



Creating a Large, Guaranteed Market for Advanced Biofuels Through a Low Carbon Fuel Standard

California adopted the Low Carbon Fuel Standard (LCFS) in April of 2009, a measure that will guarantee a market of up to 3.4 billion gallons/year of low-carbon biofuels by 2020. Eighteen other states in the U.S., the European Union and provinces in Canada are also moving forward with a low carbon fuel standard. We expect that these other regional standards will share many of the design elements of the California plan.¹ The LCFS uses a performance-based, fuel-neutral approach to reduce the carbon intensity of transportation fuels over time.² Oil price volatility over the past several years has led to increased investment risk for the biofuel sector. The LCFS helps to mitigate this impact by creating a long-term, market signal for biofuel products. The LCFS creates a stable, long-term market for cleaner fuels.

As discussed below, advanced biofuel producers are provided a number of advantages through the Low Carbon Fuel Standard compared to the federal Renewable Fuel Standard 2 (RFS2). The LCFS requirements will create a significantly larger market for ultra-low carbon biofuels in California compared to the RFS2. The market facilitated by the LCFS will be 40% to 100% larger by 2020 compared to the RFS2. The LCFS will essentially create a guaranteed market for advanced fuels and require the output of approximately 50 to 70 advanced, commercial scale biofuel production facilities.

Overall, the economics for low-carbon fuel producers include both the value of billions of gallons of fuel plus the value of LCFS credits of nearly \$1 billion in 2020, assuming a LCFS credit value of \$50/ton CO₂e.

How a Low Carbon Fuel Standard Works

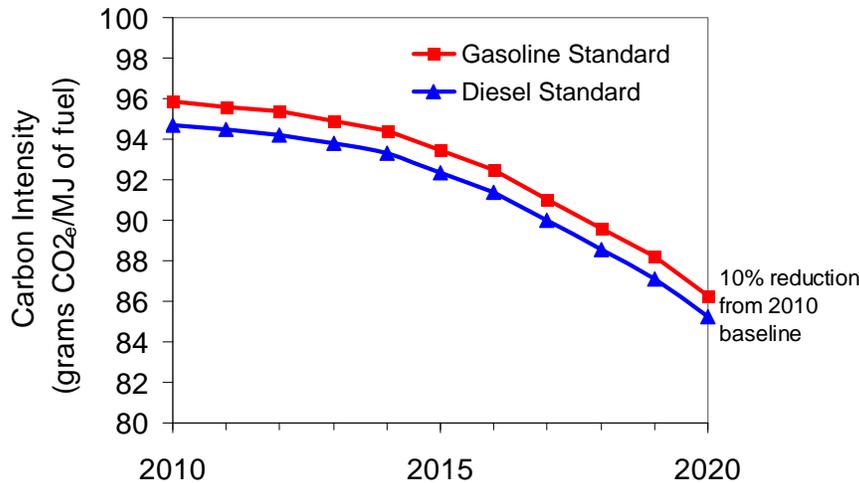
In California, the LCFS requires oil refineries and importers to achieve a 10% reduction in the carbon-intensity of their fuels by 2020 (Figure 1). The LCFS ensures that fuel providers manage their carbon liability and reduce emissions in the transportation sector through the use of low carbon alternative fuels. By using a performance-based, fuel neutral structure, the LCFS provides maximum compliance flexibility and maximize incentives for innovations that reduce greenhouse gas (GHG) emissions. Oil companies are given the flexibility to either supply a mix of fuels that, on average, meets the requirement of the LCFS or to purchase low carbon fuel credits.

¹ These states include Oregon, eleven Northeast and Mid-Atlantic states, and six Midwest states signing onto the Midwest Greenhouse Gas Accord (not including three observer states).

² International bunker fuels and aviation fuels are not currently included in the California LCFS.

Companies that produce low-carbon fuels such as advanced biofuels, electricity, natural gas, and hydrogen will thrive for two reasons: (1) the LCFS provides a guaranteed market for their fuels and (2) they can generate LCFS credits, each of which represents one metric ton of GHG emissions reduction. Oil companies are obligated to hold enough LCFS credits on an annual basis to meet the standard.

Figure 1: LCFS requirements in terms of fuel carbon intensity.



The LCFS creates a market for advanced biofuels that serve as substitutes for diesel fuel as well as those that serve as substitutes for gasoline. Some estimates of the volumes of advanced biofuels needed to meet the LCFS gasoline and diesel standards are discussed next.

The LCFS Increases the Market for Advanced Biofuels

The California LCFS establishes larger market incentives for low and ultra-low carbon biofuels compared to the federal RFS2, and does so in a performance-based manner.

The California Air Resources Board (CARB) estimates that to meet the 10% reduction requirements in 2020, the California LCFS would likely require the use of 2.4 to 3.4 billion gallons (bgal) of advanced biofuels in California (Table 1).^{3,4} By comparison, the federal RFS2

³ These volumes represent high and low cases for the LCFS. CARB (2009a), *Initial Statement of Reasons*, Vol 2, Tables E-1a, E-4a, E-6a, E-7a

⁴ According to federal definitions under the Renewable Fuel Standard (as modified by the Energy Independence and Security Act of 2007), “Advanced biofuel” refers to “any renewable fuel other than ethanol derived from corn starch” and which achieves at least a 50% GHG emission displacement. Advanced biofuels can include, for instance, biomass-based diesel, biogas, butanol or other alcohols produced through conversion of organic matter from renewable biomass. “Cellulosic biofuel” is a subset of this advanced biofuel category and refers to “any renewable fuel, not necessarily ethanol, derived from any cellulose, hemicellulose, or lignin each of which must originate from renewable biomass” and achieve at least a 60% GHG emissions displacement compared to the fuel replaced. P. 22, EPA Notice of Proposed Rulemaking, “Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program,” RIN 2060-A081, May 26, 2009, <http://www.epa.gov/otaq/renewablefuels/index.htm>

mandates specific volumes and types of biofuels to be used nationwide and is estimated to result in a 3% reduction in GHG by 2020.⁵ California's portion of the federal RFS2 mandates for advanced biofuels is estimated to be 1.7 bgal (Figure 2).⁶

Low Carbon Fuel Standard Terminology

Carbon Intensity refers to the lifecycle greenhouse gas emissions of a fuel, including direct and indirect emissions, including those from feedstock production or extraction, transport, refining or processing, distribution, and use of the fuel. The value is expressed in grams of carbon dioxide-equivalent per mega joule of fuel energy (g CO₂-eq / MJ).

LCFS Credits are measured in terms of metric tons of CO₂-eq reductions and are generated by low-carbon fuel producers providing fuel for sale in California. The amount of credits generated is calculated based on the GHG emissions reduced due to the displacement of gasoline or diesel, using the carbon-intensity values for each fuel. Oil refineries and importers are responsible to hold enough credits to meet their annual reduction requirements (e.g. 10% by 2020).

Fuel Pathway refers to a specific set of processes used by a producer to generate a finished fuel product. Each fuel pathway is represented in the LCFS with a specific carbon-intensity value. All on-road transportation fuels sold in California must have a fuel pathway represented in the LCFS. New fuel pathways can be added through a data submission and approval process.

One example of the advantage afforded to advanced biofuel producers by the LCFS can be seen when considering that RFS2 mandates are based on threshold requirements that do not incentivize biofuels beyond set emissions reduction levels. In contrast, a true performance-based system under the LCFS encourage producers to maximize the opportunity to reduce emissions. Under the federal RFS2, cellulosic biofuels, some of which may be able to achieve GHG emission reductions of 90% relative to gasoline, receive no additional incentives compared to biofuels that just achieve the threshold requirement of 60% emission reductions.

⁵ CARB (2009a), VII-1.

⁶ CARB (2009a), VIII-38. This estimate is based on California receiving a proportional share of the RFS2 fuel volumes in 2020.

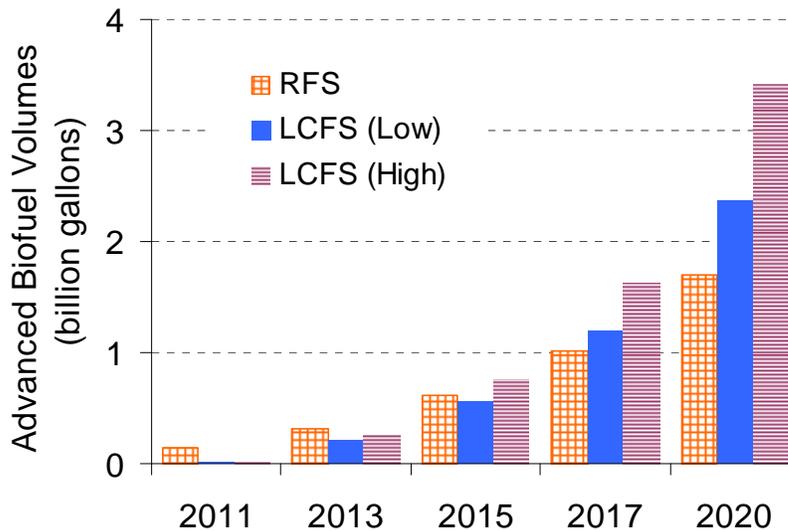
Table 1: Low and High Volume Cases (in billion gallons) for LCFS, CARB (2009), *Initial Statement of Reasons*, Volume 2. Tables E-1a, E-4a, E-6a, E-7a

Fuel Category	Low Case		High Case	
	2015	2020	2015	2020
Midwest Average Corn Ethanol	0.42	0.00	0.31	0.00
California Corn Ethanol (16% reduction)*	0.30	0.30	0.30	0.30
Advanced Corn Ethanol (20% reduction)*	0.00	0.00	0.30	0.00
Sugarcane Ethanol**	0.30	0.30	0.00	0.00
Cellulosic (e.g. energy crops)	0.19	0.79	0.28	1.29
Cellulosic (e.g. forest residue, MSW)	0.19	0.79	0.28	1.29
Biodiesel	0.06	0.26	0.06	0.28
Advanced Renewable Diesel (non FAME)	0.12	0.52	0.13	0.56

* The level of carbon reductions are in reference to the 2010 gasoline baseline.

**Note that under the high volume case, greater volumes of cellulosic-based fuels are used to meet the standard, resulting in reduced use of sugarcane ethanol and corn ethanol use over time.

Figure 2: Advanced Biofuel Volumes; California LCFS versus Federal RFS2. (Cellulosic, biodiesel, advanced renewable diesel from ARB estimates included for the comparison. Sugarcane ethanol not included)

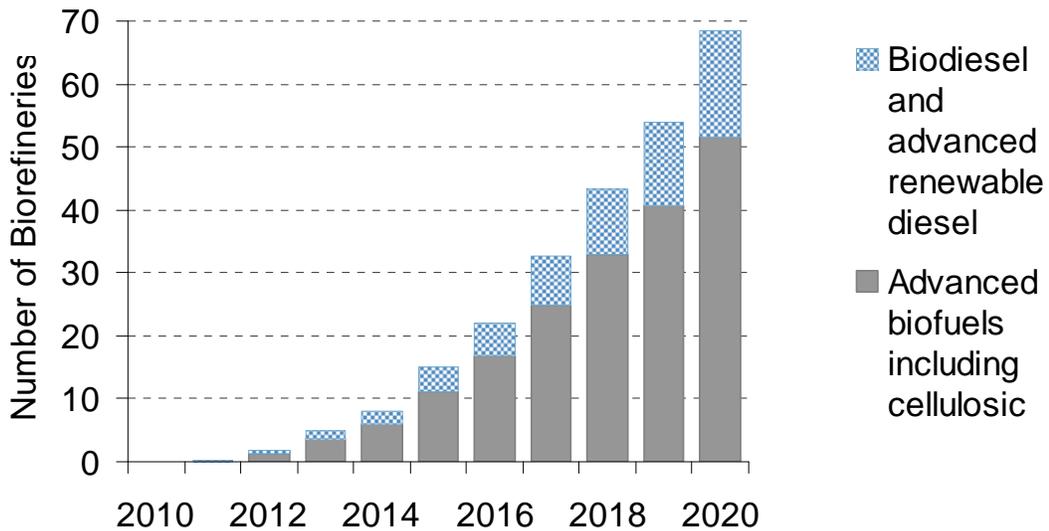


The LCFS will Spur Increased Investments in Low-carbon, Advanced Biofuels and Drive Facilities Development

Meeting the volumes of low-carbon fuels will require the construction or conversion of a number of in-state and out-of-state biofuel production facilities (Figure 3). Meeting the 2020 standard would essentially require the output of 50 to 70 mid-sized, commercial-scale facilities based on the biofuel volumes estimated above by ARB (2.4 to 3.4 billion gallons). This estimate assumes that each of these facilities, on average, produces roughly 50 million gallons per

annum.⁷ Satisfying the production of the requisite amount of low-carbon fuels between now and 2020 will drive significant investment into advanced biofuel facilities under the LCFS.

Figure 3: Estimated Number of Advanced Biofuel Facilities to Meet the California LCFS, Based on the high volume case shown in Figure 2. [Assumes each plant produces 50 million gallons per year]



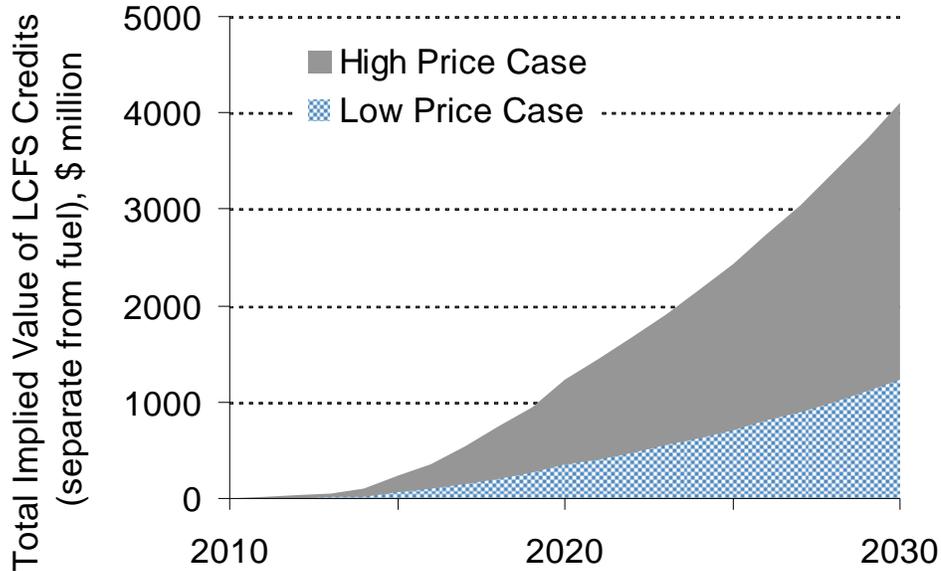
The LCFS Creates a Long-term, Stable Market Signal to Industry and Investors

Oil price volatility over the past several years has led to instability and increased investment risk in the biofuel sector. The LCFS helps to mitigate this impact by creating a long-term, market signal for biofuel products. As an example, Figure 4 below displays the potential additional clean fuel investment resulting from the LCFS, based on two theoretical price trajectories for the LCFS credit values. The low price case assumes the credit value starts at \$5/ton CO₂ in 2010 and grows to \$30 by 2030. The high price case assumes the credit value starts at \$25/ton CO₂ in 2010 and grows to \$100 by 2030. The analysis also assumes the stringency of the LCFS increases to 24% reductions by 2030.⁸

⁷ This range assumes the low and high volume case shown in Figure 2 and assumes a mid-sized, advanced biofuel facility produces 50 million gallons per annum.

⁸ This LCFS target for 2030 would be consistent with California’s overall state goals to achieve an 80% reduction in GHG emissions by 2050, below 1990 levels, and assumes that the overall transportation energy use decreases over time due to vehicle efficiency standards and other State energy and climate policies.

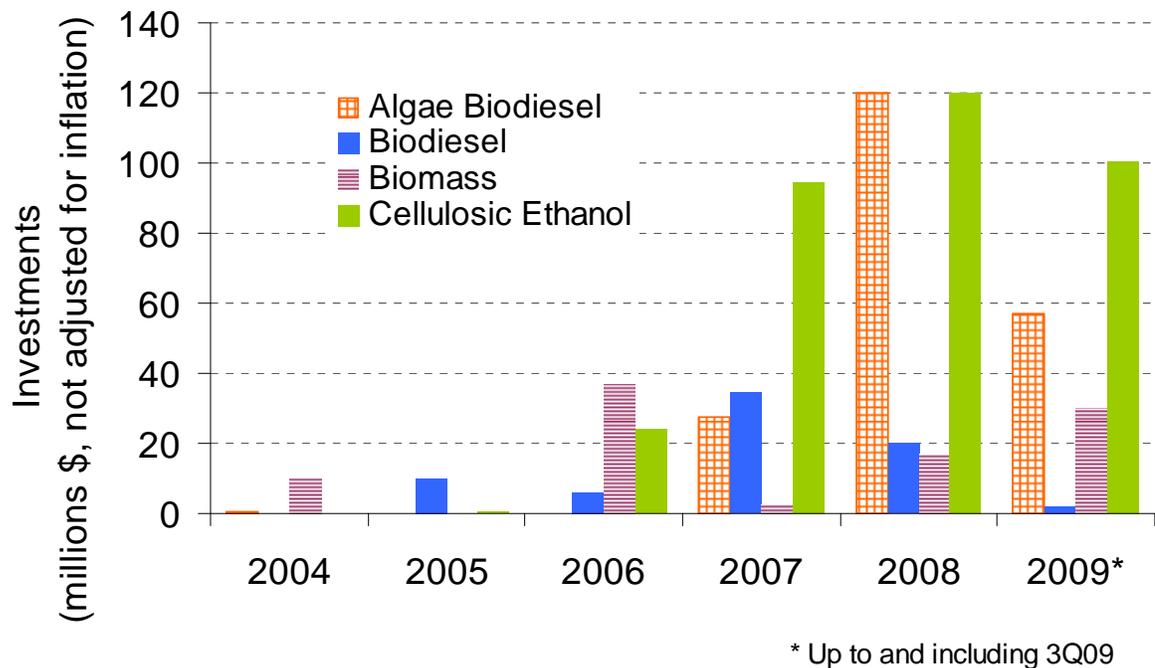
Figure 4: Implied Value Over Time of the LCFS Program For Low-carbon Fuels
Based on low price and high price trajectories for the credits. The analysis assumes the requirements grow from 10% reduction in carbon intensity in 2020 to 24% reductions in the average carbon intensity of the fuel pool.



In addition, California’s venture capital investments in advanced biofuels in the last three years are estimated to be over \$800 million (Figure 5).⁹ The LCFS will result in a larger and more stable investment climate for advanced biofuels to be developed and sold.

⁹ Includes investments in cellulosic ethanol, biogas, and algae biodiesel over the 2006 to 2008 time period.

Figure 5: California's Venture Capital Investments into Advanced Biofuels from 2002 to 2009 (up to 3Q for 2009).



Source: Cleantech Group (www.cleantech.com)

The LCFS Results in Ultra-low Carbon, Advanced Biofuels being Preferred over Conventional Biofuels

The LCFS allows all fuels to be treated in a neutral manner and assessed on their carbon-intensity value or “score,” which is not the case under the RFS2. Specific volume mandates for corn-based ethanol or grandfathering of facilities are included in the RFS2, but not in the LCFS. The exclusion of such points provides a more level playing field for advanced biofuels to compete with conventional biofuels based on their carbon score.

For example, Table 2 shows that the use of a gallon of cellulosic ethanol results in nearly five times as much GHG emission reductions as corn ethanol produced in California. Similarly, an oil company seeking to reduce the carbon content of its fuels through blending with ethanol would obtain nearly five times more LCFS credits from using cellulosic ethanol than it would from using corn ethanol. By applying preference to the purchase of the lowest-carbon intensity biofuels first, refineries and importers can meet their LCFS credit obligations with less ethanol volume. The LCFS thereby incents the procurement of the lowest carbon-intensity biofuels first, based on their carbon-intensity score.

Table 2: Comparison of Carbon-Intensities and the LCFS Credits Generated for Different Biofuels

	Carbon Intensity Score (grams CO ₂ e/MJ)	Carbon Reductions (kg CO ₂ e/gallon ethanol)	Gallons purchased to obtain one LCFS credit (metric ton CO ₂)
CA Gasoline blendstock	95.9		
Corn Ethanol (California Low CI)	80.7	1.2	820
Cellulosic Ethanol (non-food crop)	23.4	5.8	171

The LCFS Incentivizes Biofuels that Avoid or Minimize Land Use Impacts

Biofuel production can result in negative land use impacts from land conversion and the loss of plant and soil carbon. Biofuel producers utilizing methods and practices to reduce these negative land use impacts will be rewarded by the LCFS. Companies that minimize or avoid these impacts receive better carbon-intensity scores. For example, ARB is currently establishing the “criteria and a list of specific biofuel feedstocks that are expected to have no or inherently negligible land use effects on carbon intensity.”¹⁰

Biofuel producers pursuing feedstocks that avoid competition with food production and do not contribute to the detriment of natural ecosystems will have little or no land use effects on carbon intensity. As CARB cites in a guidance document,¹¹ this could include the use of feedstocks that are:

- Grown on abandoned, degraded farmland which could increase soil sequestration
- Crop residues
- Sustainably harvested wood and forest residues¹²
- Grown using double and mixed cropping
- Municipal and industrial waste streams

Table A2 in the Appendix provides a preliminary list of fuels that will have minimal or no land use effects on carbon intensity.

¹⁰ Air Resources Board Resolution 09-31, April 23, 2009, p. 15.

¹¹ CARB (2009b), *Establishing new fuel pathways under the California Low Carbon Fuel Standard: Procedures and Guidelines for Regulated Parties*, Draft, August 4 2009, citing Tilman, David, Robert Socolow, Jonathon A. foley, Jason Hill, Eric Larson, Lee Lynd, Stephen Pacala, John Reilly, Tim Searchinger, Chris Somerville, and Robert Williams. “Beneficial Biofuels—The Food, Energy, and Environment Trilemma.” *Science* 325:270-271. July 17, 2009.

¹² Ibid. CARB cites that this category would “include the slash that is currently left in place after timber harvesting, residues from milling and pulp production, thinnings from fire prevention operations, as well as wastes from management operations undertaken to reduce competition and hasten the growth of marketable trees.” Staff also note that the “Board directed the Executive Officer to work with stakeholders to define the terms “biomass” and “renewable biomass.” As part of that effort, the Executive Officer is to assess the effects of incentivizing the use of forest biomass as a fuel feedstock, as well as the protections that would be necessary to ensure the sustainable and environmentally beneficial use of forest biomass. The goal of this effort would be to certify pathways for fuels produced from forest biomass, should the use of this feedstock be found to be sustainable and environmentally beneficial.”

The use of dedicated energy or residue materials minimizes negative externalities associated with the production of biofuels. Advanced biofuel companies that are planning or currently use dedicated energy or residue materials and/or use the above feedstocks will receive greater incentives versus conventional producers who utilize food-based feedstocks.

Accounting for changes in land use also results in a greater emphasis and crediting for improved production efficiency. Fuel producers using non-food based feedstocks would be expected to have greater production efficiencies compared to food-based feedstocks, leading to inherently lower impacts. Excluding these considerations to minimize negative land use impacts in the agricultural and forest sectors would allow significantly reduced incentives for advanced biofuel producers compared to, for instance, conventional corn ethanol production.

The LCFS Creates A Process to Incorporate and Value Sustainable Certification Programs

CARB is committed in the short term to develop a plan to address sustainability components, and within two years of adoption of the LCFS to develop proposed sustainability criteria.¹³

According to the CARB's *Initial Statement of Reasons*, "from an LCFS perspective, sustainability implies that current production and use of biofuels to meet the LCFS must not adversely impact the ability to continue its use in the future. Sustainability encompasses a variety of environmental, economic, and social components. These include GHG emissions, conservation of high carbon stock land, conservation of high biodiversity land, air quality, water use, water quality, soil conservation, genetically modified organisms, labor rights, (working conditions, worker rights, child labor, forced labor), land rights (displacement of indigenous people), environmental justice, food price and food security."

Currently, there are a number of independent multi-stakeholder initiatives under development to create voluntary certification programs for sustainably produced biomass feedstocks. The most notable of these, the Roundtable on Sustainable Biofuels (RSB), is an international initiative. The RSB has brought together farmers, biofuel producers, blenders, retailers, non-governmental organizations, experts, governments and others, to develop a global set of sustainability standards that would provide the basis for independent verification and certification.¹⁴ Producers that pursue independent certification under such a sustainability standard will be well-positioned to receive credit as CARB moves forward with its plans to develop sustainability criteria for the LCFS.

Developing a Flexible System to Represent Current and New Fuel Pathways under the Low Carbon Fuel Standard

¹³ The Initial Statement of Reason (ISOR) states that, "The ARB will work together with other State agencies, national and international organizations, non-government organizations, and other interested parties to develop an appropriate sustainability strategy. By December 2009, ARB staff intends to develop a strategic plan for addressing overall sustainability provisions for the LCFS, for consideration by the Board at its first formal public review scheduled for the end of 2011."

¹⁴ RSB Website: <http://cgse.epfl.ch/page65660.html> The most current draft of the Roundtable on Sustainable Biofuels' Principles and Criteria is Version 0.5, publicly released on August 10, 2009 and available from their website. Version 1.0 is expected to be released in November.

California's LCFS currently includes a number of default fuel "pathways" representing different fuel categories and their feedstock and production methods, including but not limited to ethanol from agricultural waste, forest residue, and farmed trees (see Appendix table A1 for the current list of pathways developed so far). Additional pathways are being planned based on those fuels in production today or expected in the near-term future (Appendix Table A2).

In addition, the LCFS provides producers with the flexibility to apply for new fuel pathways based on supporting information. The LCFS also provides the option to create customized, "sub-pathways," or modified versions of current pathways based on a showing of improvement.¹⁵ Low-carbon fuel providers will therefore be incented to continually improve their overall efficiency and emissions performance.

Moving Forward with the Low Carbon Fuel Standard

California is set to move forward with the LCFS program beginning in 2010. The first year of the LCFS in California will be used as a "dry run" with mandated requirements for recordkeeping and reporting only. Full compliance with the LCFS will begin formally in the beginning of 2011. CARB will also hold two regulatory reviews, one in 2012 and another in 2015 to assess the status of the program. Further development of fuel pathways, including expanded representation of potential new fuel providers, is expected to continue throughout this time period based on data submissions from companies.

The LCFS brings to California a performance-based, fuel-neutral approach to regulating fuels. In addition to reducing the carbon intensity of transportation fuels over time, the LCFS is expected to create a stable, long-term market for cleaner fuels. It also provides the best long-term market signal for biofuel products. California's adoption of the LCFS will guarantee a market of up to 3.4 billion gallons/year of low-carbon biofuels by 2020.

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¹⁵ CARB (2009b). These options are available through a so-called "Method 2" option.

APPENDIX

Table A1: List of Current Default Pathways Developed under the California LCFS

Fuel Pathways Completed for Use in the LCFS

Fuel Pathway	Description of the Pathway
CARBOB (California Reformulated Gasoline Blendstock for Oxygenate Blending)	1 average pathway based on the average crude oil used in California refineries. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_carbob.pdf
CaRFG (California Reformulated Gasoline)	1 specific pathway combining CARBOB and a blend of an average Midwestern corn ethanol and California corn ethanol to meet a 3.5% oxygen content by weight (approximately 10% ethanol). http://www.arb.ca.gov/fuels/lcfs/022709lcfs_carfg.pdf
Ethanol from Corn	11 different specific pathways that reflect different options that are used to produce ethanol from corn. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_cometoh.pdf
Ethanol from Sugarcane	1 specific pathway for producing ethanol from sugarcane using average production processes. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_sugarcane.pdf
Electricity	2 specific pathways representing average and marginal electricity used in California. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_elec.pdf
Hydrogen	4 specific pathways reflecting different options to produce hydrogen as a fuel. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_h2.pdf
ULSD (Ultra Low Sulfur Diesel)	1 average pathway based on the average crude oil used in California refineries. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_ulsd.pdf
Compressed Natural Gas	3 specific pathways reflecting different options to produce compressed natural gas as a fuel. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_cng.pdf

Fuel Pathways Under Development for Use in the LCFS

Fuel Pathway	Description of the Pathway
Ethanol from Sugarcane	Brazilian sugarcane using bagasse for electricity production as a co-product credit
	Brazilian sugarcane using mechanized production of sugarcane
Ethanol from Cellulosic Material	Farmed trees using a fermentation process. Preliminary documentation: http://www.arb.ca.gov/fuels/lcfs/022709lcfs_trees.pdf
	Agriculture Waste
	Forest Waste. Preliminary documentation: http://www.arb.ca.gov/fuels/lcfs/022709lcfs_forestw.pdf
Biodiesel	Midwest soybeans to soy oil for conversion to biodiesel (fatty acid methyl esters - FAME). Preliminary documentation: http://www.arb.ca.gov/fuels/lcfs/022709lcfs_biodiesel.pdf
	Yellow grease, fats, and waste oil for conversion to biodiesel (FAME) ¹
	Palm oil from South East Asia for conversion to biodiesel (FAME)
Renewable Diesel	Midwest soybeans to soy oil for conversion to renewable diesel. Preliminary documentation: http://www.arb.ca.gov/fuels/lcfs/022709lcfs_rd.pdf
	Yellow grease, fats, and waste oil using co-fed stream into refinery or bio-refinery for conversion to renewable diesel ¹
Compressed Natural Gas	Remote LNG shipped to Gulfport, Texas; regasified and pipelined to California; CNG in California.
	Remote LNG shipped to Baja, CA; regasified and pipelined to California; CNG in California.
Crude	Derived from oil sands. Derived from oil shale.
Liquefied Natural Gas	Canadian NG via pipeline to LNG liquefaction facility in California; liquefied in CA for use as LNG.
	Remote LNG shipped to Baja, CA; gasified and pipelined to California; liquefied in California for use as LNG.
	Remote LNG shipped to Baja, CA; LNG trucked to California for use as LNG.
	LNG from landfill gas. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_lpg.pdf

¹ Staff has prepared a very preliminary estimate of 15 gCO₂e/MJ for biodiesel and renewable diesel produced from waste fats and oils. This estimate was used in the diesel compliance scenarios found in Chapter VI, but will not be used for regulatory purposes. Once a revised value, sufficient for use in the Regulation, is available, Staff will publish that value. Details of the preliminary analysis are available on the LCFS website

Table A2: Fuels Expected to Have No or Inherently Negligible Land Use Effects on Carbon Intensity.¹⁶

Fuel	Feedstock	Conditions/Restrictions
Biodiesel	Used cooking oil	
	Algae	Specific conditions of operation are to be determined to assess land use impacts if any. There may be a need to demonstrate sustainable production of algae without displacement of crop land..
Renewable Diesel (RD)	Inedible Tallow (sourced in the United States)	
Fischer-Tropsch Diesel	Gasification of Forest Waste, MSW, Medical Waste, Dedicated crops (such as Poplar-see "Forest Waste" and "Dedicated Crops" under "Cellulosic Ethanol," below)	
	LFG and Digester Gas	
Cellulosic Ethanol	Municipal Solid Waste	
	Food and yard waste	

¹⁶ CARB (2009b). p. 17.

Fuel	Feedstock	Conditions/Restrictions
	Switchgrass	If grown on land unsuitable for crops, then impacts are zero. Also, if grown between traditional crop growing periods, impacts from Land Use Change should be zero. Verification will be required.
	Industrial Waste	
	Perennial plants lands not suitable for agricultural use	Needs verification of land type.
	Crop Residue (stover from corn, straw from rice and wheat)	No impacts if enough residues are left on fields to ensure soil and crop health (only sustainable quantities are utilized for fuel). Requires verification.
	Vineyard Prunings	
	Forest Waste (thinnings)	Criteria Under Development
	Double cropped or mixed cropping	When a feedstock is harvested between traditional food crop plantings. This must be verified.
	Lumberyard mill residues	
	Dedicated crops (such as Poplar) on land unsuitable for food crop cultivation	Needs verification that land is unsuitable for food crop cultivation.
CNG/LNG	Landfill Gas	
	Dairy Digester Gas	
Electricity	Derived from new Solar, Wind, Hydro, or Biomass sources.	
	Derived from LFG or Digester Gas	
Hydrogen	Derived from LFG or Digester Gas using electricity from renewable sources	
	Derived from electrolysis with electricity from renewable source	