Date: May 9, 2024

To: California Air Resources Board 1001 I Street, Sacramento, California 95814

From: Jack Lucero Fleck, 350 Bay Area (Organization for identification purposes; our full team has not been able to review these comments)

Re: Amendments to the Low Carbon Fuel Standard

Redirecting the Low Carbon Fuel Standards (LCFS) Program Away from Biofuels toward Electrification

Summary

The LCFS program awarded about $3.3 billion in credits in 2022. Of these $2.5 billion went to biofuels (biomethane, biodiesel, ethanol, renewable diesel) and $0.8 billion went to electrification of transportation. (See Addendum I for details) This paper argues that most of LCFS credits should go to electrification.

Two key asks:
CARB members–do not approve increases in liquid biofuel or biomethane pathways, i.e. cap these credits at existing levels.
CARB staff–review and consider these cost effectiveness calculations along with environmental and health impacts and equity considerations.

There are many important reasons for the LCFS to stop supporting biofuels, or at least put a cap on the existing levels of support, and to shift LCFS to increase support of electrification of transportation.

- Numerous arguments against biofuels, particularly detailing environmental impacts, are laid out in this letter signed by dozens of environmental justice, health and climate organizations.
- The case against the continued expansion of biodiesel and renewable diesel as consuming unsustainable amounts of land is further argued in this paper.
- Since roughly ¾ of Greenhouse Gases (GHGs) from transportation come from cars, ¾ of LCFS credits should go to EVs. (This paper does not examine ethanol; we do note, however that ethanol cannot deliver zero emission transportation.)
- Equity is an important benefit to using LCFS credits to help low income people obtain EVs, rather than having the credits go to refineries and large dairies.

The main point of this paper is that the **cost effectiveness–**cost per metric ton (MT) of GHGs reduced–of using LCFS credits to support electrification would be better than using credits for biofuels made from soy oil. Note that the lower the cost per MT of GHG reduction, the more cost effective a fuel type/LCFS support action is. Table I shows the results of calculations in Addendum III comparing cost effectiveness of LCFS fuel types. **Feedback on any assumptions, calculations or conclusions in this paper are welcomed!** See Addendum II for an explanation of Carbon Intensity (CI), which is used in these calculations.

Table I Comparison of Cost Effectiveness of LCFS Fuel Types

Fuel Type/LCFS support	Cost per MT of GHG reduction
Electricity–Funding EV purchases & chargers	$96
Biodiesel / Renewable Diesel including used cooking oil	$114
Biodiesel/Renewable Diesel from soy oil	$142
Heavy duty ZEV truck chargers	$152 - 250
Biomethane with -99 Carbon Intensity (2022 average)	$123
Biomethane with 30 Carbon Intensity	$707
Using solar to support Level 2 EV chargers	$109 - 532
Using solar to support DC fast chargers	$196
Using grid electricity	$354

Table I shows that redirecting the LCFS program to support targeted EV purchases and chargers is a cost effective strategy. LCFS credits should be focused on low and moderate income gas “superusers” to achieve the LCFS and the State climate, equity and cost effectiveness goals.

The numbers support a policy of putting a cap on all existing biodiesel, renewable diesel (with a possible exception for Used Cooking Oil (UCO) as a feedstock) and biomethane credits. With this cap, existing biofuel production would continue, at least for the next few years, until it is phased out as LCFS stringency increases. Most credits would be directed to electrification, where they are more cost effective, least environmentally destructive, and most equitable–a win-win-win.

Regarding the current use of funds to support electrification, the argument of this paper is that most of the LCFS program should be directed toward helping low income people who currently need to drive many miles, i.e. gas superusers, switch to an EV. Currently most of the electricity credits go to charging with renewables and/or to biomethane, which are less cost effective ways to spend the LCFS funds. Addendum IV discusses this in more detail.

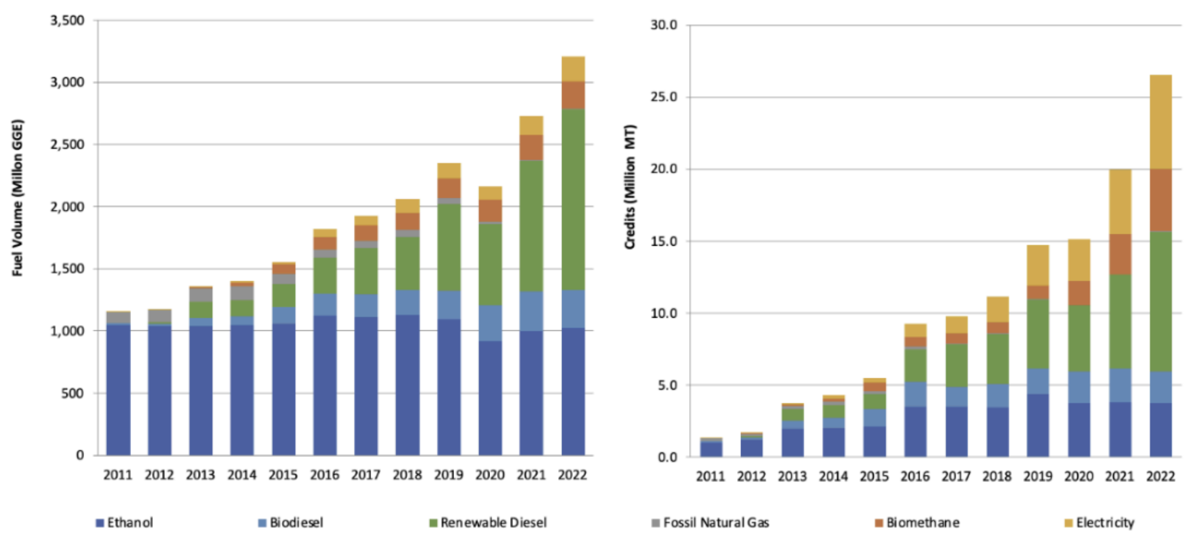
CARB has a choice to make. The LCFS program can continue its massive biofuel subsidies, or it can redirect LCFS to focusing its credits electric vehicles–cars, trucks and buses– as well as EV chargers. This redirection would be a great improvement for equity and environmental justice as well as for the climate. This conclusion is supported with calculations and further discussion in Addendums III and IV below.

Addendum I: How much are the current LCFS credits worth?

In 2022, the LCFS program gave credits as shown in Figure 1 below: (CARB LCFS dashboard)

Figure 1–Volumes and Credits in the LCFS Program

(from [LCFS Dashboard](), Fig 2 spreadsheet)



With credits having a weighted average of $125 per MT (Credit Price series from [LCFS Dashboard, Fig 4]()) in 2022, the total credit values came to $3.3 billion as shown in Table 2:

Table 2: Value of Credits in LCFS program 2022
(from Fig 2 spreadsheet in LCFS dashboard)

Credits (million MT)	2022	2022 Value - Millions of $
Biodiesel	2.2	$276
Biomethane	4.3	$543
Electricity	6.5	$817
Ethanol	3.7	$468
Renewable Diesel	9.7	$1,212
		$3,316

Table 2 shows that $817 million were credited to electricity, while $2.5 billion went to biofuels, including $2 billion to biodiesel, renewable diesel, and biomethane.

Addendum II - Explanation of Carbon Intensity

The key to understanding the LCFS is Carbon Intensity (CI). Each alternative fuel has a carbon intensity that is measured in grams of CO2 equivalent (CO2e) per megajoule of energy (g/MJ). CO2e includes greenhouse gases other than CO2 by converting the amounts of these gases to the equivalent amount of CO2. A joule is a measure of energy–it's a small number–1 kilowatt hour is equal to 3.6 million joules, or 3.6 MegaJoules (MJ).

Gasoline (CARBOB) has a CI of 101 as shown in Figure 2. source: page 17 of LCFS Basics with Notes.

Figure 2

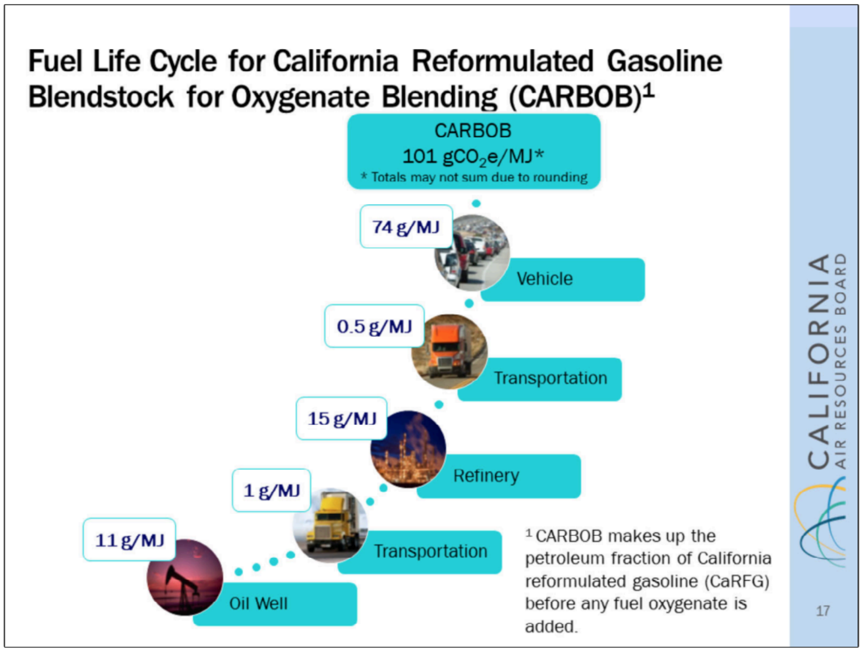


Figure 1 in Addendum I shows the volumes of alternative fuels and the credits that they earn. One credit represents 1 metric ton (MT) of GHG reduction. Fuels with a Carbon Intensity (CI) higher than the target (aka "the benchmark") pay to the LCFS to subsidize the fuels with lower CIs. The current benchmark is around a CI of 90; so gasoline with a CI of 101 has to pay for exceeding the benchmark. The lower the CI, the higher the credit–e.g. as shown in Fig. 1, biomethane has a small volume of sales, but earns a high number of credits. This is because it has a negative CI, which is discussed in Addendum III.

Addendum III – Calculations of Cost Effectiveness

A. Electric Vehicles Calculation and Discussion

The calculations below show that using LCFS credits to support purchase of EVs and chargers for targeted individuals can reduce GHGs at a cost of $96 per metric ton, i.e. well below the cost for biofuels.

Electric Vehicle Calculation

Assume LCFS incentives of $10,000 for a new EV, and $5,000 for a used EV, and that used EVs are limited to ½ of new EVs in the program.

Estimating 210 grams per kwh for California electricity (see Fig 3 from CARB below)
Estimating 12,000 miles per EV at 2.6 miles per kwh = 4600 kwh per EV per year

4600 x 210 grams = 969,000 grams = 1.0 Metric tons of GHGs per EV per year

Internal combustion Engine Vehicle (ICEV) at 12,000 miles / 25 miles per gallon x 25 lbs GHG per gallon (includes refining) x .9 CI adjustment for ethanol = 10,800 lbs of CO2

10,800 lbs of CO2 / 2200 lbs/MT = 4.9 MT per ICEV per year

Savings per car per year = 4.9 MT - 1.0 MT = 3.9 MT saved per EV

The calculation above assumes an average user with 12,000 miles per year. However, if CARB directed the subsidies to gas "superusers", i.e. drivers who use more than 1000 gallons of gas per year, say 24,000 miles per year, then the savings per EV per year is doubled to 7.8 MT as calculated below:

24,000 miles divided by 2.6 miles per kwh = 9,200 kwh
9200 x 210 grams/kwh = 1.9 metric tons for an EV
ICEV 24,000 /25 mpg = 960 gallons x 25 lbs x .90 = 21,600 lbs of CO2
21,600/2200 lbs/MT = 9.8 metric tons for a ICEV
Then an EV saves 9.8 - 1.9 = 7.9 MT per car per year
This assumes that the superuser turns in their old car for junk.

Assuming $10,000 to incentivize purchase of a new EV and $5000 for a used EV with ⅔ new and ⅓ used, with $1.5 billion in subsidies, that would be = 120,000 new EVs and 60,000 used EV sales

New EV purchase:
120,000 cars x 7.9 MT per car x 15 year life of a car = 14.2 MMT
Used EV purchase: assume
–60,000 used EVs.
–used car has a life expectancy of 7.5 years.
–no change in total vehicles (i.e. disposing of one car results in buying one more). There are 2 considerations:

a. These used EVs were being driven by regular users–i.e. 12,000 miles / 2.6 mi/kwh = 4600 kwh per year per car. 4600 kwh x 210 g/kwh / 1,000,000 g/MT = 1.0 MT per car. With a superuser, this would increase to 2.0 MT per car. This 1.0 MT increase totals: 60,000 cars x 1.0 MT x 7.5 years = 0.5 MMT increase in GHGs.

b. But assume that there is a 50% chance that the person who sells the EV buys a new EV, or is part of a series of EV used car purchases that lead to buying a new EV. Estimates vary from 50% to 80% of this probability; the calculations here use the lower number (50%) to be conservative. If the seller does buy, or lead to a purchase of, a new EV, there is a net of one less ICEV on the road, which is a savings of 3.9 MT per car. 60,000 cars x 50% EVs x 3.9 x 15 years = 1.8 MMT. This assumes that the new EV buyer is not a superuser.

This gives a net GHG decrease for 60,000 used EVs of 1.8 - .5 = 1.3 MMT.

Combining new and used results gives a total GHG reduction of 14.2 + 1.3 = 15.5 MMT

Using an LCFS total of $1.5 billion/ 15.5 MMT = **$96 per metric ton** as shown in Table 1.

Figure 3 – 2021 GHG Emissions by Scoping Plan Sector & Sub-Sector

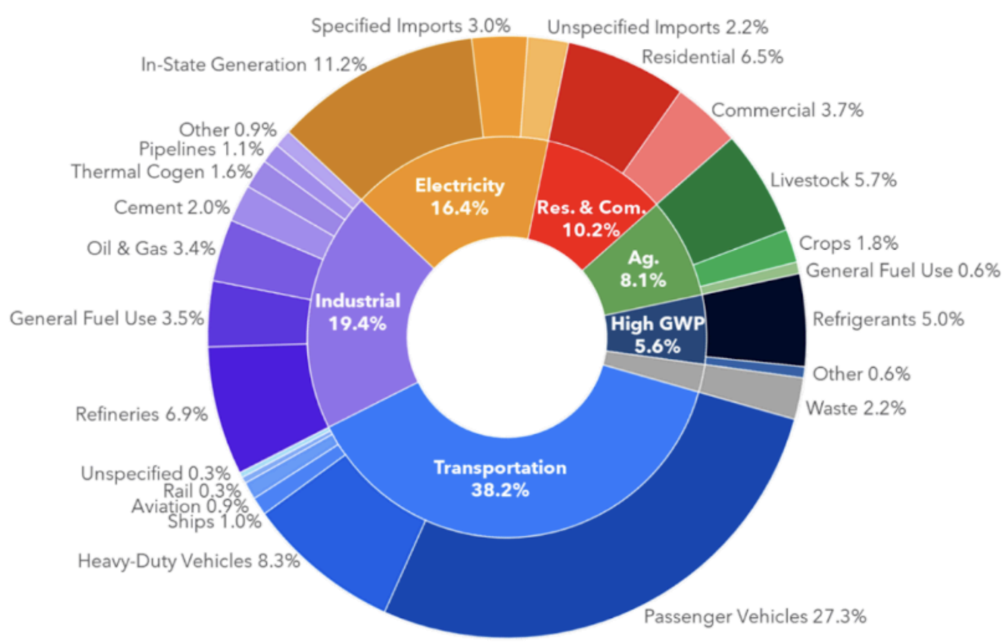


Figure 6 shows 2021 GHG emissions by Scoping Plan category. The inner ring shows the Scoping Plan sectors, while the outer shows the sub-sectors. Values do not sum to 100% due to independent rounding.

11.2% electricity x 381 MMT = 42.6 MMT/203TWH (in state) = 210 g/kwh
(42.6 x 10^{12} grams / 203 x 10^{9} kwh = 210 g/kwh)

EV Discussion:

The LCFS program currently supports the Clean Fuel Reward (CFR) program, which provides upfront incentives for purchasing of leasing a new EV in California. So the concept of using LCFS funds to support EV purchases is already a part of the LCFS program.

California had 26 million registered cars with 5.3 million new and used car sales in 2023. (1.8 million new and 3.5 million used, based on 10% of national used car sales) If the LCFS can only subsidize the purchase of 180,000 EVs (plus chargers) per year, it is important that the money be spent wisely–i.e. where it is most cost effective. If 10% of these 5.3 million cars are owned by gas superusers, that would be 530,000 cars. If half of those are low/moderate income, then that would be 265,000 superusers to target for EV purchases with LCFS support. The LCFS credits should focus on these car buyers to achieve the maximum benefits.

The calculations above suggest that used EV subsidies should be considerably less than new EV purchases given their more than 80% lower cost effectiveness–7.9 MT per new EV vs 1.3 MT for a used EV. But equity considerations for low income drivers support giving some subsidies for used EVs. The 50% lower subsidy used here could be lowered more, or the number of used EVs allowed could be decreased, both of which would improve the cost effectiveness of the program, but would reduce equity for low income car buyers.

Another criticism is that the $96 figure takes all the credit for the EV purchase, when other subsidy programs also can contribute. For example, if a car also receives a $7500 federal tax credit then the $10,000 could be seen as only contributing 10,000/17,500 = 57% of the incentive, for a cost effectiveness of $168/MT.

There is no doubt that the cost effectiveness calculations have a lot of uncertainty, both plus and minus. However, these calculations show that EV incentives are highly competitive with biofuel subsidies.

B. Biodiesel and Renewable Diesel

The calculations below show that the $1.5 billion that the LCFS credited to biodiesel and renewable diesel (from Table 2) yielded 13.2 million metric tons of GHG reduction. $1.5 billion/13.2 million = **$114 per metric ton of GHG reduced,** as shown in Table 1.

Data in Tables 3 and 4 is from the spreadsheet attached to [Fig 2 in the LCFS Dashboard](). Table 3 shows the CI for various fuels. In 2022 the CI for biodiesel averaged 28, and for Renewable Diesel averaged 37.

Table 3 – Carbon Intensity averages for LCFS Fuel Types

CI Avg	2022				2023			
	2022Q1	Q2	Q3	Q4	2023Q1	Q2	Q3	**2022 Average**
Ethanol	58.47	59.71	59.39	59.21	60.09	60.47	61.32	59
Biodiesel	27.32	27.62	29.05	29.99	32.41	28.42	30.5	28
Renewable Diesel	35.78	35.95	38	38.1	41.51	43.74	43.01	37
Bio-CNG	-61.4	-103.67	-111.5	-119.2	-93.03	-131.36	-132.15	-99
Bio-LNG	53.96	54.4	55.04	54.35	49.82	49.5	48.59	54
Electricity	27.04	27.68	24.09	41.35	42.48	47.94	48.19	30
Alternative Jet Fuel	22.67	45.46	42.36	42.41	47.16	36.67	48.75	38
Hydrogen	34.01	24.54	32.14	39.66	31.11	47.94	34.11	33

Table 4 shows the volumes of fuels in gallons of gas equivalent (gge). Using gge allows the LCFS to compare the fuels with the same standard of measure.

Table 4 Volume of fuels in LCFS (gge = gallons of gas equivalent)

Conversion to gge using energy density from Table 3 in the LCFS regulation	**2022 totals (gge)**	**Rounded total for 2022 (million gge)**
Biodiesel	306,166,029	306
Biomethane	221,146,628	221
Fossil Natural Gas	15,615,972	16
Electricity	218,472,981	218
Ethanol	1,025,105,423	1025
Renewable Diesel	1,560,372,740	1560
Other (Hyrdrogen, AJF, Renewable Naphtha, Propane)	61,685,509	62

Table 5 shows the calculation of GHG reductions from biodiesel and renewable diesel using CI 101 for fossil diesel and using CI = 28 for biodiesel and CI = 37 for renewable diesel from Table 3 above:

Table 5 Total GHG reduction from biodiesel and Renewable Diesel in 2022

Biodiesel	28/101	72% reduction	306 million gal x 25 lbs/gal / 2200lbs /MT =			3.5 MMT	x 72% =	2.5 MMT
Renewable diesel	37/101	63% reduction	1560 mil gal x 25 / 2200 =			17 MMT	X 63% =	10.7 MMT
								13.2 MMT total

For comparison, the same credit total of $1.5 billion would result in 15.5 MMT reduction for EVs – $96 per MT vs $1.5 billion/13.2 MMT for biodiesel and renewable diesel = **$114 per MT** as shown in Table 1.

C. Zero Emission Trucks and Buses

Sections A and B above show that use of LCFS credits to fund light duty EVs would be more cost effective than using the credits for biodiesel or renewable diesel. But can LCFS funding of zero emission trucks and buses compete with these biofuels?   The argument is that heavy duty vehicles are more difficult to decarbonize than light duty vehicles. Therefore, biofuels can act as a bridge fuel to give us a start on reducing emissions for heavy duty vehicles.

What do the numbers show?

It is true that the technology and the market for light duty vehicles is more advanced than for trucks and buses. However, CARB, in its Advanced Clean Fleets program argues that lower total cost of ownership of ZEV trucks are "expected to deliver a net savings of $48 billion to fleets," plus a savings of $26.5 billion in statewide health benefits from criteria pollutant emissions.   If CARB, or other government agencies, can use loans from low interest revenue bonds to finance the upfront costs, taking advantage of lower operating costs, then the issue becomes focused on charging infrastructure.

Emissions from an average truck – This calculation estimates that a typical medium duty or drayage truck emits about 28 MT of GHGs per year:

–20,000 miles per year
–8 miles per gallon
–20000/8 = 2500 gallons / year x 25 lbs of GHGs/gal / 2200 = 28 MT per truck per year.

These assumptions are estimated from Figures 4, 5, & 6 below (source) Figure 4 shows that some heavy duty trucks and transit buses use around 10,000 gallons per year, which would emit 115MT of GHGs per truck or bus. However, it is likely that these mileage numbers would exceed the current capability of battery operated trucks and buses. A separate analysis of hydrogen fuel cells and advances in battery technology would be required to compute cost effectiveness for various optional technologies, but that is beyond the scope of this paper.

An exception to this is school buses, which have much less annual mileage and fuel use. Also school buses have greater opportunity for charging since they are used fewer hours per day. California has about 25,000 school buses. Assuming a lifetime of

15 years, the state needs to replace 1,667 per year. If a subsidy of $100,000 combined with other financing programs helps to buy new school buses and relatively low cost Level 2 chargers, the total cost would be 1,677 buses x $100,000 = $167 million. This should be easily affordable for the LCFS.

Figure 4 – Fuel Use for Different Truck/Bus Types

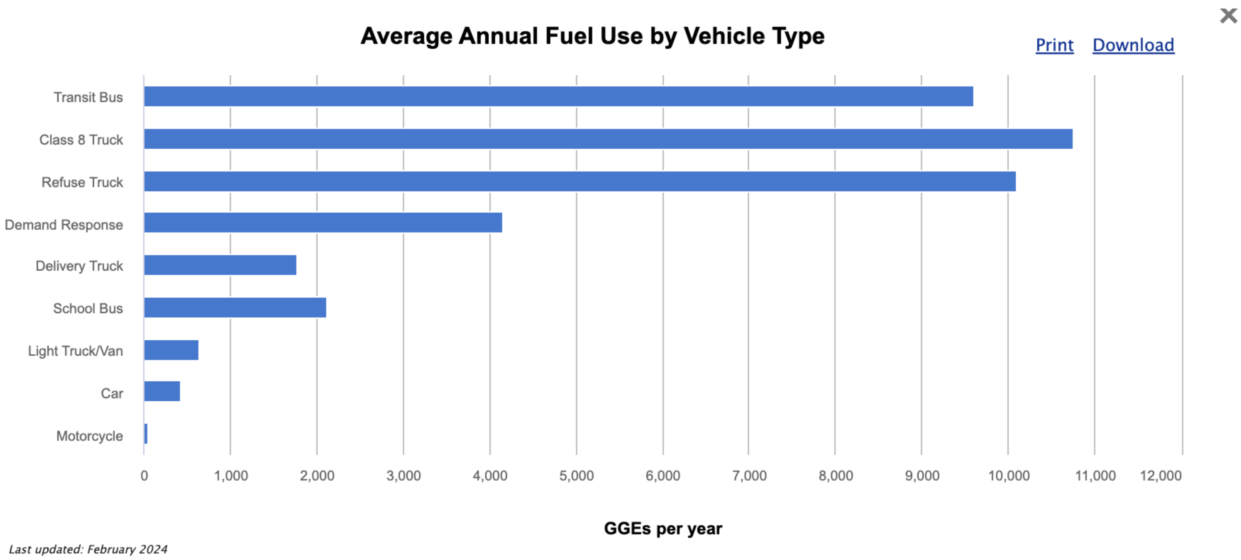


Figure 5 – Mileage by Truck/Bus Types

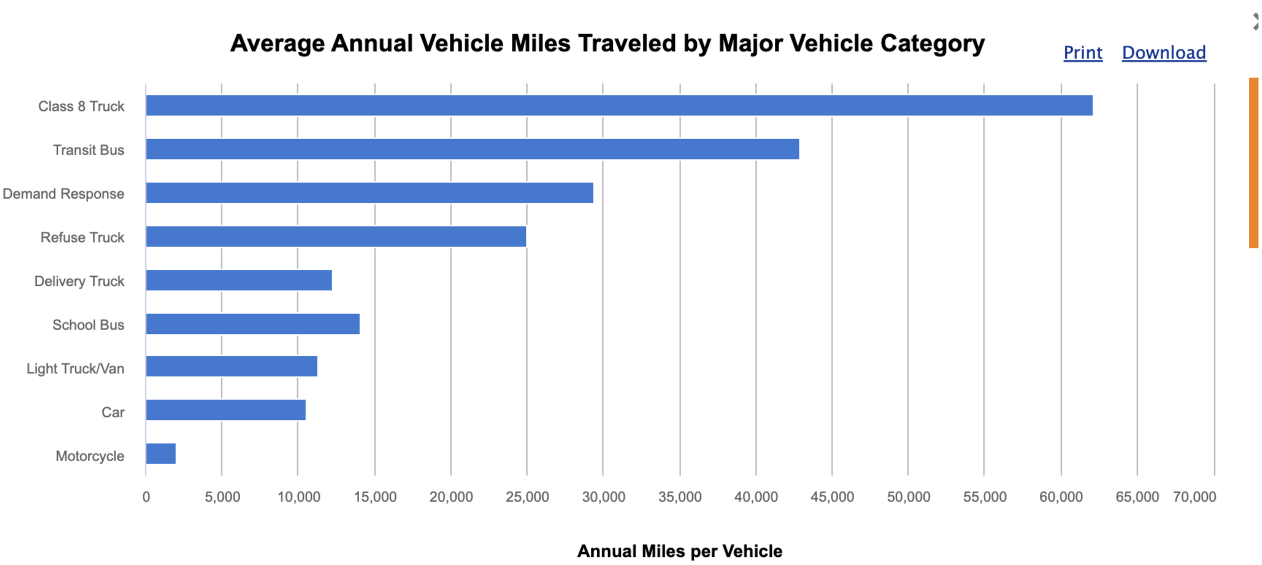
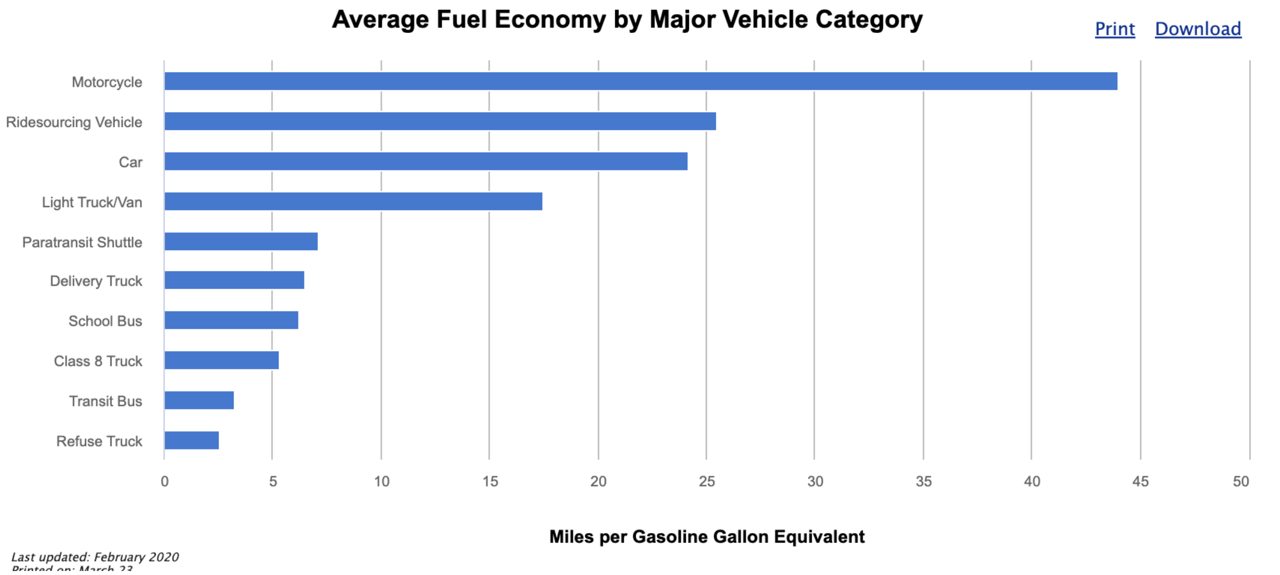


Figure 6– Fuel Economy by Vehicle Type



Emissions from an electric medium duty truck–This calculation estimates that an electric truck would average 5 MT of emissions per year.

Assume: 0.9 miles per kwh (average of several trucks from this source) and assume 210 g/kwh (Fig 3 above)

20,000 miles / .9 miles per kwh = 22,000 kwh

22,000 kwh x 210 grams/kwh / 1 million g per MT = 4.6 MT, say 5 MT

Compared to fossil diesel, the savings would be 28 - 5 = 23 MT per year

Note that these reduced emissions would be further reduced every year as the electricity grid gets cleaner. On the other hand, there is little reason to believe that emissions from biofuels would be reduced significantly over time; in fact these emissions could be increased as land use charges (see below) are re-evaluated.

Cost of Battery Electric Trucks chargers (admittedly this is a very limited sample–additional references would be welcomed)
The Port of Oakland is installing 145 chargers for drayage trucks for an estimated $50 million–$345,000 each. This comes to $360 per MT of GHG reduction based on this calculation

The Port of Oakland (Port) was awarded a Trade Corridor Enhancement Program (TCEP) grant in the amount of $41,635,000, which requires $17,841,000 of matching funds for a total of about $60 million. This covers costs for the Port to plan, design and install:

- 145 chargers for battery- electric heavy duty trucks and cargo handling equipment in the Seaport;
- one megawatt (MW) of solar panels;
- up to 6.5 MW of battery storage;
- associated substation upgrades.

I estimate that the solar panels and storage that go with this project will cost about $10 million, so the cost of the chargers and substation upgrades is $50 million. This comes to $345,000 each for 145 chargers. If a charger can service 3 trucks a day, then the cost per truck would be about $115,000. Using a savings of 23 MT per year for 20 years (20,000 miles per year per truck), that is 460 MT saved per truck. The cost would be $115,000/460MT = **$250 per MT.**

However, this article about ZEV chargers in Illinois describes 100 chargers costing $21 million–$210,000 each. This would be more cost effective than the Port of Oakland Project with about $152 per MT emission reductions.

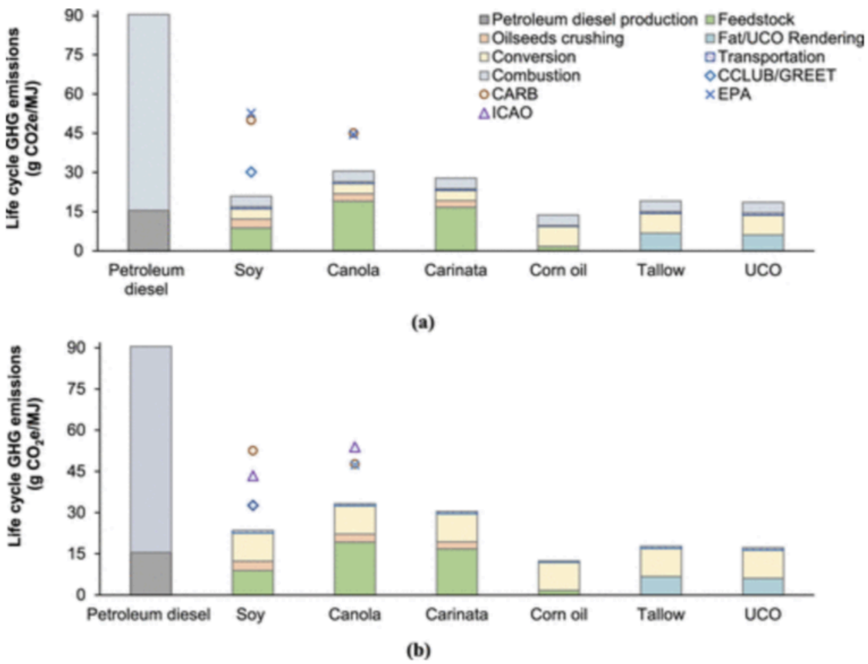
> Illinois calculation: $21 million / 100 stations = $210,000 per station.
> Again 23 MT per year x 20 years = 460 MT saved per truck.
> Each station serves 3 trucks per day = $70,000 per truck / 460MT saved over 20 years = **$152 per MT**

How does that compare to the current biofuel credits? As discussed in Addendum III - B above, the GHG reductions from biodiesel and renewable diesel average $115 per MT, which is well below both the Port of Oakland figure and the Illinois figure.

However, the CI for soy oil (about 50 as shown in Figure 7 below) is much higher than the CI for used cooking oil and tallow (around 15). Therefore, if we compare the cost effectiveness of soy oil with ZEV trucks, the results are closer. A CI of 50 results in a 50% reduction in GHGs compared to fossil diesel. Adding 306 million gallons of biodiesel to 1560 million gallons of renewable diesel in 2022 gives 1866 million gallons total produced (Table 4 above). As before, assuming 25 lbs of GHGs per gallon / 2200 lbs per MT gives:

> 1866 million gallons x 50% reduction x 25 lbs per gallon GHGs / 2200 lbs per MT = 10.6 MMT reduction. This gives a cost effectiveness for diesel made from soy oil: $1.5 billion / 10.6 MMT = **$142 per MT**

Figure 7 – CI of biofuels using various feedstocks



Source: https://pubs.acs.org/doi/10.1021/acs.est.2c00289

Figure 7 below shows the carbon intensity (CI) of both biodiesel (Fig 7a) and renewable diesel (Fig 7b). The CI of these biofuels have an added Land Use Charge of 30 for Soy and Canola, but not Corn Oil, Tallow and Used Cooking Oil (UCO). The land use charge is assessed because of these feedstocks' impact on food supplies and forests.

The low CI score for corn oil is not without controversy, but that is beyond the scope of this paper.

As noted above, the current 210 g/kwh for electricity generation should drop steadily as California aims to reach 90% clean electricity by 2035. These changes would bring the cost effectiveness of zero emission trucks below biofuels made from soy oil very soon, and eventually below Used Cooking Oil as well

These calculations support continued use of UCO for biofuels, but placing a cap on Soy Oil.

D. Biomethane

Biomethane Calculations

CARB estimates that biomethane production totaled 221 million gallons gas equivalent (gge) (Table 4) and that total credits for biomethane were valued at $543 million (Table 2)

Using Carbon Intensity = -99 (Table 3; note that this is a NEGATIVE number) gives an estimated savings of 4.4 MMT:

Gasoline has a CI of 101 and produces 25 lbs of GHG per gallon
A CI of -99 would be a decrease of 200 CI: 101 - (-99) = 200 CI
The credit would be increased by 200/101 = 2.0 times
This is the equivalent of assuming that a ICEV produces 2.0 x 25 lbs/gal = 50 lbs/gal of GHGs compared to a zero emission vehicle
221 million gallons x 50 lbs per gallon/ 2200 lbs per MT = 4.4 MMT

This is a cost effectiveness of $543 million /4.4 MMT = **$123 per metric ton of GHG reduction**

Using a more realistic CI of 30, would result in a CI reduction of 71/101 = 70%. Using 25 lbs/gallon x 30% = 7.5 lbs per gallon. 221 million gallons x 7.5 lbs/gal = 1658/2200 = .75 MMT of GHG. $543 million/.75MMT = $707. **This would be $707 per MT GHG reduction.**

As previously calculated, if the money were spent on EVs instead of biomethane, the cost per metric ton of GHG reduction would be **$96 per MT.** The total GHG reduced would be $543 million / $96 per MT = 5.7 MMT rather than 4.4 MMT using a CI of -99, and 0.75 MMT using a CI of 30.

Biomethane Discussion

Similar to liquid biofuels, biomethane cannot compete with subsidies to EVs, even with an exaggerated CI of -99. Using CI = negative 99 (the 2022 average for biomethane), gives a cost effectiveness of $123 per MT, compared to $96 for EVs. Using a more realistic CI of 30 for biomethane would increase the cost per MT to $707 MT. The only way biomethane can stay competitive is to assume a large negative CI. This requires the assumption that methane in an unavoidable byproduct of dairy farming, which is not a valid assumption.

Also, methane/natural gas comprises less than 1% of transportation fuel, so biomethane will never achieve a significant reduction in GHGs from transportation. Likewise, if used to make electricity or hydrogen, biomethane would produce a very tiny amount of electricity or hydrogen needed. By comparison, EVs already constitute about a 6% reduction in GHGs from transportation, and this increases with every EV sold.

Addendum IV - Cost Effectiveness of Electrification Options

The calculations below show that subsidizing solar plus storage is comparable to the cost effectiveness of subsidizing EV purchases. The calculations are very approximate since calculation details for cost effectiveness of different pathways are not readily available. We recognize that this topic needs more detailed analysis and development, and we hope to work with CARB and staff to develop these ideas further.

Table 6 shows that most electricity credits go to charging. The amount for supporting purchases of new and used EVs does not make the chart.

Table 6– Electricity Credits

Electricity Credits				2022			2023
Fuel Application Type	2022Q1	Q2	Q3	Q4	2023Q1	Q2	Q3
Electricity – Onroad EV charging – LDV/MDV	-	-	-	-	-	-	-
Electricity – Onroad EV charging – HDV	-	-	-	-	-	-	-
Electricity – Onroad residential grid EV charging	622,330	682,099	717,363	835,597	731,067	803,075	880,277
Electricity – Onroad incremental Low-CI residential EV charging	106,492	123,546	125,458	27,269	26,031	22,334	33,624
Electricity – Onroad non-residential grid EV charging – LDV/MDV	4,878	4,990	14,875	16,456	10,035	24,601	22,113
Electricity – Onroad non-residential low-CI EV charging – LDV/MDV	169,417	226,248	243,113	249,189	270,533	290,405	346,218
Electricity – Onroad non-residential grid EV charging – HDV	1,209	1,599	2,255	4,599	4,639	4,863	6,992
Electricity – Onroad non-residential low-CI EV charging – HDV	12,699	14,241	14,547	13,906	15,035	16,904	18,919
Electricity – Offroad fixed guideways	56,387	55,074	69,093	73,779	65,831	70,873	76,653
Electricity – Offroad eOGV	49,563	95,906	99,127	112,692	97,895	89,774	91,618
Electricity – Offroad eCHE	17,113	16,404	14,945	14,209	12,713	11,960	14,766
Electricity – Offroad eForklifts – EDU	-	-	-	-	-	-	-
Electricity – Offroad eForklifts – Reported	346,091	370,631	385,276	405,177	402,332	407,780	419,490
Electricity – Offroad eTRU	6,979	9,006	10,164	9,674	8,440	11,129	10,685
Total	1,393,158	1,599,744	1,696,216	1,762,547	1,644,551	1,753,698	1,921,355

Another important point is that 29 of the 144 electricity pathways in the electrification category are biomethane related (source). Plus some of the "Low-CI" charging pathways include biomethane. As argued in Addendum III, this is not a good use of LCFS funds. As noted above, the very large negative CI numbers in these pathways must assume that methane is an unavoidable by-product of dairies, but this is a false assumption.

The calculations below estimate that using:

- Grid electricity to charge cars gives a cost/benefit ratio of $354/MT.
- Solar plus storage which includes assuming the purchase of an EV has a cost effectiveness of $109. This is using utility rates from NEM 3.0 (the current CPUC program for rooftop solar). It does not include cost of the chargers.
- Solar plus storage to charge EVs for the general public would cost $532/MT. And it does not include purchase of an EV with related GHG reductions, as discussed below.

- Solar plus storage to charge DC fast chargers gives an estimated cost/benefit ratio of $159/MT.

As noted, there are many assumptions in each of these calculations that need to be further developed.

A. Grid Electricity

One of the LCFS pathways, listed several times in the electricity pathways, is described as "California grid electricity used as a transportation fuel in California".

This use of LCFS funds is

1. Not cost effective
2. Unlikely to be enough to incentivize electric vehicles purchases;
3. Not able to move the state toward its zero emission goals.

Regarding points 2 & 3: Using the state average of 30¢ per kwh, and taking roughly $1 billion in LCFS electricity credits, that could purchase $1 billion / 0.30 = 3.3 TWH from the grid. California produced 203 TWH in 2021, so this would be a 1.6% potential reduction in electricity prices. But such a reduction is unlikely to provide a significant stimulus to electrification.

Cost effectiveness calculation:

Assumptions:
A car gets 2.6 mi/kwh on average
12,000 miles average per year per car
25 miles per gallon
25 lbs of GHGs per gallon (includes drilling, shipping, refining)
Carbon intensity of gasoline is 90 (with ethanol), i.e 90% of CARBOB

Calculations:
1 car x 12,000 mi/year / 25 mpg x 25 lbs/mi / 2200 lbs/MT x 0.9 CI = 4.9 MT per ICEV
4600 kwh for one car per year (12,000 miles per car/ 2.6 mi/kwh = 4600kwh)
MT saved: 4600 kwh x 210 g/kwh / 1,000,000 g/MT = 1.0 MT grid electricity used for charging an EV for one year

Therefore an EV on the grid saves 3.9 MT per car per year (same result as Addendum III-A).

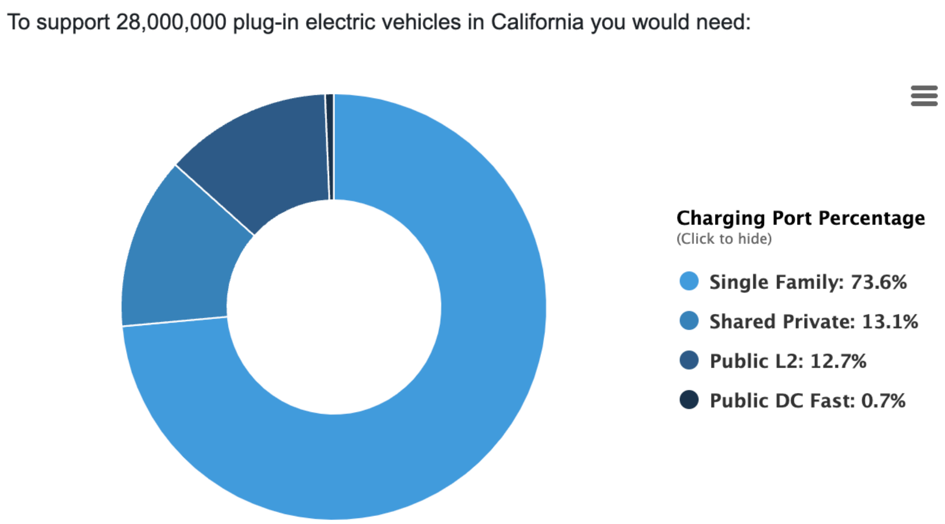
Using 30¢ per kwh as an average grid cost: 30¢ x 4600 kwh = $1,380.
If LCFS covers this cost, that gives: $1,380/3.9 MT = **$354 per MT**

B. Cost effectiveness of supporting solar for EV charging ($/MT of GHG reduction)

A key issue in this calculation is how much installing a charger can take credit for expanding purchases of EVs. If a charger, say in a home, can be credited with a person buying an EV, then it is appropriate to give credit for the 4.9 MT of GHGs that a ICEV emits per year. This gives a cost effectiveness of $109 per MT (see calculation below), which is quite good.

Figure 8 below, shows that most charging is private (86.7%) Providing solar plus storage to people who are buying an EV is a good investment, and LCFS should include that in its pathways

Figure 8 – Most Charging is done at home (Source)



However, a public charger has a harder time making such a claim. The calculations below estimate $532 per MT for using solar plus storage to charge EVs.

Assumptions:

$3.30 per watt for solar. This is an average value for rooftop solar. Utility scale solar is about half the cost of rooftop solar, but it does not receive a 30% federal credit, and it has to cover transmission, distribution and administration charges. Therefore, the resulting cost/benefit calculation is assumed to be comparable.

2.9kw of solar provides enough kwh for a car for a year: 12,000 miles/2.6 mi/kwh = 4,600 kwh; 2.9 kw makes about 4,600 kwh per pvwatts)

7% interest/discount rate

25 years life of solar plus storage
1 kwh = 210 g of GHG in California

4600 kwh needed is provided by storage/365 days/year = 12.6 kwh average per day. I'm estimating 16 kwh for the battery storage, assuming that, in a setting with numerous charging stations, the energy from the batteries could be transferred to cars that need more than average. If more energy is needed than the batteries can provide, this would come from the grid

Storage cost: $1150/Kwh (energy sage) NREL estimates about $900/kwh for a 6 hour battery for a utility scale project. I'm using the higher cost to be conservative.

80% of solar is self consumed via the batteries (20% export/import from the grid). This is a rough estimate, which takes into account peak cases where imports are needed if numerous cars need more than 16 kwh in a day. The 20% import also accounts for imports which are likely to be needed in short winter days, just as there will be some surplus to be exported in long summer days.

NEM3–pays approx 5¢ per kwh for exports (the CPUC Avoided Cost Calculation)

Capital Recovery Factor (CRF) – 25 years, i = 7% = .08581

Calculations:

Solar: 2.9kw cost: $3.30 x 2.9 = $9,600 less 30% federal tax credit = $6720

Storage: 16 kwh storage x $1150/kwh = $18,400 cost of storage for one car
30% tax credit: 70% x $18,400 = $12,880

Cost of solar + storage = $6720 + 12,880 = $19,600
Annual equipment cost: $19,600 x .08581 = $1682

Costs due to solar imports and exports:

80% is self-consumed by day use and re-plenishing the charger = 80% x 4600 kwh = 3,680 kwh

20% is exported at 5¢ per kwh (rough estimate of average avoided costs per CPUC calculations) 20% x 4600 kwh = 920 kwh x .05 = $46

Since the solar plus storage produces 3,680 kwh, the imports are 4600 - 3680 = 920 kwh. At a cost of 30¢/kwh this is a cost of $276

Total cost: $1682 - 46 + 276 = $1,912

If the grid had been used to charge the car, the annual cost would have been 4600 x 30¢ = $1380. Therefore the extra cost is $1,912 - 1380 = $532

Assuming the solar plus storage includes a new EV: This comes to 4.9 MT per year per car as shown here:

1 car x 12,000 mi/year / 25 mpg x 25 lbs/mi / 2200 lbs/MT x 0.9 CI = 4.9 MT per ICEV

Using solar assumes no GHGs from production of the electricity.

Then the cost effectiveness would be $532/4.9 = **$109 per MT.**

Without including an EV, the solar panels save 1.0 MT as calculated above in Section IV-A for grid electricity:

$532 / 1.0 MT = **$532** per MT GHG reduced

If the LCFS pathway includes paying for a charger:

1) If the charger pays for itself via charges on top of electricity rates, then the cost effectiveness remains at **$109 - 532 per MT**
2) If the charger is used by one person and costs $5,000, and the cost is spread over 25 years at 7% interest, that is $5,000 x .08581 = $429 per year.
   Then the cost effectiveness is ($532 + $429)/4.9 = **$196/MT**
   Of course this number depends on the assumed cost of the charger, which could be much less for a single family home vs. an apartment.
3) If the charger is a public DC fast charger:

   This study:
   https://www.sciencedirect.com/science/article/pii/S2213624X23000238 says:
   We find that costs can range between $122,000 and $440,000 for corridor DCFCs from the sites we studied.

   Using $200,000 as the cost of the charger
   Assuming the same 5 people use it per day (this is a wild guess–data would be helpful here), and assuming that they would not have bought an EV without the charger

   Each car saves 4.9 MT of GHG per year; so 5 cars save 24.5 MT
   $200,000 x (Cap Rec Factor, i=7%, n= 25 years) = .08581 x $200,000 = $17,162/year
   $17,162/5 cars = $3,432 per car
   Solar cost + charger cost = ($532 + 3432) = $3,964 per year

   $3964 per year / 24.5 MT = **$162/MT**

Discussion of electrification:

The cost effectiveness of supporting solar to charge an EV can be fairly strong if the cost of the charger is low. The cost effectiveness of funding high speed chargers is also not too high, and these are important to eliminate range anxiety by EV buyers. Fortunately federal infrastructure funds are now available for high speed chargers, so this does would assist LCFS funding.

The conclusion of this section is that using LCFS funds to support solar and EV charging could be a good use of the program’s funds. Proposals would need to be evaluated to see how cost effective they are likely to be.