California's Low Carbon Fuel Standard: Compliance Outlook & Economic Impacts

Final Report

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Prepared for:

California Electric Transportation Coalition

California Natural Gas Vehicle Coalition

Environmental Entrepreneurs

Advanced Biofuels Association

National Biodiesel Board

Ceres

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- Review of Compliance Scenarios
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Introduction

California's Low Carbon Fuel Standard

- In 2007 Governor Schwarzenegger signed Executive Order S-01-07 establishing California's Low Carbon Fuel Standard (LCFS), which requires a ten percent reduction in the carbon intensity of transportation fuels by 2020.
- The LCFS is a flexible market-based standard implemented using a system of credits and deficits:
  - **Carbon intensity** is measured on a lifecycle or well-to-wheels basis in units of grams of carbon dioxide equivalent per unit energy of fuel (gCO2e/MJ).
  - The LCFS is implemented using a system of **credits and deficits**. Fuels with a carbon intensity lower than gasoline and diesel earn credits. Gasoline and diesel generate deficits.
  - At the end of each year, compliance is achieved by offsetting deficits with credits. Credits can be banked and traded, and they do not lose value over time.

Scope of Work

- The objective of this study was to characterize the macroeconomic impacts of LCFS compliance, and the co-benefits. This study had two phases.
- In the first phase of work, ICF developed scenarios that represent a range of likely outcomes towards LCFS compliance.
  - Scenarios are intended to capture the range of potential market developments that would lead to LCFS compliance given our current outlook on the transportation fuel marketplace.
  - In any forward-looking exercise, it is important to note that there is some uncertainty associated with the availability of lower carbon fuels.
- In the second phase of work ICF characterized the macroeconomic impacts and associated co-benefits of LCFS compliance.
  - Macroeconomic impacts were estimated using the REMI model
  - The co-benefits we considered include: GHG emission reductions, criteria pollutant emission reductions, and petroleum reductions.

Review of Compliance Scenarios

Scenario Analysis

- ICF developed a reference scenario and two LCFS compliance scenarios, referred to as Scenario 1 and Scenario 2, in the first phase of our work to estimate the macroeconomic impacts of the LCFS. The stakeholder group developed the final compliance scenario, referred to as the LCFS Enhanced Scenario. The macroeconomic impacts reported are based on the difference between the compliance scenario and the reference scenario.
- A more detailed review of the scenarios, including the fuel volumes, forecasts, compliance options considered, and an alternative fuel market assessment are available in a separate report. That report is available online at: http://www.caletc.com/wp-content/downloads/LCFSReportJune.pdf

Summary Table

Scenario	Ethanol	Biodiesel	Adv Biofuels	Electricity / Hydrogen	Natural Gas	Assumptions for all scenarios
Reference Scenario	Limited to E10. Mostly MW corn ethanol.	Very limited; about 25 million gallons	Federal RFS2 identified as only major driver for consumption in California absent LCFS	ZEV Program: most likely compliance scenario; about 500,000 ZEVs on the road by 2020: 26k FCVs, 120k PHEVs, 350k BEVs	Based on CEC projections: about 220 million gallons	Constrained low carbon corn ethanol at 1 billion gallons (200 MGPY in California). Assumed 56% of VMT in PHEVs is electric. Banking/trading of credits is included in our analysis. Over-compliance in early years. Significant room for over-compliance in diesel sector.
Scenario 1	Ethanol blend increased from E10 in 2019-2020. Assume some E15 is consumed. 500 MG sugarcane ethanol.	420 million gallons blended into diesel by 2020: soy, waste grease, corn oil, canola.	410 MG cellulosic ethanol 89 MG drop-in gasoline substitute 125 MG renewable diesel	Proportionally similar distribution to most likely compliance scenario; total of 800k vehicles. Electricity consumed in forklifts and fixed guideway applications included	Aggressive introduction of CNG/LNG in MD/HD sectors. 900 million gallons consumption by 2020. 10% RNG consumption.	
Scenario 2	Limited to E10. 500 MG sugarcane ethanol.	560 MG blended into diesel by 2020: waste grease, corn oil, canola.	430 MG cellulosic ethanol 89 MG drop-in gasoline substitute 220 MG renewable diesel	ZEV Program compliance Electricity consumed in forklifts and fixed guideway applications included	Modest increase in CNG/ LNG consumption. 650 million gallons consumed. 10% RNG consumption.	
LCFS enhanced	Limited to E10. 230 MG sugarcane ethanol	440 MG blended into diesel by 2020: soy, waste grease, corn oil, canola.	50 MG cellulosic ethanol 89 MG drop-in gasoline substitute 130 MG renewable diesel	Accelerated adoption scenario: 1.2 million PEVs on the road by 2020 Electricity consumed in forklifts, fixed guideway, port equipment, e-TRUs, TSE, small non-road applications included	1.1 billion gallons consumption by 2020. 10% RNG consumption.	Includes credits earned through enhanced crude oil recovery techniques e.g., solar powered steam.

Introduction to REMI Modeling

REMI Model Description

ICF employed the REMI Policy Insight Plus v1.4 to measure the wider macroeconomic impacts of the compliance scenarios developed in this study. Some key aspects of the REMI Model:

- Peer reviewed structural economic modeling, forecasting and policy analysis tool
- Dynamic regional economic impact model using a combination of input-output, econometric, and computable general equilibrium techniques
- 70 NAICS-based sectors, 2 regions
- Ability to forecast impacts over time
- All results are presented in 2020 for this study

REMI Model Description, ctd

- REMI can produce a wide variety of economic and demographic outputs:
  - overall employment levels
  - employment by industry sector
  - value added output
  - output by sector
  - changes in income
  - population or demographic shifts.
- This study focused on analyzing the impacts to employment, personal income, and gross state or domestic product (GSP or GDP).
- Inputs to the REMI model for each scenario were derived from the outputs of ICF analysis of each compliance scenario. For example, the compliance scenarios modeled in REMI included expenditures for fuel production, distribution infrastructure (including transportation, storage, retail infrastructure, vehicles, and fuel pricing.

Overview of Model Inputs

Introduction

ICF developed estimates for the investments that would be required to achieve the compliance scenarios. ICF considered three broad types of expenditures:

- **Fuel production / upstream expenditures:** Many of the alternative fuels will require significant investments in expanded production. To the extent feasible, ICF identified production that would happen in California and the rest of the United States.
- **Distribution infrastructure expenditures:** While the compliance scenarios include drop-in fuels that are compatible with existing distribution infrastructure such as renewable diesel and renewable gasoline, other fuels will require infrastructure in storage terminals and refueling equipment. Distribution infrastructure costs were modeled as an increase in exogenous final demand for industries involved in equipment manufacturing or building new infrastructure.
- **Vehicle expenditures:** In the case of electricity, hydrogen, and natural gas, new light- and heavy-duty vehicles will need to be purchased to achieve the levels of fuel consumption included in the penetration scenarios.

Overview of Alternative Fuel Investments

Fuel	Fuel Production	Distribution infrastructure	Vehicle Expenditures
Ethanol	Yes; feedstock specific. Continued CA production, most from Rest of US	E15 infrastructure for S1	N/A; MY2001+ can use E15
Renewable Gasoline	Yes; focused on biomass feedstock. Produced outside of CA	N/A; drop-in fuel	N/A; drop-in fuel
Biodiesel	Yes; feedstock specific. Increased utilization in CA, balance produced in Rest of US	Yes; terminal storage, blending equipment, fueling stations	N/A; overwhelming number of diesel engines warrantied for use up to B20
Renewable Diesel	Yes; focused on tallow. Produced outside of CA	N/A; drop-in fuel	N/A; drop-in fuel
Electricity	Yes; small b/c assumed significant TOU charging and increased utilization of assets	EVSE (L1, L2, DC fast)	PEV cost curves from CalETC study (Roland-Holst 2012) Included federal tax credit
CNG	No; transportation is small fraction of total production	Yes; mix of slow- and fast-fill stations	NGVs in medium-, and heavy-duty sectors
LNG	Yes; mostly liquefied outside of CA	Yes; LNG stations	
Biomethane	Yes; injected in-state and from out-of-state	No; accounted for in CNG and LNG	

Conventional Fuels – Gasoline and Diesel

Overview

LCFS compliance yields varying levels of decreases in gasoline and diesel consumption in California. Although the reduction of petroleum consumption has positive impacts via improved energy security and increased fuel diversity, the decreased consumption of petroleum will also have direct negative impacts on the refining industry – in the same way that the investments in alternative fuels and advanced vehicles will yield positive impacts in the corresponding industries. ICF treated the reduction in gasoline and diesel consumption in the modeling as follows:

- ICF assumed that there were lost margins on 50% of those crude runs that are assumed to be displaced entirely as a result of the LCFS. These margins were estimated based on an ICF analysis of the 3-2-1 crack spread for California-based refiners (estimated at about $15/bbl)

- ICF assumed that the remaining 50% of crude runs representing the reduction in gasoline and diesel consumption in California are exported, rather than displaced entirely. For these exports, ICF assumed a corresponding decrease in revenue in the export markets because of increased freight costs (estimated at $5/bbl).

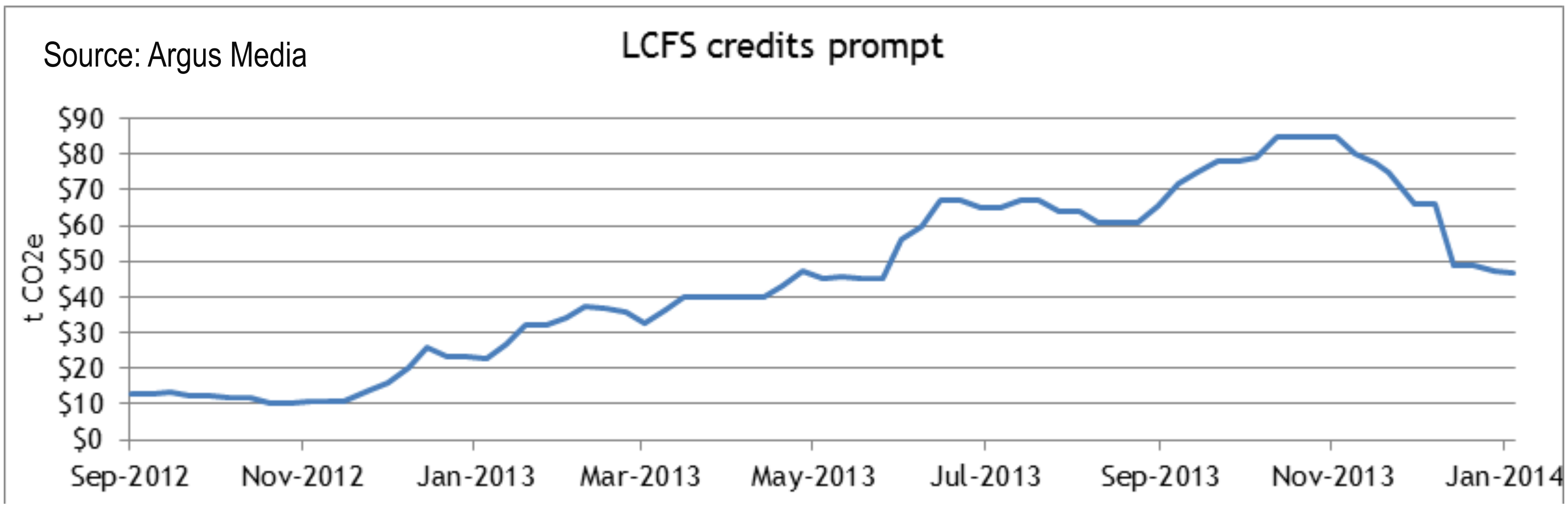
Fuel Pricing and LCFS Credit Pricing

Fuel Pricing

- One of the key limitations of REMI is that it is not explicitly an energy model. Most notably, the model is not designed to predict changes in demand and supply for fuels, or the impacts on fuel pricing. In response, ICF augmented REMI by developing a supplementary estimate of fuel prices through 2020.
- ICF considered several components of fuel pricing as inputs into the REMI modeling. We sought to capture the likely impacts on fuel pricing as a result of LCFS compliance. ICF used fuel pricing forecasts from 2011 Integrated Energy Policy Report (IEPR), adjusted for actual fuel prices reported in California for 2011 and 2012.

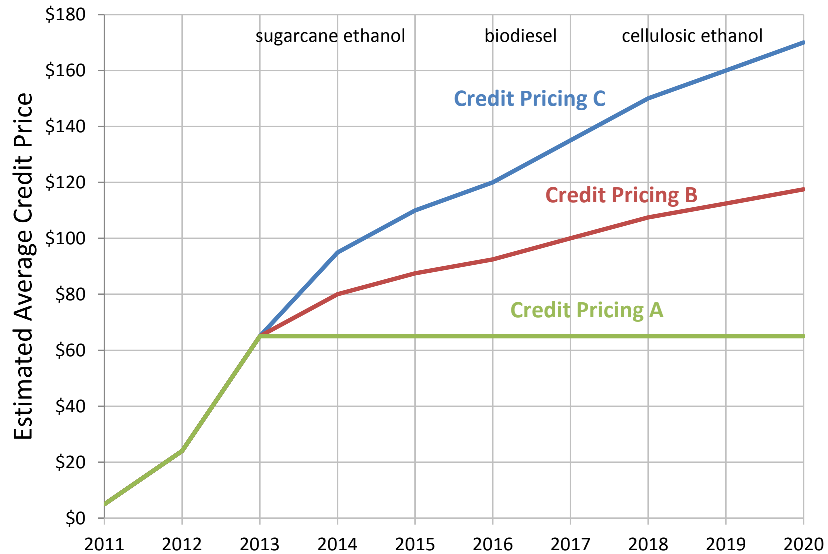
Review of LCFS Credit Prices

- The LCFS credit market today is relatively illiquid and immature. It is also difficult to determine what is driving credit prices.
  - The majority of credits are being transferred to regulated parties (mainly refiners / importers of fuel), rather than purchased in the LCFS credit market.
  - These credit transfers are currently happening at the point of blending biofuels like ethanol, biodiesel, or renewable diesel into CARBOB or diesel.
  - CARB reports 1.15 million credits have been traded via 271 credit transfers through February 2014. However, over that same period, nearly 6 million credits have been generated.



LCFS Credit Pricing

- Stakeholders identified three credit pricing variations for ICF to model with each compliance option:
  - Pricing A: Future credit prices are fixed at the weighted average of credit prices in 2013, about $65/ton
  - Pricing B: Credit prices are an average of Pricing A (see above) and Pricing C (see below).
  - Pricing C: Credit prices reach a peak of around $170/ton in 2020. The profile for credit increases is a function of what is considered the implied price of carbon based on the premium of the associated alternative fuel. The pricing is largely defined by the premium paid for a) sugarcane ethanol, b) biodiesel (from various feedstocks), and c) cellulosic ethanol.



Treatment of LCFS Credit Prices in REMI

- ICF's treatment of LCFS credit prices was based on the recipient of credits, as outlined by the regulation.
  - For entities that sell the credits or credit generators – such as ethanol producers, biodiesel producers, and natural gas refueling infrastructure owners – ICF modeled credits as a decrease in production costs.
  - ICF modeled credit purchases (made by entities producing or importing CARBOB and ULSD) as an increase in production costs.
  - In the case of credits generated through the use of electricity as a transportation fuel, ICF assumed that the value of the credit would be passed to the consumer, per the requirements of the regulation. There are provisions for entities other than utilities to earn LCFS credits for the use of electricity as a transportation fuel. However, we made a simplifying assumption that the utilities would earn all of the credits generated by electricity consumption.

REMI Modeling Results

Overview

- As noted throughout this report, ICF has generally defaulted to conservative assumptions to enhance the study’s credibility. Because the study’s assumptions are generally conservative, the results of our modeling likely understate the full magnitude of economic benefits.
- Our results focus on the following changes resulting from the three LCFS compliance scenarios compared to the Reference Scenario:
  - Changes in employment;
  - Changes in personal income; and
  - Changes in gross state product (GSP)
- The following tables report the changes from the Reference Scenario for California:
  - Absolute change
  - Percent change

REMI MODELING RESULTS

Employment

Scenarios	Credit Pricing Variations		
	A	B	C
California | EMPLOYMENT, jobs			
Scenario 1	4,100	3,900	3,700
	0.02%	0.02%	0.02%
Scenario 2	-5,300	-6,900	-8,500
	-0.02%	-0.03%	-0.04%
LCFS Enhanced	8,300	8,700	9,100
	0.04%	0.04%	0.04%

Personal Income

Scenarios	Credit Pricing Variations		
	A	B	C
California | PERSONAL INCOME, $ billions			
Scenario 1	0.44	0.44	0.44
	0.02%	0.02%	0.02%
Scenario 2	-0.28	-0.36	-0.43
	-0.01%	-0.02%	-0.02%
LCFS Enhanced	0.90	0.84	0.89
	0.04%	0.04%	0.04%

REMI MODELING RESULTS

Gross State Product

Scenarios	Credit Pricing Variations		
	A	B	C
California | GSP, $ billions			
Scenario 1	0.43	0.40	0.38
	0.02%	0.02%	0.02%
Scenario 2	-0.50	-0.64	-0.79
	-0.02%	-0.03%	-0.03%
LCFS Enhanced	0.75	0.91	0.95
	0.03%	0.04%	0.04%

Discussion

- There are net positive macroeconomic impacts for each of the three scenarios.
- The macroeconomic impacts, however, are very small.
  - The range of impacts across the parameters considered – employment, income, and GDP/GSP, vary from -0.04% to 0.04%.
  - Despite the significant investments that are necessary to comply with the LCFS, these investments are a small fraction of overall macroeconomic activity.
  - In all cases, economic growth continues – it is not reversed. Even in the case of Scenario 2, in which there are small negative impacts in California, economic growth is not reversed. Rather it is very slightly reduced from its growth trajectory.

Discussion, ctd

- Fuel diversification leads to positive impacts in California.
  - Scenario 1 and the LCFS Enhanced Scenario demonstrate positive impacts in California.
  - The ratio of income/employment (gains), a proxy for the value of the types of jobs added, is nearly double the ratio of income/employment (loss) in Scenario 2 (see next slide). Good indicator that investments towards diversification provide higher value jobs.
  - These scenarios have more significant penetration of electricity and natural gas; but still significant blending of liquid biofuels.
  - Natural gas and electricity help offset some of the higher costs attributed to blending lower carbon biofuels.
  - They also lead to significant investments in infrastructure (charging infrastructure and natural gas stations) and vehicles – both positive drivers in the model.
  - Electric vehicles also benefit from the federal tax credit, which boosts consumer spending by returning money to California.

REMI MODELING RESULTS

Discussion, ctd

- Scenario 2 yields small negative impacts in California.
  - Economic growth is not reversed; it is simply slightly reduced from its growth trajectory.
  - The income/employment ratio is lower than Scenario 1 and LCFS Enhanced Scenario – tied to reductions in growth for specific types of jobs.
  - Because ZEVs are deployed at the same level as the baseline case, there is no *incremental* benefit associated with electricity consumption as a transportation fuel or *incremental dollars* flowing to California via the federal tax credit for PEVs.
  - There are some benefits captured from electric forklifts and fixed guideway applications.
  - Scenario 2 has the most significant deployment of liquid biofuels – ethanol, biodiesel, renewable gasoline, and renewable diesel. This leads to two factors:
    - *ICF forecasts – and our data sources such as the EIA and CEC, assume higher near-term costs for liquid biofuels. With less electricity and natural gas consumption to mitigate higher fuel expenditures, this contributes to the small negative impacts.*
    - *ICF assumes that most liquid biofuels will be produced out-of-state.*

Discussion, ctd

- Several sectors consistently show positive economic impacts across all modeling scenarios, with the primary driver(s) in blue:
  - Motor vehicles, bodies and trailers, and parts manufacturing | Increased alternative fuel vehicle sales
  - Chemical manufacturing | Increased biofuel production
  - Utilities | Increased utilization of assets through electric vehicle charging
  - Electrical equipment and appliance manufacturing | EVSE deployment
  - Primary metal manufacturing | Expanded distribution and fueling infrastructure
  - Transportation (via Rail, Marine, Truck) | Liquid biofuel transport
- The Petroleum and Coal Products Manufacturing Sector has the largest percentage decrease in rate of growth in employment across all modeling runs.
  - These impacts are small, ranging from -1.0% to -0.4%.
  - In other words, these impacts are not significant enough to indicate an economic disruption such as a refinery closure.

Monetized Externalities

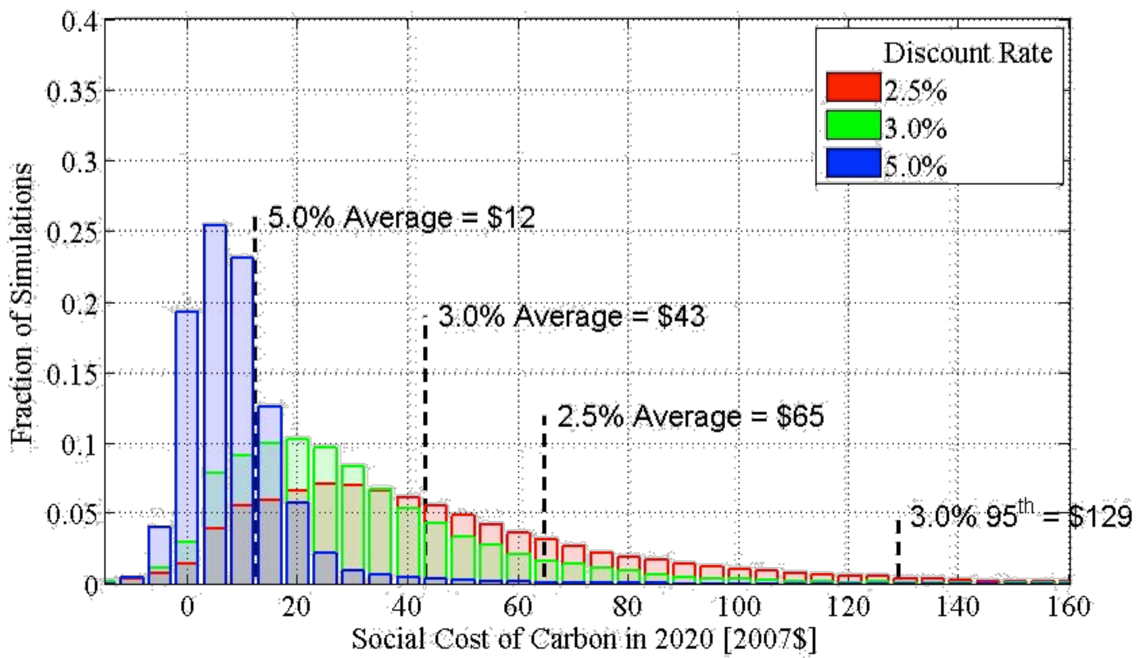
Introduction

Alternative fuels and advanced vehicles have a variety of benefits and costs. Apart from the traditional financial metrics and macroeconomic impacts associated with alternative fuel use, ICF estimated the environmental benefits and associated monetized value of:

- Reduced GHG emissions
- Reduced criteria air pollutants
- Displaced petroleum

GHG Emission Reductions

- The LCFS will result in significant economic benefits associated with avoiding damages associated with incremental increases in carbon emissions. The monetized value of damages avoided as a result of CO_2 reductions, including changes in net agricultural productivity, human health and flooding, is referred to as the social cost of carbon (SCC).



Source: Interagency Working Group on Social Cost of Carbon. Technical Update, US Government, May 2013

GHG Emission Reductions, ctd

Net Present Value of SCC for LCFS Compliance (2% Discount Rate)

Scenario	R_d`	Net Present Value of SCC ($2010 millions), 2% discount rate								
		2013	2014	2015	2016	2017	2018	2019	2020	Cumulative
Scenario 1	5%	21	35	55	73	89	103	116	131	**623**
	3%	68	117	174	238	296	352	407	469	**2,120**
	2.5%	106	180	265	365	451	533	611	709	**3,220**
	3%, 95th	193	334	499	688	866	1,039	1,212	1,407	**6,237**
Scenario 2	5%	20	32	48	64	78	101	130	155	**628**
	3%	65	108	151	208	259	346	455	556	**2,148**
	2.5%	101	166	231	320	395	524	682	841	**3,260**
	3%, 95th	185	309	434	603	757	1,022	1,353	1,668	**6,331**
LCFS En	5%	17	29	53	73	89	104	119	136	**619**
	3%	54	98	169	236	297	354	417	486	**2,111**
	2.5%	84	151	258	364	453	535	625	734	**3,204**
	3%, 95th	153	280	486	685	868	1,044	1,241	1,457	**6,213**

ˡ R_d is the social discount rate used in the modeling exercise; not the discount rate used by ICF in the analysis.

GHG Emission Reductions, ctd

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Net Present Value of SCC for LCFS Compliance (7% Discount Rate)

Scenario	R_d[1]	Net Present Value of SCC ($2010 millions), 7% discount rate								
		2013	2014	2015	2016	2017	2018	2019	2020	Cumulative
Scenario 1	5%	21	33	50	63	73	81	87	94	**502**
	3%	68	111	158	206	244	277	306	336	**1,706**
	2.5%	106	171	241	317	373	419	458	507	**2,592**
	95th	193	319	453	596	715	818	910	1,007	**5,009**
Scenario 2	5%	20	31	43	55	64	80	98	111	**502**
	3%	65	103	137	180	214	273	341	398	**1,711**
	2.5%	101	158	210	277	326	412	512	601	**2,598**
	95th	185	295	394	522	625	805	1,016	1,193	**5,035**
LCFS En	5%	17	28	49	63	74	81	89	97	**497**
	3%	54	93	154	205	245	278	313	347	**1,690**
	2.5%	84	143	235	315	374	421	469	525	**2,567**
	95th	153	267	441	593	717	822	931	1,042	**4,967**

[1] R_d is the social discount rate used in the modeling exercise; not the discount rate used by ICF in the analysis.

We estimate that the net present value of SCC for LCFS compliance in 2020 ranges from $497 million to $3.26 billion.

The low value corresponds to the LCFS Enhanced scenario using a 7% discount rate (and 5% discount rate for SCC); the high value corresponds to Scenario 2 using a 2% discount rate (and 2.5% discount rate for SCC, see previous slide)

Criteria Air Pollutants

Introduction

- Criteria air pollutants such as nitrogen oxides (NOx) and particulate matter (PM) are considered negative externalities and researchers have attempted to capture the value of avoided emissions in the form of health and environmental benefits. NOx is a precursor to photochemical ozone formation and PM is linked to an array of respiratory problems.

- Two key aspects for consideration in the review of the estimated criteria air pollutant estimates:
  - ICF only considered tailpipe criteria air pollutant emission reductions. It is possible – and in many cases likely – that the criteria pollutant emissions reductions would be larger if our analysis considered lifecycle emission reductions.
  - CARB has developed several programs to reduce criteria pollutant emissions from light-duty and heavy-duty vehicles. The avoided costs reported here are incremental to the benefits of existing CARB programs, such as the Advanced Clean Cars Program (focused on light-duty vehicles) and the Truck and Bus Rule (focused on medium- and heavy-duty vehicles).

Criteria Air Pollutants, ctd

- ICF used damage costs reported by EPA in rulemakings. The magnitude of damage costs (on a dollar per ton basis) for PM2.5 is dependent on the location of emission reductions. Areas with higher population density, for instance, tend to have higher damage costs than less populated areas. ICF developed a population-weighted average for the damage cost of PM2.5 in California, as shown in the table below.

Criteria Pollutant	2015	2020
PM2.5	$1,450,000—1,600,000	$1,600,000–1,740,000
VOC	$1,120–1,220	$1,220–1,320
NOx	$4,675–5,080	$5,080–5,590
The values are shown as ranges; EPA calculated low and high values using 3% and 7% discount rates		

Sources: Diesel Emissions Quantifier Health Benefits Methodology, EPA, EPA-420-B-10-034, August 2010. | EPA/HNTSA, Draft Joint Technical Support Document: Proposed Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, EPA-420-D-11-901, November 2011.

MONETIZED EXTERNALITIES

Criteria Air Pollutants, ctd

Monetized Benefits of Criteria Air Pollutant Reductions in LCFS Compliance Scenarios ($2010, millions)

Scenario	Pollutant		2013	2014	2015	2016	2017	2018	2019	2020	Cumulative
Scenario 1	PM2.5	low	0.0	4.2	10.0	17.5	25.7	32.2	36.5	39.6	165.7
		high	0.0	5.3	13.4	24.3	37.0	48.2	56.9	64.3	249.4
	NOx / VOC	low	0.0	0.1	0.2	0.4	0.6	0.7	0.8	0.9	3.7
		high	0.0	0.1	0.3	0.6	0.8	1.1	1.3	1.5	5.7
	NOx	low	1.3	2.9	5.0	7.7	10.8	14.4	18.4	22.8	83.3
		high	1.4	3.1	5.4	8.4	11.8	15.8	20.2	25.1	91.2
Scenario 2	NOx	low	1.2	2.4	3.9	5.9	8.1	10.7	13.6	16.8	62.5
		high	1.3	2.6	4.3	6.4	8.9	11.7	14.9	18.4	68.5
LCFS Enhanced	PM2.5	low	0.0	4.2	10.3	18.3	27.3	35.0	40.7	45.2	181.0
		high	0.0	5.4	13.8	25.3	39.3	52.4	63.5	73.3	273.0
	NOx / VOC	low	0.0	0.1	0.3	0.4	0.6	0.8	0.9	1.0	4.1
		high	0.0	0.1	0.3	0.6	0.9	1.2	1.4	1.7	6.3
	NOx	low	1.3	2.6	4.3	6.5	9.2	12.4	16.1	20.6	73.1
		high	1.5	2.9	4.7	7.1	10.0	13.5	17.7	22.6	80.1

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Low scenario: Includes low value of EPA-reported dollar-per-ton and a discount rate in ICF's analysis of 7 percent.

High scenario: Includes high value of EPA-reported dollar-per-ton and a discount rate in ICF's analysis of 2 percent.

ICF conservatively estimates the monetized benefit of criteria air pollutant emission reductions attributable to the LCFS program in the range of $63 million to $359 million.

Petroleum Displacement / Energy Security

Introduction

- Petroleum displacement by alternative fuels as part of LCFS compliance will lead to improved energy security. As outlined in a report by Paul Leiby from Oak Ridge National Laboratory regarding energy security benefits, energy security concerns arise from three problems:
  - concentrated crude oil supply in an historically unstable region
  - sustained exercise of market power by oil exporting countries
  - the vulnerability of the economy to oil supply shocks and price spikes
- Leiby estimates the benefits of energy security focusing on two components:
  - Monopsony Component: This component reflects the effect of US import demand on the long-run world oil price. The US remains a sufficiently large purchaser of foreign oil supplies that it affects global oil pricing. This demand is characterized as monopsony power.
  - Macroeconomic Disruption / Adjustment Costs: The second component of Leiby's analysis focuses on the effect of oil imports on disruptions such as a sudden increase in oil prices. These price spikes increase the costs of imports in the short run and can lead to macroeconomic contraction, dislocation, and GDP loss.

Petroleum Displacement / Energy Security, ctd

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- The most recently available results from Leiby's analysis regarding the monetized benefits of decreasing oil imports are shown in the table below for the years 2013 and 2022. ICF used the mean values and assumed a linear relationship between 2013 and 2022 to calculate the annual discrete values for energy security.

Component	2013 ($/bbl)		2022 ($/bbl)	
	Mean	Range	Mean	Range
Monopsony	11.40	3.83–19.40	9.82	3.27–16.77
Disruption Costs	7.13	3.41–10.35	7.84	3.80–11.30
Total	18.53	10.03–26.74	17.66	9.88–24.99
Source: Leiby, EPA-HQ-OAR-2010-0133-0252, September 2012				

Petroleum Displacement / Energy Security, ctd

- The monetized energy security premium for each scenario is shown in the table below for two different discount rates – 2 percent and 7 percent. ICF assumed that 50.3 percent of California's crude oil is imported based on data from the California Energy Almanac for 2011 and 2012.
- **The cumulative benefits of increased energy security resulting from the LCFS scenarios ranges from $796 million to $1.23 billion, depending on the discount rate employed in the analysis.**

Scenario		Energy Security Benefits (NPV, $2010 millions)								
		2013	2014	2015	2016	2017	2018	2019	2020	**Total**
2% discount rate	Scenario 1	16	44	82	119	152	185	216	247	**1,059**
	Scenario 2	10	31	57	88	116	177	236	302	**1,017**
	LCFS Enhanced	20	53	95	136	174	211	250	290	**1,230**
7% discount rate	Scenario 1	16	42	74	103	126	145	162	177	**844**
	Scenario 2	10	30	51	77	96	140	177	216	**796**
	LCFS Enhanced	20	50	86	118	144	166	188	207	**980**

Petroleum Displacement / Energy Security, ctd

- The proportion of foreign oil imported to California refineries has increased significantly as California reserves have been drawn down and as the Alaska North Slope production has continued to decline (starting in 1998). As recently as 2005, only 40 percent of crude oil was imported to California refineries from foreign sources. The decrease in domestic production has been offset by increases in foreign crude imports. While it is likely that ICF has under-estimated the percent of crude oil imported, recent domestic developments and the way that the LCFS is implemented give our team pause with regard to any assumptions that foreign imports are likely to increase significantly beyond the 50 percent estimate. For instance:
  - The production of domestic crude oils, such as the Bakken reserve in North Dakota and West Texas Intermediate – both of which are well suited for refining in California based on their respective crude properties – is strong and they are currently priced attractively relative to other crude oils. Similarly, there is significant potential for tight oil in California – with the EIA estimating that the Monterey/Santos Shale in Southern California has 64 percent of the onshore total shale oil resources in the lower 48 States, or about 15 billion barrels of oil.
  - There is a disincentive for refiners to seek out foreign (or domestic) crude oils that have a high carbon intensity because of the way that CARB determines the annual carbon intensity targets of the LCFS. If the carbon intensity of the crude oils that are refined increases, then the carbon intensity targets in subsequent years will be higher, thereby creating more deficits that must be offset by regulated parties.
- **In other words, it is more likely that imported crude oils will decrease more rapidly than domestic crude oils. However, we assumed a uniform petroleum displacement of imported and domestic crude oils. As a result, the range of benefits reported here is likely a low or conservative estimate of the energy security benefits.**

Summary and Conclusions

LCFS Compliance

To date, some analyses show draconian effects associated with California's LCFS. [1] But such studies harnessed assumptions and methods that lacked transparency and disregarded alternative fuel market developments. This study marks an independent effort to evaluate environmental and economic benefits. ICF uses conservative assumptions to enhance the study's credibility. Because the study's assumptions are generally conservative they likely understate the full magnitude of macroeconomic and environmental benefits.

Our analysis of the LCFS program leads to the following key takeaways:

- LCFS compliance is achievable through modest changes to fuel consumption.
  - The scenarios seek to capture the range of compliance possibilities - generally characterized as biofuel blending and advanced vehicle technology deployment.
  - A review of quarterly reports from the program combined with an alternative fuel market assessment leads ICF to conclude that the program is already working – it is driving increased volumes of alternative fuels into California, innovation, and investment.
- The LCFS program will lead to significant investments in fuel production, distribution infrastructure, and advanced vehicle technologies.

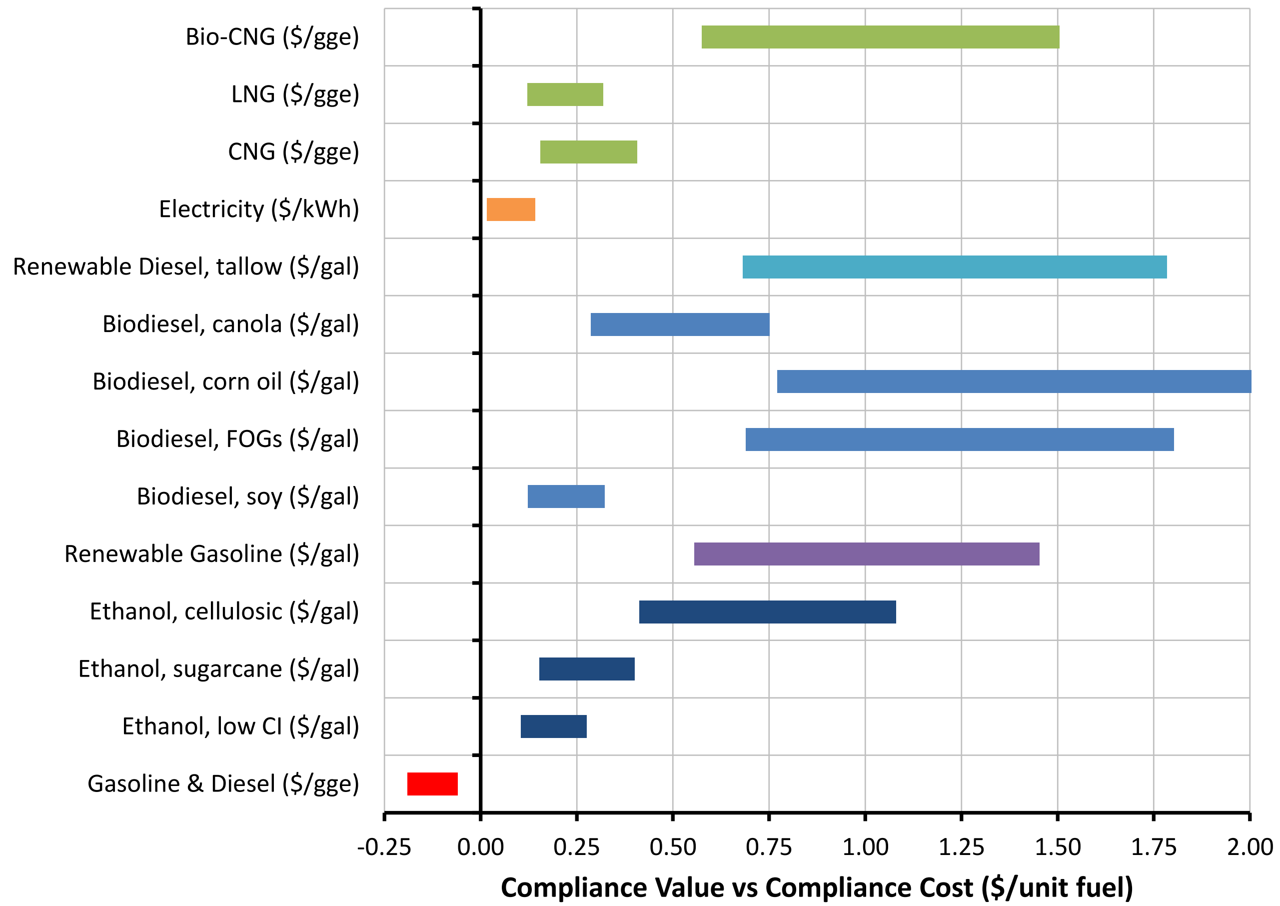
1. For instance: Boston Consulting Group, *Understanding the impact of AB 32*, June 2012 and Andrew Chang & Co, *The Fiscal and Economic Impact of the California Global Warming Solutions Act of 2006*, June 2012.

LCFS Compliance, ctd

- Based on baseline fuel price forecasts from the California Energy Commission (IEPR 2011), the credit pricing variations selected by stakeholders, and ICF's analysis of alternative fuel price forecasts, **the LCFS has a compliance cost ranging from $0.06–$0.19 per gasoline gallon equivalent**. The compliance costs have been normalized to a unit of energy – gasoline gallon equivalent – by accounting for the volumes of gasoline and diesel consumed in each scenario. The range of compliance costs reflects the variation in a) credit pricing and b) likely higher cost of blending low carbon liquid biofuels.
- As a point of comparison, gasoline and diesel prices in California have fluctuated an average of $0.75 per gallon and $0.63 per gallon annually, respectively, since 2010.

LCFS Compliance: Costs vs Value

- The compliance costs for refiners are mirrored by significant value for alternative fuels. The values shown in the graph below represent the LCFS credit range considered: $65-$170/ton



REMI Modeling

- **In all cases, investments in alternative fuels to achieve LCFS compliance yielded net positive macroeconomic impacts in 2020** – including employment, personal income, and gross domestic product (GDP). Total employment increases by up to 9,100 jobs in California.
- **The range of impacts due to the LCFS in California is small,** ranging from -0.04% to 0.04% for all the macroeconomic variables considered across all three scenarios.
- **The scenarios with the highest level of fuel diversity – Scenario 1 and LCFS Enhanced Scenario – yield net positive macroeconomic impacts** across all three credit pricing variations in California.
- **The modeling results from Scenario 2 yield small negative impacts** on employment, personal income, and GDP in California across all three credit pricing variations. This dynamic is largely driven by the fact that compliance in Scenario 2 is more dependent on liquid biofuels, are less likely to generate investment expenditures within California in the timeframe of our analysis (2020).

Research Areas for Further Study

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This study's objective is to present an independent macroeconomic assessment of the LCFS. Over the course of our research, ICF has identified three critical areas for further study.

1. **The timeline of our analysis was limited to 2020, which reflects the current implementation timeframe of the LCFS program. Many of the benefits of the LCFS – driven by fuel diversification – are likely to increase significantly in the 2025-2030 timeframe.**
   - For instance, several policy cases examined in *Transitions to Alternative Vehicles and Fuels (2013)*, published by the National Academies Press, do not yield significant monetized benefits until the 2025 timeframe and increase rapidly thereafter.
   - Given that the transportation sector is nearly 95 percent dependent on petroleum-based fuels, it is to be expected that the early stages of a transition to greater alternative fuel use will have some "start-up" costs that do not fully translate into benefits until the post-2020 timeframe. These additional benefits can be attributed to factors such as increased utilization of infrastructure assets, increased competitiveness in fuel markets, increased economies of scale in alternative fuel production, and continued incremental technological improvements.

Research Areas for Further Study, ctd

2. **It is possible to estimate LCFS compliance costs and corresponding fuel pricing impacts using an energy model. The REMI model is not an energy model, and therefore is ill-equipped to forecast fuel pricing changes as a result of increased alternative fuel use. As a result of this limitation, ICF estimated the LCFS compliance costs as exogenous parameters to REMI.**
   - In a more rigorous modeling exercise, a macroeconomic model such as REMI would be paired with an optimization model or fuel/energy pricing model.
   - This is a much more resource intensive exercise, and frankly, ICF is unaware of an off-the-shelf fuel pricing model that is sufficiently sophisticated to capture the dynamics of the LCFS and its interaction with other regulations (e.g., the federal Renewable Fuel Standard).
   - ICF does not think that the pairing of an energy model with the REMI model would materially change the results of our analysis in the 2020 timeframe; however, when considering the LCFS in the post-2020 timeframe (see previous bullet), the pairing of an energy model and the REMI model is strongly recommended to ensure a robust representation of an increasingly competitive fuels market.

Research Areas for Further Study, ctd

3. **ARB is making amendments to the LCFS that are likely to be adopted in 2014 and considering new concepts .**
   - The amendments that require further study include a cost containment provision and revised indirect land use change (ILUC) values for biofuels.
     - *The cost containment mechanism will have an impact on credit pricing in modeling scenarios, thereby changing the macroeconomic impacts and the compliance costs of the regulation.*
     - *The revised ILUC values will change the balance of deficits and credits. These changes will also require modifications to the compliance scenarios because the market demand for some biofuels will likely change significantly.*
   - The new concepts being considered by ARB include GHG emission reductions at refineries, the modification of compliance curves, and modifications to the fuel pathways.
     - *ARB is considering a concept in which refiners can earn credits for GHG reductions at refineries. These types of reductions were not considered in this analysis.*
     - *This analysis assumed a 1% carbon intensity reduction in 2014; however, the carbon intensity reductions for 2015-2020 were based on the existing regulation. Modifications to these will have an impact on the balance of credits and deficits.*
     - *ARB is also considering changing the way fuel pathways are approved. As part of this, they are considering bins for fuels with similar pathways. Depending on the size of these bins, this might have an impact on our analysis.*

Monetized Externalities

The table below aggregates the results of ICF's analysis of the monetized externalities for a) GHG emission reductions, b) criteria air pollutant reductions, and c) increased energy security benefits through petroleum displacement.

Scenario		Monetized Externalities (NPV, $2010 millions)			
		GHG Emissions SCC[1]	Criteria Air Pollutants	Energy Security	Total
Scenario 1	low	$502	$253	$844	$1,599
	high	$3,220	$346	$1,059	$4,625
Scenario 2	low	$502	$63	$796	$1,360
	high	$3,260	$68	$1,017	$4,345
LCFS Enhanced	low	$497	$258	$980	$1,736
	high	$3,204	$359	$1,230	$4,793

[1] For the low SCC estimates, ICF used the values reported at a 5 percent social discount rate; for the high SCC estimates, ICF used the 2.5 percent discount rate

Monetized Externalities, ctd

The monetized environmental and energy security benefits of the LCFS are significant and can be valued in the range of $1.4–4.8 billion out to 2020. The following numbers are shown as cumulative values out to 2020.

- The GHG reductions attributable to LCFS compliance, when monetized using the social cost of carbon, are valued at $497 million to $3.26 billion.
- The criteria pollutant reductions attributable to LCFS compliance, when monetized using avoided damage costs, are valued at about $63–359 million per year.
- The energy security benefits of displacing petroleum consumption – particularly petroleum imports – are valued at $796 million to $1.23 billion per year.

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Glossary of Abbreviations and Acronyms

ABFA	Advanced Biofuels Association
BEV	battery electric vehicle
CalETC	California Electric Transportation Coalition
CARB	California Air Resources Board
CARBOB	California Reformulated Blendstock for Oxygenate Blending
CEC	California Energy Commission
CNG	compressed natural gas
CNGVC	California Natural Gas Vehicle Coalition
CO_2	carbon dioxide
E15	Ethanol blended with gasoline at 15% by volume
E2	Environmental Entrepreneurs
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EVSE	Electric Vehicle Supply Equipment
GDP	Gross Domestic Product
GHG	greenhouse gas
GSP	Gross State Product
IEPR	Integrated Energy Policy Report (prepared by CEC)
LCFS	Low Carbon Fuel Standard
LNG	liquefied natural gas
NAICS	North American Industry Classification System
NBB	National Biodiesel Board
NGV	natural gas vehicle
NOx	nitrogen oxides
NPV	Net Present Value
PEV	plug-in electric vehicle
PHEV	plug-in hybrid electric vehicle
PM	particulate matter
SCC	Social Cost of Carbon
ULSD	ultra low sulfur diesel
VOC	volatile organic compounds