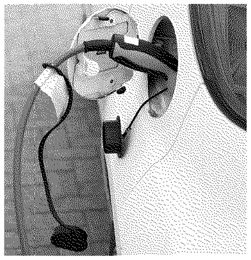


Carbon Metric

Analysis of Policies in Transportation Sector

ICF

Pacific Gas & Electric Company

CRRI Western Conference
June 2014

Overview

- Scope and Methodology
- Carbon Metric: Analytical Framework
- Results: Low Cost and High Cost
- Takeaways
- Next Steps

Transportation - Scope and Methodology

Scope	ICF was retained by PG&E to: ▪ Determine feasibility of the Low Carbon Fuel Standard Regulation (LCFS) (*as currently written, focused on 2020*) ▪ Determine the abatement quantity and abatement cost of the LCFS regulation ($ per ton) Complementary measures included in the analysis: ▪ Pavley 2 Tailpipe Emission Standards ▪ Zero Emission Vehicle Program

Methodology	▪ ICF modeled two scenarios:
	    ▪ Plausible Low Cost
	    ▪ Plausible High Cost
	▪ **Model Design**: LCFS was modeled using the deficit and credit system (gasoline and diesel yield deficits, alternative fuels yield credits) on a WTW basis
	▪ **Cost treatment**: Cost includes fuel costs, vehicle costs, and infrastructure costs, reported as NPV in 2010
	▪ **Modeling**: ICF developed an optimization model that dynamically solves for low-cost, lowest emission solution while considering inter-temporal trading and banking behavior

Carbon Metric Purpose and Key Questions

The Current Carbon Metric Analysis:

- Provides a **"status check"** on the major AB 32 measures (how will they reduce emissions and at what cost)
- Can be compared to the prior analyses conducted by ARB
- Contributes constructively to inform policy discussions at the ARB, CEC, CPUC and elsewhere

Key Questions Addressed:

Greenhouse Gas Emissions Reductions (Metric Tons, MT)	• What is the likely range of 2020 emission reduction outcomes from the primary Scoping Plan program measures as currently structured? • What is the plausible range of offset supply?
Cost of Emission Reductions ($/MT)	• What is the range of costs per unit of reductions from each measure?

This analysis can improve the implementation of AB 32 by:

- Encouraging stakeholder engagement around a standard analytical tool
- Promoting more sensible and more affordable clean energy policies

Analytical Framework - Abatement Cost Calculation

$$\textbf{Abatement Cost}\ (\$/MT) = \frac{\textbf{Net Costs}\ (2010\ NPV)}{\textbf{GHG Emissions Abated}\ (2010\ NPV)}$$

Where: ***Net Costs***

= Measure Cost Less Avoided Cost *(EE, RPS, CHP and Transportation)*

= Project Costs Less Incidental Revenues *(Offsets)*

GHG Emissions Abated

= Measure Quantity * (Avoided Emissions Intensity Less Program Measure Emissions Intensity)

(EE, RPS, CHP and Transportation)

= "Plausible Baseline" Emissions Less Project Emissions *(Offsets)*

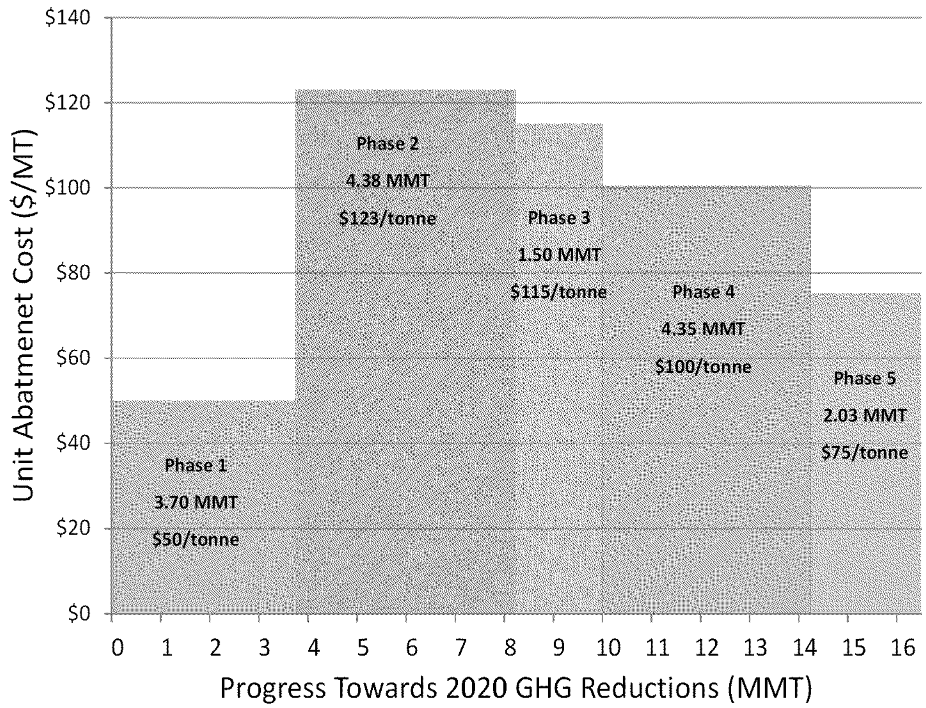
Summary of Results*

		Low Cost Scenario	High Cost Scenario
Compliance	**Compliance Outlook**	Compliance is achieved	Compliance is not achieved
Quantity of Abatement	**Quantity of Abatement (in 2020)**	16.4 MMT	15.2 MMT
	Quantity of Abatement (Cumulative up to 2020)	86.3 MMT	79.6 MMT
Cost of Abatement	**Average Abatement Cost ($ per tonne CO_2e)**	$94	$182
	Incremental Abatement Cost ($ per tonne CO_2e)	$75	$219

*Well to Wheel Basis

Results – Low Cost Scenario (1 of 2)

(1)



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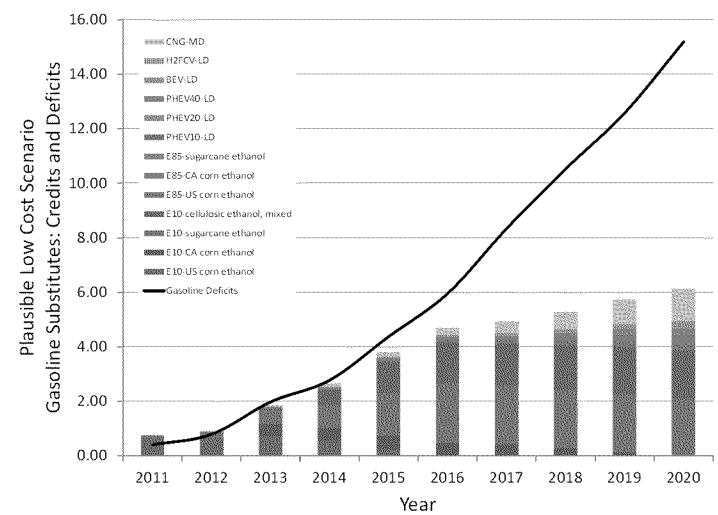

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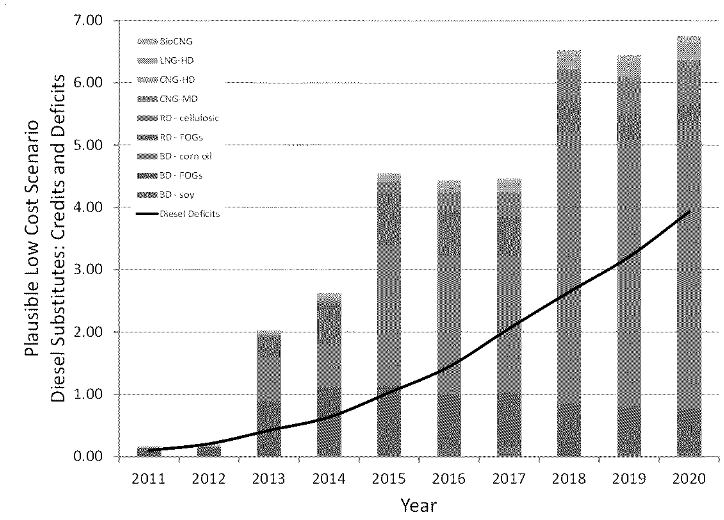

1. Abatement Curve – Low Cost Scenario
2. GHG Reductions in the Gasoline Pool
3. GHG Reductions in the Diesel Pool

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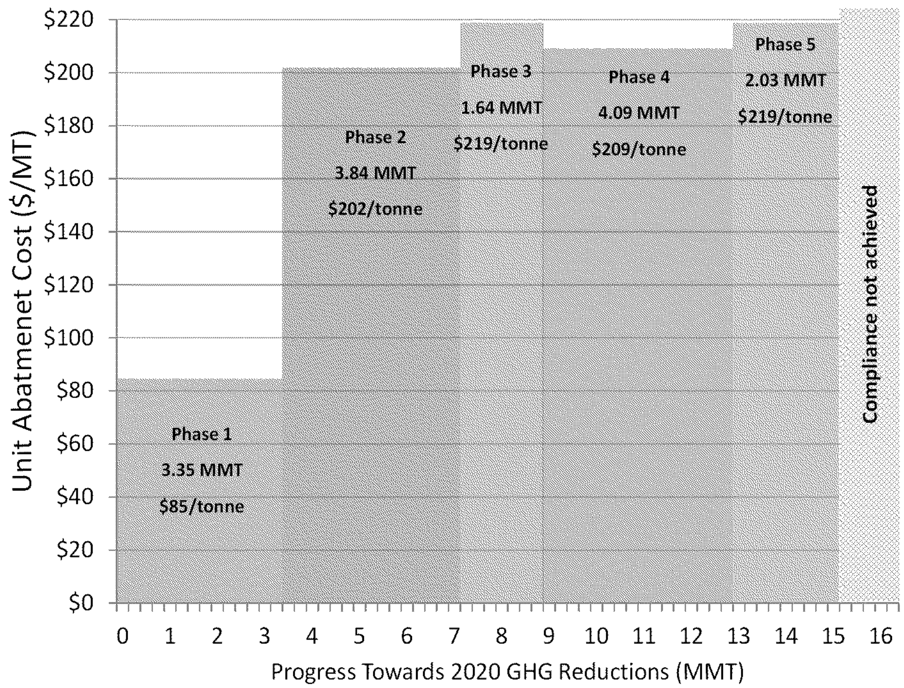
Results – Low Cost Scenario (2 of 2)

Phase	Contribution to 2020 Abatement (In MMT)	Cost of Abatement (In $/ton)	Key Drivers
Phase 1 2011-2013	3.7	$50	• Blending existing low CI corn ethanol, some sugarcane ethanol • Very low quantity of GHG reduction from CNG, electricity • Over-compliance by blending biofuels generates significant credits for banking
Phase 2 2013-2015	4.4	$123	• Midwest corn ethanol, sugarcane ethanol continue to be a significant blending component, introduction of 100 million gallons of cellulosic ethanol (11% of credits generated • Federal Biodiesel tax credit expires, leading to increased abatement cost.
Phase 3 2015-2017	1.7	$115	• Sugarcane ethanol consumption exceeds corn ethanol consumption in 2015 in the E10 market • More significant natural gas consumption in medium duty sector, with modest increase in infrastructure
Phase 4 2017-2019	4.4	$100	• Beginning to use banked credits from previous years • Corn oil-based biodiesel consumption doubles from Phase 3 • Natural gas consumption continues increase; drives abatement cost down. • Modest increases in E85
Phase 5 2019-2020	2.1	$75	• E10 market is entirely Brazilian sugarcane ethanol and cellulosic ethanol (combined 30% of credits generated) • NG continues upward penetration and reaches 13% of credits • Small contribution from PEVs as ZEV Program enters 3rd year • Banked credits, especially from diesel pool, in earlier years help achieve compliance

Results – High Cost Scenario (1 of 2)

1



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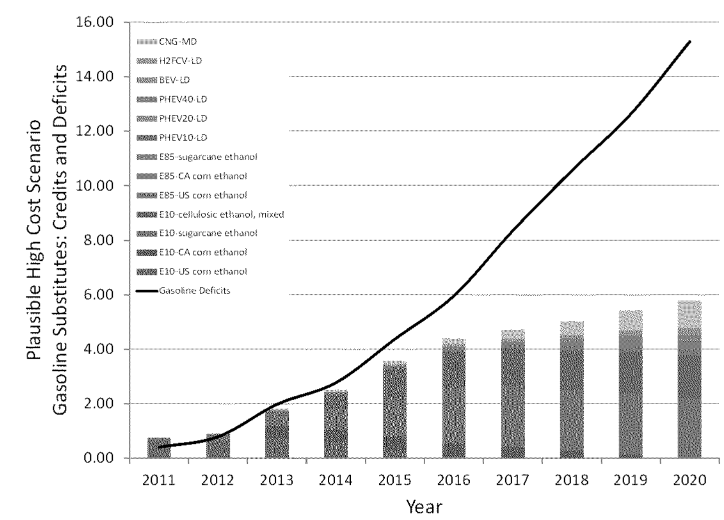

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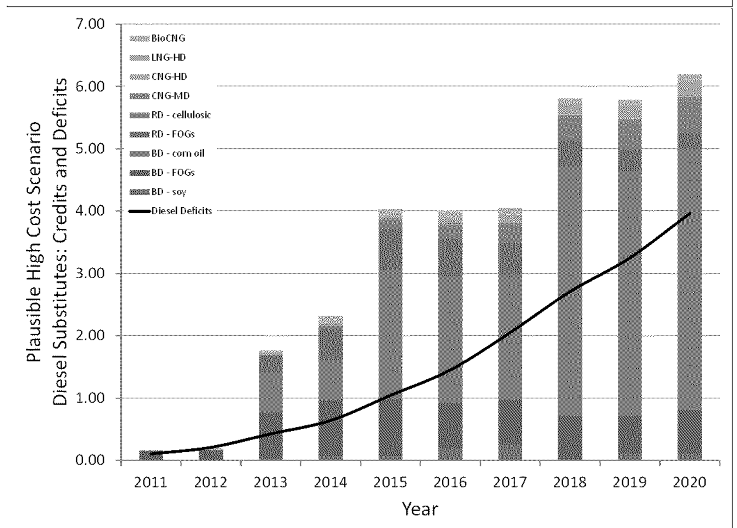

1. Abatement Curve – High Cost Scenario
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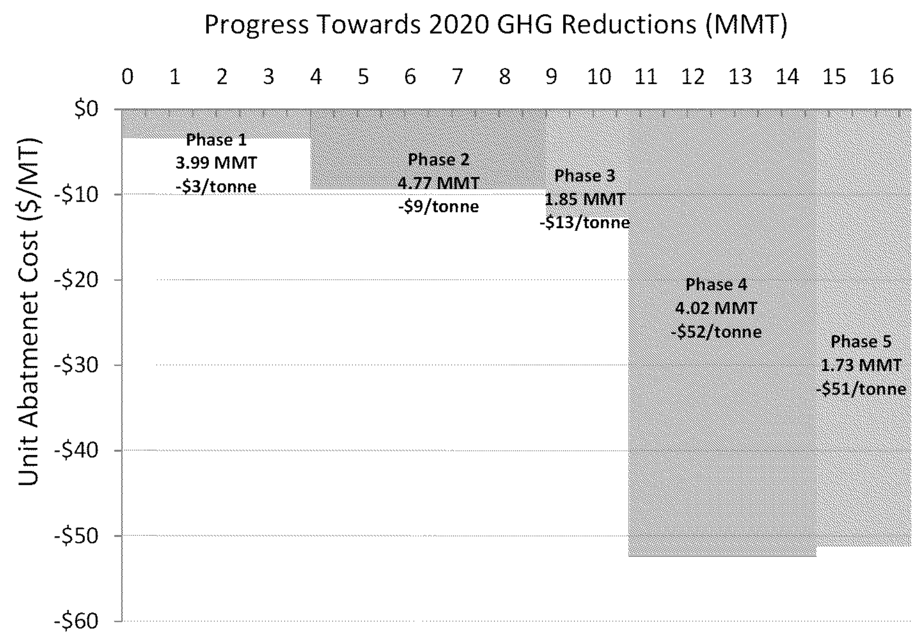
Results – High Cost Scenario (2 of 2)

Phase	Contribution to 2020 Abatement (In MMT)	Cost of Abatement (In $/ton)	Key Drivers
Phase 1 2011-2013	3.4	$85	• Blending existing low CI Midwest corn ethanol, some sugarcane ethanol • Higher biodiesel rack pricing assumptions increase abatement cost • Over-compliance by blending biofuels generates significant credits for banking
Phase 2 2013-2015	3.8	$202	• Midwest corn ethanol, sugarcane ethanol continue to be a significant blending component; modest introduction of cellulosic ethanol • Federal Biodiesel tax credit expires, leading to increased abatement cost • 1.5 million fewer credits generated than in low cost scenario: higher costs of sugarcane and corn-oil based biodiesel than low cost scenario
Phase 3 2015-2017	1.6	$219	• Beginning to use banked credits from previous years (1 year earlier than low cost scenario) • Sugarcane ethanol consumption exceeds corn ethanol consumption in 2015 in the E10 market • More significant natural gas consumption in medium duty sector, with modest increase in infrastructure
Phase 4 2017-2019	4.1	$209	• Lower volumes of low carbon biofuels consumed: sugarcane and cellulosic ethanol; corn oil- and FOG-based biodiesel • Modest increase in natural gas consumption; smaller decrease in NGV costs.
Phase 5 2019-2020	2.0	$219	• Lower supply of sugarcane ethanol and corn oil-based biodiesel • Lower deployment of NG because of higher vehicle costs • Expiration of fed tax credit for PEVs drives abatement cost increase (but not overall abatement cost)

Results – Bottoms up Scenario (1 of 2)

1



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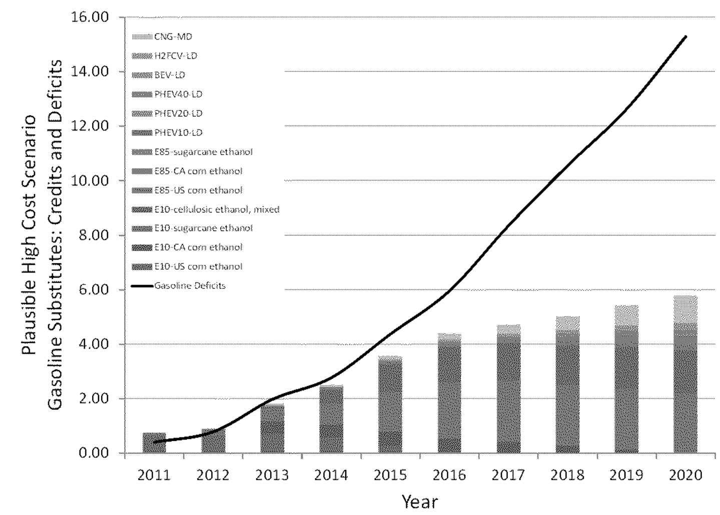

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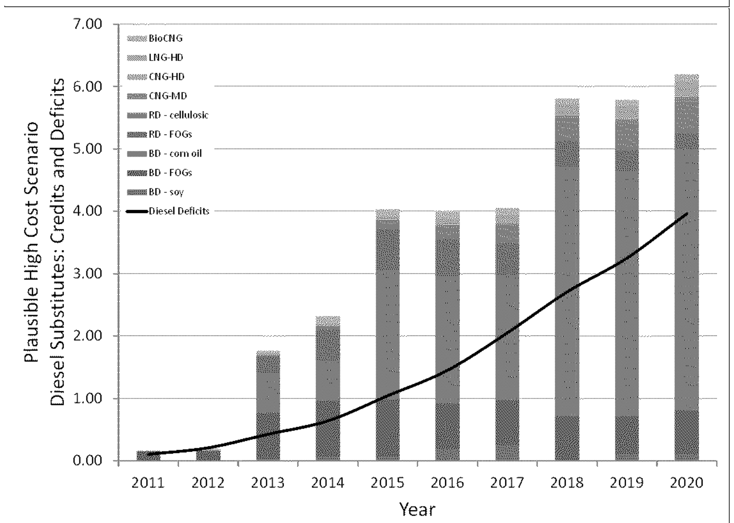

1. Abatement Curve – High Cost Scenario
2. GHG Reductions in the Gasoline Pool
3. GHG Reductions in the Diesel Pool

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Results – Bottoms Up Scenario (2 of 2)

Phase	Contribution to 2020 Abatement (In MMT)	Cost of Abatement (In $/ton)	Key Drivers
Phase 1 2011-2013	4.0 MMT	-$3	• Blending existing low CI corn ethanol, some sugarcane ethanol • Very low quantity of GHG reduction from CNG, electricity • Over-compliance by blending biofuels generates significant credits for banking
Phase 2 2013-2015	4.8 MMT	-$9	• Midwest corn ethanol, sugarcane ethanol continue to be a significant blending component, introduction of 100 million gallons of cellulosic ethanol (11% of credits generated)
Phase 3 2015-2017	1.9 MMT	-$13	• Sugarcane ethanol consumption exceeds corn ethanol consumption in 2015 in the E10 market • More significant natural gas consumption in medium duty sector, with modest increase in infrastructure
Phase 4 2017-2019	4.0 MMT	-$52	• Beginning to use banked credits from previous years • Corn oil-based biodiesel consumption doubles from Phase 3; drives abatement cost down significantly. • Natural gas consumption continues increase; drives abatement cost down. • Modest increases in E85
Phase 5 2019-2020	1.7 MMT	-$51	• E10 market is entirely Brazilian sugarcane ethanol and cellulosic ethanol (combined 30% of credits generated) • NG continues upward penetration and reaches 13% of credits • Small contribution from PEVs as ZEV Program enters 3rd year • Banked credits, especially from diesel pool, in earlier years help achieve compliance

Key Takeaways

Compliance	• **Low Cost**: Yes, by a small margin • **High Cost**: No, by a small margin • Banking and diesel pool improves compliance prospects
Quantity of Abatement	• Limited variation across scenarios • Tank to Wheel reductions (which affects C&T) is greater than Well to Wheel reductions
Cost of Abatement	• Wide variation in costs across scenarios • Low carbon biofuels expected to command a price premium, "bottoms-up" pricing would be lower
Retail Fuel Price Impact	• LCFS compliance leads to a 2 to 10% increase in retail fuel price
Alternative Fuels	• Sugarcane ethanol, corn-oil based biodiesel play a prominent role • Natural Gas Vehicles, Plug-in Electric Vehicles play a smaller role

PG&E

Next Steps

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- ARB is considering multiple changes to the LCFS in 2014:
  - Curve Smoothing:
    - Maintain 1 percent reduction target 2013 through 2015
  - Carbon Intensity:
    - Indirect Land Use Change (ILUC) emission factors for biofuels
    - Flexibility in CARBOB average carbon intensity for refiners
  - Fuel Accounting:
    - Add eligibility for electricity applications (fixed guideway transit and forklifts)
  - Cost Containment
- ARB is considering 2030 economy-wide GHG target
  - Future Analysis:
    - Account for transportation sector abatement beyond carbon intensity
    - Integrate transportation with other sectors

APPENDIX

APPENDIX

Fuel Specific Takeaways (1 of 2)

Fuel Type	CI (gCO_2e/MJ)	Expected Supply 2020	Exp. consumption in CA, 2020	Key Advantages	Constraints & Barriers	Contribution to GHG abatement
Corn Ethanol, US	77 — 97	15 billion gallons	150 million gallons	Relatively stable cost of production and abundance in volume	High carbon intensity leading to limited demand for blending	Low: Limited due to high carbon intensity values ascribed to Indirect Land Use Change
Corn Ethanol, CA	72 — 85	214 million gallons	214 million gallons	Competitive CI values, local supplier; efficient production facilities	Limited production potential	Low: Limited due to small volumes
Sugarcane Ethanol	64 — 73	2.6 billion gallons	1 billion gallons	Lower cost of production; significant export capacity; lower carbon intensity than corn ethanol	Export capacity is unclear; Brazilian domestic demand for fuel is strong; may be international demand for fuel from other regulatory drivers	Very high: projected to play a key role in compliance due to high volume and existing production capacity
Cellulosic Ethanol	25 — 35	520 million gallons	364 million gallons	Very low carbon intensity. Compatible with existing infrastructure for ethanol.	Technological breakthroughs are required to hit production targets	Moderate to High: Potentially significant if volumes materialize as projected
E85	depends on feedstock	Depends on RFS; other market drivers. 15 billion gallons of corn ethanol available.	500 million gallons	Helps alleviate blend wall for ethanol in E10. There are vehicles on the road that can use fuel	Requires expanded retail infrastructure Although vehicles on the road, limited potential for expansion in CA	Low: Minor contribution because of low volume potential.

Fuel Specific Takeaways (2 of 2)

Fuel Type	CI (gCO_2e/MJ)	Expected Supply 2020	Exp. consumption in CA, 2020	Key Advantages	Constraints & Barriers	Contribution to GHG abatement
Biodiesel	4 — 83	2.5 billion gallons	625 million gallons	At low volumes (B5), can use diesel infrastructure. Low consumption today – significant expansion potential	Higher fuel costs. Warranty concerns for higher blends. Higher blends require dedicated refueling infrastructure Some air quality concerns (B20).	Very high: Very significant; corn oil based biodiesel is a major compliance pathway because of low carbon intensity.
Renewable Diesel	20 — 82	520 million gallons	130 million gallons	Generally low carbon intensity Fungible with existing diesel infrastructure	Higher fuel costs; limited supply of feedstock	Low to moderate: Depending on feedstock availability
CNG / LNG	11 — 78	n/a	800 million dge	Cheaper than diesel. Existing vehicle technology. Growing retail infrastructure	Limited vehicle offerings today in some key markets. Retail infrastructure is expensive.	Moderate to very high: Due to fuel savings.
Plug-In Electric Vehicles	105 — 124	n/a	81 million gge	Very low carbon intensity. California early adopter market for PEVs.	Vehicle pricing remains high.	Low: Vehicle pricing remains high; increasingly important as ZEV Program takes effect.
Hydrogen Fuel Cell Vehicles	76 — 133	n/a	10 million gge	Low carbon intensity	Vehicle pricing, vehicle availability, fuel pricing, and fuel availability.	Very Low: Projected vehicle penetration in the given timeframe is very low.

APPENDIX

Transportation Assumptions - Fuel

Fuel	Cost Assumptions - Fuel	Carbon Intensity (WTW) in gCO_2e/MJ	Carbon Intensity (TTW) in gCO_2e/MJ
Gasoline Blendstock (CARBOB)	Based on rack prices derived from Bloomberg and CEC	99.18	72.90
Ultra Low Sulfur Diesel		98.03	74.10
Ethanol, US Corn	Based on spot prices at the rack derived from Bloomberg	86.46	0
Ethanol, CA Corn		80.70	0
Ethanol, Brazil Sugarcane		68.84	0
Ethanol, Cellulosic		29.00	0
Biodiesel, Soybeans	Based on rack prices forecast for biodiesel from Bloomberg	83.25	0
Biodiesel, FOGs		15.04	0
Biodiesel, Corn Oil		4.00	0
Renewable Diesel, FOGs		29.49	0
Renewable Diesel, Cellulosic		37.20	0
Compressed Natural Gas	Citygate pricing; projections from CEC and AEO	68.0	55.7
Electricity	Retail electricity rates for EV charging from major utilities	41.30	31.9
Hydrogen	Utilized current cost from Sunline Transit and escalated each year with NG costs	57.80	32.0

Transportation Assumptions - Infrastructure

Fuel	Cost Assumptions - Infrastructure
Gasoline Blendstock (CARBOB)	No additional infrastructure costs
Ultra Low Sulfur Diesel	
Ethanol, US Corn	**Low blend**: Recouping infrastructure costs (production, delivery to CA) in fuel prices **High Blend**: Cost of retrofitting existing E85 stations and the cost of construction of additional stations
Ethanol, CA Corn	
Ethanol, Brazil Sugarcane	
Ethanol, Cellulosic	
Biodiesel, Soybeans	**Low Blend**: Recouping infrastructure costs (production, delivery to CA) in fuel prices. Costs of terminal storage. **High Blend**: Required expansion of biodiesel storage at petroleum terminals and refueling stations for B20
Biodiesel, FOGs	
Biodiesel, Corn Oil	
Renewable Diesel, FOGs	
Renewable Diesel, Cellulosic	
Compressed Natural Gas	Additional retail infrastructure required
Electricity	Residential and commercial charging infrastructure costs – Cost of equipment and cost of installation. No distribution upgrade costs were considered
Hydrogen	Cost of installation 50 to 65 stations at a cost of $1.5 million per station based on CEC forecast

a. The cost increases for ethanol are relative to average corn ethanol, US
b. The cost increases for biodiesel and renewable diesel are relative to biodiesel produced from soybeans

APPENDIX

Transportation Case Construction

Fuel / Strategy	Cost Element	Low Cost Case	High Cost Case
Ethanol, E10 Fuel costs[a]	Corn ethanol, lower CI	+2-4¢/gallon	+4-6¢/gallon
	Sugarcane ethanol	+26¢/gallon	+65¢/gallon
	Cellulosic ethanol	+100¢/gallon	+150¢/gallon
Ethanol, E85 Refueling Equipment	Retrofits	$125,000	$150,000
	New stations	$300,00	$375,000
	Ratio of retrofits to new stations	40/60	20/80
Biodiesel, Fuel Costs[b]	Soy	--	--
	Corn oil	+25¢/gallon	+50¢/gallon
	FOGs	+25¢/gallon	+50¢/gallon
Biodiesel, Infrastructure Costs	Refueling infrastructure	$70,000	$100,00
	New stations	$200,00	$250,00
	Terminal storage	$120 million	$200 million
Renewable Diesel, Fuel Costs[b]	FOGs	+50¢/gallon	+100¢/gallon
	Cellulosic/waste	+50¢/gallon	+100¢/gallon
Natural Gas, Vehicle Costs	CNG, LNG vehicles	10%reduction by 2020	No vehicle price reductions
PEVs eVMT and vehicle costs	Electric vehicle miles traveled, PHEVs	+3% per year	+1% per year
	Vehicle costs	30% reduction by 2020	10% reduction by 2020
	Federal tax credit	Available through 2020	Phased out post-2018
Hydrogen FCVs	Vehicle costs	25% reduction by 2020	10% reduction by 2020

Footnotes: a. Cost premiums are relative to conventional Midwestern corn ethanol. b. Cost premiums are relative to conventional soy-based biodiesel.

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