Clean Fuels
ALLIANCE AMERICA

West Coast Experience with Lifecycle Assessments

Floyd Vergara, Esq., P.E.
Senior Policy Advisor
May 2, 2024

Overview

- Fuel Carbon Intensity (CI) & Lifecycle Assessments (LCA)
- CI Target Setting
- Generating Credits/Deficits from the CI Targets
- State GHG Inventory vs. LCA Emissions

Relevance of West Coast Experience to Vermont?

- CA, OR, and WA now have low carbon fuel standard (LCFS) programs in place (CA since 2011)
- All score fuel carbon intensity based on lifecycle assessments (LCA)
- CA and OR programs highly successful in decarbonizing fuel sector (transportation), WA still early in its program
- VT's Affordable Heat Standard and LCFS share important key elements:
  - Declining carbon intensity targets over time
  - CI targets and reductions based on fuel LCA
- Important to harmonize climate policies and methodologies across jurisdictions to achieve reductions in global climate pollution

Clean Fuels
ALLIANCE AMERICA

FUEL CARBON INTENSITY AND LIFECYCLE ASSESSMENTS

-cleanfuels.org

Carbon Intensity & Lifecycle Assessment

- University of CA 2007 whitepapers* found:
  - Reducing fuel carbon intensity based on full lifecycle assessment is key element of an LCFS program to reduce GHG emissions from transportation fuels (40% of state's GHGs)
  - Lifecycle basis allows "apples-to-apples" comparison between different fuels
  - Allows state to focus on and incentivize lower carbon fuels to facilitate transition from petroleum
  - Carbon intensity facilitates GHG reduction and innovations without use of a fuel carbon tax or a cap on fuel emissions (which could lead to fuel rationing)

- University of California, "A Low Carbon Fuel Standard for California, Parts 1 and 2," A. Farrell et al., May 2007

Carbon Intensity & Lifecycle Assessment (cont.)

- CA Low Carbon Fuel Standard, 17 CCR sec. 95481(a)(88)
  - "Life Cycle Greenhouse Gas Emissions" means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions, such as significant emissions from land use changes), as determined by the Executive Officer, related to the full fuel life cycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential.
- VT Affordable Heat Standard Act, Art. 18
  - "Lifecycle emissions" not defined but referenced in "carbon intensity value"

Carbon Intensity & Lifecycle Assessment (cont.)

Virtually identical “Carbon Intensity” definitions in CA and VT

- “Carbon Intensity (CI)” means the quantity of life cycle greenhouse gas emissions, per unit of fuel energy, expressed in grams of carbon dioxide equivalent per megajoule (gCO2e/MJ) – CA Low Carbon Fuel Standard, 17 CCR sec. 95481(a)(26)

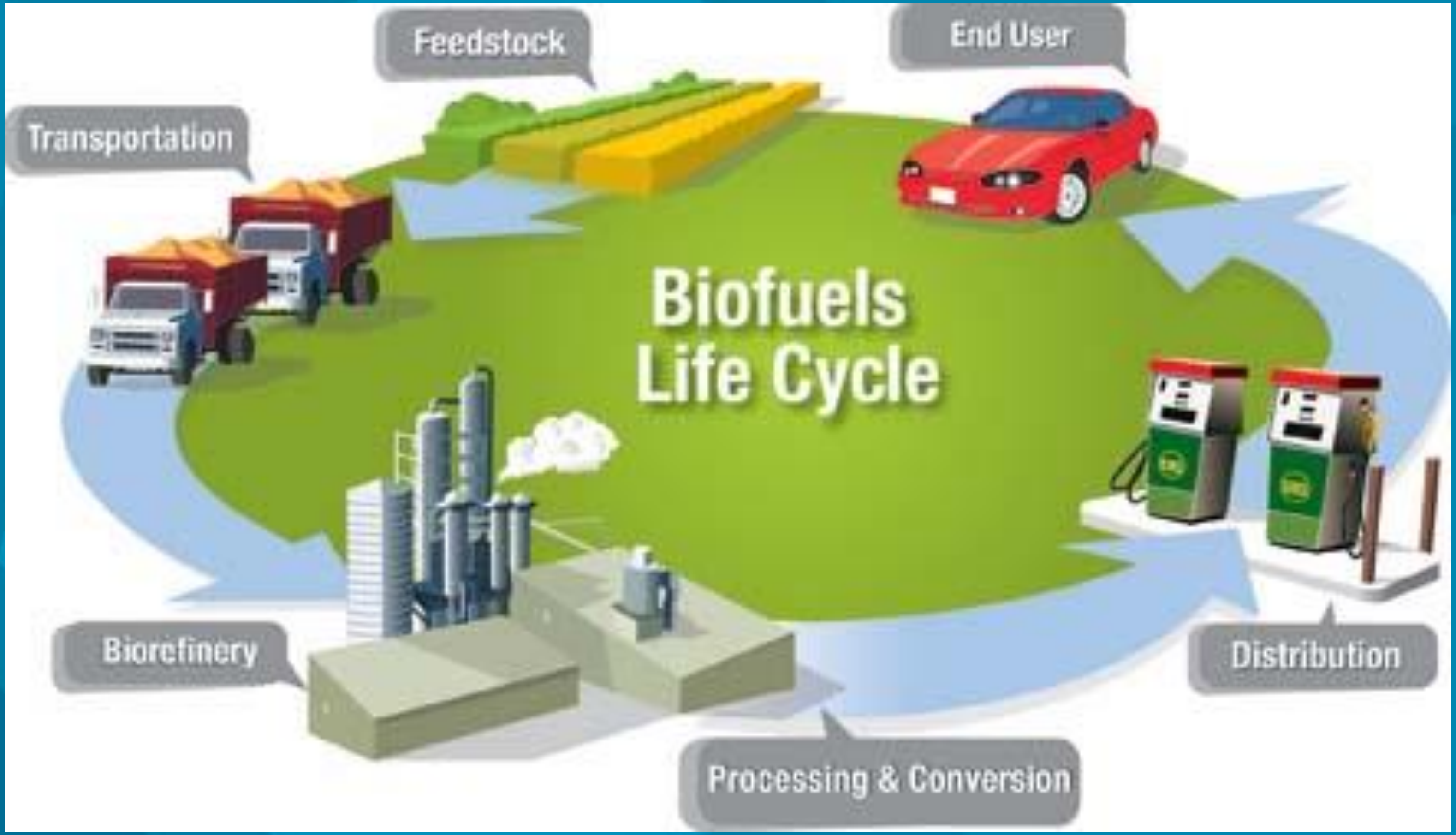
- “Carbon Intensity Value” means the amount of lifecycle greenhouse gas emissions per unit of energy of fuel expressed in grams of carbon dioxide equivalent per megajoule (gCO2e/MJ) – VT Affordable Heat Act, Art. 18, sec. 8123(1)

Carbon Intensity Calculation*

- CI includes the "direct" effects of producing and using the fuel, as well as "indirect" effects associated with certain fuel feedstocks
- CI calculated using the following tools:
  - GREET (Greenhouse gases, Regulated Emissions, and Energy Use in Technologies), used for direct carbon intensity of fuel production, distribution and use
  - OPGEE (Oil Production Greenhouse Gas Emissions Estimator), used for direct carbon intensity of crude production and transport to refinery
  - GTAP (Global Trade Analysis Project) – used for indirect land use change estimate
  - Agro-Ecological Zone Emissions Factor (AEZ-EF) – converts land use conversion estimates from GTAP into corresponding carbon releases from soil and biomass

* Adapted from "LCFS Basics," California Air Resources Board website

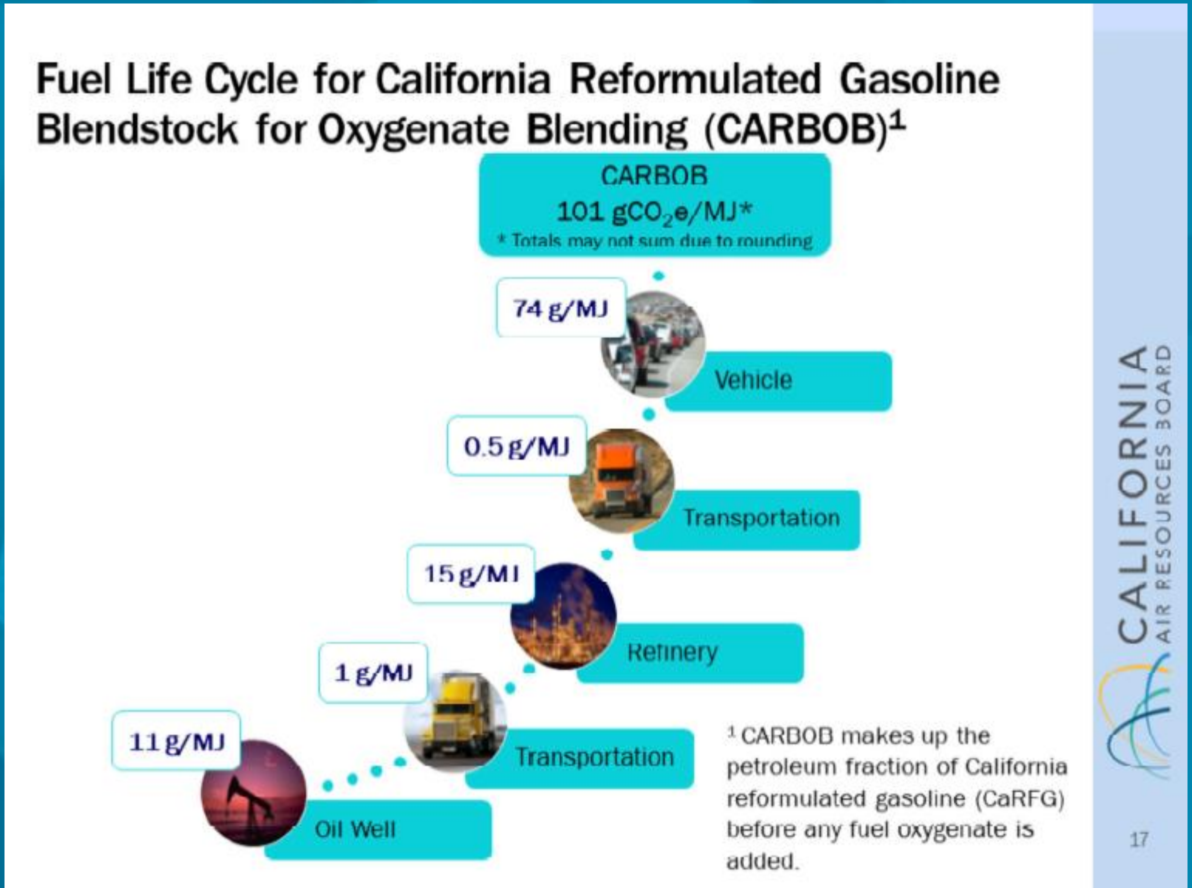
Cradle-to-Grave ("Well-to-Wheels") Lifecycle Carbon Intensity

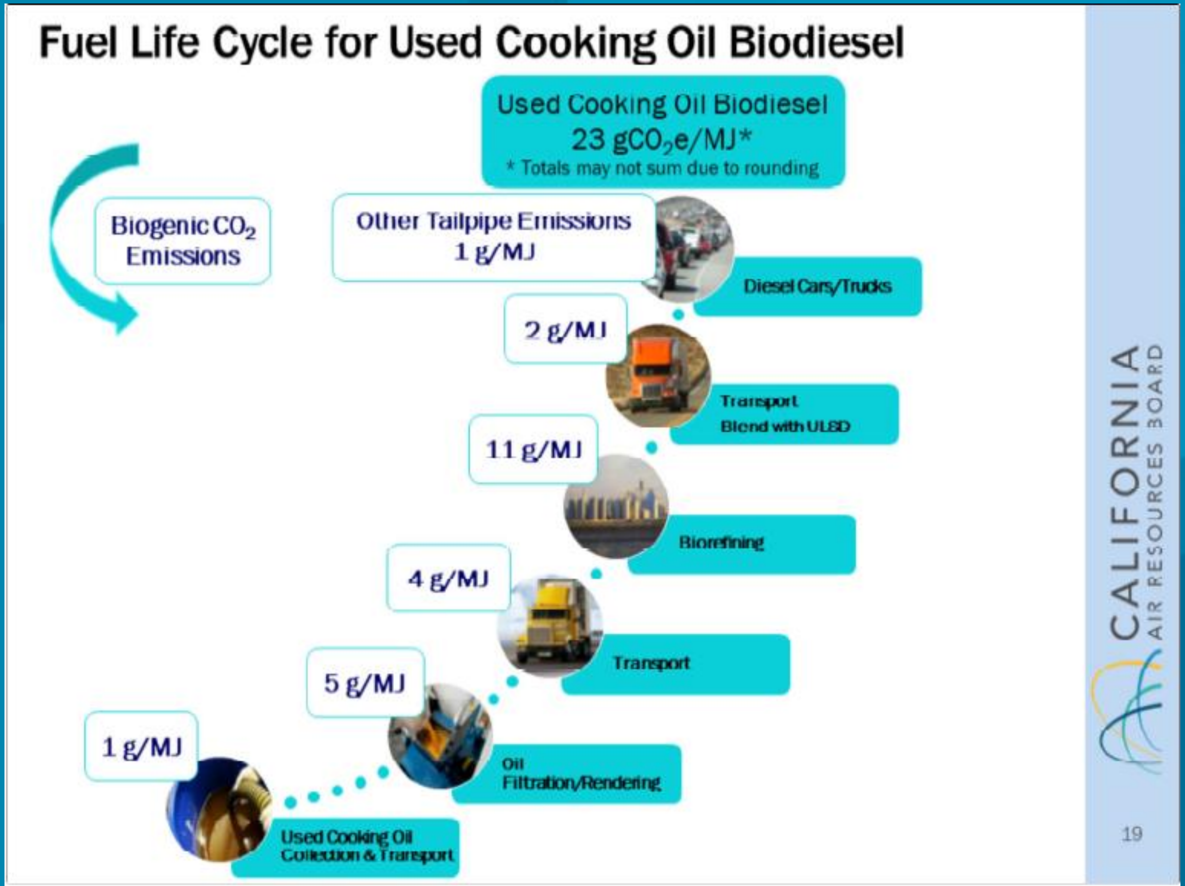


- CI determined on full lifecycle assessment
- Includes both direct emissions and indirect land use
- CI targets for liquid, gaseous fuels and electricity
- Relative to selected baseline year (e.g. 2010)

Clean Fuels ALLIANCE AMERICA

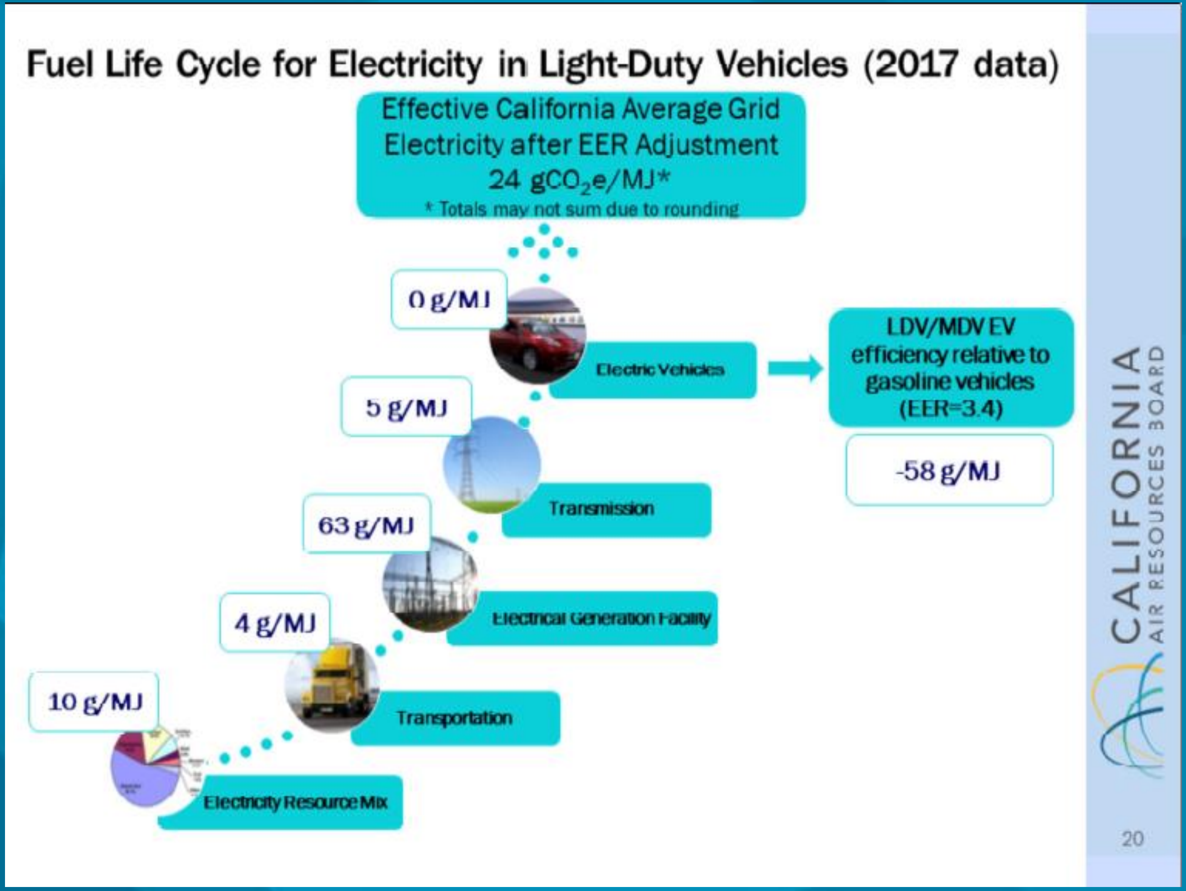
Biogenic Carbon Uptake Cancels Exhaust CO2 in Biofuels

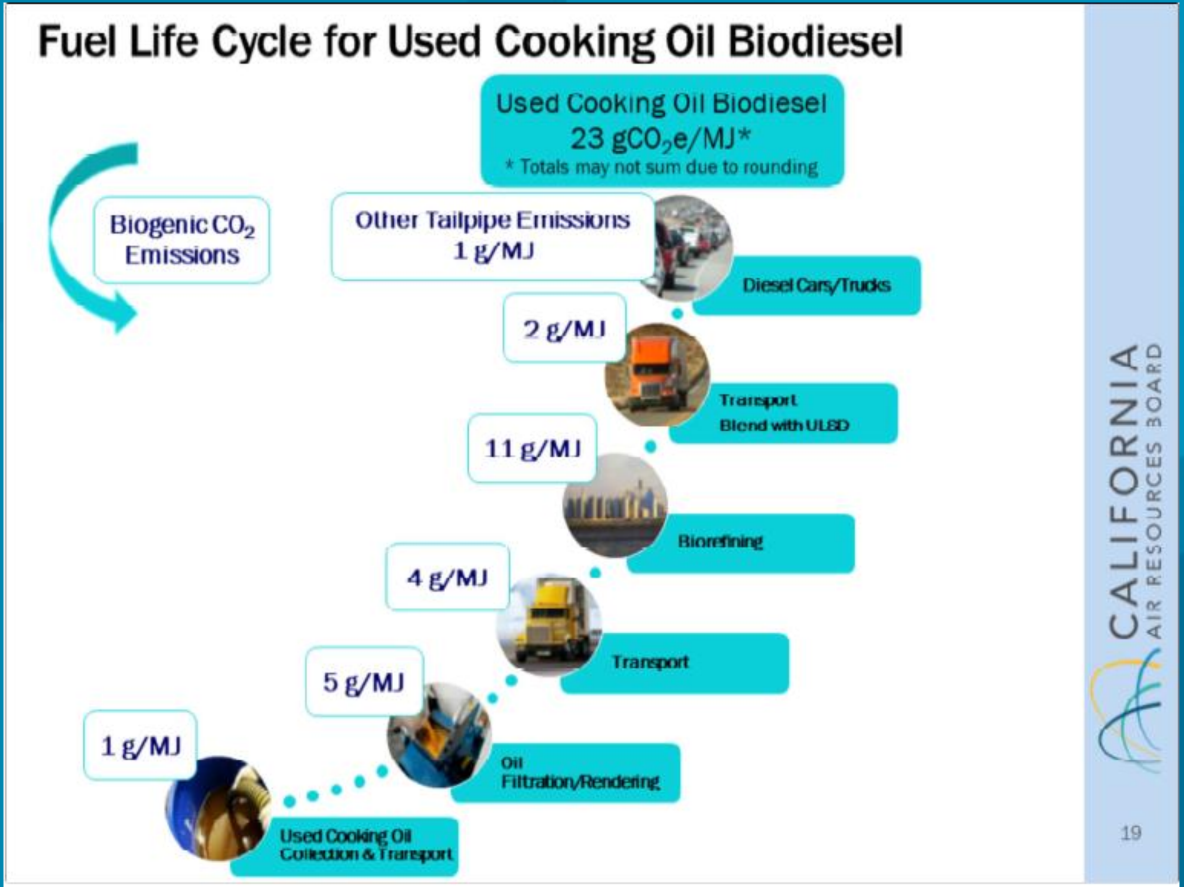




Source: LCFS Basics," California Air Resources Board website

Biofuel CIs Can Be on Par With or Lower than Electricity





Source: LCFS Basics," California Air Resources Board website

Direct CI – GREET (Greenhouse gases, Regulated Emissions, and Energy Use in Technologies)

- "Gold standard" lifecycle impacts estimator of efficiency technologies and energy systems
  - Total energy consumption (non-renewable and renewable)
  - Fossil fuel energy use (petroleum, natural gas, coal)
  - Greenhouse gas emissions (CO_2 , CH_4 , N_2O, black carbon, organic carbon, albedo)
  - Air pollutant emissions (VOCs, CO, NO_x , SO_x , PM_{10} , $PM_{2.5}$)
  - Water consumption
- Created in 1995 by Argonne National Laboratory, first of the U.S. national labs
- Publicly available, peer-reviewed, over 40,000 registered users:
  - California Air Resources Board, Oregon Dept. of Env. Quality, Washington Dept. of Ecology
  - U.S. EPA, U.N. International Civil Aviation Organization (ICAO), many others
- Wide variety of data sources: EPA eGrid, EIA energy projections, simulation programs (ASPEN Plus, EPA's MOVES), peer-reviewed publications, government & industry data

AutoSave Off ca-greet30-corre... Search Floyd Vergara

File Home Insert Page Layout Formulas Data Review View Help Comments Share

B6

CALIFORNIA AIR RESOURCES BOARD

Fuel Carbon Intensity Calculator for the Low Carbon Fuel Standard

A	B	C	D	E	F	G
LCFS Baseline Year: 2014	Release date: August 13, 2018 (corrected)			Color Legend for cells	User Inputs	Final CI
Select Feedstock and Fuel	Corn Ethanol - Dry Mill		CALCULATE		CI Summary of Corn Ethanol - Dry Mill	
	Feedstock Production Calculation		Fuel Production Calculation		Feedstock Production: 22.78	
Step 1a) Select Regional Electricity Mix for Feedstock (shown in the U.S. map far right)	1-U.S Ave Mix		Step 2a) Select Regional Electricity Mix for Fuel	1-U.S Ave Mix	Fuel Production : 33.18	
Step 1b) Select Region for Crude Oil Use	U.S. Average Crude		Step 2b) Select Region for Crude Oil Use	U.S. Average Crude	Tailpipe Emission : 0	
Step 1c) Select Region for Natural Gas Use	U.S. Average Natural Gas		Step 2c) Region for Natural Gas Use	U.S. Average Natural Gas	Denaturant : 0.9	
	Feedstock Production		Fuel Production		Indirect Land Use: : 19.8	
1) User Defined Electricity Resources Mix	User Defined Electricity for Feedstock Production		User Defined Electricity for Fuel Production		Total CI of Corn Ethanol - Dry Mill: 76.66	
Resid Oil/Fossil fuels	0.00%		0.00%			
Natural gas	100.00%		100.00%			
Coal	0.00%		0.00%			
Nuclear	0.00%		0.00%			
Biomass	0.00%		0.00%			
Hydroelectric	0.00%		0.00%			
Geothermal	0.00%		0.00%			

Disclaimer: CI above is for illustration purpose only, applicant must provide own data for CI calculation.

Overview | Region Selection | Inputs | Results | Petroleum | NG | MeOH&FTD | EtOH | Electric | Hydrogen | BioOil | Algae | RNG | Pyrolysis | IDL | Fu ...

Ready Circular References Accessibility: Investigate 100%

AutoSave Off ca-greet30-corre... Search Floyd Vergara

File Home Insert Page Layout Formulas Data Review View Help Comments Share

A1 Emission Factors of Fuel Combustion: in grams per mmBtu of fuel burned, except as noted (based on lower heating values of fuels)

Emission Factors of Fuel Combustion: in grams per mmBtu of fuel burned, except as noted (based on lower heating values of fuels)

Home Inputs

1) Emission Factors of Fuel Combustion for Stationary Applications (grams per mmBtu of fuel burned)

	Natural Gas								Diluent	Residual Oil			
	Utility/ Industrial Boiler (>100 mmBtu/hr input)	Small Industrial Boiler (10-100 mmBtu/hr input)	Large Gas Turbine	CC Gas Turbine	Small Turbine	Stationary Reciprocating Engine	NG Flaring in Oil Field	NG Kiln	Diluent Flaring in Oil Sand Field	Utility Boiler	Industrial Boiler	Commercial Boiler	Stationary Reciprocating Engine
VOC	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	100.000	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?
CO	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	50.000	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?
NOx	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	100.000	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?
PM10	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	90.000	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?
PM2.5	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	90.000	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?
SOx	0.269	0.269	0.269	0.269	0.269	0.269	0.269	30.000	67.489	#NAME?	#NAME?	#NAME?	267.327
BC	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	14.850	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?
OC	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	38.520	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?
CH4	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	2.850	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?
N2O	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	0.000	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?
CO2	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	59,015	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?
GHG EF, g	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?	56.37	#NAME?	#NAME?	#NAME?	#NAME?	#NAME?

2) Emission Factors of Fuel Combustion: Feedstock and Fuel Transportation From Product Origin to Product Destination (grams per mmBtu of fuel burned)

2.1) Emission Ratios by Fuel Type Relative to Baseline Fuel

	Ocean Tanker: Bunker fuel as Baseline Fuel						Barge: Residual Oil as Baseline Fuel							
	Diesel	Natural Gas	LPG	DME	FTD	Hydrogen	Diesel	Natural Gas	LPG	DME	FTD	Biodiesel	Renewable Diesel	R

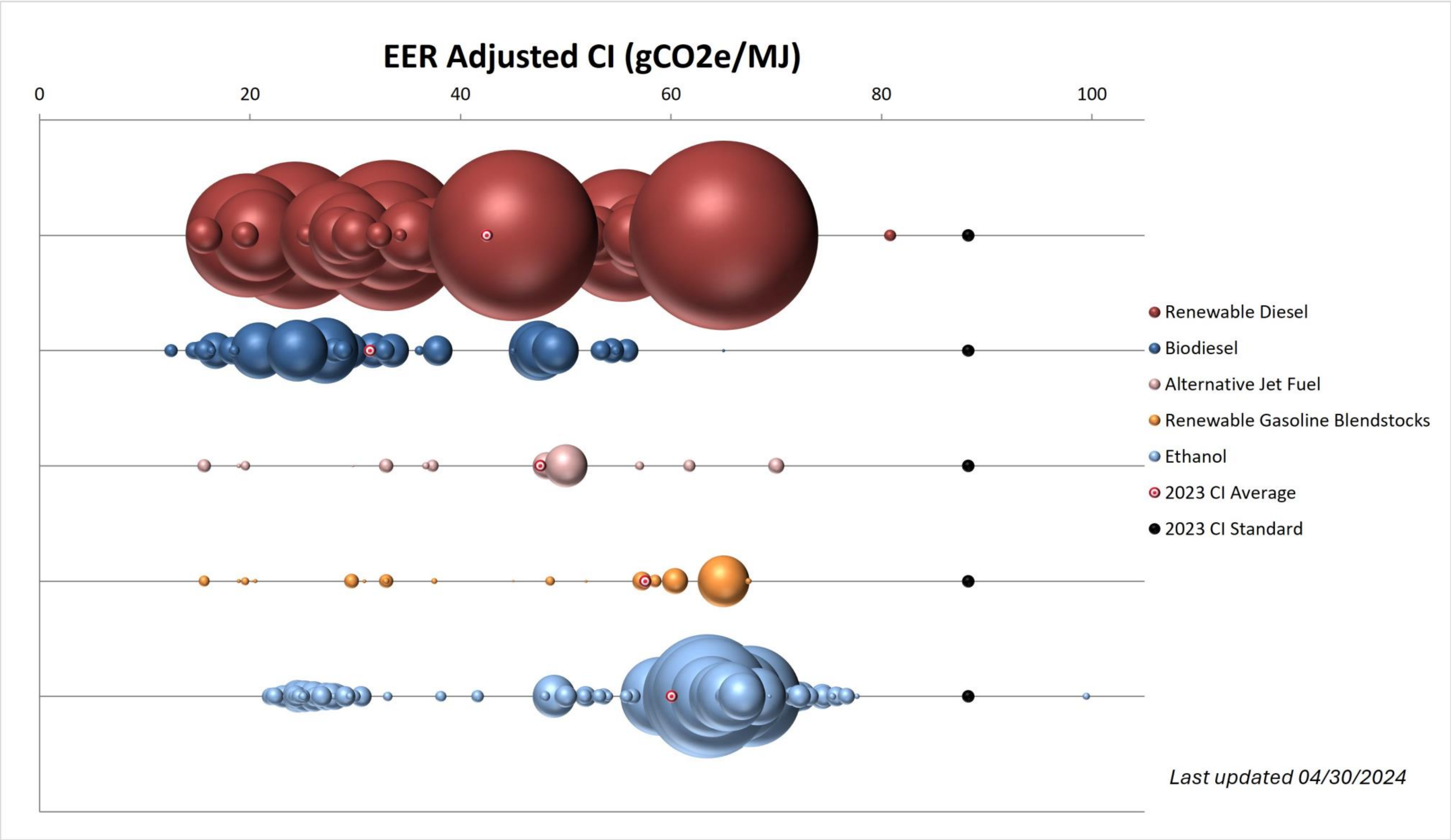
Petroleum NG MeOH&FTD EtOH Electric Hydrogen BioOil Algae RNG Pyrolysis IDL Fuel_Prod_TS EF_TS AgMining_EF_TS EF WCF ...

Ready Circular References: V100 Accessibility: Investigate 100%

Indirect CI – GTAP (Global Trade Analysis Project)

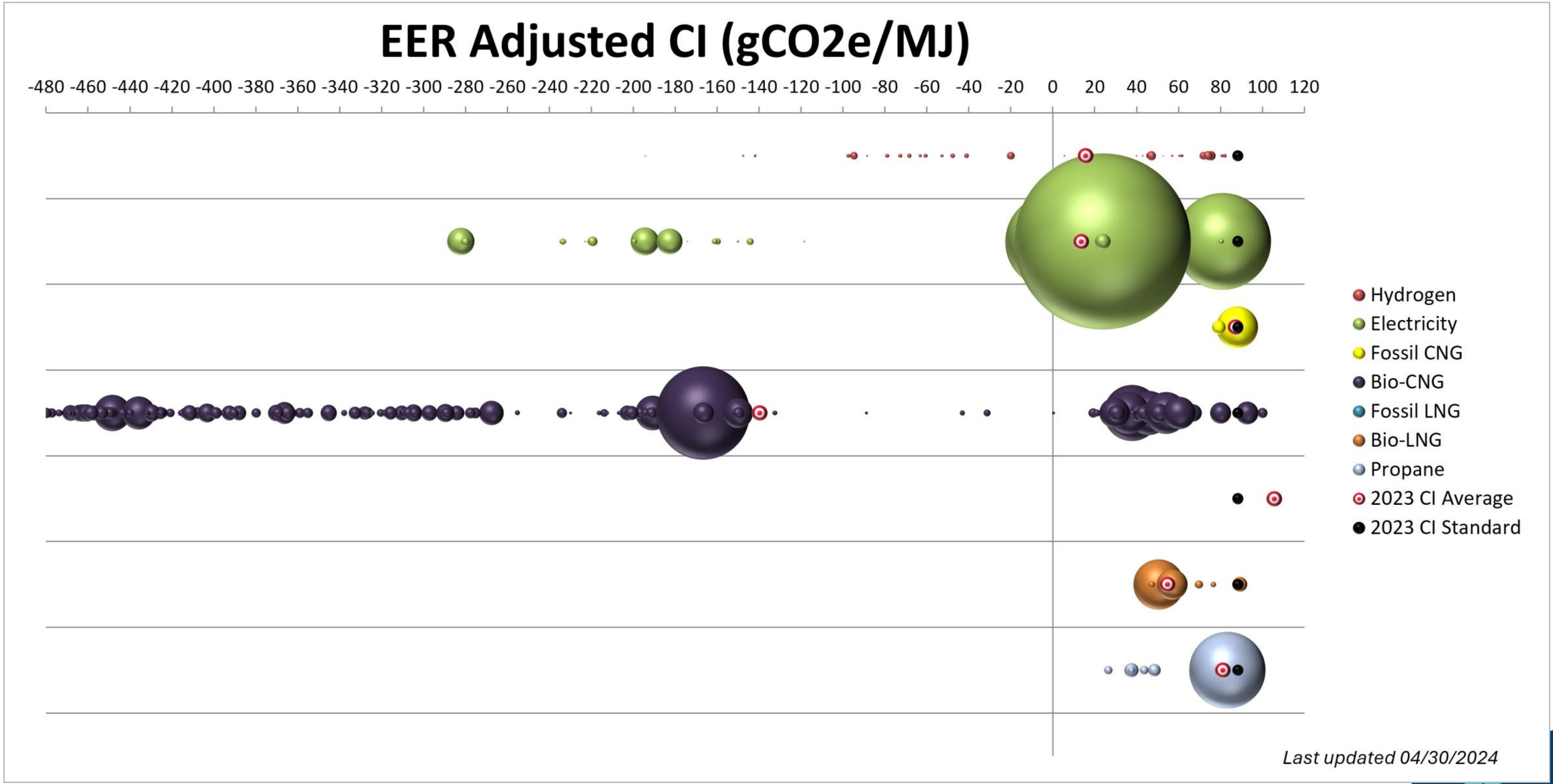
- Indirect land use change (ILUC) associated with some crop-based biofuels
- Not directly measurable but can only be inferred through modeling
- Computable General Equilibrium (CGE) models are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors
- GTAP is the one of the primary CGE models used in assessing biofuel policies and is the only ILUC estimator allowed in the LCFS
- Created in early 1990s by Dr. Thomas Hertel at Purdue University, over 7,000 network participants in 150 countries
  - California Air Resources Board, Oregon Dept. of Env. Quality, Washington Dept. of Ecology
  - U.S. EPA, USDA, US Dept. of Commerce, US ITC, WTO, many others
- Extensively peer-reviewed and published
- Land use changes inferred from policy change converted to estimated emissions through Agro-Ecological Zone Emissions Factor (AEZ-EF) model

2023 Volume-weighted Average Carbon Intensity by Fuel Type for Liquid Fuels



Source: LCFS Dashboard," California Air Resources Board website

2023 Volume-weighted Average Carbon Intensity by Fuel Type for Non-Liquid Fuels

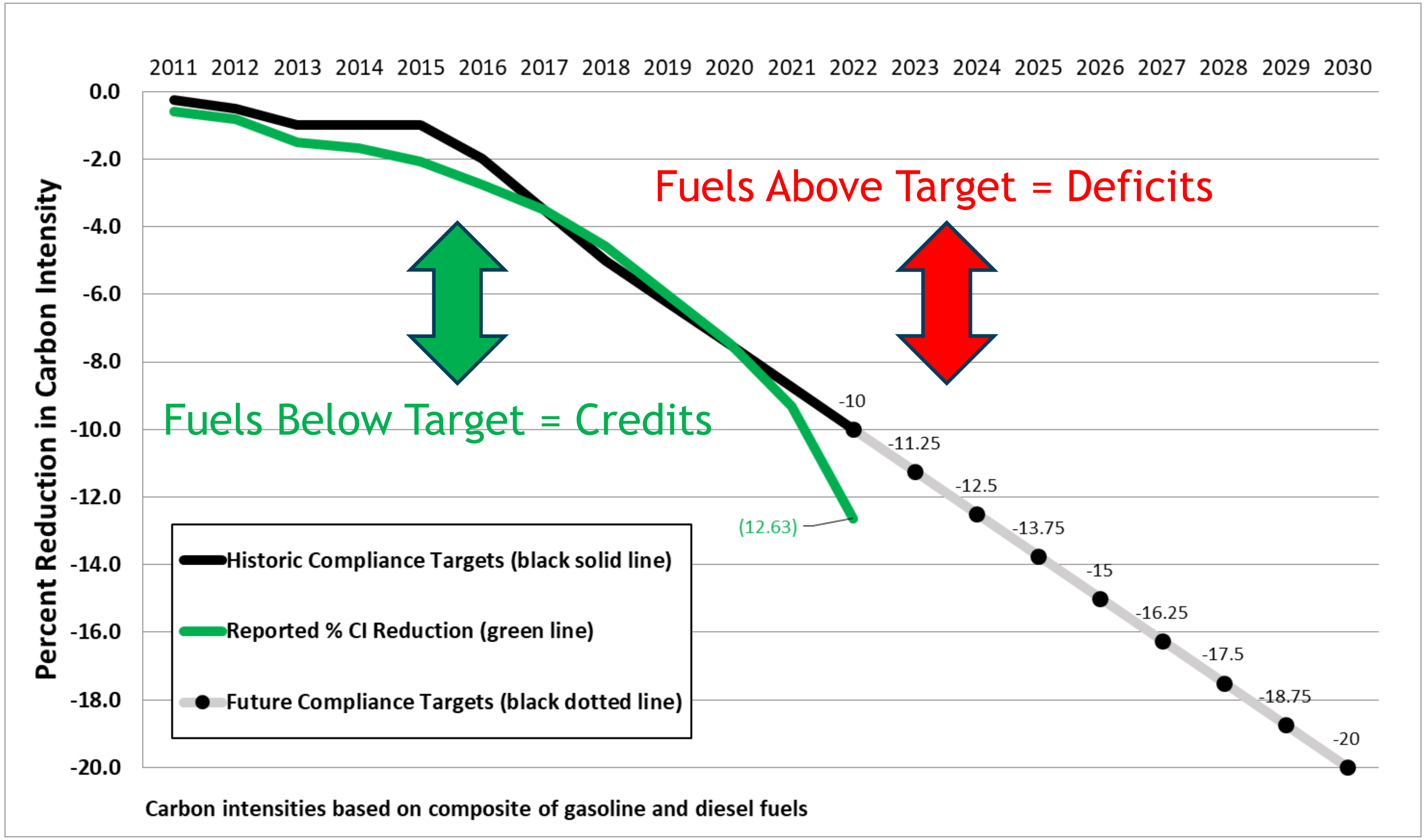


Source: LCFS Dashboard," California Air Resources Board website

CARBON INTENSITY TARGET SETTING

Annual Set of Declining Carbon Intensity (CI) Targets

- CI reduction targets informed by:
  - GHG Scoping Plan
  - Fuel/feedstock supply projections
  - Demand-side projections
  - Socio-economic modeling
  - Public health impacts
- Long time horizon provides certainty, facilitate investments & innovations
- Back-loaded trajectory for tech. development and commercialization



Percent Reductions Translate to Annual CI Targets

Carbon Intensity Benchmarks for Gasoline and Diesel Fuel and their Substitutes

Year	Gasoline Average CI (gCO_2e/MJ)	Diesel Average CI (gCO_2e/MJ)
2019	93.23	94.17
2020	91.98	92.92
2021	90.74	91.66
2022	89.50	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	80.80	81.62
2030 onwards	79.55	80.36

Carbon Intensity Benchmarks for Fuels Used as a Substitute for Conventional Jet Fuel

Year	Average CI (gCO_2e/MJ)
2019	89.37
2020	89.37
2021	89.37
2022	89.37
2023	89.15
2024	87.89
2025	86.64
2026	85.38
2027	84.13
2028	82.87
2029	81.62
2030 onwards	80.36

Source: "LCFS Basics," California Air Resources Board website

GENERATING CREDITS AND DEFICITS FROM THE CI TARGETS

§ 95486.1. Generating and Calculating Credits and Deficits Using Fuel Pathways.

(a) *General Calculation of Credits and Deficits Using Fuel Pathways.* LCFS credits or deficits for each fuel or blendstock for which a fuel reporting entity is the credit or deficit generator will be calculated according to the following equations:

(1) $$Credits_i^{XD}/Deficits_i^{XD}(MT) = \left(CI_{standard}^{XD} - CI_{reported}^{XD}\right) \times E_{displaced}^{XD} \times C$$

where:

$Credits_i^{XD}/Deficits_i^{XD}(MT)$ is either the number of LCFS credits generated (a zero or positive value), or deficits incurred (a negative value), in metric tons, by a fuel or blendstock under the average carbon intensity requirement for gasoline (XD = "gasoline"), diesel (XD = "diesel"), or jet fuel (XD = "jet");

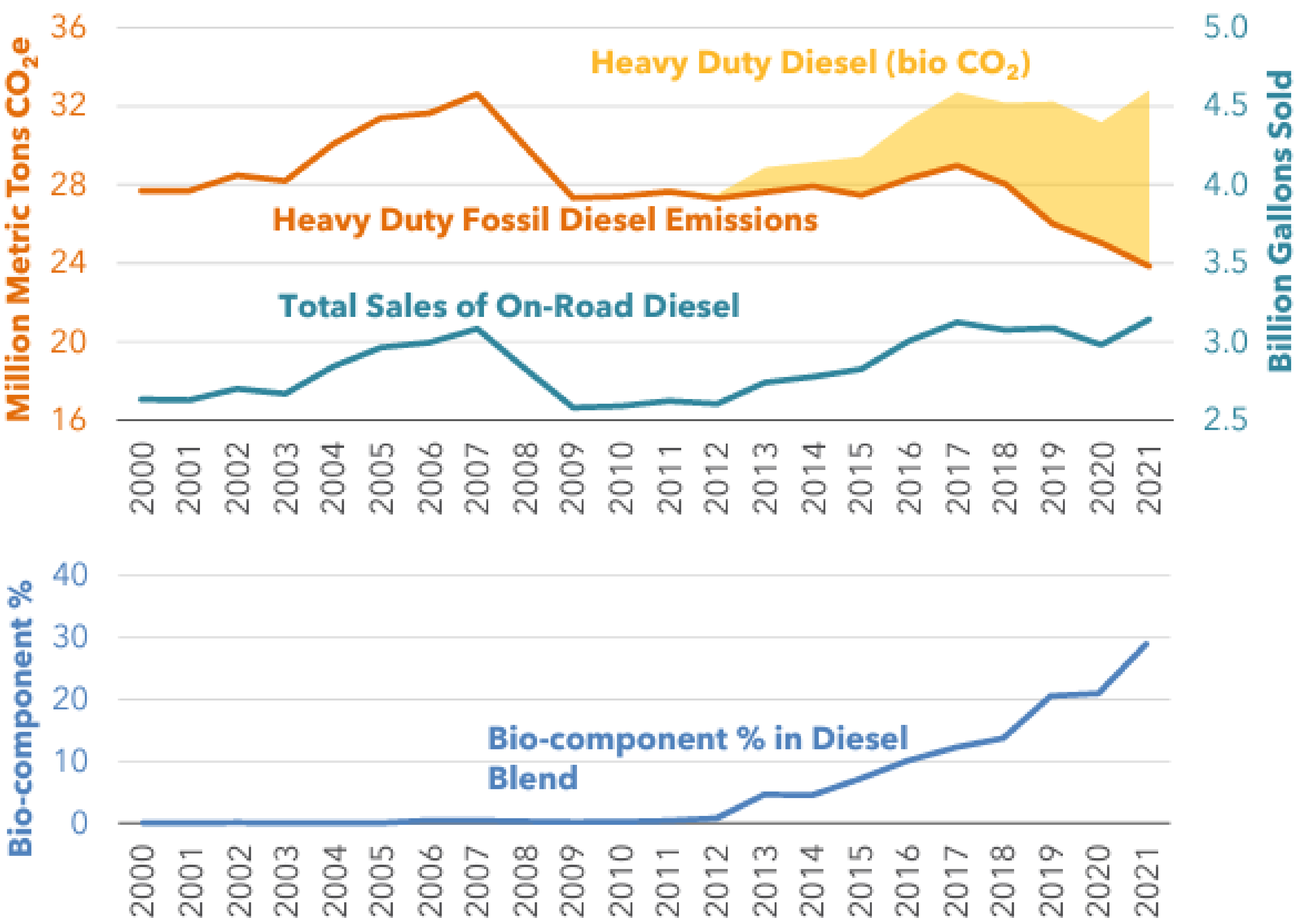
$CI_{standard}^{XD}$ is the average carbon intensity requirement of either gasoline (XD = "gasoline"), diesel (XD = "diesel"), or jet fuel (XD = "jet") for a given year as provided in sections 95484(b), (c) and (d), respectively;

$CI_{reported}^{XD}$ is the adjusted carbon intensity value of a fuel or blendstock, in gCO_2e/MJ, calculated pursuant to section 95486.1(a)(2);

Source: LCFS Regulation, 17 CA Code of Reg, sec. 95486.1

STATE GHG INVENTORY VS. LCA EMISSIONS

Figure 10. Trends in On-Road Diesel Vehicle Emissions.



Source: 2000-2021 CARB Emissions Trend Report, at 19.

THANKS!