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MISSING THE TRAIN

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David E. Dismukes, Ph.D.

Professor Emeritus, Center for Energy Studies, Louisiana State University and Distinguished Fellow and Senior Economist, Institute for Energy Research

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EXECUTIVE SUMMARY

In April 2023, the California Air Resources Board (CARB) adopted the "in-use locomotive regulation," (or "locomotive regulation" for short) that mandates the phased retirement of older diesel locomotives and requires zero-emissions (ZE) rail technologies by 2030 for certain locomotive types and by 2035 for freight locomotives. The new CARB locomotive regulation represents a transformative shift in the U.S. rail industry since it will be the first state-level mandate to impose ZE requirements on this specific transportation sector.

The regulation's implementation is contingent on the Environmental Protection Agency's (EPA) approval. California is seeking a waiver under the Clean Air Act (CAA) to enforce these stricter air emissions standards for its rail operators. If the exemption is granted, it will not only have a negative impact on California rail operations, but could open the door for other more progressive states to adopt similar regulations, thereby entirely changing rail transport in the U.S.

Key requirements of the CARB locomotive regulation include banning locomotives older than 23 years, limiting idle times, imposing stringent reporting requirements, and mandating the use of annual "spending accounts" based on emissions and energy use. While the regulation aims to reduce greenhouse gas (GHG) emissions and air pollution, significant concerns have been raised about its feasibility, impact on freight and passenger rail operations, and the broader energy infrastructure challenges.

While many industry critics and other stakeholders have questioned the merits and efficacy of the regulation, few have discussed or addressed the considerable upstream energy infrastructure requirements that will be needed if this new form of rail regulation is allowed. The CARB regulation envisions that the primary ZE technologies utilized for compliance will be electric-battery generation, hydrogen fuel cell generation, or hydrogen direct combustion as a substitute for currently used diesel fuel.

A large number of commenters have questioned the viability of these ZE technologies and whether they can be utilized in the timeframe assumed by CARB. An equally important question, however, is whether or not the supporting energy infrastructure (primarily electric and hydrogen production, transportation, distribution, and storage infrastructure) for these ZE end uses is available, and if not, how this infrastructure would be added, and at what costs, in a very narrow compliance time window.

Key Issues and Concerns with the CARB Locomotive Regulation

Energy Infrastructure Availability Challenges: The shift to ZE locomotives will place enormous pressure on California's already strained electric grid. The state's power system is already struggling with reliability issues, and adding new rail-related electricity demands will exacerbate these challenges. Furthermore, the regulation overlooks the significant infrastructure required for hydrogen production, transportation, and storage. California lacks the necessary hydrogen infrastructure and developing it would require billions of dollars in investment.

Energy Infrastructure Cost Implications: CARB estimates that the locomotive regulation will cost the industry approximately $16 billion over 25 years. However, this figure excludes the substantial costs of upgrading the state's energy infrastructure. Upgrading the electric grid, building new power plants, and developing hydrogen pipelines could drive costs far higher, potentially leading to increased prices for consumers and businesses.

Supply Chain Disruptions: California's rail system plays a critical role in national and international supply chains, particularly for goods moving through its major ports. The locomotive regulation's attempt to focus on "green" intermittent resources could lead to significant cost increases and disruptions in freight and passenger transportation, which could ripple throughout the U.S. economy. These disruptions come at a time when supply chains are still recovering from the pandemic and inflationary pressures.

Environmental Impacts: While the locomotive regulation aims to reduce GHG emissions, its actual impact may be limited. The transition to electric locomotives could lead to increased reliance on natural gas-fired power plants during peak demand, reducing the potential emissions benefits. This would be particularly true if the industry utilized resources from less intermittent RE sources to offset potential rail system reliability challenges. Similarly, the widespread adoption of hydrogen, which is primarily produced using natural gas, could result in higher or at least significantly reduced overall GHG emission benefits. While industry could use alternative "green" sources of hydrogen, production from those green resources is not at the same scale as those coming from "grey" resources. Further, these green resources could also lead to additional reliability-related issues for freight and passenger delivery.

Conclusion

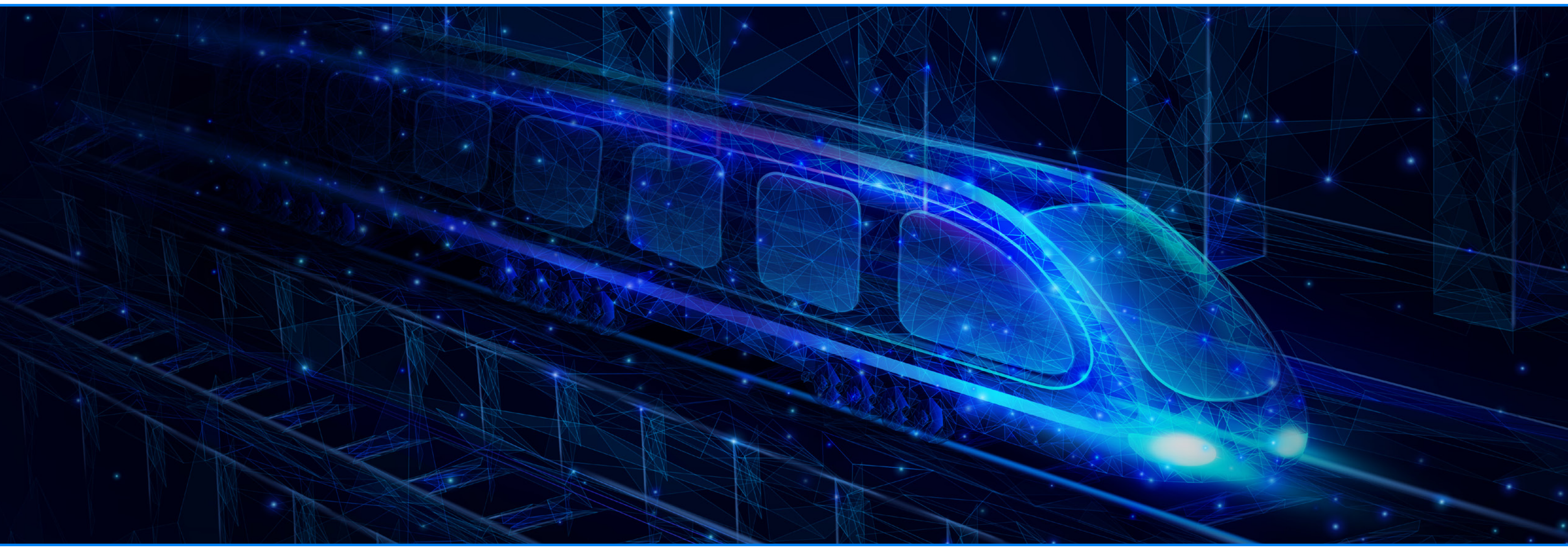
CARB's locomotive regulation is a risky proposition that could result in very high costs, for very little gain. The rail industry exhibits high-end use energy efficiency and has relatively low emissions particularly when compared to other sectors of the transportation industry: rail emissions and energy use are measurable in fractions of a percent. Yet, despite this, CARB proposes sweeping regulations that experiment with a critical U.S. economic sector for a very questionable environmental benefit.

The supporting energy infrastructure needed for the substitute ZE technologies envisioned by the locomotive regulation (both electric and hydrogen) will be considerable, particularly those associated with electric grid upgrades, and will compound an already considerable set of systematic challenges the utility industry faces in meeting other sweeping social policy goals and aspirations. The costs of building and/or reinforcing gas, power and hydrogen infrastructure to support new rail uses could also be prohibitive and will likely be borne by not just the rail industry itself but very likely all electric utility ratepayers given the typically socialized nature of these costs.

Lastly, the regulation may fail to deliver the anticipated environmental benefits, as emissions reductions could be offset by increased reliance on natural gas and other fossil fuels. As such, CARB's approach may ultimately impose more costs than benefits on the rail industry and California's economy.

SECTION 1

INTRODUCTION AND OVERVIEW



In April 2023, the California Air Resources Board (CARB) adopted its "In-Use Locomotive Regulation" (hereafter, "locomotive regulation" or "regulation") that will force the retirement of older diesel locomotives and mandate the exclusive use of zero-emissions (ZE) rail technologies in California.[1] This is the first regulation in the U.S. to set ZE requirements for locomotives. California, however, is still waiting for authorization from the Environmental Protection Agency (EPA) before this new regulation can be implemented. The new regulation will have considerably important impacts on the locomotive industry, on freight and passenger movements and costs, and, as will be discussed later, a variety of critical energy infrastructure, particularly infrastructure supporting electricity and hydrogen movement.

The new locomotive regulation applies to operators of freight line-haul, switch, industrial, passenger, and historic locomotives and will ban the operation of any locomotive

In April 2023, the California Air Resources Board adopted its "In-Use Locomotive Regulation" that will force the retirement of older diesel locomotives and mandate the exclusive use of zero-emissions rail technologies in California.

1 The final regulation was adopted by the California Office of Administrative Law in October, 2023. Title 13, California Code of Regulations, section 2478. (https://www.federalregister.gov/d/2024-03955/p-18).

TABLE 1: LOCOMOTIVE TYPES

Locomotive Type	Tier 4 Cost	Estimated Annual Maintenance Cost
Class I Line Haul	$3,100,000	$79,000
Class I and Class III Switcher	$2,700,000	$79,000
Industrial	$2,160,000	$79,000
Passenger	$7,500,000	$79,000

Source: Appendix F – Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation

that is 23 years or older from operating in California. The new locomotive regulation will also require, starting in 2030, that all switch, industrial, and passenger locomotives must operate in a ZE configuration: line-haul locomotives must comply with this ZE requirement by 2035. CARB-estimated compliance costs for these locomotives are provided in Table 1.

The new locomotive regulation will also restrict all locomotives with automatic shutoff devices to idle for periods up to 30 minutes.[2] Other locomotive operators will be required to install automatic engine stop/start (AESS) systems.[3] Exemptions could be granted for locomotives operated in ZE configurations for maintenance and safety reasons.[4]

The new CARB regulation will require California locomotive operators to utilize what are referred to as annual "spending accounts." Annual financial payments (or deposits) will be based on annual EPA-determined particulate matter (PM) and nitrogen oxide (NO_x) emissions on a locomotive-specific basis[5] and electricity usage as measured by onboard electric meters.[6] These two measures are weighted in such a fashion that annual deposits for the same level of production will increase in every future year.[7]

The locomotive regulation also includes a number of new CARB registration and reporting requirements that will require the provision of emissions spending account reports, among other requirements.[8] These reporting

2 California Air Resources Board. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation.* p. 2

3 *Ibid.* p. 46

4 *Ibid.* p. 2

5 Gable, Cameron J., and Thomas Donnelly. "CARB Approves Regulation to Reduce Railroad Emissions." Jones Day, August 2023. Accessed October 8, 2024. https://www.jonesday.com/en/insights/2023/08/carb-approves-regulation-to-reduce-railroad-emissions?utm_source=mondaq&utm_medium=syndication&utm_content=articleoriginal&utm_campaign=article

6 California Air Resources Board. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation.* p. 1

7 California Air Resource Board. *Preliminary Cost Document for the In-Use Locomotive Regulation.* March 16,2021, p. 4

8 United States District Court for the Eastern District of California. Association of American Railroads and American Short Line and Regional Railroad Association v. Liane M. Randolph *et al.*, No. 2:23-cv-01154-DJC-JDP. Order dated February 16, 2024. 3: 1 - 4: 22

requirements will also require locomotive operators to demonstrate how they intend to comply with the new rule. CARB also requires an annual $175 payment for each California-eligible locomotive.[9]

The new CARB locomotive regulation represents an extreme command and control type of mandate for the rail industry in California. This new, more hardline approach to regulating rail industry emissions is purportedly unique since some observers have noted that historically CARB has worked collaboratively with the rail industry in the past and has rarely used the hammer of regulatory enforcement to encourage better air emission performance.[10] Further, the rail and locomotive industry itself has taken a number of steps to reduce its emissions, deploying a variety of emerging technologies and practices that include the use of low-emission yard equipment, deploying low-emissions idling systems, upgrading fuel management systems, using lower emission alternative fuels such as renewable fuels, and in many instances, directly electrifying certain operations and activities.[11] Yet, despite these mostly industry-originated initiatives, the rail industry will face its first major CARB regulation in over five decades.[12]

Locomotive operators have argued that the regulations are not needed and non-attainable, and highlight the fact that, in the big picture of GHG emissions sources, rail operations are simply not a major contributor, particularly not one that is large enough to justify such a restrictive and aggressive set of new and unprecedented regulatory requirements.[13]

Domestically and globally, rail operations have some of the lowest carbon emissions of any part of the transportation sector (see Figure 1). Consider that in the U.S. alone, the rail sector accounts (2022) for about two percent of all transportation-related GHG emissions, which itself accounts for 28 percent of total U.S. GHG emissions --

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9 *Ibid*. 4: 18-22

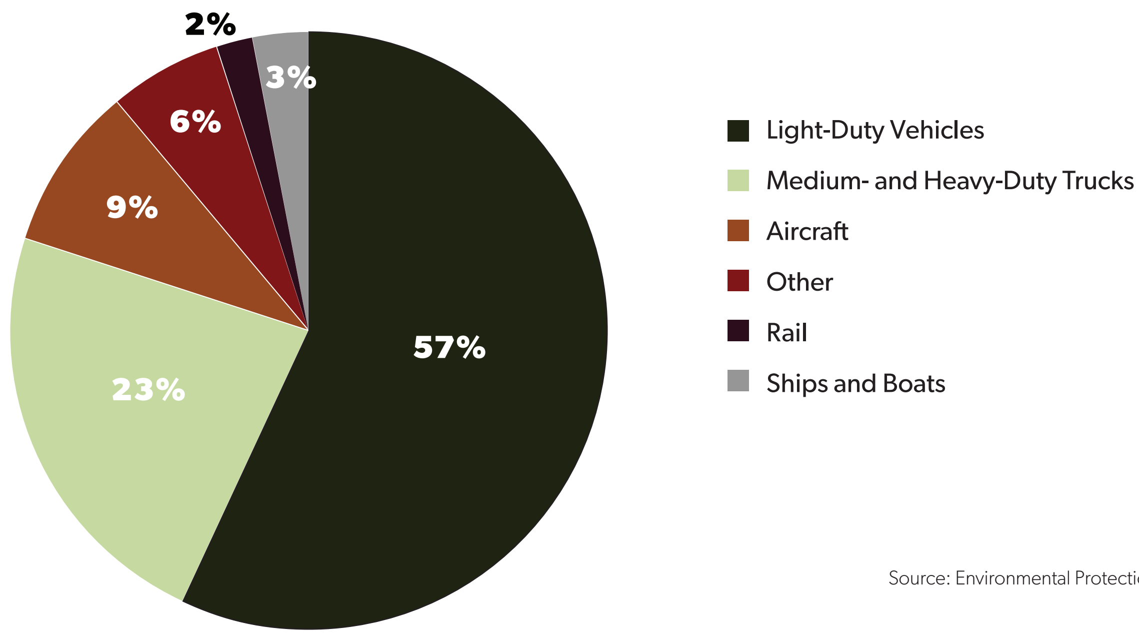
10 Association of American Railroads. *CARB's In-Use Locomotive Regulation: Rule Will Hurt the American Economy.* April 2024. p. 1

11 California Air Resources Board. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation*. pp. 42-44

12 California Air Resources Board. "Rules Log Database." Accessed October 11, 2024. https://ww2.arb.ca.gov/applications/rules-log-database.

13 Association of American Railroads. *Comments on Proposed In-Use Locomotive Regulation*. Submitted to the California Air Resources Board, April 2024. p. 2. Westinghouse Air Brake Technologies Corporation. *Comments in Response to Notice of Opportunity for Public Hearing and Comment for California State Nonroad Engine Pollution Control Standards; In-Use Locomotive Regulation; Requests for Authorization (EPA–HQ–OAR–2023–0574).* April 2024. pp. 1-2. Washington Farm Bureau. *Comments on CARB's Clean Air Act Authorization Request (EPA-HQ-OAR-2023-0574).* April 9, 2024. pp. 1-2

FIGURE 1: U.S. TRANSPORTATION SECTOR GHG EMISSIONS BY SOURCE (2022, SHARES)



Source: Environmental Protection Agency

meaning that the rail sector only accounts for only one-half of one percent total U.S. GHG emissions.[14]

In California alone, the rail sector is estimated to account for approximately two percent of transportation emissions (40 percent of total) or less than one percent (0.8 percent) of total 2022 GHG emissions.[15] Yet California accounts for as much as five percent of total 2022 U.S. freight transportation and as much as 20 percent of all U.S. rail passenger transportation (see Table 2).[16] Thus, in looking across all sectors of the California economy, the rail sector is a very efficient user of energy and a relatively low GHG emitter.

Because of technological advancement and innovation, rail continues to be unrivaled by other modes for fuel efficiency. Trains are four times more efficient than trucks, moving one ton of freight 470 miles on just a single gallon of diesel fuel.[17] Rail's lower fuel consumption also leads to lower carbon emissions overall, accounting for only two percent of all transportation-related GHG emissions.[18]

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14 See U.S. Energy Information Administration. "U.S. Energy-Related Carbon Dioxide Emissions, 2023." *Monthly Energy Review*, March 2024. https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf. Bureau of Transportation Statistics. *Transportation Statistical Annual Report 2023*. Washington, DC: U.S. Department of Transportation, 2024. https://www.bts.gov/tsar. Environmental Protection Agency. "Fast Facts on Transportation Greenhouse Gas Emissions." *EPA.gov*, June 18, 2024. https://www.epa.gov.

15 California Air Resources Board. "Current California GHG Emission Inventory Data." *CARB*, 2023. https://ww2.arb.ca.gov. California Environmental Protection Agency. "Climate Dashboard." *CalEPA*, 2023. https://calepa.ca.gov. UC Davis. "Decarbonizing California Transportation by 2045." *UC Davis News and Media Relations*, April 21, 2021. https://www.ucdavis.edu.

16 California Department of Transportation (Caltrans). *California State Rail Plan*. Sacramento: California Department of Transportation, 2023. https://dot.ca.gov. Association of American Railroads. "Freight Rail Traffic Data." *AAR*, 2023. https://www.aar.org. International Railway Journal. "Integration and Frequency at the Heart of California Rail Plan." *International Railway Journal*, March 2023. https://www.railjournal.com.

17 Association of American Railroads, "Freight Railroads Embrace Sustainability & Environmental Preservation," February 2019.

18 Environmental Protection Agency, "Fast Facts: U.S. Transportation Sector Greenhouse Gas Emissions 1990–2017," June 2019, 1.

TABLE 2: U.S. FREIGHT VOLUMES BY TOP FIVE STATES (2022, TOTALS AND SHARES)

State	Tons (thousands)	Share of Total (Percentage)
Texas	1,048,739	13.53%
Louisiana	698,408	9.01%
Illinois	399,545	5.15%
California	372,133	4.80%
Ohio	297,925	3.84%

Source: Bureau of Transportation Statistics

Despite the relative efficiency of rail operations (in terms of both energy usage and emissions), CARB has decided to move forward with a sweeping new form of regulation that will be transformative for both California and potentially other states. California's rail system is inextricably linked with the rest of the country: California rail systems link western coast major port facilities to the rest of the U.S. Thus, changes in the way these systems are configured and utilized will have large ripple effects throughout California and the rest of the country. The new CARB locomotive regulation threatens differing (multi-modal) transportation supply chains that are just now recovering from the aftermath of the pandemic, inflation, labor challenges, and structural difficulties.

CARB's locomotive regulation will likely force operators to replace, rebuild, or redeploy thousands of locomotives to achieve compliance at a time when the industry customarily acquires or remanufactures perhaps a few dozen locomotives per year.[19] CARB itself has estimated that the locomotive regulation could cost close to $16 billion in equipment and labor over 25 years, with these costs likely being passed along to consumers in the form of higher prices.[20]

California's new locomotive regulation is now in front of the EPA since CARB is seeking a waiver for this regulation under Section 209 of the Clean Air Act (CAA). This waiver process is essential because it allows California to implement its own, more stringent emissions standards, which differ from federal regulations. California is required to seek this waiver since it is prohibited from adopting alternative air emission standards under Section 209 of the CAA: this waiver is legally required even if the newly proposed standards are perceived to be more stringent and/or aggressive than those provided for by the EPA.

The EPA is currently reviewing this waiver and can only deny a waiver if (a) the state's regulations are not needed to meet compelling conditions, (b) the state's standards are arbitrary and capricious, or (c) the state's standards are not consistent with Section 202(a) of the CAA, which

19 FreightWaves. "California Passes Rule to Drastically Cut Locomotives' Emissions." *FreightWaves*, April 28, 2023. https://www.freightwaves.com. DieselNet. "CARB Adopts In-Use Locomotive Regulation." *DieselNet*, April 27, 2023. https://www.dieselnet.com/news/2023/04carb.php.

20 FreightWaves. "California Passes Rule to Drastically Cut Locomotives' Emissions." *FreightWaves*, April 28, 2023. https://www.freightwaves.com.

sets the framework for federal emissions standards.[21] If the EPA grants the waiver, California would be able to enforce its stricter rail emissions standards. Most importantly, and of additional concern, is that if this waiver is granted, it would allow other states to adopt California's standards under Section 177 of the CAA, potentially extending the regulation's impact beyond California.[22]

The EPA process is ongoing and taking comments from various stakeholders and impacted parties. The rail industry itself has raised a number of concerns about the CARB locomotive rule including:

Mandating technologies that are not yet commercially viable. The rule requires railroads to open and deposit funds into a "spending account" based on the Tier level and energy consumption for each locomotive operated in California in a calendar year. Railroads would have no choice but to purchase zero-emission technology and infrastructure that is not currently available.

Limits the useful life of over 25,000 locomotives. The rule bans the operation of any locomotive that is 23 years or older from operating in California. Starting in 2030 for all switch, industrial, and passenger locomotives, and 2035 for line haul locomotives, older locomotives can only operate in the state if they are zero-emissions locomotives.

Violates the Clean Air Act (CAA) prohibition on states regulating emissions from new locomotives. Section 209(e) of the CAA, a preemptive provision, generally bars states from regulating emissions from new locomotives or engines, including remanufactured locomotives, (which the EPA cannot waive) and on all other locomotives. The rail industry notes that CARB's rule unequivocally violates the CAA by attempting to change the locomotive fleet nationwide to new, ZE technologies and processes.

The EPA process is ongoing and taking comments from various stakeholders and impacted parties. The rail industry itself has raised a number of concerns about the CARB locomotive rule.

Violates the ICC Termination Act (ICCTA) of 1995. Congress passed ICCTA in order to assure that the federal government retains exclusive control over inherently interstate railroad operations. The ICCTA, however, prohibits states and local governments from regulating rail operations, including locomotives. Industry argues that the CARB rule targeting locomotives runs afoul of ICCTA's preemption provisions.[23]

In addition to the new regulation, CARB concurrently issued several supporting technical documents. The purpose of these documents was to identify and address the key technical issues associated with the regulations' implementation and, while not prepared in direct response to industry concerns, appear to be CARB's backup to rebut such claims regarding the technical capabilities and availability of certain emerging ZE technologies and their ability to be used within the regulation's time frame. In effect, these technical documents purportedly serve as the

21 U.S. Environmental Protection Agency. "Vehicle Emissions California Waivers and Authorizations." EPA. Accessed October 7, 2024. https://www.epa.gov/state-and-local-transportation/vehicle-emissions-california-waivers-and-authorizations.

22 *Ibid.*

23 These industry positions are summarized in: FreightWaves. "California Passes Rule to Drastically Cut Locomotives' Emissions." *FreightWaves*, April 28, 2023. https://www.freightwaves.com. DieselNet. "CARB Adopts In-Use Locomotive Regulation." DieselNet, April 27, 2023. https://www.dieselnet.com/news/2023/04carb.php.

backup, support, and documentation for all the sweeping proposals included in the new locomotive regulation. These technical documents include the *Technical Support Document* for the Zero-Emission Locomotive Conversion, which outlines the technical feasibility and pathways for converting diesel locomotives to zero-emission alternatives.[24] CARB also issued a *Guidance Document for Approval of Zero-Emission Switcher Locomotives* directed at manufacturers seeking to attain CARB approval for ZE switchers or conversion systems.[25]

The problem with these technical documents is that they provide scant attention to many of the real-world technical challenges associated with the regulation's implementation, like the commercial availability and operating history of the ZE technologies that are purported to facilitate this new rail industry. These documents are virtually silent on how the sources of ZE energy will actually be produced, transported, and stored to support CARB's new vision of the rails of the future. The locomotive regulation simply assumes that electricity and hydrogen, the two primary ZE technologies identified in the proposed regulation, will magically appear, with little to no supporting infrastructure requirements, despite the well-recognized reality that California's power grids are notorious and consistently under pressure and the fact that hydrogen infrastructure in the western U.S. is virtually non-existent. CARB's new locomotive regulations assume that current diesel locomotives will be replaced with either battery-electric or hydrogen-fueled engines, through the use of fuel cell technologies or direct combustion as an alternative fuel for onboard diesel generators.

New electric locomotives, driven from battery electricity, will need large enough battery and electric charging capacity to store the significant electricity requirements of typical rail transportation. Industry shifts to all battery-driven locomotives will have important implications for electric utilities and power grids throughout the western U.S. Likewise, if hydrogen is used extensively, impacted rail operators will need to not only procure this hydrogen from a source, but will need to move it and store if for future use.

While both technologies are being tested by various rail operators in the western U.S., and throughout the country, most are not considered "ready for prime time" at the current point in industry development. The need to reinforce electric grids to handle such new loads has been completely overlooked by the regulation's supporting technical documentation.

To date, most of the criticism of the CARB locomotive regulation has focused on the feasibility of the ZE locomotive technologies and the impacts these rules will have on freight costs, and supply chains throughout the U.S.[26] This analysis takes a bit of a unique turn, and instead, focusses on the energy industry implications that the regulation will have, in particular, how alternative energy production and infrastructure will need to be developed and buttressed to meet these substantial new ZE energy requirements. Impacts on costs and potential emissions are also considered for both technologies.

24 California Air Resources Board. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation*

25 California Air Resources Board. *Guidance Document for Approval of Zero-Emission Switcher Locomotives.* Transportation and Toxics Division Freight Technology Advancement Branch, Version 1, February 09, 2024.

26 American Fuel & Petrochemical Manufacturers. *Comments to the EPA on CARB's In-Use Locomotive Regulation.* pp. 1-3. Washington Farm Bureau. *Comments on CARB's Clean Air Act Authorization Request.* pp. 1-2. Association of American Railroads. *Comments on Proposed In-Use Locomotive Regulation.* p. 40

SECTION 2

ELECTRICITY COST UPGRADE ESTIMATES

The technical documents supporting CARB's new ZE rail regulation provide scant details on how the technological challenges of this new standard will be met. Several industry stakeholders, operators and consumers alike note that many of the technological assumptions underpinning the rule are wishful thinking, at best.[27] These technical deficiencies alone should be enough to question the proposal's efficacy. But that is not the end of the story: there is an additional and even larger deficiency in the CARB technical analysis in that it entirely fails to recognize and comprehensively address the wide range of critical supporting energy infrastructure requirements that will be needed to facilitate the use of these new, presumably mostly electric, technologies.

The scale and scope of the electric grid improvements needed to support CARB's new rail rule will be considerable. Further, California (and other states adopting similar programs) could find that the electric grid investments needed to support this initiative either confuse or raise their anticipated costs. Currently, most electric utilities are already dealing with a variety of system changes that include addressing not only reliability and resiliency, but meeting a wide range of new and unexpected electricity loads arising from the rapid electrification of buildings, passenger and fleet transportation (electric vehicles), and light manufacturing and industrial applications: all of which are moving away from mostly fossil fuels to electricity to meet broader state-level decarbonization mandates. The CARB ZE rail

27 Association of American Railroads, "Comments on Proposed In-Use Locomotive Regulation," submitted to the California Air Resources Board; Benjamin Zycher, *Comments Submitted to the U.S. Environmental Protection Agency on Behalf of the American Enterprise Institute: In re California Air Resources Board Request for EPA Waiver Authorization of the In-Use Locomotive Regulation*, April 22, 2024; Rail Passenger Association of California and Nevada, "RailPAC Comment Letter to EPA on California In-Use Locomotive Regulation," April 4, 2024.

regulation will simply add one more complication into the mix of an already tumultuous and confusing situation in electric grid planning. Rail electrification will simply further drive-up electricity bills for households, business and industry with little in terms of GHG emissions reductions.

It is difficult to know with certainty what electric grid improvements will be needed since the size, timing, and geographic scope of the changes that the rail industry will specifically adopt in response to this new regulation are unknown. There are, however, some relatively higher-level electric grid impacts and investments that are identifiable, including:

- Increased power generation costs including primary capacity needs and backup/reserve capacity to meet new rail electric loads.
- Upgrades and new investment in transmission and distribution capacity that will be needed to move electricity from generation resources to these new rail loads at both the high voltage and lower voltage levels.
- Upgrades and new system investment in the capacity of both transmission and distribution substations.
- Potential power quality investments that will be needed to assure that voltage, harmonics and reactive power requirements for the system are not undermined by the additional and unique rail load requirements.
- New regulatory and administrative costs.

2.1 POWER GENERATION REQUIREMENTS

The conversion of rail to ZE technologies that rely heavily on electrification will require new incremental power generation resources, including new power plants since there is simply not enough spare generation capacity in California to soak up this additional load.[28] This is no small challenge since California, like many other regional power pools around the U.S. are "capacity constrained" meaning that the excess generation needed to serve as a "margin" to back up the system during constrained periods is deficient and likely dangerously low.[29]

Figure 2 provides a summary of recent California grid challenges. One recent event, the 2022 summer heat wave, resulted in record electricity loads and severely threatened system integrity. During this time period, the California Independent System Operator (CAISO) issued emergency alerts to utilities to reduce loads to prevent rolling brown-outs and blackouts on the system.[30] A major catastrophe was averted during this time period, but imagine what a similar situation would have looked like had thousands of mega-watts (MWs) of additional load been placed on the system during this critical time period to accommodate electric rail loads, among other increasing electrification initiatives.

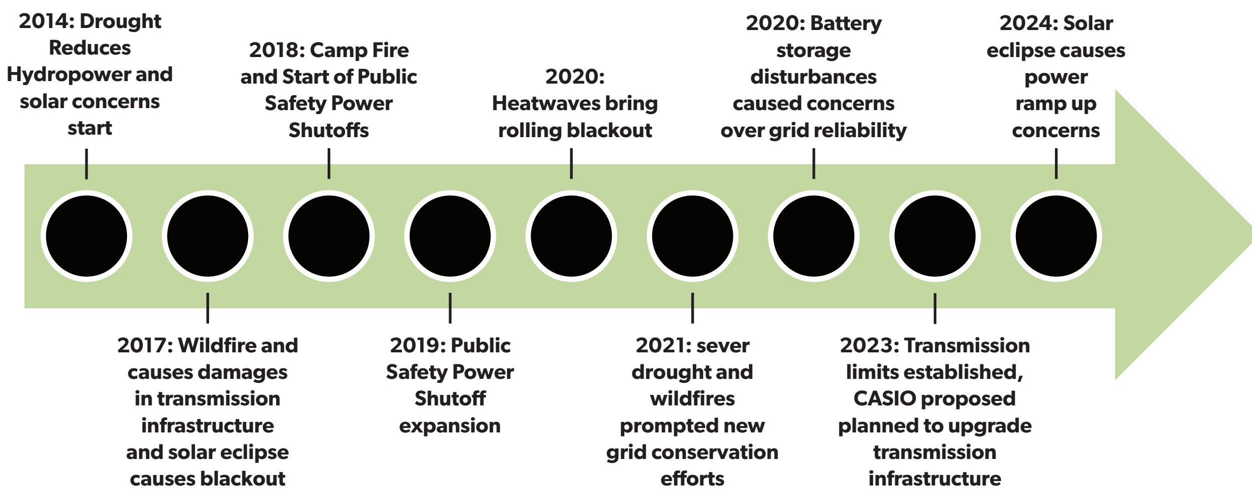
Even the level of new electrical loads arising from the new CARB rule is debatable and could be orders of magnitude off base. For instance, CARB estimates a relatively modest new electricity loads that will arise from rail electrification of 160.1 gigawatt-hours (GWh). The CARB incremental electric usage estimate, on its face, seems harmless

28 Bloom Energy, "Bloom Energy Outage Map," accessed September 26, 2024, https://www.bloomenergy.com/bloom-energy-outage-map/; MacKenzie Elmer, "California Grid Can Handle Electric Vehicle Load with Updated Infrastructure and Customer Discipline," *KPBS*, September 19, 2022, https://www.kpbs.org/news/environment/2022/09/19/california-grid-can-handle-electric-vehicle-load-with-updated-infrastructure-and-customer-discipline; Ivan Penn, "California Avoids Blackouts, but Threats to Electric Grid Continue," *The New York Times*, September 25, 2022, https://www.nytimes.com/2022/09/25/business/energy-environment/california-energy-grid-heat.html.

29 California Energy Commission. *California Energy Resource and Reliability Outlook, 2024.* Sacramento: California Energy Commission, 2024, pp. 44-47.

30 California Independent System Operator, *Summer Market Performance Report for September 2022* (California ISO, 2022), p.12.

FIGURE 2: TIMELINE OF RECENT CALIFORNIA ELECTRIC GRID CHALLENGES



Sources: California Public Utilities Commission, Office of Governor Gavin Newsom, California Energy Commission, California Public Utilities Commission.

since represents a mere 0.1 percent of current total 2022 California retail electricity loads.[31] This new electricity load estimate, however, may be grossly understated and clearly fails to put into perspective the additional number of new power plants that will have to be constructed (renewable or thermal) to back up these new loads.

The American Enterprise Institute (AEI), in its written comments, notes that CARB's estimates of the additional electricity needed to meet this new demand are flawed since these estimates are based only on one small segment of rail transportation, switcher/shunter locomotives, not all forms that can include freight and line-haul, passenger, specialty, industrial, military, and other forms of rail transportation.[32]

AEI's comments note that elsewhere in CARB's own documentation are estimates that have freight transport electricity usage at over 4,000 GWh in 2034, increasing to 6,000 GWh in 2050.[33] Estimates that exceed at least 25 times the CARB electricity estimate. As a further check on these numbers, AEI notes that the Energy Information Administration (EIA) reports 2020 rail transportation-specific diesel use of over 220 million gallons. Using a standard fuel/power conversion rate defined by the Federal Railroad Administration results in as much as 3,416 GWh of electricity, itself an estimate 21 times what was provided by CARB.[34]

As noted earlier, the electricity needed to meet this requirement says nothing about the additional power plants (i.e., electric generating capacity) that will be constructed and put into service to meet these new loads.

31 California Air Resources Board, *Yes, the California Grid Can Handle Electrification of All Switchers at All Railyards*, accessed September 25, 2024, https://ww2.arb.ca.gov/resources/fact-sheets/yes-california-grid-can-handle-electrification-all-switchers-all-railyards.

32 Benjamin Zycher, *Comments Submitted to the U.S. Environmental Protection Agency on Behalf of the American Enterprise Institute: In re California Air Resources Board Request for EPA Waiver Authorization of the In-Use Locomotive Regulation*, April 22, 2024, p. 2.

33 *Ibid.* p. 4.

34 *Ibid.* p. 4

The generating capacity needed to support this level of annual generation could be as much as 1,000 to 1,500 MWs assuming an average rail transportation sector electric load factor of 0.50 using 4,000 to 6,000 GWh of electricity usage, respectively, as the incremental change in annual energy loads. Assuming new natural gas generation capacity costs of $1,300 per installed kilowatt (kW) of capacity suggests additional generation cost of meeting these new CARB requirements of between $1.3 to $2.0 billion. Today, most grid-scale solar is comparable to natural gas generation so this is an investment cost likely not avoided by moving from fossil/thermal resources to renewable energy. If anything, the additional investment cost needed to meet this capacity requirement for renewables will likely have to be higher to offset these resources' intermittent and weak effective load-carrying capacity (ELCC) capabilities.[35]

Ironically, the move to rail electrification is not likely to result in a complete offset of GHG emissions and, in some rare instances, could lead to actually higher, not lower, overall GHG emissions depending upon how the geographic scope of those emissions is evaluated. Consider that the initial compliance year for the new CARB rail regulations starts in 2030 and 2035 (for line-haul locomotives). Clearly, power systems, even in California, will have not made a complete 100 percent leap to renewables and battery storage by this date.

In fact, estimates are that California alone will likely still have as much as close to one-quarter of its total generation still coming from fossil generation in 2030.[36] This means that while GHG emissions will be avoided directly in rail transportation, the electricity generated to meet this requirement will likely continue for several years despite various rosy outlooks that the march to 100 percent renewable generation is inevitable.

Ironically, the move to rail electrification is not likely to result in a complete offset of GHG emissions and in some rare instances, could lead to actually higher, not lower, overall GHG emissions depending upon how the geographic scope of those emissions is evaluated.

Further, given the low load factor[37] for the overall rail

35 ELCC is a metric used to quantify the contribution of a power generation source, particularly intermittent renewable sources like wind or solar, to reliably meet demand in an electric grid. ELCC metrics define the amount of additional load that can be served reliably by adding the renewable energy generation source to the system without increasing the risk of power shortages. In this manner, ELCC defines the reliability contribution of variable resources relative to firm or dispatchable generation, taking into account the variability and uncertainty of the power source. See "Effective load carrying capability." *Dictionary of Energy*, edited by C. J. Cleveland, 2nd ed., Elsevier, 2015, pp. 209-210.

36 S&P Global Market Intelligence, *Historical and Future Power Plant Capacity Data for the CAMX Subregion, CAISO Subregion (Summer), and CAISO Subregion (Winter)*, accessed September 24, 2024, via S&P Capital IQ platform

37 A load factor is a metric used in the electric industry that measures the utilization of electrical capacity. It is calculated by dividing the total energy consumed over a specific period, usually for an electric system or for a specific customer class, by the product of the maximum demand and the number of hours in that period. In more simple terms, the load factor is the ratio of average to peak electric demand with a higher number indicating less variation between peak and average loads, and a lower factor meaning greater variability. High load factor customers are thought to be more efficient since the utilize capacity more efficiently. See Penner, S. S. "Load Factor (Electricity)." Power Generation: Renewable, Non-renewable, and *Distributed Energy Resources*, Academic Press, 2016, pp. 115-117.

sector, it is likely that rail electricity use during electric system peak periods, which occur late in the date when solar and wind is less effective, will have to be met directly with natural gas-fired generation. Thus, at the margin, the degree to which GHG emissions will really be reduced, once generation and line loss efficiencies are considered, will likely be orders of magnitude lower than current CARB estimates.

What has been completely overlooked, however, are the large emission and likely cost "leakages" that will "spill over" from California and other states adopting similar provisions to those states not adopting such measures. Consider that if this regulation is allowed to stand, California rail operators are not likely to develop separate fleets of locomotives: one set operating exclusively in California, with another set being utilized to move freight to the rest of the Western U.S. (or other places in the country). Further, it is also not likely that California-originating locomotives will transfer freights at the state border from a primarily electric-charged set of locomotives to another set of locomotives that are diesel and will carry the remaining haul of the freight to a non-California location. This is no trivial matter since estimates place over 70 percent of the California rail traffic as being engaged in interstate and not strictly intrastate commerce.[38]

Thus, once California rail operators convert their fleets to electricity (or another ZE technology like hydrogen) then those fleets are likely to be used to service both California and broader interstate markets. As these electrified fleets of locomotives leave California, they are likely going to need to be charged at other destinations along their various routes, putting increasing pressure on the electric grids of other states and regions and pulling electricity from generation resources from those electric grids, that again, will likely still be preponderantly fossil-based, thus maintaining GHG emissions, drastically reducing, if not potentially increasing GHG emissions, and, at minimum dramatically increase the cost per avoided GHG emissions from having made these electric locomotive investments.

Likewise, consider the cost spillover impact this will have on other states. Given this potentially new increase in rail-based, grid-supported electricity use, new generation, transmission, and distribution investments will likely be needed. These are a set of cost leakages that are currently not considered in the new CARB rail regulations.

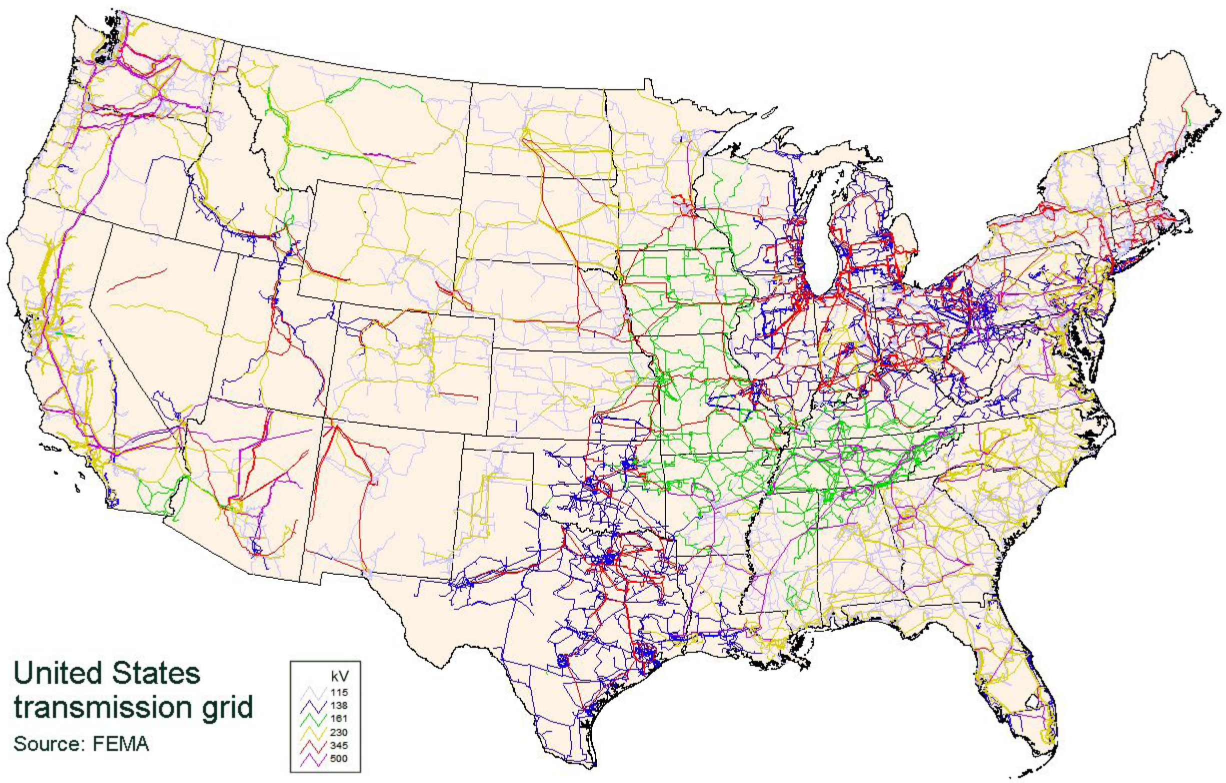
2.2 TRANSMISSION AND DISTRIBUTION LINE UPGRADES

The transmission system in the U.S. has been designed over the past century to move electricity from generation resources to distribution load centers. These systems have been interconnected by utilities over the decades and are highly interconnected (see Figure 3). Experience has shown repeatedly that transmission-related incidents in one part of the country can have ripple effects across multiple and far-reaching geographic regions.

The current energy transition, with its integration of a large number of intermittent power generation resources, is already being taxed in unusual and unexpected ways that are too numerous to discuss here. What is without question is that electrifying rail transportation in California, or any other state, will place an additional and non-trivial burden on an already pressured high-voltage electric transmission system. At a minimum, new upgrades will be needed to existing systems to accommodate these new loads, and it is highly likely that in a good part of California and other parts of the western interconnect, new, expensive investments in load-carrying capacity on the transmission system (i.e., new lines and capacity) will be necessary.

38 U.S. Department of Transportation, Federal Highway Administration. "Freight Analysis Framework (FAF5) National Summary Dashboard." Accessed September 18, 2024. https://explore.dot.gov/t/FHWA/views/FAF5_5_1VisualizationFinalv1_1_09_14_2023/NationalSummaryDashboard.

FIGURE 3: U.S. ELECTRIC TRANSMISSION SYSTEM



Source: Federal Emergency Management Agency

Consider the upgrades to existing transmission systems that will be needed. Most rail systems will need a considerable amount of capacity (power plants to call upon, including backup for extreme peak requirements) and energy (electricity delivered from these power plans) as a replacement energy resource for diesel. Current transmission lines, particularly in more rural or remote areas where rail lines may be located, are often not designed to meet large and potentially seasonal/cyclical loads. The California electric transmission system (and other states adopting similar rules) will likely, in one form or another, need to accommodate new interconnections into railyards, maintenance yards, depots, intermodal terminals, ports, and other locations where locomotives congregate for maintenance and repair purposes or to collect and move passengers and freight from one location to another. All of these types of existing rail congregation points, while likely already having some form of transmission or distribution interconnection, will need to be upgraded to accommodate these new loads. Further, most of the transmission lines in these areas are likely designed for lower load levels and will need to be enhanced to assure service quality, reliability, and resiliency.

Even with upgrades, there is only so much the existing transmission system can handle, particularly given the additional and rapid electrification initiatives being taken in California and other more climate-progressive states throughout the country. While rail conversions to electric and ZE technologies will be important, there are other vast electric conversions underway for buildings, industrial applications, and vehicular transportation not to mention unexpectedly high intrinsic growth arising from cryptocurrency mining and server requirements for various artificial intelligence applications.

Now, with states adopting the new CARB-style rail electrification initiatives, these high voltage upgrades and new incremental transmission investments will be incrementally more expensive than those that may have been done over a decade ago. The upgrades and new capacity investments will be required to me more expensive and more stringent standards that are arising through the U.S. to accommodate the new realities of operating under today's higher reliability and resiliency standards.

Thus, it is not just that existing lines will have to be upgraded to accommodate new loads but that the new upgrades and incremental conductor additions will be required to include new reliability/resiliency "bells and whistles" that include line spacers and circuit reclosers, new system automation and other remote controls. Some upgrades may require more expensive configurations that include undergrounding where, in the past, an overhead solution may have sufficed.

Consider that upgrades to existing power transmission and distribution systems themselves will range from as low as $500,000 per circuit mile of upgrade to over $2 million per circuit mile, depending upon location.[39] Higher voltage transmission line upgrades, like those upgrading 245 kilovolts (kV) or higher, will likely be more expensive on a per-mile basis, possibly even higher than $2 million per circuit mile. Likewise, distribution-level system upgrades, while likely more "affordable" than their higher voltage transmission counterparts, may be offset by (a) a larger number of circuit miles that may need to be upgraded and (b) potential urban area upgrades in major metropolitan

The upgrades and new capacity investments will be required to me more expensive and more stringent standards that are arising through the U.S. to accommodate the new realities of operating under today's higher reliability and resiliency standards.

centers that will usually require investments to the upper end of these cost estimates.[40]

Lastly, there is the issue of substation upgrades. Substations connect high and low voltage systems, stepping up power taken from a generating resource and moving it to various geographic areas where loads are located. Power is stepped down through a series of lower distribution level transformers (located at sub-transmission and distribution substations) to various load centers in both rural and municipal locations. All of this substation capacity will be impacted if yet another form of electricity use, in this instance rail transportation, is converted from liquid fuels.

The nature of substation investment, like other components of the power industry, is undergoing

39 PGAE. *2023 Final Per Unit Cost Guide*. Excel file, 2023. https://www.caiso.com/library/current-cost-guides.

40 *Ibid*.

considerable changes, mostly due to a host of infrastructure modernization initiatives. Substation automation, transformer replacements and expansions, "self-healing" development, and physical systems investments to withstand extreme weather and natural disasters (like wildfires) are just part of the normal substation investments that are driving up the cost of both transmission and distribution substations. So, not only will these substations have to be upgraded to support new rail electricity loads, but the cost of upgrading these substations to meet new standards will be higher and accelerated given these new rail electric load pressures.

Substation investments are also costly, with transmission-related substations being more expensive to upgrade and expand than their small distribution-level counterparts. Building a new substation typically costs between $10 million to $20 million, depending on capacity and location, while upgrading an existing substation might cost $1 million to $5 million.[41]

2.3 POWER QUALITY INVESTMENTS

New electricity loads such as rail transportation, which can cycle up and down in unexpected ways, can have implications for electric system power quality. In today's digital age, power quality becomes increasingly more important given the sensitivity that digital and computer driven equipment has to fluctuations in voltage, frequency, harmonics, and other forms of electrical disruptions.[42]

Electric system power quality could easily be negatively impacted by new rail electric loads. Just the mere fact that a large and not entirely understood load, with unique and differing characteristics (from other major customer classes) and differing load factors, will create initial challenges, particularly if there are charging loads on the system at various different and perhaps inconsistent times across differing geographic areas. Thus, like other parts of the system, there are planning and infrastructure requirements tied to power "quality" that go beyond the simple "quantity" needs (or line capacity) to accommodate these new loads.

There could be even more significant power quality impacts to both transmission and distribution grids if rail systems, or sub-parts of these systems, are completely electrified, rather than simply using the grid for locomotive battery charging. If new segments of the rail industry were simply electrified, grid operators would have to prepare and plan for electrical requirements to meet locomotive braking requirements, accelerating speeds, and a host of other rail operational needs and how those needs will impact power quality issues like harmonics and reactive power requirements.[43] Rail systems' use of power converters, switching electricity from DC to AC and back, will also lead to unique localized power quality challenges for grid operators (at the transmission level) and local utilities (at the distribution level).[44]

In terms of costs, these vary by type of investment and impact. At this point, it is hard to determine what these costs will be until the future composition of rail electric use and where that use occurs is known. Power quality costs are, admittedly, smaller than the ones discussed earlier for the transmission and distribution system but are also non-trivial in nature. The types of investments that will likely need to be made will include new (additional) or upgraded capacitors, voltage regulators, uninterrupted power systems (UPS), energy storage devices, various harmonic filters, static VAR compensators, and/or power converters,

41 *Ibid.*

42 Jafari Kaleybar, Hamed, Morris Brenna, Federica Foiadelli, Seyed Saeed Fazel, and Dario Zaninelli. "Power Quality Phenomena in Electric Railway Power Supply Systems: An Exhaustive Framework and Classification." *Energies* 13, no. 24 (December 17, 2020) p. 1.

43 *Ibid.* p. 13.

44 *Ibid.* p. 5.

to name a few. The cost for these types of investments can range from $500,000 to as much as $5 million per substation.[45]

Further, given the public goods nature of many power quality investments (i.e., they provide qualitative benefits to all system users), and the difficulty in "directly assigning" power quality investment costs to certain customer classes and beneficiaries, it is often the case that power quality investments are proportionately shared across all transmission and distribution customers. So, to the extent that rail systems are electrified, and have additional power quality impacts requiring additional system investments, those will likely be passed along, in some part, to other power system customers.

2.4 REGULATORY AND ADMINISTRATIVE COSTS

Lastly, it is without question that the energy use changes being mandated by CARB for rail operators alone will increase regulatory and administrative costs for not only utilities but a wide range of other electric industry stakeholder groups. The electric utility industry is both highly integrated and regulated at both the federal and state levels. Adding yet an entirely new electricity end-use sector out of thin air will require considerable effort from regulators and regulated electric utilities. This effort will be spread across a host of differing regulatory proceedings and processes.

First and foremost, existing electric utility planning processes, which include a large degree of regulatory oversight and stakeholder input, will be modified to accommodate a sizable and new energy load on the system. This planning process will have to explicitly and directly consider how electrified rail transport impacts system requirements much like the type of proceedings that have, or are occurring regularly addressing new load growth from electric vehicles, other electrification initiatives, and those attributable to new loads from data mining and artificial intelligence.

Second, there will also be a variety of new and ongoing planning investigations that will occur at the regional transmission organization level (like CAISO) to investigate the new transmission infrastructure and wholesale market requirements electrified rail loads will play on the system.

Lastly, there is the issue of future base rate cases that electric utilities will have to file with their state regulators (like the California Public Utilities Commission) in order to determine the appropriate level of system investments (line upgrades, new line capacity development, substation development and equipment investment) that will need to be recovered from ratepayers and how those specific investment costs will be recovered from specific customer classes.

Further, it is important to recognize that these regulatory and administrative costs are not restricted to utilities and regulators alone but will impact a variety of other electric utility stakeholder groups that participate in the regulatory process on a frequent basis such as consumer groups, low-income advocacy groups, industrial and large energy user groups, environmental interests, to name a few. While it is difficult to develop a specific cost for these new incremental activities, envisioning these costs running into the tens of millions of dollars of a fixed time period, like five years, is not unrealistic.

45 Eversource. *Distributed Energy Resources Project Costs.* Accessed November 13, 2024. https://www.eversource.com/content/residential/about/doing-business-with-us/interconnections/massachusetts/distributed-energy-resources-project-costs

SECTION 3

HYDROGEN SUPPLY AND INFRASTRUCTURE REQUIREMENTS

CARB's technical documents suggest that hydrogen may be a potential ZE energy resource alternative where direct electrification may not work.[46] The two primary means of hydrogen use envisioned in the CARB technical documents are (a) hydrogen on-board fuel cells (to replace on-board diesel power generation)[47] or (b) directly combusting hydrogen instead of diesel for the reciprocating engines that create onboard electricity.[48] While it is true that both hydrogen options could be facilitated, the CARB technical documents fail to appreciate the wide range of "upstream" infrastructure requirements that would be needed to facilitate the wider use of this ZE technology in rail transportation.

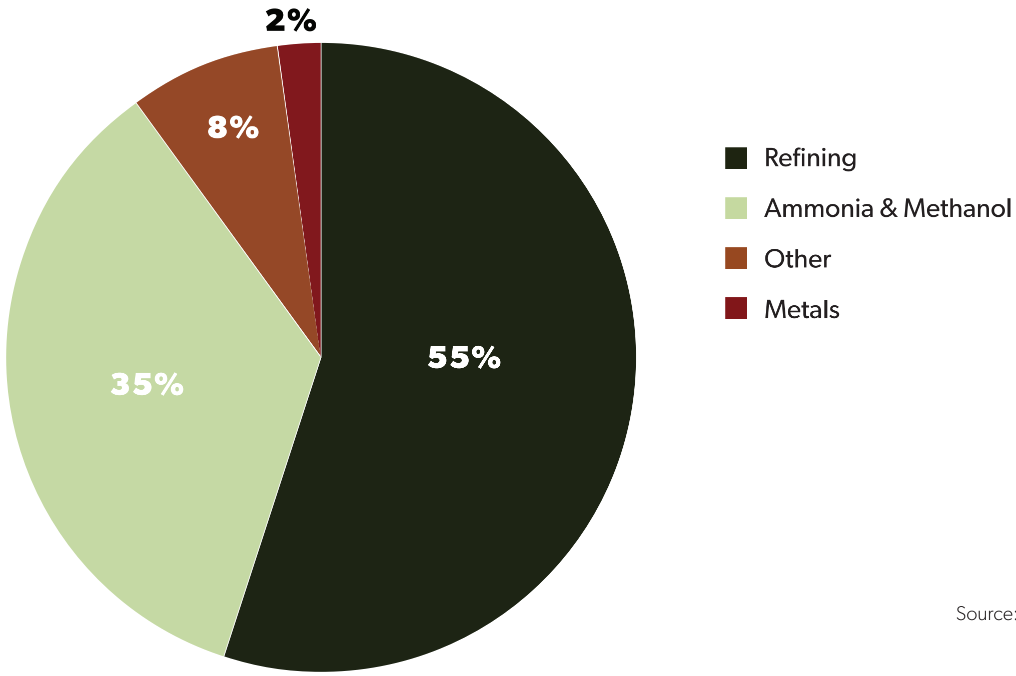
The failure to consider these upstream hydrogen requirements represents an important deficiency and represents meaningful constraints on CARB's new ZE rail requirements. Once considered, it is highly likely that additional hydrogen infrastructure requirements will likely (a) drive up the costs of utilizing hydrogen-based ZE technologies, and in some instances drive up these costs substantially; (b) could lead to constraints such that hydrogen is a substitute in name only and really will not be feasible in the near term in CARB's vision of a ZE world for rail transportation: if this happens, it means more supporting infrastructure pressure on rail-based electrification and electric systems discussed earlier; and (c) could significantly undermine the ZE emission goals of the rule in part, or in whole (i.e. GHG emission reductions could be significantly muted and in some instances could ironically increase as a result of the failure to completely appreciate these upstream hydrogen infrastructure requirements).

46 California Air Resources Board. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation*. p. 21

47 *Ibid*. p. 22

48 *Ibid*. p. 44

FIGURE 4: MAJOR HYDROGEN USES



Source: U.S. Department of Energy

3.1 HYDROGEN PRODUCTION ISSUES

Hydrogen is often touted as the most abundant element in the universe.[49] The problem is that hydrogen cannot be mined or harvested from nature: it must be extracted from other elements. Hydrogen is often touted as a versatile and more flexible energy carrier that can facilitate the decarbonization of other, more difficult-to-decarbonize sectors such as industrial end uses that rely on boilers and furnaces for high-temperature steam and heat for which there are simply no technical electrification alternatives.[50] For instance, at this point in time, there is simply no industrial-scale boiler that can make 1,000 degree F heat and 1,000 pound-per-square-inch gauge (psig) steam at the scale needed for modern commodity chemical production or refining.

Hydrogen is the simplest and lightest element on the periodic table that very simply consists of only one proton and one electron (hence the simple periodic table designation "H" only).[51] Given its elementary composition, hydrogen tends to bond with other atoms to achieve stability.[52] However, if hydrogen is to be used as an energy carrier, it usually has to be produced or extracted from other elements, the two most common being water (H_2O)

49 U.S. Energy Information Administration. "Hydrogen explained." Accessed October 3, 2024. https://www.eia.gov/energyexplained/hydrogen/#:~:text=Hydrogen%20is%20also%20the%20most,water%20(H2O).

50 Evangelopoulou, Stavroula, Alessia De Vita, Georgios Zazias, and Pantelis Capros. "Energy System Modelling of Carbon-Neutral Hydrogen as an Enabler of Sectoral Integration within a Decarbonization Pathway." Energies 12, no. 2551 (2019). p. 2

51 U.S. Energy Information Administration. "Hydrogen explained." Accessed October 3, 2024. https://www.eia.gov/energyexplained/hydrogen/#:~:text=Hydrogen%20is%20also%20the%20most,water%20(H2O).

52 Clark, Jim, and Jose Pietri. "Hydrogen Bonding." *LibreTexts*, last modified July 12, 2023. p. 1

or some hydrocarbon such as methane (CH_4).[53]

Today, hydrogen is often thought of as "rocket fuel" used for large space vehicles but it does have a number of other important industrial/commercial uses that are outlined in Figure 4. As an industrial gas, hydrogen is primarily used in the refining process through various "hydro-cracking" and "hydro-treating" processes.[54] The hydro-cracking process breaks down heavier hydrocarbons for use in other high-valued refined products,[55] while the hydrotreating process is used to remove harmful sulfur from refined products like gasoline and diesel fuel.[56]

Chemical industry hydrogen uses are plentiful and include the use of hydrogen in ammonia production, a primary component of agricultural fertilizers that have rapidly growing global demand given the need to use these fertilizers for growing food demand and production (as third world incomes grow particularly in Asia).[57] Over the past two decades, commodity chemical production has been expanding rapidly in the U.S., mostly along the Gulf Coast, but also in various places in the Midwest. These capacity expansions add to billions in new capital investments and are primarily designed to accommodate export markets around the globe, particularly those in Asia and developing countries.[58]

Commodity chemical production and refining require "meaningful" levels of hydrogen production. For instance, in 2023, U.S. refineries used as much as 10 million metric tons (Mt) of hydrogen[59], and that demand has been growing at an annual average rate of three to four percent over the past five years.[60] The chemical industry is estimated to have used as much as 10 to 12 in Mt in 2023,[61] and has also seen annual average growth in hydrogen demand of two to four percent over the past five years.[62]

The reason for highlighting this is not to digress into a chemical industry lecture but to note and show that there are very highly valued uses for hydrogen, and should ZE rail transportation in California (and potentially other comparable adopting states) utilize this fuel, it has a lot of current and projected competition. The discussion also highlights the fact that hydrogen production is simply not ubiquitous throughout the U.S. Hydrogen production capabilities (and supporting infrastructure) tend to be highly concentrated with chemical production and refining: two industries that are significantly limited in

53 Martino, Marco, Concetta Ruocco, Eugenio Meloni, Pluton Pullumbi, and Vincenzo Palma. "Main Hydrogen Production Processes: An Overview." *Catalysts* 11, no. 5 (2021). p. 3 & 10

54 Speight, James G. *Hydrotreating and Hydrocracking Processes in Refining Technology.* CRC Press, 2024. pp.1-2

55 "Hydrocracking." *ScienceDirect*. Accessed October 3, 2024. https://www.sciencedirect.com/topics/chemical-engineering/hydrocracking#:~:text=Hydrocracking%20is%20a%20cracking%20process,in%20the%20presence%20of%20hydrogen

56 Gruia, A. "Hydrotreating." In *Handbook of Petroleum Processing*, edited by D.S.J.S. Jones and P.R. Pujadó. Dordrecht: Springer, 2008. https://doi.org/10.1007/1-4020-2820-2_8

57 Ghavam, Seyedehhoma, Maria Vahdati, I. A. Grant Wilson, and Peter Styring. "Sustainable Ammonia Production Processes." *Frontiers in Energy Research* 9 (2021). p. 1

58 Spilker, Gregor. "Methanol's U.S. Revival and Global Growth Scenarios." *CME Group*, 2018. https://www.cmegroup.com/education/articles-and-reports/methanols-us-revival-and-global-growth-scenarios.html.

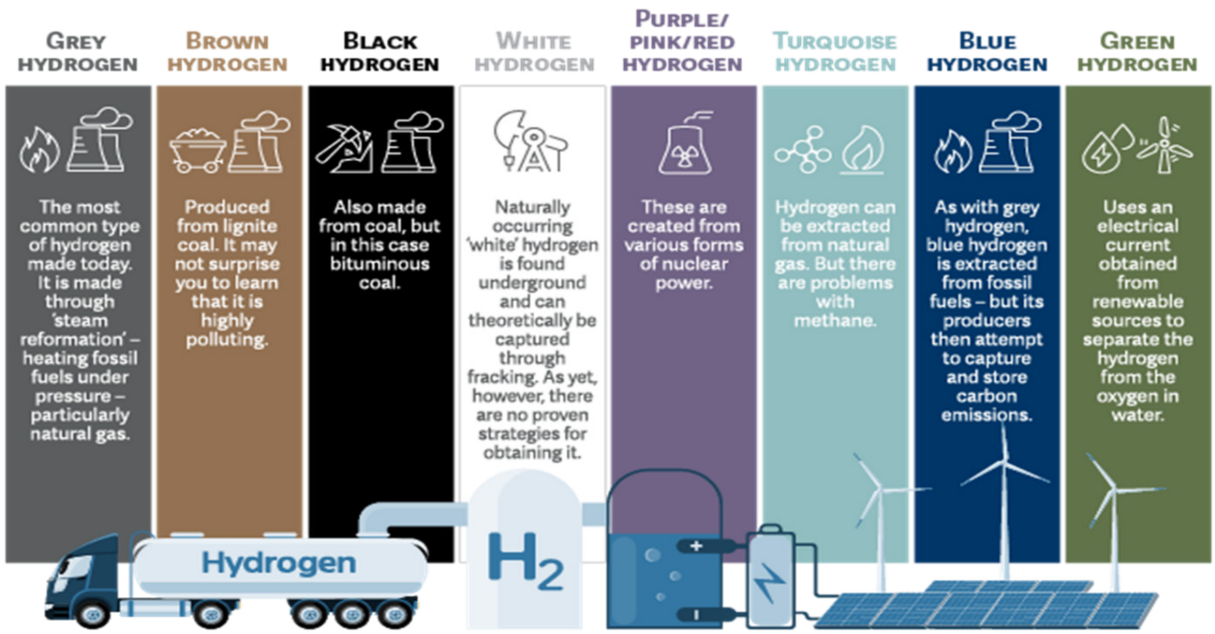
59 Energy Information Administration. "U.S. Refining Capacity Increased in 2023 with Expansions at Existing Facilities." *U.S. Energy Information Administration (EIA)*, July 30, 2024. https://www.eia.gov/todayinenergy/detail.php?id=53700.

60 International Energy Agency (IEA). "Hydrogen." *International Energy Agency.* Accessed September 27, 2024. https://www.iea.org/reports/hydrogen.

61 U.S. Energy Information Administration. "U.S. Refiners and Chemical Manufacturers Lead Hydrogen Production and Consumption." *EIA Today in Energy.* Last modified 2023. https://www.eia.gov/todayinenergy/detail.php?id=2023.

62 See U.S. Department of Energy. *Hydrogen Program Plan: Production and Utilization.* Last modified 2023. https://www.hydrogen.energy.gov. and U.S. Energy Information Administration. "U.S. Refiners and Chemical Manufacturers Lead Hydrogen Production and Consumption." EIA Today in Energy. Last modified 2023. https://www.eia.gov/todayinenergy/detail.php?id=2023.

FIGURE 5: MAJOR HYDROGEN "TYPES"



Source: Artemis Investments

California and the western U.S.

Many visions of a future decarbonized world include the use of hydrogen as a combustible fuel, and the CARB ZE rail regulations include, at least in part, part of that vision. The technical documents note that like other industrial applications, hydrogen could serve as an alternative fuel/ energy option for rail transportation[63] simply by using hydrogen in a fuel cell generator or as a combustible fuel in current diesel generators (with that the technical documents suggest are minor technical reconfigurations of existing on-board diesel electric generators).[64]

The challenge with CARB's assertions (and policy prescriptions) rests with finding appropriate hydrogen supplies and then moving those supplies to "load centers" where rail transport can cost-effectively utilize these supplies. A further issue that is not addressed in the technical documents is that growing hydrogen needs, like those envisioned in the CARB regulations, will need to be met with supplies, at least in the near term, that likely have challenging environmental attributes as show in Figure 5.

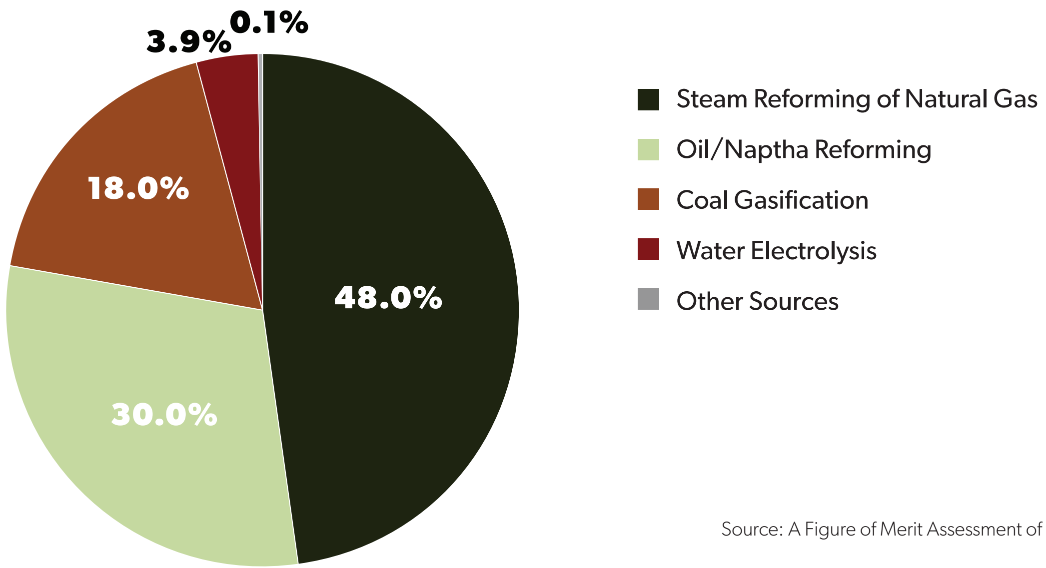
Consider that **most hydrogen is produced** from what is referred to as "grey" resources, not those that are "green" or renewable in nature.[65] What this means is that the hydrogen is produced through a process referred to as "steam methane reformation" (or SMR), and, as the name suggests, uses methane as a primary

63 California Air Resources Board. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation.* p. 21

64 *Ibid.* p. 4

65 Ochu, Emeka R., Sarah Braverman, Griffin Smith, and Julio Friedmann. *Hydrogen Fact Sheet: Production of Low-Carbon Hydrogen.* Center on Global Energy Policy, Columbia University, May 2021. p. 1

FIGURE 6: MAJOR HYDROGEN PRODUCTION TYPES AND SHARES



Source: A Figure of Merit Assessment of the Routes to Hydrogen

input. "Grey" processes usually do not include a carbon capture component where byproduct CO_2 is captured and sequestered in an underground geological formation.[66] SMR production, coupled with CO2 sequestration, is often referred to as a "blue" hydrogen production process, and while many such processes have been announced in the aftermath of the Inflation Adjustment Act ("IRA"), most are in the planning/development phase and are not operational.[67]

Thus, from a GHG emissions perspective, near-term reliance on hydrogen as a substitute fuel or input for rail transportation could be problematic. If the hydrogen is procured from traditional ("grey") production methods, there will continue to be GHG emissions that arise from this process, likely along with various methane emission issues from the natural gas chain that will be relied upon for the process' core input. Thus, the opportunities for reducing GHG from CARB's new rail regulation will be significantly reduced. If the process relies more upon a "blue" approach (traditional methods using methane/SMR coupled with carbon capture) a host of additional logistic issues arise in supporting these capture investments as well as what is often seen as public opposition issues from various environmental groups related to these hydrogen production methods.[68]

Now, it is the case that "green" hydrogen production methods can be utilized to support the potential new hydrogen needs. Green hydrogen production methods, however, are entirely different than traditional grey or blue methods using hydrocarbons (with CH_4 as an input). Green methods use water (H_20) as an input and facilitate a relatively energy-intensive electrification process to separate the hydrogen from the oxygen elements.[69] This electrification process is referred to as "electrolysis" and

66 *Ibid*. p. 2

67 *Ibid*. p. 1

68 Lerner, Sharon. "How Clean Is 'Green' Hydrogen?" *Sierra*, Fall 2023. https://www.sierraclub.org/sierra/2023-3-fall/feature/how-clean-is-green-hydrogen.

69 Ochu, Emeka R., Sarah Braverman, Griffin Smith, and Julio Friedmann. *Hydrogen Fact Sheet: Production of Low-Carbon Hydrogen*. Center on Global Energy Policy, Columbia University, May 2021. p. 1

can be "powered" from renewable energy resources like solar and wind (hence the "green" label). While this green process is exciting and has exceptional opportunities, here again, a wide range of new and additional infrastructure challenges arise that have simply not been considered in the CARB technical documents, particularly related to how this hydrogen will be produced.

First, electrolysis is rarely used for hydrogen production.[70] Further, over 95 percent of total hydrogen production is produced using grey SMR processes.[71]

While there are a variety of new "blue" project announcements, none, as of 2024, are operational, and it will likely be years before any meaningful level of blue hydrogen production facilities have reached commercial operation. This means that even if some California rail uses are dedicated to hydrogen rather than directly electrified (through charging), the carbon benefits of such a move will be greatly reduced. If the entire value chain/life cycle emissions from grey resources are considered, it could very well be the case that a higher, not lower, level of GHG emissions could arise from this new CARB rail regulation, not less.[72]

If the entire value chain/life cycle emissions from grey resources are considered, it could very well be the case that a higher, not lower, level of GHG emissions could arise from this new CARB rail regulation, not less.

Second, the scale of hydrogen production from an SMR-type process differs considerably from an electrolysis process. The scale of a "typical" or average-sized SMR unit is usually 10 times larger than a "green" electrolysis facility. While various tax incentives under the Inflation Reduction Act, and various research and development programs at the Department of Energy are working aggressively at improving the scale and efficiency of electrolysis production, it still has a very long way to go to meet the commercial scale that would be needed to accommodate the new CARB regulation.

Third, the cost of producing hydrogen is very high and increases as that process changes color from "grey," to "blue," to "green." Consider that the cost of producing grey hydrogen right now is around $0.90 to $1.78 per kilogram ("kg") or $2.13 to $4.21 per thousand cubic feet or "Mcf."[73] Blue hydrogen, which uses SMR (grey) technologies with geological carbon capture, costs around $1.20 to $2.60 per kg or $2.84 per Mcf to $6.15 per Mcf.[74] Green hydrogen, which is produced using electrolysis and renewable electricity generation (the likely preferred method for meeting CARB regulatory requirements) ranges from $3.00 per kg to $8.00 per kg.[75] These are relatively

70 *Ibid.*

71 *Ibid.*

72 Patel, Gulam Husain, Jouni Havukainen, Mika Horttanainen, Risto Soukka, and Mari Tuomaala. "Climate Change Performance of Hydrogen Production Based on Life Cycle Assessment." *Green Chemistry* 26, no. 2 (2024): 992-1006. p. 1

73 Ochu, Emeka R., Sarah Braverman, Griffin Smith, and Julio Friedmann. *Hydrogen Fact Sheet: Production of Low-Carbon Hydrogen.* Center on Global Energy Policy, Columbia University, May 2021. p. 2

74 *Ibid.*

75 *Ibid.*

high unit costs, particularly when they are compared to simply combusting relatively clean-burning natural gas, which is widely available with market prices around $2.50 to $3.00 per Mcf. Note all these are commodity costs and do not include transportation or storage costs, which are also non-trivial.

Lastly, and more importantly, there are a considerable number of competing and likely higher-valued uses for hydrogen than those anticipated for rail transportation. A large number of industrial processes have few to no substitutes for the high level of steam and heat that are required to maintain their production processes. There are no large-scale, efficient industrial boilers or furnaces, at this point in time, that are electric. Thus, these processes will likely look at the use of hydrogen at least in the short run, until other alternative technologies arise. Consider that on the Gulf Coast alone, industrial processes and power generation alone use as much as 22.6 billion cubic feet per day ("Bcf/d") of natural gas that would likely need to be shifted to some ZE fuel in the future, like hydrogen.[76] These collective industrial uses dwarf potential rail-based hydrogen use, and will likely compete for these limited hydrogen resources in a future ZE world (given the CARB regulations), likely driving up prices and potentially leading to resource availability issues. Again, real-world considerations that are not considered in the CARB documents.

3.2 HYDROGEN PIPELINES AND TRANSPORTATION CHALLENGES

While smaller volumes of hydrogen can be moved by trucks and, in some instances, ships or barges, pipelines offer the safest and most efficient means of hydrogen transportation. Today, a significant share of all U.S. hydrogen production is moved via pipelines. However, hydrogen pipeline transportation is expensive and, to date, has been dominated by private industrial gas companies and a select number of mostly integrated oil and gas companies, like Shell. Thus, the current hydrogen pipeline network can be thought of as one that is not very integrated, in some ways balkanized, owned by select companies to accommodate unique end-uses and commercial relationships, and not configured to accommodate third-party sales and transport like that seen in the natural gas industry: again, small details completely missing from the CARB technical analysis.

California will likely have to develop some form of hydrogen pipeline system to accommodate the new CARB regulation as well as its other state ZE goals. California currently has only one 27-mile hydrogen pipeline system owned and operated by Air Products to serve local refineries in the area (Chevron, Phillips66, and Marathon) that need the hydrogen to meet relatively stringent EPA clean gasoline and diesel standards.[77] California does have ambitious hydrogen infrastructure development goals that go beyond CARB's new regulation, such as the California Hydrogen Highway initiative[78] and its Hydrogen Hub initiatives, which recently secured DOE grant funding.[79] However, at this time,

76 U.S. Energy Information Administration. "Natural Gas Consumption by End Use." Last modified 2023. Accessed October 10, 2024. https://www.eia.gov/dnav/ng/ng_cons_sum_a_EPG0_veu_mmcf_a.htm.

77 Cerniauskas, Simonas, Lewis Fulton, and Joan Ogden. *Tech Brief: Pipelines for a Hydrogen System in California*. UCD-ITS-RR-23-15. Institute of Transportation Studies, University of California, Davis, March 23, 2023. pp. 3-4

78 The California Hydrogen Highway Network (CaH2Net) was initiated in April 2004 by Executive Order (EO) S-07-04 under Governor Arnold Schwarzenegger. The mission was to assure that hydrogen fueling stations were in place to meet the demand of hydrogen fuel cell electric vehicles entering California roads. See: California Air Resources Board. "Hydrogen Fueling Infrastructure." Accessed October 8, 2024. https://ww2.arb.ca.gov/our-work/programs/hydrogen-fueling-infrastructure/about.

79 "California Launches World-Leading Hydrogen Hub." Office of Governor Gavin Newsom, July 17, 2024. Accessed October 8, 2024. https://www.gov.ca.gov/2024/07/17/california-launches-world-leading-hydrogen-hub/.

and likely in the foreseeable future, these proposals are just aspirations, not *bona fide* projects based on a corporate board-approved final investment decision.

These aspirations will do little to nothing to support the use of hydrogen as a resource under the CARB regulations, reflecting an additional shortcoming that has simply failed to understand or appreciate the considerable infrastructure requirements needed to make this CARB regulation a reality. While trucks could be used in the short run, there are a host of cost, safety, and logistic concerns that make this a challenge over the longer term, highlighting that without pipelines, hydrogen use via trucks only is not a commercially sustainable alternative, particularly for the levels for ZE transport required under the CARB rule.

The technical documents supporting the CARB rule do not mention nor envision a new pipeline being needed to serve various and dispersed railyards throughout the state.[80] If hydrogen is used to meet the new rail ZE standard, additional pipeline capacity will need to be developed. Yet, developing new pipeline capacity, particularly in California, is a technical challenge and one not thought through in the CARB technical documents.

Hydrogen is the first, and lightest element in the periodic table. This leads to a number of challenges in developing and operating pipelines using this ZE energy resource. First, hydrogen pipelines will be constructed of unique and differing materials in order to ensure that hydrogen does not escape from these various pipeline systems and any supporting equipment, such as mechanical couplings, pipeline seals, meters, regulators, and compression units, to name a few.[81]

While trucks could be used in the short run, there are a host of cost, safety, and logistic concerns that make this a challenge over the longer-term highlighting that without pipelines.

Second, the pipeline materials composition differences will also have to ensure that any hydrogen that could permeate into the pipeline itself does not lead to a hardening or embrittlement of those metals, which in turn could lead to pipe integrity issues resulting in leaks or other potential safety-related incident.[82] These unique materials requirements are one reason why re-purposing existing natural gas infrastructure for hydrogen use is probably not likely: natural gas pipelines are engineered and constructed to move methane and very small amounts of other hydrocarbons and other elements, not hydrogen.[83] It is highly unlikely that any existing natural gas pipelines can, or would be, re-purposed, especially in California, for hydrogen transport. This is an important issue to consider since often hydrogen use and other ZE advocates will suggest that transport issues can be easily resolved by just converting existing infrastructure: the reality is that transforming a natural gas line to a hydrogen line is not that simple.[84]

80 California Air Resources Board. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation.*

81 Quarterman, Cynthia. *Hydrogen Policy Sprint Brief 3: Opportunities and Challenges for Hydrogen Transportation and Storage.* Atlantic Council Global Energy Center, June 29, 2021. Accessed October 9, 2024. p. 3

82 Gallon, Neil. *Hydrogen Pipelines – Design and Material Challenges and Mitigations.* EPRG Project 221/2020. European Pipeline Research Group (EPRG), December 22, 2020. pp. 14-15

83 *Ibid.* p. 93

84 Baldwin, Sara, Dan Esposito, and Hadley Tallackson. Assessing the Viability of *Hydrogen Proposals: Considerations for State Utility Regulators and Policymakers.* Energy Innovation, March 2022.

Third, given hydrogen's low energy density, it is usually transported at higher pressures, much like natural gas. For instance, most larger interstate natural gas pipelines operate at around 1,000 psig.[85] Hydrogen pipelines operate at comparable levels in the 500 to 1,200 psig range.[86] These higher pressures allow pipelines to move more hydrogen commodities but at an increased cost in not only the development of the pipeline but also the capital and energy costs associated with the compression itself.[87] The fact that a hydrogen pipeline will be operating at such high pressures will, in and of itself, likely be an issue for safety and regulation.

Fourth, there is no system of hydrogen transportation pricing and regulation. The pricing and certification of natural gas systems have existed for well over a century, if not longer. Over the past 40 years, in particular, a wide range of pricing practices, customs, regulations, markets, and institutions have arisen that govern what is generally a relatively uniform system of open-access natural gas transportation. While many of these methods and institutions could be adopted and utilized by an emerging hydrogen transport sector, they simply do not exist, particularly in California, at the current time. While this may seem like an esoteric consideration, it is critically important in assessing the cost of moving hydrogen from point "A" to point "B" since it defines how costs, prices, and ultimately how pipeline investment decisions by private developers will be made. Highly liquid and seamless markets will facilitate investment and cost-effective options for transporters, markets, and institutions that are rigid, do not have transparency, and have few opportunities for securitization, which will result in under-investment in hydrogen pipelines. Again, a topic not even addressed or considered in the CARB technical documents.[88]

Lastly, public opposition is likely to be a significant impediment to the use of hydrogen and the development of hydrogen pipelines in the state. This will be true for hydrogen pipelines in general, and those specifically needed to serve rail end-uses as envisioned by CARB's new regulations: again, a very real not even remotely considered in the CARB document.

The rationales for public opposition to hydrogen pipelines are likely multifaceted. First, consider the general issue that California is simply a difficult place to develop energy infrastructure of any type. Just because CARB designates hydrogen as a ZE technology will likely not miraculously assure rapid and non-controversial hydrogen pipeline development to meet the new requirements of the new regulation nor any other new California hydrogen loads. Just general public opposition to sitting power lines or pipelines of any sort will be a large initial hurdle for any rail operating considering moving any meaningful part of their energy use to hydrogen. This not only complicates the use of hydrogen to meet the CARB regulation but almost assures a high ZE end-use bias towards electrification rather than a more balanced electric/hydrogen usage profile suggested in the regulation's technical documents.

Second, hydrogen alone raises a number of safety-related public concerns that can be simply summarized in one word: "Hindenburg." The infamous 1937 dirigible incident presents a powerful, one-picture rebuttal to the use of hydrogen as an end-use energy resource. The explosion is perhaps one of the leading, if not the most recognized man-made safety accidents in history. It is hard to believe

85 Interstate Natural Gas Association of America (INGAA). *The Interstate Natural Gas Transmission System: Scale, Physical Complexity and Business Model.* Accessed October 4, 2024. p. 1

86 Penev, Michael, Jarett Zuboy, and Chad Hunter. "Economic Analysis of a High-Pressure Urban Pipeline Concept (HyLine) for Delivering Hydrogen to Retail Fueling Stations." *Transportation Research Part D* 77 (2019). p. 93

87 Khan, Mohd Adnan, Cameron Young, Catherine MacKinnon, and David B. Layzell. *The Techno-Economics of Hydrogen Compression.* Transition Accelerator Technical Briefs, vol. 1, issue 1. Calgary: Transition Accelerator, October 2021. p. 33

88 California Air Resources Board. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation.*

that Californians will openly embrace the use of hydrogen in trains that run in close proximity to their homes, schools, shopping malls, and businesses, much less support the siting of infrastructure that transports, fuels, or stores this energy resource. Nowhere do the CARB technical documents address this very, very likely concern nor how it will impact the deployment of substitute ZE fuels tied to the new rail industry regulation. Furthermore, the fact that pipelines will likely be moving hydrogen to railyards and other end-use locations at over 2,500 psig – over double the pressure level of already mistrusted natural gas pipelines -- is also entirely missed in CARB's technical analysis.

Third, there is growing opposition to hydrogen use, and likely their associated pipelines, by many environmental groups that see hydrogen as a fossil fuel enabler that only slows the momentum to a full transition to renewable technologies such as solar and wind. Recent comments before the U.S. Department of Treasury, as part of the process for developing a guidance document for future applicants seeking hydrogen tax incentives (IRS Code 45(v)) under the Inflation Reduction Act underscore this hostility.

For instance, the Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES) warned in a comment submitted to the Department of Treasury about the potential negative consequences of the 45V tax credit regulations. ARCHES stated that "without key amendments, the proposed Section 45V regulations will set in motion serious and harmful unintended consequences. As written, the proposed 45V criteria of incrementality, time matching, and deliverability will push projects toward non-electric, fossil-fuel-derived hydrogen production."[89] Likewise,

Thus, CARB's assumption that hydrogen will be readily accepted as an alternative rail fuel by the public, as well as various environmental stakeholders, is simply not in keeping with the usually misplaced yet strong and growing opposition to hydrogen use at both the federal and state levels.

Clean Energy Group noted that "Allowing for the offsetting of grid-powered hydrogen production emissions through these types of market mechanisms will not result in the level of low-carbon hydrogen production required to be eligible for the 45V Clean Hydrogen PTC."[90]

Thus, CARB's assumption that hydrogen will be readily accepted as an alternative rail fuel by the public, as well as various environmental stakeholders, is simply not in keeping with the usually misplaced yet strong and growing opposition to hydrogen use at both the federal and state levels.

89 Alliance for Renewable Clean Hydrogen Energy Systems. *Comment on Section 45V Regulations: Proposed Hydrogen Production Tax Credit.* Submitted to the U.S. Department of Treasury, 2023.

90 Clean Energy Group. *Clean Energy Group Response to Department of the Treasury and the Internal Revenue Service Request for Comments on Certain Energy Generation Incentives, Notice 2022-49.* Montpelier, VT: Clean Energy Group, November 2, 2022.

SECTION 4

HYDROGEN STORAGE

Rail uses are highly variable and, as noted earlier, have an electric load factor of 0.50 meaning that the difference, or variability, between average and peak energy use is about 50 percent. The higher the load factor, the lower the deviation between average and peak usage, and it is considered to represent more "efficient' usage. Load factor is an important concept in energy since higher variability usually requires energy resources to be held in reserve to meet these large expected/unexpected swings in usage. The lower the load factor, the greater the need for storage. Thus, if rail systems have an energy factor of 0.50, indicating a relatively large degree of variability between average and peak usage, some form of storage will be needed.

Once again, the CARB technical documents, while pointing to hydrogen use as reasonable ZE energy use technology for rail transportation, fail to grasp the fact that the challenge in using hydrogen is not just limited to the availability of technologies to burn/convert this hydrogen but whether the supply chain needed to get that hydrogen to those technologies even exists. We have already established that hydrogen production and pipeline transportation are limited and problematic, one additional limitation is that there are no hydrogen storage opportunities to bridge what are likely very large swings in energy use for rail transportation. Once again, this limitation is entirely missed in the CARB technical documentation.[91]

Larger-scale hydrogen use will require larger-scale hydrogen storage facilities. Simple, limited-in-scale above-ground facilities will merely not be large enough to facilitate the needed backup for important and sensitive end uses like rail transport. Most large-scale hydrogen storage is envisioned to be underground based, much like it is for natural gas. There are two main potential underground hydrogen storage facility types: reservoir-based storage and salt cavern. Both forms of storage are used extensively in the natural gas industry and have been

91 California Air Resources Board. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation.*

used safely and productively for decades. However, their use for hydrogen is still limited.

Salt caverns are currently being used to store hydrogen and are located along the Gulf Coast for industrial hydrogen load purposes. These salt caverns are located along the Texas Gulf Coast at the Air Products hydrogen storage facilities (Moss Bluff and Clemens)[92] and hydrogen storage facilities in Baytown and Mont Belvieu.[93] While these facilities are important and likely have expansion opportunities for future Gulf Coast industrial opportunities, there is no way these salt cavern facilities can be replicated in California since California has no geological salt formations.

This leaves us with the second alternative storage medium, which is underground reservoir-based storage facilities; California does have a prolific number of abandoned oil and natural gas reservoirs that could be used for hydrogen storage. In fact, California currently has some 315 Bcf of reservoir-based natural gas storage that, in theory, could serve as a technical model.[94] The problem is that while reservoir-based storage has been used for decades for underground natural gas storage, reservoirs have not been used – and are currently not being used -- for hydrogen storage anywhere in the U.S. In fact, there are only a handful of pilot and research reservoir-based hydrogen storage facilities in the world, and those are located in the Netherlands, Austria, and Argentina.[95] Again, a small detail entirely missed in the CARB regulatory process: these real-world technical limitations related to upstream infrastructure are just entirely missed, raising questions about the regulation's reasonableness and whether or not it can be compiled with in its envisioned fashion.

Again, a small detail entirely missed in the CARB regulatory process: these real-world technical limitations related to upstream infrastructure are just entirely missed, raising questions about the regulation's reasonableness and whether or not it can be compiled with in its envisioned fashion.

92 Małachowska, Aleksandra, Natalia Łukasik, Joanna Mioduska, and Jacek Gębcicki. "Hydrogen Storage in Geological Formations—The Potential of Salt Caverns." Energies 15, no. 14 (2022). p. 6

93 *Turbo Machinery International*. "ExxonMobil, Air Liquide Accelerate Hydrogen Distribution at Baytown Facility." *Turbo Machinery International*, June 25, 2024. Accessed October 9, 2024. https://www.turbomachinerymag.com/view/exxonmobil-air-liquide-accelerate-hydrogen-distribution-at-baytown-facility. *BIC Magazine*. "Air Products, Covestro Celebrate Ribbon-Cutting Ceremony for SMR Plant." *BIC Magazine*, June 20, 2018. Accessed October 9, 2024. https://www.bicmagazine.com/projects-expansions/downstream/air-products-covestro-smr-plant-ribbon-cutting-ceremony/.

94 U.S. Energy Information Administration. "Natural Gas Storage Capacity." Accessed October 4, 2024. https://www.eia.gov/naturalgas/storagecapacity/

95 Mahdi, Doaa Saleh, Emad A. Al-Khdheeawi, Yujie Yuan, Yihuai Zhang, and Stefan Iglauer. "Hydrogen Underground Storage Efficiency in a Heterogeneous Sandstone Reservoir." *Advances in Geo-Energy Research* 5, no. 4 (2021). p. 2

SECTION 5

CONCLUSIONS

CARB's new locomotive regulation represents yet another attempt to dramatically alter the use of energy, not only in California but potentially across the country. The rule unfairly attacks what has, to date, been a component of the transportation sector that has an exceptionally low level of GHG emissions and relatively high energy efficiency characteristics. Of all sectors to "double down" upon, locomotive energy use and emission is simply not one of them.

A large focus of the debate on this new rule is rightfully concentrated on how these new locomotive regulations will increase freight costs, create new supply chain constraints, and otherwise negatively impact the cost of moving goods and services in California and likely the rest of the U.S. While all these arguments have merit, it is important to recognize they are not the only deficiencies with the proposed regulation. There are several additional omitted analyses that were never conducted by CARB including: (1) the adequacy of supporting ZE energy infrastructure (electricity and hydrogen) to support new rail end-uses; (2) the extent to which reinforcements and additional infrastructure will need to be developed and how these investments will impact stakeholder costs and cost responsibilities; and (3) how the purported GHG emission benefit arising from the rule will likely be greatly reduced once full value chain evaluation is taken into consideration. Ultimately, it is very likely that this proposed locomotive rule will place considerable financial strain on the rail industry and consumers, with little, or at least greatly reduced environmental benefits

The analytic deficiencies in the CARB rule cannot be underestimated. Converting the rail sector to either battery-electric or hydrogen energy uses will require significant additional power generation, transmission, and distribution investments. If the ZE energy uses choose hydrogen resources, then there are additional infrastructure requirements running from production to transportation to storage that are not considered in the CARB rule. This is exceptionally problematic for a state like California that already has noted technical challenges meeting its already stressed electricity system, and one that virtually has zero hydrogen production capabilities and infrastructure.

The almost cavalier and dismissive lack of consideration of the electric power requirements in the CARB's technical documents is disturbing. Nowhere is there a thoughtful analysis of how California's already strained electric grid will handle the additional loads from rail electrification, especially during peak demand periods. CAISO has already struggled to meet electricity demands during heatwaves, nearly implementing rolling blackouts in 2022. Introducing large new rail-related energy demands could destabilize the grid further.

The other stark reality of the proposed rule is that using hydrogen in the near term could prove to be impossible since the state's hydrogen infrastructure is nearly non-existent. While there are remote technical potentials for the use of hydrogen fuel cells as a ZE option, the lack of a comprehensive hydrogen production, transportation, and storage network will severely limit the economic feasibility of this option without substantial public and private sector investment. California's current hydrogen infrastructure costs of a few refinery formation units and a limited 40-mile hydrogen pipeline that is already dedicated to serving California refineries to meet EPA-required clean refined product standards. Building a hydrogen infrastructure robust enough to support statewide rail operations would require billions in investment and years of development—investments that CARB has not factored into its timeline.

The new CARB locomotive regulation will also be costly – not just to the locomotive industry but particularly for electricity consumers who will undoubtedly pick up the bill for the cost of electrifying a large part of these rail systems. These new electricity investments will inevitably drive up costs, both for the rail industry and for consumers. For the rail industry, upgrading power grids, building new power plants, and developing hydrogen pipelines will result in capital expenditures far beyond those estimated by CARB's technical reports. Even CARB's own cost projections suggest compliance costs of $16 billion over 25 years, but this figure does not include the cost of upgrading or expanding the energy infrastructure needed to make ZE rail feasible.

The other stark reality of the proposed rule is that using hydrogen in the near term could prove to be impossible since the state's hydrogen infrastructure is nearly non-existent.

Rail transportation is a critical component of California's supply chain, especially for goods moving through the state's major ports. Any increase in operating costs for railroads will likely be passed down the supply chain, resulting in higher costs for businesses and consumers alike. This could lead to inflationary pressures at a time when California's economy is still recovering from the disruptions of the pandemic, inflation, and labor shortages.

These infrastructure upgrades will not only be costly but will also take years, if not decades, to complete: an applied consideration that is entirely incongruous with the current CARB regulatory timelines. Further complicating matters is the fact that renewable energy sources, such as solar and wind, which California heavily relies on, are intermittent and may not be able to provide the consistent power needed for rail operations. As a result, natural gas-fired plants may continue to play a significant role in meeting peak demand, potentially negating the GHG emissions reductions that the regulation aims to achieve.

These infrastructure challenges are not restricted to electricity alone. The proposal also envisions hydrogen as a key ZE fuel for locomotives, yet the infrastructure to support widespread hydrogen use is almost entirely absent in California. Producing, transporting, and storing hydrogen at the scale required for rail operations will require new pipelines, storage facilities, and compression systems. Hydrogen is not transported like traditional fuels—it requires specialized infrastructure due to its unique chemical properties, including its tendency to cause embrittlement in pipelines and its need to be stored at high pressures.

The lack of hydrogen production capacity is another major hurdle. While the rule touts the ZE characteristics of hydrogen, it fails to recognize that the overwhelming share of commercially available hydrogen in today's marketplace is produced by natural gas, not solar or wind. While there is limited capacity for producing "green hydrogen," which is made using renewable energy sources, the cost of green hydrogen production is prohibitively high—estimates range from $3.00 to $8.00 per kilogram, compared to the much lower cost of natural gas. Even with the recent IRA hydrogen benefits, building the infrastructure and scaling up green hydrogen production will take years, if not decades, making it an impractical solution for meeting the 2030 and 2035 deadlines set by CARB.

Beyond the technical and infrastructure challenges, the energy transition envisioned by CARB will impose additional regulatory and administrative costs on both utilities and rail operators. Utilities will need to engage in extensive planning processes to accommodate new rail-related electricity loads, and this will likely involve numerous regulatory filings, stakeholder consultations, and rate cases before the state's utility regulators (as well as the regulators of other states adopting similar rules if these are approved by the EPA). For rail operators, complying with CARB's new requirements will entail significant administrative burdens, including tracking and reporting energy usage, managing spending accounts, and ensuring that locomotives meet the ZE standards. These new regulatory obligations will add complexity and cost to an industry already operating on thin margins. These processes are time-consuming and expensive, and the costs will ultimately be passed on to consumers through higher electricity rates.

For rail operators, complying with CARB's new requirements will entail significant administrative burdens, including tracking and reporting energy usage, managing spending accounts, and ensuring that locomotives meet the ZE standards. These new regulatory obligations will add complexity and cost to an industry already operating on thin margins.

Equally important is whether CARB's regulation will achieve its intended GHG emissions reductions if the full panoply of impacts, including upstream energy infrastructure impacts, is considered. If rail electrification leads to increased reliance on natural gas-fired power plants to meet peak demand, the net emissions reductions could be far lower than anticipated. Furthermore, as ZE locomotives operate across state lines, the emissions benefits realized in California could be offset by emissions in other states that still rely heavily on fossil fuels for power generation. Likewise, dedicating systems to hydrogen will likely require more, not less upstream natural gas production, transportation, processing and storage: all activities that many environmental advocates suggest produce GHG emissions in excess of even those attributable to coal. Thus, it is questionable how a rule relying on considerable levels of hydrogen will dramatically improve GHG emission footprints in the rail sector.

In conclusion, CARB's new locomotive regulation is a misguided attempt at decarbonizing a sector that is simply not necessary. In other words, the CARB locomotive rule is simply a problem in search of a solution. While other observers have noted the transportation and supply chain challenges with its implementation, few recognize these equally important and potentially as large, impacts that energy infrastructure could play in a future decarbonized rail industry: at least one decarbonized in the manner envisioned by CARB. If the regulation regime like the one proposed by CARB is even needed, it must address the supporting energy infrastructure requirements head-on, not simply assume an "if you mandate it, the investment will come" result. Moving the rail sector to ZE technologies will undoubtedly require substantial public and private investment in both electricity and hydrogen infrastructure, as well as a more elongated timeline relative to the one envisioned by CARB. Regulations that fail to recognize these important energy infrastructure constraints will likely result in more harm than good, by increasing costs for consumers, straining the energy grid, and potentially failing to deliver the promised GHG emissions reductions.

In conclusion, CARB's new locomotive regulation is a misguided attempt at decarbonizing a sector that is simply not necessary.

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