

Research Report – UCD-ITS-RR-14-01

Status Review of California's
Low Carbon Fuel Standard

January 2014 Issue

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The Low Carbon Fuel Standard (LCFS), adopted in California in 2009, contributes to California's overall greenhouse gas (GHG) emission reduction goals under the Global Warming Solutions Act of 2006 (AB 32). It is a performance-based regulation that requires regulated parties (fuel producers and importers to California) to reduce the carbon intensity (CI) of their fuel mix by at least 10% by 2020. It sets declining annual targets, starting slowly with a 0.25% reduction in 2011 and increasing to 10% reduction by 2020. The program incentivizes the adoption of low-carbon fuels based on its calculation of the fuel's lifecycle emissions. The LCFS credits and deficits are generated based on a fuel's emissions below or above the standard. The credits can be traded or banked over time.

The periodic status review series provides updates on LCFS compliance and markets, and addresses selected special topics. Each report reviews data, analyzes trends, and identifies potential challenges. The principal data source is the California Air Resources Board (CARB), the regulatory agency administering the LCFS; summaries and data spreadsheets can be downloaded at <http://www.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm>.

This third report addresses the following topics:

1. Credits and deficits;
2. Carbon intensity of fuels;
3. Credit trading and credit prices;
4. Interactions between the federal Renewable Fuel Standard (RFS2) and LCFS;
5. Special topic: cost containment mechanisms (CCMs).

Highlights:

- Alternative fuels under the program increased from 6.3% of total transport energy use in California in 2011 to 6.8% in the first half of 2013.
 - Fuel suppliers in the program generated excess LCFS credits beyond what was required in every quarter since the program was initiated. Total excess credits through June 2013 totaled 1.64 MMTCO_{2e}, amounting to 61% more credits than required.
 - Total biofuel volumes remained relatively constant since 2011, but ethanol's contribution (primarily using corn or grain mixes) to LCFS credits decreased from 70-80% in 2011 through 2013 Q1, to 52% in 2013 Q2. An increasing share of biofuel LCFS credits came from use of waste-based fuels (biodiesel/renewable diesel from tallow or waste oils and ethanol from beverage wastes).
 - Reported use of electricity for transportation steadily increased over time, from 0.35 million gasoline gallon equivalent (gge) for 2011, to 1.22 million gge for 2012, to 1.19 million gge for the first six months of 2013. The gallons of gasoline or gasoline/ethanol blends displaced by electricity would be roughly 3.4 times these amounts of electricity used due to the inherent efficiency advantage of electric engines compared to gasoline engines.
 - LCFS credit prices increased from \$16/credit in 2012 to \$75-\$85/credit in November 2013, and dropped to around \$50/credit in December 2013.
 - Increasing LCFS credit prices combined with dropping Renewable Identification Number (RIN) prices for the national RFS in 2013 meant that the LCFS played a stronger role in incentivizing the use of biofuels including corn oil, canola and waste biodiesel/renewable diesel.
 - Proposed cost containment mechanisms, such as a cap on credit prices, are a promising method to ensure LCFS compliance costs do not exceed desired levels.
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Introduction

California’s Low Carbon Fuel Standard (LCFS), implemented starting in January 2010 by the California Air Resources Board (CARB), is a performance-based regulation requiring transportation fuel sellers (fuel producers and importers to California) to reduce the average carbon intensity (CI) of California’s transportation fuel mix by at least 10% by 2020. The standard requires reductions of 0.25%, 0.5%, and 1% in 2011, 2012, and 2013, respectively, below CI baselines established for conventional gasoline and diesel fuels sold in California. The standard requires a 2.5% CI reduction in 2015, and increases in stringency in subsequent years (reaching 10% reduction in 2020). In July 2013, the state’s Fifth District Court of Appeal ruled that the LCFS remains in effect, but CARB must correct certain aspects of the procedures by which the LCFS was originally adopted, then re-approve the program.¹ The standard’s 2014 target will remain at the 2013 level of 1% given the ruling. In September 2013, a federal appeals court upheld the LCFS, rejecting arguments from fuel makers that California’s LCFS discriminated against out-of-state producers.²

The LCFS aims to lower greenhouse gas (GHG) emissions in California’s transportation sector by creating financial incentives for innovation and deployment of low-carbon fuels. Regulated parties can meet the standard by: producing low-carbon fuels, buying them from producers to sell on the market, purchasing credits generated by others, or combining these strategies. Potential low-carbon fuels include waste- or cellulosic-based biofuels, natural gas from petroleum or biomass sources, electricity for plug-in vehicles, and hydrogen for fuel cell vehicles.

The Spring 2013 Status Review covered compliance for 2011 and 2012. We found alternative fuels provided slightly over 6% of total transportation energy and generated enough excess credits

(beyond program requirements) to cover roughly half of the 2013 obligation. We calculated the average fuel CI (AFCI) of gasoline substitutes in 2012 as 85 gCO₂e/MJ (grams of carbon dioxide equivalent per megajoule) and the AFCI of diesel substitutes as 58 gCO₂e/MJ. We reported that low-CI waste-based fuels generated 10% of biofuel credits from 1% of biofuel volumes, that most credits (78%) were generated by ethanol, and that LCFS credit prices reported to CARB rose from \$13.50/MT CO₂e in 2012 to \$27.70/MT CO₂e in early 2013 (Yeh et al. 2013).

In this issue, we review LCFS compliance from 2011 through June 2013. We examine credits and deficits generated and transport fuel energy (Section 1), fuel carbon intensity (Section 2), and credit trading and prices (Section 3). We report on the federal Renewable Fuel Standard (RFS2) and its relationship to LCFS fuels (Section 4). As a special topic, we summarize in Section 5 research findings from a recent ITS-Davis Research Report (Lade and Lin 2013) on LCFS cost containment mechanisms proposed by CARB.

1. Credits and Deficits

Through mid-2013, regulated parties generated a total of 4,337,988 LCFS credits and 2,700,488

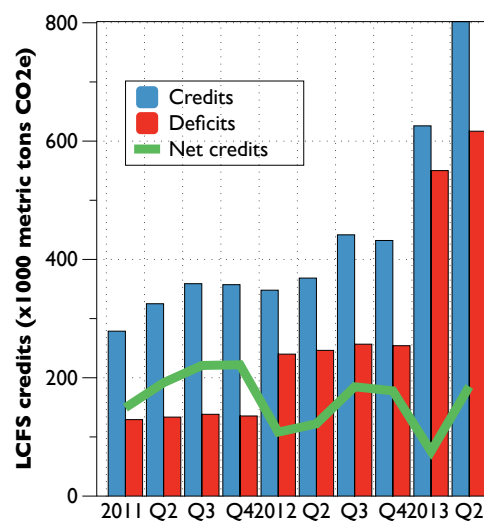


Figure 1. California LCFS carbon credits and deficits generated per quarter.

deficits (Figure 1). LCFS credits and deficits are generated based on emissions below or above the standard. The credits can be traded or banked over time. Net excess credits (credits minus deficits) were positive in every quarter (green line in Figure 1). By mid-2013, net cumulative credits – which represent CARB’s tally of metric tons CO₂e saved beyond what the program required – totaled 1.64 million, amounting to 61% more credits than necessary to cover total generated deficits to that point. Both credits and deficits generated trended up sharply in the first half of 2013.

Over the review period (2011-2013 Q2), ethanol generated 71% of credits, CNG and biodiesel (BD) about 9% each, renewable diesel (RD) 6%,

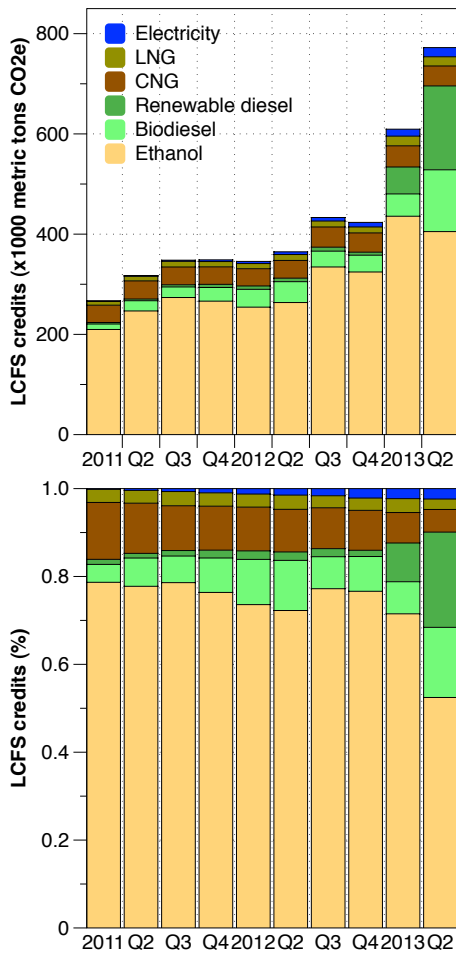


Figure 2. Total net LCFS credits by fuel type per quarter: number of credits (top) and percentage share (bottom).

LNG 3%, and electricity under 2% (Figure 2). (CNG and LNG refer to both fossil and bio-based gases.) Ethanol’s contribution to LCFS credits decreased from 70-80% in 2011 through 2013 Q1, to 52% in 2013 Q2, whereas biodiesel and renewable diesel credits increased dramatically in 2013, and generated 16% and 22% (respectively) of total credits in 2013 Q2 (Figure 2, bottom).

From 2011 to mid-2013, total biofuel volumes

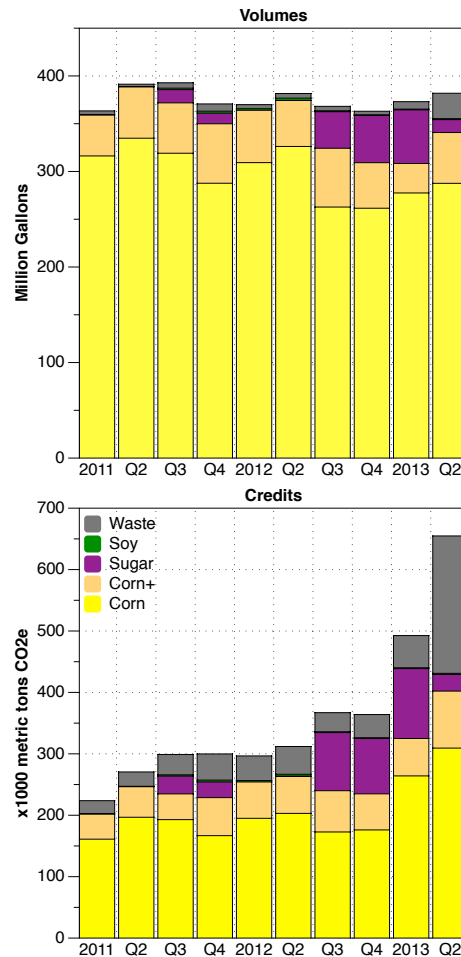


Figure 3. LCFS biofuels by feedstock per quarter: volumes (top) and number of net credits generated (bottom). “Corn” pathways include corn ethanol and corn oil biodiesel. “Corn+” pathways include fuels using mixed feedstocks: corn, wheat slurry, and sorghum, plus relatively small volumes of 100% sorghum ethanol. “Sugar” includes sugarcane ethanol and ethanol from molasses (a byproduct of raw sugar production). The “Waste” category includes diesel substitutes from tallow and used cooking oil, and waste beverages to ethanol.

remained relatively constant (Figure 3, top). Corn-based fuels (“corn” and “corn+” categories) generated 74% of biofuel credits from 93% of the total biofuel volumes (Figure 3). Total credits generated using corn-based fuels decreased from 83% (2011) to 63% (first half of 2013) of all biofuel credits. Waste-based fuels increased their share and volumes over time. They contributed 15% of biofuel credits based on just 2% of biofuel volume due to their relatively low CI rating (see next section). The contributions of sugar-based fuels (ethanol from sugarcane or molasses) ranged from 0-26% of biofuel credits generated per quarter, and cumulatively 11% of total biofuel credits and 5% of volume. Increased use of Brazilian sugarcane ethanol in the second half of 2012 (used for biofuel production into 2013) corresponded with the most severe and extensive drought in at least 25 years, which seriously affected U.S. agricultural harvests. In the same period, soy biodiesel contributed 0.3% of biofuel volume.

Alternatives to conventional gasoline and diesel contributed 6.3% (energy content) of the total LCFS transportation fuel mix in 2011. The contribution increased to 6.8% in the first half of 2013. Use of biodiesel and renewable diesel (BD/RD) nearly doubled between 2011 and 2012, and more than doubled from 2012 levels in the first two quarters of 2013 (Table 1). Reported transportation electricity energy use steadily

increased over time, from 0.35 million gasoline gallon equivalent (gge) in 2011, 1.22 million gge in 2012 to 1.19 million gge in the first six months of 2013 (or 0.6%, 1.6% and 2.3% of the total credits generated in these corresponding periods (Table 1 and Figure 2). The gallons of gasoline or gasoline/ethanol blends displaced by electricity would be roughly 3.4 times these amounts of electricity used due to the inherent efficiency advantage of electric engines compared to gasoline engines. Alternative fuels constituted 1.13 billion gasoline gallon equivalents (gge) of the total on-road California gasoline and diesel fuel pool of 17.79 billion gge, on average per year since 2011. In aggregate, fuel use rates suggest 10.4% by volume of ethanol blended in gasoline as E10 and some E85 (85% ethanol blended in gasoline), and 0.9% biodiesel/renewable diesel by volume blended with ultra low sulfur diesel (ULSD).

2. Carbon Intensity

The average fuel carbon intensity (AFCI) is trending downward (Figure 4). Data suggest that the more stringent 2013 CI requirements were met in the first half of the year through continued gradual CI reduction of the most-used alternative fuel (ethanol CI fell 4.5% from 2011 to 2013), and greater volumes of low-CI pathway fuels in the diesel pool (BD/RD). Use of conventional gasoline (CARBOB) dropped slightly

Table 1. Total transportation energy use (in billion gge for CARBOB and ULSD, and the rest in million gge) reported in California LCFS program.

	2011	2012	2013 (thru Jun)
CARBOB (gasoline)	12.87	12.79	6.14
ULSD (ultra-low sulfur diesel)	3.92	4.01	1.94
Ethanol	1.03	1.00	0.49
Biodiesel/renewable diesel	13.8	23.5	49.4
CNG/LNG	82.2	91.8	51.9
Electricity	0.35	1.22	1.19
Total	17.91	17.91	8.67
Alt Fuel (% of total energy)	6.3	6.2	6.8

in the first half of 2013 than in 2011 and 2012, thus generated fewer deficits than if consumption levels had stayed constant (Table 1).

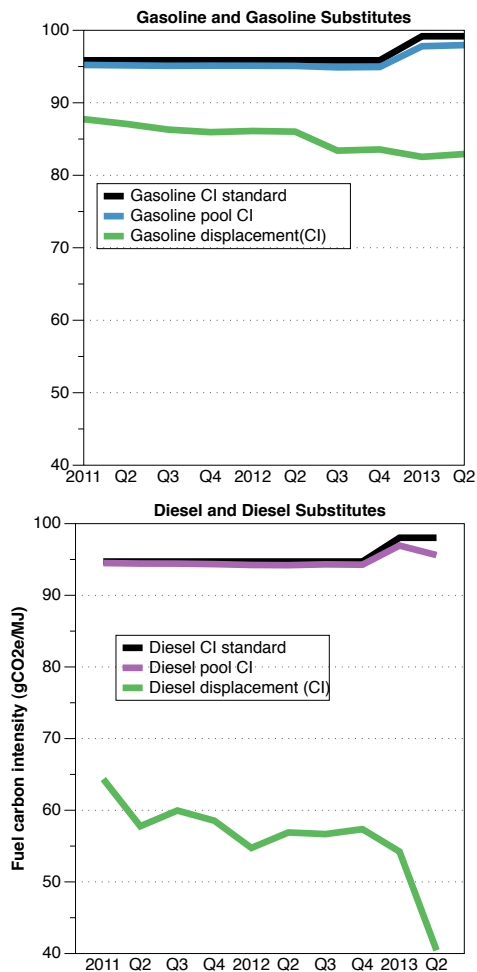


Figure 4. Average fuel carbon intensities (AFCI) of gasoline substitutes (top) and diesel substitutes (bottom).

Based on credits generated and fuel volumes used, we calculate CIs for fuel used in the LCFS (Figure 5).³ The drop in electricity CI (Figure 5, top) is due to a change in electricity’s energy economy ratio (EER), which accounts for the greater efficiency of electric engines compared with the gasoline internal combustion engine, from 3 to 3.4 starting in 2013. Waste-based fuel CI showed substantial volatility (perhaps due to switching among feedstock sources) and mixed grains CI exhibits a downward trend (Figure 5, bottom).

As of June 2013, the LCFS had 201 individual transportation fuel pathways available for use, 50 from CARB and 151 provided by regulated parties.⁵ Between January and June 2013, 16 pathway CI ratings were added with an average CI rating of 31.3 gCO₂e/MJ. The new pathways included BD/RD wastes, CNG/LNG from landfill biogas, and molasses ethanol.⁶ Figure 6 shows CI ratings for available pathways, including the 170 biofuels pathways actually in use by individual facilities as of November 2013. Regulated parties numbered 100 as of September 2013, including 172 registered biofuel producers and 277 registered biofuel production facilities as of November 2013.⁷

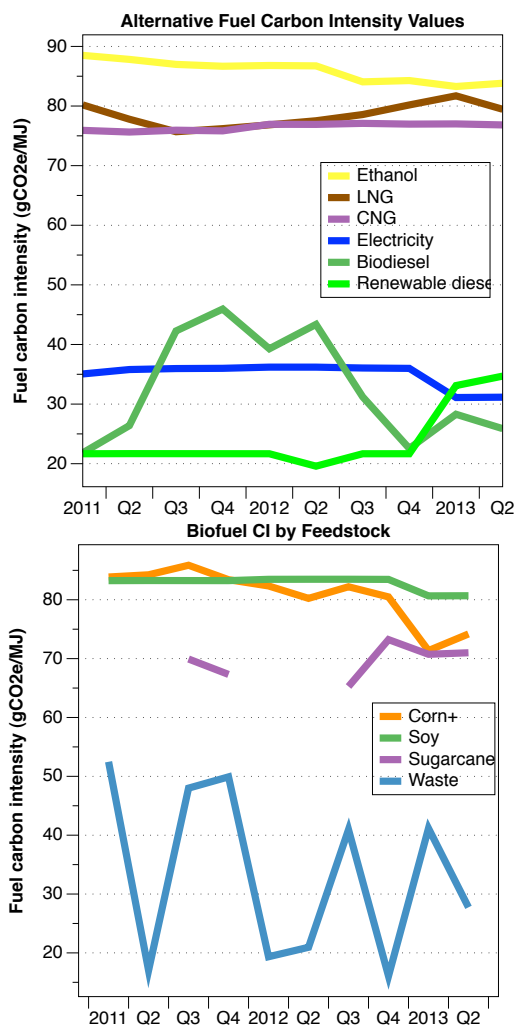


Figure 5. Change in CIs by fuel types over time (top) and by biofuel feedstock (bottom).⁴

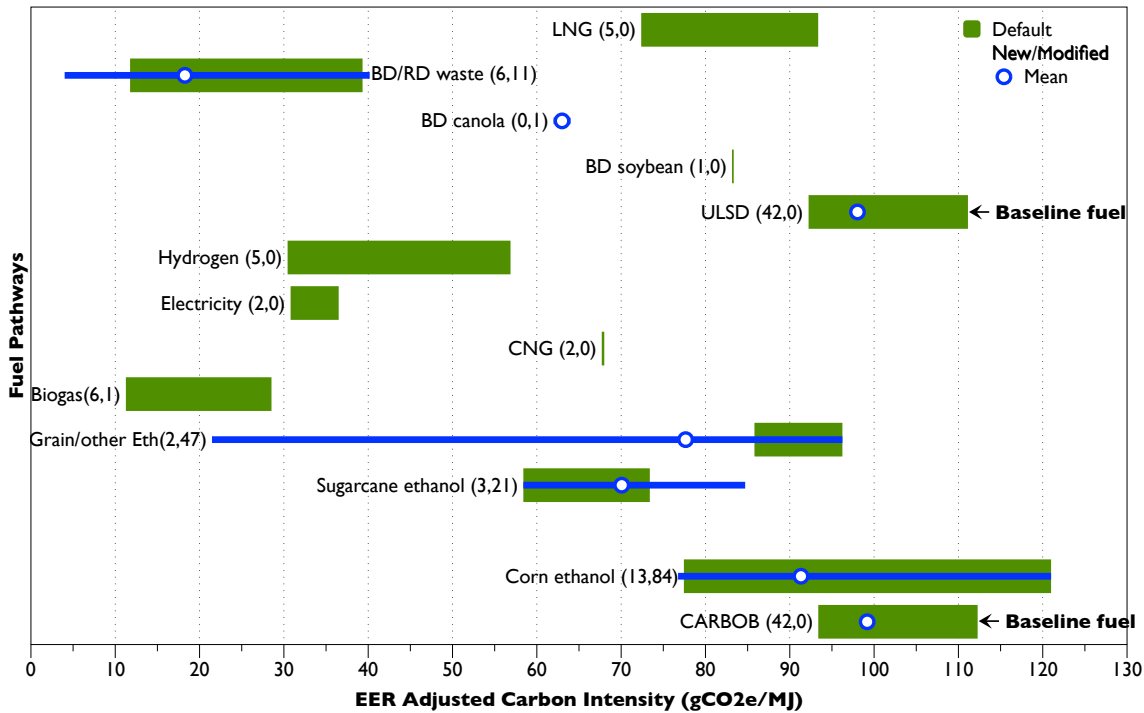


Figure 6. Carbon intensity of feedstock/fuel combinations in use in California’s LCFS as of November 2013.

Green bars represent the default ratings derived by CARB. Blue lines represent pathways in use including CARB defaults and new and modified pathways provided by regulated parties (through Methods 2A and 2B). Blue circles represent the mean of values in use. Also included are the actual gasoline (CARBOB) and diesel (ULSD) values calculated using country of crude oil origin (the mean is the average baseline value used in the regulation). Numbers in parentheses represent the numbers of pathways captured in the green bars and the blue lines (in that order). Modified values can be higher than the defaults for a particular feedstock/fuel combination due to differences in technologies used. CI values are adjusted with an energy efficiency ratio (EER) of 3.4 for electricity and 2.5 for hydrogen (gasoline displacement). “Grain/other ethanol” pathways include ethanol from corn/grain mixture (corn+ pathways), sorghum (default), molasses, and waste beverage.

3. Credit Trading and Credit Prices

Regulated parties generate, buy, and sell LCFS credits to meet compliance. Each credit is equal to 1 metric ton (MT) of CO₂e reduction below the annual LCFS standard. The transfers of LCFS credits occur without CARB involvement, although CARB requires reporting transfer of volumes (reporting of pricing is optional). We collect market information on credit trades and prices from several sources: OPIS (Oil Price Information Service) reports on daily bid/ask spreads; Progressive Fuels Limited compiles similar information in a daily biofuels market report; Argus (Argus Media Limited) reports information on transactions; and CARB summarizes transfer volumes and the average reported credit price in its LCFS reporting tool quarterly summary reports (<http://www.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm>).

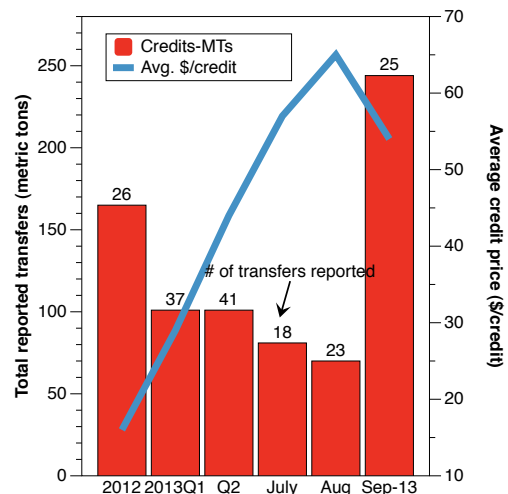


Figure 7. Total reported LCFS credits transferred (bars), number of transfers reported (text above the bars), and the average credit price reported to CARB (line). July – Sep 2013 data are presented by month.

Through September 2013, regulated parties reported to ARB transfers of 762,700 LCFS credits in 170 trades (Figure 7). Over half of credits traded in the program were transferred in Q3 2013 (395,000 credits, 62% of these in September), after state and federal courts ruled (in July and September 2013) that the LCFS could remain in effect (see Introduction). Average price per credit, as reported to CARB, increased from \$16 in 2012 to more than \$55 in Q3 2013. Since reporting of credit prices is voluntary, these reported prices may not be representative of all transactions. Of 100 regulated parties, 58 have reported transferring credits – 28 have only sold credits, 21 have only bought credits, and 9 have

bought and sold credits.

Daily price assessments from OPIS and PFL Markets Daily also indicate a rise in LCFS credit prices in 2013 (Figure 8). The two datasets agree to a great extent on bid/ask ranges for LCFS credit prices for the period they overlap (May to November 2013). LCFS credit prices increased from \$16 per credit in 2012 to \$75-\$85/credit in November 2013. According to PFL Markets Daily, prices declined to about \$50/credit by mid-December.

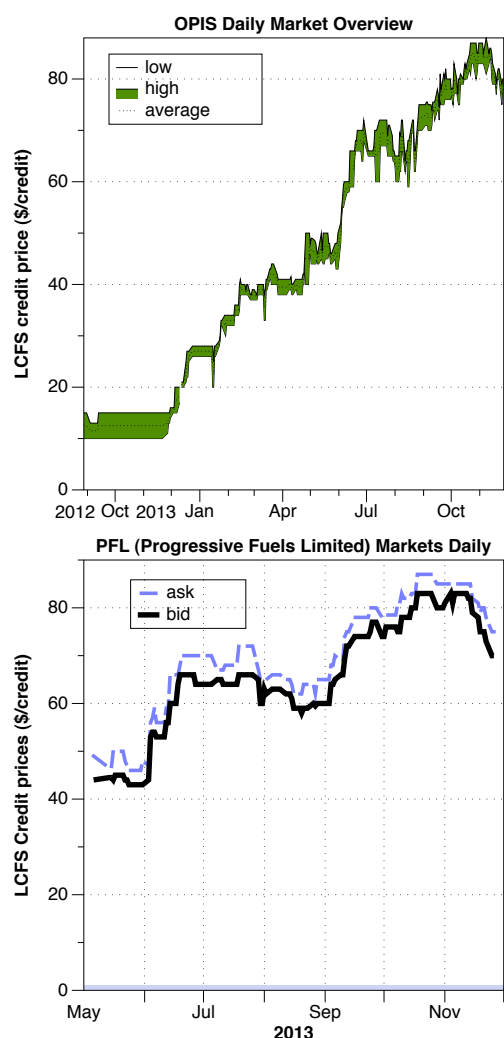


Figure 8. Range of daily price assessment (traded price range or range of bids and offers) on LCFS credit prices.

4. Federal Renewable Fuel Standard (RFS2) and LCFS Fuels

In this report, we quantify how the market mechanisms of the two policies – the RFS2 tradable Renewable Identification Numbers (RINs) and LCFS credit prices – combine to affect the economics of biofuels in the United States and California. We focused our analysis on biofuel pathways that are eligible in both programs. Non-renewable transport fuels including CNG, LNG, and electricity are eligible under the LCFS but not the RFS2, and are not discussed in this section.

4.1. Biofuel pathways in both the RFS2 and the LCFS

Figure 9 depicts average values added from the policies for selected months since Q3 2012 (when LCFS credit prices data become available) for biofuel pathways eligible under both the RFS2 and California’s LCFS.⁸ In the figure, the relative sizes of the different colored bars indicate which program adds more value per gallon, and whether California policy adds additional incentives. Blue shows value per gallon from RINs, red shows additional value per gallon if the fuel also earns LCFS credits from a fuel with the highest CI rating for the pathway used, and green shows the

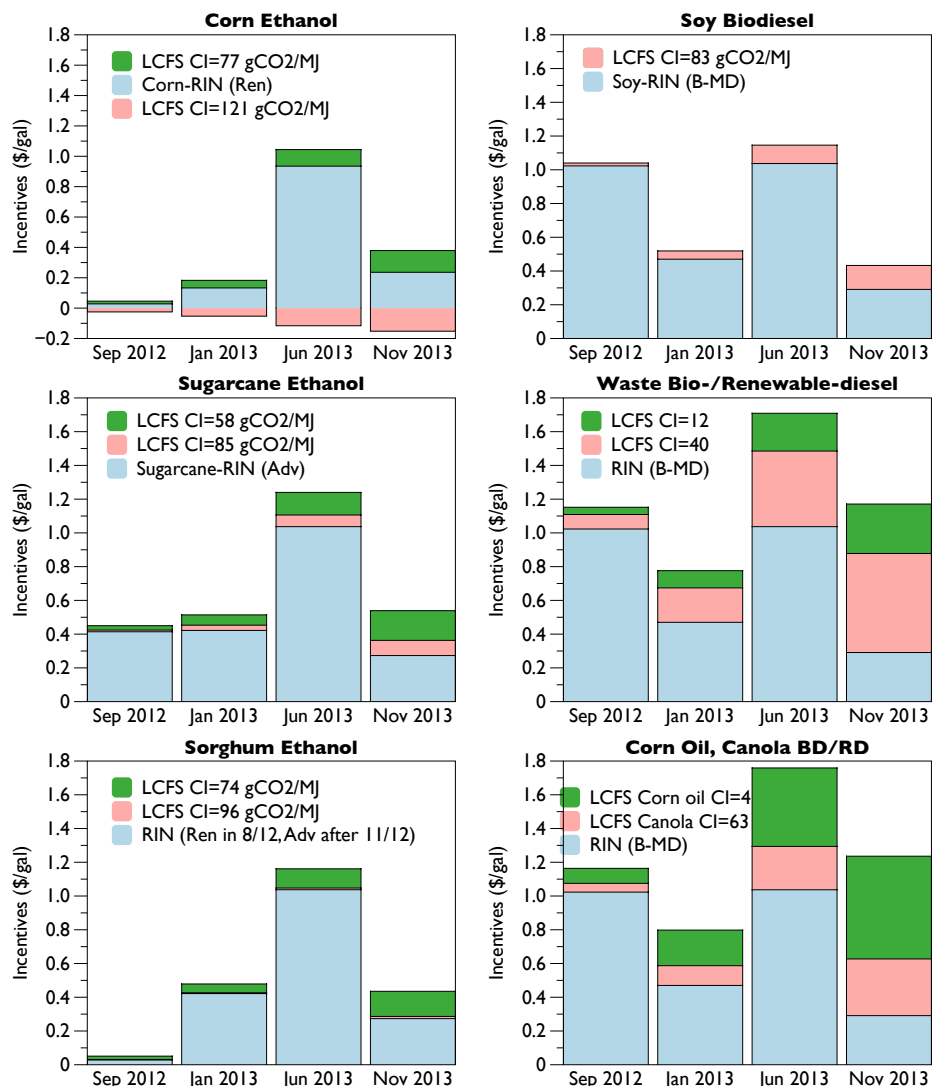


Figure 9. Premiums from RFS2 RINs and LCFS credits (based on monthly average prices) by feedstock/fuel pathway for selected months. Source: OPIS price data; CARB pathway CI ratings; EPA fuel mandate categories.

additional premium under the LCFS if the lowest-CI rated fuel is used (LCFS CI ranges based on Figure 6).

Under the RFS2, RIN values (blue bars) vary by fuel pathway depending on which nested mandate the fuel is eligible for (e.g. corn for renewable RINs and soy for biomass-based diesel RINs). Corn ethanol can only contribute to renewable RINs. Renewable RINs had the least value because they can only be used to meet one

mandate (for the renewable category). Advanced RINs (e.g., sugarcane and natural-gas-processed sorghum ethanol) had higher values since they can contribute toward meeting the more restricted advanced mandate *as well as* the renewable mandate. Biomass-based diesel RINs (vegetable oils and waste oils) were the most valuable (over \$1/gal) because they meet the specific RFS2 mandate for biomass-based diesel, and can also be used to meet advanced and renewable mandates.

Two trends characterized RIN values in 2013: 1) the convergence of RIN prices for the nested (i.e. more restricted categories such as cellulosic biofuels and biomass based diesel) and overall mandate RINs (for example, RIN values for corn ethanol and soy biodiesel were very different in September 2012, but quite close by June 2013); and 2) RIN values have fluctuated – rising substantially (from January to June 2013 in the figure), then dropping off (June to November 2013). The rise in RIN values reflected market concern over ethanol use beyond levels equivalent to 10% by volume (E10) of gasoline (often referred to as the “blend wall,” because of regulatory and technical hurdles and need for consumer acceptance for widespread consumption of higher-blend – e.g. E15 or E85 – ethanol). The market concern was also reflected in the narrowing of price spreads between RIN types, as the RIN values for renewable and advanced categories increased to levels on par with the value for biomass-based diesel RINs that can be used to meet the most categories of requirement. The decline in RIN values coincided with Congressional hearings and EPA statements over the summer about possible mandate adjustments, followed by an EPA proposal in October to adjust RF2 mandates for 2014 and possibly thereafter. The purpose was to keep mandated ethanol levels consistent with expected ethanol consumption, so less constrained by any ethanol blend wall. In this instance, the proposed overall mandate being reduced for the first time has resulted in lower RIN prices and future expected costs of the program, but less incentive to develop fuel pathways that involve consumption of higher ethanol blends or drop-in alternatives.

Under the LCFS, the value of low CI fuel incentives depends on both the LCFS credit value as well as the fuel's CI rating. Increasing LCFS credit prices combined with dropping RIN prices for the RFS2 in 2013 meant the LCFS played a

stronger role in incentivizing the use of fuels rated as low-carbon, with effects seen particularly for corn oil, canola and waste biodiesel/renewable diesel. The relatively low CI ratings of sugarcane ethanol and waste biodiesel translate into more \$/gal than corn ethanol or soy biodiesel (Figure 9). As LCFS credit values increased over time, values per gallon from LCFS credits rose (larger sizes of red and green bars over time in Figure 9). By November 2013, LCFS credits added more value than RFS2 RINs to many diesel substitute pathways with relatively low LCFS CI ratings, including corn oil, canola, and waste BD/RD.

For corn ethanol, the RIN premium was close to \$1/gal in June 2013, dropping to 23 cents/gal in November 2013. With higher LCFS credit prices in November 2013, the LCFS added a premium to low-CI corn ethanol, reaching 14 cents/gal, while high-CI corn ethanol incurred a cost of up to 15 cents/gal, since it did not meet the CI reduction requirements (Figure 9). Similarly, the sugarcane ethanol premium came mostly from the RFS2 (41 cents/gal to \$1/gal) for 2012 and into June of 2013. As RIN values decreased and the LCFS credit price increased, premiums for sugarcane ethanol from the two programs grew to roughly the same (27 cents/gal from each program) in November 2013. High LCFS credit prices in November 2013 also meant that for very low CI waste biodiesel/renewable diesel and corn oil, the LCFS premium (88 – 95 cents/gal) significantly outweighed value from RINs (29 cents/gal). As noted in Section 3, LCFS credit prices dropped to about \$50 in mid-December 2013, a decline of about 38% from November levels. Mid-December renewable RIN prices rose about 6 cents (27%) over their November average, to around 30 cents; and were between 30 and 33 cents (about 10% higher from November averages) for other mandate categories (biomass-based diesel and advanced). Premiums from RFS2 RINs therefore increased, and from LCFS credits decreased from

November levels to mid-December.

4.2. Cellulosic Biofuel

Cellulosic ethanol and cellulosic biodiesel already generated RFS2 RINs but have yet to generate LCFS credits because no cellulosic fuels have reached California's fuel market to date and no LCFS CI has been established for cellulosic fuels. Cellulosic RIN credits increased in 2013 due to commercial production by INEOS Bio and KIOR⁹ to 0.235 million gallons (MG) of cellulosic biofuel (renewable gasoline) and 0.198 MG of cellulosic diesel, from 2012 levels of 0.02 MG of cellulosic biofuel (ethanol) and 0.010 MG of cellulosic diesel. The volume remained far below cellulosic mandate levels for 2013 of 6 million ethanol-equivalent gallons. The combined value currently placed by the RFS2 and LCFS on cellulosic fuels rated as low-CI under the RFS2 is the EPA-set price of cellulosic credit waivers (42 cents/gal), approximately the combined value of sugarcane ethanol in September 2012 (see chart in Figure 9 above).

5. Special Topic: Cost Containment Mechanisms

Given that the LCFS is a performance standard that relies on market mechanisms to achieve compliance, there are uncertainties associated with the costs of compliance. High costs, low availability, or consumers' reluctance to adopt alternative fuels/vehicles could all limit the availability of low-cost fuels on the market and potentially raise the overall fuel costs that ultimately introduce additional uncertainty about program implementation. In May 2013, CARB released a white paper discussing five options that have been suggested to contain LCFS compliance costs.¹⁰

Recently the UC Davis LCFS research team

released a report¹¹ examining the effectiveness of various proposals in controlling the risk of high compliance costs and the effects of these proposals on market outcomes such as prices, low-carbon fuel use and GHG emissions. The general findings of the report are summarized below:

- **Expectations of the market matter:** Because credits can be banked and traded in the future, anticipated future costs, policy changes, technological/capacity constraints will be reflected in current credit prices.
- **Importance of cost containment mechanisms:** In the short-run, CCMs may play an important role in safeguarding the LCFS credit market, and LCFS program itself, from high credit prices and program costs.
- **Most effective cost containment designs:** Hard caps (e.g., selling emergency credits at a given price, instituting a non-compliance penalty, combined with instituting a reinvestment plan where regulated parties may contribute to a fund used to invest in low-carbon fuels) are recommended as alternative compliance mechanisms for the LCFS over soft caps (e.g. using a low-carbon fuel credit multiplier, or relaxing/freezing the standard on an annual basis) as the latter do not guarantee costs will be contained, and may have adverse effects on market outcomes (e.g. reduced incentives for very low-carbon fuel). Hard caps can guarantee cost containment and can be administered to send clear signals to the market.
- **Effects on fuel prices:** By ensuring compliance costs within the LCFS are contained, CCMs guarantee the effect of the LCFS on fuel costs are limited. The overall effect of the LCFS and CCMs on fuel prices depends on the availability and competitiveness of low-carbon fuels, the level of the CCM, and how overall fuel demand

changes in future years. Using hypothetical scenario analyses for caps ranging from \$75 to \$250/ton CO₂e, the overall impacts on fuel prices are less than 30 cents per gallon of fuel.

- **Interactions with the cap-and-trade:** Beginning in 2015 emissions from the combustion of all fossil fuels will be covered under the state's cap-and-trade program. Because the transition will leave renewable fuel emissions exempt from the cap, the relative price difference between baseline fossil fuels and more expensive renewable fuels will become smaller. As a result, the incorporation of emissions from the combustion of fossil fuels under the cap will put downward pressure on LCFS credit prices. In addition, the phase-in of fossil fuels under the cap ensures any excess emissions from fossil fuels resulting from firms using a CCM would be covered under the cap. Thus, an LCFS cost containment provision will not compromise the GHG reduction goals of AB 32.¹² Effects of the fossil fuel phase-in to the cap-and-trade program on LCFS credit prices and alternative fuel choices are important to consider in setting an LCFS CCM.

Overall, in order to be an effective policy, an LCFS CCM should be: 1) easy to implement (requiring as little regulatory oversight as possible); 2) transparent (establishing clearer price signals while reducing uncertainty and volatility in credit price to incentivize long-run investment decisions by firms); 3) include safeguards against market manipulation or unintended consequences in terms of emissions or market prices that would erode confidence and jeopardize the LCFS program.

Acknowledgments

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Endnotes

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<http://www.arb.ca.gov/lispub/rss/displaypost.php?pno=6938>

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<http://cdn.ca9.uscourts.gov/datastore/opinions/2013/09/18/12-15131.pdf>

³ For simplicity, we assume all electricity is in the gasoline pool (therefore apply the energy economy ratio (EER) relevant to the gasoline pool). Similarly, we assume all waste-based biofuels (mostly from tallow and used cooking oil) displace diesel even though the category contains an unknown quantity of ethanol from a waste beverages pathway (likely a small proportion of the total). We do not calculate a CI

for the corn category (see endnote 4).

⁴ The calculation for the waste category CI is an approximation, not exact numbers. The majority of the waste category is tallow and used cooking oil that displaces diesel, but also includes an unknown quantity of waste beverages ethanol from a single modified pathway. Information on the quantity of waste-based ethanol is needed to accurately calculate waste CI values based on CARB data for credits generated (because the CI standard for the gasoline pool relevant for ethanol is not the same as the standard for the diesel pool relevant for the fats and oils). Since the amount of waste-based ethanol is likely to be small, we choose to ignore it and calculate waste CI values as though all waste is used for pathways in the diesel pool. For similar reasons, the figure does not include corn CI since the category contains an unknown quantity of corn oil that substitutes for diesel, in addition to corn ethanol that substitutes for gasoline.

⁵ Of these, 70 have received final approval (http://www.arb.ca.gov/fuels/lcfs/lu_tables_11282012.pdf), and the rest can be used as they await CARB hearings (www.arb.ca.gov/fuels/lcfs/2a2b/052913lcfs_apps_summary.pdf), plus June postings available at <http://www.arb.ca.gov/fuels/lcfs/2a2b/2a-2b-apps.htm>).

⁶ BD/RD wastes had 8 new pathways, average CI rating 23.9 gCO₂e/MJ. Landfill biogas CNG/LNG had 5 new pathways, average CI rating 36.3 gCO₂e/MJ. Molasses ethanol had 2 pathways, average CI 22.1 gCO₂e/MJ.

⁷ <http://www.arb.ca.gov/fuels/lcfs/reportingtool/registerfacilityinfo.htm>

⁸ We ignore other factors that affect the market competition of fuels, such as relative cost of fuel production (e.g., relative feedstock prices, blending credits for use of particular feedstocks, import tariffs or other trade policies in the US and major trading partners for biofuels, such as the EU and Brazil).

⁹ <http://www.epa.gov/otaq/fuels/renewablefuels/documents/rfs-2014-standards-nprm-11-15-13.pdf>

¹⁰ The white paper is available at http://www.arb.ca.gov/fuels/lcfs/regamend13/2013052ccp_conceptpaper.pdf. The proposed cost containment mechanisms include the following proposals:

- 1) Unlimited credit window: compliance credits available for purchase by regulated parties at a predetermined price. Funds collected from the sale of these compliance credits would be

distributed to parties who use or produce low-CI fuels;

- 2) Reinvestment plan: regulated parties have the option of putting money into re-investments in a wide-range of projects related to lowering GHG emissions from transportation fuels production, transport, and use;
- 3) Credit multiplier: apply a multiplier to ultra low-carbon fuels;
- 4) Credit clearance: regulated party would be allowed to carry over deficits to the next compliance period after they buy their "pro rata" share of all available credits remain on the market;
- 5) Noncompliance penalty: pay a pre-determined penalty fee for non-compliance.

¹¹ Lade, G. E.; Lin, C.-Y. C. *A Report on the Economics of California's Low Carbon Fuel Standard and Cost Containment Mechanisms*. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-13-23: 2013.

¹² However, it might lower the portion of AB 32 goals met with transportation emission reductions. Emission reductions achieved under the cap would occur where carbon can be saved most cost effectively – not necessarily in the transportation sector.