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Controlling Greenhouse Gas Emissions from Transport Fuels

The Performance and Prospects of California's Low Carbon Fuel Standard

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Executive Summary

California's Low Carbon Fuel Standard (LCFS) is an ambitious, innovative, and controversial policy that controls greenhouse-gas emissions associated with transport fuels – a large emissions source mostly neglected by prior climate policies, with unique technical challenges of uncertainty, long time-horizons, and network effects, that hinder its response to economy-wide emissions-pricing policies. The LCFS was introduced in 2011 as one measure to pursue the goal of California's landmark 2006 climate law, returning emissions to 1990 levels by 2020. LCFS regulations were revised in 2015 and further changes are now proposed for 2019, under a new statutory target for state emissions 40 percent below 1990 by 2030.

The LCFS controls emissions from fuels over their entire life cycle, from the oil well or farm field through combustion in the vehicle engine, based on life-cycle analysis modeling. Structured as an intensity standard, it limits the average life-cycle carbon intensity (CI) of fuels sold in California to a specified target in grams CO_2 emissions per megajoule of delivered fuel energy. The target drops each year to reach 10 percent below the 2010 baseline in 2020 – a reduction of 15 million tons CO2e – with further cuts to 20 percent below 2010 proposed for 2030. The policy is implemented by a system of tradable permits, under which fuel sellers whose average CI is below the target receive credits for the emissions difference that they may transfer to those whose CI is above the target or bank for future use. Credit prices have varied widely, from around $20 per ton to more than $120. Since 2016, a credit clearance mechanism has allowed a limited deferral of obligations when prices reach $200.

Over seven years of LCFS operation, there has been a large increase in the number, source diversity, and total volume of low-CI alternative fuels used in California, which reached 9.4 percent of total supply in 2017. Fuel-market disruptions predicted by opponents have not materialized, and similar policies are proposed or adopted in several other jurisdictions, in the United States, Canada, and the European Union. The most significant questions about the policy's effective-

1 We thank Danny Cullenward, Alex Klass, Jeremy Martin, Simon Mui, Colin Murphy, Daniel Sanchez, and Sonia Yeh for valuable comments on earlier drafts, as well as all panelists and participants at the May 2015 LCFS workshop at the UCLA School of Law. We also thank Garrett Lenahan and Nathaniel Logar for assistance in editing. The authors are responsible for any remaining errors, and the views expressed in this report are solely the authors' own.

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ness concern how much of achieved CI reduction reflects new and changed production, given that some reduction can be achieved by re-allocating existing fuel supply among jurisdictions ("fuel shuffling"); and the extent to which near-term innovations making current compliance are strengthening technological pathways toward needed larger future reductions.

The LCFS has been the target of sharp policy critiques as well as legal challenges, but the critiques have mostly not addressed these serious questions. Rather, most critiques have charged that the policy is inefficient, either because its narrow focus on transport fuels (and resultant high marginal cost) is unnecessarily costly, or because its structure as an intensity standard subsidizes low-CI fuels and thus precludes its being the minimum-cost way to achieve a given current-period emissions reduction. Despite widespread repetition, these critiques suffer from two basic flaws. First, their analytic framework of current-period marginal-cost comparison misconstrues the policy's goal of promoting innovations in pursuit of large, long-term reductions, and ignores the distinct and challenging technical and market conditions of transport fuels that motivated development of the LCFS. Second, they propose as a preferred alternative policy an economy-wide emissions price that no jurisdiction has succeeded in enacting at anything close to the scope and stringency needed to motivate the targeted sectoral changes.

We discuss four major issues related to policy design and effectiveness of the LCFS, in its current form and in pursuing the targeted stronger reductions post-2020. First, fuel and technology neutrality: The LCFS aims to be neutral over the fuels and technologies it covers, imposing benefits or burdens only in proportion to each fuel's calculated life-cycle emissions. This is a useful design principle to respond to the present state of knowledge and uncertainty about future low-carbon transport: confidence that large CI reductions will be required, but substantial uncertainty over the relative prospects, benefits, and challenges of the major alternative technical routes, which include low or zero-carbon (and otherwise sustainable) biofuels, synthetic fuels (hydrogen, gas, or liquids) or electricity produced from non-carbon primary energy sources, and carbon capture or removal to extend or further reduce the life-cycle emissions of any of these approaches. In this state of uncertainty, fuel neutrality advances two linked near-term objectives: providing incentives to develop a broad range of low-CI alternative fuels; and promoting learning and eliciting information about the prospects of various alternatives, without pre-judging which will be preferred. Over time, as knowledge advances about the likely or preferred future low-carbon transport system, the value of a neutral policy will decline.

Second, policy scope: As a separate policy imposing higher marginal costs on transport fuel emissions than others, the LCFS must define a coherent boundary between transport fuels and the rest of the economy, and defend it from attempts at arbitrage to exploit the large marginal-cost disparity. Defining the boundary effectively presents several challenges. Thus far, these have been closely linked to concern about policy stringency, since expanding the policy's scope to include more low-CI fuels and uses has been one tool to manage concerns about short-term credit shortages. While the credit clearance mechanism will ease this concern in the future, defining the boundary will present continuing technology-specific challenges as targets tighten, illustrated by electric drive and carbon capture. High credit prices will strengthen incentives both for alternative fuel development, and for other activities less aligned with the policy's goals, such as developing technologies and systems that blur or dissolve the boundary, as well as fuel shuffling and related forms of emissions leakage. For example, electric drive has grown rapidly from small base, but the expected scope and speed of its further expansion remain uncertain. To the extent particular transport modes and uses go electric, the LCFS becomes less effective at providing incentives for the remaining major determinants of emissions – vehicle usage patterns, and the carbon intensity of the electricity used to charge them. Moreover, if electric switching is large but leaves some modes and uses behind, the scope of the LCFS may need to be re-defined to retain incentives for CI reductions in these modes and uses. Carbon capture and atmospheric removal technologies may offer large reductions in net emissions, but their largest potential contributions lie outside transport fuel production as presently defined. Counting carbon removal elsewhere or in other processes as reducing the CI of a transport fuel requires drawing artificial system boundaries for the CI calculation, making the carbon capture or removal more closely resemble offsets than emissions reductions. Because carbon capture is likely to have both large potential and flat marginal costs, but may reasonably be judged not to comprise a complete solution to reducing transport emissions, it is important to carefully control the pace of expansion of LCFS crediting for these technologies. The treatment proposed in 2018, crediting removals on site with fuel production processes or atmospheric removals incorporated into fuel products, strikes an appropriate and prudent balance.

Third, target stringency: To achieve large transport emissions reductions, CI targets must be progressively tightened over time to provide strong, steady incentives for development and expansion of low-CI fuels. ARB has to define this target trajectory in advance, to signal ambition, create appropriate incentives, and provide context for firms' decisions to use or bank credits. But due to unavoidable uncertainty in future progress, pre-announced target schedules will sometimes need adjustment. The key question in target-setting involves balancing the risks of two types of error: setting the schedule ambitiously, with greater risk that future relaxations will be needed; or starting with less ambition, with more risk that future tightening will be needed. Comparing the costs of the two types of error suggests that the initial bias should be toward greater ambition, both because the cost of subsequent adjustment is likely to be smaller than that of the opposite error, and because policy-making systems tend systematically to err on the side of insufficient ambition. ARB must still resist too-easy or too-early relaxation, as sustained high credit prices are necessary to generate development and investment in low-CI alternatives. But if future relaxations are needed, they can be realized in several ways, by relaxing the terms of the credit clearance mechanism or incrementally expanding policy scope to include more low-CI fuels and activities (including incremental expansion of carbon capture eligibility), as well as explicit relaxation. For the target trajectory through 2030, this reasoning suggests ARB should consider targets a few percent stronger than the currently proposed 20 percent CI reduction by 2030.

Finally, the LCFS operates in the context of other related policies, principally the federal Renewable Fuel Standard (RFS) and California's greenhouse-gas cap-and-trade system. The RFS has generated a large supply of mostly conventional biofuels that eased LCFS compliance under early weak targets, but is likely to be less relevant as LCFS targets tighten, unless it is modified to provide more effective incentives for low-CI biofuels. The LCFS has interacted strongly with cap-and-trade since the cap was expanded to include fuels in 2015. Under the resultant double coverage, the LCFS has probably suppressed cap-and-trade allowance prices and so weakened reduction incentives in other capped sectors. This interaction can be reduced by adjusting the cap to track reductions induced by the LCFS.

Expansion of LCFS-like policies in other jurisdictions will bring new interactions via potential linkage of credit trading systems and expanded demand for low-CI fuels. Linkage of LCFS trading could make larger and more liquid credit markets, but requires careful coordination of trading mechanisms (to avoid double-counting), and policy stringency (to avoid arbitrage). Linkage with current systems is not feasible due to inconsistent design, notably disparate treatment of indirect land-use change in calculated biofuel CIs. New LCFS policies, like tightening of CI targets, will strengthen incentives for production of low-CI fuels and bid up their prices, and will also increase incentives for fuel shuffling. Because shuffling is an artifact of CI variation within the current fuel supply mix, shuffled fuels are in fixed supply and will decline in relative importance as low-CI demand expands. This expansion will squeeze out claimed reductions of little merit or future promise, and will also clarify how much of present reductions is coming from shuffling, and from low-CI fuels that are real but also in relatively fixed supply, such as fuels from waste oils. As these sources reach their limits, the supply profile of other low-CI fuel options will be revealed more clearly. This will represent an additional source of uncertainty in future credit markets, although the response mechanisms already discussed – the credit clearance mechanism plus ARB's discretion to make small target relaxations under conditions of sustained shortage – are likely to provide adequate ability to respond to these conditions, as they do to uncertainties generated solely within California's credit market.

Introduction

California's Low Carbon Fuel Standard (LCFS) is an ambitious, innovative, and controversial greenhouse-gas (GHG) control policy. Implemented in 2011, the LCFS aims to reduce GHG emissions from transportation fuels, a major emissions source that had been largely overlooked in previous policies. The LCFS targets emissions from fuels not just when they are burned in the vehicle, but through their entire life cycle, including extraction, production, transport, and consumption. This puts the LCFS among the first policies to be built around life-cycle assessment (LCA). The LCFS requires a progressive series of reductions in the emissions intensity of fuels from 2011 to 2020, reaching 10 percent below 2010 levels in 2020.[2] It is projected to cut total emissions by 15 million metric tons carbon dioxide equivalent (CO_2e) in 2020,[3] or more than a quarter of projected reductions from all California GHG policies that year.[4] Amendments proposed in 2018 include further reductions in emissions intensity after 2020, reaching 20 percent below 2010 levels in 2030.[5]

Transportation is a major source of greenhouse gases, accounting for more than any other sector both in California (39 percent of state emissions)[6] and, since early 2016, in the United States (27 percent

2 Cal. Air Res. Bd., Greenhouse Gas Reductions from Ongoing, Adopted and Foreseeable Scoping Plan Measures, available at https://www.arb.ca.gov/cc/inventory/data/tables/ar4_first_update_to_scoping_plan_2014-05-22.pdf. Carbon dioxide equivalent (CO_2e) measures total heating effect of all GHGs emitted, expressed as the amount of CO_2 with the same total effect. For most transport, CO_2 makes up most of total GHG emissions. See Ralph Sims et al., Transport, in Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the IPCC, 605 n.1 (Ottmar Edenhofer et al. eds., 2014).

3 Cal. Air Res. Bd., Greenhouse Gas Reductions from Ongoing, Adopted and Foreseeable Scoping Plan Measures, available at https://www.arb.ca.gov/cc/inventory/data/tables/ar4_first_update_to_scoping_plan_2014-05-22.pdf.

4 Cal. Air Res. Bd., 2020 BAU Emissions by Scoping Plan Categories, available at www.arb.ca.gov/cc/inventory/data/tables/2020_bau_forecast_by_scoping_category_2014-05-22.pdf; see also Cal. Air Res. Bd., Proposed Re-Adoption of the Low Carbon Fuel Standard—Staff Report: Initial Statement of Reasons for Proposed Rulemaking (2014) [hereinafter 2014 Initial Statement of Reasons].

5 Cal. Air Res. Bd., Proposed Amendments to the Low Carbon Fuel Standard Regulation and to the Regulation on Commercialization of Alternative Diesel Fuel, Appendix A: Proposed Regulation Order (Mar. 6, 2018) (to be codified at Cal. Code Regs. tit. 17 § 95480 et seq.), available at https://www.arb.ca.gov/regact/2018/lcfs18/appa.pdf [hereinafter Proposed Regulation Order].

6 Cal. Air Res. Bd., California Greenhouse Gas Emission Inventory – 2016 edition (June 6, 2017), https://www.arb.ca.gov/cc/inventory/data/data.htm.

of national emissions).[7] Large reductions in total emissions thus require large cuts in transport, but this sector poses challenges that are distinct from, and more severe than, those in other emission sectors.[8] Transport relies almost entirely on petroleum-based liquid fuels, which generate high emissions but enjoy technical advantages over many alternatives due to their high energy density and easy transportability. Performance requirements for fuels vary substantially among different transport modes. Transport systems are complex networks including vehicles, fuels, rights-of-way, and fuel distribution systems, which depend on each other in ways that hinder piecemeal change. Achieving large emission cuts thus requires coordinated changes to multiple parts of these systems, while meeting the demanding technical and market requirements of each part.[9] These interactions, as well as long development times for alternative fuel systems and associated uncertainties about technology, markets, and regulations, all discourage the needed long-term development investments.

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Recognizing these challenges, many jurisdictions have decided that uniform economy-wide policies like emissions taxes or cap-and-trade systems—which in theory deliver reductions at minimum cost—will not achieve the required cuts in time, and so must be supplemented by policies specifically targeting the transport sector.[10] These policies come in three main types, which aim to influence different decision points that contribute to transport emissions. The most common policies target vehicle efficiency, aiming to reduce emissions by reducing fuel consumed per unit travel. Other policies target the level of transport activity, aiming to reduce emissions by motivating reduction in travel or switching to more efficient transport modes. In view of evident limits to the ability of these approaches alone to achieve deep emission cuts, the LCFS targets a third, previously neglected point of potential influence: the emissions content of the fuel supply.

Now in effect for seven years, the LCFS is a major element of California's climate policy. It has survived early legal challenges suffering only some implementation delays, and has generated large expansions of alternative fuel supply and significant reductions in overall carbon intensity in California's fuel markets.[11] Yet the policy remains controversial and faces continuing legal challenges and policy critiques of its effectiveness, cost, and legality.[12] In response to a lawsuit and scheduled program review, California's Air Resources Board (ARB) readopted LCFS regulations with revisions in September 2015. In effect since January 2016, the revised regulations set the policy's course through 2020.[13] New legislation adopted in 2016 and 2017 then changed the context for further LCFS revisions, by tightening California's overall GHG reduction target to 40 percent below 1990 by 2030 and giving the LCFS explicit statutory authorization through that year.[14] Following a subsequent program

7 U.S. E.I.A., Monthly Energy Review, September 2016 pp. 184-185, tbl. 12.5, 12.6, available at https://www.eia.gov/totalenergy/data/monthly/archive/00351609.pdf .

8 A. Schaefer, J.B. Heywood, H.D. Jacoby, and I.A. Waitz, Transportation in a Climate-Constrained World. (MIT Press 2009); L. Vimmerstedt et al., High Penetration of Renewable Energy in the Transportation Sector: Scenarios, Barriers, and Enablers. (NREL 2012), available at www.nrel.gov/docs/fy12osti/54442.pdf; IEA, Energy Technology Perspectives 2012 Pathways to a Clean Energy System (2012), available at https://www.iea.org/publications/freepublications/publication/ETP2012_free.pdf.

9 See, e.g., P. Leiby and J. Rubin, Understanding the transition to new fuels and vehicles, in The Hydrogen Energy Transition. (Sperling and Cannon, eds., Academic Press, 2004); J. Struben and J. Sterman, Transition challenges for alternative fuel, vehicle, and transportation systems, 35:6 Environment and Planning B 1070-1097 (2008); National Research Council, Transitions to Alternative Transportation Technologies (National Academies Press, 2008).

10 National Research Council, Policy Options for Reducing Energy Use and Greenhouse Gas Emissions from U.S. Transportation, (Report No. 307, Transportation Research Board, National Academies Press, 2011).

11 As of the third quarter of 2017, overall fuel carbon intensity had declined 3.7 percent from the 2010 baseline, with large increases in use of several low-CI fuels, notably renewable diesel, bio-methane, and electricity, as well as substantial reduction in the average CI of ethanol. See Cal. Air Res. Bd., Public Hearing to Consider Proposed Amendments to the Low Carbon Fuel Standard Regulation and to the Regulation on Commercialization of Alternative Diesel Fuels, Staff Report: Initial statement of reasons (Mar. 6, 2018), available at https://www.arb.ca.gov/regact/2018/lcfs18/isor.pdf.

12 See Cal. Air Res. Bd., California's Low Carbon Fuel Standard—Final Statement of Reasons §§ III-V (2009), [hereinafter 2009 Final Statement of Reasons] (summary of comments in first rulemaking).

13 Cal. Code Regs. tit. 17, § 95496 (2016).

14 California Global Warming Solutions Act of 2006: Emissions Limit, SB 32, Ch. 249 (signed Sept. 8, 2016); State Air Resources Board: Greenhouse Gases: Regulations, AB 197, Ch. 250 (signed Sept. 8, 2016); California Global Warming Solutions Act of 2006, AB 398 (signed July 25, 2017), available at leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB398.

review, ARB has proposed further revisions to LCFS regulations, aiming to adopt these late in 2018.[15]

This paper provides a critical review of the LCFS, particularly regarding challenges likely to arise in pursuing deeper cuts after 2020. It is based in part on discussions at a 2015 workshop held at the Emmett Institute at UCLA School of Law, which sought to bring the LCFS to broader attention among environmental law scholars and identify key legal and policy design challenges moving forward.[16] The paper draws on the workshop's background paper[17] and discussions,[18] but is substantially extended based on more recent developments and further research.

The paper opens with an overview of the LCFS, including its history, design, function, and role in California's climate policies. It then examines four large-scale elements of policy design that are central to LCFS goals and implementation, and to the major decisions required to strengthen and adapt the LCFS after 2020: 1) neutrality over alternative fuels and technologies; 2) the scope of activities and energy sources covered by the policy; 3) how fast the emission-reduction target is tightened over time, with related issues of cost control; and 4) interactions of the LCFS with related California and federal policies, in particular California's GHG cap-and-trade system and the federal Renewable Fuel Standard. The concluding section reviews the policy's overall performance and prospects in the context of the large-scale challenge of reducing transport emissions, and identifies key issues to address in adapting the policy and pursuing stronger reduction goals after 2020.

The policy remains controversial and faces continuing legal challenges and policy critiques of its effectiveness, cost, and legality.

15 Cal. Air Res. Bd., Proposed amendments to the low carbon fuel standard and to the regulation on commercialization of alternative diesel fuels (Mar. 6, 2018), https://www.arb.ca.gov/regact/2018/lcfs18/lcfs18.htm.

16 Conference, Controlling Greenhouse Gas Emissions from Transport Fuels: The Performance and Prospects of California's Low-Carbon Fuel Standard, UCLA Emmett Institute on Climate Change and the Environment (May 22, 2015), http://www.law.ucla.edu/news-and-events/1774/2015/5/22/Controlling-Greenhouse-Gas-Emissions-from-Transport-Fuels-c--The-Performance-and-Prospects-of-Californias-Low-Carbon-Fuel-Standard/.

17 Jesse Lueders, Sean Hecht & Edward Parson, Controlling Greenhouse Gas Emissions from Transport Fuels: The Performance and Prospects of California's Low-Carbon Fuel Standard (Background Paper for Conference, May 22, 2015), available at http://webshare.law.ucla.edu/Emmett/papers/LCFSConference.pdf.

18 Sessions and panelists at the 2015 workshop were as follows: Introduction and background (Edward Parson, UCLA School of Law, Ryan McCarthy, ARB); Policy Design (Deborah Gordon, Carnegie Endowment; Chris Hessler, AJW Inc.; Simon Mui, NRDC; James Rhodes, Trestle Energy LLC; Sonia Yeh, UC Davis Institute for Transportation Studies); Policy Interactions (Jeremy Martin, UCS; Colin Murphy, NextGen Climate; Michael Wara, Stanford Law School); Legal Issues and Implications (Danny Cullenward; UC Berkeley, Alexandra Klass; U of Minnesota; Ellen Peter, ARB); Overview (Dan Sperling; UC Davis Institute for Transportation Studies; Sean Hecht, UCLA School of Law).

Origins and History of California's LCFS

California's Global Warming Solutions Act of 2006 (AB 32) requires the state to reduce GHG emissions to 1990 levels by 2020.[19] The implementation program for AB 32 includes several policies that have received worldwide attention for their ambition, scope, and innovative regulatory mechanisms. Most attention has focused on the cap-and-trade program, renewable portfolio standard, vehicle efficiency standards, and land-use planning measures. In contrast, despite its innovative and ambitious role in AB 32 implementation, the LCFS received less notice until recently.

In January 2007, a few weeks after signing AB 32 into law, Governor Schwarzenegger issued an executive order stating the goal to reduce carbon intensity (CI) of California transport fuels at least 10 percent below 2010 levels by 2020.[20] The Governor assigned implementation responsibilities to the Air Resources Board (ARB), and asked it to adopt an LCFS as one of AB 32's "discrete early action" measures. In March 2009, ARB issued draft LCFS regulations, mainly based on two studies by Professors Alexander Farrell and Daniel Sperling of the University of California.[21] ARB approved final regulations in April 2010, and most provisions took effect at the start of 2011.

Results from the first six years of LCFS implementation are mostly encouraging. Use of alternative and innovative fuels has increased, reaching 9.4 percent of total supply in 2017.[22] The average CI of California fuel has decreased, due to both expansion of alternative fuels and reduction in the CI of those alternative fuels.[23] More than 300 alternative fuel production processes ("pathways") have been registered.[24] Severe fuel-market disruptions predicted by opponents have not materialized thus far.[25] Similar LCFS policies have been adopted in British Columbia and Oregon,[26] partially adopted in the European Union,[27] announced but not yet implemented nationwide in Canada,[28] and proposed but not adopted in Washington,[29] by multi-state groups in the Midwest and Northeast,[30] and at the U.S. national level.[31]

19 Cal. Health & Safety Code § 38550 et seq.

20 Cal. Exec. Order No. S-1-07 (Jan. 18, 2007), available at http://www.arb.ca.gov/fuels/lcfs/eos0107.pdf. Carbon intensity measures life-cycle GHG emissions in grams CO_2e per megajoule delivered fuel energy (gCO_2e/MJ).

21 Alexander E. Farrell & Daniel Sperling, A Low-Carbon Fuel Standard for California—Part 1: Technical Analysis (May 2007) [hereinafter, Farrell and Sperling, LCFS Part 1], available at http://www.energy.ca.gov/low_carbon_fuel_standard/UC_LCFS_study_Part_1-FINAL.pdf; Alexander E. Farrell & Daniel Sperling, A Low-Carbon Fuel Standard for California—Part 2: Policy Analysis (August 2007) [hereinafter, Farrell and Sperling, LCFS Part 2], available at http://www.energy.ca.gov/low_carbon_fuel_standard/UC_LCFS_study_Part_2-FINAL.pdf.

22 Total for first three quarters of 2017. Cal. Air Res. Bd., LCFS Quarterly Data Spreadsheet (2018), available at https://www.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm.

23 Sonia Yeh & Julie Witcover, Status Review of California's Low Carbon Fuel Standard (UC Davis Institute of Transportation Studies Research Report UCD-ITS-16-02, May 2016) [hereinafter Yeh & Witcover 2016 Status Review], available at https://steps.ucdavis.edu/wp-content/uploads/2017/05/2016-UCD-ITS-RR-16-02.pdf; see also 2014 Initial Statement of Reasons, supra note 4, at VIII-5.

24 Cal. Air Res. Bd., LCFS Pathway Certified Carbon Intensities, http://www.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm (last visited May 5, 2017).

25 Yeh & Witcover 2016 Status Review, supra note 23.

26 See Pacific Coast Action Plan on Climate and Energy (signed October 28, 2013), available at http://www.pacificcoastcollaborative.org/Documents/Pacific%20Coast%20Climate%20Action%20Plan.pdf.

27 European Union Directive 2009/30/EC.

28 Government of Canada to work with Provinces, Territories, and Stakeholders to develop a clean fuel standard, Government of Canada (Nov 25, 2016), https://www.canada.ca/en/environment-climate-change/news/2016/11/government-canada-work-provinces-territories-stakeholders-develop-clean-fuel-standard.html.

29 See Kate Prengaman, Inslee Drops Low-carbon Fuel Standard, Sparing $6M for Yakima Alternative Transportation Projects, Yakima Herald (July 28, 2015), available at http://www.yakimaherald.com/news/local/inslee-drops-low-carbon-fuel-standard-sparing-m-for-yakima/article_dc00c4d6-3570-11e5-bf26-63fdcef13b42.html.

30 See Clean Fuels Standard, NESCAUM (Northeast States for Coordinated Air Use Management), http://www.nescaum.org/topics/clean-fuels-standard (last visited Dec. 18, 2015).

31 Sonia Yeh at al., National Low Carbon Fuel Standard, Policy Design Recommendations (UC Davis Institute of Transportation Studies Research Report – UCD-ITS-RR-12-10, July 19, 2012), available at https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=1776.

Yet the LCFS has also faced many obstacles. The policy met immediate opposition from fuel industries, mainly producers of corn ethanol and petroleum fuels. Opponents have pursued three lawsuits that have delayed the program's development and still present some risks to its future operation.[32] In the 2015 re-adoption and amendment, ARB revised some program elements in response to one legal challenge.[33] In March 2018, ARB proposed further revisions to strengthen the program beyond 2020, and issued a revised environmental review in response to a second legal challenge.[34] These revisions are occurring in the context of the 2016 and 2017 statutes, which tightened California's overall emissions target to 40 percent below 1990 in 2030 and authorized both the LCFS and cap-and-trade programs through that year.[35] ARB's proposed revisions tighten the LCFS CI target to 20 percent below 2010 in 2030.

What the LCFS Does and How it Works

A. Overview

The LCFS is an intensity standard: it controls fuels' average emissions intensity rather than total emissions. It does this by assigning a carbon intensity (CI) value to every quantity of fuel used in California transport, expressed in grams CO_2e emissions per megajoule (MJ) of delivered fuel energy. The CI for each fuel is based on a life-cycle assessment (LCA) of emissions generated at each step of the "fuel pathway" by which the fuel is produced, processed, transported to California, and consumed (burned) in the vehicle. The state's average fuel CI each year must not exceed a specified target, which declines to 10 percent below the 2010 level in 2020. Compliance obligations fall on fuel suppliers,[36] who must hold the average CI of fuels they sell below the cap or compensate for any exceedance by acquiring credits from other suppliers whose average fuel CI falls below it.

Regulations define separate 2010 CI baselines for gasoline and its replacements, and for diesel and its replacements, with each group separately required to meet the 10 percent reduction. Whether a fuel is a gasoline or a diesel replacement is determined by its intended use: most fuels for light- and medium-duty vehicles are deemed gasoline replacements, while most for heavy-duty vehicles or other uses are deemed diesel replacements.[37] The program covers a wide range of alternative fuels and production methods, including gas (natural gas and bio-gas), ethanol, biodiesel, renewable diesel, electricity, hydrogen, and others. Marine and aviation fuels are exempt, as are propane, fuels for certain off-road uses (e.g., military vehicles), and fuels used in small quantities.[38] Suppliers of some fuels—including electricity, hydrogen, and some natural gas—are not required to participate, because the CI of these fuels is presumed to fall below the target. They

32 POET, LLC v. California Air Resources Board, 218 Cal. App. 4th 681 (2013) ("POET I"); Rocky Mountain Farmers Union v. Corey, 730 F.3d 1070 (9th Cir. 2013); POET, LLC v. California Air Resources Board, No. 15 CECG03380 (Cal. Super. Ct., filed Oct. 30, 2015) ("POET II").

33 See 2014 Initial Statement of Reasons, supra note 4, at III-12.

34 See Cal. Air Res. Bd., Public Hearing to Consider Proposed Amendments to the Low Carbon Fuel Standard Regulation and to the Regulation on Commercialization of Alternative Diesel Fuels, Staff Report: Initial statement of reasons (Mar. 6, 2018), available at https://www.arb.ca.gov/regact/2018/lcfs18/isor.pdf.

35 California Global Warming Solutions Act of 2006: Emissions Limit, SB 32, Ch. 249 (signed Sept. 8, 2016); State Air Resources Board: Greenhouse Gases: Regulations, AB 197, Ch. 250 (signed Sept. 8, 2016); California Global Warming Solutions Act of 2006, AB 398 (signed July 25, 2017), available at leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB398.

36 Regulations define the "regulated party" who bears the compliance obligation for each fuel. This is usually the producer or importer, with some exceptions, e.g., for electricity and natural gas, it is the distributor or owner. Parties may transfer compliance obligations. See Cal. Code Regs. tit. 17, § 95483.

37 Id. at § 95484.

38 Less than 420 million MJ per year. Id. at § 95482(c).

may, however, choose to opt in and verify their CI, which allows them to receive credits that they may then sell to suppliers of higher-CI fuels.[39]

The crediting system gives individual suppliers flexibility in how to comply. Fuels whose CI is below the current target receive credits for the tons of CO_2e avoided by their use, relative to the target.[40] A supplier may comply by keeping its annual CI below the target, or by submitting ("retiring") credits acquired from lower-CI fuel suppliers to make up for any exceedance. Exchange of credits among suppliers creates a market that drives demand for lower-CI fuels and related innovations. Credits may be "banked," or generated one year and held to meet a future-year obligation. The opposite time shift, "borrowing" credits from anticipated future reductions to meet current obligations, is not allowed. Each supplier must submit an annual compliance report showing either a positive or zero credit balance for the year, as well as quarterly progress reports.

B. A Key Innovation and Controversy: CI Calculations Based on LCA

The most novel and controversial feature of the LCFS is its use of life-cycle analysis (LCA) in CI calculations. In general, LCA aims to measure a product's environmental impact—whether emissions of a specified pollutant or some other form of impact—for its entire life cycle, from production through use and disposal. The LCFS uses LCA to estimate GHG emissions for each fuel over its entire life cycle, from the oil well or farm field through combustion in the vehicle engine, including emissions from producing, processing, transporting, storing, and burning the fuel. Emissions upstream from the vehicle tailpipe vary widely among fuels, from as little as 10 or 20 percent of life-cycle emissions for gasoline and diesel to 100 percent for electricity and hydrogen. The life-cycle approach thus gives a more accurate picture of different fuels' total environmental impact than would be provided by comparing them only at the point of combustion.

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For biofuels, the CI calculation includes emissions from land-use change (LUC) if cropland was converted from some other use to produce the biofuel. The calculation includes emissions not just from *direct* LUC at the site of fuel crop production, but also from *indirect* LUC—estimated changes in land-use elsewhere in response to shifting land from its prior use (typically human food or animal feed) to fuel. Indirect LUC (ILUC) emissions can comprise a large share of biofuel life-cycle emissions—in CARB's estimates, about one-quarter for corn ethanol, up to one-third for sugarcane ethanol, and more than half for soybean biodiesel.[41]

The LCFS uses three models to calculate life-cycle emissions.[42] Most calculations use a modified version of Argonne National Laboratory's "Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation" (GREET) model called CA-GREET, which incorporates California-specific conditions and data.[43] The model is implemented as a large spreadsheet, with thousands of inputs that can be modified to represent different fuels and processing methods. Two other models are

39 Id. at § 95482(b).

40 Credits are calculated by multiplying the energy content of fuel sold by the difference between the fuel's CI and the target. A third factor in the calculation, the "energy-economy ratio" or EER, reflects how efficiently fuel energy is converted to mechanical work in the vehicle. This aims to equalize treatment of fuels used in combustion (heat) engines and those used in intrinsically more efficient systems like electric motors or fuel cells. Id. at § 95486.

41 See former Cal. Code Regs. tit. 17, § 95486(b)(1) tbl .6 (rev.'d 2016); see also Cal. Code Regs. tit. 17, § 95488(c)(2) tbl.5 (2016). These values reflect CARB's revised estimates since the September 2015 re-adoption. There remains wide variation in ILUC estimates in the scientific literature, reflecting both uncertainties in the strength of effect and policy judgments required to reduce the land-use change effect to a single number, such as the time horizon of biofuel production over which to spread the emissions pulse from initial land conversion.

42 See Farrell and Sperling, LCFS Part 1, supra note 21, at 46 Box 2 (comparing three LCA modeling tools).

43 See CA-GREET, Life Cycle Associates, http://www.lifecycleassociates.com/lca-tools/ca_greet; see also Cal. Air Res. Bd., Proposed Regulation to Implement the Low Carbon Fuel Standard—Volume I, Staff Report: Initial Statement of Reasons IV-8 to 15 (2009) [hereinafter 2009 Initial Statement of Reasons]. The 2016 regulations shifted from CA-GREET ver. 1.8b, used in previous regulations, to ver. 2.0.

used for specific parts of the CI calculations: the Oil Production Greenhouse Gas Emissions Estimator (OPGEE) provides detail on petroleum sources and processing methods to calculate CI values for gasoline and diesel,[44] and the Global Trade Analysis Project Model (GTAP) calculates ILUC emissions by estimating trade-driven shifts in global markets.[45]

Questions about LCA models and LUC emissions were among the most contentious in initial review of the LCFS, and remain so. All LCA models require multiple estimates of uncertain quantities and decisions regarding the scope of factors included, all of which require contestable judgments.[46] There has been particular controversy over the linked use of two distinct types of LCA models. "Attributional" LCA models, like CA-GREET, provide a static accounting of emissions from current production and supply chains, but do not explicitly represent how production would change in response to changed economic, technological, or policy conditions.[47] An alternative approach, "consequential" LCA, aims to rectify this weakness by explicitly modeling the marginal effect of policy or process changes—and thus is preferable in theory—but suffers even more than attributional LCA from data limitations that restrict the emissions sources and types of change that can be considered.[48] The LCFS augments the generally attributional approach of CA-GREET with consequential methods for LUC. In this, its decisions regarding the scope of effects included in CI calculations have attracted particular criticism. For example, biofuel CI calculations include the large indirect effect from world land-use changes driven by agricultural markets, but exclude other indirect effects such as nitrous oxide (N_2O) emissions from increased fertilizer use under intensified production, or changes in fossil fuel markets due to biofuel displacement – effects that are smaller than indirect land-use change, but whose values are disputed and are clearly not zero.[49]

44 See Cal. Code Regs. tit. 17, § 95481(a)(61).
45 See id. at § 95481(a)(42); 2009 Initial Statement of Reasons, supra note 43, at IV-16 et seq.
46 Farrell and Sperling, LCFS Part 1, supra note 21, at 41–44.
47 See, e.g., Richard J. Plevin et al., Using Attributional Life-Cycle Assessment to Estimate Climate-Change Mitigation Benefits Misleads Policymakers, 18 J. Ind. Ecol. 73 (2013); John M. DeCicco, Biofuels and Carbon Management, 111 Climatic Change 627 (2012).
48 See Plevin et al., supra note 47.
49 See, e.g., D. Rajagopal, G. Hochman & D. Zilberman, Indirect fuel use change and the lifecycle impact of biofuel policies, 39 Energy Policy 228-33 (January 2011); see also B.E. Dale & S. Kim, Can the Predictions of Consequential Life-Cycle Assessment Be Tested in the Real World? Comment on "Using Attributional Life-Cycle Assessment to Estimate Climate-Change Mitigation" 18 J. Ind. Ecol. 466-67 (2014) (describing indirect effects of petroleum fuel production).

C. CI Calculation Procedures

ARB revised its process for calculating fuel CIs in 2015 to reflect the growing diversity of alternative fuels in the market. All fuels except gasoline and diesel are now grouped into two tiers.[50] Tier 1 includes 23 first-generation alternative fuels that have been in commercial production with certified LCFS pathways for at least three years.[51] These have a simple, standardized process to set their CI, based on calculations already implemented in the CA-GREET 2.0 model.[52]

Tier 2 includes all other alternative fuels, plus any fuels produced using innovative feedstocks or processes.[53] For these, there are three ways to certify fuel pathways and determine associated CIs, depending on how similar the fuel is to one that already has a certified pathway and CI value.[54] Those most similar to an already certified fuel may use that fuel's CI value, as published in a "lookup table."[55] Other fuels may apply for new CI values, either by modifying an existing pathway (Method 2A) or creating a new one (Method 2B). To limit administrative burden, proposals to modify an existing pathway must meet minimum thresholds for the change in CI and the amount of fuel supplied.[56] Proposals for new pathways must use the assumptions and calculations of CA-GREET 2.0 where applicable, and are subject to ARB technical review. This multi-layered approach lets ARB speed approval in straightforward cases and focus staff resources on more complex cases. It also lets ARB set conservatively high default CI values, while also letting suppliers claim lower values if they can persuasively demonstrate them.[57]

Gasoline and diesel, the largest-volume transport fuels, are not granted this flexibility. Although these fuels' life-cycle emissions vary substantially due to different crude sources and refining processes, all suppliers must use a single default CI value for each fuel.[58] ARB calculates the average CI for gasoline and diesel supplied to California each year and compares this to the default value. If the calculated CI exceeds the default (which has not yet occurred), the shortfall is distributed among suppliers in proportion to their production volume.[59] This approach reflects refiners' preference not to distinguish among crude sources, while also ensuring the aggregate CI of petroleum fuels does not increase. Refiners argued that distinguishing among sources would impose costly burdens with little environmental benefit, because higher-CI crudes would simply be redirected, or "shuffled," to markets outside California, with little or no change in the overall mix of fuels produced.[60]

50 2014 Initial Statement of Reasons, supra note 4, at II-10.

51 See Cal. Code Regs. tit. 17, §§ 95488(b)(1), (2); See also documentation for CA-GREET 2.0, Tier 1, available at https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm (released Sept 29, 2015). Tier 1 includes, but is not limited to: starch- and sugar-based ethanol; biodiesel and renewable diesel from conventional feedstocks; natural gas; and methane from landfill gas.

52 See Cal. Code Regs. tit. 17, § 95488(c)(3); see infra at 7 for more detailed discussion of the CA-GREET model.

53 See id.at § 95488(b)(2). For purposes of Tier 2, innovative production methods include, but are not limited to, use of low-CI process energy sources, use of unconventional feedstocks like algae oil, carbon capture and sequestration, and production process innovations that result in at least a 20 percent CI reduction.

54 See id. at § 95488(c)(4). The Tier 2 lookup table corresponds to Method 1 under the prior regulations. It provides default values based on ARB calculations for existing pathways. For example, the table includes 35 pathways and corresponding CIs for corn ethanol, depending on where the corn is grown, how it is milled and processed, what source provides the energy, and how co-products are used. Methods 2A and 2B in the new regulations correspond to the methods with the same names under the prior regulations.

55 See id. at § 95488(c)(4) tbl. 6.

56 Under the "5-10 substantiality requirement," fuels using a modified pathway must change CI by at least 5 gCO_2e/MJ, and must supply at least the energy equivalent of 10 million gallons of gasoline. Id. at § 95486(e).

57 Farrell and Sperling, LCFS Part 2, supra note 21, at 44.

58 Cal. Code Regs. tit. 17, §§ 95488(c)(4)(B), 95489.

59 See id. at § 95489(b). CI is calculated as a three-year moving average. Because calculated average CI has not yet exceeded the default, the process of assigning deficits has not been triggered. See email from Sam Wade, ARB, to Julia Forgie, October 3, 2016 (on file with authors).

60 Cal. Air Res. Bd., Proposed Amendments to the Low Carbon Fuel Standard—Staff Report: Initial Statement of Reasons for Proposed Rulemaking 33 (2011). Regulations initially distinguished a separate class of high-CI crude oil. See former Cal. Code Regs. tit. 17, § 95486(b)(2)(A) (2010) (rev'd 2012).

There are a few exceptions to this uniform treatment of gasoline and diesel. Crude producers and refiners may receive LCFS credits for using specified emission-reduction methods in their operations. Access to these credits is quite restricted, however. Prior to 2015, the only qualifying method was carbon capture and sequestration (CCS), but credits were not available in practice because ARB had not implemented a credit accounting protocol.[61] The 2015 revisions expanded the set of qualifying methods, adding solar steam and heat generation, and solar or wind-generated electricity,[62] but retained various restrictions. The methods must be used on-site at the refinery or production facility to qualify, or in the case of solar or wind electricity, provided by direct connection rather than through the grid.[63] In view of the unique challenges CCS projects pose in defining system boundaries and assessing permanence of sequestration, a draft protocol for crediting these projects was released with the proposed 2018 amendments.[64] Thus far, one crude producer has been granted production-technology credits, for use of solar electricity at an oil field in Kern County.[65] In addition, limited quantities of credits are available to refineries for incorporating renewably produced hydrogen into fuel products,[66] and to three small refineries with particularly low energy use and emissions. These three are also allowed a one-time option to have their CI deficit separately calculated rather than using the statewide average.[67] One refinery qualified to receive these credits in 2017.[68]

Refiners argued that distinguishing among sources would impose costly burdens with little environmental benefit, because higher-CI crudes would simply be redirected, or "shuffled," to markets outside California, with little or no change in the overall mix of fuels produced.

61 2014 Initial Statement of Reasons, supra note 4, at II-18.

62 Cal. Code Regs. tit. 17, §§ 95489(d), (f).

63 Id. ARB is considering further changes to refinery credits, to clarify eligible project types and ensure the accuracy of credits when refinery-wide operations adjust in response to credited investment projects. Cal. Air Res. Bd., Pre-Rulemaking Public Meeting to Discuss 2018 LCFS Preliminary Draft Regulatory Amendment Text (presentation slides from public workshop, November 6, 2017). available at https://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/110617presentation.pdf.

64 Cal. Air Res. Bd., carbon capture and sequestration protocol under the Low Carbon Fuel Standard. available at https://www.arb.ca.gov/regact/2018/lcfs18/appb.pdf (last accessed March 10, 2018) [hereinafter Carbon Capture and Sequestration Protocol).

65 Innovative Crude Oil Production Method Application, Seneca Resource Corporation North Midway Sunset Oil Field Solar Project, Kern County, California, available at https://www.arb.ca.gov/fuels/lcfs/crude-oil/innovative-crude/2016-0927_seneca.pdf (last accessed March 3, 2017); Approved Innovative Crude Oil Applications, https://www.arb.ca.gov/fuels/lcfs/crude-oil/innovative-crude/approved_innovative_crude.htm.

66 Cal. Code Regs. tit. 17, § 95489(g).

67 Id. at § 95489(e). Refineries qualify based on two criteria: a Nelson complexity index less than or equal to 5, and annual energy use less than or equal to 5 million MMBtu. See id. at § 95481(a)(55). An ARB study found three California refineries that were outliers in complexity (all < 5, while all others were > 10) and energy use (all < 5 million MMBtu per year, while the next lowest used ~ 11 million and all others exceeded 20 million)—and that the same three refineries had average CI ~ 5 gCO$_2$e/MJ below other refineries. These three qualify for credits of 5 gCO$_2$e/MJ. 2014 Initial Statement of Reasons, supra note 4, at III-48-54.

68 Cal. Air Res. Bd., 2017 Progress Report on the Low Carbon Fuel Standard. (Presentation to Board hearing, June 22, 2017), available at https://www.arb.ca.gov/board/books/2017/062217/17-6-4pres.pdf.

Legal Challenges, LCFS Re-Adoption, and Proposed Revisions

The LCFS has faced three legal challenges from regulated industries. These continue today, but have thus far resulted only in implementation delays and modest program revisions. This section explains the legal challenges and their current status, and outlines the major changes made to the policy in 2015 and proposed in 2018, partly in response to these legal challenges.

A. Legal Challenges

Regulated industries have brought three legal challenges to the LCFS: *Rocky Mountain Farmers Union v. Corey,*[69] and two lawsuits by POET LLC.[70] *Rocky Mountain Farmers* and *POET I* had the potential to derail the LCFS at the outset. Neither has blocked the program's implementation or required substantive changes thus far, but implementation experienced a delay between 2015 to 2017 due to *Rocky Mountain Farmers*, and one in 2017 and 2018, not yet fully resolved, due to *POET*.

In *Rocky Mountain Farmers*, plaintiffs from the petroleum and corn ethanol industries challenged the LCFS in federal court, unsuccessfully arguing that it violated the dormant Commerce Clause doctrine and was preempted by federal law. The dormant Commerce Clause is a legal principle that forbids state or local governments from interfering in inter-state commerce. Plaintiffs alleged that the LCFS violated this doctrine by discriminating against out-of-state fuels (by assigning higher CI values to some out-of-state corn ethanol and high-CI crude oils), and by regulating commerce entirely outside California (via the market influence of assigned CI values). They also argued that federal law preempted the LCFS, because LCFS implementation would interfere with the federal Renewable Fuel Standard (RFS). The district court held that the LCFS did impermissibly discriminate against out-of-state fuels—on its face for corn ethanol, and in purpose for high-CI crude oils—and that the LCFS constituted extraterritorial regulation.[71]

On appeal, the Ninth Circuit reversed on all three grounds,[72] but did not address the preemption issues. Plaintiffs sought review from the U.S Supreme Court but were denied. On remand, the district court dismissed or granted summary judgment to the State on many of the plaintiffs' remaining claims.[73] In response to the 2015 revisions, plaintiffs amended their complaints to include preemption claims and both facial and applied Commerce Clause challenges to both the original and 2015 regulations.[74] In light of the district court's finding that the challenged portions of the 2015 LCFS are not materially different from the original LCFS, however, these amended claims are unlikely to significantly affect the LCFS's future.

69 730 F.3d 1070 (9th Cir. 2013), cert. denied, 134 S. Ct. 2875 (2014), and cert. denied sub nom. Am. Fuel & Petrochemical Mfrs. Ass'n v. Corey, 134 S. Ct. 2875 (2014), and cert. denied, 134 S. Ct. 2884 (2014).

70 POET, LLC v. California Air Resources Board, 218 Cal. App. 4th 681 (2013) ("POET I"); POET, LLC v. California Air Resources Board, No. 15 CECG03380 (Cal. Super. Ct., filed Oct. 30, 2015) ("POET II").

71 Rocky Mtn. Farmers Union v. Goldstene I, 843 F.Supp.2d 1042 (E.D. Cal. 2011); Rocky Mtn. Farmers Union v. Goldstene II, 843 F.Supp.2d 1071 (E.D. Cal. 2011).

72 Corey, 730 F.3d at 1070 (Sept. 8, 2013). The Ninth Circuit declined review en banc. Corey, 740 F.3d at 507 (Jan. 22, 2014). The Supreme Court denied cert. Rocky Mtn. Farmers Union v. Corey, 134 S.Ct. 2875 (2014); Am. Fuels & Petrochemical Mfrs. Ass'n v. Corey, 134 S.Ct. 2875 (2014).

73 See Am. Fuels & Petrochemical Mfrs. Ass'n v. Corey, 2015 WL 5096279 (E.D. Cal., Aug. 28, 2015) (dismissing all but one of Plaintiff American Fuels & Petrochemical Manufacturers Association claims).

74 Rocky Mtn. Farmers Union v. Corey, 2016 WL 3277018 (E.D. Cal., June 15, 2016) (granting in part and denying in part plaintiffs' motions to amend their complaints).

The *POET* litigation is procedurally complex. The two cases involve procedural challenges to ARB's administrative actions, and challenges to the adequacy of the program's environmental impact analysis under the California Environmental Quality Act (CEQA).[75] In the first case (*POET I*), an out-of-state corn ethanol producer and a California air quality consultant argued that ARB violated CEQA in three ways: by approving the LCFS before completing its environmental analysis; by failing to assign responsibility for approving regulations to those conducting the analysis; and by improperly deferring enactment of measures to mitigate potential increases in nitrogen oxide (NO_x) emissions caused by increased biodiesel use. The trial court ruled for ARB on all counts but in August 2013 the Court of Appeal reversed, directing ARB to set aside its approval of the LCFS, remedy the identified deficiencies by conducting a new environmental analysis, and allow another public comment period before re-approving the regulations. The court let the regulations remain in effect based on public interest in environmental protection, but preserved the trial court's jurisdiction to set them aside if ARB failed to correct the errors in time.[76] The California Supreme Court denied review.

Among other aims, ARB's 2015 re-adoption of LCFS regulations, with a new environmental impact analysis, sought to comply with the court's mandate. Following re-adoption, the superior court found that ARB had complied with the Court of Appeal's order and dismissed the writ. Plaintiffs then appealed again, arguing that the new analysis still did not adequately analyze the potential for increased NOx emissions, and thus did not comply with the order.[77]

In October 2015, while this appeal was pending in the Court of Appeal, the same plaintiffs filed a second suit (*POET II*), alleging procedural violations in adopting the revised 2015 regulations similar to those they previously alleged for the earlier regulations in *POET I,* as well as deficiencies in the new environmental analysis that overlap with the claims made in their second trip to the Court of Appeal in *POET I*.[78] As of March 2018, this second suit is still pending in Kern County Superior Court.

The Court of Appeal issued its second opinion in *POET I* in May 2017. The Court found that the new environmental analysis did not correct all the prior CEQA violations, so ARB had not complied with its writ of mandate.[79] The key issue was the baseline year used to assess the impact of the 2015 readopted regulations. ARB's analysis used a 2014 baseline, treating the 2015 regulation as a new action to be assessed relative to then-current conditions. The court held that since the new regulations were a re-adoption of the original 2009 regulations, ARB should have compared projected NOx emissions to a 2009 baseline, when emissions were lower. The Court ordered ARB to complete a new analysis, but found the regulations were on balance likely to be beneficial, and so limited its remedy—requiring the diesel provisions to be held at 2017 levels until the writ is discharged, while leaving all other LCFS regulations in effect unchanged. The California Supreme Court again denied review, so ARB was obliged to comply with the Court of Appeal's writ.

75 See Cal. Pub. Res. Code § 21000 et seq.

76 POET, LLC v. Cal. Air Res. Bd., 218 Cal. App. 4th 681 (2013). Peremptory writ of mandate was discharged on January 5, 2016.

77 POET, LLC v. Cal. Air Res. Bd., No. F073340 (Cal. App. Ct., 5th, filed Mar. 9, 2016) (appeal from No. 09 CECG04659).

78 POET, LLC v. Cal. Air Resources Bd., No. 15 CECG03380 (Cal. Super. Ct., filed Oct. 30, 2015). The opinion was initially issued on April 10, 2017, then vacated and re-issued with minor revisions on May 30, 2017; See also Josh T. Bledsoe and Max Friedman, Twin Challenges to LCFS Advance in California Courts, With Potential Implications for State's Overall Climate Stabilization Strategy, Latham's Clean Energy Law Report, http://www.cleanenergylawreport.com/finance-and-project-development/twin-challenges-to-lcfs-advance-in-california-courts-with-potential-implications-for-states-overall-climate-stabilization-strategy/ (March 2, 2017).

79 POET, LLC v. Cal. Air Resources Bd., No. 09 CECG04659 (Cal. Super. Ct., filed Apr 10, 2017);

B. ARB Re-adoption of Revised LCFS Regulations

ARB re-adopted the LCFS regulations in September 2015 with several changes, of which five were significant. Most notably, the new regulations loosened CI reduction targets prior to 2020. The original target of 10 percent reduction in 2020 remained in place, but interim reductions through 2017 were weakened as required by the Court of Appeal's decision in *POET I*, followed by faster tightening to reach 10 percent in 2020.[80] This change generated an excess supply of credits in early years, letting suppliers bank more credits to reduce risk of shortfall later,[81] but at the cost of weakening cumulative reductions through 2020 by about 12 percent, perhaps also calling into question investors' confidence in the credibility of future targets.

A second change aimed to damp credit price spikes and mitigate any such risk to future targets' credibility.[82] A newly introduced "credit clearance market" put a cap on credit prices and provided an orderly mechanism to handle credit shortages. Under this mechanism, if the market fails to clear at a price of $200, parties who are short on credits are allowed to buy and retire fewer than they owe (distributing the shortfall among buyers in proportion to how much they are short), and to repay the rest of their obligation, with interest, within five years. In contrast to a fixed-price reserve, this approach limits price spikes and so eases immediate compliance burdens in times of scarcity, without weakening cumulative emission cuts. It also reduces political pressure to weaken the cap under future shortfalls, and may thus help maintain longer-term incentives for innovation.

Third, the regulations revised several biofuels' indirect land-use change (LUC) values.[83] Some values were reduced based on new modeling, and values were added for three new fuels: canola biodiesel, palm biodiesel, and sorghum ethanol. Because indirect LUC represents a large share of total CI for some biofuels, these changes were expected to have substantial impacts on markets for ethanol and biodiesel. Fourth, the revisions expanded the set of methods by which petroleum producers and refiners may qualify for credits, creating additional incentives to reduce petroleum fuel CI. And finally, new credits were made available for two types of off-road electrical transport, electric railroads and forklifts, increasing credit supply and slightly relaxing compliance burdens.

Proposed amendments include a new target schedule that reduces CI a further 1.25 percent each year to reach 20 percent below the 2010 baseline in 2030.

C. Proposed 2018 Amendments

In March 2018 ARB proposed further amendments to LCFS regulations, responding to both the 2015 call for another review by 2019 and the need to comply with the Court of Appeal's second writ in *POET I*.[84] In addition to various procedural and administrative changes, the proposed amendments make several changes to the coverage and stringency of the program. Most importantly, they propose a schedule for tightening CI targets beyond 2020. Starting from the 2018 target of 5 percent below 2010, the new schedule reduces CI a further 1.25 percent each year, to reach 20 percent below the 2010 baseline in 2030. This new schedule smooths the rather abrupt transition that would otherwise have occurred around 2020 due to prior court-ordered delays of pre-2020 interim targets, by slightly weakening the targets previously in effect from 2019 to 2021.

The proposed amendments also change the treatment of several fuels. Producers of alternative jet fuel and alternative fuels used in military vehicles, previously outside the program, are

80 Cal. Code Regs. tit. 17, § 95484(b) tbl.1 (2016).
81 2014 Initial Statement of Reasons, supra note 4, at III-13.
82 Cal. Code Regs. tit. 17, § 95485(c) (2016).
83 See, e.g., id. at § 95488(c)(2)(C) tbl.5.
84 Cal. Air Res. Bd., Proposed Amendments to the Low Carbon Fuel Standard Regulation and to the Regulation on Commercialization of Alternative Diesel Fuels, (March 6, 2018), https://www.arb.ca.gov/regact/2018/lcfs18/lcfs18.htm.

The LCFS's success on the dormant commerce claims in Rocky Mountain Farmers is especially important, because a loss on these would have made any state regulatory use of life-cycle assessment legally vulnerable.

allowed to opt in to receive credits. In addition, a few fuels that were previously opt-in or exempt are now required to participate, notably compressed natural gas (CNG) and hydrogen from fossil sources, and liquefied petroleum gas (LP-gas, commonly called propane). This change in part was required by planned tightening of CI targets, as some fuels – in particular fossil CNG – whose CI was formerly assumed to be below the target could no longer be treated this way as the target grows more ambitious. The revisions also include a protocol for accounting and crediting carbon capture and sequestration (CCS) projects, which will allow them to participate in the program, initially in the credit programs for crude production and refining. Finally, the proposals change the treatment of electricity used to charge EVs, aiming to strengthen incentives for renewably generated electricity and for charging at times when the overall CI of electrical generation is lower.

To comply with the Court of Appeal's order, the proposed revisions were accompanied by a new environmental analysis that aims to address the remaining deficiencies identified by the Court. ARB plans to adopt the amended regulations together with the new environmental report later in 2018, following public comments and a hearing. It would then ask the Court to discharge the writ, which would allow the amended regulations, including the new compliance schedule, to go into effect starting in 2019, as planned.[85]

To sum up the current legal status of the LCFS, various preemption and Commerce Clause challenges to both the 2012 and 2015 regulations remain before the district court in *Rocky Mountain Farmers*, and litigation on the procedural and CEQA issues raised in *POET I* and *POET II* is still pending. None of these challenges, however, has presented a serious substantive risk to the program so far. The LCFS's success on the dormant commerce claims in *Rocky Mountain Farmers* is especially important, because a loss on these would have made any state regulatory use of life-cycle assessment legally vulnerable. Such use of assessment methods that reach beyond state boundaries is now widely considered a necessary tool for effective state-level control of GHG emissions.

85 Cal. Air Res. Bd., Public Hearing to Consider Proposed Amendments to the Low Carbon Fuel Standard Regulation and to the Regulation on Commercialization of Alternative Diesel Fuels,
Staff Report: Initial statement of reasons (March 6, 2018), available at https://www.arb.ca.gov/regact/2018/lcfs18/isor.pdf.; See also Cal. Air Res. Bd., Low Carbon Fuel Standard (LCFS) Regulatory Guidance 18-01, available at https://www.arb.ca.gov/fuels/lcfs/guidance/regguidance_18-01.pdf.

For now the Ninth Circuit decision in *Rocky Mountain Farmers* has established precedent for upholding other states' LCFS programs in federal courts. In early 2015, fuel and trucking groups (including some plaintiffs from *Rocky Mountain Farmers*) challenged Oregon's LCFS on Commerce Clause and preemption grounds.[86] Both California and Washington intervened on Oregon's behalf. In September 2015, a federal district court judge dismissed the challenge, concluding in part that *Rocky Mountain Farmers* compelled dismissal of the Commerce Clause claims.[87] The court also rejected plaintiffs' preemption challenges, holding that the LCFS did not conflict with federal gasoline regulations and that plaintiffs lacked standing on their claim of preemption by the federal Renewable Fuel Standard (RFS).[88] This decision, which has been appealed to the Ninth Circuit, is consistent with many experts' views that preemption challenges to state LCFS programs lack merit.[89] Nevertheless, the LCFS and similar programs are still subject to the remaining constitutional claims before the district court in *Rocky Mountain Farmers*; and it is still possible that the U.S. Supreme Court may have the final word on both dormant Commerce Clause and preemption challenges to the LCFS and similar programs, either in pending or future litigation.

The *POET* cases may still impose further delay on the program's implementation, if the *POET I* Court finds ARB's response to its order is still inadequate or the *POET II* Court finds serious deficiencies in the re-adoption procedures or environmental review. But while new and continuing challenges may provide further opportunities for judicial review by state or federal courts, policymakers are cautiously optimistic that the LCFS will continue to survive any significant substantive challenges to the program.[90]

86 Am. Fuel & Petrochemical. Mfg. Ass'n. v. O'Keeffe, No. 3:15-cv-00467-AA (D. Or., Sept. 23, 2015); see also Hillary Borrud, Truckers, Energy Group Sue to Block Low-Carbon Fuel Standards, PORTLAND TRIB.,Mar. 23, 2015, available at http://www.pamplinmedia.com/pt/9-news/254575.

87 American Fuel & Petrochemical Mfrs. v. O'Keeffe, 134 F.Supp.3d 1270 (D. Or. 2015).

88 A separate state lawsuit challenging administrative rules for Oregon's LCFS is still pending. Saul Hubbard, Federal Lawsuit Challenging 'Clean Fuels' Program Dismissed, REGISTER-GUARD, Sept. 25, 2015, available at http://registerguard.com/rg/news/local/33541942-75/federal-lawsuit-challenging-clean-fuels-program-dismissed.html.csp.

89 Emmett Institute LCFS Conference, supra note 16 (multiple legal experts questioned the viability of the preemption challenges).

90 Emmett Institute LCFS Conference, supra note 16.

LCFS Design Decisions and Challenges—Current and Future

In view of its novelty, its ambitious aims, and the complexity and uncertainty of the environment in which it operates, the LCFS faces multiple design challenges—both in its current operation and as it is revised under tighter post-2020 reduction targets. In this section, we discuss four major elements of LCFS design: its aim to be neutral over fuels and technologies; the scope of fuels and activities it covers; its trajectory of increasingly ambitious targets over time; and its interactions with other policies. For each of these, we outline the current status and its rationale, implications of the current design and associated challenges, and coming decisions and issues as the policy is modified and tightened after 2020. Although these four elements all interact in determining the total effects of the policy, we consider them separately. The concluding section discusses interactions among these elements and suggests guidance for future LCFS program design.

In view of its novelty, its ambitious aims, and the complexity and uncertainty of the environment in which it operates, the LCFS faces multiple design challenges—both in its current operation and as it is revised under tighter post-2020 reduction targets.

A. Fuel and Technology Neutrality

Although several other California policies favor some transport fuels over others, the LCFS is described as neutral over fuels and technologies. Fuels are rewarded or burdened only according to their life-cycle GHG emissions.[91] Within the overall CI target, the mix of fuels supplied is then driven by market decisions, as suppliers balance CI reduction, cost, and other factors.[92] ARB has consistently defended the policy's neutrality against claims that it is not really neutral, for example that its "real" aim is to promote (initially) cellulosic ethanol or (more recently) electric drive. ARB has also resisted suggestions that the policy should retreat from neutrality and further differentiate among fuel types, because it expects these market responses to advance the policy's aims at minimum cost.[93]

A design principle of neutrality across fuels and technologies has several advantages. It lets the policy pursue a single objective—reducing fuel life-cycle emissions—while leaving all other decisions to markets. It lets fuels compete on a level playing field, with equal CI-reduction incentives influencing production decisions for both innovative and conventional fuels. It avoids regulatory choices that favor some technologies over others, which may be subject to error or to charges of political favoritism.[94] And by encouraging investment and development of multiple alternative fuels, it helps generate information about their performance and prospects, which is then available to inform future decisions by both regulators and market participants.

But while neutrality is a valuable design principle, it is difficult to precisely define and implement in practice. The LCFS achieves a substantial degree of neutrality by basing all CI calculations on the CA-GREET 2.0, GTAP, and OPGEE models with consistent input assumptions.[95] Yet challenges to neutrality remain, partly due to the heterogeneity of energy sources covered, whose CIs depend not just on common quantities that can be treated consistently, but also on multiple fuel-specific assumptions with distinct uncertainties, data limitations, and changes over time.

91 See 2009 Initial Statement of Reasons, supra note 43, at V-2; 2009 Final Statement of Reasons, supra note 12, at 186, 187.
92 See 2014 Initial Statement of Reasons, supra note 4, at ES-2.
93 See 2009 Final Statement of Reasons, supra note 12, at 187.
94 See 2009 Initial Statement of Reasons, supra note 43, at V-2.
95 See, e.g., Cal. Code Regs. tit. 17, §§ 95488(c)(4)(F)(1), (c)(3)(A).

For many of these fuel-specific assumptions, what neutrality means in practice is not clear. For example, large fractions of biofuel CI come from indirect land-use effects, which are clearly not zero but are subject to large and controversial uncertainties.[96] For other fuels, calculated CIs often depend on decisions allocating emissions between fuels and other outputs of the same production processes ("co-products," such as animal feed and corn oil jointly produced with corn ethanol, or heating fuels and chemical feedstocks jointly produced with gasoline). Like judgments about indirect land-use change, these allocation decisions have large effects on CI, but there is often no unambiguously neutral approach and existing professional practices and standards do not fully resolve ambiguities.[97] Electric transport poses distinct challenges to neutrality, notably in accounting for the higher operating efficiencies of electric vehicles and in ascribing a CI to the electricity used to charge vehicles.[98] On the first point, calculated "Energy Economy Ratios" (EERs) aim to reflect differences in drivetrain efficiency between electric and internal combustion vehicles, but do not consider other emissions-relevant differences in the characteristics and usage of these vehicles.[99] On the second, electricity used to charge EVs has thus far been deemed to have the average CI of all generation on the grid, but this approach introduced a significant disparity relative to gas used in CNG and LNG vehicles. Electricity and gas pose similar attribution challenges, since both are distributed through large integrated networks that make unique coupling of source and demand impossible, but gas has been allowed to attribute to vehicle fueling the marginal, lowest-CI source of renewable gas in the pipeline network.[100] On these and many similar matters, ARB's multiple specific decisions on LCFS design and implementation do a credible and serious job of pursuing neutrality, even if it is hard to fully achieve in practice.

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Neutrality will continue to be a factor in many future LCFS decisions. In considering these decisions, it is useful to highlight the major role that assumptions about regulators' knowledge and uncertainty play in policy design. In many policy areas, arguments favoring one form of policy or another often depend on what the regulator knows and does not know. When regulators know the socially preferred outcome—for example, when an environmental goal is fixed or known, and regulators confidently know the most efficient way to achieve it—policy often simply requires that known preferred approach. When regulators know less, preferred policies are less prescriptive. For example, when an aggregate environmental goal is known but regulators have limited knowledge about preferred approaches to reach the goal—e.g., about the performance of specific technologies or the capabilities and costs of each pollution source—preferred policies typically define aggregate goals and create incentives to pursue them but leave firms flexibility in how to meet the goal. Such limits to regulators' knowledge underpin the major arguments favoring market-based environmental policies such as tradable permits or emission charges over more prescriptive policies.

96 Cal. Air Res. Bd., 2015 LCFS Appendix I, Detailed Analysis for Indirect Land Use Change (2015), available at http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15appi.pdf. See also Richard J. Plevin, Michael O'Hare, Andrew D. Jones, Margaret S. Torn & Holly K. Gibbs, Greenhouse Gas Emissions from Biofuels' Indirect Land Use Change are Uncertain but May be Much Greater than Previously Estimated, 44:21 Envtl. Sci. & Tech. 8015 (Nov. 2010); Breetz, H. L. (2015). Science, values, and the political framing of indirect land use change (ILUC). In Science and the Law: How the Communication of Science Affects Policy Development in the Environment, Food, Health, and Transport Sectors 99-122 (ACS Symposium Series Vol. 1207); M. O'Hare and R. Plevin, Lessons from the ILUC Phenomenon, in Handbook of Bioenergy Economics and Policy Volume II pp. 321-344 (2017).

97 Ethanol Across America, Rethinking the Carbon Reduction Value of Corn Ethanol Fuel (Winter 2015), in Cal. Air Res. Bd., Final Statement of Reasons for Rulemaking 1590 (2015) [hereinafter Final Statement of Reasons 2015]; see also Alexander E. Farrell et al., Ethanol can contribute to energy and environmental goals. 311 science 506-508 (Jan. 27, 2006).

98 R. McCarthy & C. Yang, Determining marginal electricity for near-term plug-in and fuel cell vehicle demands in California: impacts on vehicle greenhouse gas emissions, 195 J. Of Power Sources 2099-2109 (2010).

99 See Christopher Yang, Fuel Electricity and Plug-in Electric Vehicles in a Low Carbon Fuel Standard, 56 Energy Pol. 51-62 (2012), available at http://dx.doi.org/10.1016/j.enpol.2012.05.006. Hydrogen fuel-cell vehicles have a separate EER adjustment.

100 See, e.g., Cal. Air Res. Bd., Staff Discussion Paper: Renewable Natural Gas from Dairy and Livestock Manure at 7 (Apr. 13, 2017), available at https://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/041717discussionpaper_livestock.pdf, at pg. 7. The proposed 2018 amendments would correct this disparity by letting EV charging claim similar indirect linkages with remotely generated renewable electricity, subject to various controls to prevent double-counting. See Proposed Regulation Order, supra note 5, at §95488.8(i).

Viewed from this perspective, the LCFS operates under conditions of mixed partial knowledge and uncertainty. It is clear that large cuts in overall emissions will require large cuts in the emissions content of fuels, and that the technical challenges of doing so are severe enough to justify a separate, targeted policy. But there is substantial uncertainty about how fast CI should be reduced, and even ultimately how far. Unlike other sectors, it is possible that the preferred carbon-neutral endpoint for transport—particularly for challenging modes like aviation—may involve continuing to burn some carbon-based fuels and removing the carbon from the atmosphere by other means.[101] There is still more uncertainty about the relative merits of particular alternatives: what fuel or fuels will be preferred in a carbon-free transport future, considering all relevant factors—performance, cost and other market-related factors, and societal factors such as health, environmental, and network effects; and what near and medium-term fuels provide the best path toward that uncertain endpoint.

A fuel-neutral policy advances two closely linked objectives: broadly promoting development of low-CI alternative fuels; and promoting learning and eliciting information about the relative technical and market prospects of various alternatives.

The design of the LCFS, in particular its aim for fuel neutrality, represents a response to this mix of knowledge and uncertainty. The policy gives a regulatory benefit to all low-CI fuels to support their development and expansion, without pre-judging which will be best. In effect, it treats current CI as a proxy—albeit necessarily an imperfect one—for fuels' prospects to contribute to the required large future reductions. It thereby advances two closely linked objectives: broadly promoting development of low-CI alternative fuels; and promoting learning and eliciting information about the relative technical and market prospects of various alternatives. At the same time, neutrality limits ARB's ability to act on judgments about a fuel's long-term prospects or environmental advantages that are not captured in its CI. Consequently, some fuels with low CI but limited prospects may capture rents, while others may be under-incentivized relative to their prospects.[102] Whether this is on balance good policy design depends on whether ARB is likely to

101 Johan Rockstrom et al., A roadmap for rapid decarbonization, 335 Science 1269-1271 (Mar. 24, 2017).

102 For example, some current low-CI fuels represent mature, non-innovative technologies, have limited capacity for future expansion, and are unlikely to provide smooth transitions to future, lower-CI fuels. Two fuels sometimes proposed on this basis as not meriting their favorable LCFS treatment are sugarcane ethanol, and biodiesel from waste oils. See, e.g., Todd Schatzki & Robert N. Stavins, Beyond AB32: Post-2020 Climate Policy for California 26 (The Analysis Group, January 7, 2014), available at http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/post_2020_ca_ghg%20policy.pdf.

make better assessments of fuels' likely contribution to future low-carbon transport than market actors responding to incentives based on current-period CI.

The value of a fuel-neutral policy is likely to decline over time, however, as knowledge and experience with various alternatives accumulate. ARB will learn more about multiple factors determining fuels' prospects, which may or may not be reflected in their current-period CI and market success: for example, their likelihood of delivering large future CI reductions, as distinct from their immediate gains; their broader health, safety, and environmental effects; and their network effects and interactions with other infrastructure and planning goals. ARB may choose to operationalize these judgments in policies that favor fuels they judge more promising, either by moving the LCFS away from neutrality or through other targeted policies to promote the fuels they judge more promising. If they pursue the latter route, the role of the LCFS would shift toward being a backstop policy, continuing to promote low-CI fuels broadly in case those that seem more promising experience setbacks or are unsuitable for some modes or uses.

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The LCFS's treatment of petroleum fuels, which still make up more than 90 percent of California transport fuel,[103] is a high-stakes issue that touches on several elements of policy design, including neutrality. The aggregate CI disparity between petroleum and alternative fuels is the main driver of the credit market. Gasoline and diesel presently account for less than 1 percent of LCFS credits (0.2 percent in 2015), and more than 90 percent of deficits.[104] These fuels thus drive demand, and price, for the credits that subsidize low-CI alternatives, and create incentives for their own gradual decline. The LCFS's treatment of petroleum is the largest current explicit departure from neutrality. Rather than separately calculating the CI of each refinery's product as is done for other fuels, the LCFS assigns statewide average CIs to gasoline and diesel.[105] These average CIs are calculated as the sum of three components: upstream emissions for California's average crude mix, from the OPGEE model; average refining emissions based on this crude mix; and downstream emissions from transporting and burning the fuel product, from the CA-GREET model.[106] This system thus tracks the mix of crudes coming into California and their associated upstream emissions, but does not differentiate regulatory burden among petroleum fuels by their crude sources or processing pathways, instead assigning a default average value to all.

Several practical factors support this averaging approach. Most life-cycle emissions from gasoline and diesel (70 to 80 percent) come from burning fuel in the vehicle and vary little among fuels with different crude sources and refining processes.[107] Although upstream and refining emissions do vary widely, differentiating fuels by crude source would be ineffective at reducing emissions if refiners have little choice in their crude mix, or if for those who do the main response is "crude shuffling"—re-routing the same supply mix to send low-CI crudes to California and high-CI crudes elsewhere.[108] ARB has judged that the risk of shuffling, as well as the administrative burden of separately tracking all flows within this huge fuel supply, outweigh the potential benefits of differentiating among, and perhaps reducing, the remaining 20 to 30 percent of emissions.

There is substantial interest in emissions from petroleum and there are divergent estimates of how much these vary among crude sources. One recent study by the Carnegie Endowment for International Peace examined emissions from thirty crude oils worldwide and found much larger variation among

103 Cal. Air Res. Bd., LCFS Quarterly Data Spreadsheet (2018), available at https://www.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm.

104 Cal. Air Res. Bd., Low Carbon Fuel Standard: Data Dashboard Excel Spreadsheet, http://www.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm (last visited Oct. 1, 2016).

105 See Cal. Code Regs. tit. 17, § 95488(c)(4)(F)(2) tbl. 6 (2016).

106 S. Boland & S. Unnasch, Carbon Intensity of Marginal Petroleum and Corn Ethanol Fuels 14 (Life Cycle Associates, Jan. 2014); see also Cal. Air Res. Bd., Detailed CA-GREET Pathway for California Reformulated Gasoline Blendstock Oxygenate Blending (CARBOB) from Average Crude Refined in California 42 (Feb. 2009).

107 Id. at 14.

108 See 2009 Final Statement of Reasons, supra note 12, at 23; See also Yeh & Witcover 2016 Status Review, supra note 23, at 1 n.i.

these than is present in LCFS CI calculations: a range of more than 80 percent in life-cycle emissions per barrel, including 14-fold variation in upstream emissions, 7-fold in refining emissions, and 45 percent in combustion emissions.[109] The difference from the smaller variation found by ARB partly reflects ARB's use of statewide average refinery emissions, while Carnegie explicitly modeled refinery emissions for different crude inputs. Most of the seeming disparity, however, reflects different bases for comparison. The Carnegie study compared life-cycle emissions across barrels of crude, which vary widely in the mix and emissions-intensity of products they yield—e.g., gasoline and diesel versus heavy bunker fuel or petcoke—while ARB compares across units of delivered gasoline or diesel. Carnegie also compared a wider range of crudes than are sold in California, including a few with extremely high CI. Considering California fuel markets and ARB's aim to attribute life-cycle emissions to marketed fuels rather than crudes, we expect the actual variation being suppressed by LCFS averaging for gasoline and diesel is substantially smaller than the variation across crudes found by the Carnegie study.[110]

We expect the actual variation being suppressed by LCFS averaging for gasoline and diesel is substantially smaller than the variation across crudes found by the Carnegie study.

It is sometimes proposed that the decision to average petroleum CI's should be revisited, and the LCFS should instead promote lower-CI gasoline and diesel production by separately calculating CI for each refiner based on their specific crude inputs and refining processes. While California variation in these is smaller than the worldwide variation found by the Carnegie study, it is still substantial: more than 30 gCO_2e/MJ variation in upstream emissions of crudes coming into California[111] and more than 10 g/MJ in refining emissions.[112] Although differentiating among these would initially just re-distribute deficits among refiners,[113] it would also create substantial incentives for refiners to change operations to reduce these mid-and upstream components of their calculated CI and thus their overall deficits. This response would include, in some uncertain mix, both real reductions and fuel shuffling—re-distributing current crude production between California and other markets. The mix of shuffling and real reductions would depend on factors including the CI target level, the relative magnitude of these new incentives and refiners' other decision factors, and constraints on crude supply. Estimating the response quantitatively would require modeling that is beyond our scope here, but it could be large enough to substantially reduce credit demand from petroleum fuels, perhaps even to turn some suppliers into credit sellers under current targets. Given the vast scale of petroleum markets, this would risk disrupting LCFS credit markets and weakening investment incentives for low-CI alternative fuels, while the corresponding benefits would be limited. Besides the prospect that seeming mid- and upstream reductions might be illusory if they are dominated by fuel shuffling, any real benefits achieved are likely to be small and temporary. Since most of the life-cycle emissions of petroleum fuel comes from burning it in the vehicle, achievable reductions are subject to hard limits. Any real near-term reductions that are achieved are quite unlikely to represent technical bridges to lower-CI options, and will decline in quantitative importance as targets tighten.

In view of the risks of fully differentiating petroleum fuels, ARB has taken limited, less risky steps in that direction in its introduction of credits for innovative technologies in petroleum fuel production. Credits are available or proposed for energy inputs from solar steam, solar fuel, or solar or wind-generated electricity; for renewably generated hydrogen inputs; and for capture and sequestration of carbon emissions from upstream processing or refining.[114] These represent

109 Deborah Gordon, Adam Brandt, Joule Bergerson & Jonathan Koomey, Know Your Oil: Creating a Global Oil-Climate Index (Carnegie Endowment for International Peace 2015). For updated information on global crude oils' lifecycle CI, see Carnegie Endowment for International Peace, Assessing Global Oils, http://oci.carnegieendowment.org/ (last visited February 14, 2018).

110 Jessica P. Abella & Joule A. Bergerson, Model to Investigate Energy and Greenhouse Gas Implications of Refining Petroleum: Impacts of Crude Quality and Refinery Configuration. 46:24 Environ. Sci. Technol. 13037–13047 (2012).

111 Cal. Air Res. Bd., Calculation of 2016 Crude Average Carbon Intensity Value (June 7, 2017), available at https://www.arb.ca.gov/fuels/lcfs/crude-oil/2016_crude_average_ci_value_final.pdf.

112 2014 Initial Statement of Reasons, supra note 4, at III-53 Fig. III-6; III-54, Fig. III-7.

113 Assuming the current default CI values used for gasoline and diesel are accurate.

114 Cal. Code Regs. tit. 17, § 95489(d)-(g).

a small differentiation among petroleum fuels, targeting processing emissions but not crude sources. They aim to create some incentives to reduce CI of petroleum fuels, under conditions where the incremental reduction is clear, while limiting associated risks. They represent only small departures from the averaging approach, however, because they are subject to various limits and because they are separately granted for adopting specified technologies, not integrated into the calculated CI of the fuel product.[115] Although their direct impact is likely to be small, they may help stimulate deployment of technologies that also offer reduction opportunities in other sectors. In addition, they increase overall credit supply, and offer some modest regulatory relief to petroleum fuel producers, who bear the largest burdens of the LCFS and are its most forceful political opponents. The credits may appear *ad hoc* or arbitrary, but in our view represent a reasonable way to balance the policy's multiple aims and manage associated risks.

B. Policy Scope

A second high-stakes dimension of LCFS policy design is its scope: what activities, fuels, and technologies are included. The nominal scope of the LCFS includes all energy sources used for road transport in California, now expanded to include a few small off-road uses of the same energy sources.[116] The LCFS is founded on the presumption that emissions associated with transport fuels need a separate policy, for the reasons discussed above: that transport fuels must contribute to overall emission goals, but present harder challenges than other sectors and are subject to longer lead-times, greater technical uncertainties, and stronger system-level interactions. Consequently, they require stronger early incentives to motivate investments, so viable options will be available at scale when needed.

Where critics view the LCFS's high sectoral marginal cost as definitive evidence of policy failure, the LCFS's designers and proponents view it as a desirable and intended characteristic of the policy: a feature, not a bug.

As we discuss in Section 6, the LCFS's scope limitation to transport fuels and the associated high credit prices have been the basis for the most forceful criticisms of the policy, advanced by both advocates for the petroleum industry and independent researchers.[117] Although these criticisms vary widely in their sophistication, the most prominent and widely repeated is economically elementary. The LCFS requires high-cost emissions cuts in transport fuels when other sectors offer cheaper reduction opportunities, which could be realized by enacting a uniform, economy-wide price on emissions via a tax or cap-and-trade system. The disparity in marginal costs is obvious from the much higher price of LCFS credits than cap-and-trade allowances. But the argument presumes that the LCFS's goal is current-period emissions reductions, when its actual goal is to motivate—and gain information about—alternative-fuel developments likely to advance the larger needed future reductions. Moreover, the LCFS pursues this aim under an assumed set of technological and market conditions—long lead-times, uncertainties, network effects or other technological non-convexities, as well as political constraints on the more visible and controversial economy-wide emission prices—that cause the immediate and longer-term aims to diverge.[118] Consequently, where these critics view the LCFS's high sectoral marginal cost as definitive evidence of policy failure, the LCFS's designers and proponents view it as a desirable and intended

115 Id. at §§ 95489(f), (g), 95485(d) (2016). These credits at not transferable, and are limited to 20 percent of the refiner's deficit overall, 10 percent of their deficit for hydrogen credits.

116 Cal. Code Regs. tit. 17, § 95481(a)(79) (2016).

117 See, e.g., S.P. Holland, J.E. Hughes & C.R. Knittel, Greenhouse gas reductions under low carbon fuel standards?, 1:1 Amer. Econ J: Econ Policy 106-146 (2009); See also Schatzki & Stavins, supra note 102.

118 The near-term and long-term aims can be aligned, but only under restrictive assumptions about technology, market, and policy conditions: competitive equilibrium in all relevant markets including inter-temporal markets for innovation; no network effects or other non-convexities; inclusion of all emissions under the cap-and-trade system; and no political constraints that hold the emissions price below the socially optimal level. The uniformly large violations of these assumptions in transport fuel markets are, in our view, obvious.

characteristic of the policy: a feature, not a bug. The observation that the LCFS does not deliver minimum-cost current-period reductions is thus obvious, but uninformative for assessing its effectiveness relative to its actual goal.

Yet while generic criticisms of LCFS for limiting its scope to transport fuels miss the point, defining the policy's appropriate scope still presents serious practical problems. ARB has to define the boundary of the LCFS, based on judgements about several factors. The most important is what fuels, technologies, and activities are likely to be relevant for the large required reductions in transport fuel emissions, and thus likely to contribute to the policy's goals. The boundary must also be defensible against predictable attempts to muddy it or arbitrage across it to profit from the large resultant marginal-cost disparity. Boundary-drawing decisions also implicitly affect the credit market balance and thus the overall stringency of the policy. All these factors depend on the particular mix of transport energy sources and technologies in use at any time, so boundary-drawing decisions must be periodically revisited and adjusted as these conditions change.

The boundary of the policy must be defensible against predictable attempts to muddy it or arbitrage across it to profit from the large resultant marginal-cost disparity.

ARB has managed the policy's boundaries successfully thus far, but several specific scope decisions appear mainly to have been motivated by concerns about credit market balance. The relationship between scope decisions and credit-market balance can be illustrated by considering a hypothetical decision to expand the policy's scope. Such a decision will have two effects that must be considered. First, the effect on the fuels or activities that are added: for these the key questions are whether they are sufficiently relevant to transport fuel, and thus whether their inclusion will create incentives likely to contribute materially to the emission-reduction goal. And second, the effect on the activities that were already covered, which operates via the credit-market balance and credit price. This second effect can go in either direction, depending on whether the average CI of the newly added activities is above or below the current target. Thus far, several decisions to expand the LCFS's scope, by ARB and in 2016 by the legislature, have added new, low-CI activities.[119] The 2018 amendments make additional low-CI expansions, allowing alternative fuels for aviation and military vehicles to opt into the program and receive credits.[120] Each such expansion gives two incentives to the newly added activities—to expand in scale (since the credits are a subsidy to the activity), and to reduce their CI (since this would increase the subsidy). Because the new activities' CI is below the target, the expansion also increases overall credit supply, thereby lowering credit price and weakening CI-reduction incentives for activities previously covered. Conversely, if ARB were to expand scope to add new high-CI activities—e.g., all aviation fuels or marine fuels—this would reverse two of the three incentive effects: it would increase credit demand and strengthen CI-reduction incentives for previously covered activities, while putting incentives on the new activities to reduce CI, and to contract in scale (because for these activities the policy would impose a cost increase).[121] Although no such high-CI expansions have been made thus far, the proposed 2018 amendments suggest how such expansion could occur gradually: they shift fossil CNG from optional to compulsory participation, as the planned

119 Cal. Health and Safety Code § 39730.7(d)(1)(B), 39730.7(e), and 39730.8(b)(2). The 2016 statute SB 1383 required LCFS credits to be granted to bio-methane projects on dairy farms. ARB released draft guidance to implement this provision in late 2017. See Cal. Air Res. Bd., Draft Guidance on the Impact of Adopting Regulations Pursuant to SB 1383 on the Ability to Continue to Generate Credits Under the Low Carbon Fuel Standard and Cap-and-Trade Program for the Reduction of Methane Emissions from Manure Management Operations, available at https://arb.ca.gov/cc/dairy/documents/12-13-17/dsg2_draft_dairy_crediting_guidance_121317.pdf

120 See Proposed Regulation Order, supra note 5, at § 95482.

121 This would be the effect, for example, if the LCFS were expanded to include all aviation or marine fuels. Current proposals to let small-volume producers of alternative, low-CI aviation fuels opt in to the LCFS without imposing corresponding obligations on conventional, high-CI aviation fuels, would have the same effect as prior additions of low-CI activities: expanding credit supply and lowering price. See Comment Letter by Alternative Jet Fuel Producers, February 28, 2017, available at https://www.arb.ca.gov/fuels/lcfs/workshops/02282017_ajfproducers.pdf. See also Cal. Air Res. Bd., 2017 Progress Report on the Low Carbon Fuel Standard, available at https://www.arb.ca.gov/board/books/2017/062217/17-6-4pres.pdf.

tightening of the CI target makes the prior assumption that its CI is below the target no longer reliably correct.[122]

As targets tighten after 2020, higher credit prices, in addition to strengthening incentives to develop low-CI alternative fuels, will also strengthen incentives for shuffling and other forms of leakage, and for activities that obscure or trade across the policy's boundary to exploit the large marginal-cost disparity.

As targets tighten after 2020, the same factors will remain relevant to scope decisions. Higher credit prices, in addition to strengthening incentives to develop low-CI alternative fuels, will also strengthen incentives for shuffling and other forms of leakage, and for activities that obscure or trade across the policy's boundary to exploit the large marginal-cost disparity. The stakes and difficulty of defining a boundary that is clear, defensible, and aligned with the policy's goals will thus increase. Many boundary-drawing challenges will be related to specific characteristics or uses of particular technologies. For example, some fuels and technologies are used both in transport and in other sectors. Some proposed integrated projects would jointly produce both transport fuel and electricity, making the allocation of emissions between these two outputs ambiguous. And some low-carbon transport options, notably electric drive and electrically produced hydrogen, effectively merge transport energy into an expanded electrical sector for the uses that move to those options. Illustrations of the challenges to defining LCFS scope sensibly under tighter targets and continuing technical progress are provided by the present innovative technology credit programs, carbon capture, and electric drive.

The LCFS grants credits for using specified innovative technologies in producing either biofuels or petroleum fuels (solar heat or steam, renewable process electricity, renewably generated hydrogen, and carbon capture), but in different ways for the two fuel types.[123] For biofuels, the technologies provide a procedural trigger that lets a fuel producer gain a new pathway and CI calculation. They are not separately credited, but simply included in the fuel's new calculated CI.[124] For petroleum fuels, by contrast, these technologies generate separate, non-transferable credits that are not integrated into the fuel CI. This limited departure from statewide CI averaging requires drawing distinctions that may appear arbitrary, since other methods of reducing petroleum fuel

122 See Proposed Regulation Order, supra note 5, at § 95482.

123 See Cal. Code Regs. tit. 17, § 95489(d)(1)(A) (2016) (limiting list of innovative methods for petroleum suppliers); see also id. at § 95488(b)(2)(F)(2) (providing a non-exhaustive list of innovative methods that would move an alternative fuel from Tier 1 to Tier 2).

124 Id. at § 95488(b)(2)(F)(2).

CI receive no credit, and the same technologies receive no credit when used in other sectors and industrial processes. Using sunlight instead of natural gas to generate process steam can receive LCFS credits if the steam is used in an oil refinery, but not in a chemical plant or pulp mill. Moreover, the emissions effects of these credits are likely to be real, but small. They cannot make large reductions in the CI of petroleum fuels, due to limits on their scale and use. And they are unlikely to motivate much expansion or innovation in the targeted technologies, because fuel production represents a small share of their total use. Despite the seeming arbitrariness, these boundaries are reasonable in view of the policy's aims: the included activities are more relevant, and more directly connected, to transport fuel than similar excluded activities, and the boundaries are administratively clear and defensible against arbitrage. In view of their small scale, the most significant effect of the technology credits is likely to expand credit supply, and so provide a little additional protection against shortages. They may also help defend the policy's political sustainability, by reducing the compliance burden of these particular facilities and thus benefiting a set of actors who are naturally situated to be major opponents.

One of the specified innovative technologies, carbon capture and sequestration (CCS), poses distinct additional challenges for LCFS scope decisions. CCS technologies remove CO_2 from an emissions stream, after which it is placed in some long-term stable repository underground or undersea; used in some other production process (e.g., enhanced oil recovery or enhancing plant growth in greenhouses); or embedded in various long-lived products. CCS technologies have great potential to reduce net greenhouse gas emissions: they can capture waste CO_2 from multiple processes in both petroleum and biofuel production, from electrical generating stations, or from other industrial processes. Related technologies offer the prospect of even larger contributions by removing CO_2 directly from the atmosphere.[125] The potential scale of carbon capture and removal is so large that it could be of crucial importance to climate-change policy. Indeed, international climate policy is already relying heavily on these technologies. A crucial, widely overlooked element of the emissions scenarios that meet the Paris targets of limiting global heating to 1.5 to 2°C is that nearly all of them assume future carbon removal at enormous scale, on order billions of tons per year.[126] Carbon capture and removal technologies have substantial uncertainties in their feasible deployment rate, cost, and environmental impacts, which vary widely among specific methods. In many industrial applications, CCS merely combines known, mature technologies into new integrated systems, yet has still faced significant performance, cost, and regulatory barriers and has not yet seen rapid growth like that in renewable energy. There are no CCS projects operating in California, and only a few full-scale projects in operation elsewhere, after many years of false starts.[127] Methods to remove carbon from the atmosphere—such as integrated bioenergy and carbon capture, enhanced weathering of minerals, manipulation of surface ocean chemistry, or direct air capture—have much larger potential, but are early in development and subject to large uncertainties in scalability, cost, and environmental and socio-economic impacts.[128]

In view of their large potential contribution, CCS and carbon removal merit targeted policies to promote their development. But there are at least two serious challenges to using the LCFS to

125 IPCC, Climate Change 2014: Mitigation of Climate Change, at section 7.5.5, p. 532, (Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2014), available at http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_full.pdf.

126 L. Clarke et al., Assessing transformation pathways, in Climate Change 2014: Mitigation of Climate Change 413 (IPCC Working Group 3, Cambridge University Press, 2014); see also S. Fuss, et al., Betting on negative emissions, 4(10) Nature Climate Change 850-853 (2014); E.A. Parson, Climate policymakers and assessments must get serious about climate engineering 114:35 Proc. Nat. Acad. Sci. 9227-9230 (2017).

127 Global CCS Institute, The Global Status of CCS: 2016, Summary Report (2016), available at https://www.globalccsinstitute.com/publications/global-status-ccs-2016-summary-report.

128 P. Smith et al., Biophysical and economic limits to negative CO_2 emissions, 6 Nature Climate Change 42-50 (Jan. 2016).

support these. First, large uncertainties about cost and feasible growth of these technologies imply large uncertainties in their interactions with LCFS—both in the ability of LCFS crediting to promote them, and in their effect on LCFS credit markets. The ~$100 per ton LCFS credit prices seen in 2013 and 2016 are similar to some early CCS cost estimates, suggesting that unrestricted LCFS crediting could trigger a surge of CCS investment.[129] Even if costs are higher and uptake slower than early estimates—as problems and delays in early demonstration projects suggest—large-scale CCS crediting would still represent an uncertain, potentially large disruption of LCFS credit markets. Second, carbon capture and removal projects have complex and variable relationships with fuel production, including wide variation in what they do with the captured carbon and their actual emissions effects. For example, many early CCS projects and proposals use the injected carbon for enhanced oil recovery (EOR). Moreover, CCS presents many opportunities to build integrated systems where carbon removal is not a direct part of fuel production, but instead occurs off-site or in some other industrial process that is linked to fuel production through technical, contractual, or regulatory arrangements. For example, one recent study modeled an integrated system that captured CO_2 from a natural-gas electrical generating station, injected the captured CO_2 for EOR, and produced transport fuel from the resultant crude output.[130] Other proposals for such indirect CCS linkages include linking biofuel production to CCS in electrical generation fired partly or fully by biomass, or linking chemical fuel synthesis to direct CO_2 air capture.[131] Regulatory treatment of CCS with EOR is particularly controversial, because promoting increased oil production could increase emissions and so partly offset the emissions sequestered—an effect that LCFS, as an intensity standard, would not cover.[132] Broad CCS crediting could thus obscure or erode the boundary with the rest of the economy that the LCFS must maintain if it is to direct stronger incentives toward transport CI reductions.

Carbon capture and removal projects have complex and variable relationships with fuel production, including wide variation in what they do with the captured carbon and their actual emissions effects.

But is this necessarily a problem? If LCFS credits induced a flood of indirectly linked CCS projects, and the resultant emissions reductions were additional to those required by other regulations and carefully monitored to avoid over-counting, why should those reductions not count as a success of the LCFS?[133] The answer depends on present judgments about the desired mix of fuels in the future carbon-free transport system, and the role of LCFS in promoting and learning about these. The broad technical options for such a system are known and unlikely to change: low or zero-carbon (and otherwise sustainable) biofuels, synthetic fuels (hydrogen, gas, or liquids) produced from non-carbon primary energy sources, and electricity. Carbon capture or removal can contribute incrementally to any of these, but also presents an additional option if used at large enough scale: continuing to use carbon-based fuels, perhaps even some from fossil sources, and recapturing the emitted carbon elsewhere. This approach could make large contributions to a zero-emissions transport system. But it would do so by re-defining the system to include carbon captured outside the fuel production pathway, treating carbon capture as an emissions offset and dissolving the boundary between transport fuel and the rest of the economy.

Unlimited near-term CCS crediting could make a large push toward this technical approach, which would undermine the LCFS's ability to give effective incentives to other low-carbon fuel options. This outcome would not be troublesome if it were clear that the preferred carbon-free

129 Cal. Air Res. Bd., Weekly LCFS Credit Transfer Activity Reports, www.arb.ca.gov/fuels/lcfs/credit/lrtweeklycreditreports.htm (last visited May 1, 2018).

130 James Rhodes III, Andres Clarens, Pragnya Eranki & Jane C.S. Long, Electricity from Natural Gas with CO_2 Capture for Enhanced Oil Recovery: Emission accounting under Cap-&-Trade and LCFS, (Cal. Council on Sci. & Tech., Jan. 2015) [hereinafter, Rhodes et al., CCST, CO_2 Capture].

131 Richard Martin, Test facility begins capturing carbon from air, MIT Tech. Rev. (Oct. 9, 2015), https://www.technologyreview.com/s/542226/test-facility-begins-capturing-carbon-from-air/.

132 See Carbon Capture and Sequestration Protocol, supra note 64.

133 See, e.g., Jeffrey D. Brown, California ARB's QM for CCS, and Cap-and-Trade vs. LCFS (presentation at ARB workshop on CCS), May 8, 2017, available at https://www.arb.ca.gov/cc/ccs/meetings/Stanford_Presentation_5-8-17.pdf.

The LCFS should promote carbon capture and removal, but with strict eligibility boundaries based on direct connection to transport fuel production.

transport future would rely heavily on carbon removal. But to the extent this is not yet clear—i.e., to the extent the LCFS still has the dual purposes of both motivating and learning about alternative low-carbon transport options—such a shift could prematurely foreclose a large-scale technology and system design choice. And to the extent there remains uncertainty about the feasible or desirable maximum scale of future carbon removal, it is prudent to avoid a large additional bet on that approach. While it may seem silly to worry about carbon capture growing too large or too fast at a time when the main challenge is getting it off the ground, this concern has immediate practical implications. Because of the unbounded range of constructed linkages that carbon capture can enable, the need to avoid rapid, disruptive, and potentially hard to reverse expansion has to be considered in ARB's near-term policy decisions.

For these near-term LCFS decisions, the curious implication of these concerns is that the LCFS should promote carbon capture and removal, but not too much. Concretely, this means drawing strict eligibility boundaries based on direct connection to transport fuel production. The strictest approach would treat CCS like renewable-energy inputs, granting credits only for capturing and stably sequestering carbon that would otherwise have been emitted in fuel production or refining.[134] There are many opportunities to do this, in production steps for both biofuels and petroleum fuels that produce concentrated CO_2 waste streams needing little or no separation.

ARB has been studying how to treat CCS in multiple regulatory programs,[135] and has recently proposed a slightly more liberal approach for the LCFS. Regulatory language has identified CCS projects as eligible for credits since the 2015 amendments, but CCS credits have not been available in practice while awaiting issuance of eligibility and accounting rules. ARB has now issued these in a draft CCS protocol released with the proposed 2018 amendments.[136] As in the 2015 regulations, the proposed ways to credit CCS differ between petroleum and alternative fuels. For petroleum, projects can qualify under the innovative crude production or refinery credit programs.[137] The carbon capture must be on-site but the sequestration need not be.[138] For alternative fuels, CCS can qualify a fuel for a new pathway and CI calculation, with the same condition that the capture must be on site.[139] Notably, the proposals treat carbon captured from a fuel production process and from the atmosphere the same, so long as the capture is on-site and the carbon is geologically sequestered.[140] In one potentially important change, the proposals explicitly authorize Tier 2 pathway certification for direct air capture projects that incorporate the captured carbon into fuels, an approach now being pursued by a few small startup firms.[141]

This proposed approach supports CCS development, subject to limits that are consistent with the LCFS's goals of promoting and gaining information about a wide range of alternatives. This appears to be a prudent and appropriate approach for the near term. Over time, questions of what CCS projects receive LCFS credits will have to be periodically revisited as targets tighten and experience is gained with various low-CI alternatives. Particularly important will be the treatment

134 See Cal. Air Res. Bd., Carbon Capture and Sequestration, http://www.arb.ca.gov/cc/ccs/ccs.htm (last visited Jan. 4, 2016).

135 See Cal. Air Res. Bd., Carbon Capture and Sequestration Program Concept Paper (April 2017), available at https://www.arb.ca.gov/cc/ccs/meetings/CCS_Concept_Paper_April_2017.pdf.

136 Carbon Capture and Sequestration Protocol, supra note 64. See also Cal. Air Res. Bd., Public Meeting to Discuss proposed 2018 LCFS Program Amendments (November 6, 2017), available at https://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/110617presentation.pdf.

137 Proposed Regulation Order, supra note 5, §§ 95490, 95489(c), 95489(e).

138 Id.

139 Id. at §§ 95488.1(d)(7)(B), 95490.

140 Id. at § 95490. This raises the intriguing possibility of crediting for an atmospheric carbon removal and sequestration project that is co-located with a fuel production facility—close enough to qualify as "on-site"—but has no physical connection with the fuel production process. While theoretically interesting, we judge this unlikely in practice due to the space needs of atmospheric removal projects.

141 Id. at §§ 95488.7, 95490(a)(2).

of projects including EOR, and off-site projects with contractual or administrative linkages to fuel production, neither of which is presently eligible or proposed for credits.

Future decisions on the breadth of CCS crediting could exercise significant influence over the large-scale technological alternatives for a zero-emitting transport system, in particular over how much fossil-based fuel remains in the system: zero or near zero, or more substantial continuing use offset by carbon removals elsewhere. It is presently unclear how likely this latter endpoint is, given progress underway in multiple non-fossil alternatives, and also how desirable it would be. Significant continuing fossil-fuel use would require corresponding increases in carbon capture or removal, beyond the huge removals already assumed, when total removals may be subject to yet unknown environmental impacts, risks, or limits. Yet this is a theoretically possible path for a future zero-emissions transport system, potentially available if other alternatives fall short. To whatever degree carbon capture and removal is judged a desirable component of the future zero-emissions transport system, expansive LCFS crediting could play a strong role in promoting it. In view of these high long-term stakes, scope decisions about the extent of CCS crediting much be approached with great caution.

Fully electrifying the transport sector would merge transport emissions into the electricity sector and so eliminate the rationale for the LCFS as a separate policy. But despite widespread optimistic claims, that outcome is still relatively distant and not at all certain.

Electric drive also presents distinct challenges for LCFS scope and policy design. Promoting innovation and expansion in electric drive is central to the LCFS's aims. The LCFS has included electric drive for on-road vehicles since it began in 2011,[142] and since 2016 has also granted credits for certain off-road uses, including electric forklifts and some rail systems.[143] Electric drive is generating great enthusiasm as one of the leading candidates for future non-carbon transport. Although the share of electric vehicles remains small, it has grown rapidly, in California and to a lesser degree nationwide. EVs increased from 0.5 percent of new California registrations in 2011 to 4.8 percent in 2017.[144] This rapid growth was bolstered by several policies, including California's Zero-Emission Vehicle (ZEV) requirements, state and federal tax credits, and utility policies for charging infrastructure, as well as the LCFS. EVs' share of the total vehicle fleet—and thus of energy consumed—is substantially smaller than the share of new sales, due to slow turnover of existing vehicles. After fifty-fold growth over the prior five years, electricity represented only 0.14 percent of California road transport energy in 2016.[145]

Inspired by this rapid progress, many observers already assume the route to cutting transport emissions is to electrify the sector entirely.[146] That endpoint would merge transport emissions into the electricity sector and so eliminate the rationale for the LCFS as a separate policy. But despite widespread optimistic claims, that outcome is still relatively distant and not at all certain. Even for light-duty vehicles, growth will slow from rapid recent rates as the scale of penetration increases.[147] Switching to electricity requires buying a new vehicle,[148] and EVs face

142 Id. at § 95483(e)(1).

143 Cal. Code Regs. tit. 17, §§ 95483(e)(6), (e)(7), (f)(3). While ARB initially projected small contributions from these off-road uses (rail 1 percent, forklifts 0.3 percent of total program reductions, 2014 Initial Statement of Reasons, supra note 4, at III-9, 10), off-road electrical credits were of similar magnitude to on-road credits in 2016, and substantially larger than on-road credits over the first three quarters of 2017.

144 California New Car Dealers Association, California auto outlook, Fourth Quarter 2013, available at https://www.theicct.org/sites/default/files/California%20hybrid%20share%202013%20CNCDA.pdf; California New Car Dealers Association, California auto outlook, First Quarter 2017, available at http://www.cncda.org/wp-content/uploads/CA-Auto-Outlook-1Q-2017.pdf. These percentages include 2.7 percent fully electric (battery) vehicles and 2.1 percent plug-in hybrids.

145 Cal. Air Res. Bd., Low Carbon Fuel Standard: Data Dashboard Excel Spreadsheet, supra note 104. This small share of electric transport energy represented a much larger share of LCFS credits generated, however, about 10 percent in 2016, due to the low CI of electric drive.

146 David Roberts, The key to tackling climate change: electrify everything, Vox (Sept. 19, 2016), https://www.vox.com/2016/9/19/12938086/electrify-everything; see also Electric Cars: Charging Ahead, The Economist, Feb 26, 2015, https://www.economist.com/news/books-and-arts/21645119-challenges-making-battery-operated-electric-cars-charging-ahead.

147 See Yang (2012), supra note 99.

148 At least under the present model of predominant private vehicle ownership.

substantial barriers to consumer attractiveness and large-scale expansion—mostly related to battery performance—including cost, range, other performance dimensions (e.g., load, operation in variable conditions), and charging convenience.

The value of credits is presently small relative to the EV cost premium, although this gap is likely to decrease as credit prices rise under tighter targets and cost premiums decline with increased production.

Electric drive poses unique challenges to LCFS design because its barriers to growth are unlike those of other alternative fuels, most of which are liquids that can replace or blend into existing fuels in current vehicles.[149] For those fuels, the LCFS acts mainly on fuel supply, aiming to reduce the CI of presently produced fuels and expand production of new low-CI fuels. Neither of these supply-side effects is important for electric drive. The LCFS does not aim to expand electrical generation, nor to reduce the CI of the electrical grid: electric drive is too small so far to influence these, and multiple other policies target electricity emissions more directly. Instead, the LCFS aims to reduce demand-side barriers to electric drive and promote increased consumer adoption of EVs. In view of uncertainty about how to do this most effectively, ARB distributes credits to several different types of organization, aiming to provide incentives at different points in the system and learn which approaches are most effective. Some credits go to fleet operators who charge their own vehicles. Others go to operators of public charging stations, aiming to expand charging infrastructure and ease consumer concerns about charging availability.[150] Still others go to utilities, who pass their value through to EV buyers in various ways that aim to offset the cost premium of EVs: lump-sum payments at vehicle purchase (about $500 per vehicle), annual payments (from $50 to $200 per year), or free or discounted home chargers. The value of credits is presently small relative to the EV cost premium, although this gap is likely to decrease as credit prices rise under tighter targets and cost premiums decline with increased production.[151]

The 2018 amendments propose two changes to increase credits for electrical drive.[152] One

149 Other than electric drive, the other exceptions to this are hydrogen and gas (natural gas or biogas).

150 See Cal. Air. Res. Bd., LCFS Electricity and Hydrogen Provisions, https://www.arb.ca.gov/fuels/lcfs/electricity/electricityh2.htm.

151 See, e.g., K. Podkaminer, F. Xie & Z. Lin, Analyzing the impacts of a biogas-to-electricity purchase incentive on electric vehicle deployment with the MA3T vehicle choice model, Oak Ridge National Laboratory Report (2017), available at https://www.ornl.gov/content/analyzing-impacts-biogas-electricity-purchase-incentive-electric-vehicle-deployment-ma3t.

152 Pre-Rulemaking Public Meeting to Discuss 2018 LCFS Preliminary Draft Regulatory Amendment Text (November 6, 2017), Staff presentation, available at https://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/110617presentation.pdf.

change rewards charging when the grid CI is lower, by varying the deemed CI of charging by time of day and year.[153] The other would credit EV charging with the lowest-CI generation rather than the grid average, subject to controls to prevent double-counting and ensure the claimed low-CI generation is additional to other regulatory requirements.[154] This second provision is an artifact of the inability to uniquely identify in the integrated grid the source of the energy used for charging. It aims to put electricity on equal footing with gas (CNG or LNG), which is allowed to use similar indirect accounting to credit vehicle fueling with the lowest-CI source of renewable gas in the integrated pipeline network.[155]

The goal of electrifying all transport would require going beyond road vehicles to other modes that the LCFS, with a few small exceptions, does not yet cover. Except for rail, the technical challenges of electrifying other modes are greater than for light-duty vehicles.[156] These challenges also mainly come from limits in battery performance, but their implications for safe and commercially viable operation of other modes are more severe—particularly for aviation and marine shipping, which have long been viewed as impossible to electrify. Recent progress may call this judgement into question, but only to a limited degree: demonstrated progress is along limited margins, involving efficiency gains from hybrid power systems, small vehicles, or short-distance operations on fixed schedules (e.g., ferries) where range and charging constraints are less restrictive.

The LCFS does presently cover heavy road transport, trucks and buses. Electrifying these modes also faces major technical challenges, but recent progress here is more promising than in aviation and shipping. For trucks, like other modes, the strongest progress has been in vehicle types and uses where the technical barriers to viable electric operation are less severe: for example, medium-weight trucks and niche applications like drayage, trash collection, and urban delivery where short travel distances, frequent stops, and regular operating hours reduce the impact of range and charging constraints. There are also efforts underway to partly electrify via hybrid drive trains, and to target uses where the complementary benefits of electricity—e.g., reduced air pollution or noise, or powering mobile refrigeration systems—have high value. These are real advances, but their implications for large-scale electrification of heavy trucking remain limited. Tesla's November 2017 announcement is potentially more disruptive. Their truck is still in development and it is unclear how much it will deliver on their expansive advance claims.[157] But if it does, it will be a game-changer: a fully electric class 8 truck that is commercially viable for long-haul operations.

Electrifying heavy road transport also faces major technical challenges, but recent progress here is more promising than in aviation and shipping.

The largest progress in electric drive outside light-duty vehicles, and the clearest impact of the LCFS in advancing this progress, has been in urban transit buses. Buses offer more near-term opportunities than trucks because they are centrally maintained, heavily used, and operated on fixed schedules with predictable range needs. Several hundred electric buses are already operating or ordered in California, although those operating mostly work limited hours or short routes.[158] Although electric buses cannot yet meet all transit needs, six agencies—including Los Angeles County—have decided to go all electric by 2030 or earlier. Like other fleet operators, transit systems receive LCFS credits directly for their charging, including extra credits for directly

153 Proposed Regulation Order, supra note 5, § 95488.5(f).
154 Id. at § 95488.8(i)(1).
155 Id. at § 95488.8(i)(2).
156 The one exception is rail, along with other fixed-guideway systems, which can receive their motive energy through outside conductors and so do not need to carry it on-board.
157 See, e.g., Alex Davies, Meet the Tesla semitruck, Elon Musk's most electrifying gamble yet, Wired (Nov. 16, 2017), https://www.wired.com/story/tesla-truck-revealed/; see also Alan Ohnsman, Orders Pile Up For Tesla Semi That Doesn't Yet Exist As Rival Electric Trucks Get Rolling, Forbes.com (Dec. 28, 2017), https://www.forbes.com/sites/alanohnsman/2017/12/28/orders-pile-up-for-tesla-semi-that-doesnt-yet-exist-as-rival-electric-trucks-get-rolling/#2f007504a0ae.
158 Cal. Air Res. Bd., Battery and Fuel Cell Electric Buses in California (Sept. 2017), available at https://arb.ca.gov/msprog/ict/zbusmap.pdf.

LCFS credits already offset more than half of charging costs and have been identified as a decisive factor in some systems' decisions to switch to electric buses.

connected renewable generation. LCFS credits already offset more than half of charging costs and have been identified as a decisive factor in some systems' decisions to switch to electric buses.[159] The 2018 amendments strengthen incentives for both electric buses and trucks, by increasing and pooling their EERs in addition to the proposed changes for all electric charging discussed above.[160]

Overall, the prospects for electric drive are strong, but still uncertain: they clearly merit LCFS crediting, but do not call for re-focusing low-carbon fuels policy preferentially on electricity rather than continuing to promote a wide range of low-CI alternatives through the LCFS. But the design and implementation challenges of promoting electric drive through the LCFS while maintaining neutrality are substantial. For light-duty vehicles, where technical prospects are strongest and growth is fastest, LCFS incentives are hard to target effectively. The present focus on EV purchase decisions is sensible, since these drive production growth and cost reductions, but LCFS incentives can target only some of the associated barriers and are relatively weak. For the subsequent factors determining emissions—how much EVs are driven, and the CI of charging electricity—the targeting of LCFS incentives is weak. Vehicle use and charging incentives could be better targeted with more data, by either increased separate metering or vehicle-based reporting systems. Generating mix incentives cannot be effectively targeted by the LCFS in its present form, due to the integrated grid. This will remain the job of other policies. The challenges of heavy transport are the reverse of those for light-duty vehicles. Technical challenges to electrification are greater, but separate charging improves the targeting of incentives from LCFS credits, while heavy commercial usage makes them more valuable.

Despite present obstacles, electricity holds the prospect of large expansion, perhaps even coming to dominate some modes or uses. If this occurs for some applications but others cannot readily electrify, those not electrifying may still need a LCFS-like policy to motivate continued

159 See, e.g., CALSTART, California's Clean Transportation Technology Industry, http://www.calstart.org/Libraries/Policy_Documents/California_s_Clean_Transportation_Technology_Industry_-_2016.sflb.ashx; see also Cal. Air Res. Bd., Transit Agency Workgroup Meeting, Draft Discussion Topics on Costs (Jan. 28, 2016), available at https://www.arb.ca.gov/msprog/bus/wg201601cost.pdf. Another proposed ARB rule will most strongly influence future transit fleets. The "Clean transit rule" would require zero-emission buses (EV or fuel-cell) for 25% of new purchases by 2020, 100% by 2029. The rule is opposed by both the gas industry—who want CNG buses included as "near-zero" emissions—and from some transit agencies concerned that electric bus performance may not be adequate for all transit needs by 2029.

160 Proposed Regulation Order, supra note 5, § 95486 tbl. 5.

development and expansion of low-CI fuels. This would require fundamental reconsideration of scope, most likely to exclude those modes and uses that have gone electric to keep ability to deploy effective incentives for the remainder. This prospect—which is presently remote, but still merits some advance consideration—bears some resemblance to the concerns about large-scale expansion of carbon capture discussed above. In both situations, one option grows to dominate the credit market without providing a route to eliminating all transport emissions, so incentives for further development of other low-CI options are still needed but hard to sustain. But such a scenario of rapid expansion appears more plausible for carbon capture than for electricity. Electricity would drive actual vehicles with distinct performance requirements and challenges in each use, so is likely to have increasing marginal costs. Beyond early applications in fuel production pathways, carbon capture would be an offset with only contractual and administrative links to fuel production. It would thus hold the possibility of larger and faster expansion, at constant or near-constant marginal cost, and so calls for more careful and gradual expansion of incentives.

C. Ambition and Timeline

A key element of LCFS policy design is the ambition of its required CI reduction and how this strengthens over time. Reduction opportunities vary with time, typically with small cuts confidently achievable early while larger ones take longer and are more uncertain. Some fuels may offer smooth transition paths from small early reductions to larger later ones, while others present sharper tradeoffs between immediate and long-term gains—either small early gains that lead to dead-ends, or prospects for large future cuts whose pursuit does not deliver interim gains. The LCFS target trajectory needs to manage these time tradeoffs, motivating progress without demanding the impossible, where the boundary of the possible is uncertain and advances over time.

The LCFS's market-based design eases this challenge to some degree, by leaving some decisions about time tradeoffs to markets. Firms that produce low-CI fuels may choose to bank the credits rather than using them immediately, betting that credit prices will rise as further progress grows harder. This flexibility is one-sided, however. Firms that expect future breakthroughs may not borrow against those anticipated gains by short-selling credits today. Allowing such credit borrowing would increase flexibility and provide additional funds to finance anticipated breakthroughs, but would push compliance obligations off into the future and raise the risk of failure—whether due to bankruptcy, policy change, or other intervening events.

The target schedule is always set under uncertainty about technical prospects for various low-CI fuels, and so may require periodic adjustment in response to realized experience and revised projections.

Moreover, this flexible design does not relieve ARB of the responsibility to manage the policy's ambition over time by setting the target schedule, aiming to gradually increase incentives while avoiding price spikes that might disrupt long-term incentives and jeopardize the policy politically. The schedule is always set under uncertainty about technical prospects for various low-CI fuels, and so may require periodic adjustment in response to realized experience and revised projections, as early LCFS experience illustrates. The first few years saw growing concern about potential shortfalls, mainly due to unanticipated setbacks in cellulosic ethanol. By 2015, it appeared there could be serious shortages as early as 2020.[161] This concern then faded due to unexpectedly fast growth in EVs and low-CI renewable diesel, in addition to small scope expansions and court-imposed delays in interim targets. As a result, in contrast to previously anticipated shortages, there is now a banked surplus of nearly 10 million tons of credits.

In addition to these uncertainties in low-CI fuel supply, there are also significant demand-side

161 Adam Christensen & Benjamin Hobbs, A Model of State and Federal Biofuel Policy: Feasibility Assessment of the California Low Carbon Fuel Standard, 169 Applied Energy 799 (2016).

uncertainties, of which concerns about potential fuel blending constraints are now dominant. Some alternatives can blend or drop in to replace conventional fuels without limits, but these are presently supply-constrained or not fully commercialized.[162] Other alternatives may face blending limits beyond which they require modified vehicles or new distribution infrastructure. There are claimed but disputed risks to older vehicles, as well as potential air-quality impacts, above present blend levels of 10 percent ethanol in gasoline (E10) and 5 percent biodiesel in diesel (B5). These concerns, plus conflict over who would pay for the distribution systems needed to sell additional fuel blends, have limited expansion of these fuels, both in California and nationwide under the federal Renewable Fuel Standard.

The 2016 credit clearance mechanism provides an additional tool to manage credit-market uncertainty on both the supply and demand side, which should reduce the need for frequent target adjustments.

The 2016 credit clearance mechanism provides an additional tool to manage credit-market uncertainty on both the supply and demand side, which should reduce the need for frequent target adjustments. The mechanism activates if credit prices reach $200 per ton.[163] If parties cannot acquire enough credits at that price, they may carry their shortfall forward up to five years with interest.[164] By putting a ceiling on near-term price fluctuations while also maintaining forward incentives, the mechanism limits the risk of price spikes without the threat to credibility of future targets that would be posed by repeated short-term target adjustments.

After 2020, setting the target trajectory will carry higher stakes under tighter targets and drawdown of the current credit bank. ARB's 2018 proposals include a target schedule for annual tightening of reductions to reach 20 percent below 2010 in 2030[165] slightly strengthened from an earlier proposal to cut "at least 18 percent."[166] Such pre-announced forward target schedules are necessary to signal the policy's ambition, create appropriate incentives, and provide context for market actors' decisions to use or hold credits. Several studies have examined potential 2030 reduction pathways, either to assess feasibility or to estimate the requirements of California's overall 40 percent reduction goal.[167] These pathways rely on a wide mix of fuels, with significant shifts between the early and late 2020s. Relaxing ethanol blend constraints, either by moving above E10 or expanding distribution of E85, would ease compliance for the next few years, but would contribute less to tighter targets thereafter unless there are substantial further decreases in ethanol's average CI. Larger cuts late in the decade could come from several sources: low-CI fuels like renewable diesel that face no blending constraints;[168] continued expansion of electric drive or hydrogen from decarbonized electricity; long-awaited advances in cellulosic or other low-CI biofuels;[169] or substantial expansion of carbon capture, either within fuel production processes or to produce new synthetic fuels based on air capture. ARB's illustrative compliance scenario uses a mix of these, with a slight tilt toward renewable diesel. A recent consultant study projected the proposed 20 percent cut could be achieved and exceeded by significant further progress in any of several areas: electrification of light or heavy vehicles; growth of ethanol beyond present blend limits with modest further CI reduction; advances in cellulosic fuels; or

162 Wade Brorsen, Projections of U.S. Production of Biodiesel Feedstock, Union of Concerned Scientists and International Council on Clean Transportation (July 2015), available at http://www.ucsusa.org/sites/default/files/attach/2015/07/Brorsen-RFS-Biodiesel-Feedstock-Analysis.pdf.

163 Cal. Code Regs. tit. 17, § 95485(c) (2016).

164 UCLA Emmett Institute LCFS Conference, supra note 16 (presentation by Chris Hessler).

165 Cal. Air Res. Bd., 2018 Initial Statement of Reasons, chs 5, 8, available at https://www.arb.ca.gov/regact/2018/lcfs18/isor.pdf.

166 Cal. Air Res. Bd., The 2017 Climate Change Scoping Plan Update ES4 (Jan. 20, 2017), available at https://www.arb.ca.gov/cc/scopingplan/2030sp_pp_final.pdf.

167 See Sonia Yeh, J. Witcover, G.E. Lade, & D. Sperling, A review of low carbon fuel policies: principles, program status and future directions, 97 Energy Policy 220, 231 (2016); see also ICF Incorporated, Post-2020 Carbon Constraints: Modeling LCFS and Cap-and-Trade (Feb. 2017), available at https://www.icf.com/resources/reports-and-research/2017/post-2020-carbon.

168 As in ARB's illustrative compliance scenario. See 2018 Initial Statement of Reasons, fig. V-3, available at https://www.arb.ca.gov/regact/2018/lcfs18/isor.pdf

169 Cal. Council on Sci. & Tech., Policies for California's Energy Future: Scaling up Advanced Biofuels (May 2014), available at http://ccst.us/publications/2014/2014biofuels.php.

widespread deployment of carbon capture in petroleum and ethanol production.[170] Assuming simultaneous progress on several fronts give reductions up to 26 percent.

These projected gains are all illustrative, not certain: uncertainty in low-CI fuel progress will persist after 2020, whether ARB decides to keep the proposed 20 percent target or adopts some more or less ambitious level. Even after the current bank is depleted, the credit clearance mechanism will aid continued management of uncertainty by smoothing out short-term credit shortages over periods of a few years, but it can only reduce shortage risk, not eliminate it.[171] In setting initial target schedules, there is thus always some possibility of forecast errors or unanticipated subsequent changes big enough that targets must later be adjusted.

Uncertainty in low-CI fuel progress will persist after 2020, whether ARB decides to keep the proposed 20 percent target or adopts some more or less ambitious level.

In view of this uncertainty, the most basic design decision regarding targets is how to set the advance schedule relative to current projections of future progress: should the initial target schedule be biased toward greater ambition, with accompanying risk that future relaxations will be needed; or toward less ambition, with increased risk that future tightening will be needed?

Both directions of error and subsequent adjustment are costly, but the decision can be analyzed in terms of the relative cost of the two types of error. Starting too weak then later tightening means missing available reduction opportunities; giving inadequate incentives, so weak initial projections may become self-fulfilling prophecies; and later imposing unanticipated lump-sum burdens on fuel distributors who have deficits. Starting too strong then later loosening will have two harmful effects. First, it risks reducing the credibility to low-CI investors of the initial targets. This concern is mitigated, however, if subsequent loosening is limited to conditions of sustained tight credit markets and high prices, so the effect on low-CI investors is

170 C. Malins, California's clean fuel future: assessing achievable fuel carbon intensity reductions by 2030, Cerulogy (Mar. 2018), available at https://nextgenamerica.org/wp-content/uploads/2018/03/Cerulogy_Californias-clean-fuel-future_March2018-1.pdf.

171 See calculations of price scenarios of rolling non-compliance forward, in Julie Witcover, Jeff Kessler, Anthony Eggert, & Sonia Yeh, The Low Carbon Fuel Standard, in Policy Institute for Energy, Environment and the Economy of the University of California, Davis, Achieving California's Greenhouse Gas Goals: A Focus on Transportation 71, 81, Research Report No. UCD-ITS-RR-15-14 (2015).

a small harm relative to a highly favorable position. Second, the anticipated possibility of target relaxation will give firms that benefit from weak targets incentives to resist and conceal progress in low-CI fuels, in order to make future relaxation more likely. This is unlikely to be a serious problem, however, because of the presence of many firms in fuel markets and the divergence of interests between those producing low- and high-CI fuels. The firms with the strongest interests in target relaxation will be producers of high-CI fuels, but they are likely to have little influence on the pace of low-CI development.

On balance, the cost and disruption from initially stating an ambitious target trajectory, with the accompanying risk that later small relaxations are needed, are likely to be less severe than from setting initial targets too weak and later having to tighten them.

On balance, the cost and disruption from initially stating an ambitious target trajectory, with the accompanying risk that later small relaxations are needed, are likely to be less severe than from setting initial targets too weak and later having to tighten them. The widespread presence of implicit biases toward weak ambition and favoring the status quo throughout regulatory processes further bolsters the value of explicitly tilting initial target trajectories toward more ambition. For current consideration of the LCFS target trajectory through 2030, since several plausible scenarios have been identified that reach ARB's proposed 20 percent reduction or more, this reasoning suggests ARB should consider an initial trajectory with somewhat stronger targets, up to a few percent beyond 20 percent CI reduction by 2030.

If the credit clearance mechanism as presently implemented should be inadequate to manage the resultant price pressure and subsequent small relaxations are required, these can be accomplished in three ways. One possible approach would be to modify the credit clearance mechanism to drop the five-year constraint on carrying forward deferred obligations. This would broaden the quantitative relaxation available at the $200 price, making the mechanism more closely resemble a true price cap, but this change would raise two concerns. First, by letting participants accumulate open-ended quantities of deferred obligations it would increase risk of compliance failure, by bankruptcy or other means. A compromise approach to limit this risk would be for ARB to grant such relaxations only case-by-case, subject to participant-specific assessment of default risk. Second, relying on the credit clearance mechanism as the vehicle for future relaxation would presume that the mechanism's $200 threshold price is the appropriate maximum: high enough to motivate major investment in innovations, but not so high as to risk serious disruption of fuel markets. If this is not the case, or if ARB prefers for other reasons not to rely exclusively on the clearance mechanism as the vehicle for future relaxations that may be needed, then these may also be accomplished in two other ways: by small explicit relaxation of forward CI targets; or implicitly, by incremental expansions of the policy's scope to include additional low-CI fuels and uses, as was done for electric forklifts and rail system and is proposed for alternative jet fuel. Limited expansions in credit eligibility for carbon capture and removal would be one way to achieve such small relaxation, subject to the caution above that such crediting needs to be kept under careful quantitative control. Whatever mechanism is used, ARB must rigorously resist being pressured into too-easy or too-early relaxation, as sustained high credit prices will be necessary to generate the needed development and investment in low-CI alternatives.

D. LCFS in the Context of Other State and Federal Policy

The LCFS operates in the context of other policies affecting transport fuels and their GHG emissions, both state and federal, with partly overlapping goals. Other relevant California policies include the Advanced Clean Cars and Zero Emissions Vehicles (ZEV) programs,[172] as well as various transportation and planning measures that aim to reduce vehicle-miles traveled.[173] In addition to their other goals, these policies extend the LCFS's effects on transport GHG emissions by targeting the two other routes to reducing them, vehicle efficiency and transport demand. In pursuit of California's goal that all new passenger vehicles will be ZEVs by 2050,[174] ZEV policies were strengthened in 2018 to a target of 5 million vehicles in use by 2030, with accompanying increases in rebates and infrastructure.[175] Serious pursuit of the ZEV goal would represent a sharp increase in ambition of both vehicle pollution and GHG policies, including—depending how "zero emissions" is defined in practice—a substantial tightening and re-orientation of the LCFS.[176] ZEVs are presently defined to include plug-in hybrid, hydrogen fuel cell, and battery electric vehicles, none of which necessarily has zero emissions under the life-cycle approach used by the LCFS.

The two policies that interact most strongly with the LCFS are the federal Renewable Fuel Standard (RFS) and California's cap-and-trade program. This section reviews these interactions, as they operate now and as they might under tighter reduction goals.

1. Interactions with the Federal Renewable Fuel Standard

The LCFS has strong and complex interactions with the federal Renewable Fuel Standard (RFS), which it was designed to complement.[177] The RFS and related federal policies created a national biofuels market. Established in 2005 and expanded in 2007,[178] the RFS requires a specified volume of biofuel use each year, increasing from 9 billion gallons in 2008 to 36 billion in 2022. The policy is implemented by a system of tradable credits called Renewable Identification Numbers (RINs), which are generated by producing qualifying biofuels. The compliance obligation falls on refiners and importers of gasoline and diesel, who must either blend the required volume of biofuels into their product or deliver an equivalent number of RINs. RINs remain linked to the fuel with which they were created, until blending. At that point, if a refiner has satisfied its blending obligation, it may transfer excess RINs to other blenders falling short of their obligation or, with limits, bank them for future use.[179]

Nested within the total biofuel mandate are three additional requirements for more advanced biofuel types. Each fuel type is defined, in part, by a required minimum reduction from the life-cycle CI of a baseline petroleum fuel. Conventional biofuels—in practice mostly corn ethanol—must have CI at least 20 percent below baseline.[180] Nested within this basic mandate is a requirement for

172 Cal. Air Res. Bd., The Advanced Clean Cars Program, https://www.arb.ca.gov/msprog/acc/acc.htm (last visited May 1, 2018).

173 See Sustainable Communities Act, S.B. 375, Ch. 728 Stats. (2008).

174 Governor's Interagency Working Group on Zero-Emission Vehicles, 2016 ZEV Action Plan. October 2016, available at https://www.gov.ca.gov/docs/2016_ZEV_Action_Plan.pdf.

175 California Governor's Office, Exec. Order B-48-18, Jan. 26, 2018, available at https://www.gov.ca.gov/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/.

176 CalEPA, California Announces New Under 2 MOU Signatories, International Effort to Accelerate Zero-Emission Vehicles (Dec. 3, 2015), http://under2mou.org/california-announces-new-under-2-mou-signatories-international-effort-to-accelerate-zero-emission-vehicles/.

177 2009 Initial Statement of Reasons, supra note 43, at ES-5.

178 Energy Independence and Security Act of 2007 (EISA), 121 Stat. 1492, Pub. L. No. 110-140 tit. II, subtit. A (Dec. 2007); codified at 42 U.S.C. § 7545(o).

179 See James H. Stock, The Renewable Fuel Standard: A Path Forward 6 (Apr. 2015), available at http://energypolicy.columbia.edu/sites/default/files/energy/Renewable%20Fuel%20Standard_A%20Path%20Forward_April%202015.pdf.

180 There is an exception for certain grandfathered sources. See 42 U.S.C. § 7545(o)(2)(A)(i).

a smaller amount of "advanced biofuels" with CI at least 50 percent below baseline.[181] This advanced mandate in turn contains two more mandates, one for biomass-based diesel (biodiesel or renewable diesel, also 50 percent below baseline), and one for cellulosic biofuels (60 percent below, and not made from food crops).[182] Each mandate has a separate type of RIN, and parties must comply with all four mandates in proportion to their production by delivering required quantities of all four RIN types.[183] Default values for the volume mandates are set by statute, but EPA may waive these based on supply shortfalls or anticipated economic or environmental harm.[184] EPA has used this authority to reduce the cellulosic mandate every year since 2010, because production has fallen far short of expectations, and has also reduced the other mandates since 2015.[185] These decisions were challenged, by both petroleum industry plaintiffs who wanted the mandates still lower and ethanol industry plaintiffs who wanted them higher. In July 2017, a D.C. Circuit Panel upheld the ethanol industry complaint that EPA lacked authority to reduce the mandates based on concerns about refiners' ability to use the statutory amounts.[186]

Recent controversies over the RFS and its interactions with the LCFS mainly pertain to one odd feature of RFS design: its mandates are stated as absolute volumes, but blenders must comply in proportion to their share of total fuel market. As a result, the mandates' burden varies inversely with the total size of the U.S. fuel market. For example, E10—a gasoline blend with up to 10 percent ethanol—has had a growing share of the U.S. gasoline market since the early 2000s.[187] Ethanol helps meet fuel octane and oxygenate requirements and corn ethanol is cheap, so blending small amounts into gasoline is a cost-effective way to meet those requirements, independent of the RFS.[188] The RFS mandate was initially well below 10 percent of the market and was thus non-binding, so RINs were in excess supply and traded at prices near zero through 2013. Since then, however, the mandate has grown faster than the market, reaching and sometimes exceeding 10 percent of total fuel supply since 2016.[189]

This convergence has raised sharp controversy over the feasibility of gasoline blends with more than 10 percent ethanol.[190] EPA has authorized blends up to 15 percent (E15) for post-2001 vehicles, but has not required them. The petroleum industry claims that E15 poses risks to vehicles, and some automakers have supported this claim by threatening to void warranties on vehicles fueled with blends

181 Id. §§ 7545(o)(1)(B), (o)(2)(B). Thus far, most of the "advanced" biofuel that does not also qualify for the biomass diesel or cellulosic mandates has been imported sugarcane-based ethanol.

182 Additional restrictions on qualifying fuels aim to limit incentives for land-use conversion. For example, fuel feedstocks may not come from recently cleared land (since 2007), or from federal lands.

183 RIN codes are identified as D6 for the general mandate, D5 for advanced, D4 for biodiesel, and D3 and D7 for cellulosic. A RIN may be used to satisfy its own associated mandate, or one of the broader, weaker mandates.

184 42 U.S.C. § 7545(o)(7); see also U.S. EPA, Renewable Fuel Standard Program: Overview for Renewable Fuel Standard Program, http://www2.epa.gov/renewable-fuel-standard-program/program-overview-renewable-fuel-standard-program (last visited May 1, 2018); Kelsi Bracmort, The Renewable Fuel Standard (RFS): Waiver Authority and Modification of Volumes (Congressional Research Service,February 5, 2018), available at https://fas.org/sgp/crs/misc/R44045.pdf.

185 The final mandates for 2017 were set at 19.28 billion gallons total biofuel, including 4.28 billion gallons advanced, 2 billion gallons biomass diesel, and 311 million gallons cellulosic fuels. 2018 volumes were 19.29 billion total, including 4.29 billion advanced, 2.1 billion biomass diesel, and 288 million cellulosic. Final Rule, 80 Fed. Reg. 239, 77420 (Dec. 14, 2015); Final Rule, 81 Fed. Reg. 89746 (December 12, 2016); Final Rule, 82 Fed. Reg. (December 12, 2017). See also https://www.epa.gov/renewable-fuel-standard-program/final-renewable-fuel-standards-2017-and-biomass-based-diesel-volume; Kelsi Bracmort, The Renewable Fuel Standard (RFS): An Overview (Congressional Research Service, January 24, 2018), available at https://fas.org/sgp/crs/misc/R43325.pdf.

186 Americans for Clean Energy v. Envtl. Prot. Agency, 864 F.3d 691 (D.C. Cir. 2017).

187 E10 made up more than 95% of U.S. gasoline in 2015. U.S. Energy Information Admin., Today in Energy, May 4, 2016, http://www.eia.gov/todayinenergy/detail.php?id=26092 (last visited Oct. 2, 2016).

188 Union of Concerned Scientists, The Blend Wall and the Future of the Renewable Fuels Standard, available at http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_vehicles/RFS-Blend-Wall-Factsheet.pdf.

189 U.S. EPA, Renewable Fuel Standard Program: Standards for 2018 and Biomass-Based Diesel Volume for 2019; Proposed Rule, 82 Fed. Reg. 34206 (July 21, 2017).

190 Blending constraints are not presently a concern for non-ethanol biofuels. Biodiesel production and mandates are far below any potential blend wall, while renewable diesel is a drop-in substitute that can replace diesel or blend into it in any proportion with no alterations required. Union of Concerned Scientists, supra note 166.

above E10.[191] But the claim has been increasingly disputed, including by EPA in setting the 2018 standards.[192] In addition, the U.S. vehicle fleet includes about 19.6 million "flex-fuel" vehicles (7 percent of the fleet), which can use any ethanol-gasoline blend up to E85, but relatively few stations outside the Midwest sell blends above E10.[193] Significant expansion of either E15 or E85 would greatly ease compliance with the RFS, but would require interventions to break the current deadlock: either changes in policy, market conditions, or industry strategy to allow expanded use of E15 in conventional vehicles; or some combination of expanding fueling infrastructure for higher-ethanol blends and educating flex-fuel vehicle owners about their ability to use them.[194] With RFS mandates edging above 10 percent, and industry not willing or required to blend above this level or invest in infrastructure needed to separately sell higher blends, RINs have become scarce and prices have spiked from a few cents to nearly $1 per gallon. This surge adds to long-standing price volatility and continued uncertainty about the policy's survival, which have impaired the ability to motivate long-term investment.

Interactions between the RFS and LCFS differ among fuel types. Both policies impose a cost on gasoline and diesel and subsidize certain other fuels, but they do not always subsidize the same ones. The RFS subsidizes specified types of biofuel, while the LCFS subsidizes any fuel below the current CI target. In addition, while LCFS subsidies vary with each specific fuel's CI, RFS subsidies are fixed for all fuels that fall within the same category. These complexities notwithstanding, RFS and other federal programs have clearly driven large increases in biofuel production and thereby eased compliance with the LCFS and lowered credit prices.[195]

191 American Fuel & Petrochemical Manufacturers, Fact Sheet: Renewable Fuel Standard Blend Wall (June 9, 2015), available at http://www.globalwarming.org/wp-content/uploads/2015/06/20150609-RFS-Blendwall.pdf.

192 Supra note 200.

193 Of the roughly 115,000 fuel stations nationwide, only about 3,200 offer E85. See U.S. Dept. of Energy, Alternative Fuels Data Center, http://www.afdc.energy.gov/fuels/stations_counts.html (last visited March 9, 2018).

194 See Bruce Babcock & Sebastien Pouliot, Price It and They Will Buy: How E85 Can Break the Blend Wall, CARD Policy Brief 13 (2013), available at https://lib.dr.iastate.edu/card_policybriefs/13.

195 See UCLA Emmett Institute LCFS Conference, supra note 16 (presentation by Jeremy Martin); Conference, National Ethanol Conference, Renewable Fuels Associations (Feb. 18-20, 2015) (presentation by Jeremy Martin); see also email communication from Ethan Elkind (Dec. 2015).

The RFS has helped the LCFS and shared the cost burden by motivating production of large volumes of mostly conventional biofuel, but is not presently well designed to provide effective incentives for advanced, low-CI fuels.

Uncertainty over future interactions between the two policies is dominated by uncertainty over the future form, perhaps the survival, of the RFS. If the current deadlock over ethanol blends were surmounted so E15 or E85 expanded substantially, this would ease compliance with both policies for current LCFS targets. Absent such progress, however, ethanol is likely to play only a limited role in meeting tighter LCFS targets, contributing mainly by further shifts toward low-CI ethanol rather than by increases in production volume. If the RFS were weakened or abolished, first-generation biofuels would not disappear—they would persist at some level less than 10 percent, due to market incentives independent of the policy—but more compliance burden would shift to the LCFS. One study that attempted to quantify this interaction found that abolishing the RFS would raise the price of LCFS credits about 50 percent.[196] Abolishing the LCFS would have the converse effect, but only for some biofuel types: the price of basic RINs would rise about 25 percent, but there would be little effect on RINs for biomass diesel or cellulosic fuels. This result is consistent with the observation that none of the cellulosic ethanol produced in the U.S. in 2015 was used in California.[197] It also suggests that RFS quantitative mandates, not incentives from LCFS credits, were the main drivers of markets for biomass-based diesel and other advanced biofuels through 2015, so motivating large expansion of these through LCFS credits alone would require sustained price levels higher than experienced prior to then. The RFS has helped the LCFS and shared the cost burden by motivating production of large volumes of mostly conventional biofuel, but is not presently well designed to provide effective incentives for advanced, low-CI fuels. In the future, if the RFS were strengthened to provide more effective incentives for low-CI biofuels, it could continue to help promote LCFS aims and share compliance burden. Absent such improvements, however, even if the RFS persists in close to its current form, it is likely to play a declining role in supporting the LCFS as its targets tighten beyond 10 percent after 2020.

2. Interactions with California's Emissions Trading Program

California's GHG trading program limits total state emissions from covered sources via a system of tradable emissions allowances.[198] In effect since 2012, the program initially covered electrical generating stations and industrial facilities emitting more than 25,000 tons per year. It expanded in 2015 to include petroleum transport fuels and natural gas, and now includes about 450 sources and about 85 percent of total California emissions. Starting from a 2012 baseline, the cap tightened 2 percent per year through 2014, then 3 percent per year through 2020. About 10 percent of allowances are auctioned, with the rest distributed free to current emitters. Allowance trading prices are subject to both low and high limits: an auction reserve price of $12.50 per ton, and reserve quantities of extra allowances offered for sale if prices reach $40 and $50.[199] These reserves are limited in quantity, however, so there is a risk of prices rising beyond these thresholds if reserves sell out.

Auction prices stayed narrowly above the lower limit through early 2016.[200] Then in May 2016 the auction failed to clear, with only about 10 percent of offered allowances selling at the reserve price.[201] This was attributed to several factors: shuffling of out-of-state electricity supply; insecurity about future allowance value due to a pending legal challenge and a lack of statutory author-

196 Christensen & Hobbs (2016), supra note 161.
197 Yeh & Witcover 2016 Status Review, supra note 23.
198 Rhodes et al., CCST, CO_2 Capture, supra note 130, at 16, 20. See also Cal. Code Regs. tit. 17, art. 5, subch. 10 (2013), available at http://www.arb.ca.gov/cc/capandtrade/ctlinkqc.pdf.
199 Both low and high limits are inflation-adjusted. Cal. Air Res. Bd, Overview of ARB Emissions Trading Program (Feb. 9, 2015), available at https://www.arb.ca.gov/cc/capandtrade/guidance/cap_trade_overview.pdf.
200 Climate Policy Initiative, California Carbon Dashboard, http://calcarbondash.org/ (last visited May 1, 2018).
201 Cal. Air Res. Bd., California Cap-and-Trade Program Summary of Joint Auction Settlement Prices and Results (Aug. 2016), available at https://www.arb.ca.gov/cc/capandtrade/auction/results_summary.pdf.

ity post-2020; and excess allowance supply due to reductions required under other regulations including the LCFS. ARB responded with proposed changes to treatment of allowances post-2020, which are currently pending.[202]

The 2016 legislation only partly resolved uncertainty about the program's post-2020 future. On the one hand, SB 32 made a commitment to steep emissions cuts, establishing in law the 40% reduction by 2030 previously announced by Governor Brown in 2015. On the other hand, companion bill AB 197 required the state to prioritize "rules and regulations that result in direct emission reductions,"[203] leaving ambiguity about the role of cap-and-trade in making the 40% cut. Uncertainty about the future legal status of cap-and-trade was resolved in the July 2017 legislation, which extended the program to 2030 with some modifications—notably, a requirement that the reserve allowance provision be strengthened to make a firm price ceiling.[204] Crucially, the new bills passed with the 2/3 majorities required under Proposition 26, protecting the program from further legal challenges claiming the allowance auction is an impermissible tax.[205]

But while this legislation relieved legal uncertainty about the program's future, uncertainty about its effectiveness has persisted. Allowance auctions failed to clear through February 2017, then returned to clearing at prices slightly above the floor in the four subsequent auctions through February 2018.[206] Some observers have argued that recent over-supply and low prices may be persistent characteristics of the program.[207] One recent study advanced a broader critique, arguing that uncertainty about baseline emissions makes it likely that at any time either the lower or upper price limits will be binding.[208] This argument implies that any cap-and-trade system that includes such price limits—as nearly all do—will fail to elicit progressive, price-responsive mitigation, because prices will usually not be set by market conditions but instead fixed at administratively defined endpoints. This claim would significantly weaken one of the major arguments for the preferability of cap-and-trade systems over explicit price-driven policies such as emissions taxes.

Interactions between the LCFS and the cap-and-trade system mainly arise from the 2015 expansion to bring fossil-based transport fuels under the cap.[209] These fuels now fall under both LCFS and cap-and-trade, and so can bear a cost burden and reduction incentive from both programs. ARB has described the two policies as "complementary."[210] Reductions achieved in areas where both policies apply contribute to compliance for both, with compliance and cost burden shared between the policies such that as one is tightened, the burden carried by the other is reduced.[211]

202 Cal. Air Res. Bd., Proposed Amendments to the California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms Regulation (Jan. 30, 2018), available at https://www.arb.ca.gov/regact/2018/capandtradeghg18/isor.pdf.

203 AB 197, Cal. Health and Safety Code § 38562.5(a).

204 AB 398, available at http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB398.

205 Although industry plaintiffs lost their challenge to the program's auction on that basis (see California Chamber of Commerce v. State Air Res. Bd., 10 Cal. App. 5th 604 (2017)), critics had argued that the prior lack of the required supermajority put the program at continuing legal risk (See, e.g., A. Coghlan and D. Cullenward, State constitutional limitations on the future of California's cap-and-trade market, 37 Energy Law J. 219, 255 (2016).

206 See, e.g., California Cap-and-Trade Program and Québec Cap-and-Trade System Auction information, available at https://www.arb.ca.gov/cc/capandtrade/auction/auction.htm (last visited February 28, 2018).

207 See, e.g., Chris Busch, Recalibrating California's cap-and-trade program to account for oversupply, Energy Innovation Policy and Technology LLC (March 2017), available at http://energyinnovation.org/wp-content/uploads/2017/03/RecalibratingCA_Cap-Trade_March2017.pdf; see also D. Cullenward and A. Coghlan, Structural oversupply and credibility in California's carbon market, 29 The Electricity Journal 7 (2016).

208 Severin Borenstein, James Bushnell, Frank A. Wolak, Matthew Zaragoza-Watkins, Expecting the unexpected: emissions uncertainty and environmental market design (Energy Institute at Haas Working Paper 274, August 2016) [hereinafter Borenstein et al.].

209 Cal. Air Res. Bd, Facts About: Information for Entities that Take Delivery of Fuel for Fuels Phased into the Cap-and-Trade Program Beginning on January 1, 2015, available at http://www.arb.ca.gov/cc/capandtrade/guidance/faq_fuel_purchasers.pdf. Fuel suppliers are subject to the cap-and-trade program if their annual emissions from combustion of these fuels are greater than or equal to 25,000 metric tons CO_2e.

210 2009 Initial Statement of Reasons, supra note 43, at ES-3.

211 Borenstein et al., supra note 208. See also ICF Incorporated, Post-2020 Carbon Constraints: Modeling LCFS and Cap-and-trade (February 2017), available at https://www.icf.com/-/media/files/icf/reports/2017/final-report-cap-and-trade-lcfs.pdf.

There are several differences in how the two policies treat fuels. The cap-and-trade system covers only fossil fuels; covers only combustion, not life-cycle emissions (although emissions from California refineries are separately covered); and covers absolute emissions, requiring allowances for any level above zero. By contrast, the LCFS covers all road-transport fuels, fossil and alternative; it covers emissions from the total fuel life-cycle even if these occur outside California, not just combustion; and it requires credits only for emissions above the CI target, offset by credits granted to fuels with CI below the target. Regulations state that LCFS credits may be used for compliance with cap-and-trade but not the reverse,[212] although there is some ambiguity on this point and such exchanges are unlikely in practice, since credit prices are much higher for LCFS than for cap-and-trade.[213]

Given their differences in design and coverage, interactions between the two policies are complex and not always mutually reinforcing. For example, some fuels—e.g., fossil CNG, whose CI is below the current weak LCFS target—bear a cost from cap-and-trade but a subsidy from the LCFS. Others, e.g., some high-CI biofuels, bear a cost from the LCFS but none from cap-and-trade; but these are odd cases. The largest and most important interactions are for gasoline and diesel, the fuels that bear costs from both programs. Demand for these is price-inelastic in the short term, so net costs of both policies are mostly passed through to consumers and effects of the two policies are additive.[214]

Based on emissions factors of about 9 kilograms CO_2 per gallon of gasoline,[215] the $12.50 minimum cap-and-trade price raises the price of unblended gasoline about 10 cents per gallon (9 cents for E10).[216] This ratio of slightly less than 1 cent/gallon per dollar/ton would apply proportionally for any carbon price covering only combustion emissions. The effect of LCFS credit prices is more variable across fuels, and is complicated in some cases by the presence of partly offsetting cost and subsidy within the same gallon of blended fuel. But for gasoline and diesel at present blend levels, the price effect is roughly proportional to both the credit price and the required CI reduction. Thus, under a CI cut of 2 percent (as applied in 2016), a $100 LCFS credit price gives a gasoline price increase of about 2 cents/gallon. The same credit price under a 10 percent CI cut, as currently required for 2020, would increase the gasoline price 10 cents/gallon.

In their broader economic impacts, the policies' interactions depend on various market, technological, and policy conditions.[217] We discussed above the erroneous assumptions about policy goals that underlie criticisms of the LCFS for requiring high-cost cuts in fuel when cheaper cuts are available elsewhere. A closely related criticism is that the LCFS is ineffective at reducing current emissions because of leakage: if the cap covers activities both inside and outside the LCFS and is assumed binding, then any cuts the LCFS induces in emissions under the cap will be offset by increases in other capped sectors.[218] This criticism does not strictly apply to recent quarters, when the cap was non-binding. But this is a weak rebuttal if the LCFS contributed to making the cap slack; and in any case, the cap is unlikely to remain slack under planned tighter targets. A somewhat stronger response is that this critique, like that claiming excessive cost, misconstrues the main goal of the LCFS, which is promoting large long-term reductions and innovations in alter-

212 Cal. Code Regs. tit. 17, §§ 95487 (a)(1)(C), 95487(a)(2)(A).

213 ARB's online information suggests it does not plan to allow credit exchange in either direction. Cal. Air Res. Bd., LCFS Guidance Documents and FAQs, https://www.arb.ca.gov/fuels/lcfs/guidance/guidance.htm#faqs (last visited May 2, 2018).

214 Studies of changes in the price gap between California and nearby states when fuels came under the cap support this. See Yeh & Witcover 2016 Status Review, supra note 23, at 7.

215 10 kilograms per gallon for diesel. U.S. Energy Information Administration, Carbon Dioxide Emissions Coefficients, https://www.eia.gov/environment/emissions/co2_vol_mass.php (last visited May 2, 2018).

216 The minimum auction reserve price increases by the inflation rate plus 5% each year. For 2017 auctions, it is $13.57. See Cal. Air Res. Bd., 2017 Annual Auction Reserve Price Notice (Dec. 1, 2016), available at https://www.arb.ca.gov/cc/capandtrade/auction/2017_annual_reserve_price_notice_joint_auction.pdf.

217 See Michael Wara, California's Energy and Climate Policy: A Full Plate, But Perhaps Not a Model Policy, 70 Bull. Atom. Scientists 26 (2014).

218 See Schatzki & Stavins, supra note 102.

native fuels toward that end. Relative to this goal, missing some immediate low-cost reduction opportunities in other sectors is not necessarily of the greatest importance.

The LCFS reduces cap-and-trade allowance prices, more strongly as the CI target is tightened. Depending whether you support or oppose the LCFS, this effect can be described as the LCFS easing the compliance burden of cap-and-trade (good), or weakening the cuts it achieves through leakage (bad).

But this response does not mean these interactions do not occur, or do not impair policy effectiveness. Despite differences in the two policies' scope, modeling of compliance scenarios supports the claim that the LCFS reduces cap-and-trade allowance prices, more strongly as the CI target is tightened.[219] Depending whether you support or oppose the LCFS, this effect can be described as the LCFS easing the compliance burden of cap-and-trade (good), or weakening the cuts it achieves through leakage (bad): these are different descriptions of the same effect. To the extent this effect occurs, the critics are correct that it represents a loss of low-cost reduction opportunities that would be better to realize, by keeping the cap binding and the allowance price above its floor.

This effect does not, however, imply that strong sectoral policies should be rejected when technological and political conditions warrant them, as they do for the LCFS. There are at least two ways to reduce the harmful interaction that are preferable. The simplest way would be to eliminate or reduce the double coverage, in effect reversing the 2015 decision that brought fuels under the cap and adjusting its level accordingly.[220] Given that this double coverage is in place, the interaction can also be weakened or eliminated by introducing a cap adjustment mechanism, which would reduce the cap to track estimated reductions in cap-covered emissions achieved by the LCFS. Such adaptive cap tightening could reduce the harmful interactions roughly as much as would be gained by removing LCFS-covered emissions from the cap, with less reduction of cap-and-trade revenues (possibly even an increase),[221] while still preserving the status of the cap-and-trade system as a broad, backstop policy.

Conclusions and Recommendations

Achieving large emission reductions from transport will be a huge challenge, greater than in any other energy sector. Each of the three routes to cutting transport emissions can achieve substantially more than at present. But further gains available from increasing efficiency and reducing travel demand will decline as emission targets tighten, so a growing share of the burden of further reductions will fall on the CI of fuels and energy carriers. Indeed, if the goal is zero transport emissions then aggregate fuel CI must go to zero, since neither a zero-transport society nor a zero-energy transport system is possible. Several types of alternative fuel may in principle be able to reach zero or near-zero CI: electric drive or hydrogen from non-carbon sources, chemically synthesized fuels based on free-air capture of carbon and non-carbon primary energy sources, and zero-emission biofuels—with any of these augmented by additional carbon capture to the extent their life-cycle CI cannot actually reach zero. But these alternatives all face multiple barriers to large-scale replacement of fossil fuels, including technical performance, supply constraints, limits to feasible CI reductions, other environmental and societal impacts, network and system effects, and cost. All these challenges may be surmountable, but it is unclear by what means and how soon. It thus remains uncertain which alternatives will provide acceptable paths to zero or near-zero transport emissions, and getting there through any technical pathway or combination of pathways is a project of decades, not years.

219 See Borenstein et al., supra note 208; ICF Incorporated, supra note 211.

220 Wara, supra note 217, at 26.

221 The adjustment would not reduce the scope of the cap-and-trade program, but would reduce the supply of allowances, introducing offsetting factors tending to decrease revenue (smaller quantity) and increase it (higher price). Inelastic demand for allowances would favor a net increase in revenue, but the actual effect would depend on details of the adjustment mechanism, and would require quantitative modeling to estimate.

Assessments of the LCFS must take account of the necessity, scale, and severity of this challenge. The LCFS is the first policy to address the challenge, and to do so with a design that has some prospect of driving significant movement toward the required transformation. Although statements of LCFS goals have not always been clear, its predominant goal is—and should remain—achieving long-term reductions in emissions associated with transport fuels, managing as needed the associated tradeoffs between different routes, and between nearer and longer-term progress. Both ARB and the Governor have sometimes stated other goals that are not necessarily fully aligned with this one, including reducing dependence on petroleum, diversifying the State's fuel portfolio, developing a regulatory framework exportable to other jurisdictions, and stimulating production of alternative fuels in California. Tensions among potential goals have not yet been significant, but might sharpen as targets tighten. To the extent this occurs, we suggest that future LCFS decisions should continue to prioritize promoting long-term reductions in total emissions associated with transport fuels.

Further gains available from increasing efficiency and reducing travel demand will decline as emission targets tighten, so a growing share of the burden of further reductions will fall on the CI of fuels and energy carriers.

Several design elements of the LCFS make it uniquely well configured to pursue this goal. By separately targeting transport fuels, the LCFS creates the possibility of marginal incentives strong enough to induce the required investments in exploratory, low-carbon alternatives. By controlling the complete fuel life cycle, it avoids fuel switching based on partial benefits that might be offset elsewhere in the life cycle. By imposing an intensity standard, it requires technical improvements that do not vary with the activity level—i.e., that do not tighten when transport expands and weaken when it contracts. By pursuing neutrality across fuels, it pursues the dual aims of motivating and eliciting information about diverse low-carbon alternative fuels, without pre-judging the preferred pathway. By maintaining internal budget neutrality between the costs and subsidies it distributes among fuels, it reduces consumer price impact and remains separate from larger-scale political and economic risks associated with the general state budget. And by using a market-based approach based on tradable credits within this structure, it brings the general advantages of market-based policies—flexibility, cost minimization relative to the specified policy goal, and incentives for innovation—into the context of a sectoral rather than an economy-wide policy. Its innovativeness and ambition have attracted widespread interest, and it increasingly serves as a model for policies elsewhere.

A. LCFS Stands Up to Legal Challenges and Policy Critiques

The LCFS has also attracted various attacks, including the legal challenges discussed in Section 4 as well as a wide range of policy critiques. Policy critiques have mainly targeted either the LCFS's ambition or its design. Those based on ambition are familiar from many other environmental issues and policies. They claim the targeted reductions are infeasible or excessively costly because the required quantities of low-CI fuel cannot be available in time, even in response to the strong incentives the policy will create. These criticisms are weakened by the history of similar claims advanced since the policy's inception, all refuted thus far by the progress achieved. Moreover, multiple plausible compliance scenarios have been identified to reach the proposed tighter 2030 target, and the credit clearance will ease short-term compliance if these prove too optimistic. None of these counter-arguments proves there cannot be a sharp increase in difficulty and cost under tighter targets post-2020, of course. But should this occur, ARB has the tools and record of making small adjustments as needed to manage this risk, while also keeping strong incentives in place.

The critiques based on LCFS policy design are more variable in sophistication, but all are based in one way or another on the policy being too narrow. In early years, the form of narrowness most criticized was that the policy was enacted by California, rather than nationwide or internationally.[222] Greenhouse-gas policies at larger jurisdictional levels are preferred, because cuts in smaller jurisdictions (even as large as California) can have only small effect on global emissions, and are vulnerable to "emissions leakage"— partly offsetting increases elsewhere, induced through world fuel or product markets. This is correct in principle, but not persuasive as a basis to reject California-level policies. Empirical estimates of leakage vary widely across sectors, and can be reduced by details of policy design.[223] And although the critique is typically employed to argue that smaller jurisdictions should simply wait for action at larger scale, it is silent on what to do if effective action at the preferred larger jurisdictional scale is not available—i.e., if the alternative to California action that is impaired to some degree by leakage is no action at all.

More recently, as the LCFS has survived early legal challenges and been strengthened, its critics have shifted to charging that it is inefficient—inferior in its balance of environmental benefits and costs—because it is targeted too narrowly within California. Of these critiques, the simplest and most widely repeated say it is too costly because it singles out transport rather than pursuing reductions across the whole California economy via a uniform emissions price. As noted above in the discussion of policy scope, the LCFS requires high-cost emissions reductions in transport fuels when lower-cost reduction opportunities are available elsewhere in the economy, e.g., in end-use energy efficiency, buildings, or electrical generation. Clear evidence of this disparity comes from the large price difference between LCFS credits and cap-and-trade allowances.[224] A finer-grained critique accepts the scope limitation to the transport sector, but argues the LCFS is inefficient even relative to other transport-sector policies such as a fuel tax.[225] There are two closely related causes for this claimed inefficiency, one again concerned with scope, the other with policy form. In its scope, the LCFS targets one of three points to influence transport emissions: the emissions intensity of fuel, not vehicle efficiency or transport demand. If there are cheaper reduction opportunities at these other decision points, the LFCS does not achieve minimum-cost reductions even within the transport sector. In its form, the LCFS is designed as an intensity standard. It controls an average quantity for each fuel producer rather than total or marginal emissions, equivalent to a combined tax on high-CI fuels (above the standard) and subsidy on low-CI fuels. Because the subsidy component increases production of low-CI fuels, the policy cannot achieve a given reduction at minimum cost. Moreover, as with any intensity standard, if low-CI fuel markets are highly responsive to the subsidy it is theoretically possible for the standard to increase total current-period emissions.[226]

These critiques have figured prominently in regulatory debates, and have been widely and uncritically repeated, both by industry groups opposed to the LCFS and others, as decisively

222 See, e.g., L.H. Goulder, R.N. Stavins, Challenges from state-federal interactions in US climate change policy, 101 Am. Econ Rvw. 253-257 (May 2011); J. Bushnell, C. Peterman, C. Wolfram, Local Solutions to Global Problems: Climate Change Policies and Regulatory Jurisdiction, 2 Rvw. Envt. Econ & Pol. 175-193 (Summer 2008); M.L. Fowlie, Incomplete Environmental Regulation, Imperfect Competition, and Emissions Leakage, 1 Am. Econ. Jrnl: Economic Policy 72-112 (2009).

223 Meredith Fowlie, Mar Reguant, Stephen P. Ryan, Measuring Leakage Risk (May 2016), available at https://www.arb.ca.gov/cc/capandtrade/meetings/20160518/ucb-intl-leakage.pdf.

224 See, e.g., C.R. Knittel, Op-Ed.,Markets point to leaning more on cap-and-trade, Sacramento Bee (Jan 31, 2017).

225 Critics do not always explicitly state their preferred policy, but the best alternative for their case would be a fuel tax levied on fuels' life-cycle emissions content: this would require doing the same LC analysis for each fuel as the LCFS, but would then apply a uniform tax per embedded unit of LC emissions to all fuel delivered, rather than an average intensity constraint at the point of fuel import or distribution.

226 See, e.g., G.E. Helfand, Standards vs. standards: the effects of different pollution restrictions, 81 Amer. Econ Rvw 622-634 (1991); see also S.P. Holland, Taxes and trading versus intensity standards: second-best environmental policies with incomplete regulation (leakage) or Market Power, 63 J. of Envt'l Econ. and Mgt. 375-387 (2012); D. Lemoine, Escape from Third-Best: Rating Emissions for Intensity Standards, 67 Envt'l and Res. Econ. 789-821 (2017). No empirical example of this perverse effect has ever been identified, and it is difficult to demonstrate even in quantitative simulations. For example, the simulations of Holland et al. (supra note 117, tbl. 2 and 3, pp. 133-134) demonstrate the opposite effect: various LCFS targets, while highly costly, reduce total emissions by more than the required fractional reduction in fuel CI.

showing it to be a foolish policy. But they do not make this case, for several reasons. First, the policy's claimed inferiority depends strongly on details of the modeling formulation. Even within the static, comparative-cost framework employed by the most sophisticated critics, the LCFS's inefficiency can be readily reversed under various plausible alternative formulations: for example, in a macroeconomic framework that considers the excess burden of input taxes;[227] in the presence of market power or incomplete emissions control across jurisdictions;[228] or if economy-wide emissions prices are held below their socially optimal level by political constraints.[229]

There are also two more basic weaknesses of these critiques, one concerned with the economics of policy design and one with the political economy of regulation. First, the static comparative-cost framework the critiques employ, based on current-period marginal-cost comparisons, cannot represent the distinct conditions of transport and fuels that motivated development of the LCFS: multiple potential technological pathways, all subject to large uncertainties, long development times, and strong network and system effects. To the extent these conditions impair the response of transport fuels to broad incremental policies, and reductions in this sector are needed to achieve deep overall emissions cuts, then critiques that ignore these conditions—and their conclusions that the LCFS is inferior to either an economy-wide emissions price or a fuel tax—are irrelevant to evaluating the policy in view of its actual goals and the conditions in which it operates.

Current-period marginal-cost comparisons cannot represent the distinct conditions of transport and fuels that motivated development of the LCFS: multiple potential technological pathways, all subject to large uncertainties, long development times, and strong network and system effects.

Second, the broader policies critics identify as preferable to the LCFS face severe political obstacles that have thus far prevented them from being enacted, in effective form and at the required level, in any jurisdiction. The policies claimed superior would impose a uniform emissions price, either economy-wide or across the transport sector. To assess the plausibility of such policies as alternatives to the LCFS, it is instructive to consider how high a broader emissions price would have to be to achieve the LCFS's targets. The most prominent academic criticism of the LCFS provides estimates of that price level in its quantitative simulations: for a 10 percent CI reduction, the required emissions price ranges from about $1,000 to $12,000 per ton CO_2 under alternative assumptions about ease of substitution in the economy, corresponding to a fuel price increase of 60 cents to $12.50 per US gallon.[230] If you reject that target—either because you reject a separate fuel CI target, or because a 10 percent is too large—using economy-wide emissions prices even to achieve weaker, widely accepted near-term reduction goals has thus far been politically unachievable. No jurisdiction has enacted a broad emissions policy strong enough to match recent estimates of social damage of emissions, despite arguments for the theoretical superiority of such policies being well known for forty years. All such policies in force are either impaired by broad exemptions, or held far below estimates of socially optimal levels.[231]

Unlike these hypothetically superior but nowhere-enacted emissions policies, the LCFS is in force, at a level that is deploying strong incentives to reduce fuel-related emissions. It is

227 L.H. Goulder, M.A.C. Hafstead, and R.C. Williams, General equilibrium impacts of a clean energy standard, 8 Amer. Econ. J.: Econ. Policy 186-218 (2016).

228 S.P. Holland (2012), supra note 226.

229 J.D. Jenkins & V.J. Karplus, Carbon pricing under binding political constraints, (UNU-WIDER Working Paper 44/2016, April 2016).

230 Holland et al. (2009), supra note 117, tbl. 2 and 3, pp. 133-134. The quoted values are the shadow value of an additional ton of emissions under the specified LCFS constraint.

231 The most recent "Social Cost of Carbon" exercise estimated marginal damage from 2015 emissions (model average at 3% discount rate) as $36/t$CO_2$. Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (August 2016), available at https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf. By contrast, a recent survey of emissions policies worldwide found that only four jurisdictions (Sweden, Switzerland, Finland, and Norway) had policies with nominal emissions prices above $31/t$CO_2$e, all impaired by large exemptions. World Bank Group, Carbon Pricing Watch 2016, available at https://openknowledge.worldbank.org/handle/10986/24288.

likely that the same design elements that are major targets of criticism, notably its internal budget neutrality, have contributed to its enactment and survival. In addition to considering the conditions that motivated the enactment of the LCFS, criticisms of the policy would also be more persuasive if they considered these evident, long-standing constraints on feasible alternative policies. Otherwise, even if their technical claims are stronger than we argue they are, these wholesale attacks on the LCFS effectively advocate continued inaction on transport greenhouse-gas emissions.

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Rejecting these wholesale attacks does not, however, imply that the LCFS cannot be improved. Its effectiveness and value depend on its fit with the technological and market conditions in which it operates, in the large and the small: large-scale structural characteristics of the transport system create the need for a targeted fuel policy, while more specific characteristics of alternative fuels—their performance, prospects, and constraints—inform the details of effective policy design. These conditions, and their implications for policy design, will change as the transition to low-carbon transport proceeds. In the near term, petroleum will remain the largest share of California transport fuel; LCFS credit prices will motivate continued innovation and expansion in a diverse mix of low-CI alternatives, under continuing uncertainty about the future fuel mix; and the LCFS will continue to serve the dual purposes of both motivating and eliciting information about low-carbon alternatives. Over the longer term, accumulating experience and advancing knowledge will help clarify the preferred future low-carbon transport energy system, and the decline in petroleum fuels' share will accelerate as alternative fuels expand. The scale of the needed transition, and the changing needs and opportunities it presents over time, will affect all elements of design of the LCFS and related policies.

B. Challenges for LCFS Policy Design

We have discussed LCFS policy design in terms of four major challenges—large-scale design choices regarding fuel neutrality, policy scope, and target trajectory; and managing its interactions with related policies—as these are currently implemented, and as they may need to adjust under changing conditions. In this concluding section, we summarize the highlights and draw out implications for continued operation of the LCFS as targets tighten after 2020.

1. Fuel and Technology Neutrality

ARB has vigorously defended the merits of LCFS neutrality across covered fuels and technologies, and has done a good job realizing neutrality in practice despite the difficulties of doing so precisely. We have characterized neutrality as a useful design principle for the present state of knowledge regarding low-carbon alternative fuels: confidence that large CI reductions are needed, but uncertainty about the relative merits and prospects of particular technical alternatives to pursue this. In this context, neutrality allows the LCFS to advance two linked near-term objectives: promoting a broad range of low-CI alternative fuels, and promoting learning and eliciting information about the prospects of various alternatives. Over time, however, as knowledge advances about the preferred mix of fuels and technologies for the low-carbon transition, the value of this information-eliciting objective will decline. As this occurs, preferred policies will shift away from fuel neutrality toward policies that manage the transition to the preferred endpoint effectively and efficiently.

2. Policy Scope

Defining the appropriate scope of the policy will be a continuing challenge, whose specific requirements shift over time as particular technologies advance. As long as the LCFS continues as a separate policy imposing high marginal costs on transport fuel emissions, it must continue to define the boundary between transport fuels and the rest of the economy, and to defend this boundary from attempts at arbitrage to exploit the large marginal-cost disparity.

ARB has successfully defended the policy's boundaries thus far, but its precise scope decisions appear mainly to have addressed concerns about short-term credit shortages. With the credit clearance mechanism easing this concern, other issues will figure more prominently in future scope-related decisions. Expected higher credit prices will strengthen incentives both for alternative fuel development, and for other activities that are not, or are not necessarily, aligned with the policy's goals: developing technologies and systems that blur the boundary, as well as shuffling and other forms of leakage. Under these conditions, boundary-drawing challenges will be more severe, but in ways that are highly technology-specific.

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Some boundary-drawing challenges are concrete and immediate, some more speculative and longer-term. Near-term challenges include maintaining incentives for further emissions reductions in alternatives where the LCFS has weak ability to do so, like usage patterns and the primary source energy for electrical and hydrogen vehicles. These further reductions may depend on other policies targeting electricity generation, or new policies targeting transport-electricity interactions such as charging patterns for EVs. Further in the future, boundary-drawing challenges may include how to maintain incentives for low-CI fuel development in areas left behind by possible large-scale technology shifts, e.g., for other modes if electricity comes to dominate light-duty vehicles; and deciding how large or fast a shift to a particular alternative the LCFS should promote to avoid premature commitment to a potentially sub-optimal endpoint. This may be a particular concern for carbon capture and removal, which may be capable of rapid expansion at near-constant marginal cost, but represent a compromise with the core goal of cutting transport emissions. Expansive LCFS crediting of carbon removal with only administrative or contractual linkages to fuel production could inadvertently steer toward a future transport sector with substantial continuing fossil fuel use, deemed to be offset by removals elsewhere. Absent an explicit judgment in favor of such a system, crediting decisions for remote carbon removals should proceed cautiously in view of the possibility for such strong response.

3. Target Trajectory

Achieving large reductions in fuel emissions is a long game, relative to which year-to-year progress and fluctuations are imperfect measures of progress. Target adjustments thus far have mainly responded to legal challenges and concern about short-term credit shortages, which are now likely to be less salient considerations. As targets tighten, sustained higher credit prices are both likely, and necessary to create incentives for needed investments and innovations. But future progress in low-CI alternatives, and thus the trajectory of future credit prices, remain unavoidably uncertain. ARB thus needs to retain the ability to adjust previously announced target schedules in response to large departures from projected progress. Given this uncertainty, the most basic design decision regarding targets is how to set the advance schedule relative to current projections of future progress: should the initial target schedule be biased toward greater ambition, with accompanying risk that future relaxations will be needed; or toward less ambition, with increased risk that future tightening will be needed?

Analyzing this decision in terms of the relative costs of the two types of error, the cost and disruption from initially stating an ambitious trajectory then later making small relaxations as needed are likely to be less severe than those from starting too weak and later tightening. On this basis, we propose that initial target schedules should be set on the ambitious side relative to present projections of likely progress. For proposed targets through 2030, this reasoning suggests that ARB's 20 percent proposal is on the conservative side, and they should consider a somewhat more ambitious trajectory with targets a few points beyond 20 percent CI reduction by 2030. If small future relaxations are later required, these can be accomplished in three ways: by relaxing the carry-forward limit on the credit clearance mechanism, subject to some conditions; by explicit small reductions of future targets; or by small scope expansions to include additional low-CI fuels or uses, including limited expansions of credit eligibility for carbon capture and removal. Whatever method is considered, ARB must vigilantly resist too-easy or too-early relaxation, as sustained high credit prices will be needed to generate desired development and investment in low-CI alternatives.

This interaction does not argue against the value of strong sectoral policies like the LCFS where conditions warrant them, but it does counsel against including the same activities under both a strong sectoral policy and a broad cap.

4. Interaction with Related Policies

The LCFS will continue to operate in the context of other related policies, including the federal RFS and California's cap-and-trade system as well as LCFS-like policies adopted in other jurisdictions. The major interactions with RFS and cap-and-trade and their implications for policy design are now relatively clear. A strengthened RFS that provided more effective incentives for low-CI biofuels would help promote LCFS aims and share compliance burden. Absent such improvements, however, the RFS is likely to play a declining role in supporting LCFS as its targets tighten. Regarding cap-and-trade, the theoretical arguments that the LCFS impairs cap-and-trade effectiveness by depressing allowance prices are strong, even if empirical evidence does not yet clearly distinguish this from other possible causes of low allowance prices. This interaction does not argue against the value of strong sectoral policies like the LCFS where conditions warrant them, but it does counsel against including the same activities under both a strong sectoral policy and a broad cap. If such double coverage is for practical purposes unavoidable, the resultant downward pressure on the allowance price can be mitigated by creating a mechanism to adjust the broad cap to track reductions achieved under the narrower sectoral policy. Although detailed modeling would be needed to estimate the quantitative response to such an adjustment mechanism, the likelihood of inelastic allowance demand suggests that concerns about reduced auction revenue need not be a barrier to consideration of such an adjustment mechanism.

The initial aim that the LCFS should provide a model for adoption in other jurisdictions is being realized,[232] with similar policies enacted or in development in several jurisdictions. Potential interactions of the LCFS with these parallel policies raise more substantial uncertainties than its interactions with RFS and cap-and-trade, of which two are especially prominent. First, it has been periodically proposed that these policies should be linked by inter-jurisdictional trading of credits. Such linkage would create larger and more liquid credit markets, but would require both careful control of trading and accounting mechanisms to prevent double-counting, and coordination of policy stringency and design.[233] Recent linkage of California's cap-and-trade system with Quebec and Ontario provides parallel experience of some relevance, although the structures of the policies are different. LCFS linkage is not practical thus far, however, due to

232 See 2009 Initial Statement of Reasons, supra note 43, at ES-4.
233 Yeh et al., supra note 167, at 231.

inconsistencies in policy design, so linked markets might present large arbitrage opportunities. Most notably, the policies in force in British Columbia and Oregon, and proposed in Canada, differ from California's in excluding indirect land-use change from calculated fuel CI.[234]

The more immediate uncertainties from additional LCFS policies, particularly in large jurisdictions like Canada, concern effects on low-CI fuel markets, including interactions between new fuel supply and shuffling. Of the criticisms advanced against the LCFS, one of the best founded is that its achievements are over-stated due to fuel "shuffling." We discussed concerns about shuffling petroleum fuels above, but it is not limited to them. Shuffling is a particularly direct form of emissions leakage, an artifact of policies enacted in jurisdictions that are smaller than relevant markets. It can occur when one jurisdiction enacts a policy that confers value on an environmental attribute that varies across existing production of the good, as the LCFS confers value on lower-CI fuels. In addition to the incentives the policy creates to reduce fuel CI and expand production of low-CI fuels, it then also creates incentives to re-allocate existing production to direct lower-CI fuel to California and higher-CI fuel elsewhere. Both responses are bound to occur, with the effectiveness of the policy depending on their relative size. One reason the LCFS decided to assess petroleum fuels by statewide average CI rather than individualized pathways was the expectation that shuffling of crude sources would dominate the response to individualized pathways. Some amount of shuffling is also surely present in responses of other fuel markets to LCFS, but the difference between newly motivated low-CI production and moving existing production around cannot be observed except imperfectly and anecdotally, so the relative size of the two responses is uncertain.[235]

LCFS policies in other jurisdictions and tighter California targets will both increase demand for low-CI fuels. They will thereby strengthen incentives for production, investment, and innovation in low-CI fuels, and bid up their price to the extent production cannot expand apace. They will also increase incentives for shuffling, as other jurisdictions compete with California for both newly produced and shuffled fuels. But because shuffling is by definition an artifact of CI variation among the existing fuel supply mix, shuffled fuels are in fixed supply. The opportunity for shuffling will thus decline in relative terms as markets for low-CI fuels expand. The same will apply to low-CI fuel sources that represent real reductions but are in relatively fixed supply and thus have limited prospects for future expansion, such as fuels produced from used cooking oils and other fats. While reducing the importance of such deceptive or quantity-limited reductions will enhance understanding of progress and the effectiveness of incentives, this process will also carry additional challenges, to the extent expanded demand reveals worse than anticipated difficulties in expanding production of low-CI fuels with greater long-term promise. Tighter targets and expansion of new parallel policies will thus both strengthen incentives for low-CI fuel development, and sharpen the question of LCFS's ability to motivate large-scale innovations as opposed to incremental improvements—a question that neither the LCFS's early achievements nor its early struggles fully resolve. This will represent an additional source of uncertainty in future credit markets, although the response mechanisms already discussed—the credit clearance mechanism plus ARB's discretion to make small target relaxations under conditions of sustained shortage—are likely to provide adequate ability to respond to these conditions, as they do to uncertainties generated solely within California's credit market.

The opportunity for shuffling will decline in relative terms as markets for low-CI fuels expand.

234 Christensen & Hobbs, supra note 161, at 800.

235 Shuffling may be a particular concern in LCFS-like policies enacted in jurisdictions that are major net fuel exporters. This is not a concern in California, but would apply strongly, for example, to the proposed Clean Fuels Standard in Canada. Because the LCFS is a consumption-side policy, its application in a jurisdiction with large ability to re-allocate fuel between domestic and export markets, either by physical movement or accounting convention, would leave large opportunities for such re-allocation to overwhelm claimed reductions unless emissions accounting relative to jurisdictional boundaries is rigorously controlled.

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