable land for biofuel feedstock incentivizes the clearing of land to make up for the lost production. Beyond emissions, concern has been voiced about the potential for upward pressure on food prices due to crop-based biofuels as well, with increased burden falling on the world’s poorest.

Due to the complexity of the agronomic and economic systems involved, there is substantial variation in estimates of ILUC impacts for biofuel production pathways that are either currently consumed in large volumes in California or are likely to emerge over the next decade. A significant and sustained investment in research and modeling within these spaces could reduce the uncertainty and improve the ability of modeling tools to adapt to the innate variability of these systems. Such research, however, would be extremely unlikely to yield results within the next 1-2 years. Given the anticipated LCFS rulemaking in 2023, even if such an investment were immediately forthcoming, it would not be available in time to inform immediate policy making. As such, the very real concerns about sustainability impacts from crop-based biofuels may need to be addressed without definitive quantitative modeling as a basis; a more approximate solution may be required.

As staff consider how best to design and implement such a solution, a review of existing literature can identify several conclusions that have strong support. First, it is important to accurately define the types of feedstock that provisions targeting crop-based biofuels or feedstocks, such as a cap, any crop-based treatment would seek to limit. Commonly used labels such as “crop-based,” or “waste-based,” are insufficiently precise to provide an effective framework for policy in this case. Feedstocks based on off-season cover crops, for example, may entail lower risk of impacts on food markets, land use choice, or other sustainability indicators under certain circumstances. The word “crop” is included in their name, however. Similarly, many “waste” oils, such as tallow or used cooking oil, would be used for the production of animal feed or other products if they were not used for biofuel production. As such, they still possess both economic and material or energy value, and should not by default be treated as true wastes for regulatory purposes. Even where a precise definition can delineate between true wastes and other feedstocks, these can often be readily substituted for each other by end users.[4] Such substitution functionally links uses of wastes to demand for crop-based products like vegetable oil, and means that even true wastes likely generate a non-zero ILUC impact. To effectively limit the risk of indirect impacts, a precise definition is required; terms like “waste” or “crop-based” may not support effective policy, and could give stakeholders an inaccurate impression regarding the scope of such a limitation. Staff should consider criteria such as the risk of significant ILUC impacts, competition for land or growing inputs, or changes on farm sector growing practices when defining which feedstocks may be subject to such a cap. A precise definition and differentiation of waste are also important to avoid a risk of fraud, and the definition may be developed based on a clear process for designation. Since waste oil feedstocks are more favorable to avoid such indirect impacts, there is a risk of false labeling.[5]

Second, while crop-based biofuels, notably corn-based ethanol and vegetable oil-based biodiesel or renewable diesel, do offer the potential to reduce life cycle GHG emissions when they displace petroleum fuels, they do not appear to have a clear pathway to reduce their emissions to the very low levels required for the state to meet its long run climate targets. They are, in short, transitional fuels. This does not diminish their value; the work done in the DtZ report clearly demonstrated that meeting a 40% GHG reduction target within the transportation sector by 2030 is unlikely to occur without a significant contribution from such transitional fuels. At the same time, the fertilizer and energy inputs needed to grow feedstocks for crop-based fuels are such that these fuels are unlikely to achieve sufficiently low life cycle GHG impacts to meet the demand for very low-carbon transportation fuels in California, such as the <20 gCO_2e/MJ 2030 target or <12 gCO_2e/MJ 2040 target set out in [Driving California's Transportation Emissions to Zero](). Even large-scale deployment of CCS on crop-based

[4] See: https://theicct.org/wp-content/uploads/2022/01/impact-renewable-diesel-us-jan22.pdf for a discussion on substitution of lipid feedstocks for biomass based diesel alternatives.
[5] See: https://theicct.org/wp-content/uploads/2022/08/lipids-cap-ca-lcfs-aug22.pdf for an appendix on waste oil fraud.

pathways appears unlikely to yield low enough CI to meet long-run targets.[6] This suggests that there is little risk of closing off pathways that would contribute to long-run targets by including measures to limit crop-based fuels in some way.

Third, adding measures to limit crop-based fuels should be undertaken only with awareness of the relative magnitude and likelihood of relevant risks. First-generation biofuels, such as corn ethanol and vegetable oil based diesel substitutes provide GHG and air pollutant reductions when they displace petroleum fuels, in addition to other economic and energy supply benefits. They can, however, lead to unsustainable farming practices, of particular significance is the conversion of land with particular ecological or conservation value, or land with a large amount of embodied carbon. When such land is converted, lost carbon or disrupted ecosystems may take significantly more than a decade to recover, if recovery is possible.[7] If we assume that there exists an optimal amount of first-generation biofuels to consume - that is, one which maximizes the benefits such fuels provide and minimizes their harms - then the goal of limiting such fuels should be to promote consumption at this level. Under-consumption, relative to the theoretical optimal level, means California loses the opportunity to reduce emissions in the near term, as well as other benefits such fuels would provide. Over-consumption would mean more land is converted to produce biofuel feedstock than optimal. Under-consumption of such fuels could be addressed by policy shifts, such as the relaxation of limiting measures, which would likely bring more of the capped fuels into California within a relatively short period of time; additional capacity can usually be developed and brought online within a few years. Over-consumption of fuels can lead to undesired amounts of land conversion and of emissions associated with that conversion. Even if the land were subsequently returned to a natural state the amount of time it would take for the lost carbon and disturbed ecosystems to recover would almost certainly exceed a decade. Some lost carbon or ecosystems may not be able to be recovered due to climate change or other external factors. As such, the risk of overconsumption of first-generation biofuels, such as those made from crop-based feedstocks, is likely to be of greater magnitude and longer duration than the risk of under-consumption. This suggests that a target on these fuels should err on the side of under-consumption.

Any mechanism apart from an assessed CI value that would limit a particular fuel type’s credit-generating potential under the LCFS would represent a significant departure from the program’s historical method of operation, and could have unexpected impacts on the credit market, credit value, and compliance paths. As such, ideas (e.g., some kind of cap) should be broadly discussed, explored, and vetted through the expert as well as the stakeholder community.

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[6] E.g. Deployment as discussed by Sanchez, et al. https://www.pnas.org/content/115/19/4875

[7] E.g. https://doi.org/10.1016/j.foreco.2010.02.019

Equity Impacts

Staff have indicated an interest in better understanding the impacts of programs like the LCFS on equity and environmental justice. California seeks to ensure that its energy, transportation and climate policies help address historical inequities present in existing social, economic, and policy systems.

Precisely characterizing and quantifying equity impacts of transportation fuels is challenging because many critical impacts, especially exposure to local air pollutants like particulate matter and ozone, are heavily dependent on an understanding of place. Proximity to sources of pollution, for example, greatly affects the health risks experienced by nearby populations. At present, researchers lack precise data regarding where alternative fuels are consumed, what type of vehicles they're consumed in, and what impacts these fuels may have on vehicle activity. These data are necessary to evaluate pollutant exposure in populations of interest, or support the design of targeted policies to reduce such exposure. Existing data on alternative fuel use is primarily aggregated at the state level; we know with high certainty the total consumption of electricity or renewable diesel in heavy duty vehicles, for example, but we have very little data on where those vehicles drive, so it is difficult to produce accurate estimates of their effects on pollutant exposure by sensitive populations. Providing more data regarding where alternative-fueled vehicles drive would help fill this gap. Localizing vehicle activity to air basins or ZIP codes would allow significantly better, though still imperfect, resolution on the distributional impacts of alternative fuel use.

Researchers, including colleagues at UC Davis, have sought to fill this gap using models and other simulation tools. Recently published work has demonstrated that the adoption of low carbon fuels has reduced the disparity in exposure to air pollutant emissions along both racial and ethnic dimensions.[8] Similar work has just been submitted for peer-reviewed publication that finds similar outcomes from the proposed expansion of Oregon's Clean Fuels Program, a policy based largely on the LCFS.[9] These results align with the broad consensus among transportation researchers that has emerged over more than a decade: disadvantaged communities are disproportionately impacted by air pollution from petroleum-fueled transportation, particularly from diesel vehicles, and displacement of petroleum by the alternatives supported by the LCFS is likely to yield a net reduction in this disparity. This effect is amplified by the tendency of fuel policies like the LCFS to see over-compliance among diesel fueled vehicles as compared to gasoline ones.[10] This indicates that the fundamental effect of fuel carbon intensity policies like the LCFS is likely to be equity-enhancing, at least over the first

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[8] https://doi.org/10.1016/j.scitotenv.2022.155230

[9] The technical report and summary results from this project can be found here. Air Quality Impacts of the Proposed Expansion of Oregon's Clean Fuels Program | Policy Institute. The article detailing the equity focused work on this project is under peer review and we will provide it to CARB once it is published..

[10] See: Multijurisdictional Status Review of Low Carbon Fuel Standards, 2010–2020 Q2: California, Oregon, and British Columbia for demonstration of this trend in CA, OR and BC.

1-2 decades of effect. As LCFS targets tighten further, we expect to see significant reductions in air pollutant emissions, but further research is needed to understand how such reductions would be spatially distributed.

In addition to the air quality impacts on environmental justice, the LCFS can affect fuel costs in a way that affects economic equity. Lower-income Californians typically spent a greater fraction of their personal income on transportation and/or transportation fuel than their middle or upper-income counterparts. The LCFS establishes a market in which charges are assessed on high-carbon fuels, and the resulting revenue supports lower-carbon alternatives. To the extent that lower-income people depend on gasoline, a high carbon fuel that generates most of the deficits under the LCFS, they may be exposed to gas price increases. To date, these increases have generally been smaller in magnitude than seasonal gas price variability or signals from global supply shocks. Policy makers will need to continue to evaluate the price impacts of the LCFS and ensure that to the greatest degree possible, lower-income residents are not unduly burdened by any price impacts. This can be accomplished by providing alternatives to petroleum - or other high-carbon fuels - to meet their transportation needs. California has adopted a portfolio of policies with this intent, including support for transit and active mobility, affordable housing, electrified community ridesharing, and electric vehicle purchase by lower-income residents. It is important to note that many of the programs that can mitigate cost impacts driven by the LCFS are adopted and implemented independently of the LCFS. While it may be conceptually possible to integrate direct protections for lower-income residents in the LCFS, the program’s design and function may not be well-suited to doing so efficiently. Policy makers should judge the equity impacts of California’s transportation system holistically, and mitigation of potential equity risks from a given program may be more effective or efficient when implemented through other programs.

Credit Generation from Electric Forklifts and Other Sources

At the July 7th workshop, staff outlined a potential phase-out of electric forklift credit generation, aligned with regulatory requirements of a shift to electric forklifts. This follows the existing life cycle analysis (LCA) approach in the LCFS – existing regulations provide a basis against which actions under the LCFS are credited. Where other state policies require actions that would reduce emissions, those emission reductions would not be credited under the LCFS because they were non-additional, that is, the reductions would have occurred even in absence of the LCFS. While there are several conceptual frameworks under which additionality can be assessed, the presence of an enforced regulatory mandate creates a clear delineation under virtually all LCA frameworks. For the purposes of assessing CI impacts under the LCFS, this delineation would clearly exclude actions required by other state policy from generating credits or reducing the carbon intensity of fuels. This also aligns with well-accepted best practices in the public policy literature: when incentives are used to advance technological or market transitions, they should not be given for actions that would have occurred absent the incentive. A transitional or phase-down period can help ensure that market signals are consistent and minimize volatility, but ultimately performance standards like the LCFS are most effective and efficient when additionality is required to access incentives.

As California's transportation fuel system progresses towards its long-term goal of achieving carbon neutrality, the question of additionality is likely to occur again, as technologies that were once supported by the LCFS are either required by other policies, or achieve market competitiveness on their own merits. Electric forklifts may be one of the early examples of this phenomenon, since proposals for a zero-emission forklift regulation have been circulated with the intent to adopt them in 2023. While the aggregate emissions from forklifts are small enough that details of the process for removing them from the LCFS may have comparatively small impacts on emissions, the approach used here may set a precedent that applies to future vehicles, fuels, or technologies.

Staff requested feedback on other fuels that might be likewise phased out. There are a number of fuels and/or pathways that may eventually be required by rule or statute, as California progresses through its transition to a sustainable, carbon-neutral transportation system. CARB should seek to maintain the integrity of the LCFS, and the strong link between reduced emissions and incentives by evaluating the additionality of emissions reductions when evaluating LCFS pathways. While each regulation will need to be evaluated on a case-by-case basis, a regulatory requirement will typically render emissions reductions from a fuel incentive program like the LCFS non-additional. A more complex problem may arise when evaluating whether a technology's attainment of market competitiveness renders emission reductions it provides non-additional for the purposes of LCFS credit generation. The Driving California's Transportation Emissions to Zero report examines a likely example of this in the Fuels section. Current modeling of EV costs and deployment projects that most classes of light-duty EV will be purchase price competitive or cheaper than comparable internal combustion engined vehicles by the early to mid 2030's. Operational costs of EVs are already lower than comparable conventional ones as well. Given the likely need for continued incentives in the fuel space for hard-to-electrify applications, the value of continued LCFS incentives for vehicles that already entail lower costs is questionable. Maintaining LCFS incentives for EVs at their current level could divert incentive revenue away from low carbon fuel pathways that still need assistance to deploy at commercial scale in favor of pathways that have already developed a mature and self-sustaining market. Accordingly, staff may need to consider developing a set of criteria by which to judge if and when a technology has achieved a sufficiently secure market position that additional LCFS incentives would not result in additional emissions reduction.

We also note that current methodological tools within LCA may offer an opportunity to convert additionality from a binary parameter to a continuous one. For example, rather than making a determination about whether the emissions reduction from a given project are or are not additional to existing regulation or market activity, LCFS pathways could scale credit generation in proportion with the penetration of the technology in question. For example, per-vehicle EV or e-forklift credits are presently calculated using a method that implicitly assumes they displace an internal combustion engined vehicle. Instead of this approach, which functionally requires the determination of additionality as an all-or-nothing parameter, the per-vehicle credits could be multiplied by the fraction of their vehicle class that use conventional, internal combustion engines. As each class of vehicle progresses through its transition to a predominantly low or zero carbon technology, over time additional vehicles would generate a smaller number of credits. This obviates the need to make binary determinations of additionality, and also mitigates some of the credit market balance problems that may arise around light-duty EV credits, as discussed in Driving California's Transportation Emissions to Zero. Switching to a proportional determination of additionality would entail several significant departures from the LCFS historical mode of operation, and would need to be thoroughly researched and modeled to ensure that there are no unintended consequences from such a change.

Once again, we thank CARB staff for the thorough and transparent discussion of the LCFS program and potential changes. We look forward to continued collaboration throughout the coming months. If we can clarify or add anything to this letter, please do not hesitate to reach out. We can be reached by email at cwmurphy@ucdavis.edu or by phone at 530-754-1812.

Signed,

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