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NREL
NATIONAL RENEWABLE ENERGY LABORATORY





CEC ARFVTP Benefits and Market Transformation Update

Presenter – Christopher Neuman

Chad Hunter, Margaret Mann, Christopher Neuman, Dana Stright

Overview / Introduction

- NREL was contracted in 2012 to assess annual benefits of the ARFVTP for the California Energy Commission
  - Benefits (annual and cumulative)
    - GHG emissions
    - Petroleum reductions
    - Other pollutants
  - Market transformation benefits
    - Increased infrastructure
    - Enhanced industry capability and know how
    - Building upon success
  - Based on funded projects by State of California, administered by the California Energy Commission under the ARFVTP

Project Classification

Fueling Infrastructure

- EVSE – Electric Vehicle Service Equipment (Chargers)
- Non-EVSE
  - Biodiesel
  - Natural and Renewable Gas
  - E85 Ethanol
  - Hydrogen

Vehicles

- Light Duty BEVs and PHEVs
- Electric Commercial Trucks
- Gas Commercial Trucks
- MD-HD Truck Demonstration
- Manufacturing

Fuel Production

- Biomethane
- Diesel Substitutes
- Gasoline Substitutes

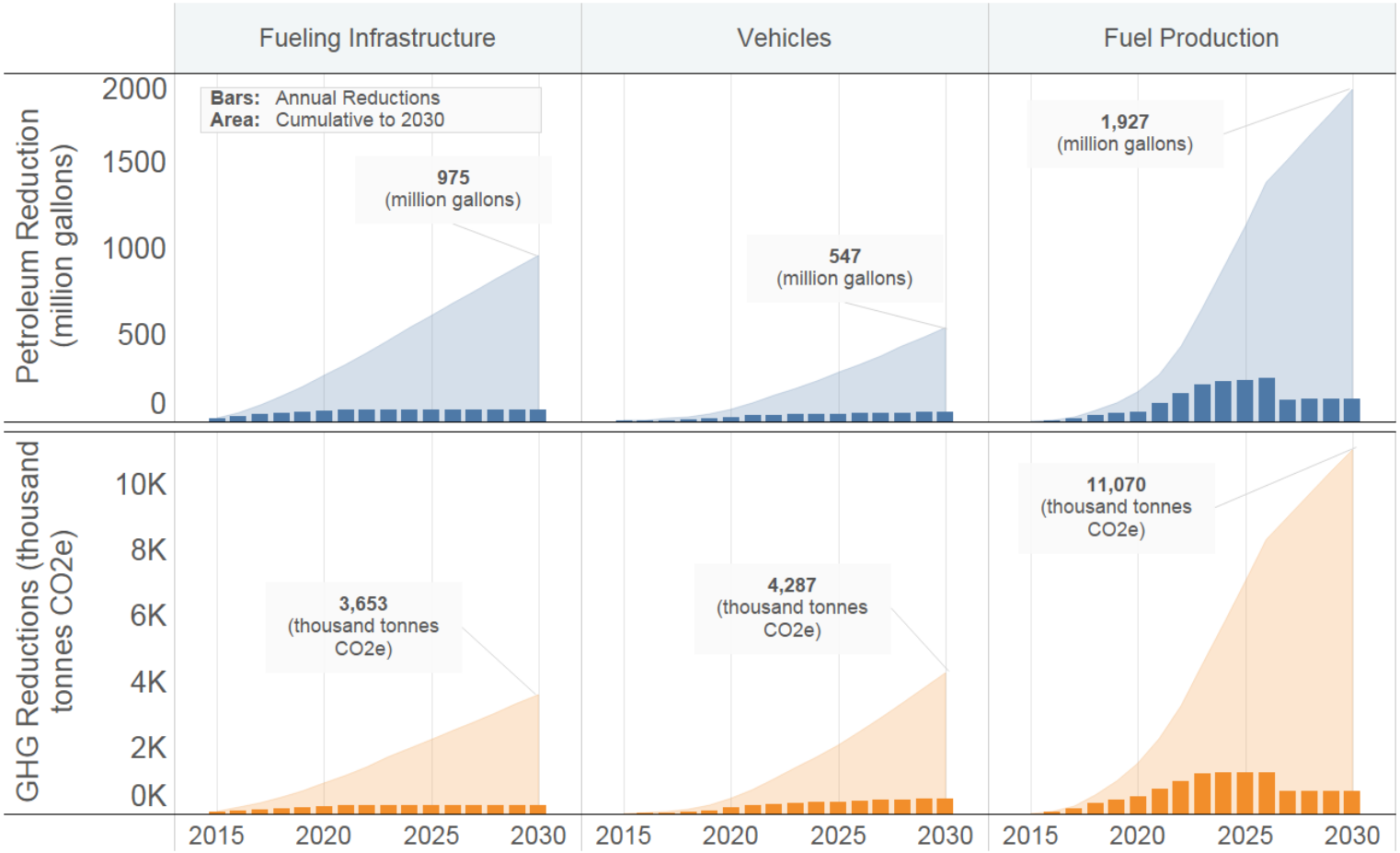
Petroleum fuel reductions are calculated differently for each category of project

As of July 2019

EXPECTED BENEFITS PRELIMINARY RESULTS

Cumulative Reductions to 2030 Preliminary – July 2019

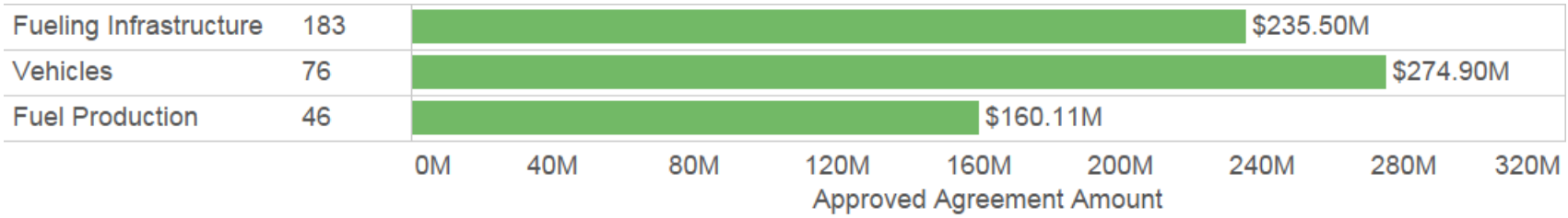
	Cumulative Petroleum Reduction (millions gallons)	Cumulative GHG Reductions (thousand tonnes CO2e)
Fueling Infrastructure	975	3,653
Vehicles	547	4,287
Fuel Production	1,927	11,070
Grand Total	3,449	19,010



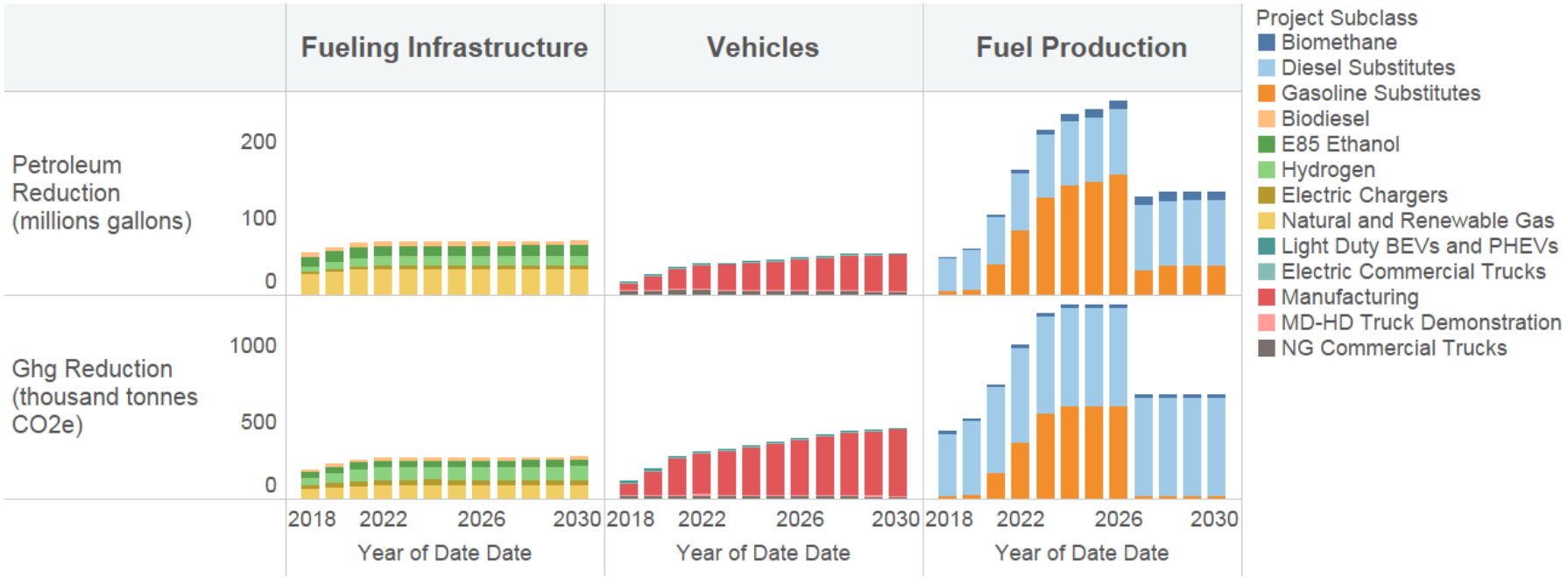
Total Agreements and Approved Funding Amount – July 2019

Project Class	Project Subclass	Total Agreements	Approved Agreement Amount
Fueling Infrastructure	Biodiesel	3	$3.86M
	E85 Ethanol	3	$6.35M
	Electric Chargers	81	$90.46M
	Hydrogen	37	$109.90M
	Natural and Renewable Gas	59	$24.93M
Vehicles	Electric Commercial Trucks	1	$4.00M
	Light Duty BEVs and PHEVs	8	$28.05M
	Manufacturing	14	$29.11M
	MD-HD Truck Demonstration	46	$133.28M
	NG Commercial Trucks	7	$80.46M
Fuel Production	Biomethane	18	$70.71M
	Diesel Substitutes	17	$57.00M
	Gasoline Substitutes	12	$32.40M
Grand Total		305	$670.50M

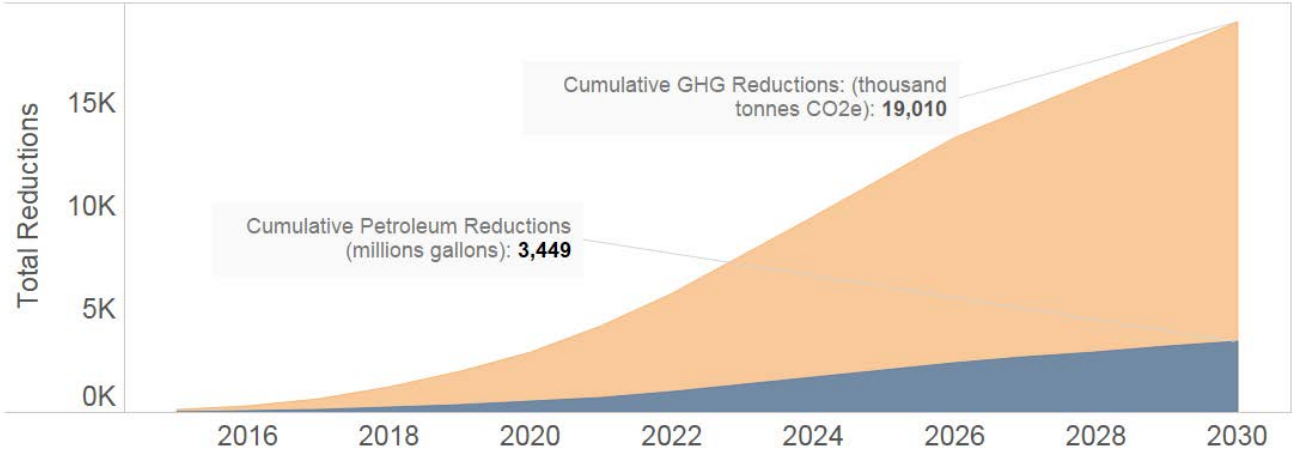
Total agreements and funding levels for Benefit Categories



Preliminary Annual Benefits Calculations by Subclass – July 2019



- The area chart shows the cumulative Total GHG and Petroleum Reductions over all categories and subclasses.



Preliminary Annual Benefits Calculations by Subclass – July 2019

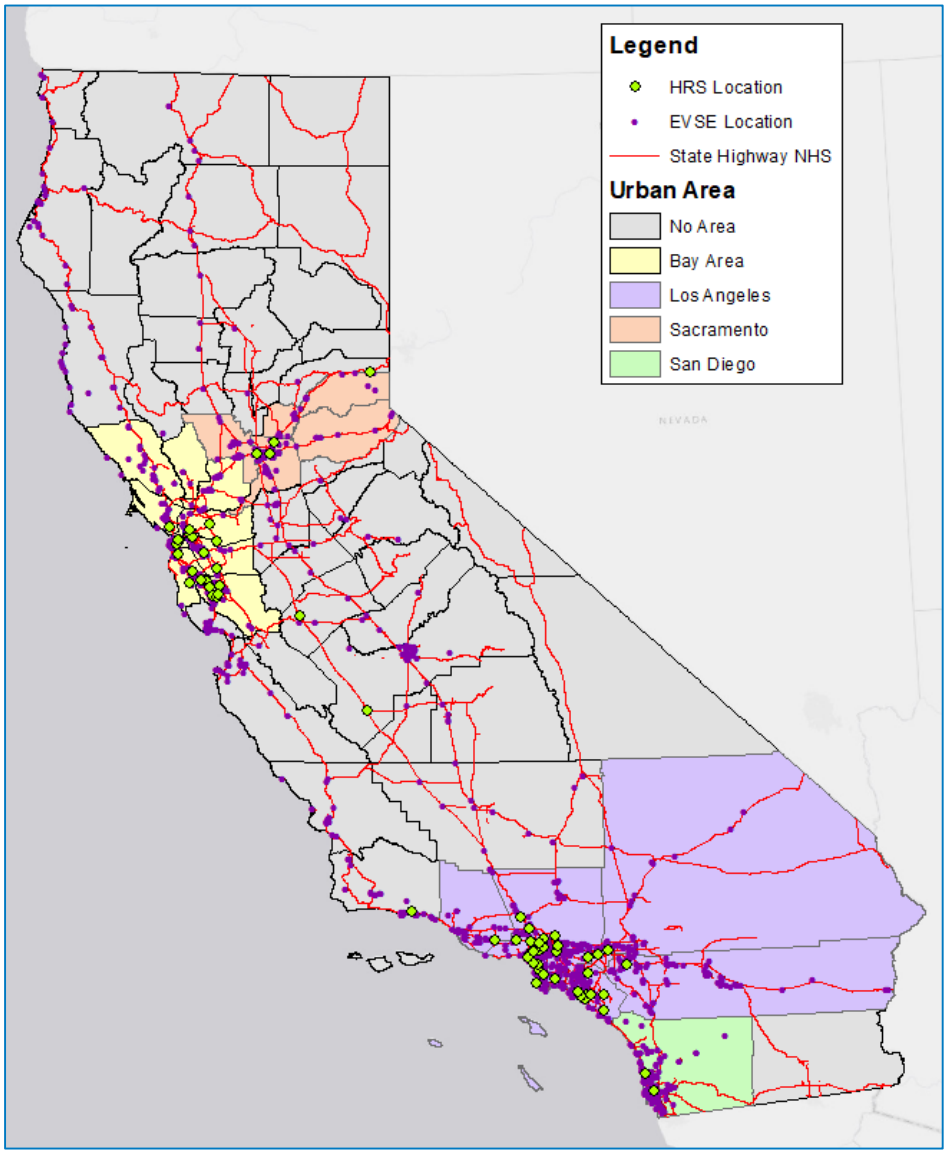
Benefit Category	Project Subclass	Petroleum Reduction (millions gallons)			Ghg Reduction (thousand tonnes CO2e)		
		2019	2025	2030	2019	2025	2030
Fueling Infrastructure	Biodiesel	5.83	5.83	5.83	21.63	21.63	21.63
	E85 Ethanol	13.09	13.92	13.92	39.62	42.13	42.13
	Electric Chargers	3.57	4.90	4.90	27.06	37.11	37.18
	Hydrogen	6.26	11.60	12.56	44.34	82.19	89.01
	Natural and Renewable Gas	26.95	33.71	33.71	62.05	85.51	85.51
Vehicles	Electric Commercial Trucks	0.41	0.26		3.35	2.13	
	Light Duty BEVs and PHEVs	1.61	1.14	0.88	12.19	8.68	6.69
	Manufacturing	9.43	38.18	48.92	79.60	336.55	437.64
	MD-HD Truck Demonstration	0.81	1.47	1.25	6.07	10.57	9.29
	NG Commercial Trucks	5.45	5.08	3.56	14.84	13.84	9.68
Fuel Production	Biomethane	1.32	10.59	11.81	19.58	22.58	22.58
	Diesel Substitutes	43.92	85.43	85.66	409.89	642.98	642.98
	Gasoline Substitutes	4.08	147.71	37.94	13.50	608.57	18.80
Grand Total		122.72	359.82	260.94	753.73	1,914.47	1,423.13

- Seven Agreements have a life end date of 2030, two occur before the end of 2029. Eighty-nine additional projects have a life end date of 2035.

As of July 2019

MARKET TRANSFORMATION PRELIMINARY RESULTS

Updated Market Transformation Benefits Spatial



Revised Area Aggregation

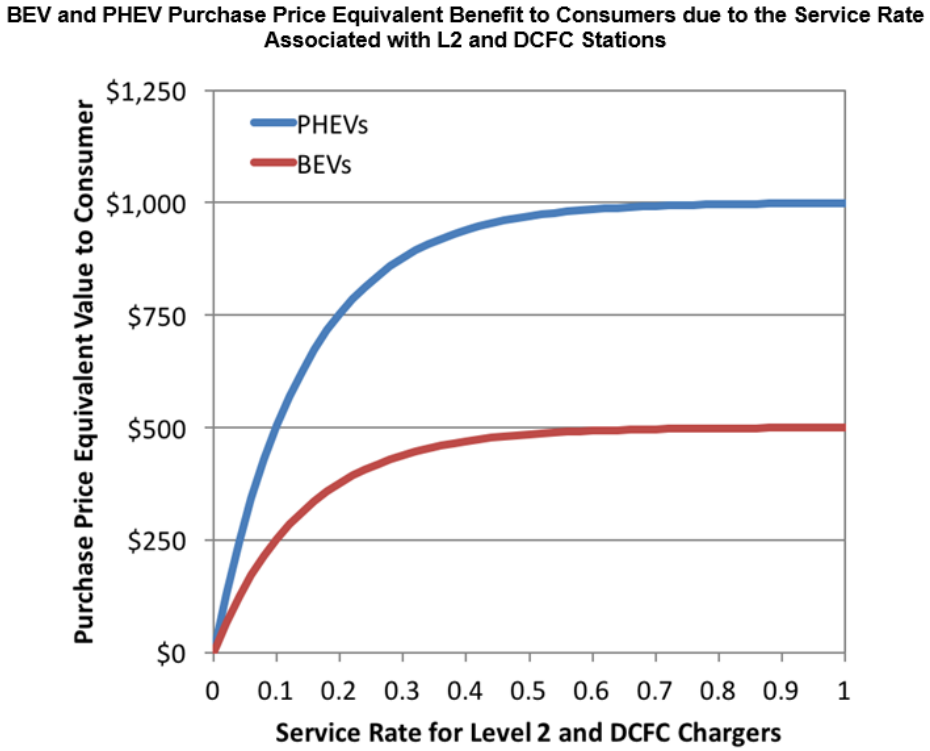
- Improved fidelity and repeatability through the use of latitude/longitude utilization.
- Urban areas were grouped via metro area from a county perspective.
- Addition of state highway overlays to more efficiently examine the benefits of connecting cities.
- Removal of the concept of generalized charger location with improved knowledge of exact position.

Updated Market Transformation Benefits EVSE

Urban Area	Gasoline Stations	Level 2 Public chargers		DC Fast Chargers	
		Before ARFVTP	After ARFVTP	Before ARFVTP	After ARFVTP
Bay Area	1164	395	1,209	13	75
Los Angeles	2813	135	1,653	3	852
San Diego	599	107	1,029	1	26
Sacramento	378	80	450	1	49
Total	4954	717	4341	18	1002

- **Los Angeles shows the greatest increase in both level 2 and DC fast chargers as a result of funding.**
- **All increases in EVSE shown are a direct result of Energy Commission funding.**

Updated Market Transformation Benefits EVSE



Maximum benefit effect of increased charger availability

- Shows the maximum perceived benefit customers receive based on charger availability.
- These seemingly counterintuitive numbers aim to account for the range anxiety associated with BEVs, which could potentially lead BEV drivers to forego a given trip exceeding their battery range.

Updated Market Transformation Benefits EVSE

Vehicle Purchase Price Equivalent Benefit to Consumers for Increased EVSE Availability by Urban Area

Urban Area	Benefit of EVSE Availability (Before and After ARFVTP)				Change in the Benefit of EVSE Availability due to ARFVTP					
	PHEV		BEV		Expected Value		Minimum Value		Maximum Value	
	Before ARFVTP	After ARFVTP	Before ARFVTP	After ARFVTP	PHEV	BEV	PHEV	BEV	PHEV	BEV
Los Angeles	$14	$174	$8	$170	$159	$162	$78	$0	$233	$255
Bay Area	$113	$385	$66	$226	$272	$160	$208	$0	$624	$526
San Diego	$50	$421	$28	$236	$371	$208	$80	$0	$240	$218
Sacramento	$58	$329	$33	$205	$270	$172	$63	$0	$188	$184

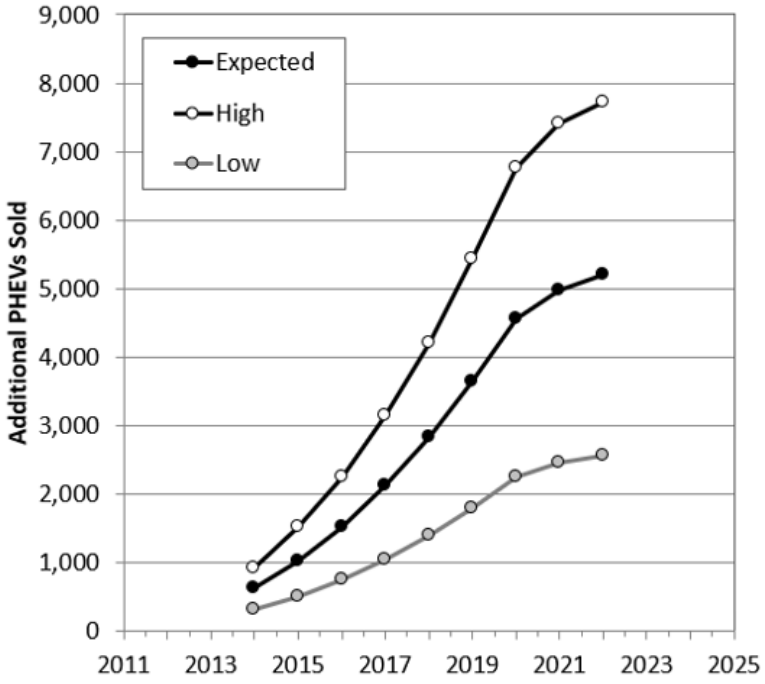
Note: Minimum benefit results assume B*V values of $500 for PHEVs and $0 for BEVs, and maximum benefit results assume B*V values of $1500 for PHEVs and $1000 for BEVs (uniform distributions from NRC 2013 study)

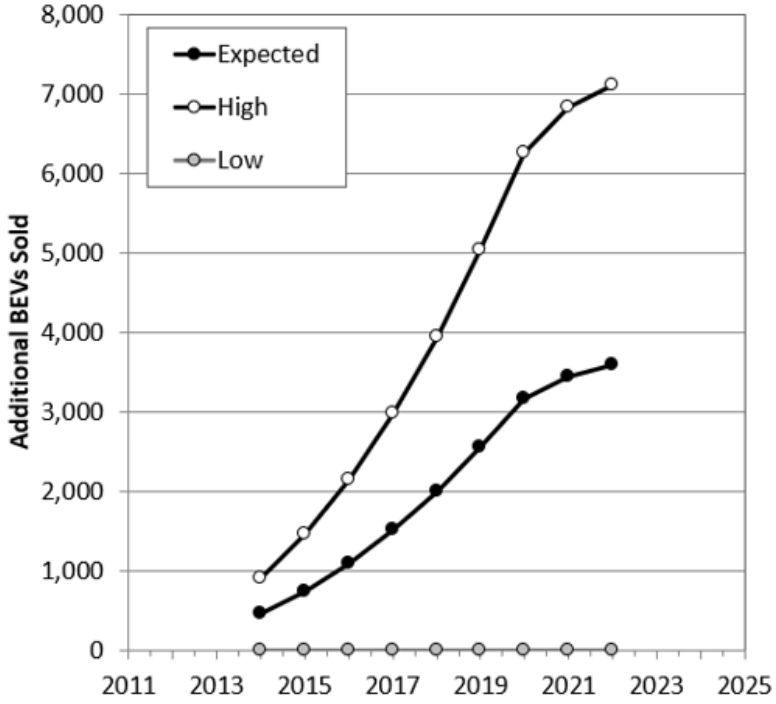
Perceived Cost Reductions

- The benefits of increased public EVSE availability, monetized in the form of equivalent vehicle purchase price, are shown above.
- Overall in the state of California the effect of more PEV charger locations reduced the perceived cost by $268/PHEV and $176/BEV.
- The effect was most apparent in San Diego where PHEVs which saw an overall perceived cost drop of $371/PHEV this is due to the ratio of EVSE to conventional fueling stations.

Updated Market Transformation Benefits EVSE

Additional PHEVs and BEVs Deployed due to an Increase in Public EVSE Availability





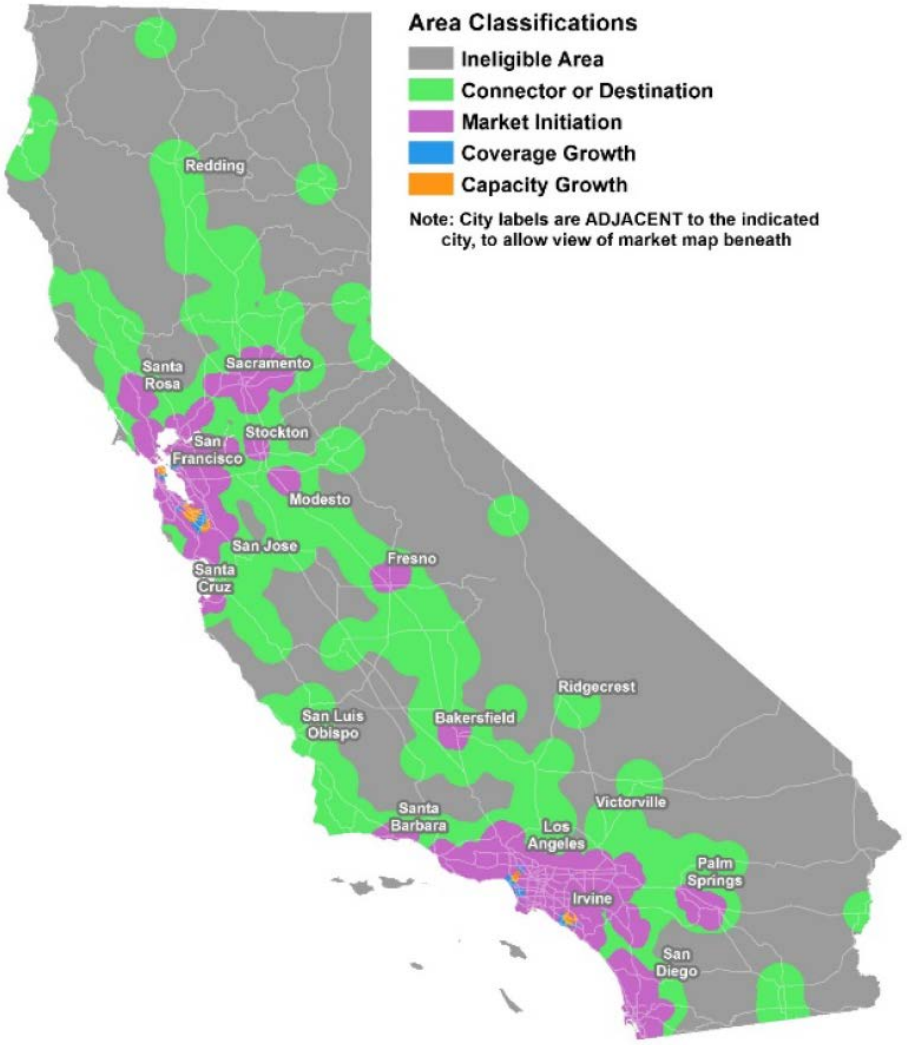
Vehicles Sold

- Total PEVs sold due to increased EVSE availability top 45K by 2022.

Updated Market Transformation Future HRS Work

New Work

- New methodologies are being considered to better explain the value created by an increase in HRS.



Credit: **CEC HYDROGEN DRAFT SOLICITATION CONCEPTS**

Updated Market Transformation Benefits Fuels

Summary of Fuel Production Projects and Annual Outputs

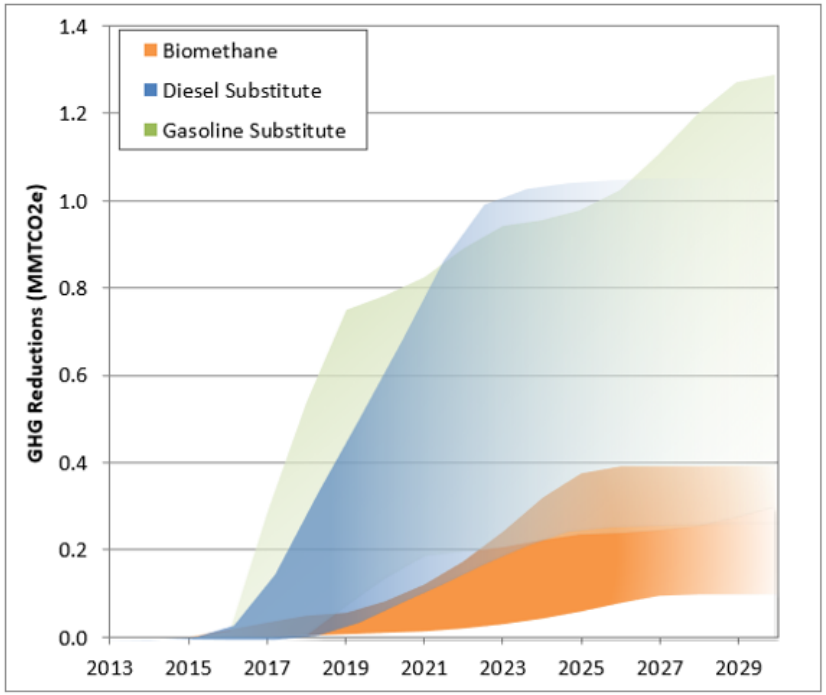
Project #	Awardee	Fuel Product	Displacing	Funding ($M)	Output	Units
ARV-10-016	City of San Jose	Biomethane	Natural Gas	$1.90	146,000	DGE
ARV-10-026	Clean World Partners LLC	Biomethane	Natural Gas	$1.32	507,826	DGE
ARV-12-021	Environ Strategy Consultants Inc.	Biomethane	Natural Gas	$1.21	1,000	DGE
ARV-10-023	G4 Insights Inc.	Biomethane	Natural Gas	$1.23	1,085,682	DGE
ARV-12-031	Blue Line Transfer Inc.	Biomethane	Natural Gas	$2.59	117,124	DGE
ARV-10-052	CR&R Incorporated	Biomethane	Natural Gas	$4.52	865,000	DGE
ARV-10-053	Pixley Biogas LLC	Biomethane	Natural Gas	$4.67	761,729	DGE
ARV-10-040	Northstate Rendering Co Inc.	Biomethane	Natural Gas	$5.46	370,000	DGE
ARV-10-003	SMUD (formerly Eurisko Scientific)	Biomethane	Natural Gas	$1.79	1,000	DGE
ARV-11-021	Clean World Partners	Biomethane	Natural Gas	$6.00	394,477	DGE
ARV-14-028	City of San Mateo	Biomethane	Natural Gas	$2.45	160,000	DGE
ARV-14-037	City of Napa	Biomethane	Natural Gas	$3.00	328,000	DGE
ARV-14-029	Colony Energy Partners Tulare LLC	Biomethane	Natural Gas	$5.00	2,870,000	DGE
ARV-15-054	City of Petaluma	Biomethane	Natural Gas	$3.00	57,000	DGE
ARV-15-067	Quantitative BioSciences Inc.	Biomethane	Natural Gas	$2.00	180,000	DGE
ARV-16-028	CR&R Incorporated	Biomethane	Natural Gas	$3.10	966,482	DGE
ARV-16-XXX	California Bioenergy LLC	Biomethane	Natural Gas	$3.05	500,000	DGE
ARV-16-XXX	Anaheim Energy LLC	Biomethane	Natural Gas	$3.08	2,490,000	DGE
ARV-17-009	County Sanitation Districts of Los Angeles County	Biomethane	Natural Gas	$2.50	761,000	DGE
ARV-16-027	City of Manteca	Biomethane	Natural Gas	$1.62	140,000	DGE
ARV-18-020	City of Roseville Biofuels	Biomethane	Natural Gas	$3.00	668,700	DGE
ARV-18-XXX	East Bay Municipal Utility District	Biomethane	Natural Gas	$1.82	1,000	DGE
ARV-18-XXX	Monterey Regional Waste Management District	Biomethane	Natural Gas	$3.00	12,000,000	DGE
ARV-18-XXX	Califonia Grinding, Inc.	Biomethane	Natural Gas	$3.00	5,190,000	DGE
ARV-19-XXX	Five Points Pipeline LLC	Biomethane	Natural Gas	$4.53	12,046,817	DGE
ARV-19-XXX	Technology & Investment Solutions LLC	Biomethane	Natural Gas	$2.00	947,000	DGE

New Fuels Projects

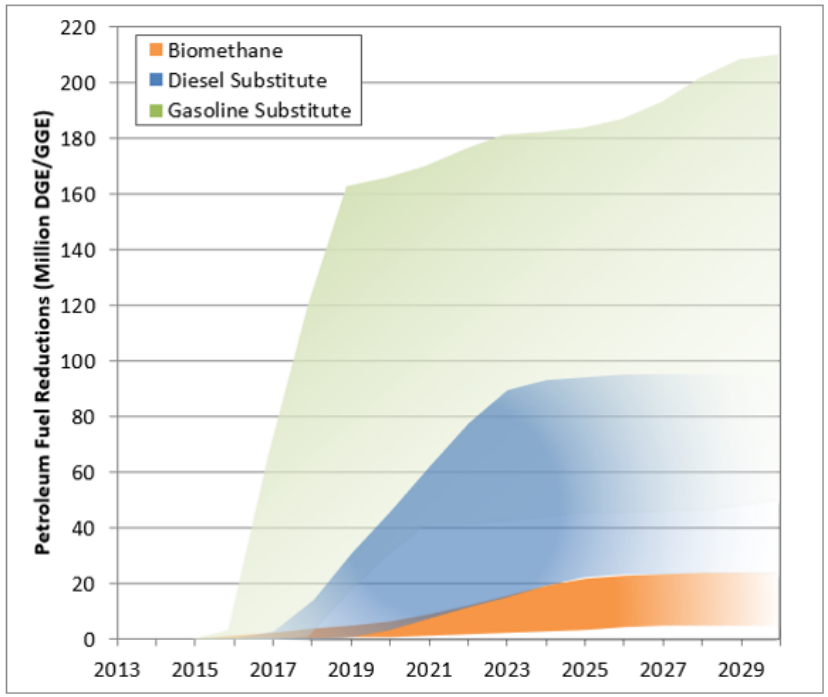
- Six new biomethane projects were proposed, the addition of these projects marks a 50% increase expected output, and 30% increase in total funding.
- Two new biodiesel projects were proposed, the addition of these projects marks a 3% increase expected output, and 6% increase in total funding.
- Two new ethanol project were proposed, the addition of these projects marks a 15% increase expected output, and 31% increase in total funding.

Updated Market Transformation Benefits Fuels

Market Transformation Fuel Production GHG Reductions by Fuel Type



Market Transformation Fuel Production Petrol Fuel Reductions by Fuel Type



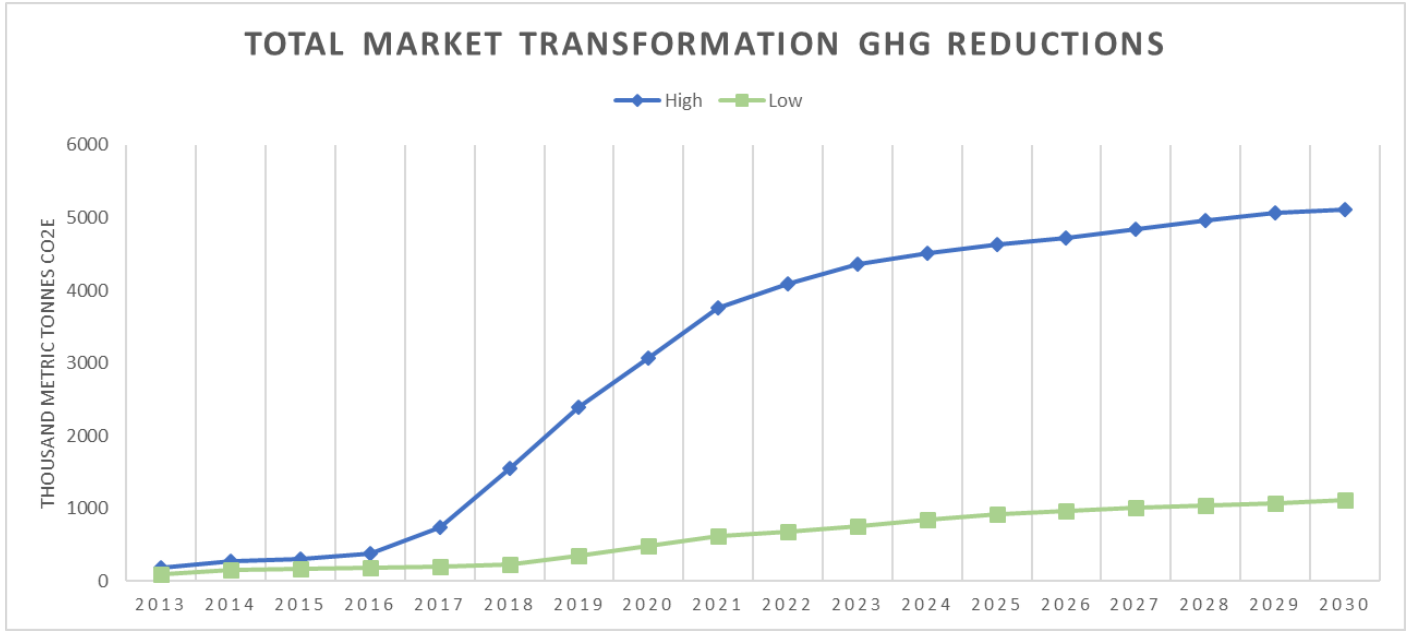
New Fuels Projects

- GHG Gains
  - 48.4% Increase in biomethanes GHG reductions
  - 7.3% Increase in biodiesel GHG reductions
  - 8.4% Increase in ethanol GHG reductions
- Petroleum Reduction Gains
  - 27.9% Increase in biomethanes petroleum reductions
  - 1.4% Increase in biodiesel petroleum reductions
  - 2.8% Increase in ethanol petroleum reductions

Updated Market Transformation Benefits Summary

Summary of Market Transformation GHG Reductions

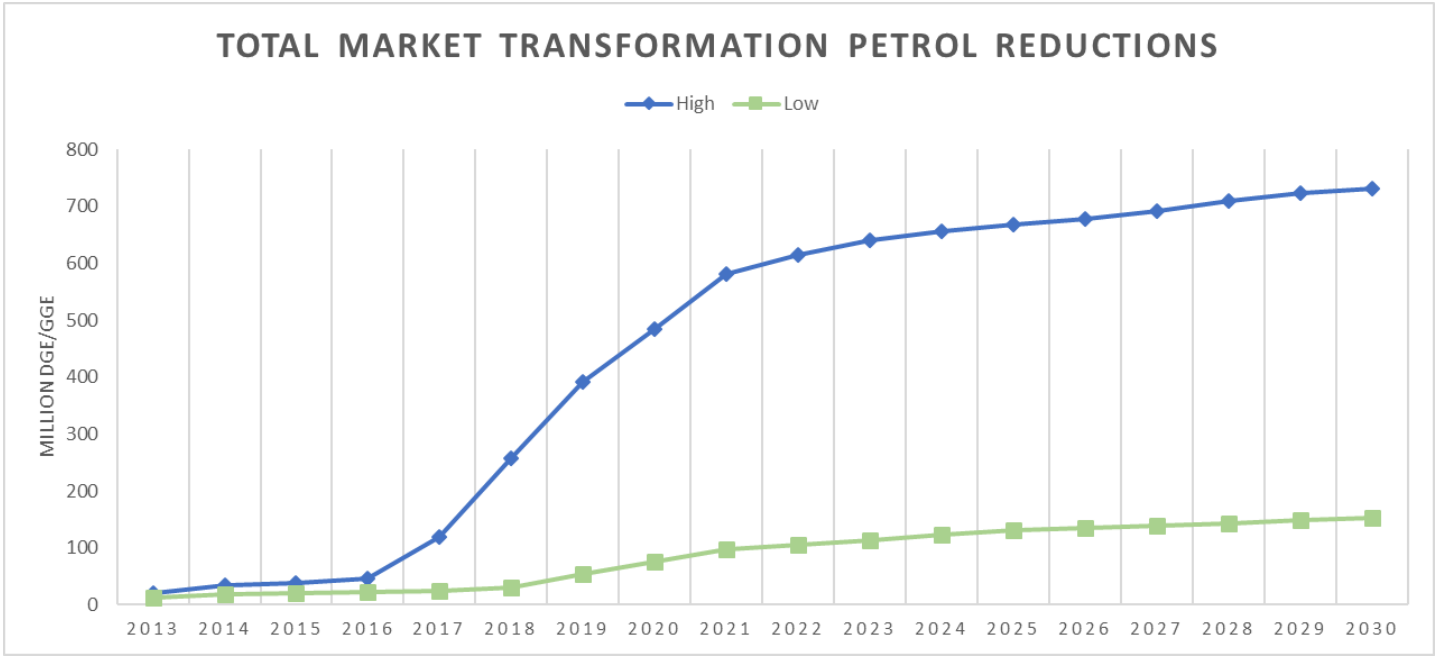
GHG Reductions (10^6 Tonnes CO_2e)		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Vehicle Price Reductions	High	181	281	305	337	377	422	475	539	591	627	647	667	687	708	731	758	787	820
	Low	102	154	162	172	184	195	208	222	232	242	252	261	271	281	291	302	313	326
ZEV Industry Experience	High	-	2.4	5.2	8.2	12	15	19	22	25	28	31	34	37	40	43	46	48	51
	Low	-	2.6	5.6	9.0	13	16	20	24	27	31	34	37	41	44	47	50	53	56
Next Generation Trucks	High	-	-	-	-	-	378	757	1,135	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513
	Low	-	-	-	-	-	18	35	53	71	71	71	71	71	71	71	71	71	71
Next Generation Fuels	High	-	-	-	-	357	738	1,142	1,368	1,626	1,922	2,173	2,301	2,393	2,463	2,546	2,641	2,712	2,730
	Low	-	-	-	-	-	-	89	185	285	342	407	481	543	575	598	616	636	660
Total	High	181	283	310	345	746	1,554	2,392	3,064	3,755	4,090	4,365	4,516	4,630	4,724	4,833	4,957	5,061	5,114
	Low	102	156	168	181	196	229	353	484	616	686	763	850	925	970	1,006	1,038	1,073	1,112



Updated Market Transformation Benefits Summary

Summary of Market Transformation Petroleum Reductions

Petrol Reductions (Million DGE/GGE)		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Vehicle Price Reductions	High	21.5	33.7	36.6	40.8	46.5	53.6	62.4	71.4	80.6	88.4	94.9	101	108	115	121	128	135	141
	Low	12.1	18.5	19.7	21.3	23.2	25.5	28.2	30.9	33.7	36.3	38.7	41.1	43.5	45.9	48.2	50.6	53.0	55.4
ZEV Industry Experience	High	-	0.4	0.8	1.2	1.7	2.2	2.8	3.3	3.9	4.5	5.1	5.7	6.3	7.0	7.6	8.2	8.8	9.4
	Low	-	0.3	0.7	1.2	1.7	2.1	2.7	3.2	3.7	4.3	4.9	5.5	6.1	6.7	7.3	7.9	8.5	9.1
Next Generation Trucks	High	-	-	-	-	-	64.5	129	193	258	258	258	258	258	258	258	258	258	258
	Low	-	-	-	-	-	2.6	5.1	7.7	10	10	10	10	10	10	10	10	10	10
Next Generation Fuels	High	-	-	0.2	4.8	71.2	137	197	217	239	263	283	291	295	299	306	315	321	323
	Low	-	-	-	-	0.0	1.2	17.8	34.4	49	54	60	66	71	73	74	75	76	79
Total	High	21.5	34.0	37.6	46.9	119	258	392	485	581	614	641	656	667	679	693	709	723	732
	Low	12.1	18.9	20.5	22.5	24.9	31.4	53.8	76.1	97	105	113	123	131	135	140	144	148	153



EXPECTED BENEFITS METHODOLOGY

Energy Commission Provided Data

- All
  - Project start and end date
  - Project status (to exclude cancelled)
  - New fuel (feedstock) and replaced fuel type (for GHG reductions)
  - Project class and subclass
- Fuel Production
  - Project subclass (to identify energy density of replaced fuel)
  - Fuel production throughput
- Vehicles
  - Replaced vehicle and fuel type (for VMT and FE)
  - Number of vehicles
- EVSE
  - Number of charge points by type (i.e., L1 commercial, L2 commercial, L2 residential, DCFC)
- Non-EVSE Infrastructure
  - Fuel production throughput

We assume lifespan of infrastructure is 50 years and vehicles is 16 years unless otherwise specified

Electricity Dispensed per Charge Point from EVI-Pro

- The EVI-Pro model uses 2012 California Household Travel Survey to determine number and type of EVSE required to support California's EV adoption goals
- EVI-Pro outputs projected utilization of charging stations by location and type: electricity throughput (avg kWh/plug/year) is used to calculate benefits of EVSE
- Equivalent electric miles are obtained by dividing the electricity dispensed by the average efficiency of electric vehicles, 0.25 kWh/mile

EVSE type (level and location)	Average electricity throughput (kWh) per charge point per year	Equivalent electric miles per charge point per year
Shared L1	846	3,383
Shared L2	3,987	15,948
Residential MUD L2	2,773	11,093
Public DCFC	16,922	67,690

BACK UP

- History of Data Process and PostgreSQL model
- Petroleum Reduction Calculations
- GHG Reduction Calculations
- CA VISION v2.1
- Updated Feedstock Carbon Intensities

History of Data Process and PostgreSQL model

- Excel Model, started calculations in early 2012
  - Complexity, versioning, integrity, updates
- PostgreSQL
  - Migrated to PostgreSQL for reproducibility, consistency and integrity
  - Several Iterations the since 2014
  - 2016 developed query chain model mapping from Excel Model
  - 2017 Refined Model; simplified and de-normalized schema
    - Query Chain
    - Lookups
    - Timestamp functions/triggers
  - SQL archived in GitHub > reproducibility and portability (backups)
  - 2019 Updated model using data from CEC
- Results & Reporting
  - Tableau

Petroleum Reduction Calculations

(millions of gallons)

Fuel Production

petroleum_reduction = fuel_production_throughput * pct_operation / 1000000

Percent operation (of given year) is based calculated assuming operation begins nine months before project end date, and ramps up over 3 years [vehicles have no ramp up period]

Vehicles

petroleum_reduction = vmt_per_year[*vehicle type, replaced fuel*] * vmt_depreciation[*vehicle type, replaced fuel*] / fuel_economy[*vehicle type, replaced fuel*] * number_of_vehicles * pct_operation / 1000000

VMT, VMT depreciation and fuel economy are from the CA VISION model

EVSE

petroleum_reduction = emiles/fuel_economy[*LDA, GAS*] * pct_operation / 1000000

emiles = level_one_comm_charge_points * (3383) + level_two_comm_charge_points * (15948) + level_two_res_charge_points * (11093) + dc_fast_charge_points * (67690)

Number of charge points are multiplied kWh/chargepoint/year from NREL's EVI-Pro model and divided by vehicle's efficiency

Non-EVSE Infrastructure

petroleum_reduction = fuel_production_throughput * pct_operation / 1000000

GHG Reduction Calculations

(million kg of CO2e)

ghg_reduction (kg CO2e) = ghg_differential (g CO2e/MJ) * petroleum_reduction (gal) * energy_density (MJ/gal) / 1000

- ghg_differential is based on the difference in carbon intensity of the replaced fuel (e.g., gasoline or diesel) and the alternative fuel, where values come from LCFS Fuel Pathway Table and CA/ANL GREET models
  - Mapped by fuel feedstocks
  - Used carbon intensities from CEC database (Agreements_combined) when specified
- energy_density is based on values from CA GREET v2.0, for the displaced fuel [~115.8 MJ/gal gasoline; ~135.5 MJ/gal diesel]

CA VISION v2.1

Released Feb. 2017

CA VISION provides:

- Fuel economy
- VMT and VMT depreciation
- NOx and PM2.5 emissions

Projects must have specified:

- Replaced vehicle type (from list)
- Replaced fuel type (GAS, DSL, ELE, PHEV, HYD, CNG, NG)
- New fuel type (from list above)

Table 2: Vehicle Categories in the PVM and HDV Modules

EMFAC Vehicle ID	Vision Model	Description
LDA	PVM	Light-Duty Automobiles (i.e. Passenger Cars)
LDT1	PVM	Light-Duty Trucks (0-3,750 lbs GVWR)
LDT2	PVM	Light-Duty Trucks (3,751-5,750 lbs GVWR)
MDV	PVM	Medium-Duty Trucks (5,751-8,500 lbs GVWR)
UBUS	PVM	Urban Buses
SBUS	PVM	School Buses
OBUS	PVM	Other Buses
LHD1	HDV	Light-Heavy-Duty Trucks (GVWR 8501-10000 lbs)
LHD2	HDV	Light-Heavy-Duty Trucks (GVWR 10001-14000 lbs)
T6 Ag	HDV	Medium-Heavy Duty Diesel Agriculture Truck
T6 CAIRP heavy	HDV	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR>26000 lbs
T6 CAIRP small	HDV	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR<=26000 lbs
T6 instate construction heavy	HDV	Medium-Heavy Duty Diesel instate construction Truck with GVWR>26000 lbs
T6 instate construction small	HDV	Medium-Heavy Duty Diesel instate construction Truck with GVWR<=26000 lbs
T6 instate heavy	HDV	Medium-Heavy Duty Diesel instate Truck with GVWR>26000 lbs
T6 instate small	HDV	Medium-Heavy Duty Diesel instate Truck with GVWR<=26000 lbs
T6 OOS heavy	HDV	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR>26000 lbs
T6 OOS small	HDV	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR<=26000 lbs
T6 Public	HDV	Medium-Heavy Duty Diesel Public Fleet Truck
T6 utility	HDV	Medium-Heavy Duty Diesel Utility Fleet Truck
T6TS	HDV	Medium-Heavy Duty Gasoline Truck
T7 Ag	HDV	Heavy-Heavy Duty Diesel Agriculture Truck
T7 CAIRP	HDV	Heavy-Heavy Duty Diesel CA International Registration Plan Truck
T7 CAIRP construction	HDV	Heavy-Heavy Duty Diesel CA International Registration Plan Construction Truck
T7 NNOOS	HDV	Heavy-Heavy Duty Diesel Non-Neighboring Out-of-state Truck
T7 NOOS	HDV	Heavy-Heavy Duty Diesel Neighboring Out-of-state Truck
T7 other port	HDV	Heavy-Heavy Duty Diesel Drayage Truck at Other Facilities
T7 POAK	HDV	Heavy-Heavy Duty Diesel Drayage Truck in Bay Area
T7 POLA	HDV	Heavy-Heavy Duty Diesel Drayage Truck near South Coast
T7 Public	HDV	Heavy-Heavy Duty Diesel Public Fleet Truck
T7 Single	HDV	Heavy-Heavy Duty Diesel Single Unit Truck
T7 single construction	HDV	Heavy-Heavy Duty Diesel Single Unit Construction Truck
T7 SWCV	HDV	Heavy-Heavy Duty Solid Waste Collection Truck
T7 tractor	HDV	Heavy-Heavy Duty Diesel Tractor Truck
T7 tractor construction	HDV	Heavy-Heavy Duty Diesel Tractor Construction Truck
T7 utility	HDV	Heavy-Heavy Duty Diesel Utility Fleet Truck
T7IS	HDV	Heavy-Heavy Duty Gasoline Truck
PTO	HDV	Power Take Off

Updated Feedstock Carbon Intensities

(for GHG Reduction Calculations)

Fuel	Fuel System Description	Carbon Intensity (g CO2eq/MJ)	Source
Gasoline	AVG California Gasoline Blend	**97**	(A)
Diesel	AVG California Diesel	**100**	(A)
Biodiesel	rapeseed transesterification	**40**	(C)
Biodiesel	used cooking oil (UCO) transesterification, where "cooking" is required	**22**	(B)
Biodiesel	tallow transesterification	**35**	(B)
Biodiesel	90% UCO, 10% soy	**25**	(B)
Biodiesel	50% Soy, 40% Corn, 10% UCO	**42**	(B)
		32	(B)
		29	(B, C)
		80	(B)
CNG	75% NG, 25% Dairy Gas		
CNG	50% dairy waste, 50% wood waste		
CNG	LFG to LNG, with 90% liquefacton efficiency		
CNG	waste water treatment AD w/CCS		
LNG	North American NG delivered via pipeline; liquefied in CA using liquefaction with 90% efficiency		
LNG	dairy digester Biogas to LNG liquefied in CA using liquefaction with 90% efficiency		
LNG	70% LNG, 30% Dairy Biogas		

LCFS carbon intensity of conventional fuels has been updated – changes all of the GHG reductions of fuel pathways even if alternative fuel carbon intensity is the same

Ex: Given alternative feedstock of UCO --

ghg_differential = *Diesel CI – UCO Biodiesel CI* = 100 – 22 = 78 g CO2e/MJ

ghg_reduction = 78*135.5*petroleum_reduction/1000

(A) CARB. 2015. LCFS Final Regulation Order, LCFS Compliance Schedule (Tables 1 and 2), https://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf
(B) CARB. 2017. LCFS Pathway Certified Carbon Intensities, Fuel Pathway Table https://www.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm
(C) CARB. 2015. CA-GREET 2.0 (Tier 1 or 2)
(D) ANL. 2016. GREET.net model v1.3.0.13107
(E) CARB. 2012. Final Regulation Order. Table 6. Carbon Intensity Lookup Table for Gasoline and Fuels that Substitute for Gasoline. Sacramento. 107pp. http://www.arb.ca.gov/fuels/lcfs/lu_tables_11282012.pdf
(F) ANL. GREET. version 2012r2. Modified pathways
(G) S&T2 Consultant. GHGenius. Modification for the Transportation Energy Futures project