BATES WHITE
ECONOMIC CONSULTING

Low Carbon Fuels Standards Market Impacts and Evidence for Retail Fuel Price Effects

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I. Executive Summary

California's Low Carbon Fuel Standard (LCFS) Program was the first comprehensive state initiative to promote the development, production and use of low-carbon transportation fuels, aimed at progressively reducing the carbon intensity of transportation fuel in the state. The program provides a technology-neutral, flexible, and consequently efficient, mechanism to advance decarbonization of the transportation sector, and has successfully spurred the expansion and diversification of low-carbon fuels since its introduction in 2011.

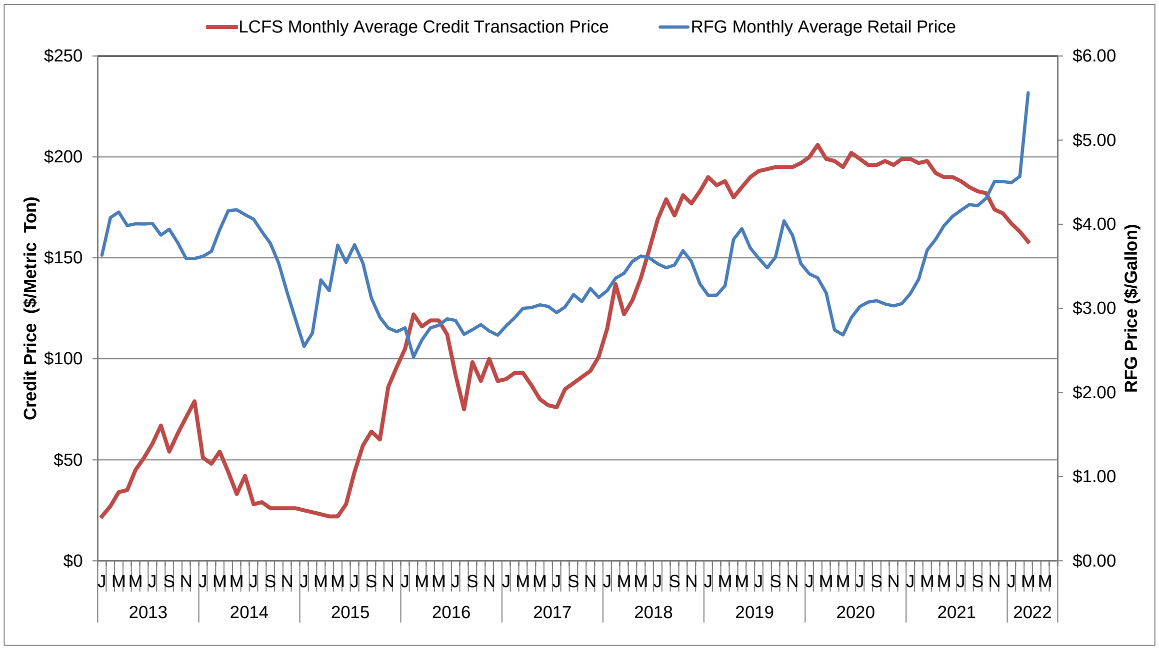
As other states explore the value of implementing clean fuel standards (CFS) programs, there is a corresponding interest in understanding the potential costs of decarbonizing transportation fuels through such a mechanism, and particular attention to the experience to date in California. Consumer prices of fuel in California are higher than any other state (except Hawai'i). This was true before the LCFS was implemented and it remains true today. However, a closer examination of the California program demonstrates that current pricing of low-carbon fuel alternatives relative to petroleum fuels offer consumers price savings.

Bates White was engaged by the Low Carbon Fuels Coalition to evaluate the primary drivers of transportation fuel prices in the state and to determine whether the California LCFS program has a discernible impact on retail gasoline pricing. The following is a summary of findings:

- The primary driver of fuel price movements is the cost of crude oil, while other California-specific factors, such as taxes and the Cap-and-Trade Program for greenhouse gas emissions have readily-quantifiable impacts on retail fuel prices. The combination of crude oil price, Cap-and-Trade costs and taxes explains fully 90% of regular gasoline pricing over time.

- An examination of historical data on the components of retail gasoline prices in California shows that the residual "unexplained" price, which encompasses all pricing factors that cannot be directly quantified, has grown in recent years, but is not linked to the implementation of LCFS or administration of the program over time. Compared to the four years prior to LCFS implementation, the first four years of the program saw a *decrease* in the margin of retail gasoline price over wholesale spot price, indicating clearly that LCFS was not responsible for increasing retail prices.
- From a consumer perspective, renewable fuels induced under the LCFS program currently provide cost savings relative to petroleum fuels. In particular, renewable diesel and E85 provide lower-cost alternatives to petroleum diesel and gasoline, respectively. Consumers can avoid any potential LCFS-related cost, and indeed enjoy a net benefit from lower fuel prices, by accessing these alternative fuels.
- The California LCFS Program has induced substantial growth and diversification in alternative transportation fuels, including electricity, that mitigate compliance costs and also reduce price impacts by increasing the volume of fuel in the market.
- An assessment of observed market prices shows conclusively that the LCFS program price effect at the pump is not a significant driver of retail fuel prices in California. Though retail fuel prices in California are high relative to other states, there is no statistically significant correlation between the price of LCFS credits and the price of retail gasoline, which are shown in Figure 1 for the period 2013 through March 2022.

Figure 1: LCFS Credit Price and Retail Gasoline Price[1]



- Recent price spikes in petroleum prices, particularly following Russia's invasion of Ukraine, demonstrate that fuel prices remain primarily a function of prices set in global markets. The recent market turmoil highlights the value of alternative fuels programs – in diversifying transportation fuels away from fossil sources, enhancing consumer access to cheaper alternatives fuels, and reducing U.S. reliance on other petroleum producing countries.

II. Introduction and Overview of Low Carbon Fuels Standard Programs

A low carbon fuels program, or low carbon fuel standard, is a policy that requires transportation fuels to meet a certain energy-related greenhouse gas (GHG) target, such

[1] LCFS credit prices via CARB (https://ww2.arb.ca.gov/resources/documents/weekly-lcfs-credit-transfer-activity-reports); CaRFG prices from EIA.

as a specific carbon intensity (CI), within a specified jurisdiction and timeframe.[2] Currently, some states such as California have established an LCFS, while others such as Minnesota, New Mexico, New York, and Colorado are considering its adoption.[3] In summary, objectives of low carbon fuels programs include:

- Decarbonization of transportation fuels
- Reduction of criteria pollutants and toxic air pollutants from transportation fuel emissions
- Increased demand for and production of low carbon fuels
- Reduced demand for and production of fossil fuels
- Diversification of fuel supply and enhancement of fuel security

The LCFS provides a technology-neutral, flexible, and consequently efficient, mechanism to advance decarbonization of the transportation sector.

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[2] Congressional Research Service, "A Low Carbon Fuel Standard: In Brief". Available at: https://sgp.fas.org/crs/misc/R46835.pdf. Minnesota, New Mexico, New York have active clean fuel standard bills under consideration in 2022.

[3] *Id.*

III. The California LCFS Program

A. Overview

The California LCFS is a market-based program created to reduce the state's GHG emissions and other smog-forming and toxic air pollutants by improving vehicle technology, reducing fuel consumption, and increasing transport mobility options.[4] Under the California Global Warming Solutions Act of 2006 (Assembly Bill 32 or AB 32), the California Air Resources Board (CARB) identified LCFS as one of the nine discreet early action measures taken to reduce California's GHG emissions which cause climate change.[5] The specific focus of this program is on reducing the CI of California's transportation fuel pool and providing an increasing range of low-carbon and renewable alternatives, in order to reduce petroleum dependency and achieve air quality benefits.[6]

B. Implementation mechanism and timeline

The LCFS sets annual CI benchmarks for gasoline, diesel, and the fuels that replace them, with the benchmarks decreasing over time.[7] The CI is expressed in grams of carbon dioxide (CO_2) equivalent per megajoule of energy provided by the fuel (gCO_2/MJ), based on the principle that each fuel has 'life cycle' GHG emissions that include CO_2, methane (CH_4), nitrous oxide (N_2O), among others.[8] This life cycle assessment using CI examines the GHG emissions associated with the production, transportation, and use of a given

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4 California Air Resources Board, "Low Carbon Fuel Standard: About". Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about

5 California Air Resources Board, "Low Carbon Fuel Standard: About". Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about

6 California Air Resources Board, "Low Carbon Fuel Standard: About". Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about

7 California Air Resources Board, "LCFS Basics". Available at: https://ww2.arb.ca.gov/resources/documents/lcfs-basics

8 California Air Resources Board, "Low Carbon Fuel Standard: About". Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about

fuel.[9] Significant indirect effects on GHG emissions, such as changes in land use for some biofuels, are also taken into account.[10]

The CI score for every fuel is compared to a benchmark which declines each year. The fuels which have a CI higher than the benchmark for that year generate deficits, while those with a CI lower than the benchmark generate credits. For each compliance period, transportation fuel providers must demonstrate that the mix of fuels they supply for use in California meets the CI standard. If the regulated party is a deficit generator, it can achieve annual compliance by ensuring that the amount of credits it has earned or acquired from another party is equal to or greater than the deficits it has incurred.[11] The LCFS allows the market participants to determine the mix of fuels they will be using to reach the program targets.[12]

The adoption of the LCFS in California has led to an increase in the use of low carbon fuel and has incentivized fuel producers to decrease the CI of their fuels. A noteworthy aspect of the program, since its first adoption, has been the 'back-loading' of compliance curves to allow time for the development of low-CI fuels and advanced vehicles. This is evident in the three-year period from 2013 to 2015, when the benchmark CI was frozen by court order. This program design choice has led to an expectation that excess credits generated in the early years of the program would be available for use in more stringent future years, if needed.[13]

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9 California Air Resources Board, "LCFS Basics". Available at: https://ww2.arb.ca.gov/resources/documents/lcfs-basics

10 California Air Resources Board, "Low Carbon Fuel Standard: About". Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about

11 California Air Resources Board, "Low Carbon Fuel Standard: About. Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about

12 California Air Resources Board, "LCFS Basics". Available at: https://ww2.arb.ca.gov/resources/documents/lcfs-basics

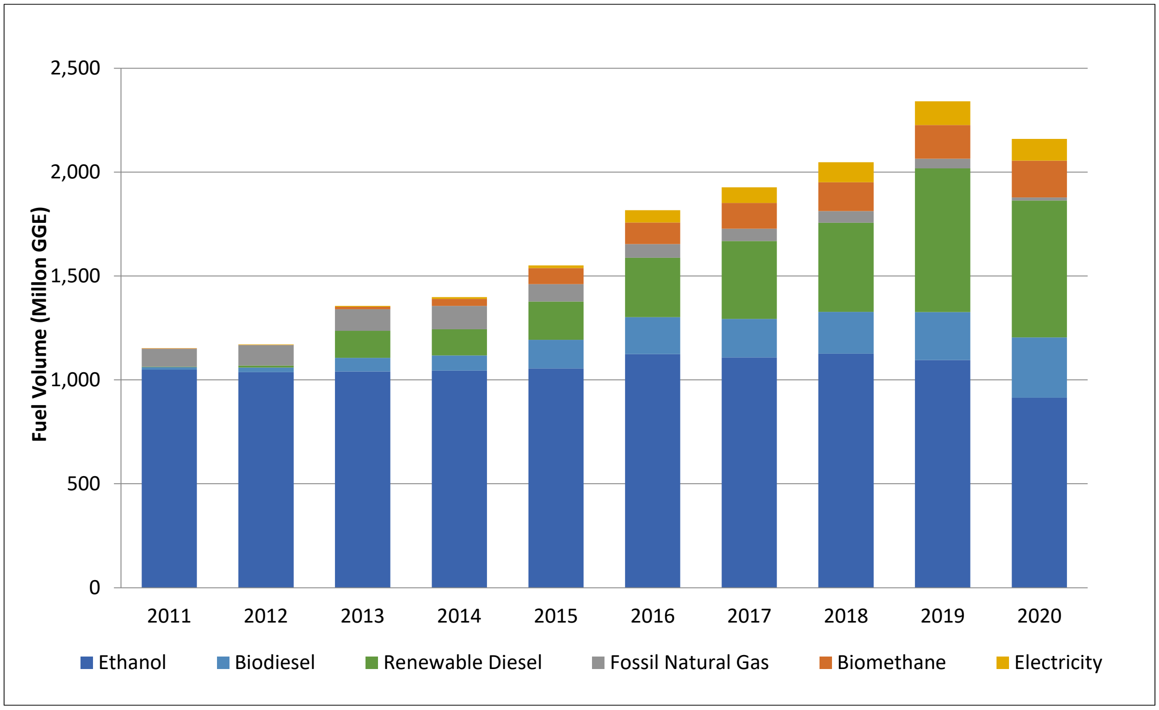
13 California Air Resources Board, "LCFS Basics". Available at: https://ww2.arb.ca.gov/resources/documents/lcfs-basics

The LCFS was originally adopted in 2009, with implementation beginning in January 2011. The program was amended in 2011 and re-adopted in 2015, with further amendments in 2018 and 2020. A summary of these milestones is provided in the Appendix.

C. Summary of California LCFS program data

Prior to implementation of the LCFS program, California fuel standards, including the phase-out of methyl tertiary butyl ether (MTBE) as an oxygenate additive in gasoline at the end of 2003, resulted in significant quantities of ethanol being blended in gasoline – at approximately 10% by volume. Implementation of LCFS requirements has promoted substantial growth in the use of other low-carbon intensity transportation fuels, particularly renewable diesel, biomethane (renewable natural gas/RNG), biodiesel and electricity. Figure 2 shows the volume of non-petroleum transportation fuels (in gasoline gallon equivalents) used in California from 2011 through 2020.

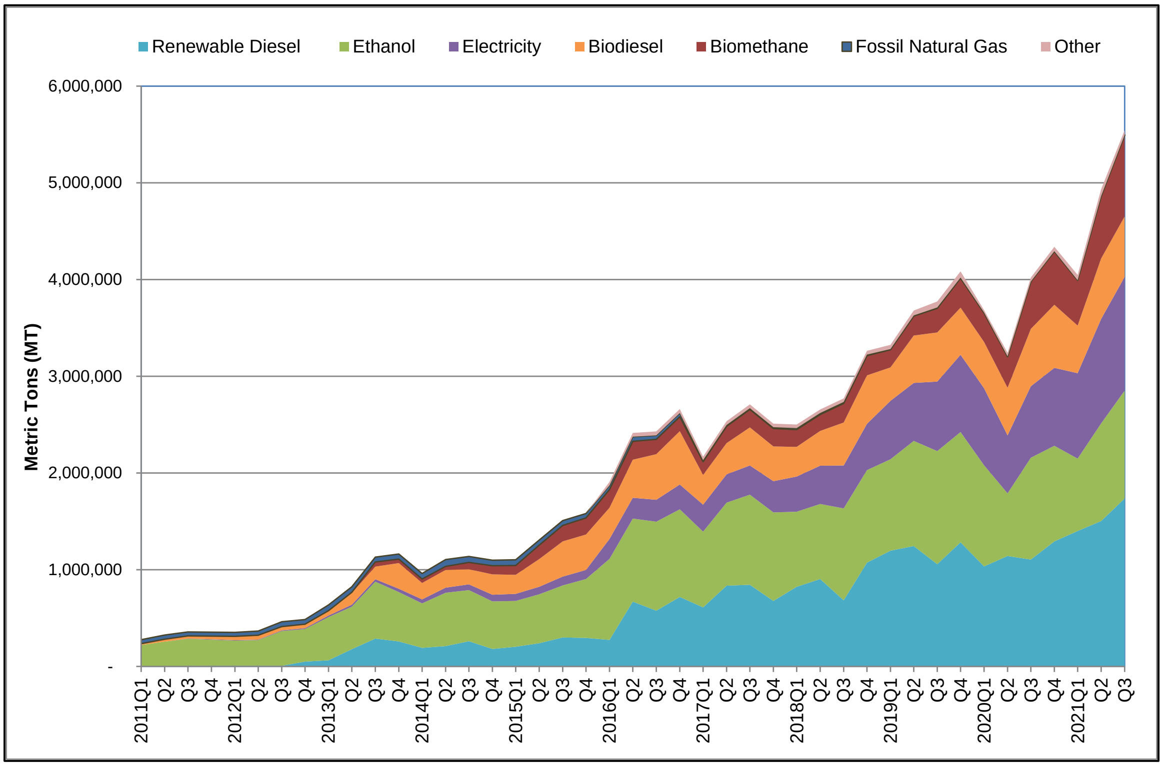
Figure 2: California LCFS Alternative Fuels Volumes by Year (MM GGE)[14]



The total volume of LCFS credits has grown to more than 17 million metric tons on an annual basis, with a substantial diversification of credits across fuel types other than ethanol. Figure 3 shows the credits produced from each fuel type by quarter beginning in 2011.

[14] CARB, https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard.

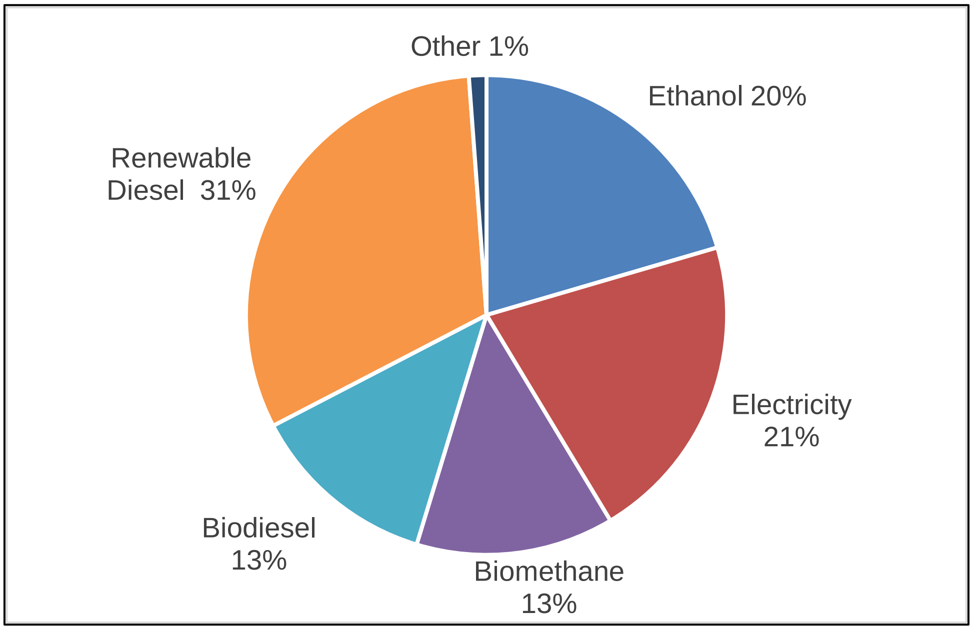
Figure 3: LCFS Credits by Fuel Type, by Quarter (Metric Tons)[15]



Based on the most recent available data, through Q3, 2021, ethanol represented approximately 20% of LCFS credits, compared to 79% at the beginning of 2011. The LCFS program has prompted substantial diversification of alternative fuels with lower carbon intensity that consequently generate more LCFS credits per gallon. Renewable diesel, with an average carbon intensity less than a third that of petroleum diesel, accounted for 31% of LCFS credits over the most recent annual period, while electricity represented 21% of the total. The percentage shares of LCFS credits over the four quarters through Q3 2021 are shown in Figure 4.

[15] CARB, https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard.

Figure 4: Annual Share of LCFS Credits by Fuel Type, Through Q3 2021[16]



LCFS has been successful in promoting significant displacement of petroleum fuels. Figure 5 shows the combined volumes of petroleum gasoline (designated CARBOB, referring to CARB specification gasoline before oxygenate blending, BOB) and diesel fuel in liquid gallons, with estimated volumes of displaced petroleum fuel in gasoline gallon equivalent.

[16] CARB, https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard.

Figure 5: Petroleum Fuel Displacement[17]

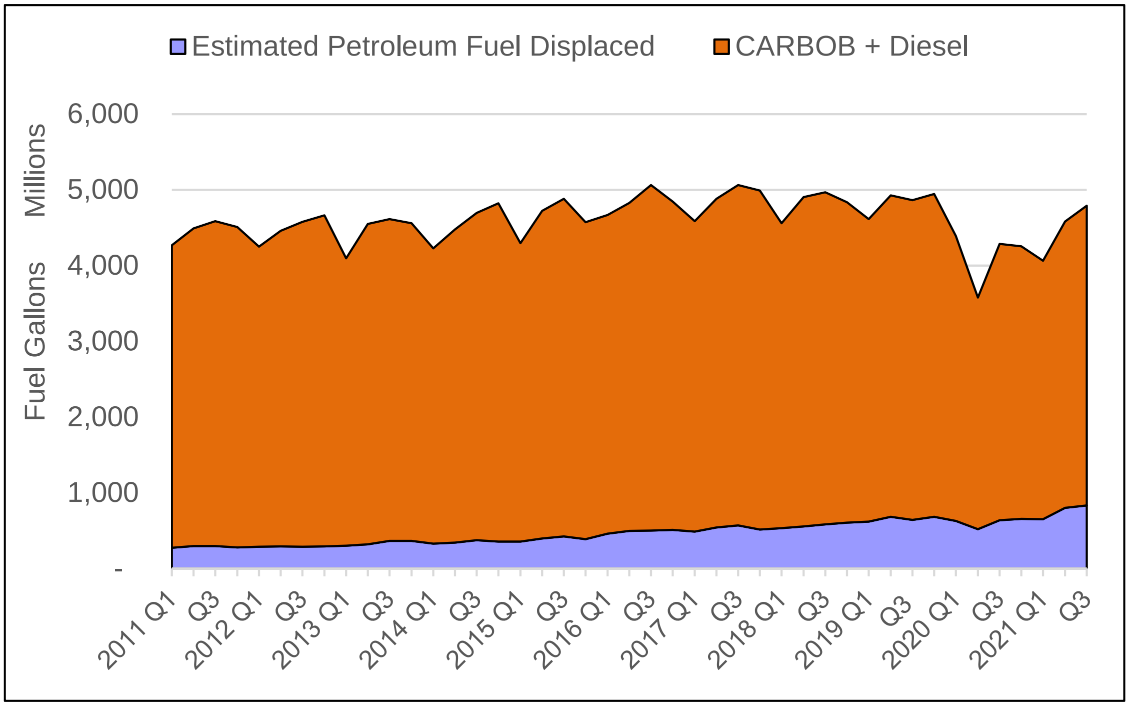
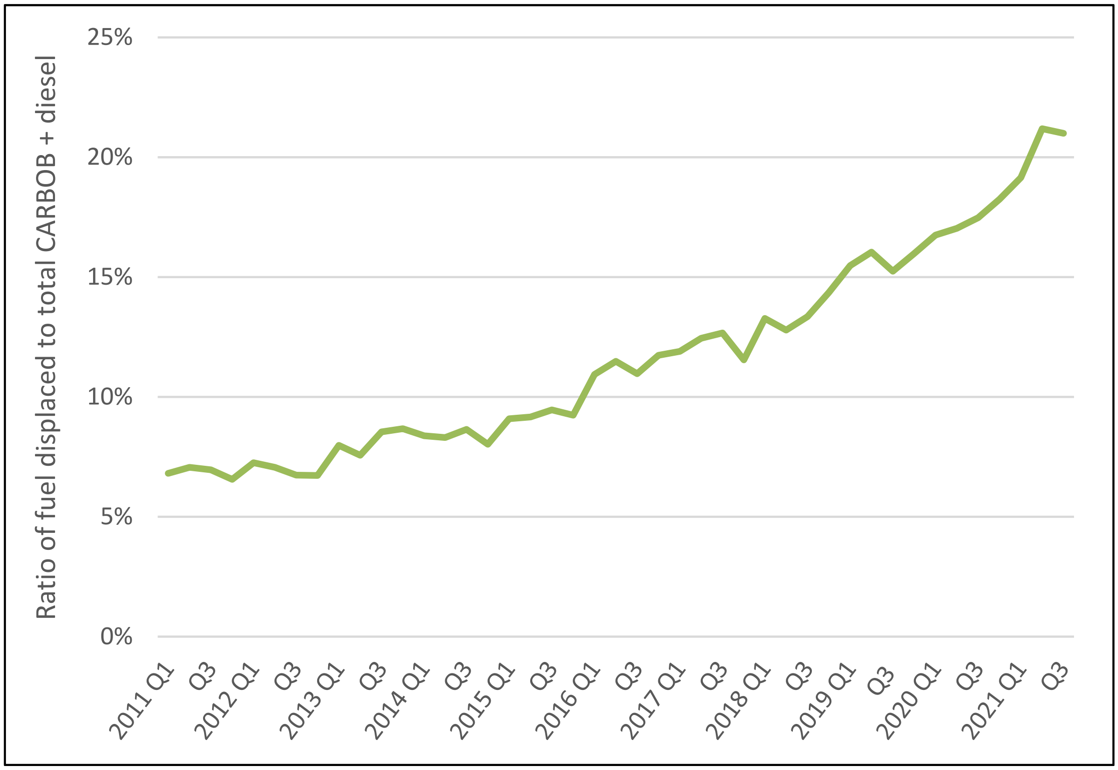


Figure 6 shows the continued, in fact accelerating, growth of displaced petroleum fuel relative to total petroleum fuel in the California market.

[17] CARB, https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard.

Figure 6: Ratio of Displaced Fuel to combined CARBOB and Diesel Volumes[18]



The data presented above indicate that the California transportation fuels market has changed substantially over the nearly eleven years of LCFS implementation, consistent with the intent of the program:

- Increasing volumes of low carbon intensity fuels have been drawn into the market;
- There has been substantial diversification of alternative fuels, with five distinct types each exceeding 10% of the LCFS credit pool;
- Alternative fuels with low carbon intensity, such as renewable diesel and electricity, have achieved growing shares of the transportation fuels market;

[18] CARB, https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard.

- Renewable diesel and biodiesel have grown to represent approximately 29% of the total transportation diesel pool.[19]
- Significant volumes of petroleum fuel have been displaced.

Impacts of the LCFS program on the fuel costs borne by consumers are more challenging to evaluate because of the range of factors that drive fuel pricing in the California market. The next section of this report provides an overview of the market context and key price drivers, followed by an analysis of price effects that can be linked to the LCFS program specifically.

IV. Significant Drivers of California Fuel Prices

The California market for transportation fuels is distinguished by its large size and other distinct features – particularly state fuel blend specifications – that increase the cost of producing, distributing and retailing fuels in California relative to other U.S. states. The isolation of the California market, and its reliance on a small number of large refineries means that it is exposed to substantial price effects from supply disruptions, and those market effects may persist well beyond resolution of the supply disruption. State taxes on fuel are also substantially higher in California than the U.S. average.

As we quantify in Section VI, costs specific to complying with LCFS requirements are a small component of retail pump prices, whether the effect is assessed based on empirical price data where the LCFS product is not quantifiable, or based on a calculation of maximum potential impact.

Significant factors influencing transportation fuel prices in California are summarized below.

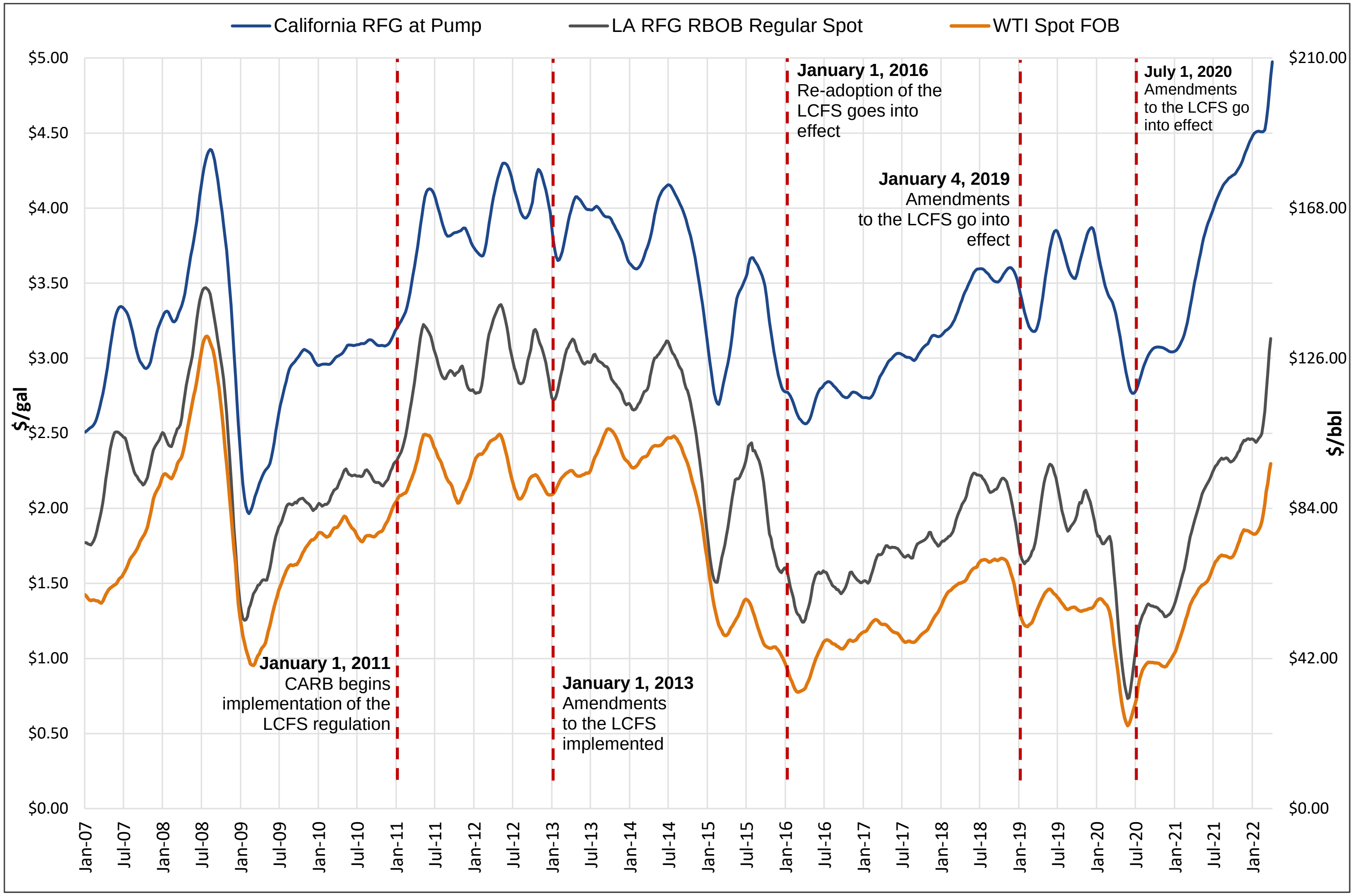
[19] Based on four quarters through Q2 2021; CARB data for biodiesel and renewable diesel as a share of California diesel sales from EIA.

A. Crude Oil Price

The primary driver of both petroleum spot prices and blended retail fuel is the underlying crude commodity price. This is evident in Figure 7, which shows 3-month rolling average prices for West Texas Intermediate crude (WTI), shown in $/barrel on the right vertical axis (and equivalently in $/gallon on the left vertical axis), the spot price for Los Angeles RBOB reformulated gasoline, and retail RFG at the pump.

In statistical terms, the correlation coefficient between the WTI and RFG pump price series in the figure is 0.70, which can be interpretated to say that 70% of the variation in retail pump prices is explained by contemporaneous changes in the WTI crude price.

Figure 7: California Gasoline Pricing, 3-month Rolling Average, Through March 2022



B. CaRFG fuel blend specifications

Beginning in 1992, California implemented state-specific blend specifications for motor gasoline – the California Reformulated Gasoline (CaRFG) regulations – intended to reduce smog-forming emissions. Expanded requirements were promulgated in 1996 and 2003, addressing a range of fuel additives, establishing regulations by season, and extending evaporative emissions restrictions to refineries and all other regulated properties.[20] California's warm climate also means that summer-blend gasoline is required over a longer period than in other states with seasonal smog-mitigating fuel requirements.

The standards for CaRFG and evaporative emissions limits increase the cost of production and distribution of gasoline in California relative to other states, typically amounting to a 10-15 cents per gallon price difference between California and the U.S. average. [21]

C. California excise and sales taxes

Combined state excise taxes and local sales taxes are significantly higher in California than for most other U.S. states. The current California excise tax rate is $0.51 per gallon, which has risen 45% since 2011, while the average sales tax is approximately 2.25%, which adds another $0.08 per gallon, roughly.[22] California's combined tax on gasoline of

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[20] CARB; https://ww2.arb.ca.gov/our-work/programs/fuels-enforcment-program/california-reformulated-gasoline

[21] California Energy Commission, *California's Petroleum Market.* Available at: https://www.energy.ca.gov/data-reports/energy-almanac/californias-petroleum-market

[22] California Energy Commission, *Estimated Gasoline Price Breakdown and Margins.* Available at: https://www.energy.ca.gov/data-reports/energy-almanac/transportation-energy/estimated-gasoline-price-breakdown-and-margins

$0.59 per gallon is nearly double the average gasoline tax rate of $0.30 per gallon in other states, based on data as of August 2021.[23]

D. Isolation of the California fuels market

While fuel refineries in California are typically able to supply sufficient gasoline to meet in-state demand as well as to export fuel outside the state, the limited refinery capacity able to produce fuel to required specifications means that refinery disruptions can have significant market impacts. The three largest California refineries account for 51 percent of total state refinery capacity for CARB reformulated gasoline, and the five largest refineries account for 70 percent.[24] Unplanned refinery outages have substantial impacts on supply and market prices, because alternative sources of supply are distant, and securing and delivering product that meets California fuel specifications requires significant advance notice. When local production is insufficient, California imports gasoline, typically from international sources via marine shipments that require two to three weeks between order and delivery. The higher cost of purchasing and delivery these international shipments can drive transitory but significant price spices following refinery outages, whether for periodic maintenance or because of unplanned events.[25]

E. Cap-and-Trade Program

California's Cap-and-Trade (C&T) Program, which specifies declining limits on statewide greenhouse gas (GHG) emissions, was implemented beginning in 2013 and extended to encompass transportation fuel as of January 1, 2015. Fuel suppliers must report GHG emissions from supplied fuel, and are obligated to secure and surrender a corresponding number of allowances and offset credits for each compliance period. The

[23] EIA; https://www.eia.gov/petroleum/marketing/monthly/xls/fueltaxes.xls.

[24] California Energy Commission; https://www.energy.ca.gov/data-reports/energy-almanac/californias-petroleum-market/californias-oil-refineries

[25] California Energy Commission, *Estimated Gasoline Price Breakdown and Margins.* Available at: https://www.energy.ca.gov/data-reports/energy-almanac/transportation-energy/estimated-gasoline-price-breakdown-and-margins

C&T compliance cost per gallon of fuel is a relatively straightforward calculation based on the GHG emission rate and the going allowance price. The estimated "cap-at-the-rack" price effect for in November 2021 was approximately $0.24/gallon, based on the monthly auction settlement price of $28.26/MT.[26]

V. Additional Factors That May Impact Retail Gasoline Prices But Cannot Be Directly Isolated

If the effects of California state taxes and the Cap-and-Trade Program are combined with the fundamental crude price, these factors explain more than 90% of the observed retail price movements from 2007 to 2021. The remaining 10% of price changes reflect a range of variable price factors, including the cost of fuel additives, costs and profit margins for refining, distribution and retailing, supply disruptions, and possible effects from the LCFS program. These are factors that cannot be directly isolated as components of the retail fuel price. In section VI, below, we analyze pricing data to estimate a residual element of retail gasoline prices that would include LCFS effects as well as other factors. Additional price components and drivers are summarized below.

A. Costs and Profit Margins for Refining

The California Energy Commission reports on gasoline price components, including "refiner margin," but uses that term as the cost of refining crude into finished product and refiner profit margins on a combined basis.[27] There are no publicly-available data that distinguish the components of the refiner margin.

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[26] CARB, https://ww2.arb.ca.gov/sites/default/files/cap-and-trade/carbonallowanceprices.pdf.

[27] CEC, "Estimated Gasoline Price Breakdown and Margins."; https://www.energy.ca.gov/data-reports/energy-almanac/transportation-energy/estimated-gasoline-price-breakdown-and-margins.

B. Costs and Profit Margins for Distribution and Retailing

Distribution and retailing margins are similarly considered inclusive of profit margins. Retailing and distribution includes various transportation and storage fees incurred once gasoline is moved from the bulk terminal, as well as marketing, and costs and profits of operating retail gas stations.[28] Environmental regulations aimed at controlling emissions of smog-forming volatile organic compounds (VOCs) impose restrictions on transportation and storage that tend to add to distribution and retailing costs.

C. Fuel Additives

Additives to refined gasoline include oxygenates and proprietary fuel additives that may be incorporated in branded fuel. Rules governing reformulated gasoline require oxygenation, which causes fuel to burn more cleanly than conventional gasoline, reducing emissions of VOCs and nitrogen oxides. The primary oxygenate blended in reformulated gasoline is ethanol.

D. Supply Disruptions

The isolation of the California market, noted above, is a cause of price separation with other U.S. states. It also allows for econometric comparisons of cost drivers that are specific to the California market. As addressed in the next report section, the challenge is to quantify the distinct effects of the various influences of fuel prices. With respect to impacts from LCFS, a naïve comparison of price differentials without accounting for other cost drivers will exaggerate estimates effects from LCFS alone.

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[28] *Id.*

VI. Assessment of Retail Fuel Price Effects from the California LCFS

The potential impact of LCFS on the retail price of transportation fuel depends on a number of factors, but for any given point in time is fundamentally bounded by the cost of low-carbon alternative fuels that must be blended with petroleum-based fuels in order to achieve the specified carbon intensity reduction targets. That cost will vary according to the availability, cost and carbon intensity of alternative fuels.

Moreover, the "cost" of compliance is determined relative to relying exclusively on petroleum fuel, and when low-carbon fuels are less expensive than petroleum gasoline or diesel, as is currently the case in California, meeting LCFS targets can *reduce* retail fuel prices.

The price of petroleum fuel is determined fundamentally by world crude oil prices, which fluctuate constantly, and also by local supply influences, particularly the volume of refinery production, which has been affected by periodic plant outages in recent years. The prices of alternative low-carbon fuels can also be variable, as they depend on the price of feedstock inputs. Trends in non-feedstock costs are influenced by technological innovation and increased production scale, both of which are promoted by the LCFS program and which tend to reduce the unit cost of production and compliance costs.

A. Fuel diversification reduces compliance costs

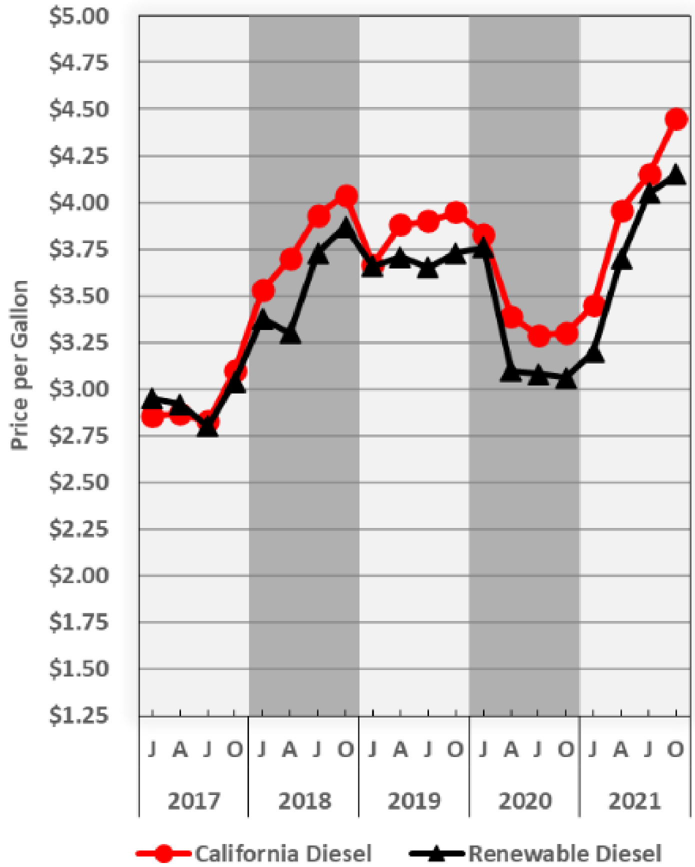
By supporting demand for low-carbon alternative fuels, and reliable revenue streams for alternative fuels producers, the LCFS program promotes increased investment in productive capacity, development of new technology and new low-carbon pathways, and improvements in productive efficiency. LCFS also creates price mitigating effects from the induced diversification and expansion of fuel supply, both of which are evident in the LCFS program summary figures in Section III.

By design, LCFS provides for diverse and flexible compliance options. In particular, because the program requires carbon intensity reductions for blended fuel without specifying volumes or shares for any particular category of alternative fuel, market participants can offer competing products to obligated parties to achieve compliance at lowest cost. As previously noted, the volume and diversity of alternative fuels have grown significantly since the implementation of LCFS. Over time, exploitation of new feedstocks, development of new and improved production methods, and the increased scale of production tend to reduce the cost of achieving carbon intensity reductions.

Both renewable diesel and ethanol currently provide lower-cost alternatives to petroleum diesel and gasoline, respectively. Consumers can avoid any LCFS compliance costs, and indeed enjoy a net benefit from lower fuel prices, by accessing these alternative fuels.

Figure 8 shows reported California retail pump prices for renewable diesel and petroleum diesel, from 2017 to 2021. For most of this period, renewable diesel has been priced lower than petroleum diesel.

Figure 8: Reported California Retail Price of Renewable Diesel and Petroleum Diesel, 2017-2021[29]



Reproduced from Clean Cities Alternative Fuels Price Report.

E85 fuel, which includes up to 85 percent ethanol, also offers California consumers potential to save money relative to petroleum fuel.[30] Retail price data show that for most of 2021 E85 was priced at a discount greater than $1 per gallon relative to regular gasoline. Even after accounting for E85's lower energy content, E85 offered a cost

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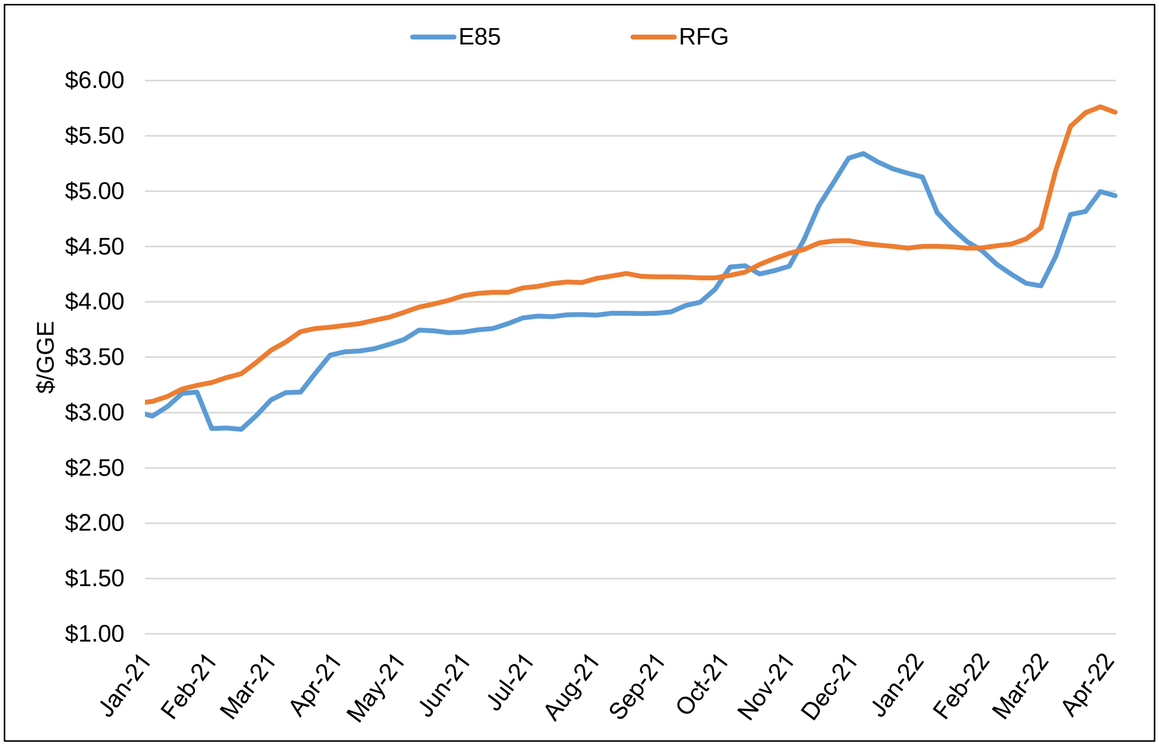
[29] U.S. Department of Energy, "Clean Cities Alternative Fuels Price Report," October 2021, figure, page 20; https://afdc.energy.gov/files/u/publication/alternative_fuel_price_report_october_2021.pdf.

[30] Nationally, E85 may contain between 51% to 83% ethanol, depending on location and season. See: https://www.eia.gov/renewable/afv/users.php?fs=a&ufueltype=E85.

advantage for consumers with the ability to switch – i.e. those with flex-fuel vehicles. Figure 9 shows reported average retail prices for E85, converted to gasoline-gallon equivalent (GGE) and for CaRFG for January 2021 through March 2022.

Figure 9: California Retail E85 and RFG Prices, 2021-22 ($/GGE)[31]



Renewable natural gas (RNG), or biomethane, also represents an economic alternative to petroleum fuel, primarily for commercial and transit use in place of diesel-fueled vehicles, and has grown significantly under LCFS, currently accounting for 12 percent of annual LCFS credits (see Figure 4). Like renewable diesel, RNG is a "drop in" fuel, indistinguishable from its fossil counterpart, and RNG can be distributed within the existing natural gas system. In recent years, the retail price of compressed natural gas (CNG) has generally been significantly below that of diesel fuel, on a diesel gallon equivalent basis (i.e. for the same energy content as a gallon of diesel). As of October

[31] Figure derived from California retail E85 data from OPIS, and RFG price data from EIA.

2021, the reported average West Coast price of renewable CNG was $2.88 on a diesel gallon equivalent basis, while diesel fuel was $4.38/gallon.[32]

B. Aggregate fuel supply effects

The increase in aggregate fuel supply induced by LCFS also has the potential to mitigate price impacts from program compliance. With multiple sources of alternative fuels, fuel buyers have the opportunity to negotiate better prices for both low-carbon fuels and for petroleum-based fuels. In practice, this negotiation effect may be muted in the California market because of the relative dominance of petroleum fuel producers who control production, distribution and retailing, either directly or through branded contract arrangements. Nonetheless, the substantial volumes of alternative transportation fuels, including electricity, that LCFS has induced mitigate price impacts simply by increasing the volume of fuel in the market.

This mitigating supply effect is enhanced by the LCFS credit banking mechanism, which allows excess credits to be banked for application in future periods. That may make it economic to over-comply now based on the availability of a low-cost alternative fuel offer, and bank the excess credits for use in a future period when the carbon intensity target is more stringent.

C. Market price data confirm that LCFS is not a major driver of California fuel prices

An assessment of observed market prices shows that the LCFS price effect at the pump is not a major driver of retail fuel prices in California. This is an important conclusion, because retail fuel prices in California are high relative to other states, but the differential is not substantially attributable to the LCFS program.

[32] The quoted price for renewable CNG is that for transportation CNG, which is 98% RNG based on the most recent four quarters of reported data, through Q3 2021. CARB, LCF Quarterly Data Spreadsheet, accessed via https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries.

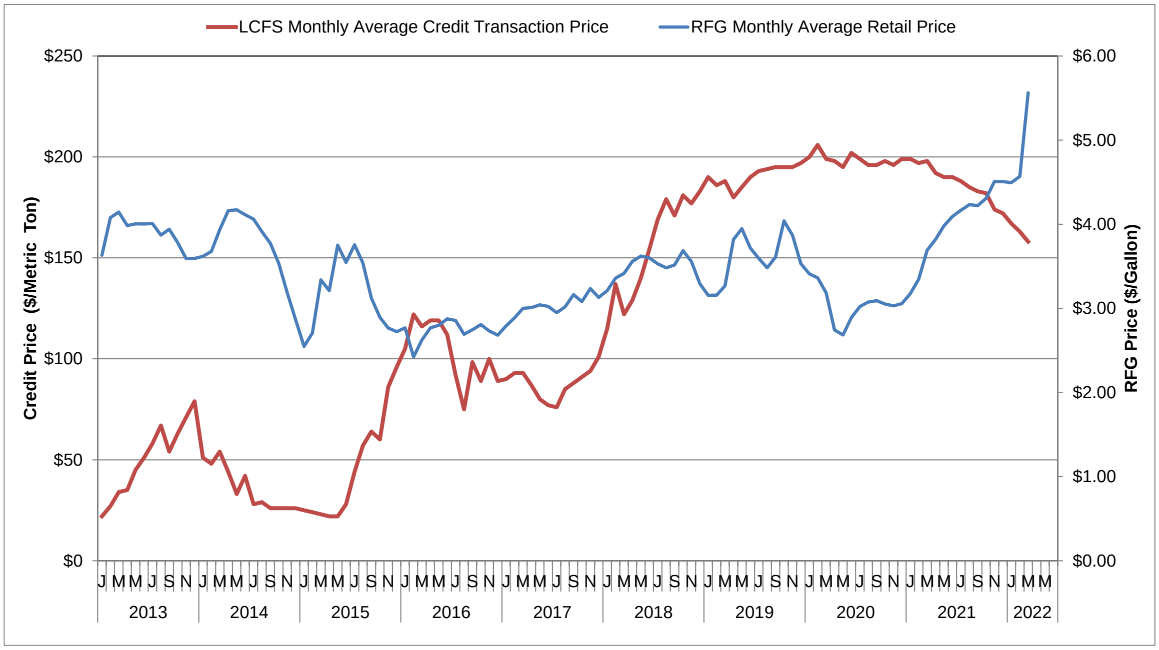
As discussed in Section IV, fully 90 percent of the price movement of retail gasoline in California is explained by a combination of crude price, state taxes and effects from the Cap-and-Trade Program.

In evaluating potential LCFS effects, it helpful to consider the context of fuel pricing in the years prior to LCFS implementation. As can be seen in Figure 7, from the beginning of 2007 to August 2008, the 3-month average price of CaRFG rose from $2.50/gallon to $4.30/gallon, then dropped below $2.00/gallon by April 2009, then rose back above $3.00/gallon before LCFS was implemented in January 2011. The margin of retail RFG price over the wholesale petroleum gasoline spot price (RBOB) also widened significantly prior to LCFS implementation, and averaged nearly $0.90/gallon over 2009-10.

D. LCFS Credit Prices Are Not Correlated with Retail Gasoline Price

Under the LCFS program, carbon-intensity reduction is demonstrated through credits that are issued to low-carbon fuels used in transportation, with fuels that provide greater carbon-intensity reduction receiving proportionally more credits. The program allows these credits to be traded separately from the low-carbon fuel, and average credit transaction prices are reported by CARB. The LCFS credit prices provide a reference for program compliance costs, though one with important caveats, discussed in Section VI.F., below. Figure 10 shows average monthly LCFS credit prices and average monthly California retail gasoline prices from 2013 through November 2021. Visually, it is evident that there is little or no relation between prevailing transaction prices for LCFS credits and retail gasoline prices. This is confirmed through a formal assessment of price correlation over the period, which gives a result of 0.06, which is statistically indistinguishable from zero.

Figure 10: LCFS Credit Price and Retail Gasoline Price[33]



E. California-Specific Factors Influencing Gasoline Prices

With respect to the assessment of California-specific effects on pump prices, the relevant part of Figure 7 is the difference between the spot RBOB price and the retail price of blended fuel at the pump. This price differential reflects the costs of blended alternative fuels and additives, costs associated with the California greenhouse gas Cap-and-Trade (C&T) Program, and taxes.

There are four broad periods with different circumstances and price periods that are relevant to the assessment of potential LCFS price effects, summarized in Table 1. The first two periods are: 1) the four year period from 2007 through 2010, prior to implementation of LCFS; and, 2) the first four years of the LCFS program, 2011 through 2014. The average price difference between the retail RFG pump price and the petroleum

[33] LCFS credit prices via CARB (https://ww2.arb.ca.gov/resources/documents/weekly-lcfs-credit-transfer-activity-reports); CaRFG prices from EIA.

gasoline spot price in the first, pre-LCFS, period – after accounting for known price effects from taxes and C&T – was approximately $0.41/gallon, and the average price difference in the second period, the first four years of the LCFS program, was approximately $0.25/gallon. Implementation of LCFS was clearly not responsible for increasing retail prices relative to spot, since the unexplained difference *decreased* in the latter period, indicating that initial implementation of LCFS had no effect on retail gasoline prices.

Table 1: Key Periods of Gasoline Price Differentials Between Retail and Spot

Period	Description	Avg. RFG price above Spot, Taxes and C&T $/gal.
2007-2010	4 years pre-LCFS	$0.41
2011-2014	4 years initial LCFS	$0.25
2015-2019	6 years pre-COVID	$0.58
2019-2020	2 years COVID	$1.04

The next period of note is the subsequent five years, from 2015 through 2019, when the unexplained retail versus spot differential was significantly higher, at approximately $0.58/gallon. However, in assessing potential LCFS impacts, the appropriate reference is the observed pre-LCFS price differential of $0.41/gallon. If that is the expected differential in the absence of the LCFS program – reflecting the range of other California-specific price factors discussed above – then is the difference between the $0.58/gallon and $0.41/gallon that is relevant, which is $0.17/gallon. During this period there were significant increases in LCFS credit prices, from below $50/MT in early 2015 up to around $100/MT, which prevailed through 2016 and 2017, then rising through 2018 to about $180/MT and then to near $200/MT by the end of 2019, followed by a decline to below $170/MT in 2021. This pattern in credit prices can be seen in Figure 10, above. Though LCFS credit prices rose significantly in the 2015 through 2019 period, the required carbon intensity reduction, and therefore the volume of credits required for compliance, remained relatively low, such that the implicit maximum LCFS price impact would have been less than $0.10/gallon over the period.

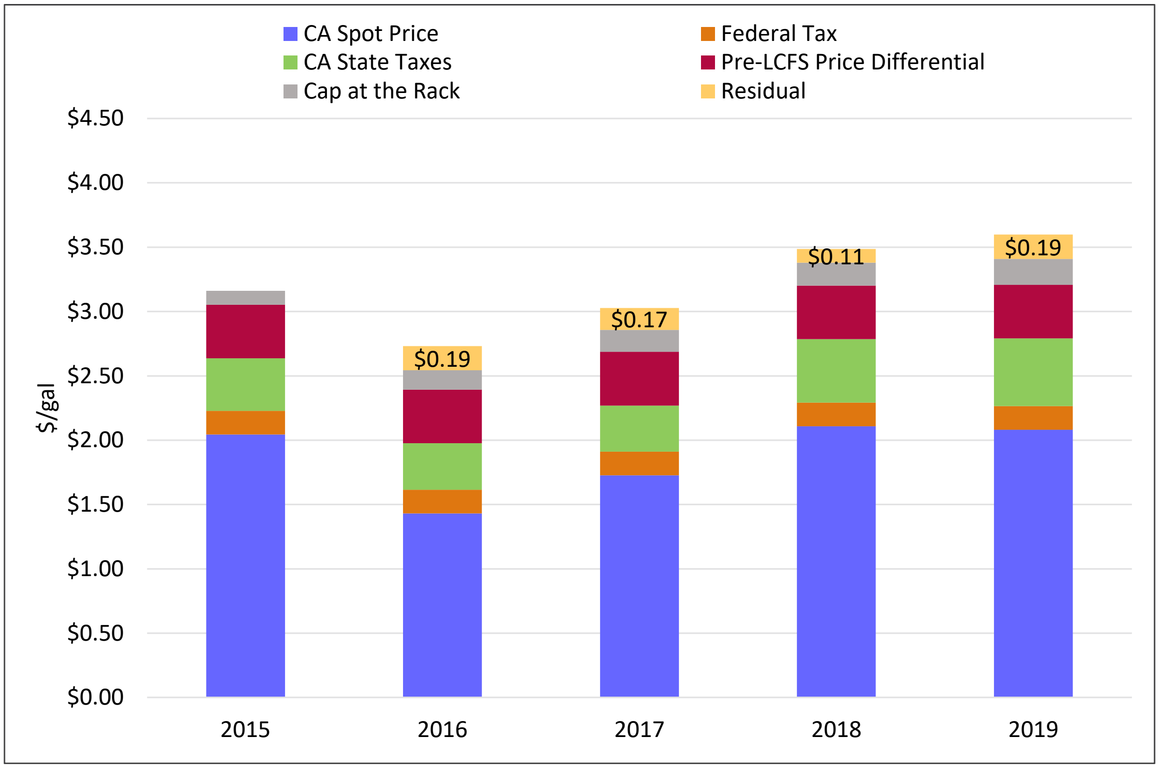
The unexplained retail price differential already accounts for effects from state taxes, which increased from approximately $0.41/gallon in 2015 to around $0.53/gallon by 2019, and also accounts for the extension of the California C&T program to encompass transportation fuel as of January 1, 2015. Estimated "cap-at-the-rack" price effects based on C&T allowance prices increased from under $0.15/gallon to approximately $0.20/gallon over this period.

An important additional event that had significant market price effects in this period was the major refinery outage in February 2015 at ExxonMobil's Torrance facility, representing approximately 20% of the region's capacity.[34] The refinery outage had a large effect on spot and retail prices, which can be seen in early-to-mid 2015 price spike in Figure 7, with spot prices increasing more than 50%, and effects continuing through the end of the year. Though the plant outage would be expected to have a direct effect only on spot prices, there was also a modest increase in the retail price differential, possibly reflecting demand chasing limited supply.

Figure 11 shows a buildup of identifiable price components making up the retail price of gasoline in California from 2015 through 2019. The figure includes the observed spot price, federal and state taxes, the estimated price effect from the C&T program, and the average pre-LCFS margin for the 2007-2010 period of $0.41/gallon. The residual "unexplained" amount, which encompasses all unquantified factors including potential LCFS effects, but also components such as increased margins, is shown as the last segment at the top of each bar, with the associated value in $/gallon.

[34] EIA, "Petroleum refinery outage in California highlights markets' quick price reaction," February 27, 2015; https://www.eia.gov/todayinenergy/detail.php?id=20152.

Figure 11: Price Components of California Gasoline, 2015-2019



F. Indicative calculation of price impact for CaRFG

As a check to the empirical analysis, it is also possible to bound the potential price impact from the LCFS program by calculating a maximum impact directly from credit prices. LCFS credit prices, expressed in dollars per metric ton ($/MT), are reported according to current period transactions. Because the prices are associated with marginal transactions – i.e. transactions needed to demonstrate compliance in the period – the prices likely represent an overestimate of the actual, average, cost of compliance, which includes the use of banked credits from prior periods.[35] The marginal credit price multiplied by the number of credits required to demonstrate compliance in each period per gallon of

[35] In the context of generally rising prices, the marginal price will always be higher than the average.

gasoline is therefore the maximum price effect assignable in principle to the effect of LCFS on retail gasoline prices.

A calculation of the maximum effect on retail gasoline prices from the LCFS program is presented in Table 2 for reformulated gasoline, applying LCFS values and credit price data for 2019, the last year before COVID-related market disruptions. As discussed further below, 2020 and 2021 are of doubtful reliability for assessing effects from the LCFS program, because of the unusual patterns of demand over two years of the COVID-19 pandemic. We estimate a maximum price impact for retail gasoline from the LFCS requirement in 2019 of $0.14 per gallon. This is close in magnitude to the empirical residual value of $0.19/gallon for 2019 shown in Figure 11, and also indicates that there are additional price factors not accounted for in that assessment.

Table 2: Calculated LCFS Maximum Gasoline Price Impact 2019

Fuel	Carbon Intensity, gCO2e/MJ	Energy content, MJ/gallon		Carbon Intensity, gCO2e/gallon
	(a)	(b)		(c)=(a)x(b)
Ethanol	58.54	80.5	(1)	4,714
Petroleum gasoline	101.00	118.3	(2)	11,946
2010 CaRFG (10% ethanol)	99.44	114.5	(3)	11,386
2019 target CaRFG	93.23		(4)	10,676
Required gCO2e reduction per gallon			(5) = (3)-(4)	711
LCFS 2019 average credit price, $/MT			(6)	$192
Maximum implicit compliance cost per gallon			(7) = (5)x(6)/10^6	$0.14

Table 2 shows the calculation of an implicit maximum impact on gasoline prices at the pump associated with compliance with LCFS requirements. However, there are several important caveats and additional considerations. First, as the summary calculation indicates, the maximum potential effect depends on the targeted carbon intensity reduction as well as the prevailing credit price. These are functions of the particular policy and program design, and the California context demonstrates that these have significant effects on the analytical result. For example, the carbon intensity reduction target was -5.0% for 2018, and the average credit price was $156/MT, which gives a maximum implicit price impact on CaRFG of $0.09/gal., and the corresponding values for 2017 were a target reduction of -3.5% and $87/MT, giving a maximum implicit price impact of $0.03/gal.

Second, previously noted, the reported LCFS credit transaction prices represent a marginal, rather than average cost, and will, in the context of generally rising prices, over-estimate the average cost of compliance. Recent LCFS credit prices are significantly below the $192 average for 2019. For the January through March quarter of 2022, credit transaction prices have averaged approximately $159/MT.[36]

Third, and particularly important from the consumer perspective, renewable fuels induced under the LCFS program current provide cost *savings* relative to petroleum fuels, as discussed in Section VI.A, above. California's relatively high retail fuel prices are overwhelmingly a function of petroleum fuel prices. It is clear that lower-cost renewable fuels are available in the California market, and there are economic opportunities to expand the sale and use of alternative fuels further, lowering the average compliance cost across all fuel. Identifying the market frictions that might explain the constrained use of lower-cost renewable fuels is beyond the scope of this report.

G. 2020 and 2021

The final period summarized in Table 1, encompassing 2020 and most of 2021 (at the time of writing), have an even greater differential between retail and spot gasoline prices, averaging $1.96/gallon and leaving an "unexplained" residual averaging about $0.55/gallon. As noted above, this period, with unprecedented economic and fuel demand effects associated with the COVID-19 pandemic, is not reliable for assessing retail fuel price effects from LCFS. One notable feature of the data can be seen in Figure 7 in the middle of 2020, when spot prices dropped almost to the WTI crude price, but retail gasoline prices fell much less, thus significantly widening the retail versus spot differential. The price difference went from approximately $1.66/gallon in December 2019 to approximately $2.31/gallon in June 2020. The differential fell to just under

[36] Volume weighted average, data from CARB Weekly LCFS Credit Transfer Activity Reports; https://ww2.arb.ca.gov/resources/documents/weekly-lcfs-credit-transfer-activity-reports

$2.00/gallon in early 2021, but has since widened to around $2.50/gallon in the September 2021 through March 2022 period, despite the fact that the LCFS credit price was falling significantly in the same period.

The unusual fuel pricing trends since the beginning of 2020 have been experienced nationally, but have been particularly pronounced in California. Overall drivers of these pricing trends include the following factors:

- **The pandemic causes refiners to cut gas production**

  Around April of 2020, lockdown mandates, work from home measures, and a sharp reduction in non-essential travel resulted in a drop in US demand for automotive gasoline. This created an excess of gasoline inventory in the US, causing pump prices to plummet to below $2/gal.[37] The drop in prices in turn led oil refiners to cut their gas production by nearly 40% in May of 2020, and some refiners shut down plants permanently, spurred by the fear that gasoline demand might never fully rebound. In addition to the challenging market conditions caused by the substantial decrease in demand, increasing market interest in renewable diesel production and pre-existing plans to scale down or reconfigure petroleum refineries also contributed to the closure of many refineries in 2020.[38] Compared to the 135 operable refineries listed in the US at the beginning of 2020, the start of 2021 had 129 refineries listed as either operating or idle.[39] Refinery closures shrank the overall refining capacity in the US by 4.5%, marking the

[37] "The simple explanation for rising US gas prices". Available at: https://qz.com/2092389/the-simple-explanation-for-rising-us-gas-prices/

[38] "Refinery closures decreased U.S. refinery capacity during 2020". Available at: https://www.eia.gov/todayinenergy/detail.php?id=48636

[39] "Refinery closures decreased U.S. refinery capacity during 2020". Available at: https://www.eia.gov/todayinenergy/detail.php?id=48636

beginning of 2021 as the lowest annual capacity figure to start the year since 2015.[40]

- **Refinery production is unable to keep up with rising gas demand**

  In 2021, with increasing vaccination rates and easing of public health restrictions, the demand for gasoline began rising substantially. However, oil refineries were unable to ramp up production at the same pace, because of the lengthy process of restarting stalled plants or opening new ones. As a result, consumption of the previously excess supply of gas caused the national gas inventory to fall 6% below its pre-pandemic levels – the most significant drop in more than three years – which in turn led to a sharp rise in prices.[41]

- **Crude oil prices rise as a result of reduced production from OPEC+ members**

  In February of 2021, members of the Organization of Petroleum Exporting Countries (OPEC) and partner countries (OPEC+) announced a reduction of crude oil production, which caused world crude oil prices to rise, driving spot and retail pump prices to rise sharply.[42]

- **Crude price spike following the invasion of Ukraine**

  World crude prices jumped above $100 per barrel for the first time since 2014 following Russia's invasion of Ukraine in February 2022. The disruptive effects on world crude markets could be persistent, with continued military action,

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40 "Refinery closures decreased U.S. refinery capacity during 2020". Available at: https://www.eia.gov/todayinenergy/detail.php?id=48636

41 "The simple explanation for rising US gas prices". Available at: https://qz.com/2092389/the-simple-explanation-for-rising-us-gas-prices/

42 "Here's Why Gasoline Prices Are High And Going Higher". Available at: https://www.forbes.com/sites/davidblackmon/2021/03/25/gasoline-prices-are-high-and-going-higherheres-why/?sh=b649056332f0

extensive economic sanctions on Russia by Western nations, and the exit from Russia by major energy companies such as Shell and BP.

Though these factors are not exclusive to California, the distinct structure and dynamics of the California market may exacerbate effects in the state. In particular, increased price margins between retail and wholesale fuels resulting from market shocks are notably persistent in California. Long after the direct shock is resolved, price effects appear to linger. An example of this is the increased fuel prices that followed the Torrance refinery explosion in 2015. The price jump attributable to the resulting supply shock persisted long after the facility returned to full production capacity in 2016, reflecting an unexplained "mystery surcharge."[43] While the excess margin of retail over wholesale gasoline prices, after accounting for production costs, taxes, and C&T and LCFS effects, averaged about $0.20/gallon from 2000 through 2014, the excess jumped to $0.70/gallon in the immediate aftermath of the refinery outage, and despite the facility's return to production in 2016, fell back only partially, averaging $0.22/gallon in 2018.[44] The widening margins in 2020 and 2021 are similarly unexplained by accounting for fundamental costs.

In 2019, the California Energy Commission (CEC) conducted assessment of California retail gasoline pricing, documenting a significant widening of retail margins in the state from 2011 to 2018.[45] In particular, the CEC report found that retail margins for higher-priced retail brands compared to lower-priced brands were nearly twice the California average retail margin. These high retail margins can have nothing to do with LCFS, because the LCFS program has no differential effect based on brand or fuel grade. The CEC report was unable to identify a definitive cause of excess retail margins in California, but indicated that further analysis was warranted into retail pricing practices.

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[43] Severin Borenstein, "Trying to Unpack California's Mystery Gasoline Surcharge," HAAS Energy Institute Blog (Oct. 2018); https://energyathaas.wordpress.com/2018/10/15/trying-to-unpack-californias-mystery-gasoline-surcharge/

[44] *Id.*

[45] California Energy Commission, https://www.energy.ca.gov/sites/default/files/2019-11/Gas_Price_Report.pdf

VII. LCFS effects looking forward

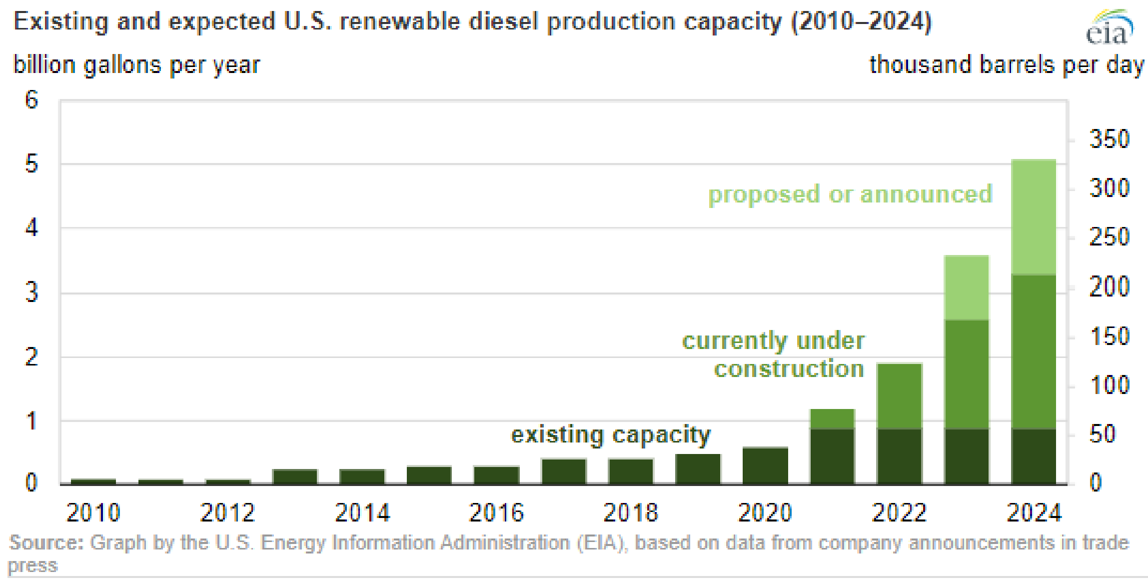
As described above, LCFS credit prices are only partly a function of decreasing target carbon intensity values over time. The recent pullback in LCFS credit prices is partly the result of pandemic effects, particular the drop in overall fuel demand, which reduced the needed compliance volumes of low-carbon fuels. Looking forward, there are two important factors that will likely mitigate the effects of increasingly stringent LCFS targets: expected expansion of renewable diesel production capacity in California, and continued growth of electric vehicles as well as renewable electricity generation in the state.

A. Renewable Diesel Growth

A number of renewable diesel projects are currently under construction or are in pre-construction development, which could lead to a significant increase in renewable diesel capacity in the U.S. through 2024. Major factors contributing to this growth include higher state and federal targets for renewable fuel, favorable tax credits, and conversion of existing petroleum refineries into renewable diesel refineries.[46] Figure 12 shows a compilation of data from EIA on renewable diesel production capacity that may enter commercial operation over the next three years.

[46] "U.S. renewable diesel capacity could increase due to announced and developing projects". Available at: https://www.eia.gov/todayinenergy/detail.php?id=48916

Figure 12: Existing and expected renewable diesel production capacity (2010-2024)[47]



The low evaluated carbon intensity of renewable diesel, particularly for fuel produced from waste fats and oils, makes it a particularly valuable fuel both for California LCFS program compliance, and for meeting obligations under the federal RFS program. This value has incentivized investments in new production capacity, particularly in California.[48]

While most new renewable diesel capacity will be in the West Coast, some projects have been announced for the Gulf Coast as well. According to the EIA, majority of the renewable diesel produced in the Gulf Coast will likely be consumed by California as well as other western states such as Oregon and Washington, in order to meet future LCFS program targets.

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[47] "U.S. renewable diesel capacity could increase due to announced and developing projects". Available at: https://www.eia.gov/todayinenergy/detail.php?id=48916

[48] "U.S. renewable diesel capacity could increase due to announced and developing projects". Available at: https://www.eia.gov/todayinenergy/detail.php?id=48916

Former petroleum refineries are also planning to begin production of renewable diesel. Within the state of California, Marathon Petroleum refinery in Martinez plans to start producing renewable diesel beginning in 2022, ramping to full production capacity of 730 million gallons/year by 2023, and Phillips 66's Rodeo Renewed project in San Francisco plans to be converted completely by 2024 to produce 800 million gallon/year of renewable fuels.[49, 50]

Challenges and risks to the expansion of renewable diesel capacity include availability of fat, oil, and grease feedstocks. Increased renewable diesel production has put upward pressure on many renewable diesel feedstocks. The near-term financial viability of new renewable diesel capacity will depend significantly on feedstock availability and pricing.[51]

B. Electric Vehicles and Renewable Generation

California has multiple initiatives to increase the use of electric vehicles and phase out the use of internal combustion engines in transportation. In June 2020, CARB adopted a new rule requiring that all new commercial trucks and vans sold in California be zero emission by 2045.[52] A September 2020 executive order directed that all new cars and passenger trucks sold in California be zero emission by 2035.[53] The expansion of electric vehicles in the state will be mapped onto an electricity generation system that has the largest quantity of solar generation in the U.S., and expected continued growth in wind generation. These sources of low variable cost generation will allow electricity as a transportation fuel to be relatively low cost, encouraging adoption of electric vehicles in

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49 "U.S. renewable diesel capacity could increase due to announced and developing projects". Available at: https://www.eia.gov/todayinenergy/detail.php?id=48916

50 Marathon: https://www.marathonpetroleum.com/Operations/Renewable-Fuels/

51 "U.S. renewable diesel capacity could increase due to announced and developing projects". Available at: https://www.eia.gov/todayinenergy/detail.php?id=48916

52 https://ww2.arb.ca.gov/news/california-takes-bold-step-reduce-truck-pollution

53 https://www.gov.ca.gov/2020/09/23/governor-newsom-announces-california-will-phase-out-gasoline-powered-cars-drastically-reduce-demand-for-fossil-fuel-in-californias-fight-against-climate-change/

advance of the state mandates. The expected growth in very low carbon intensity electricity as a transportation fuel will help meet LCFS targets and will tend to keep LCFS credit prices low.

Appendix - California LCFS Timeline and Milestones

Date	Milestone
November 25, 2009	CARB approves the LCFS regulation to reduce the CI of transportation fuel used in California by at least 10% by 2020, with respect to a 2010 baseline[54]
April 15, 2010	The LCFS regulation is approved by the Office of Administrative Law (OAL) and becomes effective[55]
January 1, 2011	CARB begins implementation of the LCFS regulation[56]
December 16, 2011	CARB conducts a public hearing to consider for approval and adoption the proposed amendments to the LCFS regulation, in order to clarify, streamline, and enhance certain provisions of the regulation[57]
November 26, 2012	Amendments to the LCFS are approved by the OAL and become effective[58]
January 1, 2013	Amendments to the LCFS are implemented[59]

54 California Air Resources Board, "LCFS Basics". Available at: https://ww2.arb.ca.gov/resources/documents/lcfs-basics

55 California Air Resources Board, 2009 Rulemaking Documents: "OAL Approval Notice". Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2009/lcfs09/oalapplcfs.pdf

56 California Air Resources Board, 2011 Rulemaking Documents: "Updated Informative Digest". Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2011/lcfs2011/uidrev.pdf

57 California Air Resources Board, 2011 Rulemaking Documents: "Executive Order R-12-012". Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2011/lcfs2011/lcfseo.pdf

58 California Air Resources Board, 2011 Rulemaking Documents: "OAL Notice of Approval". Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2011/lcfs2011/lcfsoalapp.pdf

59 California Air Resources Board, 2015 Rulemaking Documents: "Initial Statement of Reasons for Proposed Rulemaking". Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2015/lcfs2015/lcfs15isor.pdf

Date	Milestone
September 2015	CARB re-adopts the LCFS to address procedural deficiencies in the way the original regulation was adopted[60]
November 16, 2015	Re-adoption of the LCFS is approved by the OAL[61]
January 1, 2016	LCFS re-adoption becomes effective[62]
2018	CARB approves amendments to the regulation, which include strengthening and smoothing the CI benchmarks through 2030 in-line with California's 2030 GHG emission reduction target enacted through the California Global Warming Solutions Act of 2016 and emissions limit (Senate Bill 32 or SB 32); New crediting opportunities are added to promote zero emission vehicle adoption, alternative jet fuel, carbon capture and sequestration (CCS), and advanced technologies to achieve deep decarbonization in the transportation sector [63]
January 4, 2019	Amendments to the LCFS are approved by the OAL and become effective[64]
November 21, 2019	CARB conducts a public hearing to consider and adopt the proposed amendments to the LCFS regulations[65]

60 California Air Resources Boards, LCFS Regulation – "2015 Re-Adoption of the LCFS Program". Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-regulation

61 California Air Resources Boards, "LCFS Regulation". Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-regulation

62 California Air Resources Boards, "LCFS Regulation". Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-regulation

63 California Air Resources Board, 2019 Rulemaking Documents: "Updated Informative Digest". Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/lcfs2019/uid.pdf

64 California Air Resources Board, 2019 Rulemaking Documents: "Resolution 19-27". Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/lcfs2019/res19-27.pdf

65 California Air Resources Board, 2019 Rulemaking Documents: "Executive Order R-20-002". Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/lcfs2019/execorder.pdf

Date	Milestone
May 27, 2020	Amendments to the LCFS are approved by the OAL[66]
July 1, 2020	Amendments to the LCFS become effective[67]

[66] California Air Resources Board, "LCFS Regulation". Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-regulation

[67] California Air Resources Board, "LCFS Regulation". Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-regulation