CARB has presented a misleading picture of rail vs. truck emissions

Californians for Electric Rail

August 19, 2025

The California Air Resources Board (CARB) has long misled the public about rail transportation. For several years now, CARB has been publicly promoting the idea that trucks are a cleaner way to move freight than trains. We must ask why CARB has continually shown a bias towards road over rail in freight transportation, despite the fact that moving a ton-mile of freight by rail consumes at most 1/3rd the energy and resulting greenhouse (GHG) emissions as by truck.

CARB has also taken positions against rail electrification for years. This history is detailed in the April 2024 letter to the U.S. EPA by the Rail Passenger Association of California (RailPAC), against CARB's proposed In-Use Locomotive Rule, with attached white paper titled "RailPAC Analysis of California Air Resources Board (CARB) Reports and Policies on Rail Transportation: Why CARB has long been an obstacle to rail electrification and sustainable rail transportation in California"[1]. This was followed by a joint August 2024 letter, by RailPAC with Streets for All and Californians for Electric Rail[2], to CARB in protest of continued misinformation regarding electric rail on the CARB website. In addition, the way CARB's proposed In-Use Locomotive Rule was written, carbon-intensive fossil fuel hydrogen would have been considered "zero emissions", so the oil and gas industry could have heavily pushed for hydrogen (greenwashed fossil fuel) rail on all the public agencies and railroads, crowding out proven overhead wire electrification. Thankfully the California State Rail Plan[3] that was released in December 2024 did call for overhead wire electrification of mainlines, and Caltrans has backed off the hydrogen enthusiasm somewhat.

CARB's 'Trucks vs. Trains" emissions analysis methodology is problematic and misleading

The oft-cited CARB 'truck vs. train' emissions analysis done back in 2020[4] is highly tailored to specific, now-nullified regulations and should not be used as a general reference for broader policies. Rather than providing actual emissions measurements, CARB modeled emissions while unreasonably assuming perfect compliance with the Advanced Clean Trucks and Advanced

[1] https://www.railpac.org/wp-content/uploads/2024/04/Docket-EPA-HQ-OAR-2023-0574-RailPAC-comment-letterwhite-paper-2024.04.04.pdf
[2] https://docs.google.com/document/d/1eOu0jM10szwmozkaCEFTImpEG1fTXPfZ9tg7ttWBALg/edit?tab=t.0
[3] https://dot.ca.gov/programs/rail/california-state-rail-plan
[4] https://ww2.arb.ca.gov/resources/fact-sheets/truck-vs-train-emissions-analysis

Clean Fleets rules regulating truck emissions, while assuming no improvement in rail emissions. Three years after this report was published, in 2023 CARB passed the In-Use Locomotive Rule, rendering the comparison null, and now, in 2025, both the Advanced Clean Fleets and In-Use Locomotive Rules have been nullified. Rather than highly specialized models, in this new reality we should be using real-world data to drive policy directions. Unfortunately, environmental organizations (well-meaning though naïve on this specific technical issue), including NRDC[5], Earthjustice[6], Evergreen Action[7] and the Moving Forward Network[8], have in the past couple years uncritically promoted CARB's "trucks are now cleaner than trains" claims as gospel. This is misleading many thousands of environmentally minded people who would otherwise be rail supporters. A March 23, 2023 *Los Angeles Times* editorial also referenced CARB's misleading 'tucks vs. trains' analysis[9]. A proper debunking of these claims is thus long overdue.

CARB's Trucks vs. Trains Analyses has three main flaws:

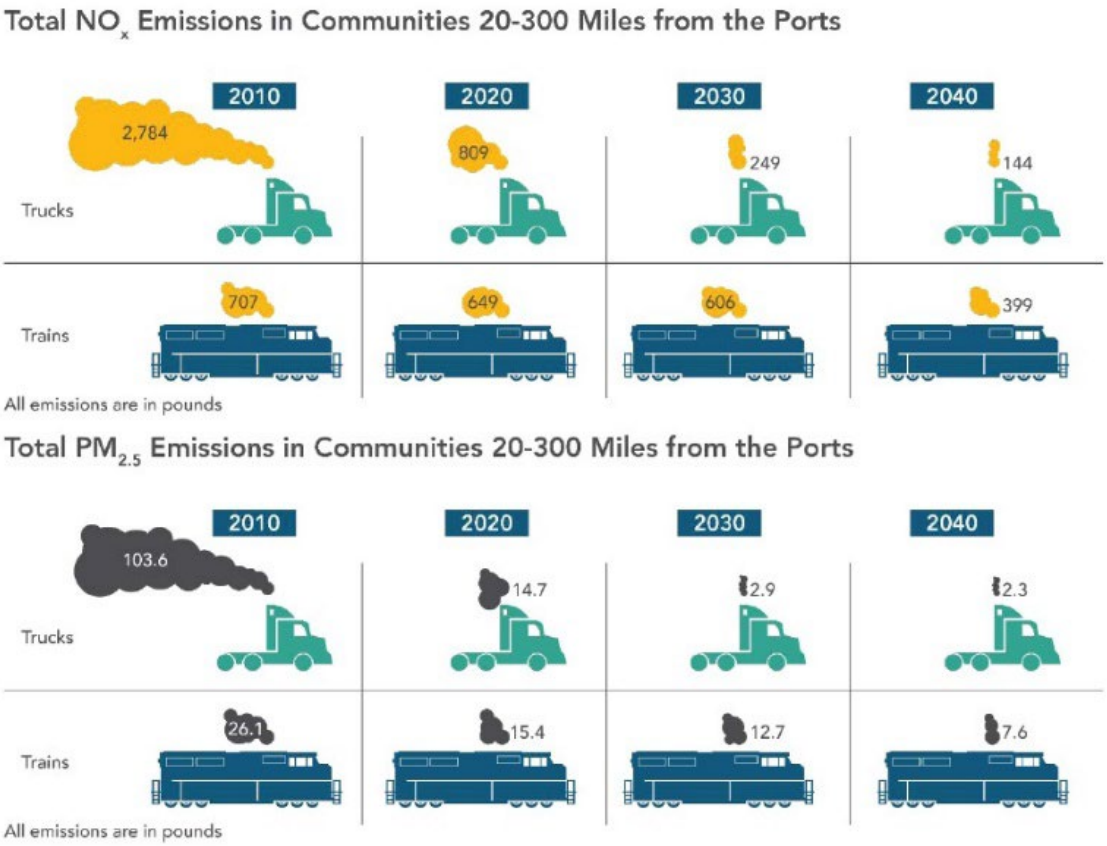
- Trucks vs. Trains estimates for criteria pollutants are based on modeling unrealistic assumptions, not real data
- CARB's analysis ignores additional hazards associated with trucks, in particular significant non-tailpipe particulate emissions
- CARB's analysis fails to consider greenhouse gas emissions and energy efficiency, where trains clearly come out on top, undermining existing policy around vehicle miles traveled (VMT) reduction

CARB must be upfront about the limitations and shortcomings of their "Trucks vs. Trains" analysis and move faster on policy to promote overhead catenary electrification and modal shift for freight rail.

Criteria pollutant emissions – are trucks really dirtier than trains?

CARB's analysis compares the emissions of a single, 4 locomotive train consist with the equivalent in long-haul trucks. Their estimates claim that in 2020, the same trip by truck had about 20% higher NO_x emissions than rail, and roughly comparable $PM_{2.5}$ emissions, within 20-300 miles of California ports. This suggests that for medium-haul trips like this one, *mode shift to rail would actually improve air quality.*

[5] https://www.nrdc.org/press-releases/california-and-environmental-groups-successfully-defend-zero-emissions-rail-rule
[6] https://earthjustice.org/experts/yasmine-agelidis/california-is-bringing-rail-into-the-zero-emissions-era
[7] https://www.evergreenaction.com/blog/trains-are-a-climate-solution-just-not-in-the-united-states
[8] https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://downloads.regulations.gov/EPA-HQ-OAR-2023-0574-0167/attachment_1.pdf&ved=2ahUKEwjEoJHD2eqOAxWbIkQIHSnUIRYQFnoECDMQAQ&usg=AOvVaw0hk9qdvLd_qdM7ky0o5fie
[9] https://www.latimes.com/opinion/story/2023-03-20/train-air-pollution-california-regulations



But according to CARB by 2030, rail NO_x emissions on that same trip would be 2x higher and $PM_{2.5}$ would be 4x higher than for trucks. How realistic is this? CARB's data sources for locomotive criteria emissions appear reasonable, as described on pgs. 9-10 of CARB's September 23, 2020 document explaining the 'trucks vs. trains' methodology [10]:

> "For the baseline scenario, the analysis used tier distribution data from the unpublished draft locomotive line haul emissions inventory dated August 2020 (Appendix B). The baseline scenario only includes projected natural turnover. There is an alternative scenario in which trains are 100 percent Tier 4 until 2034, and 100 percent Tier 5 from 2035 and beyond; the purpose of this scenario is to show that shifting freight from truck to train only reduces emissions when Tier 4 or cleaner locomotives are used."

However, even if we assume that the train emissions calculations are accurate for pre-Tier 4, Tier 4 and Tier 5 locomotives, the emissions calculations for trucks are highly suspect. On p. 12 of 'trucks vs. trains' methodology document, Figures 5 and 6 (below) show a very dramatic drop in truck NO_x emissions "in communities within 20 miles of the ports" in the year 2023, due to the assumption back in 2020 that "2010 Truck and Bus Regulation moves towards full implementation in 2023". However, the "Train (Baseline)" NO_x level after this suspiciously

[10] https://ww2.arb.ca.gov/sites/default/files/2024-02/Truck%20vs%20Train%20Methodology%209-23-2020_0.pdf
The "unpublished" inventory source mentioned on p. 9-10 has subsequently been published:
https://ww2.arb.ca.gov/resources/fact-sheets/carb-fact-sheet-class-i-locomotive-operators

dramatic drop expected in 2023 is shown to be about 45 lbs., while the "Truck (with ACT, Low NO_x, HD I/M" is shown to be 30 lbs. (dramatically dropping from over 60 lbs. the prior year).

Figure 5. NO_X emissions in communities within 20 miles of the Ports 2010 – 2050

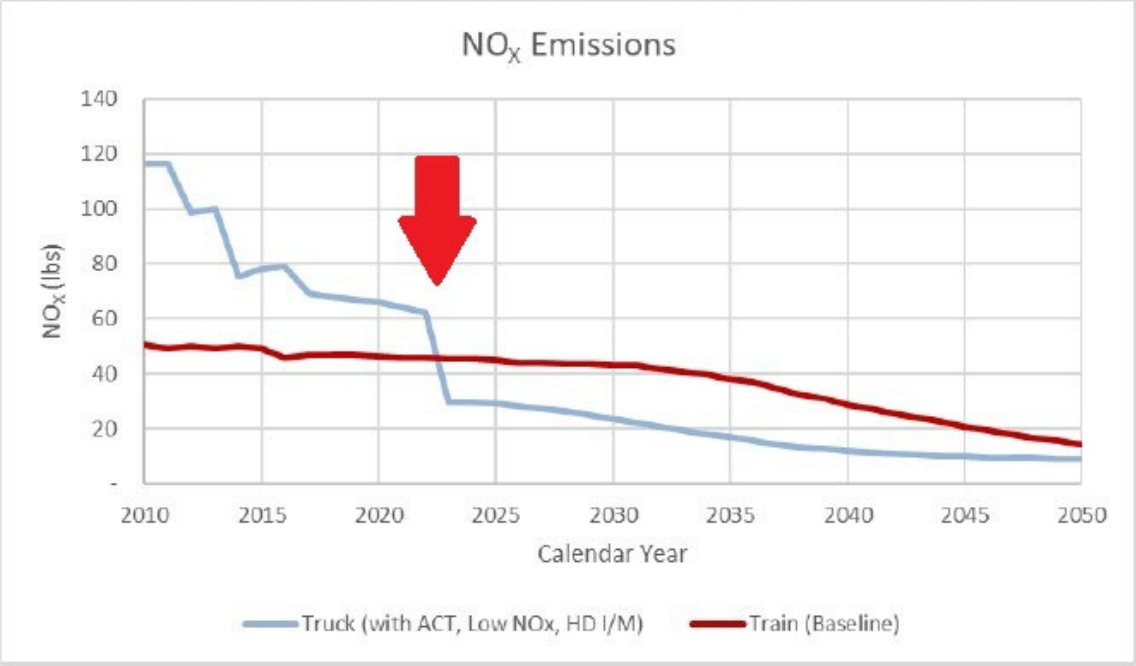
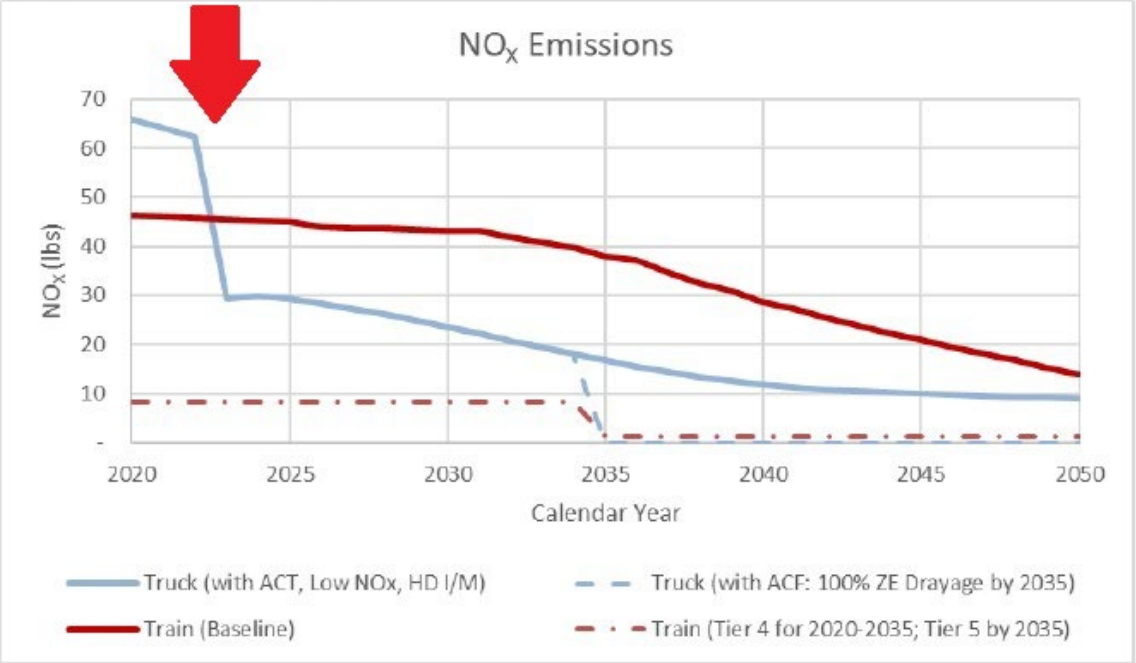


Figure 6. NO_X emissions in communities within 20 miles of the Ports 2020 – 2050 with alternate scenarios



Similarly, Figures 7 and 8 on p. 13 show a very dramatic drop in truck $PM_{2.5}$ emissions "in communities 20-300 miles from the Ports.." in 2023 (red arrows added for emphasis):

Figure 7. $PM_{2.5}$ emissions in communities 20-300 miles from the Ports 2010 – 2050

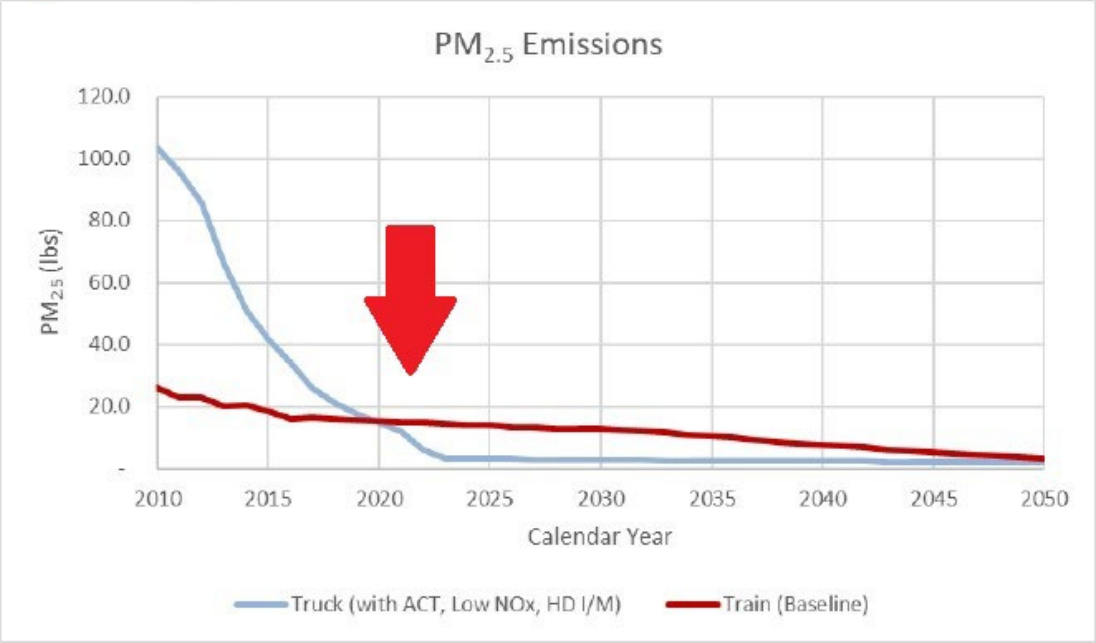
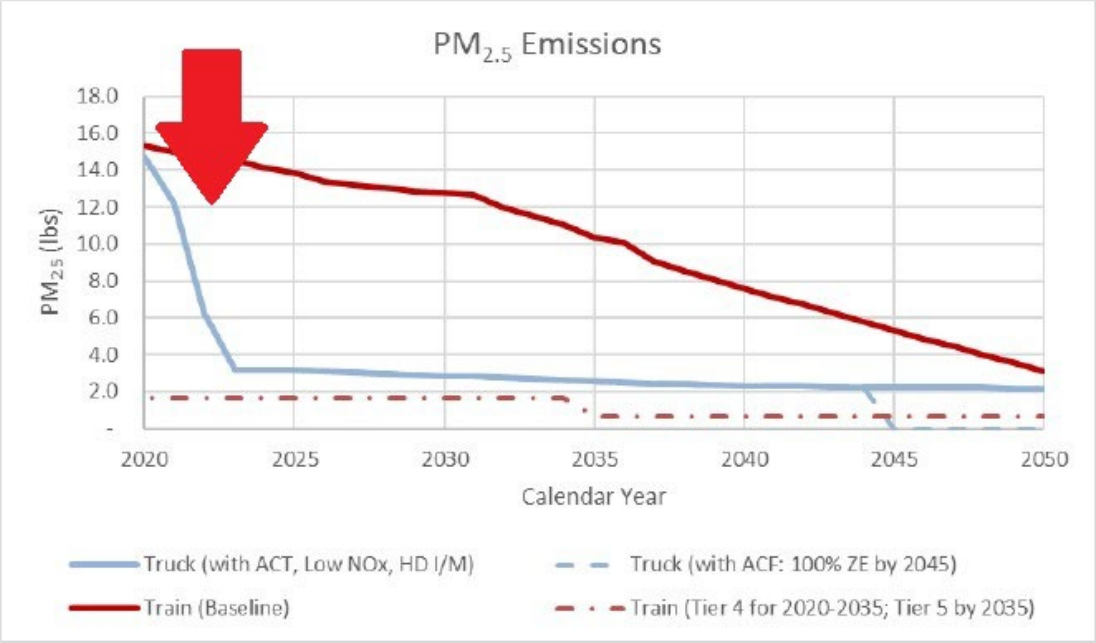


Figure 8. $PM_{2.5}$ emissions in communities 20-300 miles from the Ports 2020 – 2050 with alternate scenarios



Figures 9 and 10 on p. 14, "NO_X emissions in communities 20-300 miles from the Ports", show the same story (red arrows added for emphasis):

Figure 9. NO_X emissions in communities 20-300 miles from the Ports 2010 – 2050

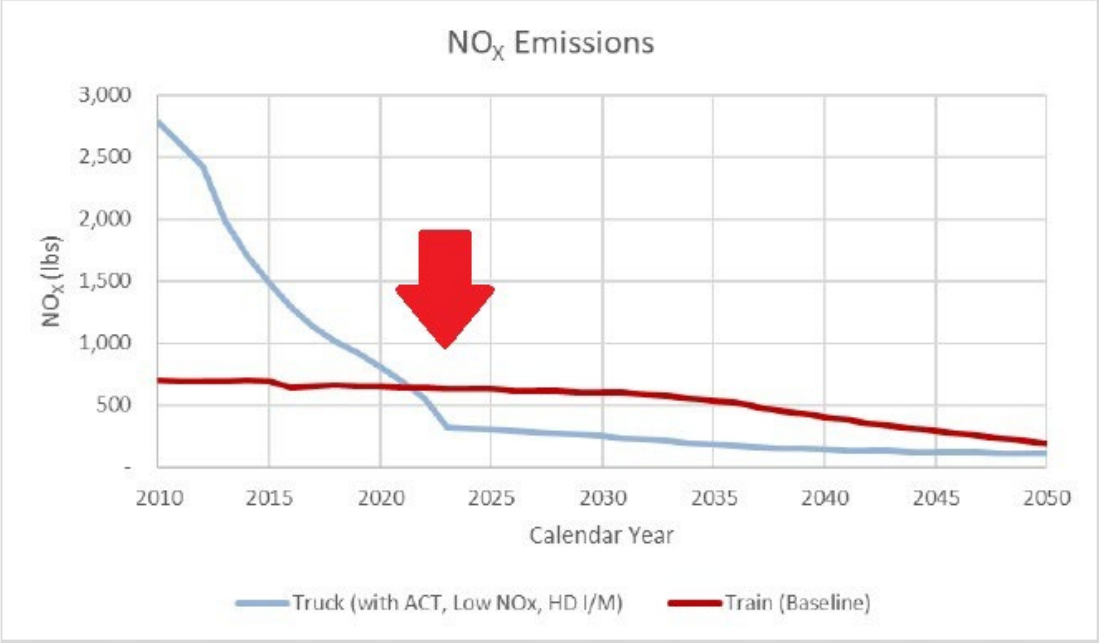
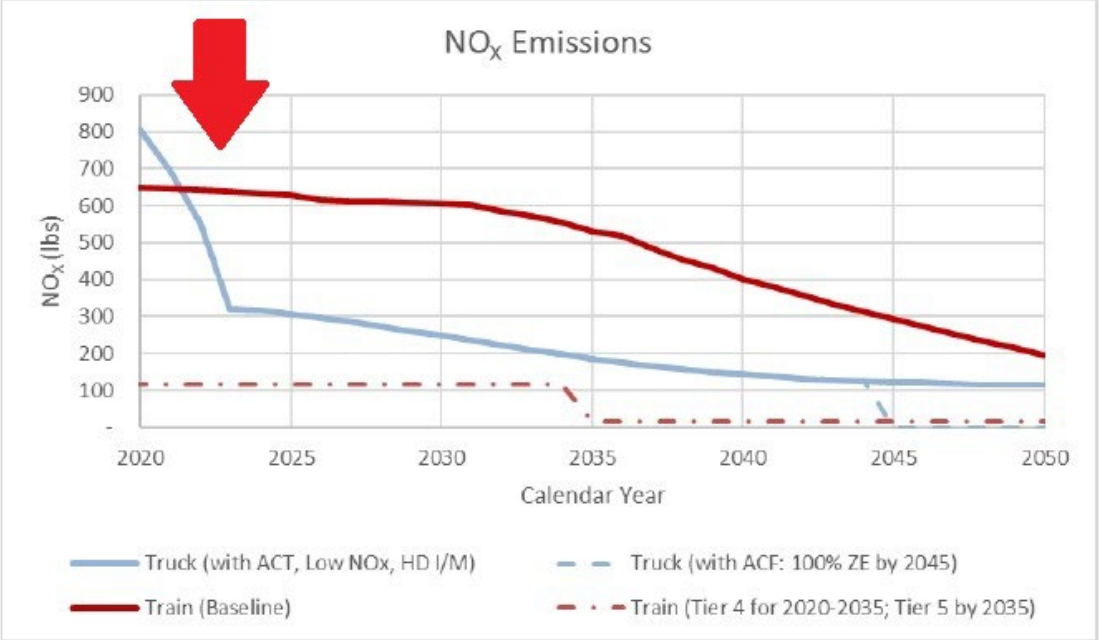


Figure 10. NO_X emissions in communities 20-300 miles from the Ports 2020 – 2050 with alternate scenarios



Despite the optimistic scenario for truck emissions projected by this 2020 CARB analysis, the Advanced Clean Trucks (ACT) rule[11] did not go into effect in 2023. It technically went into effect on January 1, 2024[12], though was not immediately enforced. The amended version of the ACT rule that went into effect at the beginning of 2025 dropped the mandate to sell a certain percentage of zero emissions trucks in California[13], and in June 2025 the Republican-controlled Congress revoked the EPA's waiver for ACT.[14]

The proposed Advanced Clean Fleets (ACF) rule was effectively dropped by CARB in December 2024[15]. However, the CARB 2020 trucks vs. trains analysis methodology assumed that ACF would be implemented, presumably by the year 2023 (p. 5-6)[16]:

> "The analysis accounted for the Advanced Clean Fleets Regulation, even though it is not present in the META Tool, by adding an alternate scenario in which drayage truck emissions are set to zero, starting in 2035 and all truck emissions are set to zero, starting in 2045. The Advanced Clean Fleets Regulation is expected to be presented to the Board in 2021/2022."

As stated in Appendix A on p. 16, the truck "Baseline (with ACT, Low NO_X, HD I/M)" scenario assumes an "Advanced Clean Trucks zero emission sales requirement: 5% in 2024 to 40% in 2032". What was the actual turn-over rate in the truck fleet, compared to what CARB's back in 2020 assumed it would be for the then-future time period of 2021-2024? How does the regulation affect continued use of existing higher polluting trucks, and does the promised "full implementation" match actual practices in real world?

CARB has touted that 6% of medium and heavy-duty vehicles sold in 2023 were zero emissions[17]. However, that number includes buses, which have been heavily incentivized toward zero emissions through the Innovative Clean Transit Rule, and the number is unhelpfully not broken down by vehicle class. The two largest manufacturers by sales on the list, Rivian and Ford, at 60% and 23% respectively, only manufacture medium-duty vehicles[18]. Other reports

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[11] https://ww2.arb.ca.gov/news/california-approves-groundbreaking-regulation-accelerates-deployment-heavy-duty-zevs-protect

[12] https://www.freightwaves.com/news/battles-over-californias-advanced-clean-trucks-rule-rage-far-beyond-state-line

[13] https://www.truckpartsandservice.com/regulations/industry/article/15707162/carb-amends-advanced-clean-trucks-rule-in-face-of-pushback

[14] "Congress revokes Advanced Clean Trucks waiver, creating ambiguity for refuse fleets", ESG Dive https://www.esgdive.com/news/advanced-clean-trucks-waiver-revoked-refuse-fleets/749559/

[15] https://www.freightwaves.com/news/carb-in-a-stunner-drops-request-for-epa-waiver-on-advanced-clean-fleets-rule
https://www.freightwaves.com/news/the-day-after-speculation-abounds-on-california-trucking-regulation-with-no-acf

[16] https://ww2.arb.ca.gov/sites/default/files/2024-02/Truck%20vs%20Train%20Methodology%209-23-2020_0.pdf

[17] "Advanced Clean Trucks Credit Summary Through the 2023 Model Year", CARB, https://ww2.arb.ca.gov/resources/fact-sheets/ACT-Credits-Summary%202023

[18] "List of Certified Medium and Heavy-Duty ZEVs", CARB, 2024. https://ww2.arb.ca.gov/applications/list-certified-medium-and-heavy-duty-zevs

suggest about 1,946 zero emissions buses were purchased in California in 2023[19]. Assuming the remainder are heavy duty trucks, this leaves less than 200 ZE heavy duty trucks sold in 2023, far less than 5% of total. Sales data may not represent actual in-use fleet share, if zero emission trucks prove unreliable or are troubled by fuel shortages or charging issues in real-world use. Looking at 2024 *registrations*, only 0.7% of medium and heavy-duty vehicles registered were zero emission[20]. Of these registered zero emission medium and heavy-duty vehicles, a plurality were buses and only 1389 (23%) were heavy duty trucks. Nationwide, only 0.4% of *heavy-duty trucks* registered in 2024 were zero emissions.[3]Emissions from the present fleet based on standard maintenance practices could be greater than is implied by the age distribution of the fleet. The practical reality is that truck fleet operators have been slower to adopt electric trucks than CARB assumed back in 2020, due to high costs, limited range and performance, and lack of sufficient electric truck charging infrastructure.

It is important to note that these analyses were designed by CARB to motivate the need for a faster transition to zero emissions or cleaner engines in the rail sector, not report real-world environmental impacts of different modes. We agree with the general need to speed up the transition to zero emissions rail, specifically overhead catenary electric rail, but CARB's assumption that electric rail adoption will never happen absent a regulation is also unreasonable. While it is true that the US freight railroad industry has been reticent to invest in electrification in recent years, private US freight railroads have electrified in the past, notably the Milwaukee Road in the mid-20th century. More recently, the Pacific Harbor Line has acquired 5 battery-electric locomotives in cooperation with CARB[21], with 3 more to be used on other railways, despite the In-Use Locomotive Rule never taking effect. Caltrain is successfully operating overhead electric passenger trains on right of way shared with freight, and the 2024 State Rail Plan calls for 1500 miles of electrified track, most of which will be shared with freight. The buildout of this infrastructure will further push the needle towards electrification. Given the In-Use Locomotive Rule is no longer in operation, CARB must move away from these assumptions and pursue other strategies to speed up the electrification of railways.

When making assumptions about the rate of adoption of different technologies, CARB fails to consider technical maturity. Heavy-duty, long-haul trucking has traditionally considered to be a "hard to electrify sector". While electric truck technology is improving rapidly, it is still undergoing research and development, and may experience the short-term setbacks associated with any immature technology. By contrast, electric trains have been in widespread, real-world

[19] "Zeroing in on ZEBs", Calstart, 2024. https://calstart.org/wp-content/uploads/2024/02/Zeroing-in-on-ZEBs-2024_Final-022324a.pdf

[20]" Medium- and Heavy-Duty Zero-Emission Vehicles in California", California Energy Commission, April 2025 https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics-collection/medium; "Department of Motor Vehicles
Statistics for Publication for the Period of January 1 through December 31, 2024", 2025
https://www.dmv.ca.gov/portal/file/department-of-motor-vehicles-statistics-pdf/

[21] "Pacific Harbor Line Moves Toward Zero-Emission Operations with More Green Locomotives; Receives 12th ASLRRA Safety Award" Anacostia, https://www.anacostia.com/news/pacific-harbor-line-moves-toward-zero-emission-operations-with-more-green-locomotives-receives-12th-aslrra-safety-award/

use for a century, and make up the majority of trains in use in large countries with heavy freight loads such as India, China, and Russia.

In summary, CARB's assertion that trucks will be cleaner than trains in the future assumes perfect adherence to truck regulations that no longer exist, and widespread adoption of zero-emission trucks that is not borne out by real world experience five years later. *Sticking only to the portions of their analysis backed with real data, their own research actually suggests mode shift to rail would produce a modest decrease in smog-forming NO_x emissions.*

The CARB Trucks vs. Trains Analysis ignores important local impacts

CARB's analysis considers only tailpipe emissions, ignoring substantial brake and tire dust emissions. On the 'Truck vs. Train Emissions Analysis FAQ' page (dated November 12, 2021)[22] they also admit that they don't care about tire and brake wear, and its effects on health and the environment, even though it is quantified (emphasis added):

> "The analysis focuses on exhaust emissions to provide a direct comparison of truck and train emissions. Non-exhaust emissions, such as tire and brake wear, will become the only source of $PM_{2.5}$ emissions from truck operation, other than $PM_{2.5}$ associated with electricity generation, once their exhaust emissions reach zero. For the full 300 miles, in the scenario used for the Truck vs. Train Emissions Analysis, tire and brake wear would contribute roughly ***9.5 extra pounds of $PM_{2.5}$ in 2023***, before implementation of the Advanced Clean Trucks Regulation, and 8 pounds of $PM_{2.5}$ after 2035. However, the analysis does not include these emissions because CARB's locomotive models do not include similar non-exhaust emissions. The analysis only compares exhaust emissions, pending further research for non-exhaust emissions from locomotives."

Non-exhaust emissions for locomotives are intrinsically lower than for trucks due to operating on steel wheels on steel rails, with lower friction and the total absence of the petroleum products associated with tires and asphalt. Incorporating tire and brake wear, trucks almost certainly had higher $PM_{2.5}$ emissions than trains in 2020 in addition to higher NO_x emissions, at least for the 300 mile scenario where they provide estimates of non -tailpipe emissions.

CARB's own research suggests that brake and tire dust contribute a greater or equal share of ambient $PM_{2.5}$ in Southern California than tailpipe emissions.[23] Additionally, some studies suggests that brake wear particles are more harmful to the lungs, posing a greater public health risk, than diesel PM.[24] Truck road wear, tire dust, and brake emissions are better studied than for trains for the simple reason that they are intrinsically higher – trains operate steel wheels on steel

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[22] https://ww2.arb.ca.gov/resources/fact-sheets/truck-vs-train-emissions-analysis-faq

[23] "Final Report: Real-world tire and brake wear emissions". Jung et al. University of California CE-CERT on behalf of CARB, 2020. https://ww2.arb.ca.gov/sites/default/files/2022-06/18RD017%20-%20Final%20Report.pdf

[24] "Copper-enriched automotive brake wear particles perturb human alveolar cellular homeostasis" Parkin et al., *Particle and Fibre Toxicology*, 2025. https://particleandfibretoxicology.biomedcentral.com/articles/10.1186/s12989-024-00617-2

rails, with none of the petroleum products in tires or asphalt and much less surface area, resulting in less friction and fewer emissions.

Importantly, the ZE truck transition will not substantially reduce non-tailpipe emissions. While brake emissions may be reduced somewhat by regenerative braking on electric trucks, the greater weight associated with large batteries will increase road wear and tire emissions. CARB's own modeling suggests that the share of non-tailpipe particulate emissions will increase over time with ZEV adoption.[25] Ignoring particulate emissions for an analysis that considers ZEV adoption is a massive oversight that skews the analysis in favor of trucks.

Through similar mechanisms, trucks contribute significantly to water pollution. Tire dust is the largest single source of environmental microplastics, and tires release a compound, 6PPD-quinone, that is found in natural waters at levels harmful to salmon[26]. While trucks significantly contribute to these emissions, trains do not by virtue of steel wheels. While this may be outside of CARB's scope by not impacting air, it is nevertheless an important environmental impact that should be factored into high-level decision-making.

Closely related to tailpipe emissions is pavement damage from trucks, which in addition to creating particulate emissions can also endanger bicyclists, pedestrians, and auto drivers. Economic Roundtable found that warehouse-related truck routes in Southern California alone cause $243 million annually in uncompensated costs[27] that must be borne by the public. While roads are heavily subsidized by the public and a major drain on local finances[28], basic maintenance on railroads is largely paid by the freight operators themselves. Like non-tailpipe emissions, pavement damage is likely to worsen with the zero-emissions transition, as trucks acquire heavy batteries.

CARB's analysis also fails to consider safety, an important local impact of freight movement. Nationwide, trucks were responsible for 86.5% of all freight-related fatalities and 96% of freight-related injuries in 2022[29], despite moving only 65% of freight. Truck-related crashes are on the rise, and as with non-tailpipe emissions, are expected to worsen with ZEV adoption as vehicles get heavier. Again, a real head-to-head comparison of truck vs train impacts would factor in these important impacts.

While rail also has local non-air quality impacts, many of these can be readily mitigated with one-time infrastructure investments. For instance, rail safety can be further improved through

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[25] *Brake & Tire Ware Emissions*, CARB , https://ww2.arb.ca.gov/resources/documents/brake-tire-wear-emissions

[26] "Microplastics from Tire Particles in San Francisco Bay Fact Sheet", San Francisco Estuary Institute, https://www.sfei.org/sites/default/files/biblio_files/SFEI%20Microplastics_from%20tire%20particles%20in%20SF%20Bay.pdf

[27] "Exhausting Our Air: Environmental and Human Costs of Diesel Trucks" Economic Roundtable, 2023. https://economicrt.org/publication/exhausing-our-air/

[28] "The Real Reason Your City Has No Money" Strong Towns, 2017. https://www.strongtowns.org/journal/2017/1/9/the-real-reason-your-city-has-no-money

[29] "Freight Transportation Safety", Bureau of Transportation Statistics. https://data.bts.gov/stories/s/Freight-Transportation-Safety/vu39-vtqh

grade separations that both reduce disruptions to local transport and improve freight reliability. Noise can be reduced with quiet zones (and electrification). Equivalent impacts from trucks are harder to mitigate.

CARB's omission of these local impacts unique to trucks heavily skews their results towards trucking and paints a misleading picture.

CARB's analysis ignores greenhouse gas emissions and energy use

While ignoring non-tailpipe impacts, CARB also ignores the most important tailpipe emission of all: carbon dioxide and other greenhouse gases. Looking at the CARB's 'trucks vs. trains' methodology document[30], right from the introduction (p.1) it proclaims "The analysis did not consider greenhouse gases. Based on these emissions projections and this analysis, trucks will be the cleaner mode to move cargo by 2023". The conclusion claiming 'trucks are cleaner than trains' similarly admits that this does not include greenhouse gas emissions (p. 10):

> "Section C. Results
>
> Drayage trucks have been able to move containers with lower $PM_{2.5}$ emissions than trains in communities within 20 miles of the Ports since 2012, due to the implementation of the 2007 Drayage Truck Regulation. As the 2010 Truck and Bus Regulation moves towards full implementation in 2023, trucks become cleaner than trains in all scenarios – long haul $PM_{2.5}$ emissions in communities 20-300 miles from the Ports become lower in 2020, long haul NO_X emissions become lower in 2022, and drayage NO_X emissions become lower in 2023.
>
> Tier 4 and 5 locomotives can move containers with lower emissions than trucks in communities within 20 miles of the Ports through 2035, until the Advanced Clean Fleets Regulation goal of 100 percent zero emission drayage trucks is achieved. The analysis also shows Tier 4 and 5 locomotives can move containers cleaner than long haul trucks until the Advanced Clean Truck Fleets Regulation (ACF) brings all trucks to zero emissions in 2045…
>
> **The analysis focused on PM2.5 and NO_X exhaust emissions; it did not consider greenhouse gases.** [emphasis added]"

The promised 2023 figures for truck NO_x and $PM_{2.5}$ are quite suspect as described above, but the fundamental value judgement that CARB is making is that NO_x and $PM_{2.5}$ are the only emissions worth considering, and that *greenhouse gas emissions do not matter*, nor do truck tire and road wear, and other embodied environmental impacts of trucks.

On the FAQ page for the CARB Truck vs. Train Emissions Analysis, they admit that this analysis is overly simplistic[31]:

[30] https://ww2.arb.ca.gov/sites/default/files/2024-02/Truck%20vs%20Train%20Methodology%209-23-2020_0.pdf

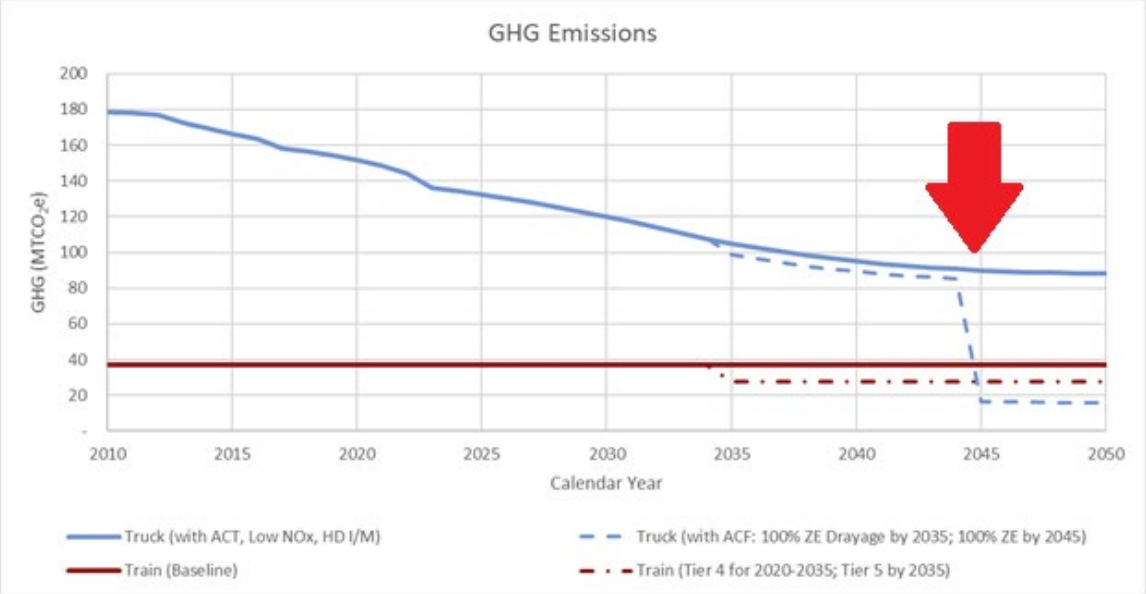
[31] https://ww2.arb.ca.gov/resources/fact-sheets/truck-vs-train-emissions-analysis-faq

> "The analysis is a straightforward, community-friendly comparison of truck and train emissions for general use, regardless of a specific location within the State. More detailed truck and locomotive data specific to a certain region could better reflect the emissions for that particular region or route, but the analysis would no longer apply broadly to all California communities."

In the below graph labeled "Figure 1", CARB admits that GHG emissions from 'Trains (Baseline)' is calculated as less than 30% that of 'Trucks (with ACT, Low NO_x, HD I/M)'. However, it shows that truck GHG emission will dramatically drop below Train (Baseline) in the year 2045, because it assumes all trucks will be ZE by then in a sudden dramatic expansion in keeping with the now-defunct ACF rule. However, the Train (Baseline) GHG never changes at any point in the future because the working assumption is that no zero-emissions (electric) freight trains will ever exist:

> "Figure 1 includes an informational comparison of the well-to-wheel GHG emissions between trucks and trains, for the entire 300 mile trip. Consistent with the Truck vs. Train Methodology, drayage trucks are assumed to be 100 percent zero emissions by 2035, and the truck fleet is assumed to be 100 percent zero emissions by 2045. Figure 1 shows that although trains have consistently had lower GHG emissions, the gap is closing, and a full zero emissions truck fleet will emit less well-to-wheel GHGs than diesel trains.

Figure 1. Well-to-wheel GHG emissions from 300 mile trip 2010 - 2050 with alternative scenarios



This sudden precipitous drop of truck GHG emissions in the year 2045 is highly speculative since it is 20 years in the future, and unrealistically assumes rapid compliance with ACF, rather than the more gradual phase in before and after the deadline that you might expect. While it is carefully calculated to be below the expected Tier 5 diesel locomotive emissions, the difference is quite small. However, it's worth pointing out that under more realistic scenarios, CARB's own model shows trains with significantly lower GHG emissions than trucks even with the now-defunct ACT.

For many years, CARB has divorced air quality impacts and greenhouse gas emissions, failing to consider and where the electricity or hydrogen comes from (or how much energy, water or emissions is used to produce it) in their definition of "zero emissions". Thus, they include hydrogen fuel cell trucks as zero emission, even though the vast majority of hydrogen on the market is sourced from fossil fuels and is not carbon-neutral. Indeed, heavy duty trucking is often claimed to be one of the few applications where hydrogen is more feasible than electrification[32]. If this theory is correct and a significant portion of the 2045 "zero" emissions fleet is fuel cell vehicles, greenhouse gas emissions from trucking are unlikely to be lower than rail. CARB also neglects to mention how much more electricity it would take to move the same tons of cargo via electric rail vs electric truck, because they are working under the assumption that electric freight trains will never exist. They also assume, or at least imply, that electric trucks would be 100% powered by renewable energy in the future, a change from the 2016 CARB locomotive reports, which tried to denigrate electric freight rail by implying new coal-fired plants would have to be built to power it. It bears repeating that the number of trucks needed to haul the same cargo as a train would use at least three times more electric energy, whatever its sources. If the grid is less than 100% renewable, this inefficiency will result in higher greenhouse gas emissions from electric trucks relative to electric trains. The renewable energy assumption for ZEV trucks should be tempered with the actual grid resources projected forward a half dozen years or so. "Zero-emissions" trucks, like locomotives, all have an embedded GHG emissions footprint for their manufacture and mining of materials. The lifecycle GHG emissions of "zero-emissions" trucks thus will not be zero. Like the comparative GHG emissions of trucks vs. trains, the embedded emissions in manufacturing a locomotive are much less than the equivalent number of trucks.

In summary, CARB must absolutely consider greenhouse gas emissions and tire/road wear pollution in their environmental evaluation of trucks. Ignoring CARB's unrealistic assumptions about emerging technologies, rail comes out slightly ahead when comparing real-world tailpipe criteria pollutant emissions. When non-tailpipe emissions are added, rail comes out unequivocally ahead. And when we consider greenhouse gas emissions, rail wins out easily.

Both passenger and freight mode shift from road to rail are essential to reduce GHG emissions from transportation

Mode shift from highway to rail is necessary for electrification of freight movement. To illustrate the math, consider this simplified thought experiment:

The Ports of LA and Long Beach together generate about 60,000 truck trips per day. Assuming each truck trip is a round trip requiring 1 MWh of electric charging energy, that is a total daily energy requirement of 60,000 MWh for electric truck charging. Dividing this by 24 hours in a day means this is an average electrical load of 2,500 MW. Annually, that is 21,900 GWh of electric energy. For comparison, Diablo Canyon nuclear generating station (8% of the state's total electric energy) generates less than this amount – about 18,000 GWh annually[33]. So to

[32] Zero Emission Long-Haul Heavy-Duty Trucking", Clean Air Task Force, 2023. https://cdn.catf.us/wp-content/uploads/2023/03/13145547/zero-emission-long-haul-heavy-duty-trucking-report.pdf
[33] https://www.pge.com/en/about/pge-systems/nuclear-power.html

electrify all of the trucks serving the Ports of LA/Long Beach, it would take about 10% of California's existing electric energy consumption[34]. The 2,500 MW of capacity will require power grid upgrades around the region, and especially around San Pedro Bay. Even if we cut the assumed electric truck charging energy per round trip to only 500 kWh, we are still talking about 5% of the state's electricity consumption- a very significant amount. If all that freight moved by the 60,000 daily truck trips went by electric rail instead of electric trucks (rail mode handling 100% of landside port freight movement is only theoretically possible, but just for the point of discussion), the average electric load would at most 800 MW, but likely less (or 2-3% of state's current electricity consumption).

Even casting aside the additional environmental and societal costs due to trucks, from a purely energy consumption perspective, comparing zero emissions all-electric trucks to zero emissions all-electric trains- it is economically, environmentally superior and more reliable to move the freight by train instead of truck. That's 1/3rd the solar panels or wind turbines needed to do the same job. Simply put, we cannot rely on electric trucks as the crutch. The same general fuel consumption ratio holds when comparing diesel truck to diesel-powered train. For truly sustainable freight transportation that does not emit greenhouse gases, we absolutely need more freight mode shift to rail. When talking about transportation emissions and energy use, we need to understand and appreciate the scientific facts shown in the below graphics:

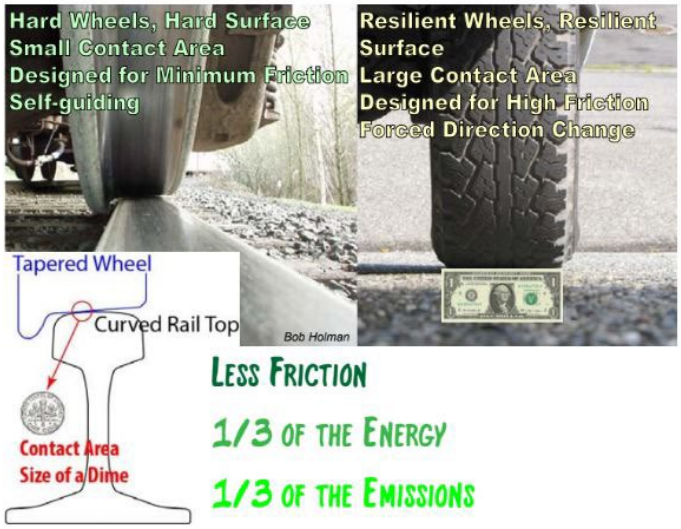
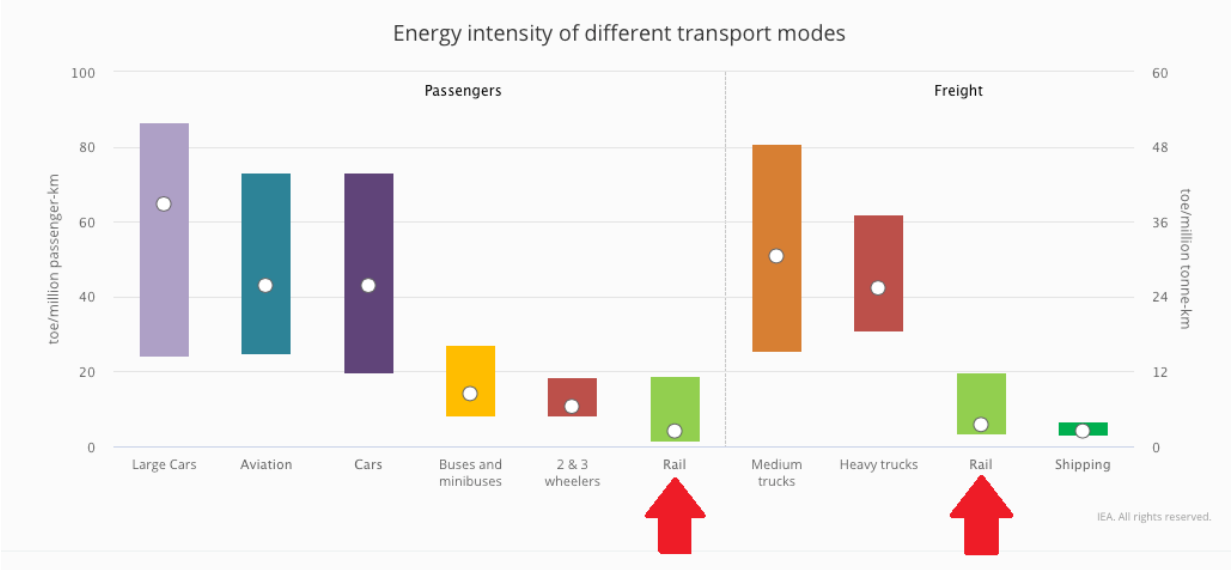


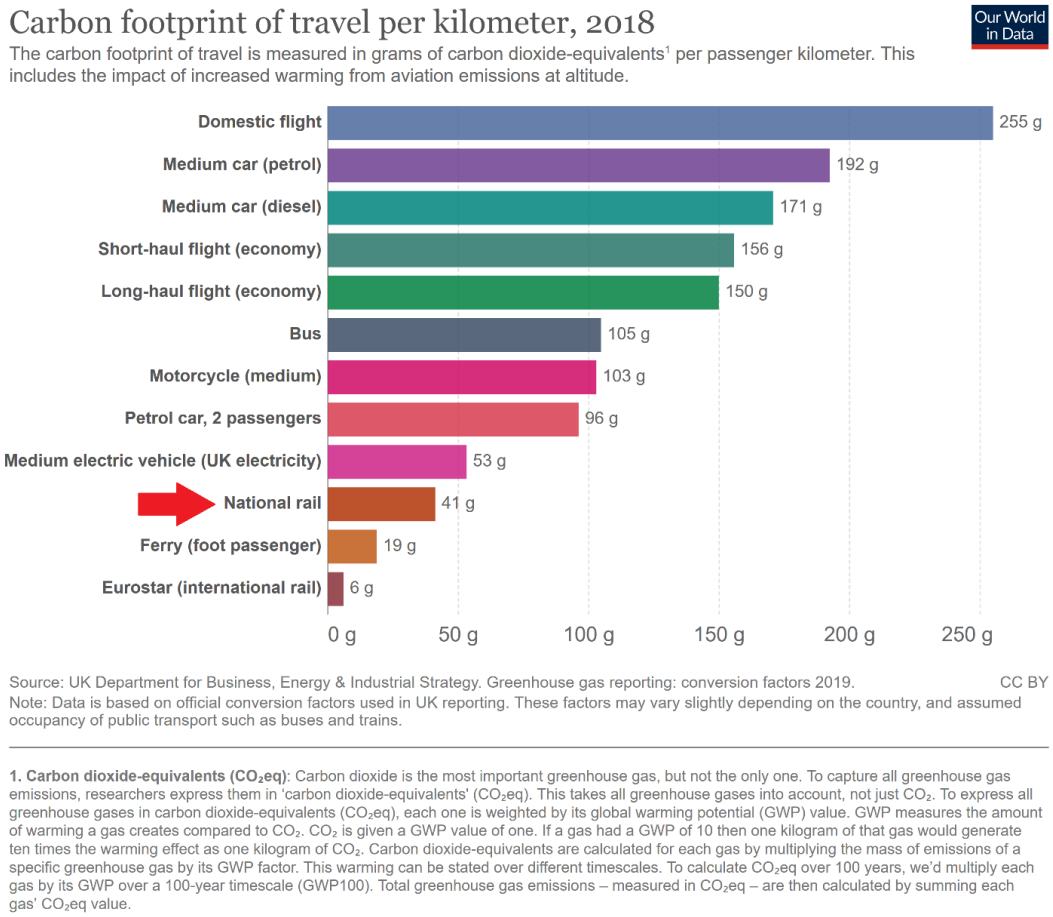
Diagram by Thomas White, VTD Rail Consulting

The relative energy intensity ratio of rail versus road vehicles shown in the above graphic remains the same if we are comparing diesel train to diesel truck or electric train to electric truck.

[34] https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2023-total-system-electric-generation



Graph: International Energy Agency [red arrows added for emphasis]



Graph from *Our World in Data* - figures shown for transportation modes in the UK[35], where the National Rail network is partially electrified (Creative Commons CC BY 4.0). Red arrows added for emphasis.

[35] https://ourworldindata.org/transport

The 2018 California State Rail Plan, section 3.1.7 (p. 116), "Policy 3: Reduce GHG Emissions and Other Air Pollutants" states:

> "A 2009 FRA study reported that a double-stack container-trailer-freight rail car moves freight three to five times more fuel-efficiently than a truck.[162] Each freight train carries much more total weight than a single combination truck, so each train movement reduces truck traffic on highways and reduces GHG emissions."

Electric trains are the most energy efficient way to move freight on land, moving a ton with as little as one-tenth the energy used by diesel truck. A 2017 report by US DOE Argonne National Laboratory[36] explains this in detail. Moving a ton-mile of freight by rail requires at most a third the energy of moving it by truck, due to the difference in mechanical friction of steel versus rubber wheels. Every truck on the road still adds to congestion, crash risk (trains being statistically much safer per freight ton-mile), tire/road wear, and brake dust pollution (the human health impacts of brake dust are only beginning to be understood). A truly transformative zero-emissions transportation future would involve electric trains transporting goods as much as possible, instead of merely converting trucks to a different fuel source. In one prime example, the Alameda Corridor was designed with enough overhead clearance for catenary wires over the tallest double-stack container trains. CARB should recommend electric trains using OCS on the publicly owned three-track railroad corridor for the Ports of L.A. and Long Beach. It is currently operating at well under half of its throughput capacity, something one cannot say about the 710 Freeway; when clogged with electric or hydrogen-powered trucks it is still a clogged freeway.

The road-to-rail mode shift scenario provides an opportunity for much-needed freight rail electrification in the LA Basin and Inland Empire, with a captive electric locomotive fleet operating between the ports and Barstow/Yermo/Indio[37]. A 2016 CARB report on freight locomotives stated that about 60% of all locomotive diesel fuel energy (and resulting pollution) consumed by all freight trains in Southern California occurs on the steep grade Cajon Pass segments of BNSF and Union Pacific, between the Inland Empire and Barstow. This segment of railroad track has great potential for regenerative braking to put energy back in grid on downhill travel. The Barstow/High Desert area is already a major solar power generation hub, so a ready clean source of power for electric trains is already available. Coincidentally, in 2022 the BNSF Railway announced its Barstow International Gateway project, a proposed large 'inland port' on the west side of Barstow. Contained in this proposal are plans for short-haul intermodal freight trains between Barstow and the Ports of LA/Long Beach, which would potentially get thousands of trucks off Southern California highways each day.

Building an overhead wire rail electrification system is expensive, but it is going to be less expensive overall than moving the same amount of freight with electric trucks. As described in the Port of LA/Long Beach example above, electric rail is vastly more energy efficient than electric trucks, which is an important consideration for not overstressing the power grid with electric transportation and for providing affordable, reliable power for all.

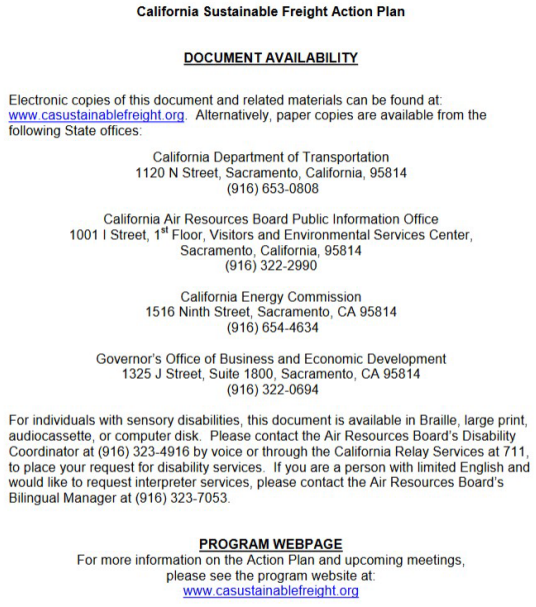
[36] https://www.osti.gov/biblio/1375453

[37] https://calelectricrail.org/wp-content/uploads/2025/04/Cajon-Sub-OCS-electrification-appendices-BYanity-2025.01.19.pdf

CARB's "trains vs. trucks" emissions claims contradict policy goals to reduce truck VMT

CARB's own *2022 Scoping Plan for Achieving Carbon Neutrality*[38] states a goal to "achieve a per capita VMT reduction of at least 25 percent below 2019 levels by 2030 and 30 percent below 2019 levels by 2045." While this 2022 scoping plan document makes vague mention of improved public transit as a means to reduce VMT, it makes no explicit mention whatsoever of rail transit (streetcar, light rail, subway/BART/metro), intercity/regional passenger rail, or mode shift of freight from truck to rail. CARB needs to realize and publicize that rail transportation is absolutely essential for reducing VMT. There is in fact no way for car or truck VMT to be reduced in California by 30% without greatly *increased* use of rail transportation[39].

Why does CARB keep promoting truck freight movement, and discouraging moving freight by rail? Despite CARB's vague calls for reducing VMT in a general sense, when it comes to freight, CARB seems hellbent on *increasing* truck VMT. Back in 2016, under Governor Brown, CARB put out the California Sustainable Freight Action Plan[40], which did briefly mention short-haul rail and increasing track capacity. This plan is something one would think that CARB (with CalSTA & Caltrans) would update periodically. However, the whole effort to adopt sustainable freight practices appears to have died as soon as the report was released nine years ago. The website that was created for the plan (see screenshot below from page 3 of the California Sustainable Freight Action Plan), http://www.casustainablefreight.org/ , is now directed to a website promoting the trucking industry.



California Sustainable Freight Action Plan

DOCUMENT AVAILABILITY

Electronic copies of this document and related materials can be found at: www.casustainablefreight.org. Alternatively, paper copies are available from the following State offices:

California Department of Transportation
1120 N Street, Sacramento, California, 95814
(916) 653-0808

California Air Resources Board Public Information Office
1001 I Street, 1st Floor, Visitors and Environmental Services Center,
Sacramento, California, 95814
(916) 322-2990

California Energy Commission
1516 Ninth Street, Sacramento, CA 95814
(916) 654-4634

Governor's Office of Business and Economic Development
1325 J Street, Suite 1800, Sacramento, CA 95814
(916) 322-0694

For individuals with sensory disabilities, this document is available in Braille, large print, audiocassette, or computer disk. Please contact the Air Resources Board's Disability Coordinator at (916) 323-4916 by voice or through the California Relay Services at 711, to place your request for disability services. If you are a person with limited English and would like to request interpreter services, please contact the Air Resources Board's Bilingual Manager at (916) 323-7053.

PROGRAM WEBPAGE
For more information on the Action Plan and upcoming meetings, please see the program website at:
www.casustainablefreight.org

[38] https://ww2.arb.ca.gov/sites/default/files/2023-04/2022-sp.pdf

[39] Also of note, this 2022 report also asserts that line haul freight and passenger rail will rely primarily on hydrogen fuel cell technology in the future, without any explanation or justification as to why, or any analysis given for different alternatives.

[40] https://ww2.arb.ca.gov/our-work/programs/california-sustainable-freight-action-plan

In contrast to CARB, the 2024 California State Rail Plan[41], published by Caltrans, calls for investments to increase freight rail mode share, and for specific investments in on-dock rail, freight rail capacity, and new yard infrastructure that is located farther from population centers and disadvantaged communities. While the freight section disappointingly does not call for freight rail electrification, this is still much better than CARB's general attitude:

> As in many cases, the most efficient mode to transport freight is rail, and because of this, Caltrans encourages mode shift from over-the-road trucking to the rail system. Shifting freight to rail also frees up additional capacity at airports and on highways, which reduces congestion on those existing facilities and improves the movement of both goods and people. The rail network is well-connected to the state's harbors and can expedite freight away from the harbor to appropriate, efficient sorting locations. Caltrans will support freight projects that work towards achieving this goal because it reduces maintenance costs on state highways and is more environmentally friendly. Since California's ports are surrounded by major population centers, efficiently moving freight to sorting locations can also reduce impacts on communities that have been affected by goods movement.

CARB's promotion of the incorrect assertion that trucks are cleaner than trains actively works against this policy. Even after the release of the State Rail Plan, CARB has continued to feature a graphic claiming trucks release fewer $PM_{2.5}$ emissions than trains on its Class I Locomotives Fact Sheet[42], despite this analysis failing to include non-tailpipe particulate emissions as discussed above. Our critical analysis of CARB's methods agrees with Caltrans' assertion that rail is more efficient and has lower impacts on communities affected by goods movement, in terms of air quality, safety, and infrastructure. Why aren't CARB and Caltrans coordinating?

Tradeoffs Between Greenhouse Gas Emissions and Air Quality

Even if CARB's predicted 2023 emissions for truck NO_x were accurate, it shows that NO_x is about 30-40% less than rail for the 2023-2025 timeframe, dropping about 50% less by 2030. However, GHG emissions by truck would still be at least 300% higher than train. Admittedly this is a tough choice: NO_x and PM sickens and can kill people locally. But is reducing these two criteria emissions by 30%-50% worth tripling your greenhouse gas emissions to do the same job? And increasing road and tire wear or accidents caused by more trucks on the roads? Isn't the solution ultimately electric trucks *and* locomotives?

When we dismiss CARB's claims that trucks are cleaner than trains, it is important to emphasize that CARB's analysis did not evaluate railyards. Proximity to railyards has been associated with

[41] California State Rail Plan, 2024, p. 40, https://dot.ca.gov/-/media/dot-media/programs/rail-mass-transportation/documents/california-state-rail-plan/2024-ca-state-rail-plan-a11y.pdf

[42] "CARB Fact Sheet: Class I Locomotive Operators", CARB, archived June 23 2025. https://web.archive.org/web/20250623162243/https://ww2.arb.ca.gov/resources/fact-sheets/carb-fact-sheet-class-i-locomotive-operators

childhood respiratory disease[43], and rail workers experience elevated rates of lung disease[44]. Yard operations have quite different environmental impacts than line-haul operations for many reasons, including a significantly older and more polluting pool of locomotives[45], less stringent emissions standards for switcher locomotive tiers[46], and more idling and continuous, all-day operations. Acknowledging the local impacts of railyards does not mean throwing the baby out with the bathwater and maligning all rail operations.

Rail yards are essential to railroad operations and must continue to operate to shift freight from trucks. But while their impacts are highly concentrated, yards are a relatively small share of California rail infrastructure, making meaningful emissions reductions on short timescales relatively achievable. Switcher locomotives make up about 5% of the fleet operated by Class I railroads, with about 500-600 operating in the state[47], so replacing them with a cleaner fleet is doable with targeted policy and public cost-sharing. Operationally, they are relatively easy to replace with Tier 4 or battery electric locomotives because of their lower horsepower and short distances traveled.

CARB should develop targeted policy to rapidly improve air quality at rail yards without reducing rail modal share or increasing VMT. One such example could be a "cash for clunkers" program that finances one-to-one replacement of pre-Tier 1 yard switchers with low emission replacements. It is worth noting that intermodal railyards are magnets for trucks, and mode shift to rail for short haul (under 200 mile) trips normally taken by heavy-duty trucks thus may actually reduce pollution at yards by reducing truck-rail transfers and truck idling.

Modal shift to zero emissions, combined with overhead electrified rail, eliminates any perceived conflict between air quality improvements and greenhouse gas emissions reductions, simultaneously reducing local air quality impacts from rail while reducing both greenhouse gas emissions and criteria pollutant emissions from trucking. Indeed, electrification and mode shift are closely connected, as high levels of traffic make a better financial case for electrification[48]. Similarly, electrification may encourage new types of freight service due to lower operating costs, analogous to the "Sparks Effect" seen in passenger rail.

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[43] "Respiratory Health Risks for Children Living Near a Major Railyard", *Journal of Community Health*, 2015 https://link.springer.com/article/10.1007/s10900-015-0026-0; "Assessing environmental injustice in Kansas City by linking pediatric asthma to local sources of pollution: a cross-sectional study*". BMJ Open,* 2024 https://bmjopen.bmj.com/content/14/7/e080915

[44] "Chronic obstructive pulmonary disease mortality in railroad workers"*, Occupational and Environmental Medicine, 2008* https://pmc.ncbi.nlm.nih.gov/articles/PMC2658724/

[45] "2020 National Emissions Inventory Locomotive Methodology", Eastern Research Group, 2022. https://gaftp.epa.gov/air/nei/2020/doc/supporting_data/nonpoint/Rail/2020_NEI_Rail_062722.pdf

[46] "Locomotive Fact Sheets", CARB. https://ww2.arb.ca.gov/our-work/programs/reducing-rail-emissions-california/locomotive-fact-sheets

[47] "Locomotive Fact Sheets", CARB. https://ww2.arb.ca.gov/our-work/programs/reducing-rail-emissions-california/locomotive-fact-sheets

[48] "Cost and Benefit Risk Framework for Modern Railway Electrification Options", University of Texas for FRA, 2025**.** https://railroads.dot.gov/elibrary/cost-and-benefit-risk-framework-modern-railway-electrification-options

Conclusion

In summary, CARB's 'Truck vs. Trains" emissions analysis from 2020 is based on problematic and misleading methodology, and cannot be relied upon to inform critical decisions on the future of freight transportation in California. Unfortunately, policy makers and public interest/environmental organizations uncritically accept as gospel and promote CARB's false assertions about trucks and train emissions. In addition, CARB's "trucks are cleaner than trains" emissions claims contradict CARB's own stated policy goals to reduce road vehicle VMT.

CARB needs to do the honorable thing and remove the highly misleading "trucks are cleaner than trains" assertions from its website and other public materials. It must provide an updated analysis with the latest scientific and technical information available. Environmental organizations and others who have uncritically promoted these dubious claims need to do the same.

CARB also needs to formally acknowledge and promote the fact that both passenger and freight mode shift from road to rail is essential to reduce GHG emissions and many other negative environmental social impacts of transportation. Further, CARB needs to aggressively promote rail electrification, a proven and economical solution long used widely around the world, as a critical means for California to achieve a truly zero-emissions transportation system.