Analysis of Benefits Associated With Projects and Technologies Supported by the Clean Transportation Program: 2023 Executive Summary

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Introduction

- In 2007, California Assembly Bills (AB) 118 and 109 created the Clean Transportation Program (CTP), which authorized the California Energy Commission (CEC) to fund projects concerning alternative fuels and advanced transportation technologies to help attain the state's climate change policies. In 2013, AB 8 extended the expiration of the CTP to January 2024.
- AB 109 also requires CEC to prepare a report summarizing the benefits resulting from the program.
- Since then, CEC has collaborated with National Renewable Energy Laboratory (NREL) to prepare and publish biannual reports summarizing CTP's benefits related to petroleum displacement, greenhouse gas (GHG) reductions, air pollution, and more.
- This report updates the input data, calculation methodologies, and resulting outputs from the CEC's 2021 report [1].
- The results to be incorporated in the CEC's final Integrated Energy Policy Report (IEPR) might change.

1. California Energy Commission. 2021. *Analysis of Benefits Associated With Projects and Technologies Supported by the Clean Transportation Program*. Sacramento, CA: CEC. CEC-600-2021-039. https://doi.org/10.2172/1886868.

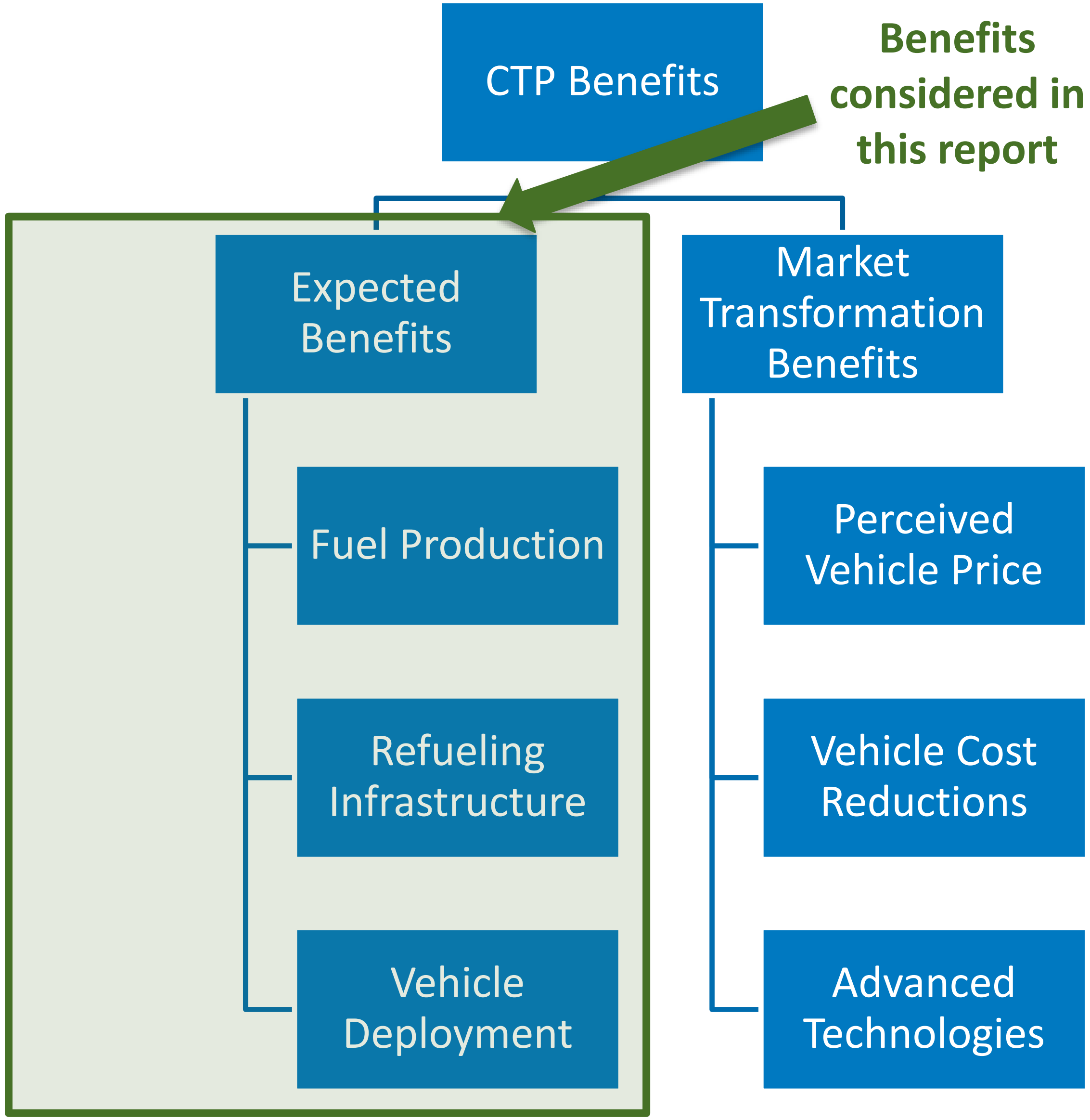
Goals of CTP-Funded Projects

As stated in the 2021 benefits analysis report and in AB 8 [1,2], the goals of CTP-funded projects are to:

- Develop and improve alternative and renewable low-carbon fuels.
- Enhance alternative and renewable fuels for existing and developing engine technologies.
- Produce alternative and renewable low-carbon fuels in California.
- Decrease, on a full-fuel-cycle basis, the overall impact and carbon footprint of alternative and renewable fuels and increase sustainability.
- Expand fuel infrastructure, fueling stations, and equipment.
- Improve light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and non-road vehicle fleets.
- Expand infrastructure connected with existing fleets, public transit, and transportation corridors.
- Establish workforce training programs, conduct public education and promotion, and create technology centers.

1. California Energy Commission. 2021. *Analysis of Benefits Associated With Projects and Technologies Supported by the Clean Transportation Program*. Sacramento, CA: CEC. CEC-600-2021-039. https://doi.org/10.2172/1886868.
2. California Assembly Bill 8. Statutes of 2013, Perea, Chapter 401. http://www.leginfo.ca.gov/pub/13-14/bill/asm/ab_0001-0050/ab_8_bill_20130928_chaptered.pdf

Scope of This Analysis



Types of Benefits

- **Expected benefits** accrue because of the direct displacement of petroleum-based fuels or vehicle technologies.
- **Market transformation benefits** accrue because of CTP funding shifting the underlying market dynamics and accelerating the adoption of alternative fuel vehicles.

Benefit Outcomes

✓ Displaced petroleum consumption
✓ GHG emissions reductions
✓ Criteria pollutant reductions
✓ Jobs supported
✓ Equity and social benefits.

Modeling Horizon

- Benefits accruing from 2013–2035.

Summary of Evaluated Projects

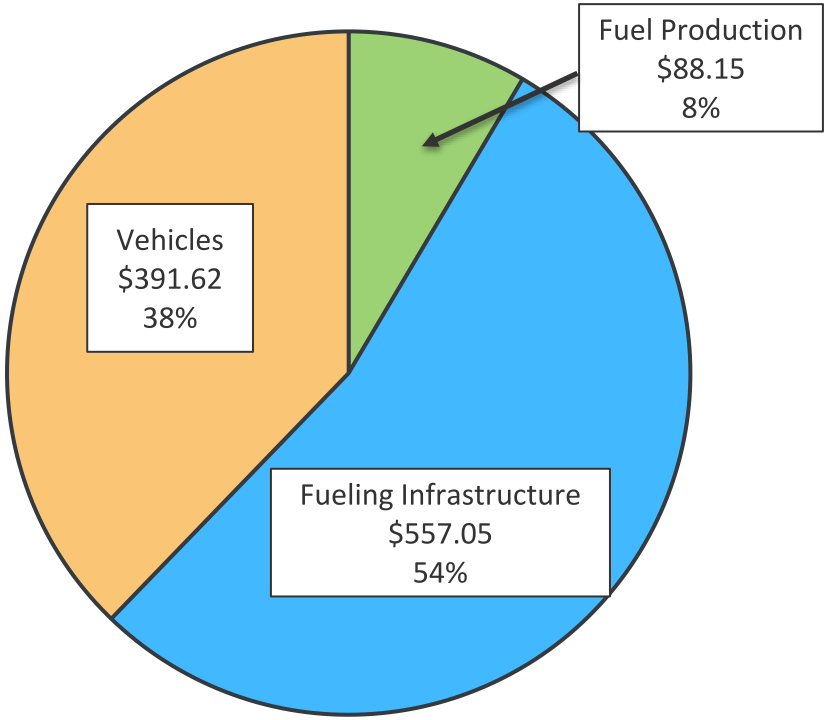
Projects Funded Under the CTP Included in This Analysis

Project Type	# of Projects Analyzed	CTP Funding Analyzed ($ millions)
Biomethane Production	12	$35.9
Gasoline Substitutes Production	5	$10.7
Diesel Substitutes Production	10	$41.5
Electric Vehicle (EV) Charging – Light Duty (LD)*	621	$288.6
EV Charging – Medium and Heavy Duty (MD/HD)	89	$72.2
Hydrogen Refueling Stations – LD	71	$128.2
Hydrogen Refueling Stations – MD/HD	4	$25.5
E85 Fueling Stations	19	$1.3
Natural Gas Fueling Stations	42	$14.9
Manufacturing (Infrastructure)	8	$26.4
Natural Gas Commercial Trucks	13	$51.3
Light-Duty Battery-Electric Vehicles (BEVs) and Plug-In Hybrid Electric Vehicles (PHEVs)	4	$2.8
Clean Vehicle Rebate Project (CVRP) and Hybrid and Zero Emission Truck and Bus Voucher Incentive Project (HVIP) Support	2	$22.5
MD/HD Truck Demonstration	33	$79.8
Manufacturing (Vehicles)	30	$235.2
Other	0	$0
Total	***963***	***$1,036.8***

Projects are grouped into three classes:

- Fuel production
- Fueling infrastructure
- Vehicles

Project Funding by Class (million $)



* Project data for the California Electric Vehicle Infrastructure Project (CALeVIP) were estimated using available information on the program's website. See Slide 38 for more details.

Methodology Updates From Previous Analysis

Several updates to the 2021 analysis are introduced [1]:

- The scope of the analysis is limited to projects funded in the last 10 years (since 2013).
- Additional project categories are added to the analysis, namely MD/HD EV charging and hydrogen (H_2) refueling infrastructure projects.
- The life cycle emissions parameters (i.e., carbon intensity [CI]), are updated to reflect the latest Low Carbon Fuel Standard (LCFS) data [2].
- The CIs of replaced fuels (i.e., gasoline and diesel fuels) in each year are assumed to be the LCFS benchmarks for those fuels, rather than the CI of the fuel itself [3].
- The assumed infrastructure life spans are shortened to reflect generally observed trends:

Project Class	Project Subclass	Current Life Span (Years)	Previous Life Span (Years)
Fuel production	-	20	40
Fueling infrastructure	-	10	20
Vehicles	-	10	16
-	Manufacturing	10	50

1. California Energy Commission. 2021. *Analysis of Benefits Associated With Projects and Technologies Supported by the Clean Transportation Program*. Sacramento, CA: CEC. CEC-600-2021-039. https://doi.org/10.2172/1886868.
2. CARB. 2023. "LCFS Pathway Certified Carbon Intensities." https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities.
3. CARB. 2020. *Low Carbon Fuel Standard*. https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf.

Petroleum Displacement Estimates

Fuel Production Projects

- For fuel production projects, benefits are calculated based on a 1:1 displacement of petroleum with the alternative fuel throughout the project's lifetime. Petroleum reductions (PET_{red}) are based on:
  - The reported annual fuel throughput (FP), converted into the energy unit of the replaced fuel.
  - The percent operation of the project (P_{year}): Each project is assumed to begin accruing benefits 9 months prior to its completion date, with its fuel production defined by a linear ramp-up to full capacity over a 3-year timeframe.

$$PET_{red} = FP \cdot P_{year}$$

Light-Duty EV Charging Infrastructure

- For electric vehicle supply equipment (EVSE) projects, PET_{red} is based on:
  - The number of e-miles supported annually by each charger (VMT_{alt}).
  - The fuel economy of the replaced fuel vehicle (FE_{rep}) from the California Air Resources Board's (CARB's) California Vision 2.1 model* [1].
  - P_{year}: Project starts operating 9 months before completion date, with 3-year ramp-up to full utilization.
- The petroleum reductions can then be expressed as:

$$PET_{red} = \frac{VMT_{alt} \cdot P_{year}}{FE_{rep}}$$

- E-miles enabled by the chargers depend on their expected utilization, which is estimated through EVI-Pro2, the Alternative Fuels Data Center, and internal estimates.

Charger Utilization Percentage by Year and Type

Year	L2 Public	L2 Multifamily Home	L2 Workplace	DC 50 kW	DC 150 kW [a]
2020	4.53%	4.53%	7.13%	6.12%	6.12%
2021	4.64%	6.38%	8.12%	6.89%	6.89%
2022	4.94%	8.46%	9.58%	7.76%	7.76%
2023	5.07%	10.23%	10.44%	8.63%	8.63%
2024	5.23%	12.01%	11.86%	9.50%	9.50%
2025	5.76%	14.66%	12.44%	10.37%	10.37%
2026	5.76%	14.66%	12.98%	11.24%	11.24%
2027	5.65%	14.40%	14.04%	12.11%	12.11%
2028	5.60%	14.27%	14.62%	12.98%	12.98%
2029	5.59%	14.25%	15.07%	13.85%	13.85%
2030	5.76%	14.66%	15.40%	14.72%	14.72%

[a] DC 150-kW project utilization estimates are assumed to be identical to DC 50 kW. See Slide 41 for the correlation between assumed utilization and e-miles.

* Vehicle-specific parameters are assigned based on vehicle type assignments listed in Slides 39–40.

1. CARB. 2023. "Vision Scenario Planning." Accessed Oct. 4, 2023. https://ww2.arb.ca.gov/resources/documents/vision-scenario-planning.

Medium- and Heavy-Duty EV Charging Infrastructure

- Because utilization data for MD/HD EVSE are not as easily obtained as LD projects, a different approach for calculating petroleum reduction is taken. In this case, PET_{red} is based on:
  - Vehicle miles traveled by the replaced vehicle (VMT_{rep}).*
  - FE_{rep} from CARB's California Vision 2.1 model.
  - P_{year}: Project starts operating 9 months before completion date, with 3-year ramp-up to full vehicle utilization.
  - The number of vehicles supported by the project (N).
- The petroleum reductions can then be expressed as:

$$PET_{red} = \frac{VMT_{rep} \cdot N \cdot P_{year}}{FE_{rep}}$$

- The number of vehicles supported by EVSE is provided for most projects. When the number of vehicles is not provided, one vehicle per charging port is assumed.

* See Slide 42 for estimated charger utilization based on the provided vehicles' VMT.

Non-Electric Fueling Infrastructure

- For non-EVSE refueling infrastructure projects, annual PET_{red} is based on:
  - Reported FP in gasoline gallon equivalent (GGE).
  - P_{year}: Project starts operating 9 months before end date, with 3-year ramp-up to full refueling capacity.
  - Fuel economy of the alternative vehicle relative to the replaced vehicle, or the energy economy ratio (EER).

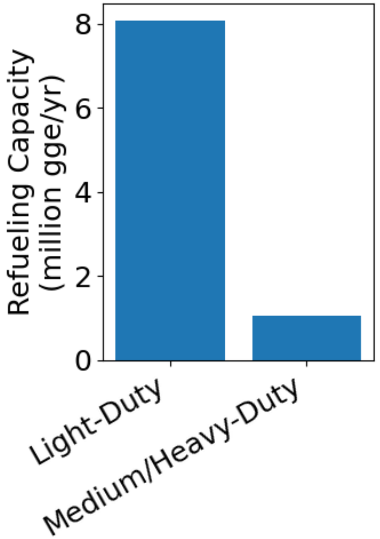
$$PET_{red} = EER_{alt} \cdot \mathrm{FP} \cdot P_{year}$$

- For H_2 projects, a utilization factor of 44% of daily capacity is applied to calculate the effective fuel throughput based on the station's refueling capacity. This factor is estimated based on empirical station utilization data from CTP projects.

Fuel Conversion to GGE [1]

Fuel Type	Conversion Units	Conversion Factor
Diesel	GGE/gallon	1.155
E85	GGE/gallon	0.734
Electricity	GGE/kWh	0.031
Gasoline	GGE/GGE	1
Hydrogen	GGE/kg	1.019

H_2 Refueling Infrastructure Projects Summary



1. U.S. Department of Energy. 2023. "Fuel Conversion Factors to Gasoline Gallon Equivalents." https://epact.energy.gov/fuel-conversion-factors.

Vehicle Deployment Projects

- Each alternative fuel vehicle deployed is assumed to displace a conventional vehicle.
- PET_{red} depends on:
  - VMT_{rep}
  - FE_{rep}
  - P_{year}: Vehicles supported by each project start operating 9 months before the project's end date, with 3-year linear ramp-up to full utilization.
  - Number of vehicles deployed (N).

$$PET_{red} = \frac{VMT_{rep} \cdot N \cdot P_{year}}{FE_{rep}}$$

- The vehicles' VMT and fuel economy estimates were obtained from the CARB Vision 2.1 model.
- New alternative fuel vehicles are assumed to displace conventional internal combustion engine vehicles.

GHG Reduction Estimates

GHG Reduction Calculations

- For each project, GHG emission reduction factors in grams of carbon dioxide equivalent per megajoule (gCO_2e/MJ) are calculated based on:
  - The CI of the alternative fuel and the fuel it replaces ($CI_{alternative}, CI_{replaced}$).
  - The alternative fuel vehicle's EER (EER_{alt}).

$$k_{GHG} = CI_{rep} - CI_{alt}/EER_{alt}$$

- The CI of the replaced fuel in each year is assumed to be the LCFS CI target for that fuel in that year*[1].
- For fuel production projects, CI_{alt} was provided for each project and is assumed constant over time.
- For EVSE and EV projects, CI_{alt} is the California grid average as reported in the 2020 LCFS regulation [1].
- For other refueling infrastructure and vehicle projects (biofuels and hydrogen), we assume the GHG emissions reduction factor is the volume-weighted average CI of the relevant fuel in California in 2022 [2].
- The EERs are collected from the 2020 LCFS regulation [1].
- Then, the GHG reductions can be calculated based on the emission reduction factor (k_{GHG}), PET_{red}, and the replaced fuel energy density (ED_{rep}):

$$GHG_{reduction} = PET_{red} \cdot ED_{rep} \cdot k_{GHG}$$

* See Slides 43–44 for additional information regarding the CIs and EERs assumed based on the project. CIs of all alternative fuels are held constant over time.

1. CARB. 2020. *Low Carbon Fuel Standard*. https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf.
2. CARB. 2023. "LCFS Pathway Certified Carbon Intensities." https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities.

Air Pollution Improvements

Air Pollution Improvements for EVSE Projects

- For EV charging infrastructure projects, reductions in nitrogen oxides (NO_x) depend on:
  - VMT_{alt}
  - The NO_x emissions factor of the replaced vehicle (NOX_{rep}) and the alternative vehicle (NOX_{alt}).
  - P_{year}:

$$NOX_{red} = VMT_{alt} \cdot (NOX_{rep} - NOX_{alt}) \cdot P_{year}$$

- Conversely, particulate matter ($PM_{2.5}$) reductions (PM_{red}) depend on similar parameters, in addition to:
  - $PM_{2.5}$ emissions factor of the replaced vehicle (PM_{rep}).
  - $PM_{2.5}$ emissions factor of the alternative vehicle (PM_{alt}).

$$PM_{red} = VMT_{alt} \cdot (PM_{rep} - PM_{alt}) \cdot P_{year}$$

Air Pollution Improvements for Other Refueling Projects

- For other refueling infrastructure projects, annual NOX_{red} depends on:
    - The station FP
    - FE_{rep}
    - NOX_{rep} and NOX_{alt}*
    - P_{year}

$$NOX_{red} = FP \cdot FE_{rep} \cdot P_{year} \cdot (NOX_{rep} - NOX_{alt})$$

- Annual PM_{red} depends on similar parameters, in addition to PM_{rep} and PM_{alt}:

$$PM_{red} = FP \cdot FE_{rep} \cdot P_{year} \cdot \left(PM_{rep} - PM_{alt}\right)$$

* Vehicle-specific parameters are assigned based on vehicle type assignments listed in Slide 39.

Air Pollution Improvements for Vehicle Projects

- Annual NOX_{red} depends on:
  - VMT_{rep}
  - P_{year}
  - Number of vehicles (N).
  - NOX_{rep} and NOX_{alt}:

$$NOX_{red} = VMT_{rep} \cdot P_{year} \cdot N \cdot (NOX_{rep} - NOX_{alt})$$

- Annual PM_{red} depends on similar parameters, in addition to PM_{rep} and PM_{alt}:

$$PM_{red} = VMT_{rep} \cdot P_{year} \cdot N \cdot \left(PM_{rep} - PM_{alt}\right)$$

* Vehicle-specific parameters are assigned based on vehicle type assignments listed in Slide 39.

Expected Benefits Summary

Expected Benefits Summary Tables

Annual expected benefits are shown by project subclass and evaluation year:

	Petroleum Fuel Reductions (million gallons/year)				GHG Reductions (thousand metric tons CO_2e/year)			
Project Type	2020	2025	2030	2035	2020	2025	2030	2035
Fuel Production - Biomethane	0.11	5.44	5.84	5.84	1.44	155.34	163.50	163.50
Fuel Production - Diesel Substitutes	11.18	18.08	18.08	18.08	92.06	142.43	127.04	127.04
Fuel Production - Gasoline Substitutes	7.21	7.47	7.47	7.47	14.11	9.24	3.86	3.86
Fueling Infrastructure - E85 Ethanol	2.40	2.50	0.00	0.00	7.46	5.97	0.00	0.00
Fueling Infrastructure - Electric Chargers - LD	1.79	21.87	61.87	22.56	14.11	156.53	398.35	145.22
Fueling Infrastructure - Electric Chargers - MD/HD	0.05	1.22	5.36	4.70	0.44	10.31	39.70	34.39
Fueling Infrastructure - Hydrogen - LD	2.56	13.19	17.71	2.72	14.15	63.33	72.30	11.10
Fueling Infrastructure - Hydrogen - MD/HD	0.00	0.19	1.43	1.53	0.00	0.74	4.27	4.59
Fueling Infrastructure - Natural and Renewable Gas	10.20	10.81	0.15	0.00	24.23	16.19	0.02	0.00
Vehicles - CVRP and HVIP Support	1.45	1.08	0.00	0.00	11.42	7.72	0.00	0.00
Vehicles - MD/HD Truck Demonstration	0.47	1.08	0.42	0.00	3.42	5.99	1.60	0.00
Vehicles - Light-Duty BEVs and PHEVs	0.00	0.03	0.02	0.00	0.01	0.21	0.14	0.00
Vehicles - Natural Gas Commercial Trucks	0.58	2.46	1.99	0.00	1.07	2.72	0.55	0.00
Total	**37.99**	**85.41**	**120.35**	**62.90**	**183.92**	**576.72**	**811.33**	**489.69**

Expected Benefits Summary Tables (continued)

Annual expected benefits are shown by project subclass and evaluation year:

	NO_x Reductions (tons/year)				$PM_{2.5}$ Reductions (tons/Year)			
Project Type	2020	2025	2030	2035	2020	2025	2030	2035
Fueling Infrastructure - Electric Chargers - LD	1.23	12.98	36.88	13.51	0.12	1.61	1.73	0.63
Fueling Infrastructure - Electric Chargers - MD/HD	0.28	8.65	39.44	35.01	0.00	0.41	3.82	3.43
Fueling Infrastructure - Hydrogen - LD	0.70	3.35	4.17	0.60	0.07	0.41	0.20	0.03
Fueling Infrastructure - Hydrogen - MD/HD	0.00	0.40	2.78	2.80	0.00	0.01	0.05	0.05
Fueling Infrastructure - Natural and Renewable Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vehicles - CVRP and HVIP Support	1.79	1.77	0.00	0.00	0.08	0.06	0.00	0.00
Vehicles - MD/HD Truck Demonstration	3.41	7.63	2.29	0.00	0.11	0.20	0.02	0.00
Vehicles – Light-Duty BEVs and PHEVs	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00
Vehicles - Natural Gas Commercial Trucks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**7.42**	**34.81**	**85.58**	**51.92**	**0.39**	**2.71**	**5.82**	**4.14**

Expected Benefits to Disadvantaged and Low-Income Communities

Cumulative Expected Benefits in 2035 in Disadvantaged and Low-Income Communities

Benefits to Disadvantaged Communities (DACs)

	Petroleum Reductions (million gallons)	GHG Reductions (thousand tons)	NO_x Reductions (tons)	$PM_{2.5}$ Reductions (tons)
Inside DAC	536.80	3,718.45	252.34	19.72
Outside DAC	488.14	3,051.23	337.71	25.58
Statewide	440.90	2,920.85	263.26	15.26

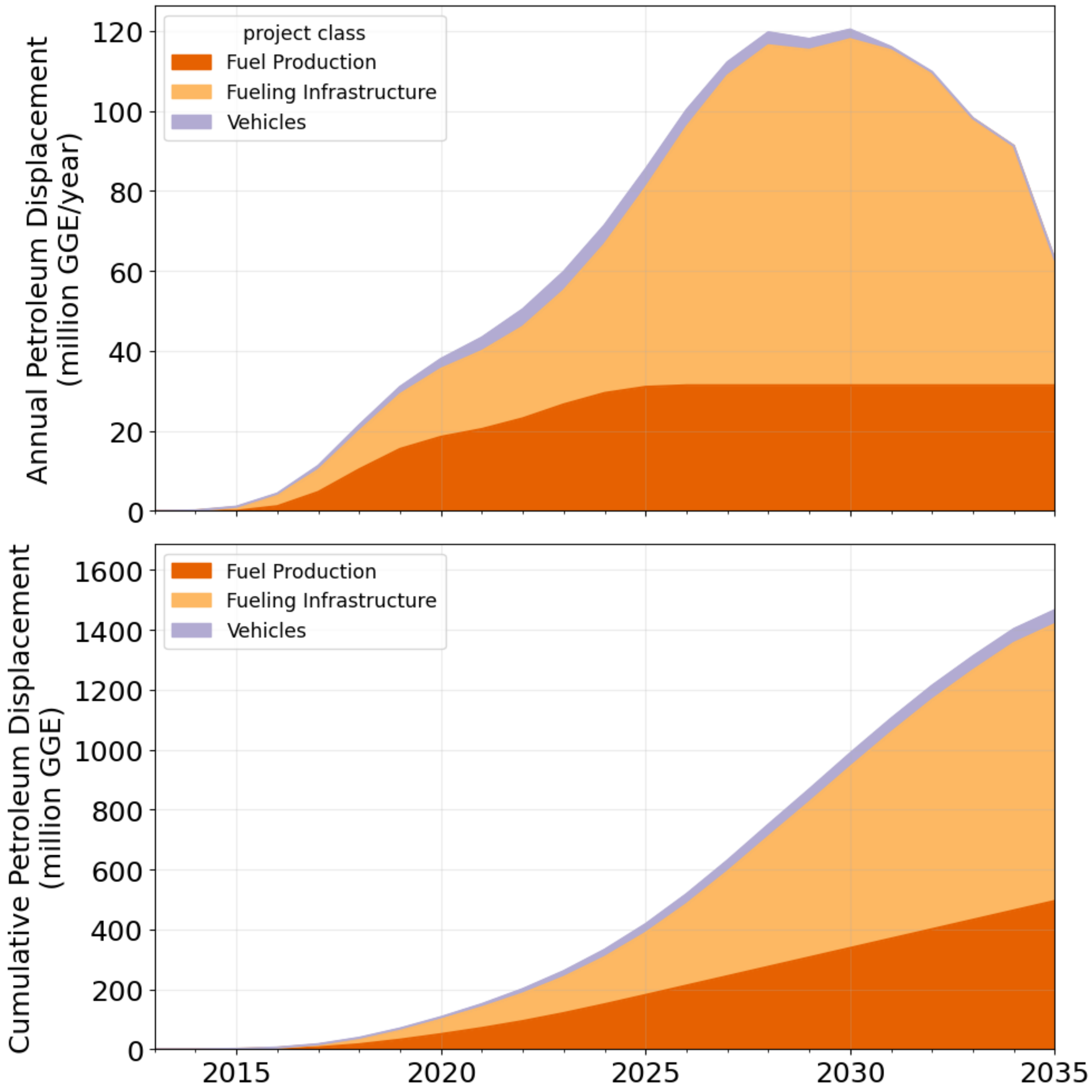
Benefits to Low-Income Communities (LICs)

	Petroleum Reductions (million gallons)	GHG Reductions (thousand tons)	NO_x Reductions (tons)	$PM_{2.5}$ Reductions (tons)
Inside LIC	535.56	3,501.99	247.44	13.39
Outside LIC	489.39	3,267.69	342.60	31.92
Statewide	440.90	2,920.85	263.26	15.26

- Projects without DAC/LIC designations were assumed to be outside of DAC/LIC areas.
- Projects whose funded activities are not attributable to a specific address are defined as “statewide” projects and are not considered in the DAC/LIC analysis.
- 54.9% of GHG emissions reductions are concentrated in DACs and 51.7% are concentrated in LICs.

Benefits by Project Subclass in Detail

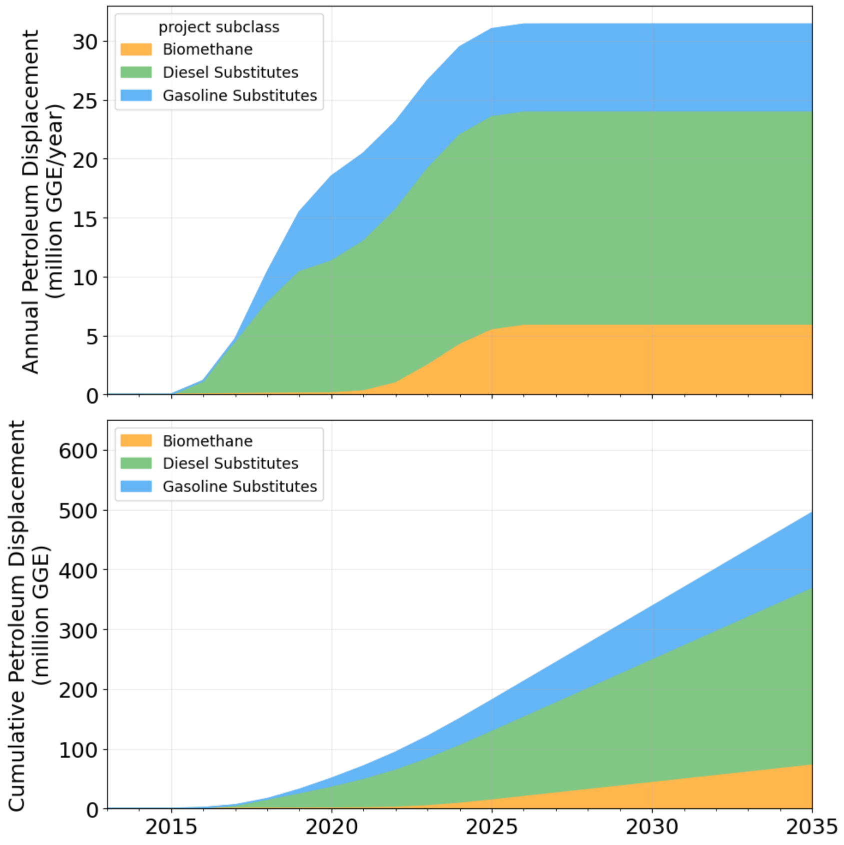
Petroleum Reductions



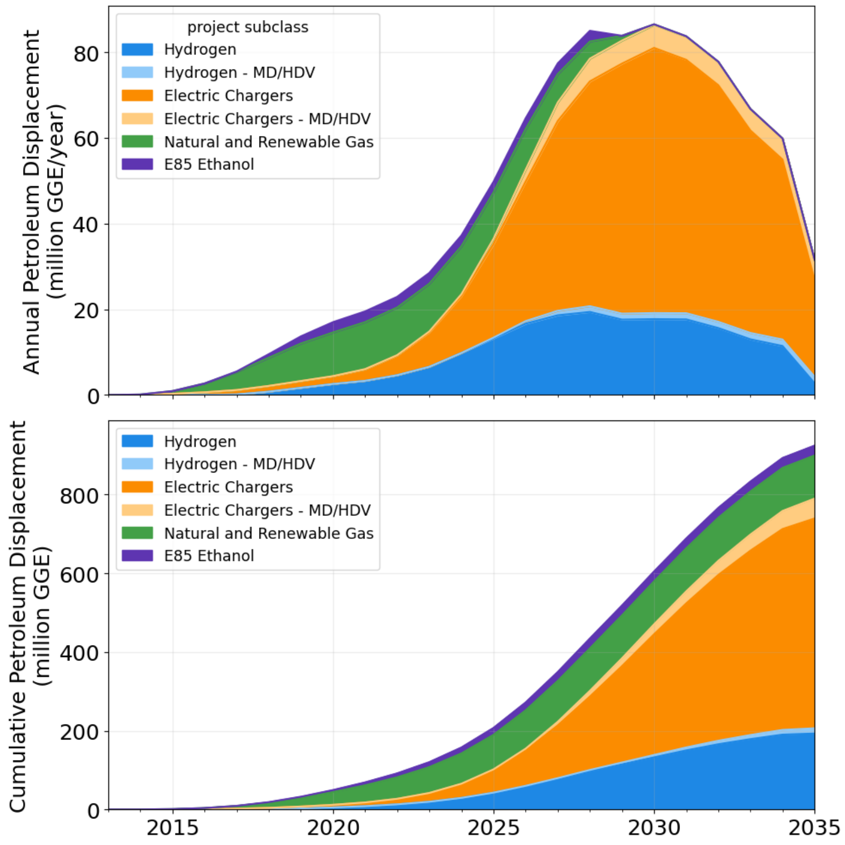
- Among CEC-funded projects, fueling infrastructure is the largest contributor to petroleum displacement.
- Among CEC-funded fueling infrastructure projects, the main contributions are from deployment of EV chargers (37.1% of cumulative petroleum reductions) and H_2 refueling stations (13%).
- Alternative fuel production projects generate the second most cumulative petroleum reductions (38.5%), dominated by biomass-based diesel (22.1%) and biomethane (7.10%).

Petroleum Reductions

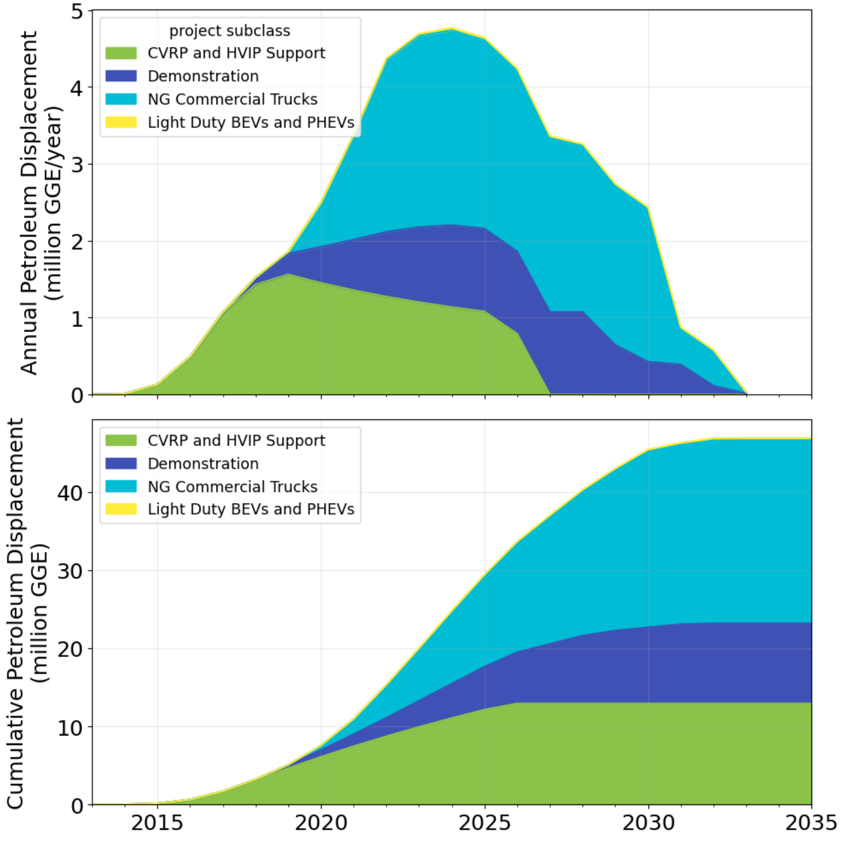
Fuel Production



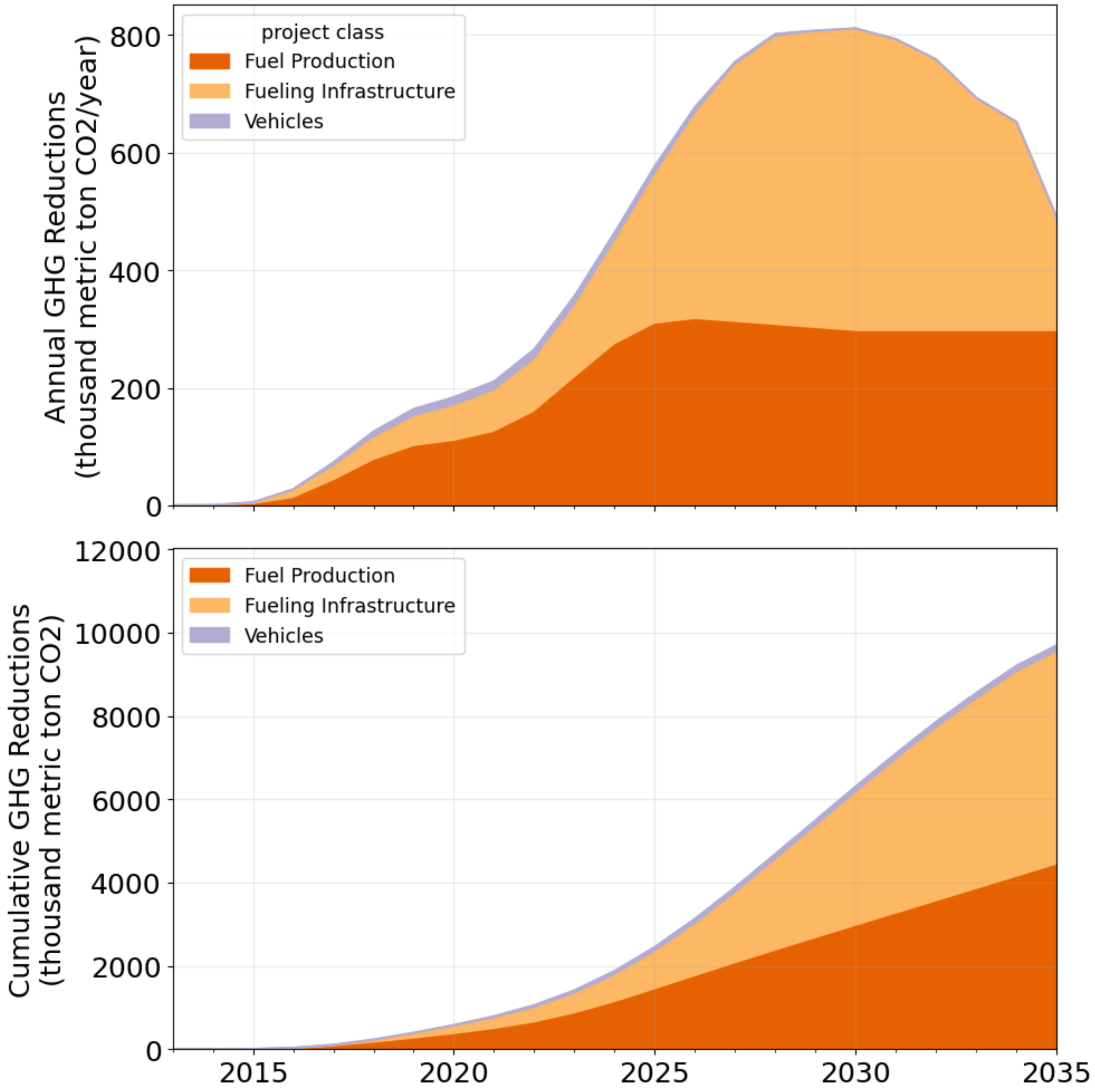
Fueling Infrastructure



Vehicles



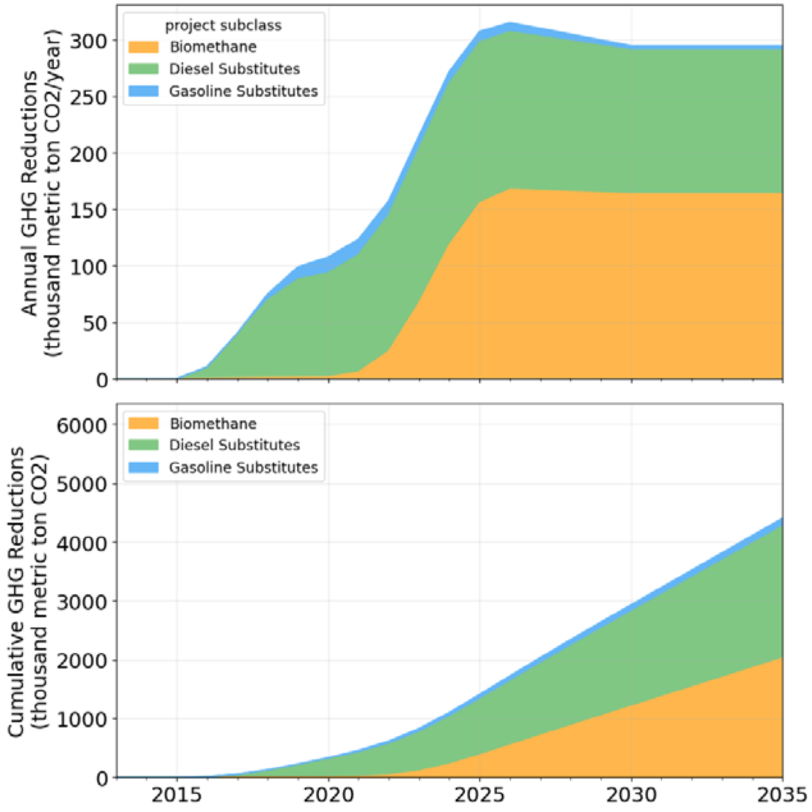
GHG Emissions Reductions



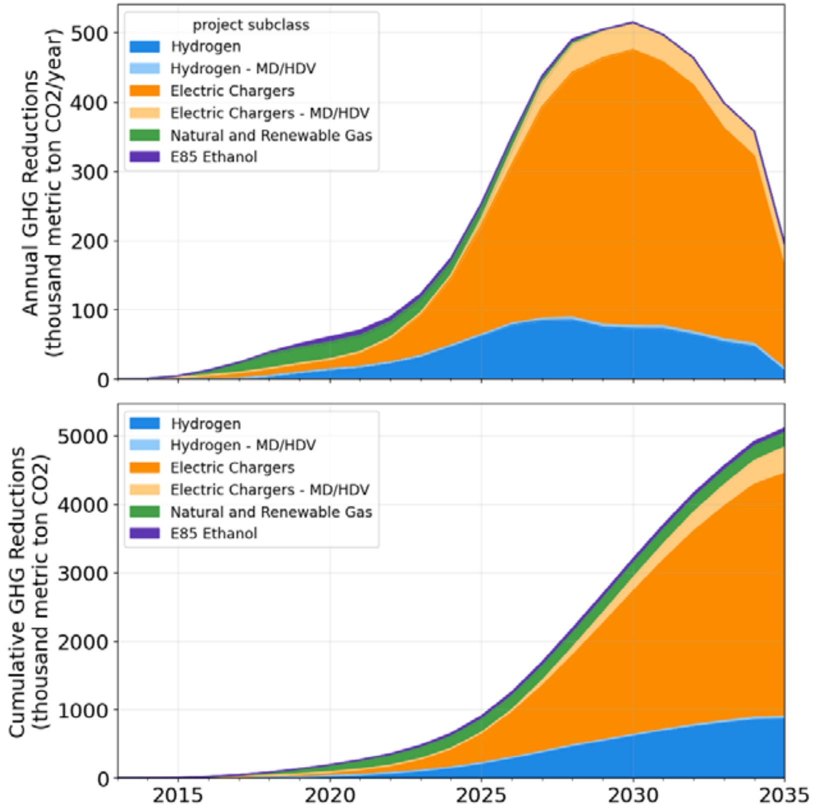
- GHG reductions are a function of petroleum displacement and GHG emissions factors (CI).
- Petroleum reductions from H_2 refueling infrastructure have limited impacts on GHG reductions relative to EVSE due to H_2's relatively higher CI.
- GHG reductions are largely due to fuel production projects (accounting for 52.8% of cumulative benefits) and refueling infrastructure projects (45.5%).
- The outsized impact on GHG emissions reductions (relative to petroleum displacement) of biomass-based diesel and biomethane are due to their lower CIs relative to ethanol.

GHG Emissions Reductions

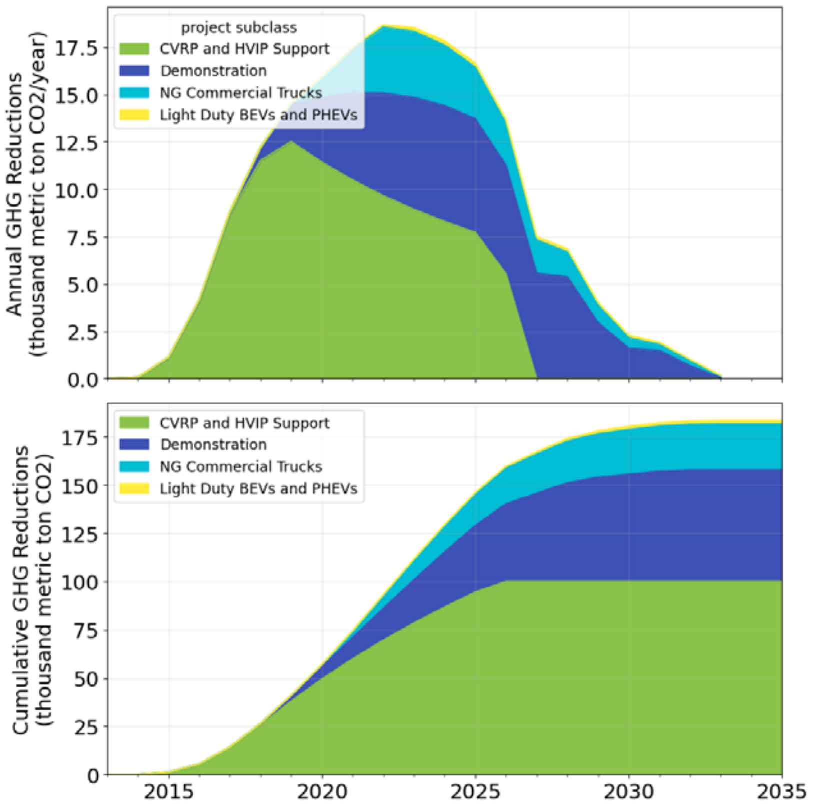
Fuel Production



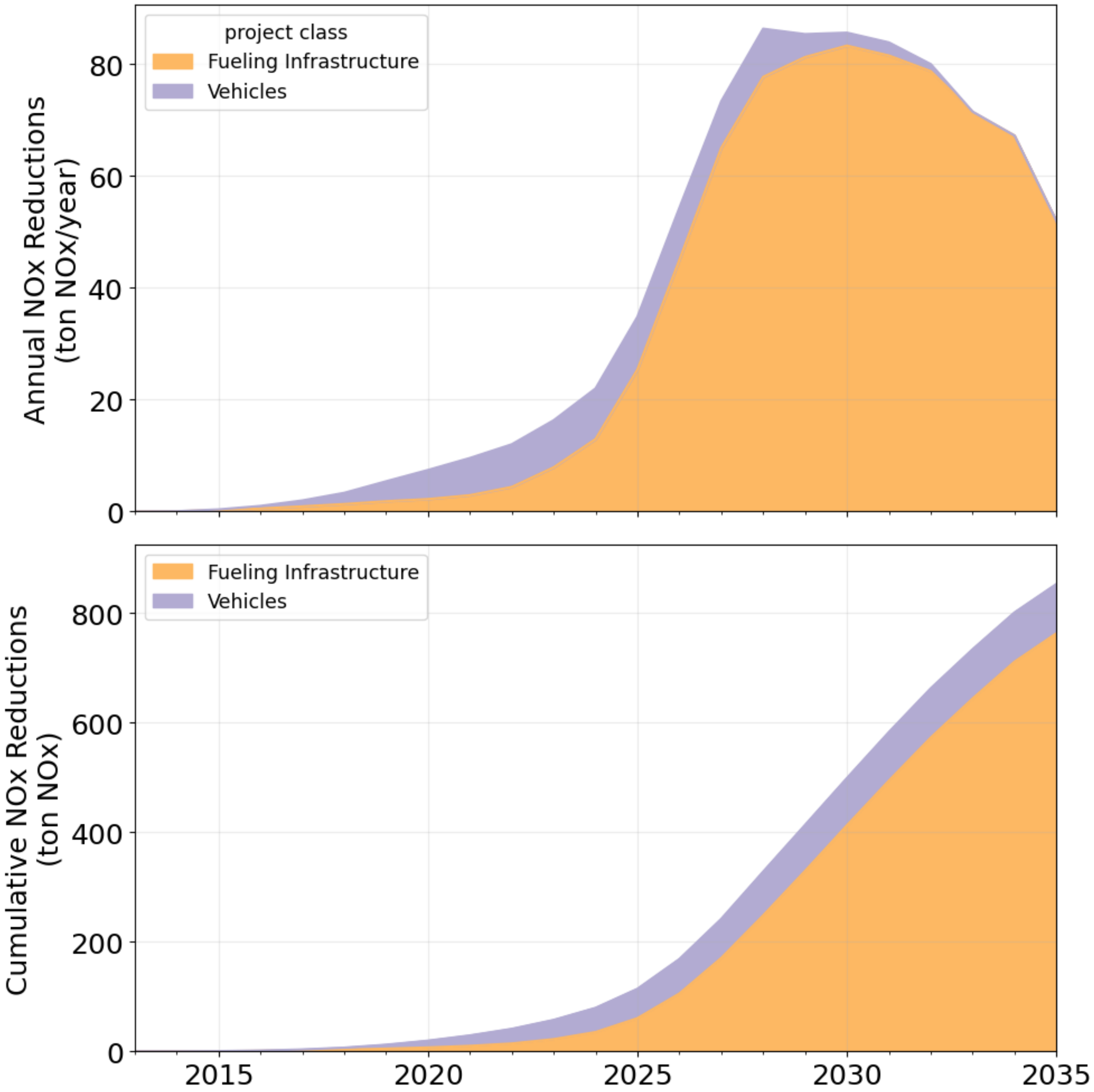
Fueling Infrastructure



Vehicles



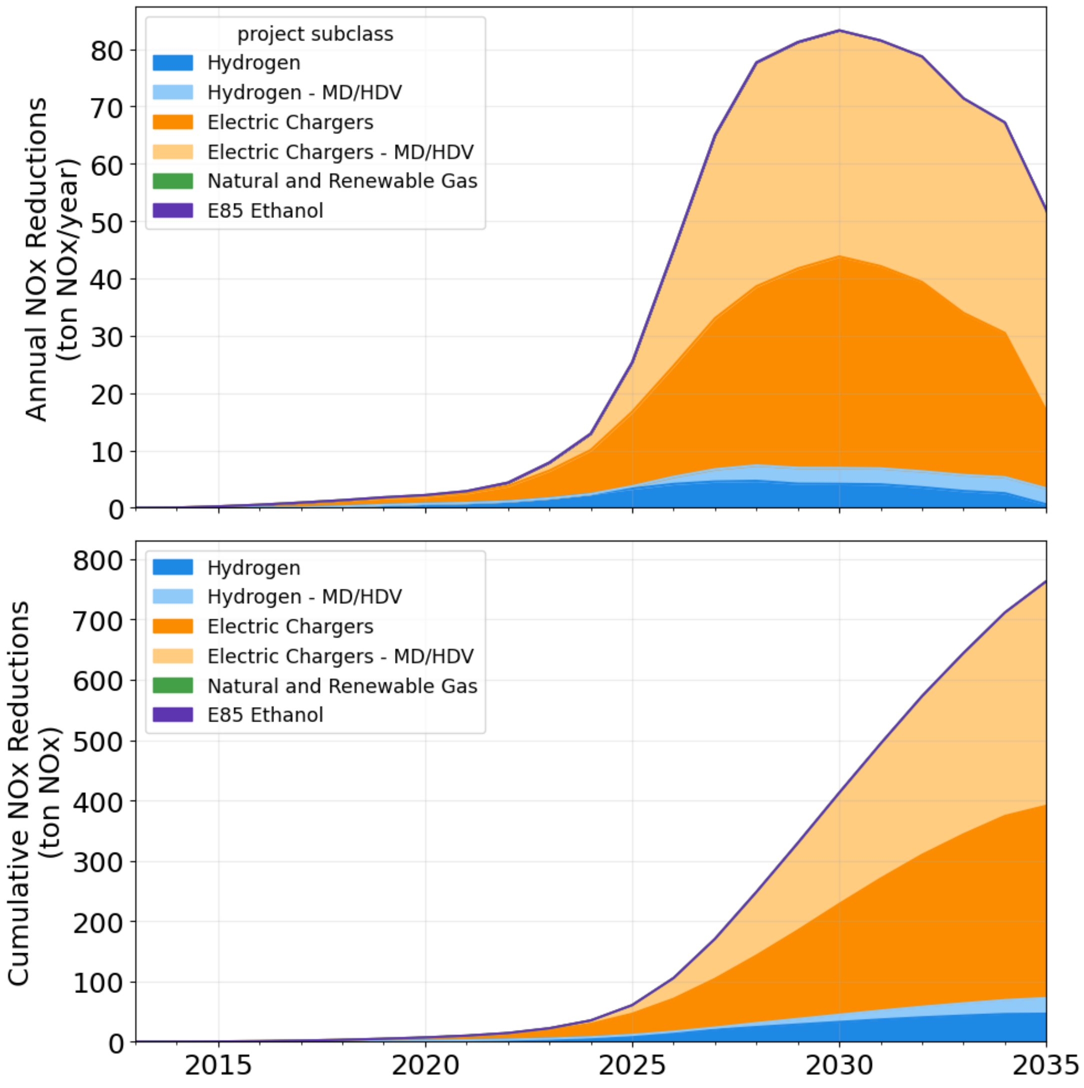
NO_x Emissions Reductions



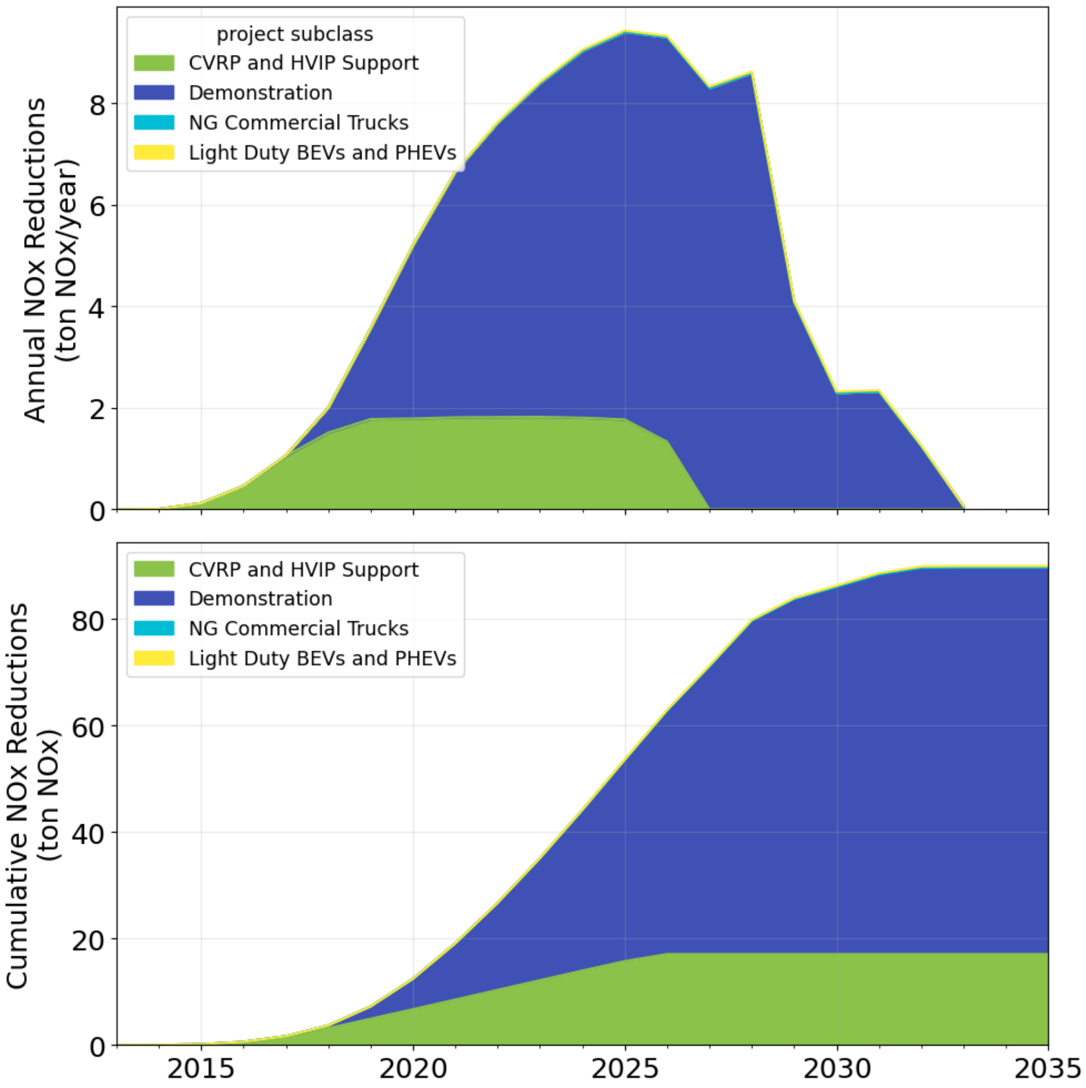
- As in the 2021 analysis, fuel production projects here are not assumed to result in direct air quality improvements.
- Vehicle projects have a significant early impact on NO_x, while an augmented focus on fueling infrastructure projects results in their benefits significantly increasing after 2025.
- Ultimately, fueling infrastructure projects account for most of the NO_x reductions, particularly due to LD and MD/HD EV charging infrastructure (accounting respectively for 36.9% and 44.4% of cumulative benefits).

NO_x Emissions Reductions

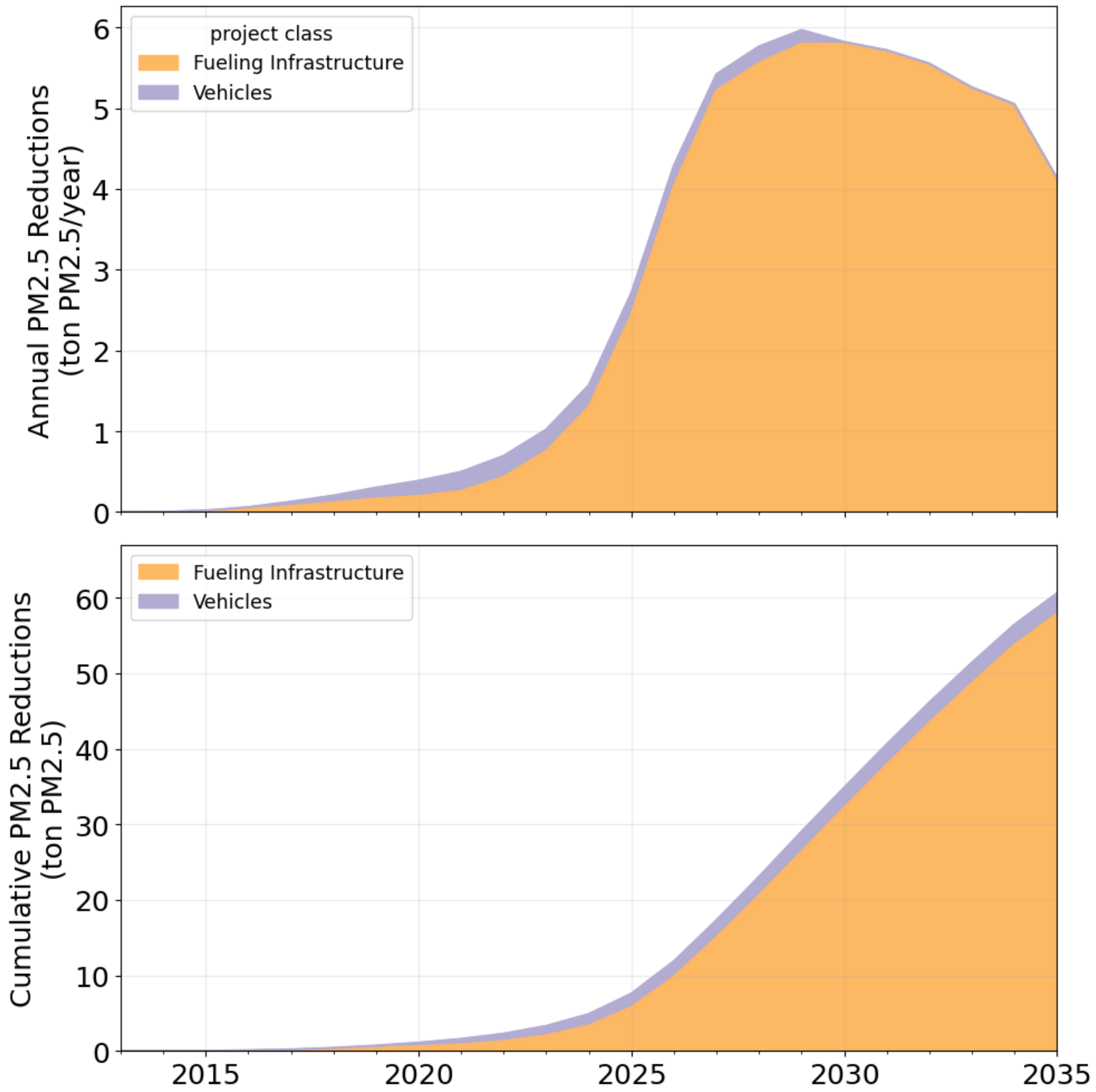
Fueling Infrastructure



Vehicles



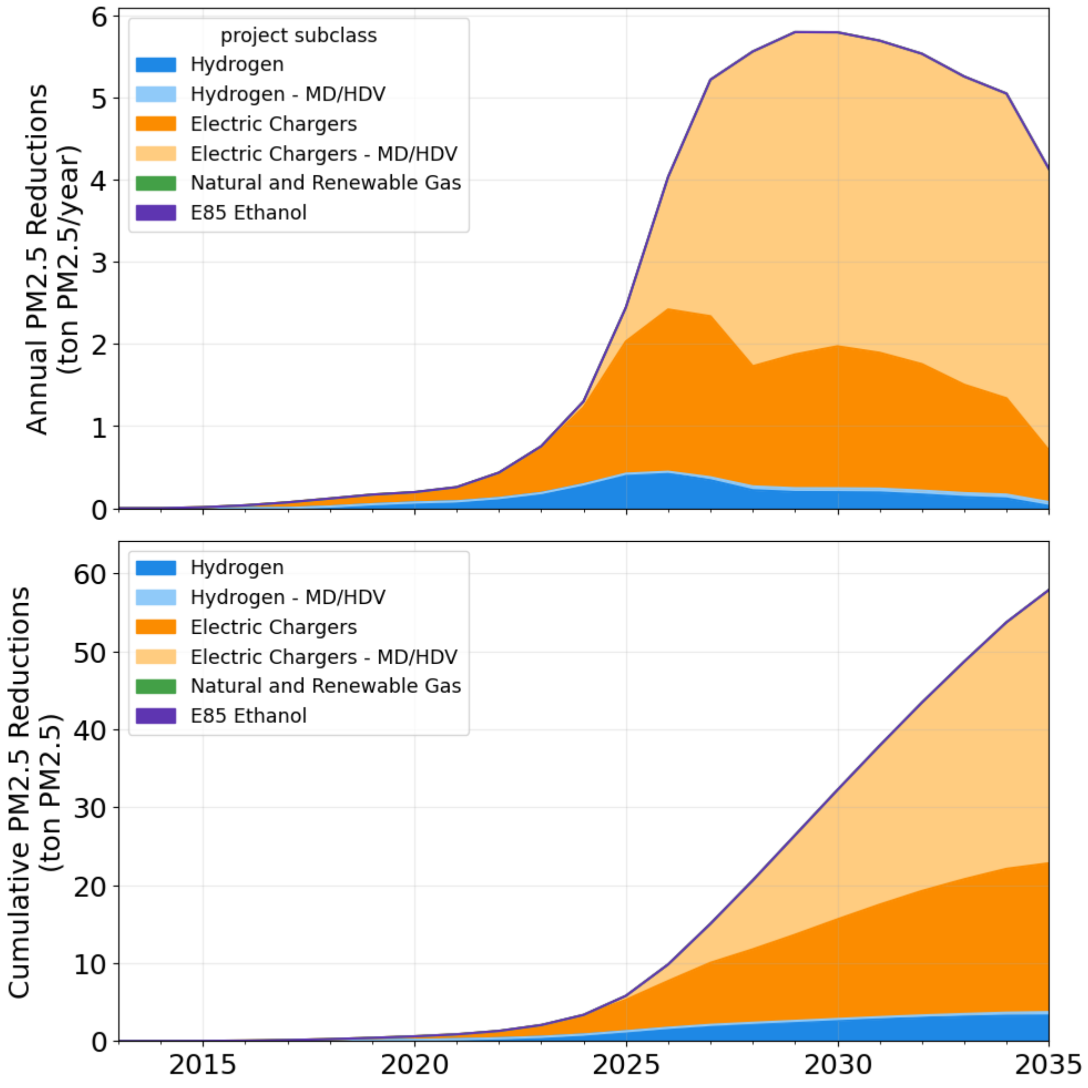
$PM_{2.5}$ Emissions Reductions



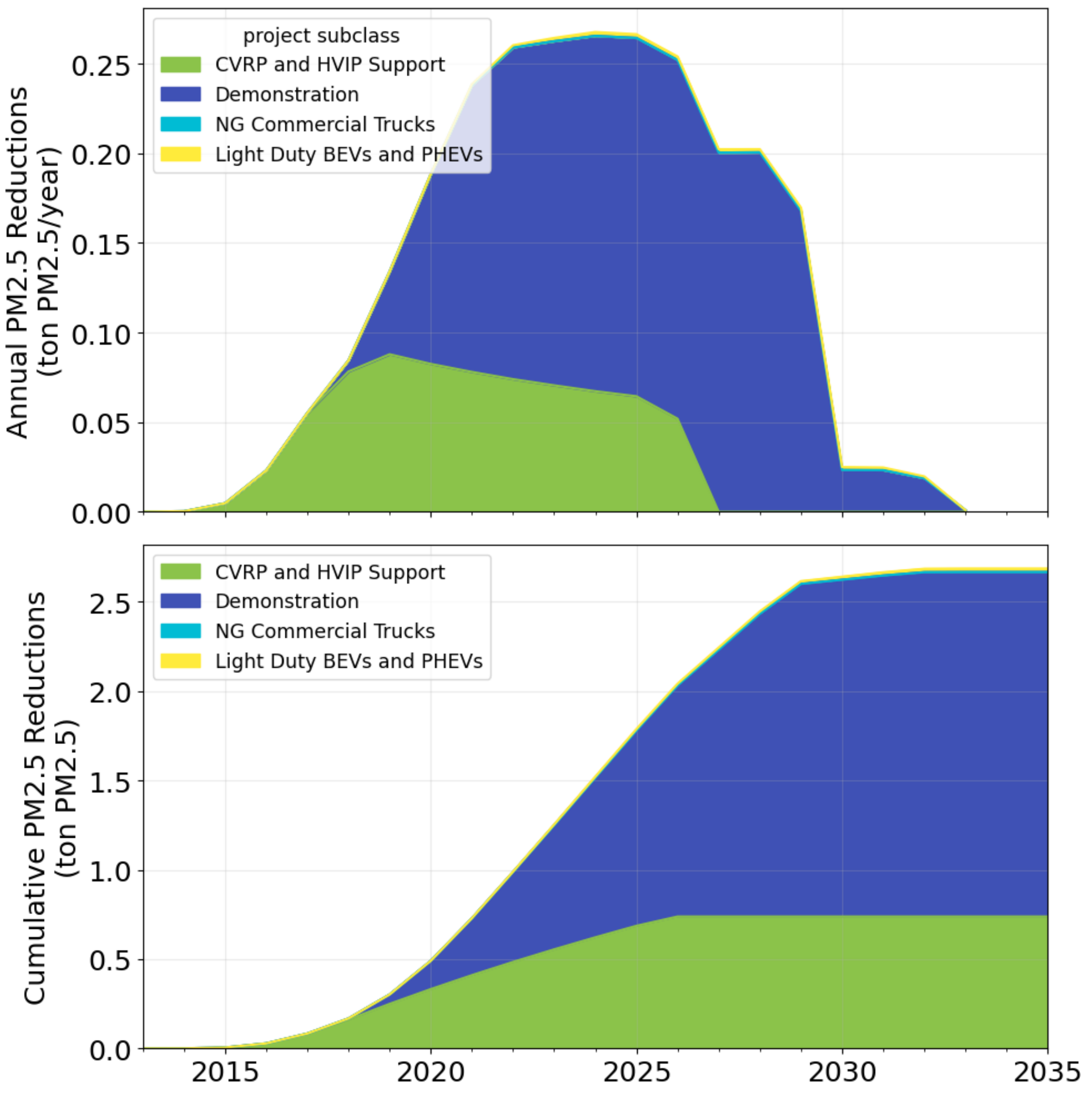
- As in the 2021 analysis, fuel production projects here are not assumed to result in direct air quality improvements.
- The vast majority of $PM_{2.5}$ reductions are attributed to fueling infrastructure projects. Annual benefits increase rapidly through 2030 before tapering off.
- Within fueling infrastructure projects, the largest $PM_{2.5}$ reductions are generated by LD and MD/HD EVSE projects, accounting for 30.4% and 59.5% of cumulative benefits, respectively.

$PM_{2.5}$ Emissions Reductions

Fueling Infrastructure



Vehicles



Conclusions & Next Steps

Conclusions

- NREL estimated the expected benefits of a portfolio of transportation-related projects funded through CEC's Clean Transportation Program over the past decade.
- The expected benefits from the projects were estimated in terms of displaced petroleum, GHG emissions reductions, and reductions in criteria air pollutant emissions.
- The methods for conducting the analysis largely emulate those employed to generate the 2021 CTP benefits report, with some updates to the assumptions, data, and methodology [1].
- CEC awards for fuel production and vehicle deployment projects have declined over time and therefore have annual benefits. However, biodiesel and biomethane production projects account for 51.6% of cumulative GHG emissions reductions, partly due to their longer assumed life spans.
- Refueling infrastructure projects generate the greatest share of GHG emissions reductions beginning in 2025, primarily from light-duty EV infrastructure projects, which account for 31.6% of all cumulative benefits.
- MD/HD infrastructure projects are the greatest contributor to air pollution reductions (44.4% in NO_x and 59.5% in $PM_{2.5}$) due to the displacement of diesel fuel.

1. California Energy Commission. 2021. *Analysis of Benefits Associated With Projects and Technologies Supported by the Clean Transportation Program*. Sacramento, CA: CEC. CEC-600-2021-039. https://doi.org/10.2172/1886868.

Future Work

Several improvements can be made toward better accuracy of the results from this analysis, including (but not limited to):

- Incorporating more detailed CALeVIP internal project data.
- Updating EV chargers' utilization assumptions with estimates based on observed behavior.
- Improving H_2 refueling station utilization data with more up-to-date and accurate estimates.
- Evaluating market transformation benefits supported by projects funded through the CTP, including jobs created and other socioeconomic benefits.
- Updating vehicles’ estimated characteristics such as fuel economy, miles traveled, and criteria air pollutant emissions factors.

Thank You

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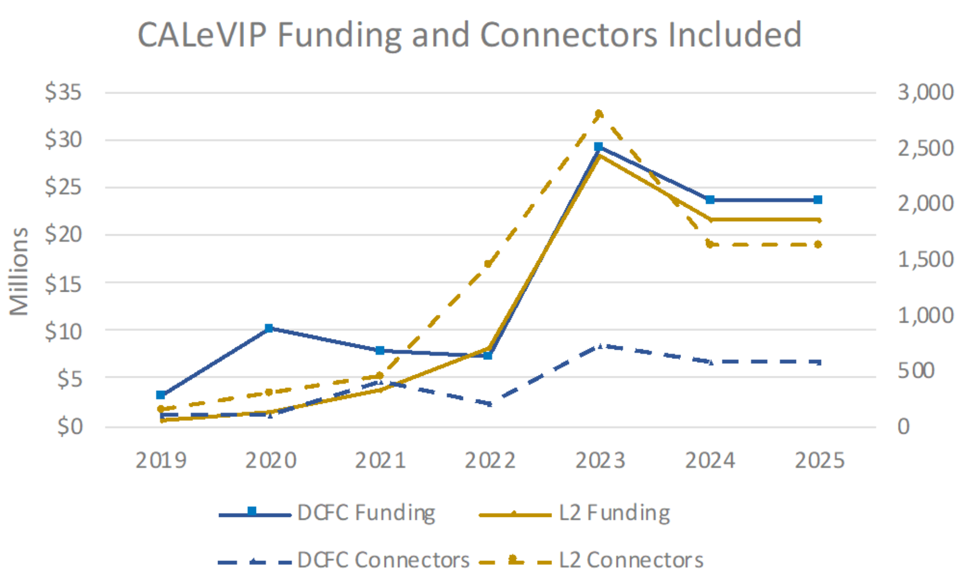
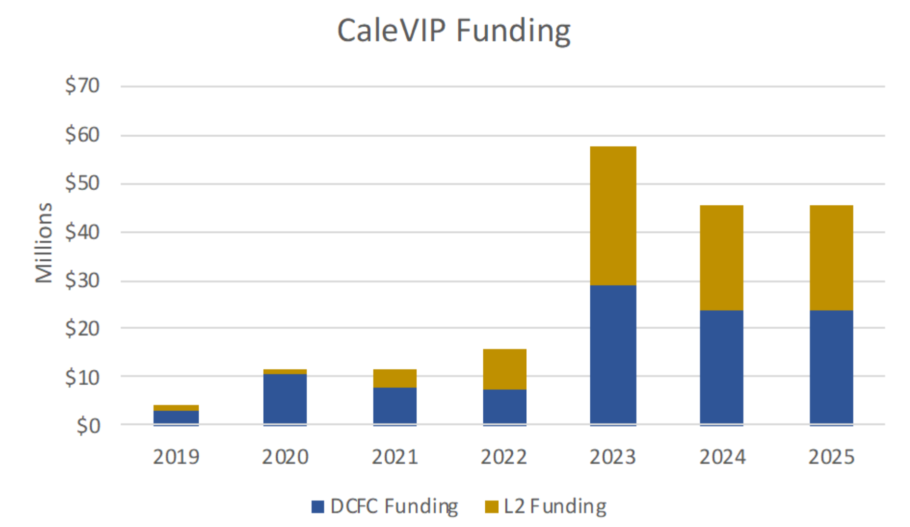
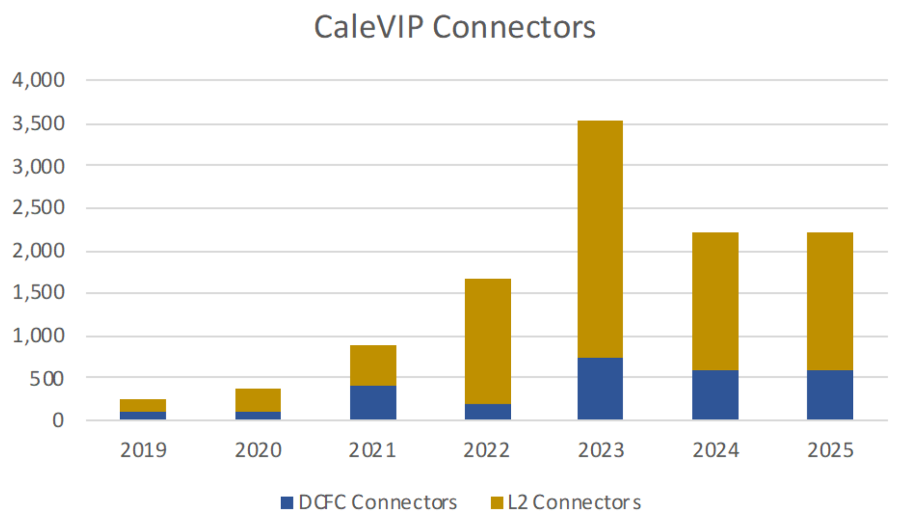
NREL Transforming ENERGY

CALeVIP Electric Vehicle Infrastructure Assumptions







- Project features were extracted from the CALeVIP dashboard [1].
- For 2019–2022, only completed projects are included.
- 2023: projects completed in 2023 + 1/3 projects in progress.
- 2024 and 2025: 1/3 projects in progress for each year.
- The “in progress” projects that are allocated is the difference between the cumulative “in progress” projects and completed projects in 2023 (to avoid double-counting).

Source	Cumulative Funding (million $)	Cumulative Number of Ports
CALeVIP online data dashboard [1]	$191.51	11,146

1. California Energy Commission. 2023. “CALeVIP Rebate Statistics Dashboard.” Accessed Sept. 15, 2023. https://calevip.org/rebate-statistics.

Vehicle Type Assumptions for Fuel Production and Refueling Infrastructure

Fuel production and refueling infrastructure projects for biomass-based diesel, ethanol, and natural gas are assigned the following vehicle types.* The vehicle types are matched to EMFAC Vehicle IDs to determine the fuel economy of the conventional vehicle being replaced.

Alternative Fuel	Vehicle Type	EMFAC Vehicle ID	Replaced Fuel
Biodiesel/Fischer-Tropsch Diesel/Renewable Diesel	Heavy-Duty Diesel CA International Registration Plan Truck	T7 CAIRP	Diesel
Ethanol	Light-Duty Automobile	LDA	Gas
Natural gas	Other buses	OBUS	Diesel

* EVSE and H_2 refueling infrastructure project descriptions specify the type of vehicle served by the infrastructure.

Vehicle Parameter Assumptions

Assumed vehicle efficiencies and pollutant emission factors as a function of replaced fuel, vehicle type, and year [1].

			Fuel Economy (miles/GGE)				NO_X Emissions Factor (gNO_x/mile)				$PM_{2.5}$ Emissions Factor ($gPM_{2.5}$/mile)			
Replaced Fuel	**Vehicle Type**	**EMFAC Vehicle ID**	**2020**	**2025**	**2030**	**2035**	**2020**	**2025**	**2030**	**2035**	**2020**	**2025**	**2030**	**2035**
Gasoline	Light-Duty Car	LDA	33.15	39.88	39.8	39.85	0.021	0.015	0.015	0.015	0.020	0.020	0.019	0.019
Gasoline	Light-Duty Truck	LDT1	28.67	37.79	37.73	37.77	0.021	0.015	0.015	0.015	0.020	0.020	0.019	0.019
Diesel	Light-Duty Car	LDA	38.78	46.69	46.7	46.82	0.024	0.005	0.005	0.005	0.020	0.018	0.018	0.018
Diesel	Light Heavy Duty	LHD1	21.19	21.2	21.24	21.26	0.073	0.047	0.047	0.047	0.039	0.038	0.038	0.038
Diesel	Urban Bus	UBUS	4.16	4.16	4.16	4.16	1.815	1.815	1.815	1.814	0.374	0.374	0.374	0.374
Diesel	School Bus	SBUS	6.73	6.73	6.73	6.71	1.027	1.029	1.031	1.038	0.324	0.324	0.324	0.324
Diesel	Other Buses	OBUS	8.04	8.03	8.02	8.01	0.433	0.434	0.439	0.442	0.061	0.061	0.061	0.061
Diesel	Heavy-Duty (>26k lbs)	T6 Instate Heavy	9.21	9.24	9.27	9.33	0.860	0.849	0.810	0.781	0.061	0.061	0.061	0.061
Diesel	Heavy-Duty (<26k lbs)	T6 Instate Small	8.98	9.01	9.03	9.07	0.806	0.818	0.805	0.796	0.061	0.061	0.061	0.061
Diesel	Heavy-Duty Out-of-State	T6 OOS Heavy	9.26	9.3	9.34	9.39	0.947	0.936	0.925	0.921	0.061	0.061	0.061	0.061
Diesel	Heavy-Duty CA Registered Truck	T7 CAIRP	6.96	7.02	7.06	7.08	0.884	0.831	0.800	0.790	0.038	0.038	0.038	0.038
Diesel	Drayage Truck (Other)	T7 Other Port	6.8	6.81	6.82	6.81	0.985	0.953	0.950	0.966	0.038	0.038	0.038	0.038
Diesel	Drayage Truck (South Coast)	T7 POLA	6.59	6.63	6.67	6.68	1.433	1.359	1.284	1.266	0.038	0.038	0.038	0.038
Diesel	Solid Waste Collection Truck	T7 SWCV	2.45	2.45	2.45	2.45	1.891	1.891	1.891	1.891	0.043	0.043	0.043	0.043
Diesel	Heavy-Duty Single-Unit Truck	T7 Single	6.97	6.98	6.98	6.99	0.831	0.849	0.866	0.875	0.038	0.038	0.038	0.038
Diesel	T7 Single Construction	T7 Single Construction	6.94	6.93	6.91	6.9	0.885	0.931	0.975	1.004	0.038	0.038	0.038	0.038
Diesel	Heavy-Duty Tractor	T7 Tractor	7.12	7.13	7.15	7.17	0.848	0.849	0.828	0.812	0.038	0.038	0.038	0.038

1. CARB. 2023. “Vision Scenario Planning.” Accessed Oct. 4, 2023. https://ww2.arb.ca.gov/resources/documents/vision-scenario-planning.

Light-Duty EVSE Project E-Miles and Charger Utilization

Charger Utilization (% of daily capacity)

Year	L2 Public	L2 Multifamily Home	L2 Workplace	DC 50 kW	DC 150 kW*
2020	4.53%	4.53%	7.13%	6.12%	6.12%
2021	4.64%	6.38%	8.12%	6.89%	6.89%
2022	4.94%	8.46%	9.58%	7.76%	7.76%
2023	5.07%	10.23%	10.44%	8.63%	8.63%
2024	5.23%	12.01%	11.86%	9.50%	9.50%
2025	5.76%	14.66%	12.44%	10.37%	10.37%
2026	5.76%	14.66%	12.98%	11.24%	11.24%
2027	5.65%	14.40%	14.04%	12.11%	12.11%
2028	5.60%	14.27%	14.62%	12.98%	12.98%
2029	5.59%	14.25%	15.07%	13.85%	13.85%
2030	5.76%	14.66%	15.40%	14.72%	14.72%

E-Miles Supported (miles/year)

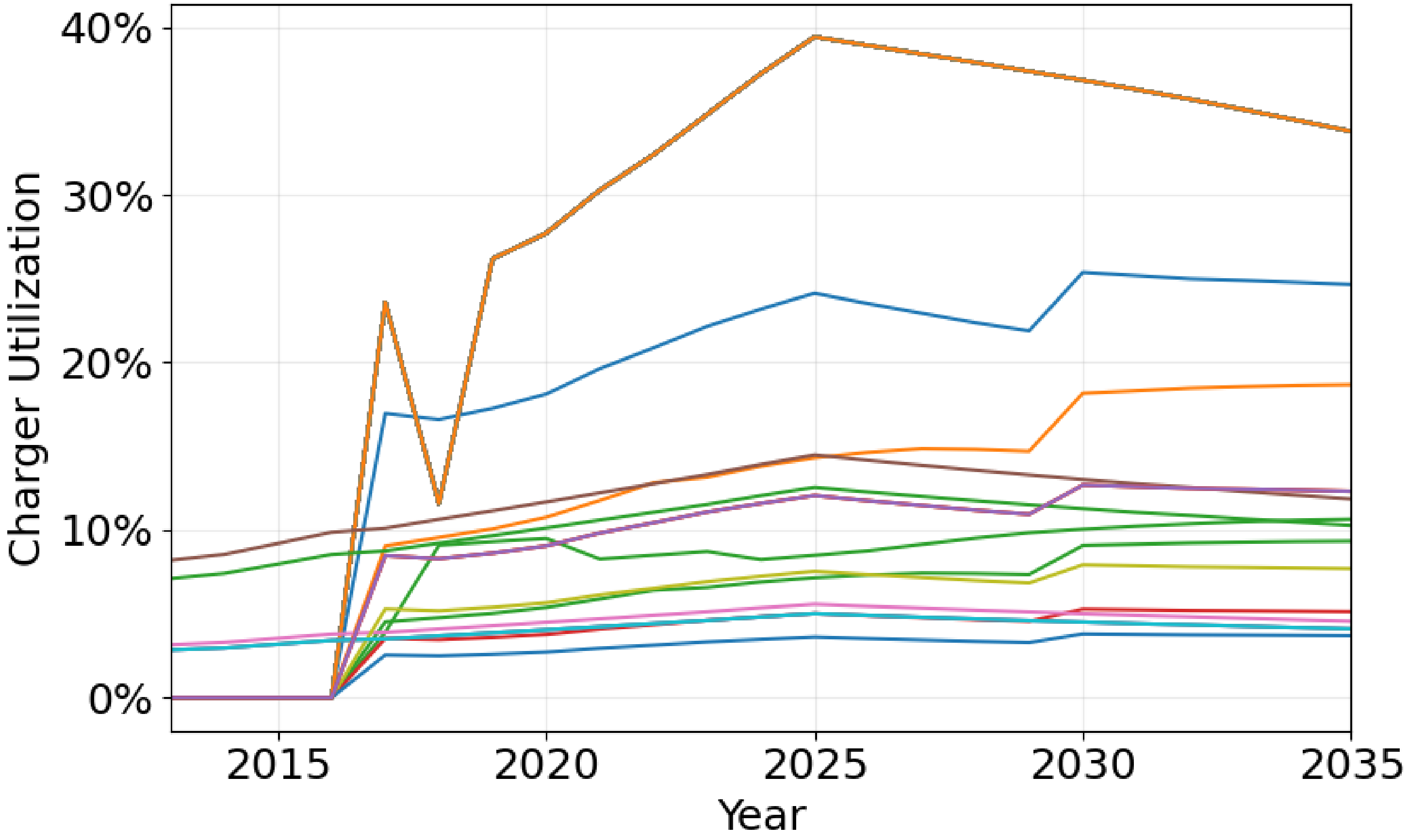
Year	L2 Public	L2 Multifamily Home	L2 Workplace	DC 50 kW	DC 150 kW*
2020	11,421	11,421	17,977	107,224	321,671
2021	11,711	16,105	20,496	120,724	362,172
2022	12,473	21,338	24,175	135,961	407,884
2023	12,784	25,803	26,333	151,198	453,595
2024	13,186	30,305	29,914	166,436	499,307
2025	14,524	36,981	31,379	181,673	545,019
2026	14,527	36,983	32,754	196,910	590,730
2027	14,257	36,331	35,413	212,147	636,442
2028	14,117	35,990	36,881	227,384	682,153
2029	14,099	35,947	38,028	242,622	727,865
2030	14,525	36,981	38,864	257,859	773,577

Based on the assumed charger utilization, vehicle efficiency (0.25 kWh/mi), and the provided chargers' power and number of ports, the number of e-miles supported by each charger can be calculated.

* DC 150kW charger utilization is assumed to be the same as DC 50kW charger utilization

Utilization – MD/HD EVSE

The following figure shows charger utilization for MD/HD EVSE projects as estimated based on the VMT, number of vehicles, number of charging ports, and available charging power. Each line in the plot represents one of the 75 MD/HD EVSE projects included in the analysis.



California LCFS Parameters [1]

Year	Gasoline Standard (gCO_2e/MJ)*	Diesel Standard (gCO_2e/MJ)*
2011	95.61	94.47
2012	95.37	94.24
2013	97.96	97.05
2014	97.96	97.05
2015	97.96	97.05
2016	96.5	99.97
2017	95.02	98.44
2018	93.55	96.91
2019	93.23	94.17
2020	91.98	92.92
2021	90.74	91.66
2022	89.5	90.41
2023	88.25	89.15
2024	87.01	87.89
2025	85.77	86.64
2026	84.52	85.38
2027	83.28	84.13
2028	82.04	82.87
2029	80.8	81.62
2030	79.55	80.36
2031	79.55	80.36
2032	79.55	80.36
2033	79.55	80.36
2034	79.55	80.36
2035	79.55	80.36

Fuel	Unit	Energy Density
Gasoline Blendstock (CARBOB)	(MJ/gal)	119.53
Reformulated Gasoline (CaRFG)	(MJ/gal)	115.83
Diesel	(MJ/gal)	134.47
Pure methane	(MJ/ft^3)	102
Liquefied natural gas	(MJ/gal)	78.83
Compressed natural gas	(MJ/therm)	105.5
Electricity	(MJ/kWh)	3.6
Hydrogen	(MJ/kg)	120
Ethanol	(MJ/kg)	80.53
Denatured ethanol	(MJ/gal)	81.51
Biodiesel	(MJ/gal)	126.13
Renewable diesel	(MJ/gal)	129.65
Alternative jet fuel	(MJ/gal)	126.37
Propane	(MJ/gal)	89.63

EV Class	EER	Replaced Fuel
LD	3.4	Gasoline
HD Truck	5.0	Diesel
Bus	3.1	Diesel
Locomotive	3.3	Diesel
Cargo	2.7	Diesel

Fuel Cell Vehicle Class	EER	Replaced Fuel
LD	2.7	Gasoline
HD	1.9	Diesel

* We assume that the gasoline and diesel standard remain at 2030 levels from 2031 to 2035.

1. CARB. 2020. *Low Carbon Fuel Standard*. https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf

Carbon Intensity Assumptions

For refueling infrastructure projects, vehicle projects, and fuel production projects (where a CI was not provided), we assume a CI based on the observed feedstock mix in California in 2022:

Fuel	Feedstock	Source	CI (gCO_2e/MJ)
Electricity	Grid average	CARB LCFS Current Certified Pathways (GREET 3.0)	81.42
Hydrogen	54% fossil natural gas, 44% renewable, 2% electrolysis	CARB LCFS Quarterly Summary	110.77
Compressed natural gas	Fossil compressed natural gas	CARB LCFS Lookup Table	79.21
Ethanol	83% corn, 12% biomass, 5% other	CARB LCFS Quarterly Summary	58.84
Fischer-Tropsch diesel	Municipal solid waste	CARB LCFS Current Certified Pathways (GREET 3.0)	14.78
Biodiesel	31% distiller's corn oil, 32% used cooking oil, 25% tallow, 12% soy/canola oil	CARB LCFS Quarterly Summary	28.5
Ethanol*	Sweet sorghum*	CARB LCFS Quarterly Summary	50.15
Compressed natural gas*	Food scraps*	CARB LCFS Quarterly Summary	−28.2

* Used for projects whose feedstock is specified.