Low Carbon Fuel Standards Program (LCFS)

–Jack Lucero Fleck 12-19-22
Jack@350BayArea.org

I. Summary

Achieving 40% Greenhouse Gas (GHG) reductions by 2030 in accordance with California's SB32 will be difficult. Scientific consensus has developed around sobering evidence that the window for mitigating the climate crisis is closing faster than expected, making achievement of the 40% GHG reduction target by 2030 extremely urgent.

To help meet this goal, the LCFS is a major project of the California Air Resources Board (CARB). The LCFS charges producers of dirty fuels to subsidize alternative fuels. In 2021 the LCFS issued 20 million metric tonnes (MMT) of credits at an average of $188 per tonne[1] (1 credit = 1 metric tonne) for a total of $3.8 billion for alternative fuels. (from the LCFS Data Dashboard, spreadsheet by clicking on Fig. 4) Clearly, this is a program that climate activists need to understand.

The core concept of the LCFS–making the polluters pay for producing dirty fuels–is a good one. The main criticism of the program is that it is subsidizing biofuels, which are not really qualitatively better than the fossil fuels they are replacing. The LCFS may also support Carbon Capture and Storage technology, which is expensive and of doubtful value, and also extends the life of fossil fuel production. On the other hand, the LCFS subsidizes electricity and, potentially, clean hydrogen for transportation, which is a very good thing.

This report looks at how the LCFS could continue and expand its funding for truly clean fuels, primarily electricity, and cut back on funding biofuels.

A main conclusion is that prospects for biofuels in vehicular transportation are very short-term, and will have a minimal role by 2035. Unfortunately, biofuels may cause as much or more damage as they provide benefits, as discussed below in the section on biofuels. (page 14)

[1] The average price in 2022 has fallen to around $60 per tonne.

Another main conclusion of this report is that, in spite of the difficulties, the prospects of deep GHG emission cuts in the years after 2030, when 100% of auto sales are likely to be EVs, are very good.

II. Explanation of the LCFS

The key to understanding the LCFS is Carbon Intensity (CI). Each alternative fuel has a carbon intensity that is measured in grams of CO2e per megajoule of energy.[1] Gasoline has a CI of 101 as shown in Figure 1. source: page 17 of LCFS Basics with Notes.

Figure 1

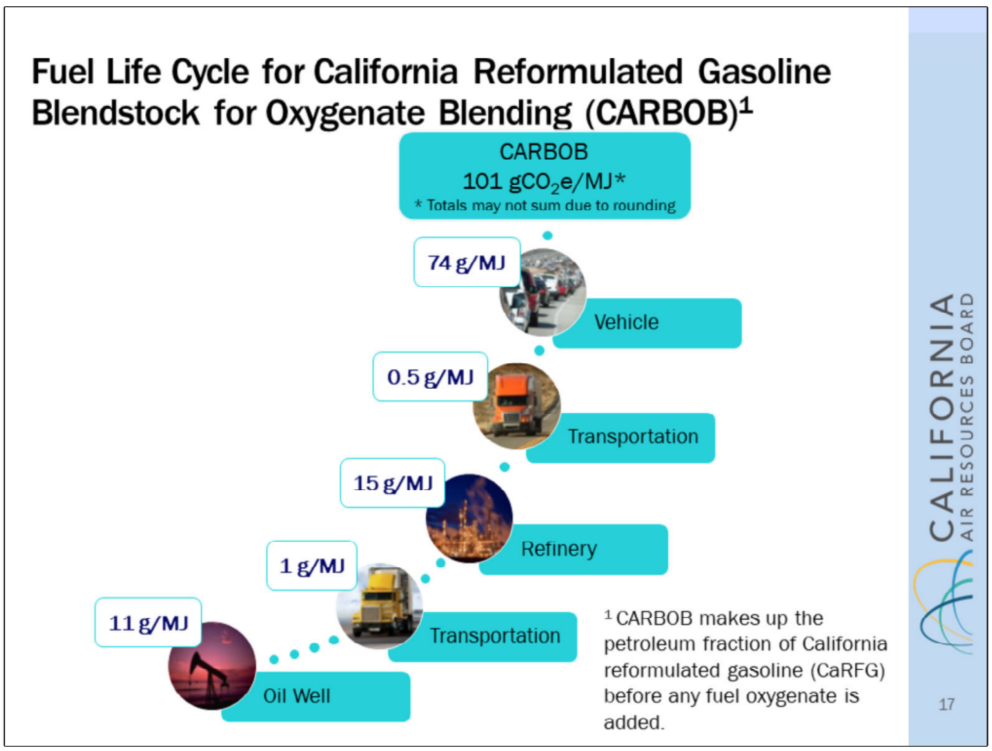
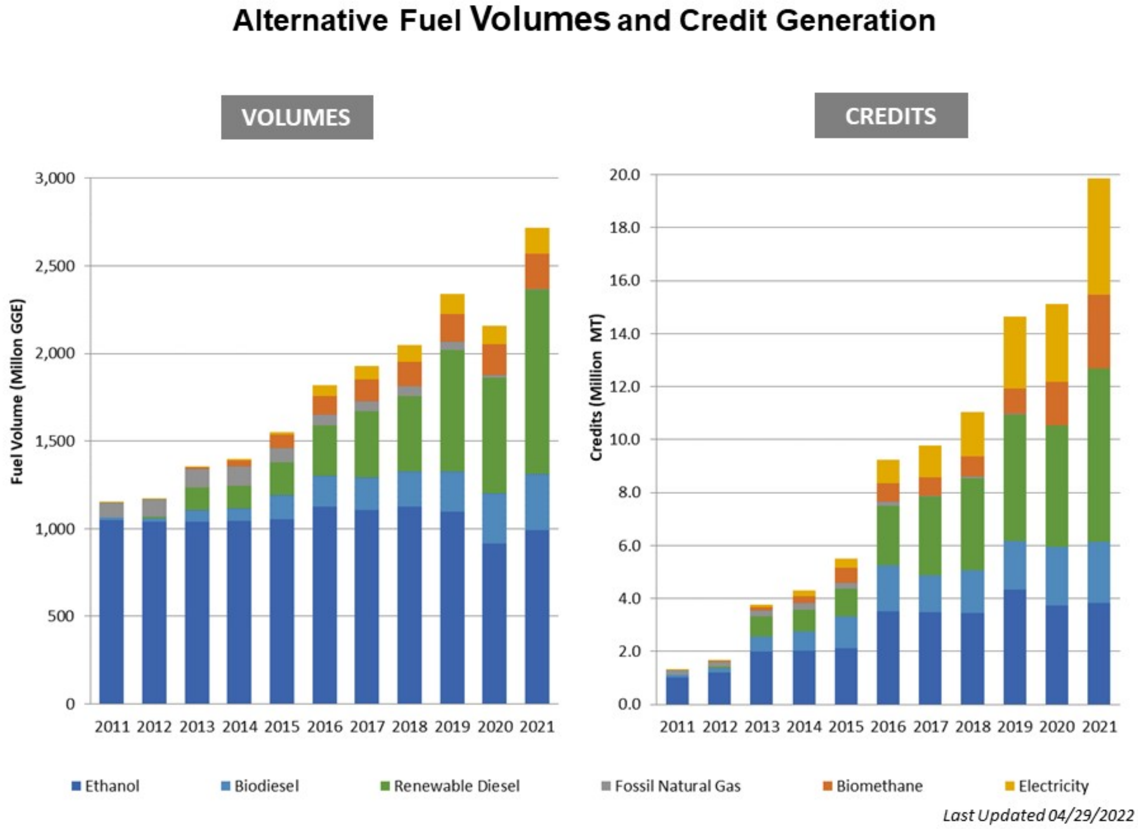


Figure 2 below shows the volumes of alternative fuels and the credits that they earn. One credit represents 1 metric tonne (MT) of GHG reduction. Fuels with a Carbon Intensity (CI) higher than the average (aka “the benchmark”) pay to the LCFS to subsidize the fuels with lower CIs. The lower the CI, the higher the credit–e.g. as shown in Fig. 2, ethanol has a high volume of sales, but a relatively lower number of credits than other fuels, while electricity has a small volume, but a large number of credits.

[1]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)

Figure 2 (from [LCFS Dashboard])



The CI Averages for fuels are shown in the "Fuels" tab on the spreadsheet linked to Figure 3 in the LCFS Data Dashboard. Table 1 shows CI's for the most important fuels for 2021:

Table 1 – CI for primary fuels

Fuel Type	**CI (g/MJ)**
Biodiesel	28
Biomethane	-5
Fossil Natural Gas	80
Electricity	27
Ethanol	60
Renewable Diesel	36
Gasoline (and diesel)	101

Taking the CI for each fuel and multiplying it by the volume of that fuel (also from Fig 2 data link in LCFS Dashboard) and then dividing it by the total volume of all fuels gives a weighted average for the CI for all fuels. A calculation is shown in Table 2 below for 2021. The CI of Electricity is divided by 3.4 (Energy Efficiency Ratio–EER) to account for its extra efficiency.

Table 2–2021 Calculation of CI

	CI/EER	Volume–GGE[1] Millions	CI x Volume
Biodiesel	28	318	8904
Biomethane	-44	202	-8888
Fossil Natural Gas	80	5	400
Electricity[2]	23	149	3427
Ethanol	60	994	59640
Renewable Diesel	36	1,049	37764
Gasoline[3]	101	12396	1251996
Diesel[3]	101	2517	254217
Total		17630	1607460
Average CI =		91.2	

[1]Gallons of Gas equivalent (GGE) is the amount of alternative fuel it takes to equal the energy content of one liquid gallon of gasoline.

[2] Electricity value of 23 is taken from CATS model, which is lower than the Fuels Tab value of 27; see Addendum point 6

[3] Gasoline & Diesel = total in 2021 from fuels tab, "volumes", linked to Fig 3 in the LCFS Data Dashboard

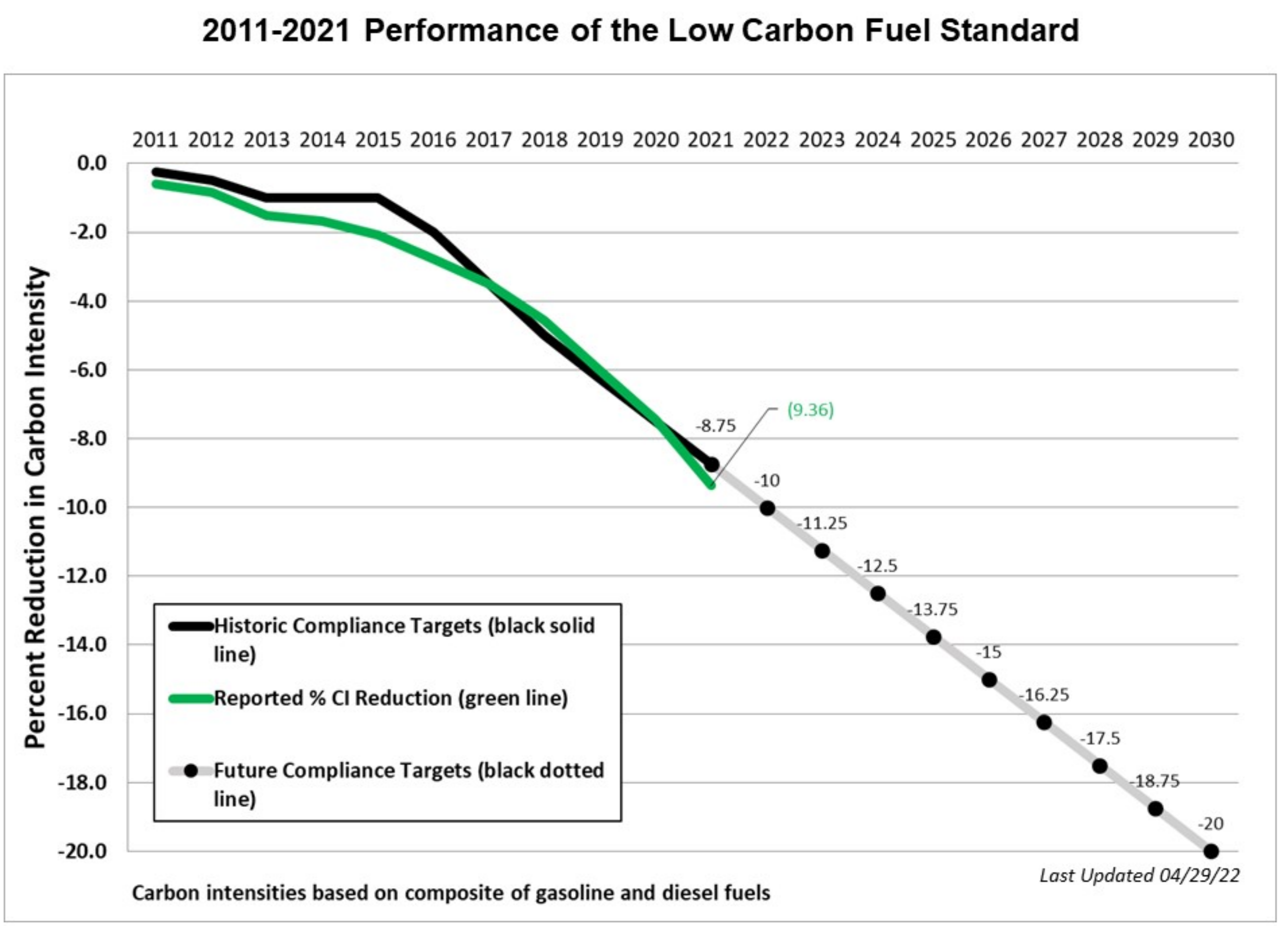
The calculated overall CI of 91.2 g/MJ in 2021 in Table 2 is 9.7% below the CI of gasoline, which has a CI of 101 as noted above. Figure 1 in the Data Dashboard–shown below as Figure 3–shows previous and projected decreases in CI; it estimates the drop in CI to be 9.36% in 2021, i.e. pretty close to the estimate from Table 2.

Table 2 shows that the average CI is based on the CI for the various fuels used in California and their volumes. This average CI may be lowered by reducing the CI for fuels used and/or by increasing the volumes of fuels with lower than average CIs.

If the total energy consumed by transportation were constant, this would predict almost a 10% drop in GHGs from transportation since the program began ten years ago. As discussed below, there has been no actual drop in GHGs from transportation since the program began in 2011.

The State's formal goal is to achieve a 20% reduction in the CI by 2030 as shown in Figure 3. But CARB is considering increasing that to as much as a 35% reduction. ***The Transportation sector cannot achieve the State's goal of 40% GHG reduction by 2030 (SB 32) without a much stronger reduction in the CI than 20%.***

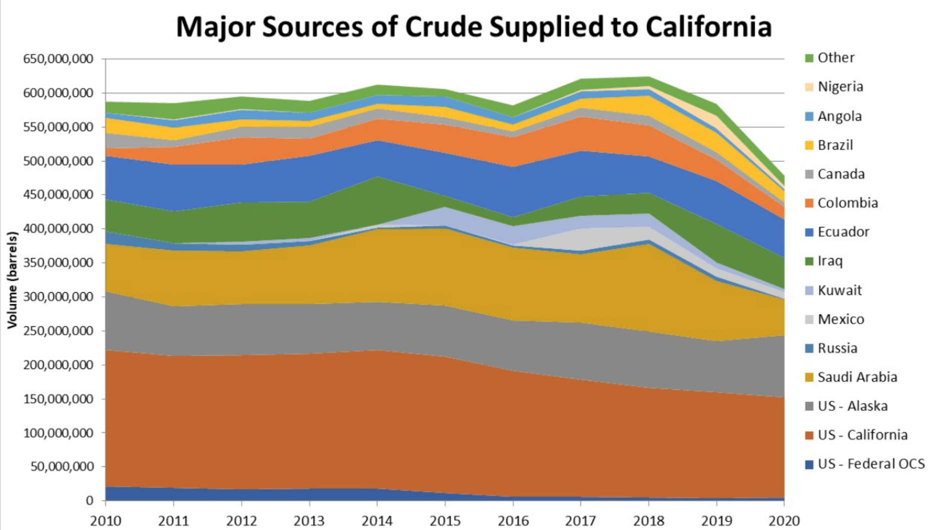
Figure 3



Is the program working?

Fig 4 below shows that the use of gasoline and diesel in California has not dropped since LCFS began in 2010, except for the Covid impacted years of 2020 and 2021. Source: Figure 8 in the LCFS Data Dashboard.

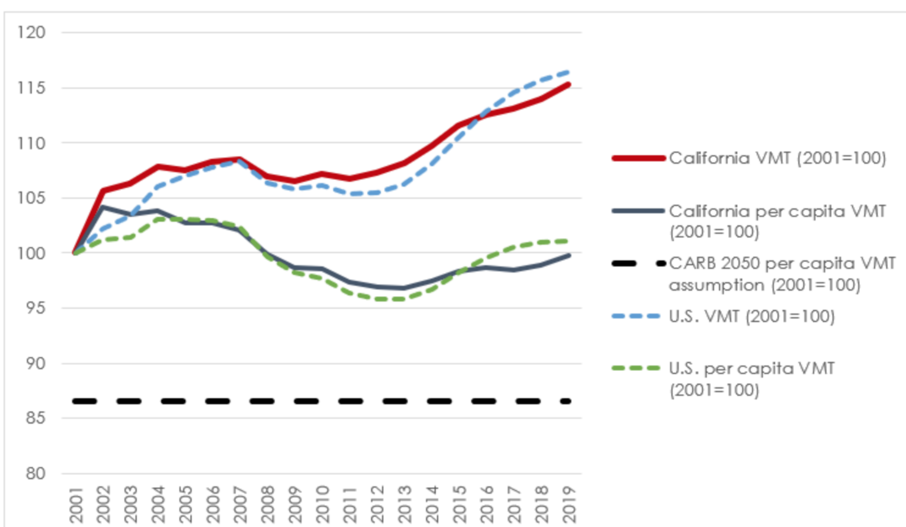
Figure 4



This figure depicts the major sources of crude oil supplied to California Refineries from 2010 to 2020. Crude oil from California, Alaska, and 11 countries account for over 95 percent of the volume supplied to California in any given year.

Figure 4 suggests that the main benefit of the LCFS so far has been to avoid an <u>increase</u> in California oil consumption and GHG emissions, rather than achieving an actual decrease as is urgently needed. The main reason for this failure to reduce GHGs has been an increase in Vehicle Miles Traveled (VMT) since 2010. According to Figure 5 below [from Caltrans](), VMT has increased by about 8% since 2011, which more or less negates the 9.4% reduction in CI in that same period.

Figure 5–VMT increasing trend



CARB's 2022 Scoping Plan Update accurately states, "Sustained VMT reductions have been difficult to achieve for much of the past decade, in large part due to entrenched transportation, land use, and housing policies and practices." (Page 193) In fact there is no concrete plan by CARB, Caltrans, or Metropolitan Planning Organizations to achieve significant cuts in VMT (see discussion in Addendum Point 2).

But real cuts in GHGs are possible by combining electrification with modest VMT reductions. This paper will explore various scenarios in which the State reduces its Greenhouse Gases toward the goal of zero emissions without relying on problematic biofuels, biogas or Carbon Capture and Sequestration (CCS) to do so.

III. Alternative Scenarios: What can be done to promote more cuts in GHGs from transportation?

Note: At this point, this analysis explores various options and scenarios, so the discussion is necessarily more speculative than the preceding analysis. The numbers are still based on CARB, California Energy Commission (CEC), and other state sources for information wherever possible, and calculations are shown or linked to the Addendum. But there are many ways to view this, so this analysis is more of a way to spur discussion than a definitive proposal.

We encourage others to explore and develop their own creative scenarios. We do think that the spreadsheet developed above is a useful tool to explore alternative scenarios as shown below. We welcome comments and suggestions on these scenarios.

Scenario 1: 20% Reduction in CI by 2030

As noted, CARB's present goal is to reduce the average CI by 20% by 2030 as part of its goal to achieve 40% GHG reductions by 2030. Below is a set of assumptions, alternative fuel volumes and CI's, that could achieve this.

There are two factors in addition to CI which can help California reach its climate goals in transportation–reducing VMT, and improving fuel efficiency (i.e. miles per gallon–mpg). From the rough calculations in points 1 & 2 in the Addendum, there could be an 8% GHG reduction from light duty vehicles from these two factors by 2030. These factors are worked into the average CI calculations here by reducing the volumes of gasoline and ethanol in the spreadsheet. Unfortunately, it must be noted that no Metropolitan Planning Organization has been able to stop the growth in VMT, let alone achieve reductions.

Additional assumptions in Table 3 are listed here:

- CI of ethanol drops from 60 to 50 g/MJ – Addendum point #3
- CI of electricity drops from 23 to 14 as the grid gets cleaner (Addendum Point #4)
- Ethanol volume reduces to 686 million GGEs– Addendum point #3
- Electricity for cars increases by 8 times (8 million EVs compared to 1 million in 2021) = 8 x 149 m GGEs =1192 million GGEs)
- Truck electrification reduces 400 million GGEs; calculation in Point 5 in the Addendum. Total electricity volume = 1192 + 400 = 1592
- Gasoline drops to 8553. (Addendum point 3)
- Biodiesel and renewable diesel volumes use CARB's Mobile Source Strategy (MSS) estimates (page 194)
- Biogas stays the same as 2021 (202 GGEs from Figure 2 data link in the LCFS Dashboard)
- Diesel is decreased by the amount switched to renewable diesel (51), biodiesel (182) and Electric Trucks (400) = 633, but increased by 8% for all diesel and biodiesel assuming 1% increase per year for truck traffic = 8%x 2517 = 201. Total for fossil diesel = 2517- 633 + 201 = 2085

Table 3–Calculation of Average CI in 2030 with CARB MSS projections
Goal is 20% reduction in CI by 2030

	CI/EER	Volume–GGE	CI x Volume
Biodiesel	28	500	14000
Biomethane	-44	202	-8888
Fossil Natural Gas	80	5	400
Electricity	14	1592	22288
Ethanol	50	686	34300
Renewable Diesel	36	1,100	39600
Gasoline	101	8553	863853
Diesel	101	2085	210585
Total		14723	1176138
Average CI =	79.9		

The good news in Table 3 is that the CI achieves the goal of 20% reduction–a CI of 79.9 projects a reduction of 20.1% from a starting level of CI = 100 in 2012.

The bad news is that, even with a very aggressive goal of reducing VMT (5%), improving fuel efficiency of gas cars (3%), and achieving 8 million electric light duty vehicles and 250,000 electric trucks, the total reductions in GHGs from vehicles are still only about 20%, i.e. well short of the at least 40% needed. And the LCFS doesn't count the more difficult-to-achieve emissions from aviation, shipping, trains, and off-road vehicles.

Scenario 2: Increase mileage assumed by EVs

One adjustment to the LCFS numbers in Table 3 could be in the miles driven by an EV. As calculated in point #4 in the Addendum, 149 million gallons in GGE reductions for EVs equates to only about 5200 miles of electric driving per year. However, according to the CATS model (page 5) . EVs are driven an average of 10,400 miles per year, compared to 12,433 miles for ICEVs. This would change the gas savings per EV from 149 gallons per year to 287 gal/year. (see Addendum Point 4), and the CI drops to 75.3 as shown in Table 4.

Note on gasoline: Assuming that more miles driven per year on EVs should reduce the gallons of gasoline consumed, but this calculation gets complicated, so, to be conservative, Table 4 shows the same values for gasoline and ethanol as Table 3.

Table 4–Assuming 10,000 miles per EV

	CI	million GGE	CI x GGE
Biodiesel	28	500	14000
Biomethane	-44	202	-8888
Fossil Natural Gas	80	5	400
Electricity	14	2696	37744
Ethanol	50	666	33300
Renewable Diesel	36	1,100	39600
Gasoline	101	8553	863853
Diesel	101	2085	210585

Total		15807	1190594
Average CI =		75.3	

Table 4 shows a 24.7% decrease in CI and therefore GHG emissions from vehicles by 2030, without any increase in biofuels.

How can we increase this reduction?

Scenario 3: Increase number of EVs to 10 million:

One achievable step would be to increase the number of EVs from 8 million to 10 million. This would drop the Average CI to 69.9 as shown in Table 5.

- Electricity increases by 12/8 x 2296 = 3440 + 400 diesel = 3840 (also see Addendum #4b)
- Gasoline drops to 7809 and ethanol drops to 626. See Addendum point #3 for calculation.

Table 5

10 million EVs in 2030 with CARB MSS assumptions for biofuels

	CI	**Volume(million gallons of gas equivalent–GGE)**	**CI x Volume**
Biodiesel	28	500	14000
Biomethane	-44	202	-8888
Fossil Natural Gas	80	5	400
Electricity	14	3840	53760
Ethanol	50	626	31300
Renewable Diesel	36	1,100	39600
Gasoline	101	7809	788709
Diesel	101	2085	210585
Total		16167	1129466
Average CI =		69.9	

Table 5 shows that with a 2030 EV adoption target of 10 million by 2030, the state can achieve a 30.1% reduction in CI without increasing biofuels. This is an appropriate goal for CARB to adopt for LCFS.

Could we adopt more EVs to achieve a 40% reduction? California is currently on track to achieve 100% EV sales in 2031 (see Addendum Point #7a), with 8 million EVs on the road in 2030, so 10 million does not seem out of reach. To reach 10 million EVs solely based on new car sales–i.e. not counting any buy-backs of existing cars–the state would need to reach 100% EV sales by 2027 and aggressively increase sales in the years before that. (Addendum Point 7c)

Several funding additions are likely to accelerate the pace of EV adoption:

- The federal infrastructure bill with its National Electric Vehicle Infrastructure funding
- The Inflation Reduction Act,
- The state's one time surplus of $54 billion in 2021,
- Several billion dollars a year from the LCFS depending on the price of credits. In 2021 as shown in Figure 2 above, 149 million GGEs of electricity generated 4.4 million credits. At that rate, 3270 million GGEs as shown in Table 5, would generate almost 100 million credits. Even at $50 per credit, that would be $5 billion per year. This is also calculated in Addendum 4d.

These funding factors, coupled with current sales trends, all make accelerating EV sales to reach 10 million EVs by 2030 a distinct possibility. It's possible that the state could move even faster, which would be highly desirable given the urgency of the climate crisis.

A confounding factor re: speed of EV adoption is EV charging infrastructure. The trifecta of significantly ramping up charging station installations, assuring a high degree of charging reliability, and prioritizing rollout of a high percentage of DC fast charger units is a major challenge, but is all achievable.

Scenario 4: Increase hydrogen made from electrolysis of water using clean energy

Making electrolytic hydrogen affordable has been referred to as the "moon shot" by the Biden administration. To give this a big boost, the Inflation Reduction Act (IRA) is proposing a $3 per kg subsidy for electrolytic hydrogen. This could be a problem if a lot of hydrogen is produced using electrolysis from the existing power grid. Figure 6 shows that the CI for hydrogen using California's grid is 164; the CI would be higher in states that have less renewable electricity than California.

More hydrogen would also be a problem if it continues to be made primarily from methane, releasing CO2 in the process. As shown in Figure 6, the CI for hydrogen produced by Steam Methane Reforming (SMR) is 100 - 150.

These CI values need to be divided by hydrogen's Energy Efficiency Ratio (EER), which is around 2.0 (from the data sheet linked to Figure 7 in the LCFS Dashboard), to give the adjusted CI. This gives a CI of 50 - 75 for SMR and around 82 for California's grid. The LCFS should oppose subsidies to these forms of hydrogen in favor of hydrogen made from electrolysis using clean energy (clean hydrogen)

Figure 6 also shows that clean hydrogen has a CI of 10.51. Dividing that by 2 gives an adjusted CI of 5. .

Figure 6 (GREET Lookup Table)

Table F.1. Hydrogen Lookup Table Pathways

Fuel Pathway Code	Pathway Description	Total CI gCO_2e/MJ
HYF	Compressed H_2 produced in California from central SMR of North American fossil-based NG	117.67
HYFL	Liquefied H_2 produced in California from central SMR of North American fossil-based NG	150.94
HYB	Compressed H_2 produced in California from central SMR of biomethane (renewable feedstock) from North American landfills	99.48
HYBL	Liquefied H_2 produced in California from central SMR of biomethane (renewable feedstock) from North American landfills	129.09
HYEG	Compressed H_2 produced in California from electrolysis using California average grid electricity	164.46
HYER	Compressed H_2 produced in California from electrolysis using solar- or wind-generated electricity	10.51

With the IRA subsidy, the price of clean hydrogen has suddenly become competitive with SMR hydrogen. And the subsidy brings the price well below the cost of hydrogen with Carbon Capture, Utilization and Storage (CCUS). (source)

The question remains as to how much hydrogen will be produced from clean energy in coming years. In the 2nd Quarter of 2022, hydrogen production amounted to about 750,000 GGEs (fuels tab). This compares to 53 million GGEs for electricity, 350 million

GGEs for renewable diesel, and over 3 billion GGEs for gasoline. I.e hydrogen is currently statistically insignificant.

But with the new IRA subsidy and other potential funding (including from LCFS), clean hydrogen should increase rapidly. Hydrogen, if it's clean, can address long haul heavy duty vehicles, freight trains, ships and other industrial uses. There are widely varying estimates of how fast hydrogen production will grow. [This document from the International Energy Agency] estimates that hydrogen will grow from less than 1 MMT to 180 MMT by 2030, and of that, 65 MMT will be clean hydrogen and 30 MMT will be produced with SMR using Carbon Capture and Storage (CCS).

If we use the current volume of 750,000 GGEs in the 2nd quarter of 2022, that would be 3 million GGEs per year. A factor of 65 would bring that to 195 m GGEs. This would give the results shown in Table 6, reducing the average CI from 69.9 to 69.1, a 30.9% CI reduction.

Table 6
Year 2030 with 65 times increase in clean hydrogen from 2022

	CI	**Volume(million gallons of gas equivalent–GGE)**	**CI x Volume**
Biodiesel	28	500	14000
Biomethane	-44	202	-8888
Fossil Natural Gas	80	5	400
Electricity	14	3840	53760
Ethanol	50	626	31300
Renewable Diesel	36	1,100	39600
Gasoline	101	7809	788709
Diesel	101	2085	210585
Hydrogen	5	195	975
Total		16362	1130441
Average CI =		69.1	

What about biofuels?

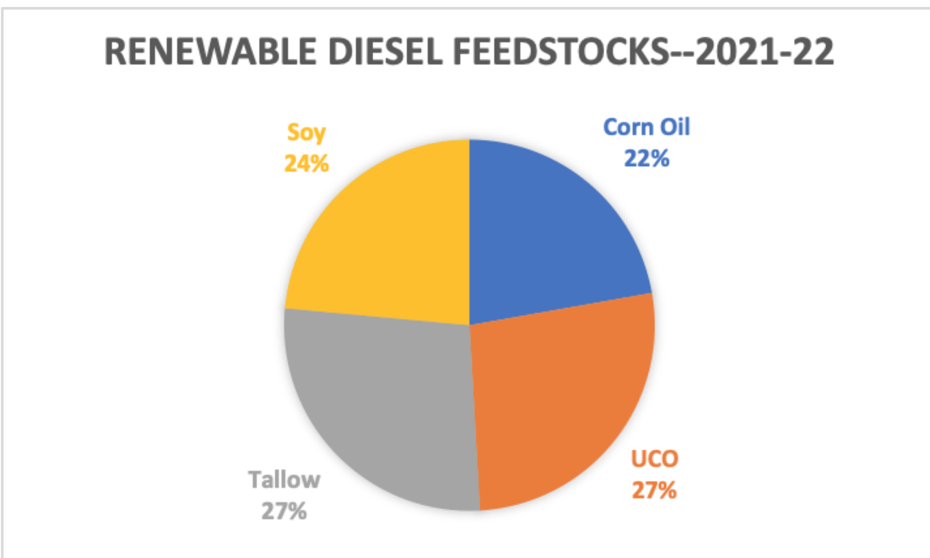
Renewable diesel production in 2021 was 1049 million GGEs. As discussed below, in the past 4 quarters, renewable diesel exceeded the CARB MSS estimated level of 1.1 billion GGEs in 2028. Refineries at Martinez and Rodeo are planning to add 1400 million GGEs if they fully build out.

Is this expansion of biofuels a) realistic, b) necessary and c) desirable?

a) **Are feedstock supplies realistic? Used Cooking Oil (UCO) and Tallow vs Soy and Corn Oil**

As shown in Figure 7, just over half of renewable diesel today is produced with Tallow and UCO. However, the supply of these is limited. Soy oil has more than doubled in the past few years and will likely be the main feedstock going forward. Corn Oil is a byproduct of ethanol production, which is projected to decline as ICEVs are phased out; corn oil is also a food product, which calls into question its use as a fuel feedstock.

Figure 7 (Source: Fuels Tab from Figure 3 in LCFS Dashboard)



Is this sustainable? Assume soy would account for 80% of the growth in feedstock, and renewable diesel doubles–this would be about 800 million GGEs of soy oil. One acre of soybeans produces 76 gallons of soy oil. Therefore, 800 million gallons would require 800/76 = 10.5 million acres. At 640 acres per square mile, that would be over 16,000 square miles of soybeans. This would be about 1/4 of the state of Iowa, which is already pretty much taken up by corn and soybeans. And we certainly don't want to destroy the Amazon forest, or any forests by planting soybeans; the loss of sequestered carbon in trees is much greater than small amounts of carbon in soybeans, and needs to be accounted for. So, in spite of the plans of Marathon and P66, this is not a sustainable course of action. ***The State should prohibit importing soy oil due to this massive land use impact.***

CARB's Mobile Source Strategy has a much more modest expectation for the growth of biofuels, based on a 20% CI reduction goal. They say, "After 2030, BD and RD volumes are assumed to be constant at 500 m gallons and 1.1 billion gallons annually respectively." The problem is that CARB wasn't expecting renewable diesel to hit 1 billion gallons until 2028 using the LCFS Compliance Scenario Calculator, whereas in reality, it is already at 1.15 billion gallons in the past four quarters. (Fuels Tab)

The existing soy oil being used for renewable diesel requires about 5000 square miles (240 million gallons/76 gallons per acre/640 acres/sq mi) This is already excessive and should not be allowed to increase.

b) **Are biofuels necessary? Scenario 5–Calculation of CI in 2035:**

CI for light duty vehicles will be plummeting by 2030, especially assuming 100% of new vehicles are EVs. In addition, the technology for ZEV trucks should be more advanced, enabling higher percentages of ZEV trucks in the overall fleet. Table 7 estimates the average CI in 2035 based on these assumptions:

- The state will add 1.8 million EVs every year after 2030. I.e. there will be a total of 19 million light duty EVs in 2035
- Electricity is calculated at 7468 million GGEs in 2035. See Points #5 and #6 in the Addendum.
- Gasoline is reduced to 4105 million GGEs. See Point #3c in the Addendum.
- Electric diesel trucks reduce diesel use to 472 m GGEs. See Point #5 in the Addendum
- CI for electricity is reduced to 5–90% clean energy. Addendum Point #4a.
- Hydrogen increases at the same rate as 2022-2030 (65 fold increase in 8 years would be 105 fold increase in 13 years) 105 x 3 = 315.

Table 7: Calculation of Avg CI in 2035

	CI	GGE (millions)	CI x GGE
Biodiesel	28	500	14000

Biomethane	-44	202	-8888
Fossil Natural Gas	80	5	400
Electricity	5	8551	42755
Ethanol	50	329	16450
Renewable Diesel	36	1,100	39600
Gasoline	101	4105	414605
Diesel	101	472	47672
Hydrogen	5	315	1575
Total		15579	568169
Average CI =		36.5	

Tables 5 and 6 showed that reaching the goal of 40% GHG reduction by 2030 will be difficult without biofuels–the 30.9% reduction shown in Table 6 is well short of 40%. However, Table 7 shows that in the years beyond 2030, biofuels will not be needed to achieve dramatic reductions in GHGs from transportation. The calculated CI in 2035 of 36.5 is a 63.5% reduction. If VMT can make gains consistent with the MSS estimates, the average CI in 2035 would be even lower.

c) Is there still a role for biofuels?

Table 6 from the CATS model, shown below, shows that the CIs for waste oil–tallow and used cooking oil– are much lower than for virgin oil–corn oil and soy. This means that waste oil may still receive a small LCFS subsidy as late as 2035–i.e. their CIs are lower than the benchmark of 36.5 But corn oil and soy will stop receiving subsidies around 2032 as the CI falls from 67.4 in 2030 to 36.5 in 2035, hitting 55 around 2032.

Table 6. Carbon Intensity Estimates for Bio-/Renewable Die:

Technology	Carbon Intensity Estimate (gCO_2e/MJ)
BD Virgin Oil	55
BD Waste Oil	25
RD Virgin Oil	56
RD Waste Oil	31

Since the projected time period for the useful role for biofuels is short, even without further regulatory action discussed below, the LCFS should send market signals to manufacturers to stop investing in biofuel infrastructure. This may be a case where additional legislation is needed.

d) Are biofuels desirable? How can their subsidies be reduced?

Even if the CI for biofuels could be reduced, say with CCS as discussed below, would that be desirable? Biofuels still pollute frontline communities near refineries and diesel engines pollute neighborhoods near freeways, ports, and warehousing facilities. Since biofuels cannot achieve zero emissions, their benefits are only marginal and short term. CARB should make every effort to discourage any further expansion of biofuels.

One step to discourage biofuel production would be to impose a land use assessment of 20g/MJ on the soy CI, bringing it up to around 75g/MJ. This assessment is already done for ethanol. This would decrease the current subsidy by over 50%. (Addendum 4d) This would also eliminate biofuel subsidies by 2029, given the aggressive decline in average CI to 69.1 in 2030 as shown in Table 6.

Corn oil is also a food source, like soy oil, and should therefore be discouraged for use as a fuel. Corn oil is a byproduct of ethanol production, which, as mentioned, already has a land use assessment, so it may not be appropriate to add such a land use assessment to the CI for corn oil. However, since it is a food product, it should not be treated as waste, and its CI should be assessed differently than, say, used cooking oil.

A good solution would be to cap soy oil and corn oil production at their current levels–i.e. no more projects should be approved by CARB. This would allow existing producers to continue, but stop any added production. This same proposal applies to biogas as discussed next.

What about biogas?

Another controversial issue is biomethane or biogas. This can be made from digesters at waste plants, landfills or dairies. Biogas from landfills has a CI around 60 and therefore, like biofuels, has a short term, limited future with LCFS.

However, biogas from dairies has an average CI of **minus 293!** (CATS model, page 13) That negative CI makes it eligible for huge subsidies. The subsidies are so great that some dairies are making more revenue from their LCFS credits than from selling milk! This creates a perverse incentive to expand production beyond actual consumer demands for dairy products. The issue of negative environmental impacts of large dairies and landfills needs to be addressed by California's EPA. The LCFS should not be encouraging any increase in the size of dairies.

Tables 1 - 7 above show biomethane volume constant at 202 million GGEs. The CI is shown as -44 from the Fuels Tab of LCFS Figure 3, Average CI Table, 2021. -44 is also close to the weighted average shown in Figure 6; this accounts for a combination of dairy and landfill biogas. CARB should cap biogas from dairies at its current level of production to avoid distortions of the dairy business. As with biofuels, existing production can be continued, but should not be allowed to expand.

What about aviation?

Even if biodiesel and renewable diesel are not increased for trucks, and ethanol is phased out for gasoline, proponents of biofuels argue that they can be used for jet fuel for aviation to reduce GHGs in this difficult-to-reduce application. Opponents respond that people living near refineries still face pollution and health impacts from production of biofuels, and that biofuels will never get us to zero emissions. It may be that aviation could be permitted to use biofuels as they are phased out of vehicle use. The state could continue current biofuel production levels, but biofuels still should not be allowed to expand production.

What about Carbon Capture and Sequestration (CCS)?

CCS is being heavily touted and funded in both federal and state climate programs. As mentioned, it is projected to be used in biogas production. Environmental justice groups correctly point out that CCS does not reduce many deadly emissions from refineries and pollution from dairies. From the viewpoint of LCFS, in the case of fossil fuels, CCS cannot lower the CI to the point where they should qualify for any funding from the LCFS. In the case of biofuels, CCS could potentially lower the CI to the point where biofuels could continue receiving credits for a few years more than discussed above. For example, the CATS model (page 12), states that the CI for ethanol could be lowered to 35 by using CCS. However, right now there are no CCS installations in California, and the technology is likely to be expensive if it ever works. The prospect of installing large amounts of CCS infrastructure, which will be a stranded asset in 10 - 15 years is not prudent. LCFS funding should go to accelerating the adoption of zero emission vehicles–cars, trucks and buses, not to unproven and costly CCS projects.

How clean are Electric Cars?

The answer to this primarily depends on how clean the generation of electricity is. Fortunately, the CIs calculated by the LCFS include well to wheel emissions. This means that the cleaner the source of the electricity, the lower the CI. With 100% clean electricity, which the state is aiming to achieve by 2040 or sooner, the CI for grid powered electricity should be zero, and electric vehicles should have zero emission.

The LCFS does not include the emissions for producing vehicles. This blog post, using the Argonne Laboratories' Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model. does address this question, and finds that EVs running on clean electricity are about 87% cleaner than ICEVs when you take into account the extra GHGs to produce batteries as well as solar panels and wind turbines. This shows that continued efforts to reduce VMT are important, as well as efforts to recycle battery materials and reduce the carbon footprint of car manufacturing.

Revenue from LCFS

The subsidy for an alternative fuel is calculated by multiplying the number of credits it earns times the value of a credit. The value of a credit fluctuates; one year ago the price was around \$150 per credit, but the current price is around \$60 per credit. 1 credit = 1 Metric Tonne of CO2e reduced. Credits for feedstocks are calculated by this formula from the CATS model

$$Cr_t = \left(CI_{benchmark,t} - \frac{CI_t}{EER_t}\right) \times \gamma_t \times EER_t \times 1x10^{-6} \qquad \text{Equation 6}$$

The formula uses the difference between the CI of the benchmark and the adjusted CI of the feedstock, and multiplies it by the volume in GGEs, plus Energy Efficiency Ratio (EER) and some constants to convert GGEs to Metric tonnes. Calculations in Addendum Point 4(d) give the following subsidies for electricity for 2021, 2030, and 2035:

2021: 4.2 million credits x \$50 = \$210 million (Table 2 volumes; using \$50/credit as a basis for comparison with 2030 & 2035; actual credit price in 2021 was \$188)
2030: 100 million credits x \$50 = \$5.0 billion (Table 6 volumes)
2035: 95 million credits x \$50 = \$4.8 billion (Table 7 volumes)

If these numbers hold true, the LCFS program could be a very powerful tool for elimination of GHGs from transportation!

A more specific example would be a zero emission transit bus. Calculations in Addendum Point 4d indicate that a bus would earn a subsidy of around $16,000–not a lot if the cost of a bus is over $500,000, but it would still be helpful.

Scenario 6–Calculation of CI in 2045

While Scenario 4 shows only a 30.9% reduction in CI (and therefore GHGs) in 2030 -- i.e short of the SB32 goal of 40% reduction, the situation is more positive in 2035 as shown in Table 7. The situation is much more positive in 2045. Table 8, with 100% of light duty vehicles and most trucks running on clean electricity or clean hydrogen, shows a CI of 0.3–i.e. 99.7% GHG reduction.

Table 8
CI calculation in 2045

	CI	Volume(million gallons of gas equivalent–GGE)	CI x Volume	Comments
Biodiesel	28	0	0	transfer 500 GGEs to hydrogen
Biomethane	-100	202	-20200	lower CI to -100
Fossil Natural Gas	80	5	400	
Electricity	0	11330	0	340 GGE/car x 30 million EVs = 10200 plus trucks minus 12% VMT reduction
Ethanol	50	10	500	transfer 319 to electricity; keep some for PHEVs
Renewable Diesel	30	472	14160	transfer 1100 GGEs to hydrogen; lower CI to 30
Gasoline	101	100	10100	transfer 4005 to electricity; keep some for remaining PHEVs
Diesel	101	0	0	transfer 472 to renewable diesel
Hydrogen	0	1915	0	lower CI to 0
Total		15579	4960	
Average CI =		0.3		

IV. Summary

The numbers presented in the spreadsheets and figures in this analysis of the LCFS tell a number of stories. Figure 2 shows that the LCFS is generating 20 million credits. However, most of those credit subsidies ($3.7 billion in 2021) are going to problematic biofuels and biogas.

Tables 2 - 7 show a steady lowering of the average CI, solely by increasing the volume of electric vehicles and by reducing the CI for electricity. Tables 5 and 6 show that the state can achieve a 30% reduction in CI, which is a proposed goal by CARB staff, without any increase in biofuels or biogas.

Table 7 shows that by 2035, subsidies for biofuels, except those made with used cooking oil and tallow, will be eliminated. Tables 5 and 6 also suggest that the number of credits for electricity could generate about $5 billion per year by 2030, which would be a great boost to electrification of transportation and elimination of GHGs from transportation.

Table 8 shows that the state can reach essentially 100% zero emission transportation in 2045, again without biofuels or CCS, and with the existing level of biomethane.

Note that the financial benefits of electrification of transportation, according to the Standardized Regulatory Impact Assessment (SRIA) for the Advanced Clean Cars II rule, far outweigh the costs. So there is every economic reason to proceed with electrification as fast as possible.

It is the recommendation of this report that CARB take these actions:

1. *Reject any applications for expanded production of biofuels or biogas*
2. *Adopt a 30% reduction in average CI standard for 2030.*
3. *Aggressively pursue electrification of cars, trucks & buses as well as VMT reductions.*

V. ADDENDUM – Calculations in this LCFS Analysis

1. **Improved miles per gallon for ICEVs--** If there is a 2% improvement per year (page 93 of the MSS), by 2030 new cars will get 8 x 2 =16% more miles per gallon. The average for cars from 2022 - 2030 will be 8%. However, about half of the cars now on the road will still be on the road in 2030, so the average improvement will be 1/2 x 8% = 4%. This will apply to the 20/28 = 71% of the vehicles which still are ICE (assuming 8 million EVs in 2030), i.e. a total reduction of 4% x 71% = **3%** This would raise fuel efficiency from 25 mpg in 2021 to 26 mpg in 2030.

2. **Vehicle Miles Traveled:** The new Scoping Plan goal is 25% VMT per capita reduction by 2030, and 30% per capita VMT reduction by 2045 (Page 193, 2022 Scoping Plan). As noted in the Scoping Plan quoted on page 7 of this report, VMT reductions are very challenging. And there are no concrete plans on how to achieve the goal of 30% VMT reduction by 2045.

   Therefore, to be cautious, instead of a 25% reduction in per capita VMT by 2030 goal, this paper will use the Scoping Plan goal of 30% per capita reduction by 2045. The per capita reduction needs to be converted into absolute reduction by taking population growth into account. If population grows at 1% per year, there would be about 25% population growth by 2045; this would predict a 25% VMT absolute increase. But coupled with 30% per capita VMT decrease, the actual absolute decrease would be 12.5% (1.25 x .70 = .875) by 2045. Assuming linear decrease, in 2030 this would be 10/25 x 12.5 = **5%**

3. **Ethanol and Gasoline–CI and volumes**

   Reduction in ethanol CI: Gasoline in California currently has 10% ethanol, and this percentage is not expected to change. However, the MSS says on page 83, "CARB staff estimated emissions from producing gasoline in 2020 and 2030, accounting for the anticipated lower carbon-intensity ethanol fuel blends in reformulated gasoline (E10 fuel) due to the 2018 Low Carbon Fuel Standard (LCFS) amendments." The exact amount of the improvement is not specified, but if the current Carbon Intensity (CI) of 60 for ethanol, could be reduced to 50, that would lower the CI for gasoline by 10% x 10 = **1.0%**; this is a reduction of the CI of gasoline from 97 to 96 (From a conversation with Stephen d'Esterhazy from CARB's Industrial Strategies Division on March 30, 2021, the adjusted CI for gasoline can be calculated by 10% x 60 (CI for ethanol) + 90% x 101 (CI for California gasoline) = 97. 10% x 50 + 90% x 101 = 96 CI for gasoline with ethanol in 2030.)

Volume of gasoline: The “fuels tab”, Volumes table, linked to Fig 3 in the LCFS Data Dashboard–Quarterly Summary–adds to a volume of 12396 million gallons of CARBOB (and 2517 for Diesel) in 2021. One way to estimate gasoline volume in 2030 is to use the 8% reduction estimated in Points 1 & 2 for VMT and Fuel Efficiency, and then reduce that volume by the increase in EVs from 1 million to 8 million out of 28 million vehicles = 25%. This gives a total decrease in gasoline by 8% (.92) x 25% (.75) = 31% (.69) in 2030. 12396 x .69 = 8553 (Table 3)

Reduction in ethanol volume: This same reduction applies to ethanol. The data tables linked to Figure 2 in the LCFS Data Dashboard show a 2021 volume for ethanol of 994 GGEs. 994 x .69 = 686 GGE m GGEs. (Table 3)

10,000 miles per EV. This increase in GGEs for electricity could create a further decrease in gasoline, but to be conservative, Table 4 leaves the volumes of gasoline and ethanol unchanged from Table 3.

10 million vehicles (Table 5) gives an additional 2/28 reduction in ICEVs = 7.1% for an overall reduction from EVs by 9/28 = 32% (factor = .68). Adding 8% VMT/Fuel efficiency (factor = .92) we get: .92 x .68 = .63 This lowers both gasoline and ethanol to 37% below 2021 levels. 12396 x .63 = 7809 – gasoline; 994 x .63 = 626 ethanol. (Table 5)

19 million EVs in 2035 (Table 7). The reduction from 2021 would be 18/28 = 64%. Computing GGEs with VMT/Fuel efficiency, we get 12396 x .92 x .36 = 4105 m GGEs gasoline
Ethanol: 994 x .92 x .36 = 329 m GGEs

4. **EV calculations**

a) CI and mpg equivalent:

Using the CATS model (page 13) to calculate CI/EER. In 2022 CI = 76.73/3.4 = 22.6, say 23, gCO2e/MJ
For 2030 (page 14): CI = 47.78 (page 14). CI/EER = 47.78/3.4 = 14 (Tables 3 - 6)
For 2035, using the SB 1020 goal of 90% clean electricity by 2035: In 2021, the CI of 77 is based on approximately 50% zero carbon energy; increasing that to 90% would be a reduction of 40/50 = 80%. This gives a CI of 0.2 x 77 = 15.4.. CI/EER = 15.4/3.4 = 5 (Table 7)

Assuming 8 million out of 28 million light duty vehicles to be EVs by 2030 (from–Mobile Source Strategy (MSS) and current trends), and assuming:

- 3/4 of EVs are Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs) and 1/4 are Plug-in Hybrid EVs (PHEVs), from figure 15 from CARB's 2020 Mobile Source Strategy (MSS)
- PHEV miles are 70% battery and 30% gas, (high end of the estimate on page 93 of the MSS)

CI for EVs: 75% x 22.6 (from the CATS model above) + 25% (70% x 22.6 +30% x 97) = 16.9 + 11.2 = 28 – This accounts for PHEVs higher CI.
Improvement = 97/28 = 3.5 x better than ICEVs. This is the equivalent of 87 mpg (25 mpg x 3.5 = 87 mpg) in 2022 for all EVs and PHEVs.

In 2030: the adjusted EER CI for PHEVs should be: (70% x 14 + 30% x 96) = 39 and the average adjusted EER CI for all LDVs would be: 2/28 x 39 + 6/28 x 14 + 20/28 x 96 = 74. The average CI for EVs would be: 75% x 14 + 25% x 39 = 20
This is 96/20 = 4.8 x better than ICEVs. This is the equivalent of 125 mpg (4.8 x 26 mpg)

With 10 million EVs the reduction would be: 2.5/28 x 39 + 7.5/28 x 14 + 18/28 x 96 = 69. This gives a reduction of (97 - 69)/97 = 29% compared to 2021.

b) Miles driven per year:

There were 1 million EVs on the road in California in 2021 (CEC) The total volume of gasoline equivalents for EVs was estimated by CARB at 149 million GGE in 2021. (Fuels tab from Fig 3 in LCFS Dashboard) This means each EV was given credit for 149 gallons of gas saved. This estimate of 149 gallons per EV predicts that an average EV is driven 5200 miles per year as calculated here:

ICEV = 5200/25 mpg = 208 gallons
EV = 5200 miles/87 mpg = 60 gallons (87 mpg is calculated above in point 4a)
208 - 60 = 148 gallons saved (approximately = 149 as shown in Table 2)

If we continue to use 5200 miles per EV, the gallons saved in 2030 would be:
–ICEV = 5200/26 mpg = 200 gallons (assuming improvement from 25 mpg to 26 mpg for ICEVs)
–EV = 5200/125 =42 gallons
200 - 42 = 158 gallons saved–i.e. 9 gallons more per EV than at present

Using 10,000 miles instead of 5200 miles, we get 10000/5200 = 1.92 x 149 = 287 GGEs per vehicle per year (Table 5).

Using 287 GGEs per vehicle, we calculate
8 million x 287 = 2296 + 400 for trucks = 2696 GGEs (Table 4)

Using 12,000 miles per EV:

12,000/5200 = 2.31 x 149 = 344 GGEs per veh per year (Table 5)

c) Number of EVs raised to 10 million in 2030

10 x 344 = 3440 EVs + 400 diesel EVs = 3840 (Table 5)

For 2035 with 19 million electric cars and 700,000 ZEV trucks: Add 19 x 344 = 6536 GGEs for cars plus 2015 GGEs for trucks (point 5 below) = 8551 million GGEs (Table 6)

d) Revenue from LCFS credits for electricity:

Page 17 calculation: The subsidy for any feedstock is based on the number of credits it receives. The credits are calculated using the difference between the benchmark and the CI for the feedstock. For a soy CI = 55 and a benchmark of 91, the difference is (91-55) = 36. If the CI is raised to 75, the difference becomes 91 -75 = 16. This is a reduction of (36-16)/36 = 55%.

2021 (Table 2): benchmark = 91 gram/MJ. CI/EER = 23 g/MJ. 91 - 23 = 68 g/MJ = difference between benchmark and CI for electricity.
τ = 3.6 MJ/kwh x 33.7 kwh/GGE x 149 m GGE = 18,077 million MJ
Credits for electricity = (91-23) x 18000 x 3.4 x 1 x 10^{-6} MT/gram = 4.2 million tonnes
(this compares to 4.4 million tonnes in Figure 2 of the LCFS dashboard, so the calculations shown below are probably a little low if they follow this pattern)

Subsidy for a transit bus using 2021 numbers.. Assume 50,000 miles per year (source) and 6 miles per gallon (source); **Δ** = 68. EER adjustment = 4.2 for a bus
68 g/MJ x 50,000/6 gal x 4.2 x 10^{-6} MT/g x 134.47 MJ/Gal = 320MT = 320 LCFS credits. If a credit is worth $50, that would be about a $16,000 subsidy per bus.

2030: benchmark (Table 6) = 67. CI/EER for electricity = 14. **Δ** = 63
τ = 3.6 x 33.7 x 3840 = 466,000 million MJ

Credits = 63 x 466,000 x 3.4 x 1 x 10^{-6} = 100 million tonnes
If the credit price is $50 per tonne, that would be $5.0 billion per year for electrification of transportation

2035: benchmark = 31.7 (Table 7) CI = 5 (calculated In 4a above).
Δ = 32 - 5 = 27
τ = 3.6 x 33.7 x 8551 = 1.04 million MJ
Credits = 27 x 1,040,000 x 3.4 x 1 x 10^{-6} = 95 million credits
Again, if credits = $50 each, that would be $4.8 billion.

5. **Trucks** From Figures 19, 21, and 23 in the MSS:

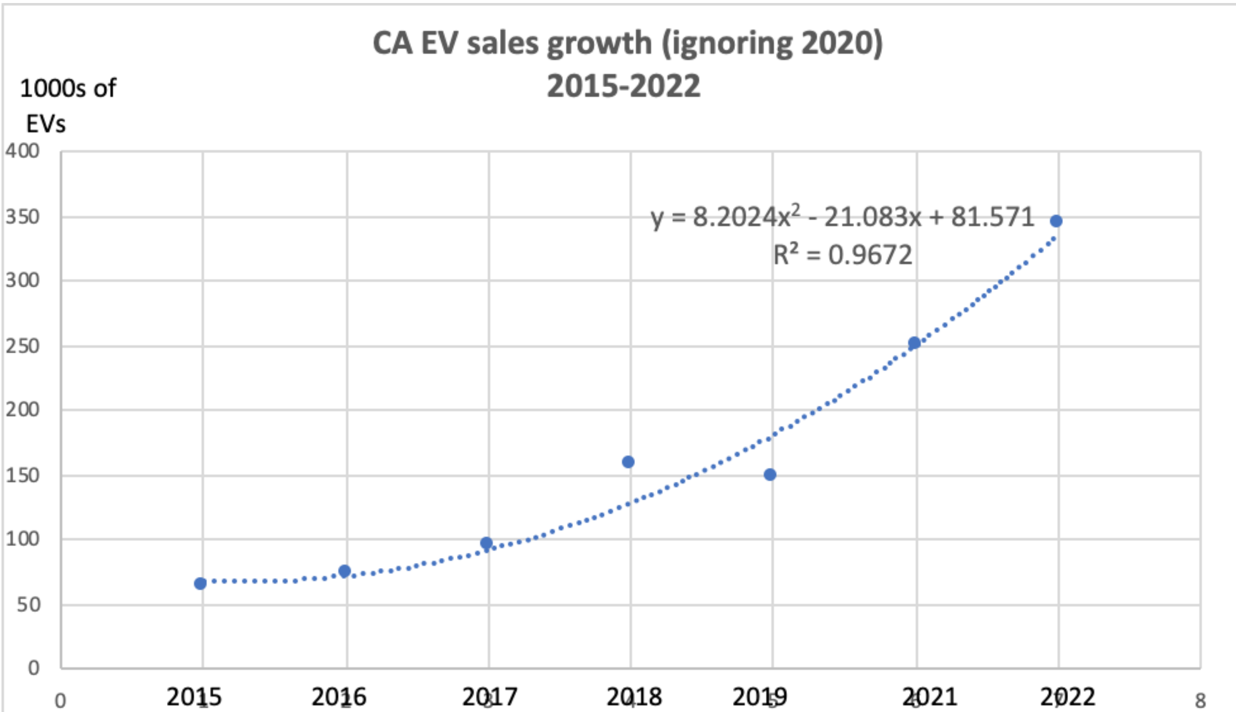
750,000 MDV create 7.2 MMT of emissions
7.2 MMT of emissions x 2200 lbs perMMT / 750,000 trucks x 25 lbs emissions/gal x 10^6 = 845 gal/MDV truck/year
650,000 HDV use 2.4 billion gallons of fuel
2.4 x 10^9 /650,000 trucks = 3692 gal/HDV truck
In 2030:
100,000 HDVs x 3692 gal/truck and 50,000 MDVs x 845 gal/truck will be EV according to MSS = 411 million gallons per year, say 400 with rounding

In 2035 from Figures 21 and 23 in the MSS
500,000 HDV x 3692 gal/HDV = 1846 million gallons
200,000 MDV x 845 gal/MDV = 169 million gallons
Total = 2015 million GGEs
This subtracts 2015 - 400 (previously subtracted) = 1615 GGEs from diesel uses.
Diesel is 2085 in 2030 based on Table 6. 2085 - 1615 = 472 GGEs (Table 7)

6. Trends in EV Sales/Number of EVs in California

a) Current trend

Figure 8



The area under this curve extended to 2030 gives the total number of EVs on the road. This total through 2030 is equal to this integral:

$$\int_{1}^{15} \left(8.2024x^2 - 21.083x + 81.571\right) dx$$

This integral = 8 million EVs in 2030. The quadratic formula in the graph also gives the number of EVs sold in 2031 as 1.8 million which is equal to 100% of sales.

b) CARB's EV sales projection in the Advanced Clean Cars II program (ACC II)

The graph below in Figure 9 shows projected EV sales using numbers from ACC II. Using the formula created by Excel shown on the graph, and projecting to 2030, we get a total of 6.8 million EVs on the road in 2030 (assuming annual sales of 1.8 million). When asked why ACC II is using a lower number than the MSS, CARB Board member Dan Sperling explained that California wanted to make sure that its regulations were replicated in many states, and therefore was a bit cautious in its projections. In this paper, we are using numbers that are tied to California's current sales trends and the MSS projections shown below in Figure 15 from the MSS. (shown below Figure 9)

Figure 9

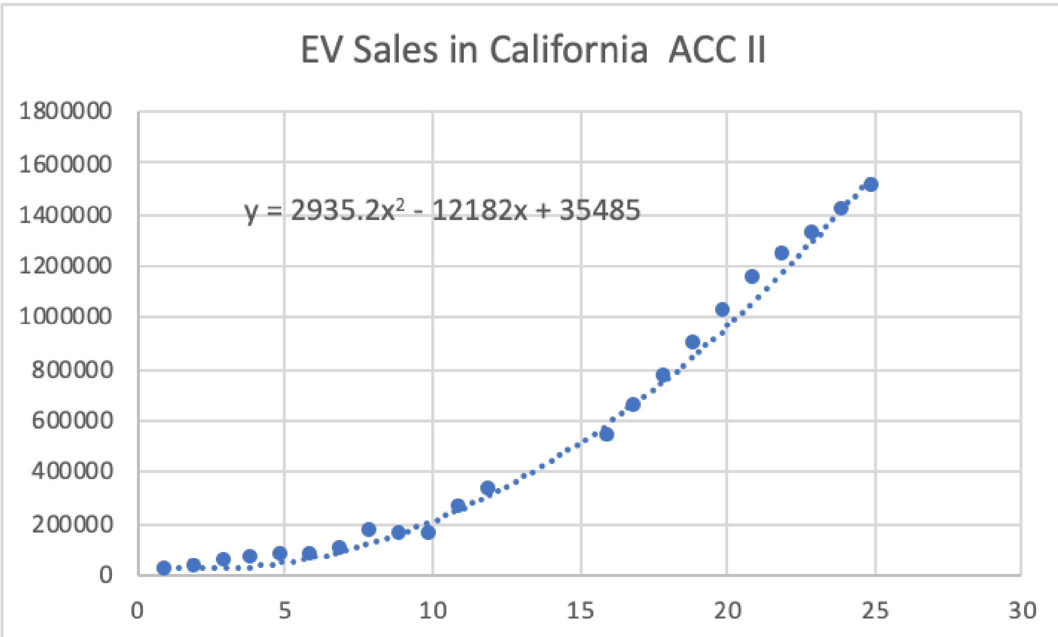
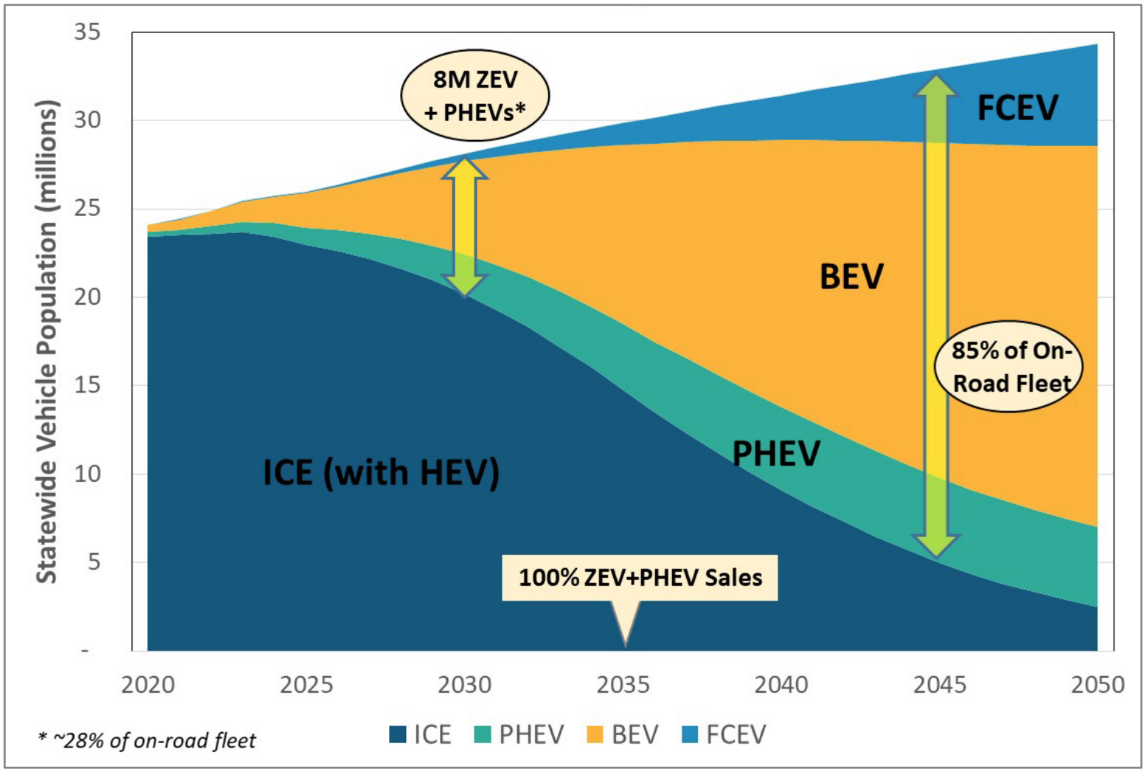
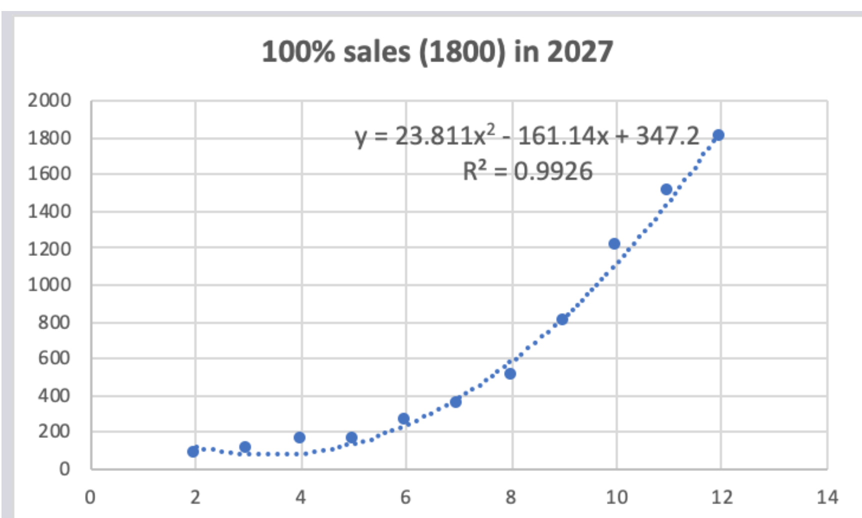


Figure 15 – Statewide Light-Duty Vehicle Technology Penetration in the On-Road Fleet



c) To reach 10 million EVs by 2030:



This graph, showing 100% EV sales in 2027, gives 6 million EVs on the road in 2027. This would mean more than 10 million in 2030 (3 years x 1.8 million/year = 5.4 million)

7. State GHG emissions graphs from CARB

Figure 1-8: 2019 State GHG emission contributions by Scoping Plan sector

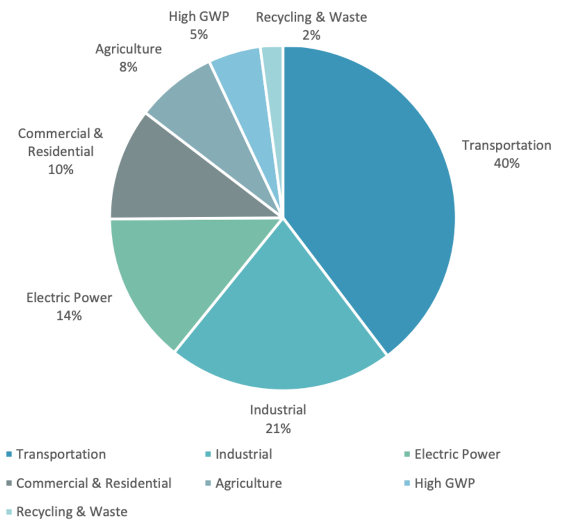
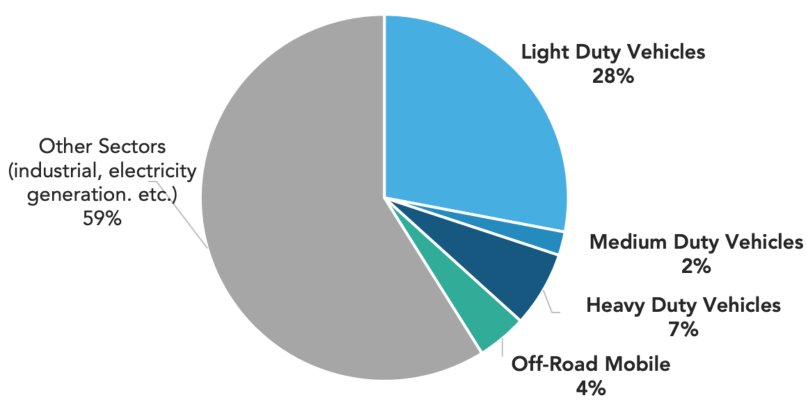


Figure 7 - 2017 Statewide GHG Emissions by Sector



44