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Status Review of California's Low Carbon Fuel Standard, 2011–2015

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Status Review of California's Low Carbon Fuel Standard, 2011–2015

Highlights

- From 2011–2015, the average fuel carbon intensity (AFCI) of all alternative fuels reported to the program declined 21 percent, from near 86 grams carbon dioxide equivalent per mega-joule of fuel energy (gCO_2e/MJ) to just over 68 gCO_2e/MJ.
- Alternative fuels contributed 6.2 percent of California's transportation fuels by energy content in 2011 and 2012, and reached 8.1 percent in 2015. Fuels other than liquid biofuels comprised 10.9 percent of alternative fuel transport energy in 2014 and 2015.
- From 2011–2015, the LCFS required a reduction of 9.2 million metric tons (MMT) CO_2e from the baseline. The total emissions reductions reported for the same period was 16.8 MMT CO_2e, or 7.4 MMT more than required by the regulation (overcomplying by 81 percent).
- Increases in alternative fuel use came primarily from biodiesel, renewable diesel, biogas and electricity. Use of ethanol, the largest renewable fuel by volume, remained close to a "blendwall" of 10 percent blended with gasoline, the maximum allowed without alternative infrastructure.
- Total electric vehicle miles traveled (eVMT) in 2015 is estimated to be around 1.3 billion miles based on reported electricity consumption of 431 gigawatt-hours (GWh) or 13 million gasoline gallon equivalent (GGE). None of the 2.2 million gallons (1.5 million GGE) of cellulosic ethanol used in the U.S. in 2015 was consumed in California.
- LCFS credit prices have shown considerable variation. The average credit price was $20 early in the program (and while the standard was frozen at 1%). Prices have remained above $100/credit thus far in 2016. The overall nominal value of all credit transfers was calculated at $430 million (December 2012–April 2016).
- Other jurisdictions' LCFS programs, including the European Union Fuel Quality Directive, the British Columbia Renewable & Low Carbon Fuel Requirements Regulation, and the Oregon Clean Fuels Program, share many features with California's LCFS but have distinct provisions as well.

Introduction

California's Low Carbon Fuel Standard (LCFS) is an integral part of the overall strategy to reduce greenhouse gas (GHG) emissions in California. The primary objectives of an LCFS, sometimes referred to as a clean fuel standard, are to: (i) reduce GHG emissions from the transportation sector; (ii) incentivize innovation, technological development, and deployment of low-emission alternative fuels and alternative fuel vehicles; and (iii) provide a framework for regulating transportation sector GHG emissions within a broader portfolio of climate policies. In advancing these objectives, an LCFS is notable for its design as a technology-neutral performance standard.[i] The policy does not include mandates for any particular fuel, technology, or compliance strategy. Instead, it defines an average carbon intensity (CI) standard, measured in grams carbon dioxide equivalent per mega-joule of fuel energy (gCO_2e/MJ), which all regulated parties must achieve across all fuels they provide within the jurisdiction. To meet the standard, regulated parties may employ any combination of strategies, including: (i) producing low carbon fuels; (ii) purchasing low carbon fuels from other producers; (iii) purchasing credits generated by producers of low carbon fuels; or (iv) banking credits across compliance years for future use.

In 2016, the standard requires a reduction of 2 percent in CI for gasoline and diesel fuel pools from 2010 baseline levels, up from 1 percent in 2013–2015, on the way to 10 percent by 2020. The standard was frozen at 1 percent reduction from

2013–2015 due to a court ruling. The California Air Resources Board (ARB) formally re-adopted the rule in 2015 with procedural changes and other amendments (1).

This issue reviews LCFS compliance metrics from 2011 through 2015: transport fuel energy and LCFS credits and deficits (Section 1), carbon intensity of fuels (Section 2), and credit trading and prices (Section 3). As special topics (Section 4), we provide a very brief review of existing low carbon fuel standard (clean fuel) programs in other jurisdictions, and briefly summarize a recent journal article on California compliance.

Table 1. Total transportation energy use reported in California's LCFS program (million gge).

	2011	2012	2013	2014	2015
Gasoline (CARBOB)	12,948	13,089	12,788	13,093	13,323
Diesel (ULSD)	3,905	4,026	3,831	3,875	3,884
Ethanol	1,015	1,005	1,008	1,012	1,038
Biodiesel	13	21	63	71	133
Renewable diesel	2	10	127	122	179
NG	82	94	100	109	76
Biogas	1.8	1.8	12	30	77
Electricity	0.4	1.3	3.6	8.5	13.0
Hydrogen					0.003
Total	17,968	18,249	17,933	18,322	18,722
Total alt fuel	1,115	1,134	1,314	1,354	1,515
Total alt fuel (percent of total energy)	6.2%	6.2%	7.3%	7.4%	8.1%
Non-biofuel portion of alt fuel	7.6%	8.6%	8.8%	10.9%	10.9%

1. Transport Energy and LCFS Credits and Deficits

The contribution of alternative fuels to total transportation energy in the state increased over the period. Alternative fuels contributed 6.2 percent of California's transportation fuels by energy content in 2011 and 2012; their contribution grew to 8.1 percent in 2015 (Table 1). Increases in alternative fuel use came primarily from biodiesel, renewable diesel, biogas and electricity. The state increase in biodiesel, renewable diesel and biogas occurred alongside increased use nationally to meet the federal Renewable Fuel Standard (RFS). Use of renewable natural gas (biogas) as a transport fuel has risen sharply since it became eligible to meet the cellulosic mandate of the RFS in 2014 (2). Among alternative fuels, fuels other than liquid biofuels comprised nearly 11 percent of transport energy in both 2014 and 2015. Use of ethanol, the largest renewable fuel by volume used in California and the U.S., remained close to a "blendwall" of a maximum 10 percent by volume blend with gasoline without alternative infrastructure.[ii] State consumption of E85, a high ethanol blend fuel that requires a flex-fuel vehicle, has not greatly increased. No cellulosic ethanol was consumed in California in 2015 out of the 2.2 million gallons (1.5 GGE) used in the U.S. (2).

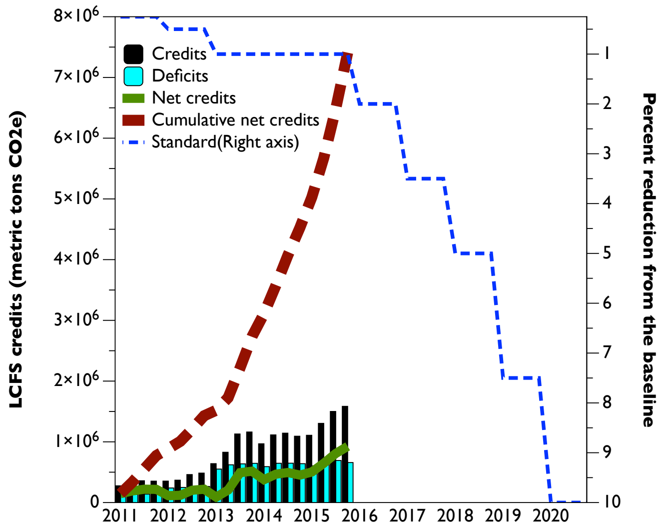

Figure 1. California LCFS carbon credits and deficits generated per quarter. Also shown are cumulative net credits (red line), and the required CI reduction over time (blue line). Data source: (3).

Greater use of electricity as a transportation fuel in California accompanied higher sales of battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV). The state has strong incentives to increase market penetration of these vehicles, and California constituted 46 percent of national BEV and PHEV sales from 2011–2015 (4). The stock of electric vehicles in the state grew from around 60,000 in 2014 to nearly 197,000 in March 2016 (5). Total electric vehicle miles traveled (eVMT) in 2015 is estimated to be around 1.3 billion miles based on electricity consumption of 431 gigawatt-hours (GWh) or 13 million gasoline gallon equivalent (GGE).[iii]

Transport fuels with final sale in California generate program credits and deficits. Through 2015, regulated parties had generated a total of 16.6 million LCFS credits and 9.1 million deficits under the program, where each credit or deficit represents 1 MT CO_2e of emissions relative to the annual standard (Figure 1, left axis). The carbon intensity standard tightens over time; in 2011 the standard required a 0.25 percent reduction and in 2020 it requires a 10 percent reduction (Figure 1, right axis). Net cumulative credits, representing accumulation of credits beyond levels needed for compliance to date, totaled 7.4 million through 2015.

From 2011–2015 the LCFS required emissions reductions of 9.2 million metric tons (MMT) CO_2e from baseline levels. This number is calculated based on the standard, on program CI values, and on actual fuel use. Reported total emissions reductions for the same period were 16.8 MMT below baseline levels, exceeding the regulatory requirement by 7.4 MMT or 81 percent. The overcompliance may be due to the frozen standard, regulated parties' strategic decisions to bank credits with the expectation of decreasing their future compliance costs, or both.

The alternative fuel compliance mix (Figure 2 left) reveals relative contribution of different fuel categories to credit generation (Figure 2 right). Liquid biofuels (ethanol, biodiesel and renewable diesel) accounted for around 84 percent of the credits generated between 2011 and 2015 (Figure 2). In 2015, credits in the diesel fuel pool surpassed those in the gasoline pool for the first time, due to substantial growth in credits from biodiesel, renewable diesel and biogas. Ethanol generated 78 percent of credits in 2011 and 38 percent of credits in 2015. Sugarcane ethanol generated 5 percent of total credits for 2011–2015, and contributed close to 11 percent of credits in 2012–2013 as the 2012 U.S. drought affected domestic corn production.

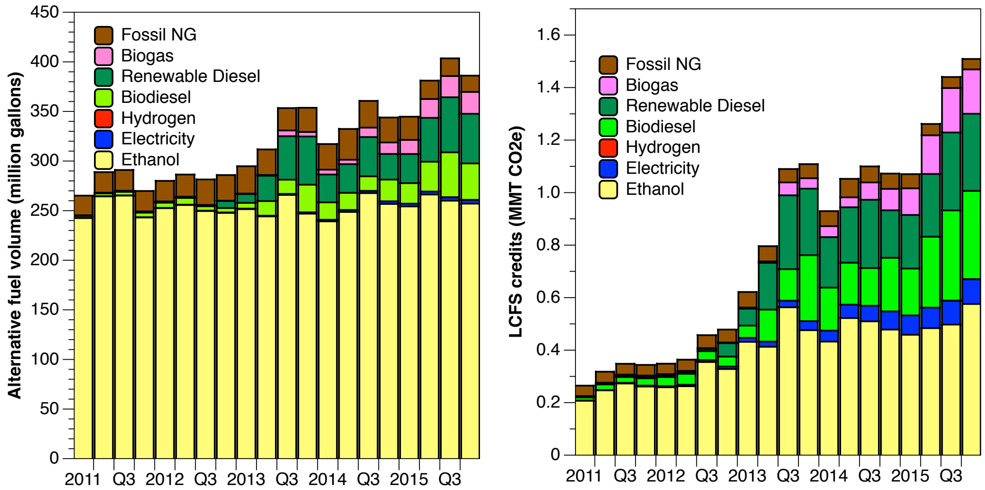

Figure 2. Volumes of alternative fuels and total net LCFS credits by fuel type by quarter. Data source: ARB (3).

2. Carbon Intensity of Fuels[iv]

From 2011–2015, the average CI of all alternative fuels reported to the program declined 21 percent, from near 86 gCO_2e/MJ to just over 68 gCO_2e/MJ (Figure 3). Reductions in the diesel pool were greatest largely due to increased use of biogas and bio/renewable diesel made from very low CI-rated feedstocks such as used cooking oil and tallow (Figure 3). Credits are fungible across the fuel pools (excess credits generated from the diesel pool are available to compensate credit shortfalls in the gasoline pool). Ethanol CI as rated in the program declined over 7 percent from 2011–2015, from 87.5 gCO_2e/MJ to 81.7 gCO_2e/MJ (Figure 3).

We summarize pathway CI ratings through 2015. By December 2015, ARB listed 402 certified transportation fuel pathways and associated CI ratings under the LCFS. There were 495 fuel facilities registered in the program (8).[v] Most (almost 70 percent) were ethanol; 25 percent were biomass-based diesel (biodiesel/renewable diesel). Figure 4 shows ranges of certified pathway CI ratings and number of pathways by fuel category, as well as their average CI ratings (based on reported fuel use in the program).

Under the recent re-adoption, ARB revised the pathway processing system as well as the models used to generate CI ratings (see footnote 4) to distinguish between mature production processes and technologies (Tier 1) and fuel pathways with newer technologies (Tier 2), with a goal of allowing ARB staff sufficient time to analyze newer technologies. More discussion of the updated system can be found in the regulation (9) and our more detailed review in Yeh and Witcover et. al. (10).

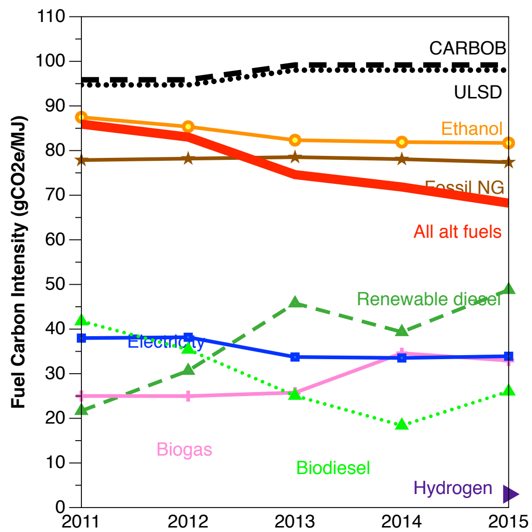

Figure 3. Annual average CI of gasoline, diesel and alternative fuels, 2011–2015. Data source: ARB (3).

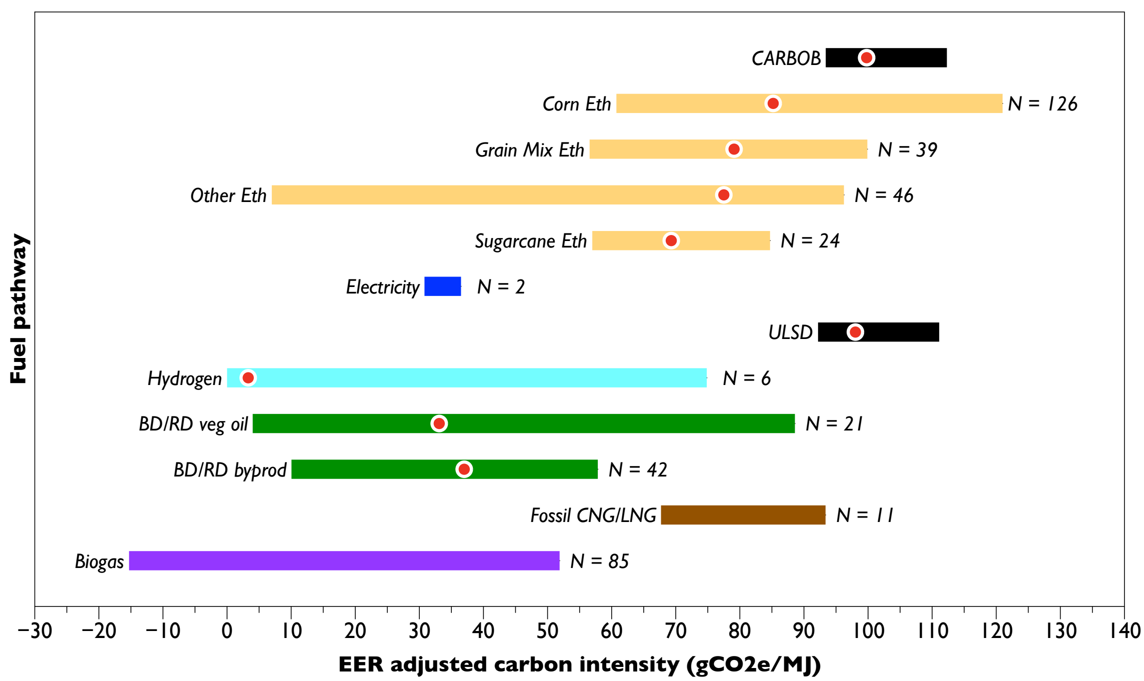

Figure 4. CI rating ranges and number of pathways for feedstock/fuel combinations in California's LCFS, 2015 data. Colored bars represent CI ranges for pathways certified in the program and available for use. Black bars show CI ranges for California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB) and Ultra-Low Sulfur Diesel (ULSD) pathways accounting for country of crude oil origin. Red circles represent average CI ratings after adjusting for energy efficiency ratios (EERs) of 3.4 for electricity and 2.5 or 1.9 for hydrogen (for gasoline and diesel pools, respectively). For CARBOB and ULSD, red circles show the single value used to calculate the California average CI ratings for reference fuels (blended gasoline and diesel). "BD/RD byprod" is biodiesel and renewable diesel from animal fat or used cooking oil. "BD/RD veg oil" is biodiesel and renewable diesel from soy, canola, or corn oil. "Grain mix" ethanol pathways include corn/sorghum, corn/sorghum/wheat mixes. "Other ethanol" uses as feedstocks sorghum, molasses, waste beverages, or agricultural residue. Source: (11, 12)

3. LCFS Credit Trading and Prices

LCFS credits are exchanged "over the counter" through bilateral trades between obligated parties. The market determines the credit price based on supply (credits generated by low carbon fuels) and demand (credits needed to cover deficits generated by higher carbon fuels). The credit price directly determines the size of incentives to low carbon fuels and disincentives (additional costs) for high carbon fuels.[vi] A positive credit price reflects that the program is binding, i.e., that the policy has an impact on the transportation carbon intensity, and more specifically the expected marginal compliance cost. LCFS credit prices are uncertain due to uncertainty in factors that affect these expected costs, including policy (potential changes in the LCFS and other fuel policies primarily the federal biofuel program, the Renewable Fuel Standard or RFS2), fuel prices, and commercial development of low-CI fuels. All of these factors can contribute to credit prices deviating from a theoretical marginal compliance cost (13).

LCFS credit prices have shown considerable variation (Figure 5). Credit prices increased to $80 in 2013 as the standard's stringency increased, then declined to around $20–$25 per credit while court cases about the regulation were ongoing. Credit prices increased again beginning in July 2015, after ARB began the proceeding to re-adopt the LCFS and re-instate a compliance schedule of increasing stringency toward the 2020 10 percent reduction target. The overall nominal value of all credit transfers was calculated at $430 million (December 2012–April 2016), from data in ARB reports. The number of entities that only bought credits remained roughly the same, but the total number of entities that had bought and sold, or sold only, more than doubled (Figure 5c).

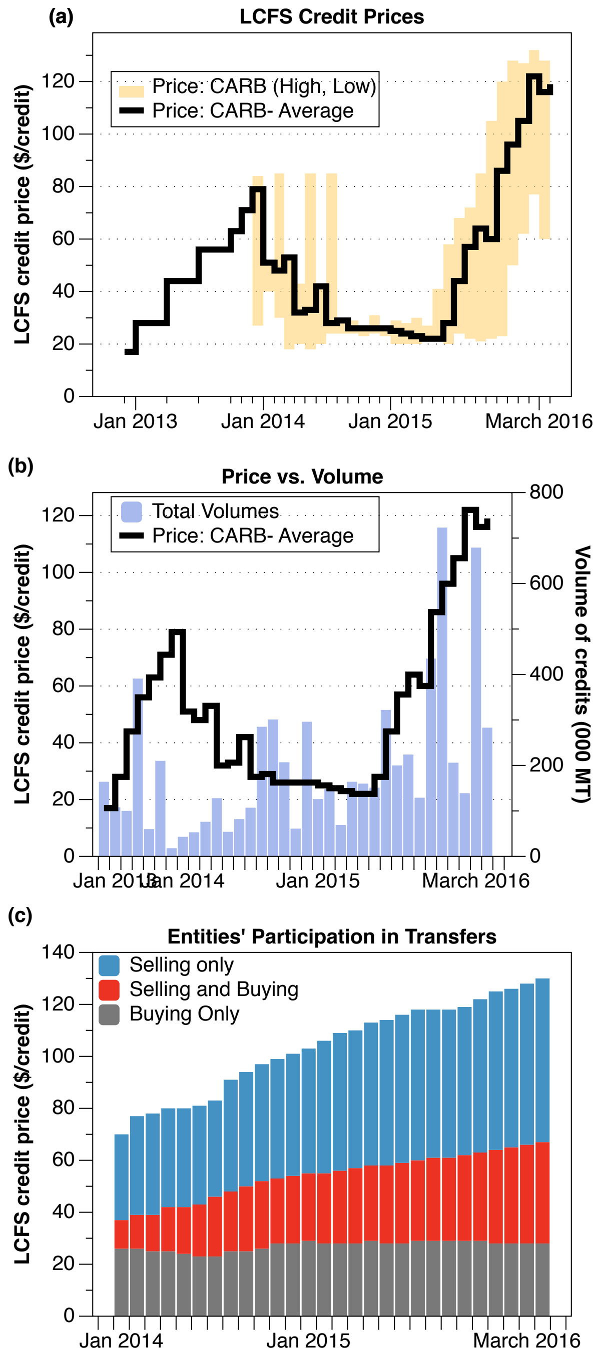

Figure 5. Range and average LCFS credit prices (a); credit price vs. credit volumes (b); and entities' participation in transfers (c). Data source: (14)

4a. Special Topic: Other LCFS Programs

LCFS programs are also in effect in other jurisdictions. Here we briefly review these other programs and highlight key differences from California's LCFS. In Washington state, legislative action in 2015 effectively prohibited executive action on a clean fuels program to meet state-legislated climate targets until 2023. More detailed comparison of these programs is provided in the supporting information of Yeh and Witcover et al. (10). Potential harmonization of these programs was discussed in an earlier issue, Yeh and Witcover (15).

4a.1 European Union Fuel Quality Directive

EU legislation adopted in 2009 (Directive 2009/30/EC) included a requirement to reduce the GHG intensity of EU transportation fuel by 6 percent in a revision of the Fuel Quality Directive (or FQD, Directive 98/70/EC), essentially a low carbon fuel standard, alongside a separate target (in the Renewable Energy Directive, or RED) that renewable fuels comprise 10 percent of EU transportation energy by 2020. The FQD can be met through a combination of renewable fuels, other alternative fuels (like electricity or hydrogen), or upstream emissions reductions in fossil fuel production.

Under the FQD, European member states are responsible for enforcing national targets and sustainability criteria (16), which include GHG intensity reduction threshold requirements for eligible bio-based fuels. These threshold requirements are currently 35 percent, rising to 50 percent in 2017 and 60 percent in 2018 for facilities starting up in or after fall 2015. Emissions from indirect land use change (ILUC) must be reported but are not counted in assessing GHG intensity reductions, and energy from agricultural land-based crops is capped at 7 percent of transport energy (the bulk of the 10 percent by 2020 RED target). The decision on the cap came after a long debate on environmental impacts of land-based renewables and appropriate ILUC values for policy. There are no stated policy goals for bioenergy in transportation beyond 2020. Thus far, Germany is the only member state to implement the FQD as the primary policy instrument for satisfying both directives (FQD and RED)(17).

4a.2 British Columbia Renewable & Low Carbon Fuel Requirements Regulation

In 2010, British Columbia began implementation of the Renewable & Low Carbon Fuel Requirements Regulation (RLCFRR) in support of a goal to lower provincial greenhouse gas (GHG) emissions by 33 percent by 2020. Similar to the EU rules, BC's regulation has two parts: (i) The Renewable Fuel Requirement sets renewable content targets for gasoline and diesel, and (ii) The Low Carbon Fuel Requirement mandates a 10 percent reduction in transport fuel carbon intensity by 2020.

The RLCFRR does not include ILUC in its lifecycle accounting, but states that it is potentially significant and that GHG impacts from this source should be considered. The RLCFRR includes an alternative means to generate program credits – so-called "Part 3 agreements." Part 3 agreements are entered into by the implementing agency and obligated parties, for generation of a pre-specified number of credits upon completion of pre-specified verifiable milestones considered by the agency to further the low carbon transport energy goals of the regulation. Unlike the regulations in California and the EU, at this time the RLCFRR does not include provisions for upstream credit generation by CI reductions in production of conventional fossil fuels.

Recent government estimates of GHG emissions reductions due to the program totaled 904,868 MMT, equivalent to emissions from about 190,500 cars (18). There has been no public report on compliance since the program's first compliance year (2013, a 1.25 percent CI reduction standard), nor public announcement of credit trades to date. Potential explanations for this lack of information include that the standard has not yet been binding, that compliance via Part 3 agreements or other mechanisms for credit generation by regulated parties has been adequate, or that regulated parties are not in compliance. The agency has reported entering into several Part 3 agreements (in 2014, for roughly 130,000 credits to be generated as agreed-upon milestones are reached), and issued a form for tracking credit trades in 2015. Administrative penalty for compliance violations is set at $200 per uncovered deficit.

4a.3 Oregon Clean Fuels Program

The Oregon legislature authorized the state Environmental Quality Commission to develop low carbon fuel standards for Oregon in 2009 with a goal of reducing the average CI of Oregon's transportation fuels by 10 percent over a 10-year period. The governor instructed the Department of Environmental Quality to begin a rulemaking for an Oregon Clean Fuels Program in 2012. Last year, Oregon lifted a 2015 sunset on the program through legislative action. The program's first compliance year is 2016 (0.25 percent reduction from its baseline values).

Oregon uses similar lifecycle analysis methods to those in California for fuel CI ratings, but applies emission factors consistent with end-use of fuel in Oregon, and uses a different emissions factor model for ILUC estimates for corn ethanol (see Table SI.1 in Yeh and Witcover et al. (10)). Oregon accepts California-certified pathways and plans to recertify pathways in 2016 in step with the California process to reflect the model updates included in the LCFS re-adoption. Regulated parties can submit new pathways using an online process similar to California's.

Several aspects distinguish Oregon's program from California's LCFS. Because Oregon adopted its Clean Fuels Program after renewable fuel blending requirements were already in place, its baseline fuels include biofuel blends of E10 and B5. In California, baseline gasoline blends were below E10 with very low levels of biodiesel sold in the state prior to implementation. Oregon's initial compliance report will cover two compliance years (2016 and 2017). Another major difference is that Oregon has no oil refineries (while California has 18); for this reason, a significant percentage of fuel comes into the state blended at racks in Washington state (less significant coming from Idaho). The transporters of those fuels into Oregon have less direct ability to influence the carbon intensity of the fuel than would a refiner. Oregon also has a number of regulated parties who are not participating in California's LCFS, and therefore are less familiar with the regulation.

4b. Special Topic: Recent Academic Study on LCFS Compliance

A recent peer-reviewed academic study used scenario analysis in an economic model to examine LCFS compliance through 2020. The study points out the stringency of the program and suggests a need for dramatic change in the liquid fuel mix from 2015 conditions for compliance. It found that the number of banked credits and liquid fuel mix to date are insufficient to cover compliance targets through 2020, and that meeting those targets will likely require more aggressive blending of biomass-based diesel starting in 2016 (considerably beyond the share of biodiesel and renewable diesel blended in 2015)(19). Its simulation focused on the non-cellulosic liquid fuels market and used: currently available fuels; no changes in CI ratings over time; CI ratings in effect prior to the recent update (see Section 2); and some restrictions on U.S. alternative fuel imports reflecting potential infrastructure constraints to rapid scale-up.[vii]

Note

This is an abridged and slightly modified version of an original article "A Review of Low Carbon Fuel Policies: Principles, Program Status and Future Directions" by Sonia Yeh, Julie Witcover, Gabriel Lade, and Daniel Sperling submitted to the journal *Energy Policy* on March 31, 2016 for peer-review. The contents of the two will differ due to separate review and editorial processes. We acknowledge the feedback and suggestions provided by Bill Peters of Argus Media on an earlier version of the article.

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Endnotes

[i] While all alternative fuels are treated the same under an LCFS, conventional fuels may be differentially treated (with goals of encouraging innovation in fossil fuel production and avoiding shuffling of large volumes of fossil fuels).

[ii] A 15 percent ethanol by volume blend (E15) has been approved for the U.S. by the EPA for passenger vehicles of model year 2001 or newer, but not in all states (and not in California).

[iii] The 2015 EV fleet composition was 59 percent BEV, 14 percent PHEV10 (a vehicle that can be driven solely by an electric motor for 10 miles without consuming gasoline), 9 percent PHEV20, and 18 percent PHEV40 (6). The average annual eVMT was estimated at 2,910 miles for PHEV10; 4,203 miles for PHEV20; 9,112

miles for PHEV40 and 9,642 miles for BEVs, based on data collected nationally from 21,600 vehicles. The national data came from eight plug-in electric vehicle (PEV) models tracked between 2011 and 2013 (7). Sources of uncertainty in the estimate include the representativeness of national samples of eVMT estimates taken between 2011 and 2013 for California's average driving of 2015.

[iv] Note that this section provides a status report on program CIs *at the time fuel volumes were used and credits generated in the program,* as reported in the previous section. The LCFS re-adoption included an update to CI models and associated ratings for all fuels – gasoline and diesel baselines as well as alternative fuels. The updates resulted in lower estimates for indirect land use change emissions and therefore lower CI ratings for many fuels using land-based feedstocks. ARB has started to transition legacy pathways to its updated rating system, and pathways certified starting in 2016 are under the new system. ARB now posts and updates CI ratings on an ongoing basis; current CIs are available at http://www.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

[v] To generate credits, fuel facilities and a description of the physical route of the fuel (modes of transport to end use) for biofuels must be registered in the program. A single pathway with fuel reported does not appear among certified pathways: renewable diesel with unspecified feedstock ("RNWD-Other"). Uncertified diesel pathways can be used with the reference diesel CI rating with approval from ARB. The pathway generated deficits in 2013-2015 and has a calculated CI of 98 gCO_2e/MJ (and is accounted for in Figure 3).

[vi] Effective subsidy or tax $\left(\frac{\$}{gallon}\right) = LCFS\ credit\ price\ \left(\frac{\$}{MTCO2_e}\right) \times (CI^{XD}_{standard} - \frac{CI_i}{EER^{XD}_i}) \times E^{XD}_{displaced} \times \frac{1\ tonne\ CO_2e}{10^6 gram\ CO_2e}$, where $CI^{XD}_{standard}$= fuel carbon intensity standard (XD = gasoline or diesel) for a given year in gCO_2e/MJ; CI_i= fuel carbon intensity of fuel *i* (gCO_2e/MJ); EER^{XD}_i= Energy Economy Ratio (dimensionless) that adjusts for the engine efficiency when fuel *i* is used compared to gasoline or diesel; and $E^{XD}_{displaced}$= amount of gasoline or diesel displaced (MJ/gal) which equals the energy of fuel *i* times EER^{XD}_i.

[vii] In contrast, in the ARB scenario used for the re-adoption: a) **CI ratings** were updated based on revised models and fell over time for existing fuels; b) **import potential** was higher; and d) **relative production costs** were not explicitly modeled.