Framework for a Technology Innovation for Energy-Efficient Railyards (TIEER) Pilot Study

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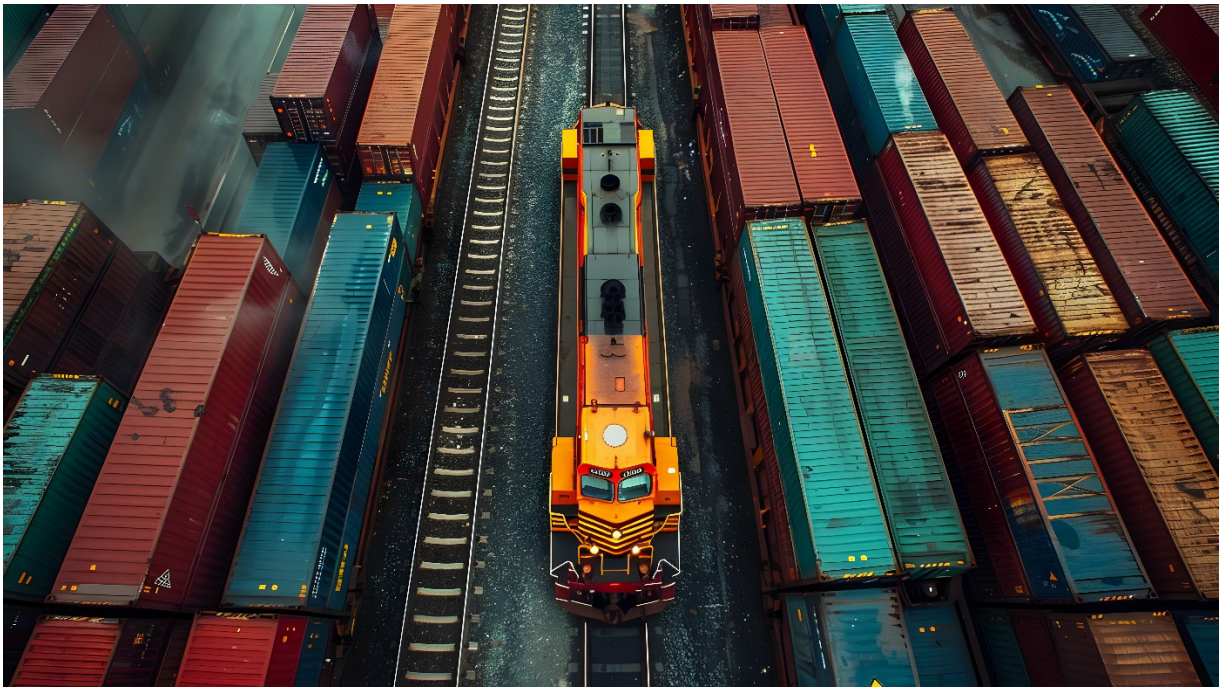

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14. ABSTRACT

Locomotives, trucks, and cargo-handling equipment in and around railyards contribute to air pollution concerns for surrounding communities and railyard workers. The Federal Railroad Administration (FRA) is exploring a Technology Innovation for Energy-Efficient Railyards (TIEER) Initiative, which would focus on implementing zero-emissions projects. This report discusses the concept of TIEER, the benefits of replacing or retrofitting equipment to zero-emission versions, including the opportunity to modernize and optimize equipment tailored to the railyard's needs, and considerations for conducting a TIEER pilot study. This report also provides an overview of zero-emissions technologies, funding opportunities for zero-emission equipment, and case studies of select zero-emissions projects.

15. SUBJECT TERMS

Locomotive, railyard, criteria pollutant, greenhouse gas (GHG), air quality, zero emission

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Term
AC	Alternating current
ATVM	Advanced Technology Vehicles Manufacturing
BE	Battery-electric
BNSF	Burlington Northern Santa Fe
CARB	California Air Resources Board
CCS	Carbon capture and storage
CMAQ	Congestion Mitigation and Air Quality
CN	Canadian National
CNG	Compressed natural gas
CO_2e	Carbon dioxide equivalent
CORE	Clean Off-Road Equipment
CPKC	Canadian Pacific Kansas City
CREATE	Chicago Rail Efficiency and Transportation Efficiency
CRISI	Consolidated Rail Infrastructure and Safety Improvements
CT DOT	Connecticut Department of Transportation
DB	Deutsche Bahn
DEF	Diesel exhaust fluid
DERA	Diesel Emissions Reduction Act
DISCO CAT	Discontinuous catenary
DNL	Day-night average sound level
DOC	Diesel oxidation catalyst
DOE	U.S. Department of Energy
DPF	Diesel particulate filter
EGR	Exhaust gas recirculation
EJ	Environmental justice
EPA	U.S. Environmental Protection Agency
ERIG	Emissions Reduction Incentive Grants
ETC	Equitable Transportation Community
EVSE	Electric vehicle supply equipment
FECR	Florida East Coast Railway
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
GHG	Greenhouse gas
KLW	Knoxville Locomotive Works
LECT	Locomotive Emission Comparison Tool
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NJ TRANSIT	New Jersey TRANSIT
NOx	Nitrogen oxides
NTAD	National Transportation Atlas Database
PHEV	Plug-in hybrid electric vehicle
PM	Particulate matter
PPE	Personal protective equipment

Abbreviation	Term
RNG	Renewable natural gas
RTG	Rubber-tired gantry
SBCTA	San Bernadino County Transit Authority
SCR	Selective catalytic reduction
SERA	Sierra Northern Railway
SIP	State implementation plan
TNM	Traffic Noise Model
TRL	Technology readiness level
UP	Union Pacific
USDOT	U.S. Department of Transportation
ZE	Zero emissions
ZEMU	Zero emission multiple unit
TIEER	Technology Innovation for Energy-Efficient Railyards

Equipment Glossary

Battery system: Battery system refers to the batteries installed in standard railcars or tenders. This does not include any necessary modifications to locomotives or cables to connect the batteries to the locomotive to provide power.

Crane: Cranes handle a variety of tasks in railyards, such as handling freight, maintaining or laying track, installing signals, and recovering materials after accidents. Depending on the purpose of the crane and type of yard, cranes can be situated on flat cars to move along the tracks or mounted to the ground.

Drayage truck: Drayage trucks are responsible for moving freight short distances, often between modes of transport. For example, a drayage truck may deliver a container from a railyard to a nearby port or warehouse or vice versa.

Line-haul locomotive: Line-haul locomotive means a locomotive that does not meet the definition of switch locomotive. Note this includes both freight and passenger locomotives.

Locomotive: A locomotive is a self-propelled piece of on-track equipment designed for moving or propelling cars that are designed to carry freight, passengers, or other equipment, but which itself is not designed or intended to carry freight, passengers (other than those operating the locomotive), or other equipment.

Passenger locomotive: A passenger locomotive is a locomotive designed and constructed for the primary purpose of propelling passenger trains and providing power to the passenger cars of the train for such functions as heating, lighting, and air conditioning.

Railcar mover (shunter): Railcar movers, also known as shunters, move railcars within a railyard. Railcar movers encompass a variety of equipment designed to move railcars, such as road-rail vehicles, road vehicles, and stationary equipment.

Road-switchers (road-switch locomotives): Road-switchers, also known as road-switch locomotives, are switch locomotives used to haul freight short distances along rail lines and may be used to shunt railcars within a railyard.

Side loader: A side loader lifts and transfers cargo materials efficiently from or to the ground, or from or to trailers or rail wagons to minimize wait times.

Switcher (yard-switch locomotive): Switch locomotive means a locomotive powered by an engine with a maximum rated power (or a combination of engines having a total rated power) of 2300 hp or less, where total power includes auxiliary engines in the calculation if the engines are permanently installed on the locomotive and can be operated while the main propulsion engine is operating, but not including the power of auxiliary engines that operate only to reduce idling time of the propulsion engine.

Yard truck: A yard truck, also known as shunt truck, spotter truck, terminal tractor, or hostler, moves trailers or cargo containers within a railyard.

1. Background and Purpose

Locomotives, trucks, and cargo-handling equipment in and around railyards contribute to air pollution for surrounding communities and railyard workers. For example, diesel exhaust from older locomotive engines, if not mitigated with proper aftertreatment, contains high levels of particulate matter (PM) which can increase the risk of certain cancers, respiratory illness, and heart disease, and may lead to premature death. People with heart or lung diseases, children, pregnant people, and older adults are particularly susceptible to the effects of PM (HEI 2015; EPA PM Health Effects).

From 2007 to 2009, the California Air Resources Board (CARB) developed health risk assessments for 17 major railyards in California using emissions inventories and air dispersion modeling prepared by Union Pacific (UP) and Burlington Northern Santa Fe (BNSF). Findings from these studies demonstrated the near-source and regional health risks from railyard emissions. For example, at the UP Oakland Railyard, researchers identified 33 sensitive receptors—14 schools and 19 childcare centers—within one mile of the facility and measured elevated cancer risk within surrounding residential areas due to diesel PM. Eleven of these sensitive receptors were found to have an estimated cancer risk of > 100 chances per one million (CARB, 2008), compared to a baseline cancer risk of 40 chances per one million (NCI 2024).

Typical railyard activities include receiving inbound trains, switching rail cars, loading and unloading intermodal trains, building outbound trains, and repairing freight cars and intermodal equipment. Many railyards allow other trains to pass through without stopping. All these activities rely heavily on diesel-fueled equipment—from older locomotives to on-road trucks to refrigerated rail cars—exposing workers and surrounding communities to diesel PM and other toxic air pollutants. If just three uncontrolled diesel switchers are replaced by battery-electric (BE) switchers, it is estimated that PM emissions at one port could be reduced by over three metric tons annually, as well as provide reductions of other criteria pollutants, greenhouse gases (GHG), and noise (Stagl, 2023).

Given the impacts associated with railyard emissions, the Federal Railroad Administration (FRA) is exploring a Technology Innovation for Energy-Efficient Railyards (TIEER) Initiative that focuses on implementing zero-emissions projects. The TIEER Initiative would begin with a pilot study to better understand where future zero-emissions projects could have the greatest benefits and how FRA can help railroads, railyard owners and operators, and state and local agencies with project planning and implementation. The primary objectives of the pilot study would be to determine whether an upgrade to zero-emissions equipment is technically feasible and can meet a railyard's needs from a safety and operational standpoint.

What equipment will a TIEER pilot include?

FRA anticipants that the TIEER pilot study would consist of replacing combustion engine equipment dedicated to a railyard (e.g., switchers, cranes, drayage trucks, side loaders, railcar movers, and yard trucks) with ***zero-emissions electric or hydrogen fuel cell versions*** for the purpose of achieving measurable reductions in railyard emissions.

This report is exploratory and conceptual in nature. It describes the concept of a TIEER pilot, addresses the benefits of replacing or retrofitting equipment to zero-emission versions, including the opportunity to modernize and optimize equipment tailored to the railyard's needs, and discusses considerations for conducting a TIEER pilot study. This report also provides an overview of zero-emissions technologies, funding opportunities for zero-emission equipment, and case studies of select zero-emissions projects.

While a TIEER pilot study would focus on replacing railyard equipment with zero-emissions versions, other sources of railyard emissions, such as those from repair shops, maintenance facilities, and backup power generation, could be considered for emissions reductions on a case-by-case basis as candidate yards are evaluated.

FRA's TIEER pilot study could follow four general phases, with additional details and processes further defined as each phase is implemented:

- Phase 0: Characterize a TIEER Pilot Study (current report)
- Phase 1: Identify and Prioritize Candidates, and Select a TIEER Pilot Railyard
- Phase 2: Implement TIEER Conversion of One Railyard and Conduct Measurements/Modeling
- Phase 3: Monitor Equipment Performance and Railyard Operations

2. Performance Metrics

Performance metrics can help measure the benefits, risks, and costs of a TIEER pilot. Metrics can be tailored to specific railyards and may include changes in railyard emissions as well as changes in noise levels, worker safety and satisfaction, and the operational performance of the yard. Performance data will be collected before, during, and after the pilot project, including a minimum three- to five-year monitoring period. Table 1 lists potential performance metrics and approaches for evaluating the metric. TIEER cost considerations are discussed in further detail in Sections 4 and 6.

Table 1. Performance Metrics

Performance Metric	Evaluation
Reduction in fuel use	Reduction in fuel consumption can be estimated based on the miles and/or hours that electric or hydrogen fuel cell equipment is used in a railyard during the pilot study. ZE equipment may see different levels of activity from combustion counterparts, thus average ZE activity can be used to estimate the expected fuel savings from replacing the combustion equipment. Fuel use estimates can also be used to estimate reductions in carbon dioxide (CO_2) and other greenhouse gas emissions.
Reduction in criteria pollutant emissions and, if feasible, concentrations in ambient air	Reductions in criteria pollutant emissions can be both modeled and measured, accounting for seasonality and peak periods. Emissions reductions may be determined based on the reduction in fuel use calculated using the *FRA Locomotive Emissions Comparison Tool (LECT)* for the replacement of diesel locomotives and the *Federal Highway Administration (FHWA) Congestion Mitigation and Air Quality Improvement (CMAQ) Emissions Calculator Toolkit* for other yard vehicles and equipment. Air quality monitors can be used to collect before and after measurements of PM, nitrogen oxides (NOx), and other pollutants. Changes in air quality could be estimated (via dispersion modeling) to characterize benefits to surrounding communities using Environmental Protection Agency (EPA) data, methodologies, and tools for evaluating the societal benefits of reducing pollution, such as EPA's *Environmental Benefits Mapping and Analysis Program - Community Edition (BenMAP-CE)*.
Reduction in noise	The reduction in noise (typically measured as day-night average sound level, or DNL) could be both modeled and measured, accounting for seasonality and peak periods. Sound level meters can be used to collect before and after measurements of noise levels. Noise levels could also be estimated using modeling tools such as FHWA's *Traffic Noise Model* (TNM) or a spreadsheet tool developed for the Chicago Rail Efficiency and Transportation Efficiency (CREATE) program which adopts the Federal Transit Administration's noise assessment procedures.
Worker safety and satisfaction	Worker safety and satisfaction could be evaluated using surveys to gain insights into worker concerns, perceptions, challenges, and benefits associated with using pre-upgrade and post-upgrade equipment. The pilot

Performance Metric	Evaluation
	participant could provide records on safety issues.
Operational performance	Operational performance could be evaluated by reviewing changes in railyard efficiency (i.e., throughput) in yard operations, as well as costs, time, and effort associated with repairs and maintenance. The pilot participant could provide the operational data.

3. Railyard Inventories

To help assess performance of a TIEER pilot study, detailed equipment information should be collected to develop estimates of baseline conditions and potential improvements in emissions, noise, and other metrics. This equipment inventory would detail all equipment used in a railyard, such as switchers, tractors, cranes, and heavy-duty trucks, and include information on usage and associated emissions. The Equipment Glossary at the front of this document describes typical equipment and systems found within railyards.

Equipment and operations vary widely across different railroad types depending on size and primary purpose (rail freight, passenger, intermodal freight, or some combination). Freight railyards are characterized by high amounts of switcher activity to assemble and disassemble trains, and intermodal yards include on-road and non-road equipment to transfer cargo between transportation modes. There is also variation within yard types; a Sierra Research report found that emissions from equipment in intermodal yards vary by cargo type and facility-specific operations, and can represent a range of 35-76 percent of a railyard's total PM emissions (Douglass et al., 2010). Class I railyards often maintain dedicated switchers, where locomotives are assigned to single yard. In Class II and Class III yards, locomotives are typically used for both switching and hauling, referred to as road-switchers, performing yard jobs and hauling commodities to regional customers and other terminals (Fenno, M., New York, Susquehanna & Western Railway, 2024).

To fully capture railyard equipment and operations and assess TIEER project performance, a railyard equipment inventory would ideally include (but would not be limited to) the following fields:

- Equipment Unique Identifier (ID)
- Equipment Type (e.g., switcher locomotive, drayage truck, crane)
- Operation (Process Type), e.g., freight, inspections, fuel distribution, repairs, or maintenance
- Manufacturer, if known
- Manufacture Year
- Re-Manufacture Year, if applicable
- Emissions Tier, if applicable
- Fuel
- Average Annual Activity (in hours)
    - Track activity by notch position, if known
- Average Annual Fuel Use (in gallons diesel equivalent)

Once a railyard equipment inventory is developed, emission reductions from replacing existing diesel locomotives with zero-emission locomotives can be calculated using tools such as FRA's Locomotive Emissions Comparison Tool. The LECT uses the baseline locomotive type and emissions tier, replacement engine type and emissions tier, and annual fuel use metrics to calculate emissions reductions. Emissions reductions from replacing and retrofitting non-locomotive railyard equipment can be calculated using FHWA's CMAQ Emissions Calculator Toolkit, specifically the Construction and Intermodal Equipment, and the Diesel Truck and Engine Retrofit & Replacement tools. For detailed guidance on development of

a rail emissions inventory, see Chapter 8 of EPA's Ports Emissions Inventory Guidance document.

The sections below provide equipment and emissions inventories from EPA's 2020 National Emissions Inventory (NEI) and CARB's Locomotive Emissions Resources. These inventories can help FRA understand where to target future TIEER efforts and what types of information to collect as part of a pilot project. Focusing zero-emission upgrades on Tier 0/1 and pre-Tier 0 locomotives may provide a cost-effective approach for reducing a railyard's emissions. Refer to Figure 1 for EPA locomotive emissions standards of NOx and PM; note that actual emissions from in-use equipment may differ from the standards.

EPA standards are based on Tiers, where Tier 0 represents the lowest standards for older locomotives and Tier 4 represents the most stringent standards for newer locomotives. Refer to Appendix A for more detail on locomotive emissions standards.

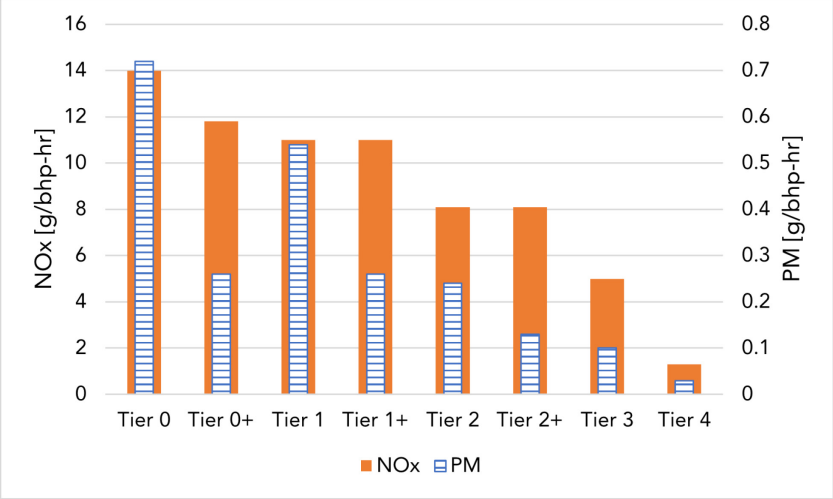

Figure 1.Switcher emission standards for NOx and PM. The '+' sign indicates locomotives that were remanufactured in year 2008 or later (Source: CARB).

National Emissions Inventory, Rail Sector. For the 2020 NEI, the EPA collected fleet mix and fuel use by Tier from the six Class I[1] freight railroads, Class II and Class III railroads,[2] commuter rail systems, and Amtrak. The Class I switcher engine fleet mix (Figure 2) included 98 percent Tier 0, 0+, and "not classified" (uncontrolled, pre-1960s) engines.

[1] Canadian National Railway did not provide updated 2020 data so the 2017 fuel data and switch engine counts of 169 were used as-is for 2020.

[2] There are approximately 630 Class II and Class III railroads (short lines) in the U.S. Data on Class II and III locomotive operations is publicly available from Bureau of Transportation Statistics' National Transportation Atlas Database 1,359 (NTAD).

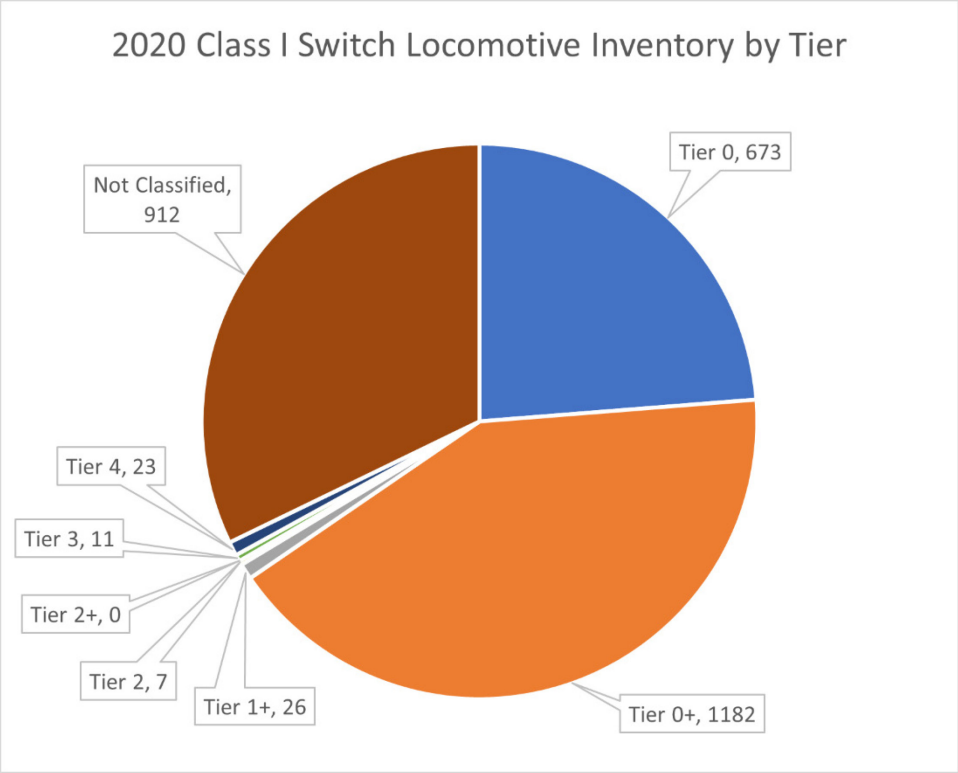

Figure 2. Class I yard switcher fleet profile from 2020; 98 percent of the fleet has Tier 0 or "not classified" engines (Source: Eastern Research Group, Inc).

The 2020 NEI emissions inventory is provided below (Figure 3). Emissions from Class I switcher locomotives exhibited the second highest emissions across all pollutants and GHGs, below emissions from Class I line-haul locomotives. Overall emissions from railyards are expected to be higher as the NEI does not track emissions from railyard equipment.

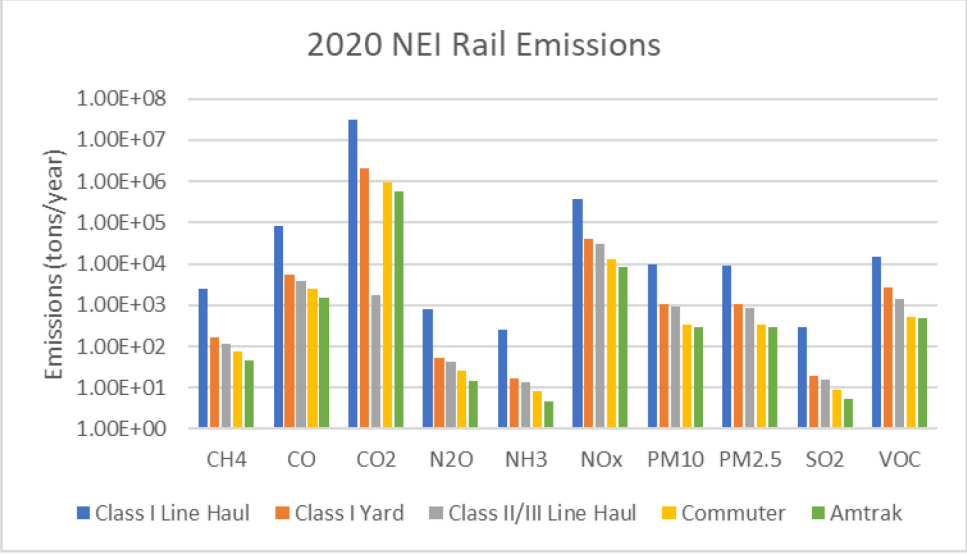

Figure 3. Locomotive emissions (tons/year) by sector from the 2020 NEI (Source: Eastern Research Group, Inc).

California Locomotive Fleet. CARB periodically compiles data on locomotives across California. In 2020, 4.8 percent of locomotives met Tier 4 standards (Figure 4). In 2023, California passed the In-Use Locomotive Regulation[3], which will only allow locomotives less than 23 years old to be used after 2030, unless operated in a zero-emission configuration. The EPA has not yet ruled on this regulation at the time of publication. The regulation also puts zero-emission requirements on switcher and passenger locomotives with an original build date of 2030 and later, and on freight line-haul locomotives with an original engine build date of 2035 and beyond (CARB, n.d. **d**).

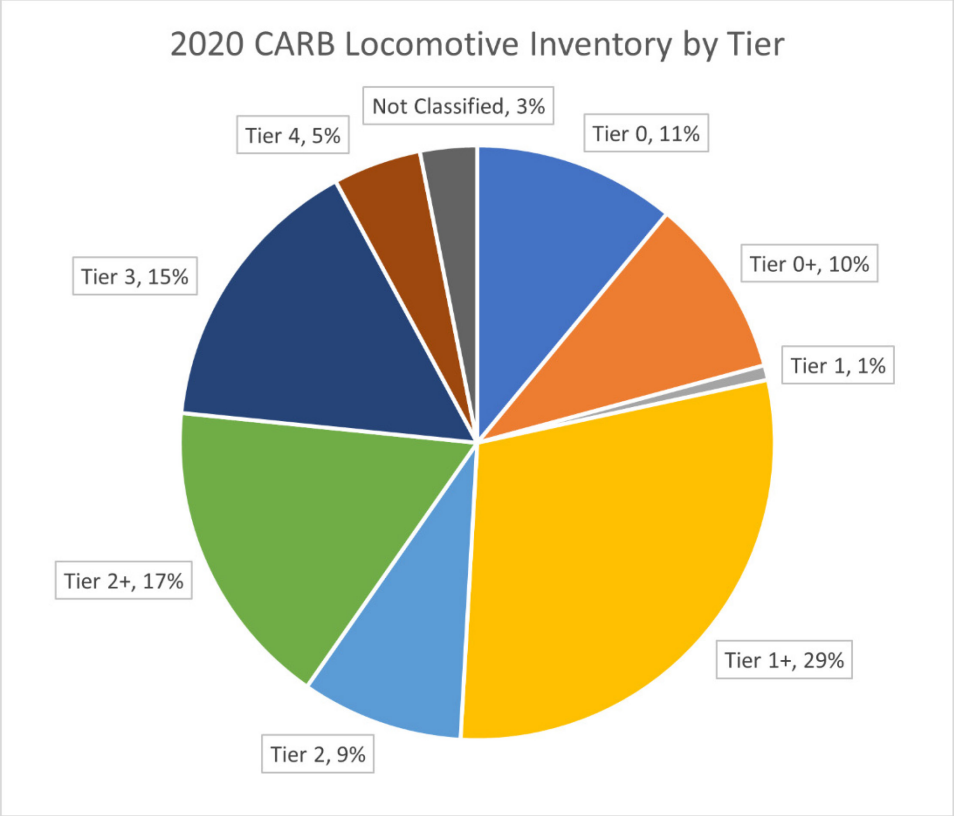

Figure 4. 2020 California locomotive population by Tier (Source: CARB).

[3] Section 209(e) of the Clean Air Act includes provisions that prohibit states from regulating certain non-road engines or vehicles, and requires that EPA authorize California standards and other requirements related to emissions controls. In February 2024, CARB requested EPA authorization to adopt its In-Use Locomotive Regulation and provide a waiver pursuant to Section 209(e) of the Clean Air Act.

4. TIEER Pilot Considerations

This section describes factors to consider when assessing a railyard for a pilot study. While there would likely be several types of benefits of a railyard conversion to a TIEER, the main objective of a TIEER pilot would be to showcase the reductions railyard emissions, which may result in air quality improvements to nearby communities (likely communities experiencing environmental justice concerns), and which a more widespread (i.e., nationwide) TIEER program could achieve. Since older equipment has less stringent pollution controls (if any), targeting railyards with mostly older equipment would likely provide a greater opportunity to reduce a railyard's overall emissions. Thus, an ideal candidate railyard for TIEER conversion would probably include a sufficient number of older diesel locomotives such that equipment upgrades would have a measurable beneficial impact. However, there are several other factors to consider that could impact the ease of implementation and overall success of a TIEER pilot study. Table 2 identifies relevant assessment criteria and provides context for considering those criteria.

Table 2. Criteria to consider when selecting a candidate yard for a TIEER pilot study

TIEER Criteria	Considerations
Railyard operations	
Number/age of line-haul locomotives	Removing the oldest and most active line-haul locomotives may present the greatest emissions reduction opportunities. In 2020, 87 percent of the Class II/III line-haul fleet were Unclassified or Tier 0 (Eastern Research Group, 2022).
Number/age of switcher locomotives	Targeting railyards with high numbers of old switcher locomotives may provide the greatest emissions reduction opportunities. In 2020, 97 percent of Class I switchers were Unclassified or Tier 0 (Eastern Research Group, 2022).
Percentage of switcher activity vs. pass-through traffic	Class II/III railroads often use the same locomotives for hauling and switcher activities, while Class I railroads and larger railyards may have dedicated switcher locomotives assigned to a yard. Most railyards also have some level of pass-through activity from freight and passenger trains. Although the TIEER pilot will focus on equipment dedicated to railyards, understanding the breakdown between switching and hauling activity is important for accurate emissions accounting.
Number/age of other equipment	Railyards with larger quantities of non-locomotive equipment, such as cranes and yard trucks, provide additional opportunities for emissions reductions.
Capacity/throughput in terms of mileage, passenger-miles, ton-miles, etc.	Railyards with higher capacity and throughput (people and/or goods) may carry greater emissions reduction potential. Hours of operation and annual fuel use could also be considered.
Existing and future fueling infrastructure	A railyard's capacity to accommodate the infrastructure for hydrogen fuel cell equipment or electric charging infrastructure and a potentially heavier electric demand on the grid should be considered.

TIEER Criteria	Considerations
Ease of Implementation	
Owner and operator willingness	The willingness of railyard owners and equipment operators to participate in a pilot study might evolve as familiarity with TIEER concepts, potential economic, environmental, and public health benefits, available funding, and worker-related benefits are conveyed, and as any preconceptions about zero-emission equipment are addressed. Facilitating collaboration among railyard owners and equipment owners and operators, if different, will be necessary for the success of a pilot program. It may be easier to convert non-locomotive equipment, such as yard trucks or railcar movers, if those are owned by a railroad rather than other entities, like private customers.
State and local regulations, policies, goals	State and local regulations and policies that support air quality, GHG, and clean energy goals may allow for zero-emission upgrades. A TIEER pilot study could help a facility or region meet these requirements and/or goals. Consideration may also be given to railyards in nonattainment or maintenance areas with targets defined in a State Implementation Plan (SIP), especially those railyards that are also within disadvantaged communities (refer to *Exposed population* below).
Funding eligibility	Federal, state, or local funding might be available. The deadlines for applying and timeline for receiving such funding should be understood. See the appendix for a list of rail funding opportunities.
Easy-to-convert equipment	Ease of conversion depends on the equipment type, operations, and technology. For example, it may be easy to convert a fleet to electric equipment, but power upgrades may be cost-prohibitive. The per-dollar emissions benefit of more complex upgrades should be considered, as well as the long-term financial savings expected to accrue. Railyard employees must be trained to use and maintain new equipment and incorporate activities like regular charging into schedules. Consider whether there are existing training programs or educational materials provided by OEMs.
Community involvement	The public should be engaged early and often as part of a TIEER pilot. Community leaders and action groups can help relay concerns about railyard operations and communicate risks and benefits of zero-emissions equipment with the public. Refer to Section 5, *Equity and Environmental Justice*.
Exposed population	A TIEER pilot should consider the total population that could benefit from reduced emissions, as well nearby communities that may be experiencing additional environmental justice concerns. The federal Justice40 initiative may provide an additional source of funding for pilot projects where investments benefit disadvantaged communities. Refer to Section 5, *Equity and Environmental Justice* and DOE-led *U.S. Transportation Decarbonization Blueprint: An Action Plan for Rail*.

TIEER Criteria	Considerations
Contributions of other pollution sources	Many railyards are located in busy industrial areas and along freight corridors. Consider the proximity of the railyard to other sources of pollution, such as highways. An overburdened community with multiple pollution sources may be an optimal location for a TIEER project.
Weather/climate	Sensitivity of technologies to extreme weather conditions may be considered. For example, battery-electric equipment may need special conditioning in very hot or cold conditions.

5. Equity and Environmental Justice

The Justice40 initiative is a government-wide initiative created by the Biden-Harris administration to address many decades of underinvestment in disadvantaged communities. The primary goal of Justice40 is to ensure 40 percent of benefits from certain federal investments flow to disadvantaged communities. Through Justice40, USDOT is working to identify and prioritize projects that will bring resources to communities most impacted by climate change, pollution, and environmental hazards.[4]

Environmental justice should be a factor in identifying a TIEER pilot, as resulting emissions reductions will improve the local and regional air quality, affecting public health outcomes of nearby communities. However, conversion of a railyard to zero-emissions may not necessarily lead to substantial improvements in local air quality because railyards are often located in areas with a high density of manufacturing and freight activity. Several environmental justice exploration dashboards are available to examine the environmental burden in communities. USDOT developed the Equitable Transportation Community (ETC) Explorer to explore five components of underinvestment in transportation: transportation insecurity, climate and disaster risk burden, environmental burden, health vulnerability, and social vulnerability. The ETC Explorer was designed to complement the Climate and Economic Justice Screening Tool (CEJST) developed by the White House Council on Environmental Quality, adding additional insight into the transportation disadvantage component of CEJST. To supplement the ETC Explorer, the Justice40 Rail Explorer was developed with a specific focus on the impact of rail infrastructure (grade crossings, railyards, and rail corridors) on communities. The DOE developed the Energy Justice Mapping Tool, which classifies disadvantaged communities based on the cumulative burden from 36 indicators that reflect fossil dependence, energy burden, environmental and climate hazards, and socio-economic vulnerabilities. EPA's EJScreen can be used to further explore socioeconomic and environmental information. Additionally, some states have developed state-specific environmental justice screening tools.

To fully capture environmental justice concerns, community engagement should be incorporated before, during, and after the development of a TIEER pilot. For example, during the NEPA analysis of any federally funded project, the public are often provided an opportunity to submit comments on NEPA documents. Public meetings allow for opportunities to educate the public and public officials on zero-emission technology, and to address concerns or preconceptions people may have, including those related to safety and health.

A TIEER pilot should also consider educating railyard equipment operators on the reliability of zero-emission technology, as new users of battery electric equipment may worry about reliability and experience charge anxiety (refer to Section 9, *Recommendations for Conducting a TIEER Pilot*).

[4] https://www.transportation.gov/equity-Justice40

6. TIEER Technologies, Costs, and Potential Hurdles

This section details technology that could be utilized in a TIEER pilot study. It also identifies potential technology-related challenges that may hinder deployment. Real-world examples are included for each technology to provide a snapshot of the current state of development, testing, and deployment in railyards. Estimated costs of specific technologies are also included in each subsection. These costs are for new equipment unless a retrofit is explicitly stated. It is important to note that these cost estimates are non-exhaustive due to a lack of publicly accessible and available data. Additional expenses may be incurred, such as installation, grid upgrades, labor, charger location identification, and staff training. Furthermore, equipment not listed in the cost tables may be applicable for conversion or replacement in a pilot study. Refer to Appendix B for additional information regarding the technology readiness level (TRL) for each technology.

While a TIEER project calls for the replacement of all equipment with zero-emissions alternatives, this transition is expected to be costly, and operational and logistics considerations may present hurdles to immediate adoption of all zero-emissions equipment. As a result, intermediate steps like low-emissions technology may be necessary. Refer to Appendix C for additional information, costs, and real-world examples of low-emissions approaches.

6.1 Battery-Electric

Battery-electric railyard equipment is powered by batteries that can be recharged through wayside connections to the grid, also known as ground charging equipment, and/or regenerative braking. For additional power and long-haul operations, battery tenders—railcars filled with batteries—can extend the range. As battery technology has improved, the cost has significantly declined while the energy density has greatly increased (CARB, 2023). Annual maintenance costs for battery-electric locomotives are estimated to be ten percent of that for diesel-electric (CARB, 2021). Battery-electric locomotives are increasingly available as retrofit solutions for yard operations; however, power and energy requirements need to be carefully considered to ensure technical feasibility and cost-effectiveness. Table 3 outlines estimated costs associated with battery-electric technologies.

Potential Hurdles and Considerations

- **Grid**: The power demand from battery-electric equipment must be considered to identify 1) the impact on the electrical grid, and 2) whether improvements are necessary to meet the added demand.
- **Infrastructure**: Infrastructure, such as charging stations, must be in place, and additional associated costs of installation, location identification and potential yard reconfiguration, and maintenance must be considered.
- **Lifetime**: Modern batteries must be replaced every 10-15 years. Proper charging, discharging, and operating temperatures must be considered to ensure the longevity of batteries. Second-

life applications of batteries, such as for energy storage or backup power for a railyard, may reduce waste and improve reliability.

- **Recharge Time**: Battery charging time is significantly longer than diesel fueling. To reduce the impact on operations, batteries may be swapped, which would then require additional considerations for battery storage and swapping procedures.

Current State of the Practice

This section highlights a few examples of promising technologies and recent deployments relevant to railyards, and is not meant as a comprehensive list of feasible technology. For additional examples, refer to the **Zero Emission Rail Project Dashboard** created by CARB.

- **Parallel Systems**: Parallel Systems is focused on efficient and expanded rail operations with an automated, battery-electric modular vehicle system, consisting of self-propelled rail cars, that can operate on short-haul routes. This system is currently being field-tested in Pueblo, Colorado, and an additional pilot study on short lines in Georgia, pending FRA approval.
- **Salt Lake City Intermodal Terminal**: The Utah Department of Environmental Quality was awarded $110,000,000 in Clean Ports Program funding for electric drayage trucks, locomotives, and cargo handling equipment, as well as charging infrastructure and solar generation.
- **Wabtec Corporation**: Wabtec offers line-haul locomotives and switchers with their FLXdrive battery technology. The haul capabilities are comparable to diesel locomotives, though the ranges are shorter. UP has ordered six of these battery-electric locomotives for yard operations to be delivered by 2026.
- **Watco**: Watco, a short-line railroad owner, was awarded up to $19,843,062 in FY2023-2024 Consolidated Rail Infrastructure and Safety Improvements (CRISI) Grant Program funding to acquire and repower eight non-tiered and Tier 0 diesel-electric locomotives with eight battery-electric locomotives. The locomotives will operate at Watco facilities in Montana, Oregon, Tennessee, Texas, and Washington.
- **Zephir:** Zephir offers a range of electric railcar movers to meet different weight and towing needs.

Table 3. Costs associated with battery-electric technology.

Equipment	Cost Estimate (U.S. Dollars)	Cost Unit
Line-haul locomotive	4.5–8 million[1]	Per locomotive
Passenger locomotive	10–12 million[1]	Per locomotive
Switchers	3–5 million[1]	Per locomotive
Battery system	1 million[2,a]	Per battery system
Battery tender	3–5 million[1,2]	Per tender
Charging equipment	100,000–250,000[1]	Per MW capacity
Charging infrastructure installation	7.48[3]	Per MWh
Electricity	32.87[3,b]	Per MWh
Crane	10,000–3.5 million[4]	Per crane
Drayage truck[c]	150,000–250,000	Per drayage truck
Side loader	Not available	N/a
Railcar mover	750,000–1.25 million[1]	Per railcar mover
Yard truck	270,000[5,d]	Per yard truck

[a] Estimated cost in 2030.
[b] Cost in California.
[c] Estimated cost of a new medium/heavy-duty truck; drayage trucks used in yards are often re-purposed on-road trucks taken out of service and used for yard operations only.
[d] Cost includes charging and infrastructure costs.
Sources:
[1] (CARB, 2021)
[2] (CARB, 2023)
[3] (Popovich et al., 2021)
[4] (Renderman, 2023)
[5] (Ruderman, 2022)

6.2 Catenary

Overhead wires called catenary can provide electricity to directly power locomotives. Catenary power is the most energy-efficient approach to decarbonization and a viable option for routes with high utilization and higher levels of tonnage per mile (Schlunk & Shurland, 2022). In general, the more trains that can use a fixed catenary infrastructure, the more cost-effective the investment in that infrastructure will be. In dense corridors like urban areas, there is a particularly high return on investment as well as emissions-reduction potential. Catenary is well established outside the U.S 99 percent and 62 percent of rail in Switzerland and the EU, respectively, runs on catenary, versus just one percent in the U.S. (Zenith et al., 2019). However, catenary alone may not be feasible for all yard operations. Overhead catenary lines may block equipment, such as cranes loading and unloading containers, or the maneuvering of switchers may necessitate a costly and complex network of catenary. Catenary may also be used for equipment like trucks that follow a set path repeatedly throughout the yard.

Discontinuous catenary (DISCO CAT) combines battery-electric and catenary to meet power needs. In this arrangement, for example, a road-switcher for a short-line could operate mainly on battery power within the yard and rely on catenary power for short haul runs. This reduces the capital costs associated with continuous (end-to-end) catenary and does not require a second power source on the locomotive (e.g., a diesel engine) when out of the catenary range– the locomotive is always powered by batteries

and the catenary, when present, recharges the batteries. Additionally, the complexity of a railyard switching network and high cost associated with modifying infrastructure, such as bridges, to allow for wire clearance is avoided, as locomotives can switch to battery-electric power. Table 4 outlines estimated costs associated with catenary. An international cost estimate is included for reference, as costs globally are much lower than in the U.S., potentially demonstrating that with continued investment, competition, and supply chain development, catenary costs can decrease over time (Zenith et al., 2019).

Potential Hurdles and Considerations

- **Cost**: The high capital cost of catenary may be prohibitive or impractical for railyards due to the complexity of a railyard switching network or the disruption of operations by overhead catenary.
- **Grid**: The power demand from catenary must be considered to identify the impact on the electrical grid and whether improvements may be necessary to meet the added demand reliably. New substations to provide electricity to the catenary lines at the proper voltage may need to be constructed.
  Infrastructure: The feasibility of catenary installation across the railyard without disrupting operations must be considered. For example, the height of bridges or cranes may not provide enough clearance for catenary above trains.
- **Switching**: Within railyards, switcher movement to construct and deconstruct trains may require a complex network of catenary. As a result, DISCO CAT could be considered as an alternative to meet the needs of railyard operations.

Current State of the Practice

This section highlights select examples of promising technologies and recent deployments relevant to railyards, and is not meant as a comprehensive list of feasible technology. For additional examples, refer to the **Zero Emission Rail Project Dashboard** created by CARB.

- **ABB**: ABB, a company focused on electrification and automation, has supported track electrification projects across Europe, including in Switzerland, Germany, and Lithuania.
- **Amtrak**: The 600-mile Northeast Corridor route uses catenary. Amtrak and NJ Transit are currently collaborating to inspect the catenary between Trenton, New Jersey, and New York City to improve service reliability and reduce disruptions, which have been a recent concern.
- **Brightline West**: The high-speed line under development that will connect Las Vegas, Nevada and Rancho Cucamonga, California, will be powered by catenary.
- **Carol Mine Railway**: The locomotives operating in the closed rail system at an iron ore mine in Labrador City, Canada, are powered by catenary and are fully automated.
- **KVU Green**: A study of non-electrified Norwegian rail lines, called KVU Green, found that DISCO CAT was the most affordable approach to electrification.

Table 4. Costs associated with catenary.

Equipment	Cost Estimate (U.S. Dollars)	Cost Unit
Line-haul (US)	50 million[1,a]	Per mile
Line-haul (Norway)	2.8 million[2,b]	Per mile
Passenger	25.8–30 million[1,a]	Per mile
Electricity	0.06–0.07[1]	Per kWh

[a] Cost estimate includes all-electric, catenary compatible, locomotive, catenary infrastructure, and infrastructure modification (e.g., vertical clearance). The line-haul estimate accounts for the higher voltage needed over passenger rail.
[b] Cost estimate based on the Norwegian government's projected cost for a rail electrification project.
Sources:
[1] (CARB, 2021)
[2] (Zenith et al., 2019)

6.3 Hydrogen

Hydrogen fuel cells can be used with batteries to power locomotives with 30 percent or greater efficiency than diesel-electric models (CARB, 2023). Fuel cells meet the base load energy demand while batteries provide additional power when peak power is necessary. Maintenance costs for hydrogen locomotives are estimated to be one-quarter those of diesel-electric equipment, providing cost savings to offset the upfront costs of hydrogen (CARB, 2021). Diesel-electric locomotives can be converted to hydrogen fuel cell power using hydrogen conversion kits (CSX, 2024). Table 5 outlines estimated costs associated with hydrogen fuel cell technologies. For information about hydrogen in internal combustion engines, refer to Appendix C: Near-Zero Technologies, Costs, and Potential Hurdles.

Potential Hurdles and Considerations

- **Certification**: Like all locomotive technologies, hydrogen-powered locomotives and tenders (whether storing hydrogen as a compressed gas or cryogenic liquid) require an FRA safety certification before use in the U.S.; however, hydrogen technologies have not been extensively evaluated and may require more scrutiny and time to meet FRA safety standards.
- **Emergency Response**: Although hydrogen is a stable fuel source, it is still a very flammable gas, and fires and explosions can result from improper handling. Hydrogen flames are nearly invisible to the naked eye, odorless, and tasteless, making hydrogen leaks and fires difficult to detect without specialized equipment.
- **Infrastructure and Supply**: Infrastructure, such as refueling and storage stations, must be in place, and additional associated costs of installation, location identification, and maintenance must be considered. A hydrogen delivery method, such as tanker truck or pipeline, must be identified to provide reliable access to fuel.
- **Public Concern**: While numerous studies have supported the safety of hydrogen fuel use, public concern and doubt about safety are still common. Communication campaigns and community engagement may be useful in allaying concerns.
- **Training**: Personnel must understand the signs of a hydrogen fire and how to properly handle associated incidents, such as creating a perimeter, utilizing personal protective equipment (PPE), and employing a fire detection system.

Current State of the Practice

This section highlights examples of promising hydrogen technologies and recent deployments relevant to railyards, and it is not meant as a comprehensive list of feasible technology. For additional examples, refer to the **Zero Emission Rail Project Dashboard** created by CARB.

- **Alstrom**: In 2023, Alstrom launched the first commercially operating hydrogen train in North America. The passenger train travels along a 90-kilometer route in Quebec and is powered by green hydrogen.
- **Canadian Pacific Kansas City (CPKC)**: CPKC developed a hydrogen-powered line-haul locomotive in 2022, and it has since successfully completed revenue runs in Calgary, Alberta. CPKC is now focused on expanding its hydrogen-powered fleet.
- **CSX**: CSX converted a diesel locomotive to hydrogen power in 2023, using a hydrogen conversion kit created by CPKC. The locomotive is currently undergoing field testing in Huntington, West Virginia.
- **San Bernadino County Transit Authority (SBCTA)**: In August 2024, SBCTA presented the Zero Emission Multiple Unit (ZEMU) which is hydrogen powered and will carry passengers along the Arrow Line as soon as early 2025.
- **Sierra Northern Railway (SERA)**: SERA is converting three diesel switchers to hydrogen power. Field testing will take place in SERA's West Sacramento railyard.

Table 5. Costs associated with hydrogen fuel cells.

Equipment	Cost Estimate (U.S. Dollars)	Cost Unit
Line-haul locomotive	6–7 million[1]	Per locomotive
Passenger locomotive	12–16 million[2]	Per locomotive
Switchers	2.75–3.8 million[2]	Per locomotive
Infrastructure with daily fuel delivery (75.4 kg/day)	221,000[2]	Per station
Electrolysis generation and fueling infrastructure (831 kg/day)	3.7–5.5 million[2]	Per station
Fuel	2019 = 3.98[2] 2050 = 4.11[2]	Per kg

Sources:
[1] (Argonne National Laboratory, 2024)
[2] (CARB, 2021)

6.4 Example Railyard Conversions

A TIEER pilot would replace all equipment dedicated to a railyard with zero emission alternatives, presenting significant capital costs. The total cost will vary based on the scale and type of operations at each railyard. Table 6 and Table 7 provide estimated costs to replace diesel equipment with battery-electric equivalents in a hypothetical large and small railyard, respectively, to give a sense of the investment needed to fund a complete TIEER conversion. Cost estimates were derived from available literature and reports (refer to Section 6.1). Additional expenses, such as grid upgrades, labor, charger location identification, and staff training, are not included in the total estimated costs as they are highly variable based on the specific conditions of the railyard. For these hypothetical railyards, it was assumed half of the old switchers would be replaced while the other half would be repowered (i.e., the chassis is reused).

Table 6. Large railyard cost estimate.

Equipment	Equipment Count	Total Cost ($)
New BE switchers	12	48,000,000
Battery system for converted switchers	12	12,000,000
Charging equipment	20	3,950,000
BE cranes	16[a]	30,500,000
BE railcar movers	15	15,000,000
BE yard trucks	30	8,100,000
	Total Cost:	**117,550,000**

[a] The equipment includes 3 gantry cranes, 3 bulk material cranes, and 10 smaller capacity cranes.

Table 7. Small railyard cost estimate.

Equipment	Equipment Count	Total Cost ($)
New BE switchers	6	24,000,000
Battery system for converted switchers	6	6,000,000
Charging equipment	6	1,100,000
BE cranes	5[a]	10,150,000
BE railcar movers	3	3,000,000
BE yard trucks	6	1,620,000
	Total Cost:	**45,870,000**

[a] The equipment includes 1 gantry crane, 1 bulk material crane, and 3 smaller capacity cranes.

7. Funding Opportunities

7.1 Federal Funding Opportunities

The following federal funding opportunities may be relevant for projects aimed at reducing rail emissions. Refer to Appendix D and Appendix E for more details and a comprehensive list of grant programs.

Advanced Technology Vehicles Manufacturing (ATVM) Loan Program: This U.S. Department of Energy (DOE) loan program provides low-cost debt capital for fuel-efficient vehicle and eligible component manufacturing in the United States. This program may be applicable to TIEER projects as locomotives are now considered eligible vehicles under the Bipartisan Infrastructure Law.

Consolidated Rail Infrastructure and Safety Improvements (CRISI) Program: This FRA discretionary grant program provides funding for projects that improve the safety, efficiency, and reliability of intercity passenger and freight rail. Class I railroads do not qualify for funding on their own, but do qualify if they partner with another eligible organization per 49 U.S.C. 22907(b)(10). This program may be applicable to TIEER projects as previous rounds have provided funding for zero-emission rail technology like BE locomotives.

Congestion Mitigation and Air Quality Improvement (CMAQ) Program: This FHWA formula program provides funding to states for transportation projects designed to reduce traffic congestion and improve air quality. Focus is placed on areas that are in nonattainment of the national ambient air quality standards. The CMAQ Program could provide a funding source for TIEER projects, including retrofit and replacement of locomotives and cargo-handling equipment.

Diesel Emissions Reduction Act (DERA) Funding: This EPA discretionary grant program provides funding for emissions reductions solutions such as retrofit technologies, alternative fuels and zero-emissions engines, idle reduction technologies for diesel vehicles, engines, and equipment. The DERA program generally targets older, dirtier diesel engines that lack modern emission control systems in areas of poor air quality. This program may be applicable to TIEER projects as previous rounds have provided funding for zero-emission rail technology like BE locomotives.

7.2 State Funding Opportunities

The following state funding opportunities are directly focused on reducing rail emissions. Refer to Appendix E for further detail and additional grant programs that may be relevant.

Clean Off-Road Equipment Voucher Incentive Project (CORE): This voucher incentive program, operated by CARB, encourages users to purchase or lease currently commercialized zero-emission off-road equipment. Eligible equipment includes terminal trackers, large forklifts, railcar movers, freight locomotives, and more. This program may be applicable to TIEER projects by offsetting the cost of replacing railyard equipment with zero-emissions alternatives in the state of California.

Locomotive Idle Reduction Grant: This discretionary grant opportunity, run by Minnesota Pollution

Control Agency, provides locomotive owners funding to purchase and install EPA certified SmartWay idle reduction technology and automatic start/stop technology. Eligible locomotives must have idled at least 1,500 hours/year in Minnesota during the previous two years prior to upgrade, and the applicant must intend to operate said locomotive in Minnesota for at least five years. This grant program may be applicable to TIEER projects that utilize near-zero emissions technology, as described in Appendix C.

Emissions Reduction Incentive Grants Program (ERIG): This discretionary grant program, operated by the Texas Commission on Environmental Quality, provides funding to repower or replace older locomotives, marine vessels, stationary equipment, or non-road equipment to reduce NOx emissions in Texas. Applicants with eligible projects may request additional funding for on-site refueling infrastructure, such as for electricity or hydrogen, which may be applicable to TIEER projects.

Port Electrification Grant: This competitive grant program, run by the Washington State Department of Transportation, is available to all public port districts in the State of Washington. It is intended to fund either smaller projects or a small part of a larger project, where state funds would enable the project to be completed. Examples of eligible projects that may be applicable to TIEER projects include truck and locomotive replacement with electric vehicles, electric power upgrades, and zero-emission charging infrastructure.

8. Case Studies

8.1 Flexible Solutions for Freight Facilities – San Joaquin Valley Zero and Near-Zero Emission Enabling Freight Project[5]

Overview

The Flexible Solutions for Freight Facilities, a BNSF-led project, demonstrated zero and near-zero emission technologies on locomotives and around railyards. Zero and near-zero emission equipment were demonstrated at BNSF's Stockton and San Bernardino intermodal yards. Each facility demonstrated a hybrid-electric rubber-tire gantry crane featuring an advanced battery system that achieved greater than 70 percent fuel efficiency. The San Bernardino facility also deployed a full-electric side loader and an electric Class 8 drayage truck used for short-haul drayage operations. The project included electrical infrastructure upgrades and electric vehicle supply equipment (EVSE). The total project funding was $45.2M, which consisted of a CARB contribution of $22.6M and matching funds in the amount of $22.6M (CARB, n.d. **b**).

A primary goal of the project was to demonstrate the hybrid consist concept, including how to optimize fuel efficiency. This project also compared new battery electric technologies at railyards in terms of ease of use and efficiency relative to the existing technology and identified obstacles to adoption of new technologies. Emissions reductions associated with the project are highlighted in Table 8.

Table 8. Annual emissions reductions from the Flexible Solutions for Freight Facilities project (CARB, n.d. b).

Equipment	Equipment Count	Fuel Savings (gal)	CO_2 (ton/year)	CO (ton/year)	NOx (ton/year)
Battery-electric locomotive	1	35,000	385.81	0.02	0.55
Drayage Truck	1	2,122	24.09	0.05	0.26
Hybrid Rubber-Tired Gantry (RTG)	2	14,915	170.05	0.24	0.05
Side loader	1	4,180	69.23	0.14	0.10

Equipment

This project funded five pieces of zero and near-zero equipment/vehicles deployed at BNSF's Stockton and San Bernardino railyards including (CARB, n.d. **b**):

- One Wabtec Battery Electric Locomotive (Stockton)
- Two Mi-Jack hybrid-electric rubber-tire gantry cranes (Stockton and San Bernardino)

[5] (CARB, n.d. **b**)

- One Taylor Machine Works, Inc., full-electric side loader (San Bernardino)
- One BYD all-electric Class 8 drayage truck (San Bernardino)

Infrastructure: This project provided for the accompanying electrical upgrades and EVSE equipment at Stockton and San Bernardino used for charging the equipment:

- One wayside charger to recharge the battery-electric locomotive batteries (Stockton)
- One RTG EVSE (Stockton)
- EVSE for the Class 8 drayage truck and electric side loader (San Bernardino)

Lessons Learned

The final report for the Flexible Solutions for Freight Facilities project includes several lessons learned (CARB, n.d. **b**):

- Early and constant communication with utility vendors and contractors is key for successful electric charging infrastructure. Meeting onsite up to a year in advance of desired implementation is essential to a successful deployment.
- Consider a battery energy storage system to take advantage of off-peak charging and provide emergency backup power.
- Project partners, not the awarded agency, are responsible for ensuring prevailing wage requirements are met.
- Provide sub-contractors and vendors the milestone descriptions and deliverables from the start of the project to ensure accurate invoicing and reporting.
- Equipment operators were initially hesitant to use the new technology due to various factors, such as early reliability issues, but usage increased over time. Workforce education should be taken into consideration to address training needs and the data collection process.
- Future battery-electric locomotive development will focus on addressing the limitations of this demonstration and building a unit that is a drop-in replacement for a diesel locomotive. The single largest advancement needed for development is the increase in energy storage.

8.2 California Collaborative Advanced Technology Drayage Truck Demonstration Project[6]

Overview

This project focused on demonstrating zero and near-zero emission truck technologies for Class 8 heavy-duty on-road trucks used to transport cargo to or from California's ports and intermodal railyards. New drayage truck technology was deployed in and around the Ports of Long Beach, Los Angeles, Oakland, Stockton, and San Diego. The project included four original equipment manufacturers: BYD Motors, Kenworth Truck Company, Peterbilt Motors, and Volvo Technology of America, LLC. The project finished in April 2022 (CARB, 2022). The total project funding was $40.1M, which consisted of a CARB contribution of $23.7M and matching funds in the amount of $16.5M

[6] (CARB, n.d. **a**)

(CARB, n.d. **a**).

Equipment

The project deployed 44 pre-commercial and commercial Class 8 zero and near-zero emission drayage trucks and infrastructure (CARB, n.d. **a**):

- 25 BYD battery electric trucks with 100–124-mile electric range
- 12 Peterbilt/Meritor battery electric trucks with 100–150-mile electric range
- 2 Kenworth compressed natural gas (CNG) range extended plug-in hybrid electric trucks with a 50 EV and 200-mile HEV range
- 3 Volvo diesel plug-in hybrid electric trucks with 30-mile electric/400-mile range and 2 battery electric trucks with 150-mile electric range

Lessons Learned

The final report for the Advanced Technology Drayage Truck Demonstration project includes several lessons learned (CARB, n.d. **a**):

- Kenworth: Supply chain issues and other challenges with creating hybrid electric trucks indicate that commercial vehicle supply chain is not ready to produce and support hybrid electric trucks at volume. Continued refinement of hybrid electric drivetrain to operate in all electric and hybrid electric modes is needed.
- Peterbilt: Managing charging rates, infrastructure costs, different range and efficiency depending on duty cycles by fleets is required, as is faster onboard charging and energy storage design.
- Volvo: Continue to refine the two proven technologies for seamless operation, provide further validation and design consideration of plug-in hybrid electric vehicle (PHEV) battery/engine interface, and continue evaluation of battery management systems for robustness.

8.3 Multi-Class Heavy-Duty Zero-Emission Truck Development Project for Intermodal and Warehouse Facilities[7]

Overview

This project demonstrated 26 battery electric yard trucks and service trucks, in two phases and at three freight facilities: BNSF Railway intermodal facilities at San Bernardino and Los Angeles, and a Daylight Transport facility in Fontana, California. All three locations are in the top 10 percent of disadvantaged communities in California according to CalEnviroScreen 2.0. The total project funding was $19.3M, which consisted of a CARB contribution of $9.1M and matching funds in the amount of $10.2M (CARB, n.d. **c**).

[7] (CARB, n.d. **c**)

Equipment

The project included the following electric equipment (CARB, n.d. **c**):

- BNSF Los Angeles: 1 BYD 5F model service truck, 10 BYD 8Y yard trucks, 10 200 kW alternating current (AC) Chargers, and 11 data loggers.
- BNSF San Bernardino: 2 BYD 5F model service trucks, 10 BYD 8Y yard trucks, 10 200 kW AC Chargers, and 12 data loggers.
- Daylight Transport Fontana: 3 BYD 8Y yard trucks, 3 100kW AC chargers, 3 data loggers.

Lessons Learned

The final report for the Zero-Emission Truck Development Project for Intermodal and Warehouse Facilities includes the following lessons learned (CARB, n.d. **c**):

- Plan for administrative time required to support the project, including coordination among fleet operators, equipment manufacturers, and local governments. For example, city governments may be able to help with delays related to installing charging infrastructure.
- Driver input was key and essential to the design process. There was a lot to be learned from the end users about ergonomic preferences, visibility requirements, etc. This project highlighted the importance of an independent operation of a fifth wheel, for example.

9. Recommendations for Conducting a TIEER Pilot

A TIEER pilot study should primarily be designed to demonstrate measurable reductions in railyard emissions in order serve as an example for other railyards and state and local agencies that might be considering TIEER projects. In addition, a pilot should be able to serve as a model for a larger (future) TIEER program that could garner widespread Congressional interest. The TIEER pilot would also provide health and safety benefits for surrounding communities and railyard workers, as well as demonstrate the capacity for long-term cost savings for the railyard owner/operator. This report describes six key performance measures that could be used to demonstrate pilot success:

- reduction in fuel use,
- reduction in criteria pollutant emissions,
- reduction in CO_2 emissions,
- reduction in noise,
- improvements in worker safety and satisfaction, and
- no reported declines in operational efficiency.

Indicators for each measure should be detailed and assessed in the field (with assistance from modeling where necessary) before and after pilot project implementation. The top two measures—reduction in fuel use and reduction in emissions—go hand-in-hand in terms of cost savings to railyard owners and operators and benefits to local air quality. The co-benefits of replacing old fossil-fuel-burning equipment with electric versions may include a reduction in noise exposure to workers and the surrounding community. While using any kind of mechanical and electrical equipment involves risk and requires necessary training on safe operation, the use of zero-emission equipment eliminates the risk of diesel fuel spills or exposure to fumes. Finally, some zero-emission equipment may require less downtime for repairs and maintenance, leading to more efficient railyard operations and lower costs in the long-term.

In addition to collecting performance measure data, the following recommendations may be considered during pilot design, implementation, and monitoring:

- **Initial selection**:
  - Select a railyard that will provide opportunities for significant emissions reductions and an owner/operator willing to collaborate closely with FRA on a pilot project.
  - Converting a larger railyard with a greater volume of older diesel equipment may provide the highest emissions reductions. However, smaller short line railyards may have fewer resources and opportunities for equipment purchases, so upgrading their switchers and other railyard equipment could also provide considerable emissions benefits.
- **Infrastructure to support ZE equipment**:
  - Battery electric and hydrogen equipment require more sophisticated infrastructure than diesel counterparts. Ensure that anticipated energy needs can be met, as infrastructure

upgrades to supply the required energy may have significant implications on project cost and schedule.

- **Environmental justice**:
  - Determine the proximity of the pilot location to communities experiencing environmental justice concerns and measure railyard impacts on both total population and disadvantaged population (within a 1,000-meter radius, for example). Screening-level dispersion modeling could be used to estimate air quality benefits to assist in the TIEER pilot selection process.
- **Railyard contribution to emissions**:
  - Ensure that monitoring equipment is available for measuring air quality before and after the pilot project and place monitors within the railyard, at the fence line, and at sensitive receptors (schools, hospitals, etc.) in adjacent communities.
  - Coordinate closely with the EPA and relevant state and local authorities on air quality monitoring planning, equipment installation, calibration, and maintenance, and interpretation of results, including validation of modeled concentrations. Consult with air quality monitoring experts on equipment selection and placement.
  - Establish a post-implementation monitoring period (e.g., 3 years, 5 years) to track progress towards emissions and local air quality goals.
- **Regulatory Landscape**:
  - Some states and jurisdictions may have established emissions reduction targets and/or regulations and policies that support low and zero-emission projects in railyards.
  - Similarly, railyards located within nonattainment or maintenance areas may receive further attention and funding. TIEER projects could potentially be programmed within a State Improvement Plan (SIP) to help meet air quality targets.
- **Education and Training**:
  - Implement a training program at the start of the pilot project to ensure workers become comfortable with new zero emission equipment. Provide training on maintenance, like the safe operation of high voltage systems, and communicate potential benefits of new equipment in terms of human health and safety.

While a TIEER pilot is an opportunity to showcase significant railyard emissions reductions that may translate to health and environmental benefits, it is also an opportunity for FRA to gain insights on how to implement future zero-emission conversions at the national scale efficiently and effectively. This could include, but is not limited to, issues related to the safety of various zero-emissions technologies (FRA certification of non-diesel fueled locomotives, for example) and mechanisms for funding equipment replacements in the absence of a larger pool of funds earmarked specifically for TIEER.

This report culminates Phase 0 of a multi-phased TIEER initiative. Phase 0 provides the foundation for selecting/prioritizing (Phase 1), conducting (Phase 2), and evaluating (Phase 3) a TIEER pilot. These phases together would then serve as a larger foundation for a potential nation-wide TIEER program that would seek to convert all railyards in the U.S. to zero emissions, pending future administration priorities and funding availability.

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Appendix A: Estimated In-Use Locomotive Emission Factors

Emission regulations for locomotive engines are applied through the EPA and are based on the year in which the locomotive was originally manufactured or remanufactured. Locomotives manufactured before 1973 are all Uncontrolled (or pre-Tier 0), while those manufactured or remanufactured in or after 1973 must be built to the standards designated by the manufacturing year. The emission factors differ for line-haul locomotives and switchers, as summarized in Table A1.

Table A1. Locomotive Emission Factors[8]

			Emission Factors (g/bhp-hr)			
Fuel Type	**Year of Manufacture**	**Tier[9]**	**NO_X**	**PM**	**HC**	**CO**
Diesel (Line-haul)	Pre-1973	Uncontrolled	13.00	0.32	0.48	1.28
	1973-1992	Tier 0	8.60	0.32	0.48	1.28
	1973-1992	Tier 0+	7.20	0.20	0.30	1.28
	1993-2004	Tier 1	6.70	0.32	0.47	1.28
	1993-2004	Tier 1+	6.70	0.20	0.29	1.28
	2005-2011	Tier 2	4.95	0.18	0.26	1.28
	2005-2011	Tier 2+	4.95	0.08	0.13	1.28
	2012-2014	Tier 3	4.95	0.08	0.13	1.28
	2015+	Tier 4	1.00	0.015	0.04	1.28
Diesel (Switch)	Pre-1973	Uncontrolled	17.40	0.44	1.01	1.83
	1973-2001	Tier 0	12.60	0.44	1.01	1.83
	1973-2001	Tier 0+	10.60	0.23	0.57	1.83
	2002-2004	Tier 1	9.90	0.43	1.01	1.83
	2002-2004	Tier 1+	9.90	0.23	0.57	1.83
	2005-2010	Tier 2	7.30	0.19	0.51	1.83
	2005-2010	Tier 2+	7.30	0.11	0.26	1.83
	2011-2014	Tier 3	4.50	0.08	0.26	1.83
	2015+	Tier 4	1.00	0.015	0.08	1.83

Tiers with '+' are applicable only to locomotives that were originally manufactured in the corresponding Year of Manufacture range and remanufactured in 2008 or later; EPA holds these remanufactured locomotives to a higher emissions standard.

[8] EPA, 2009. Emission Factors for Locomotives; EPA, 2023. EPA Regulatory Overview: Locomotives. MSTRS Spring Meeting.

[9] The EPA Tiers may also be applied to diesel-battery hybrids (diesel engine emissions) and other technologies and fuels, such as biodiesel. New locomotives built today must be certified to meet Tier 4 standards.

Appendix B: Technology Readiness Level

Table B2. Definition of TRLs (Source: NASA)

TRL	Definition	Description
Research		
1	Basic principles observed and reported	Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.
2	Technology concept and/or application formulated	Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.
3	Analytical and experimental critical function and/or characteristic proof-of-concept	Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard or brassboard implementations that are exercised with representative data.
Development		
4	Component/subsystem validation in laboratory environment	Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.
5	System/subsystem/component validation in relevant environment	Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
6	System/subsystem model or prototyping demonstration in a relevant end-to-end environment	Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
Deployment		
7	System prototyping demonstration in an operational environment	System prototyping demonstration in an operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.
8	Actual system completed and "mission qualified" through test and demonstration in an operational environment	End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.
9	Actual system "mission proven" through successful mission operations	Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.

The technology readiness level (TRL) ratings provided in Table B2 were determined through a review of literature and company reports for each technology listed.

Table B2. Zero-Emission and Near-Zero-Emission TRLs

Technology	Equipment	TRL
Battery-Electric	Line-haul locomotive	6
	Passenger locomotive	6
	Switcher	9
	Crane	9
	Drayage truck	9
	Yard truck	9
	Railcar mover	9
Catenary	Line-haul locomotive	9
	Passenger locomotive	9
Discontinuous Catenary	Line-haul locomotive	6
	Passenger locomotive	9
	Switcher	6
Hydrogen	Line-haul locomotive	6
	Passenger locomotive	6
	Switcher	7
After-Treatment	Diesel oxidation catalyst	9
	Diesel particulate filters	9
	Exhaust gas recirculation	9
	Selective catalytic reduction	9
Hybrid	Line-haul locomotive	7
	Passenger locomotive	7
	Switcher	7
	Crane	9
Dual-Mode	Line-haul locomotive	6
	Passenger locomotive	8
Renewable Diesel	Line-haul locomotive	8
	Passenger locomotive	8
	Switcher	8
Compressed Fossil-Fuel Natural Gas	Drayage truck	9
	Yard truck	9
Renewable Natural Gas	Line-haul locomotive	5
	Passenger locomotive	5
	Switcher	5
Upgrades to Tier 3 or 4	Line-haul locomotive retrofit (NC, Tier 0, Tier 0+ to Tier 3)	9
	Line-haul retrofit locomotive (NC, Tier 0, Tier 0+ to Tier 4)	9
	Passenger locomotive retrofit (Tier 2 to Tier 4)	9
	Switcher retrofit (Tier 0, 1, 2, 3 to Tier 4)	9

Appendix C: Near-Zero Technologies, Costs, and Potential Hurdles

I. After-Treatment Systems

After-treatment systems, such as diesel oxidation catalyst (DOC), diesel particulate filter (DPF), selective catalytic reduction (SCR), and diesel exhaust fluid (DEF), and engine systems like exhaust gas recirculation (EGR) reduce emissions associated with internal combustion engines. After-treatment systems may be added to existing diesel yard equipment, included in a rebuild, or purchased as part of new equipment to reduce emissions. The installation of these systems in conjunction with the technologies listed below (hybrid, renewable diesel, renewable natural gas, or upgrades to Tier 3 or 4 engines) may be an intermediate low-emissions step to a TIEER. DOC removes hydrocarbons, carbon monoxide, and PM from exhaust by oxidizing them and converting them to CO_2 and water vapor. DPFs remove PM by collecting and oxidizing carbon. EGR reduces NOx emissions by capturing exhaust gas, cooling it, combining it with intake air, and recirculating it to use in combustion again. SCR systems remove NOx by combining exhaust with DEF—an aqueous solution typically with approximately 32 percent urea—to convert NOx into nitrogen gas and water vapor. Table C1 outlines some estimated costs associated with after-treatment systems and technologies.

1.1 Potential Hurdles and Considerations

- **Space**: Installing after-treatment systems may require additional space on board in retrofits and at railroad facilities.
- **Temperature**: In cold climates, DEF reserves in SCR systems must be monitored since it is only usable in liquid form and can freeze at temperatures below -11°C.
- **Training**: Rail employees must be trained in the proper implementation and maintenance of after-treatment systems.

1.2 Current State of the Practice

This section highlights a few examples of promising technologies and recent deployments relevant to railyards and is not meant as a comprehensive list of feasible technology.

- **Caterpillar Inc.**: Caterpillar offers a locomotive SCR system that is on EPA's Verified Technologies for Clean Diesel list.
- **Progress Rail & Norfolk Southern**: Progress Rail and Norfolk Southern Corporation collaborated to build a Tier 4 road-switcher that utilizes a DEF and SCR after-treatment system.
- **Wabtec**: Wabtec's Tier 4 locomotives utilize EGR. As of May 2024, there were over 1,000 of these locomotives in service.

Table C1. Costs associated with after-treatment systems.

Equipment	Cost Estimate (U.S. Dollars)	Cost Unit
Diesel oxidation catalyst	Not available	N/a
Diesel particulate filter	50,000[1]	Per unit
Selective catalytic reduction (locomotive)	928,594[2,a]	Per grant
Selective catalytic reduction (drayage truck)	27,679[2]	Per unit

[a] During the 2009-2010 Emerging Technologies Diesel Exhaust Reduction Act (DERA) grant roll out, CARB received this amount of money to retrofit one line-haul locomotive with SCR technology.

Sources:

[1] (EPA, 2010)

[2] (EPA, n.d. **b**)

2. Diesel-Electric Hybrid

With up to 80 percent lower fuel consumption (in certain modes) than traditional diesel-electric models, hybrid diesel battery-electric locomotives are a viable option to reduce emissions (Union Pacific, 2024). Through a mother-slug design, the locomotive (mother) runs on diesel that is supplemented with battery power supplied by batteries located in a tender (slug). For low power use scenarios, the diesel generator can be switched off, allowing the batteries to supply all power. This allows the locomotive to operate with zero emissions, improving overall efficiency and reducing diesel usage. While the batteries can be recharged by the diesel generator, they can also be recharged without emissions through regenerative braking or electric charging equipment located throughout a railyard or along routes. Hybrid diesel battery-electric cranes, trucks, and other railyard equipment are currently used at intermodal yards across the U.S. Table C2 outlines some estimated costs associated with hybrid technologies.

2.1 Potential Hurdles and Considerations

- **Length**: The additional length of the mother-slug design added to a locomotive may not be accommodated in all railyards.
- **Training**: Additional training is necessary so employees understand the strengths and limitations of each power source, how to switch power sources, and where each may be used along lines.

2.2 Current State of the Practice

This section highlights a few examples of promising technologies and recent deployments relevant to railyards and is not meant as a comprehensive list of feasible technology.

- **Canadian National (CN)**: CN purchased its first hybrid diesel battery-electric line-haul locomotive in April 2024. The locomotive is currently being tested under different operation and weather scenarios in British Columbia.
- **Port of Houston**: The Port of Houston Authority received $3 million of DERA funding to retrofit eight diesel rubber tire gantry cranes with hybrid diesel-electric motors. By the end of 2024, 57 of the total 147 RTG cranes at the port will be hybrid, demonstrating the feasibility of this technology for railyards as well.

- **UP**: UP is testing a prototype hybrid diesel battery-electric locomotive in North Little Rock, Arkansas. UP, along with its partner ZTR, will be deploying five other hybrid locomotives and collecting test data.

Table C2. Costs associated with hybrid (diesel/battery-electric).

Equipment	Cost Estimate (U.S. Dollars)	Cost Unit
Locomotive	3.2 million[1]	Per locomotive
Crane	375,000 - 3 million[2,3]	Per crane
Drayage truck	N/a	N/a
Yard truck	N/a	N/a
Railcar mover	N/a	N/a

Sources:
[1] (Canadian National, 2024)
(Container News, 2023)
3 (EPA, 2024)

3. Dual-Mode

Another hybrid option is dual-mode locomotives which combine power from catenary and diesel. The advantage of this model is that locomotives can operate with zero emissions in areas with constructed catenary, such as urban areas or railyards, without the need to switch units before entering areas without catenary (Cambridge Systematics, Inc, 2012). Dual-mode locomotives provide more flexibility than traditional diesel-electric or catenary locomotives while reducing emissions. Additionally, the high cost associated with modifying infrastructure to allow for wire clearance is avoided, as locomotives can switch to diesel power. Table C3 outlines some estimated costs associated with dual-mode technologies.

3.1 Potential Hurdles and Considerations

- **Space**: Retrofitting diesel locomotives to accommodate catenary systems may require additional space in the chassis for equipment.
- **Training**: Additional training is necessary to educate employees on how to switch power sources and emphasizing that catenary should be used wherever possible

3.2 Current State of the Practice

This section highlights a few examples of promising technologies and recent deployments relevant to railyards and is not meant as a comprehensive list of feasible technology.

- **Connecticut Department of Transportation (CT DOT)**: CT DOT purchased six dual-mode passenger locomotives in 2023 with an estimated delivery date of 2027. In 2020, CT DOT also purchased 27 locomotives of the same model which are expected to arrive in 2025.
- **New Jersey TRANSIT (NJ TRANSIT)**: In 2020, NJ TRANSIT purchased eight ALP-45A dual-mode locomotives to add to their fleet of 17 others.
- **Siemens**: In March 2024, Siemens announced a dual-mode locomotive designed for freight and developed for Deutsche Bahn (DB) Cargo in Germany. DB Cargo has ordered 150 such locomotives. Initially, these locomotives will operate within a fully automatic marshalling yard in

Halle. Additionally, Amtrak's new Airo trains[10], with an anticipated debut in 2026, will be dual-mode and manufactured by Siemens.

Table C3 Costs associated with dual-mode (catenary/diesel).

Equipment	Cost Estimate (U.S. Dollars)	Cost Unit
Line-haul locomotive	6–10 million[1,2]	Per locomotive
Passenger locomotive	9–12 million[3]	Per locomotive

Sources:
[1] (Cambridge Systematics, Inc., 2012)
[2] (CARB, 2016)
[3] (CTDOT, 2023)

4. Upgrades to Tier 3 or 4 Engines

Retrofitting or replacing equipment to meet Tier 3 or 4 engine standards reduces emissions and takes advantage of the longevity of the locomotive chassis. For example, repowering a Tier 0 switcher to Tier 4 removes around nine tons of NOx emissions annually (Ramboll, 2019). Appendix A outlines the specific emissions factors by Tier for line-haul locomotives and switchers. Other railyard equipment can also be upgraded to Tier 3 or 4 EPA standards. Table C4 outlines some estimated costs associated with upgrades to Tier 3 and 4 engines.

4.1 Potential Hurdles and Considerations

- **Cost**: While Tier 3 upgrades are the same size as lower tiers, Tier 4 upgrades require the installation of a new engine and additional treatment equipment to reach the strict emissions requirements. Upgrades to Tier 4 require additional space onboard, leading to a higher cost than Tier 3 retrofit upgrades.

4.2 Current State of the Practice

This section highlights a few examples of promising technologies and recent deployments relevant to railyards and is not meant as a comprehensive list of feasible technology.

- **Columbia Corridor Association (CCA)**: CCA partnered with EVRAZ Portland, a steel company, to replace an older switch locomotive with a Tier 4 compliant locomotive. CCA received $348,320 in DERA funding for this project.
- **Knoxville Locomotive Works (KLW) & Cummins Inc**: KLW successfully repowered a line-haul locomotive to be Tier 4 compliant using a Cummins Inc. Tier 4 engine and SCR system in 2022. Today, this locomotive is operating on CN Railway, and the conversion kit is available commercially.
- **Progress Rail**: Progress Rail focuses on repowering older locomotives to meet Tier 3 and Tier 4 compliance. These services are offered for freight and passenger locomotives.

[10] Airo trains are manufactured by Siemens in California and include sustainability features like improved fuel efficiency and lower emissions relative to Amtrak's existing fleet: https://www.amtrak.com/amtrak-airo

- **Tacoma Rail**: Tacoma Rail was awarded up to $8,316,000 in FY2023-2024 CRISI funding to acquire and repower four Tier 0 diesel-electric switch locomotives with four Tier 4 diesel-electric switch locomotives in Tacoma Rail's Tacoma, Washington railyard.

Table C4. Costs associated with upgrades to Tier 3 and 4.

Equipment	Cost Estimate (U.S. Dollars)	Cost Unit
Line-haul retrofit (NC, Tier 0, Tier 0+ to Tier 3)	275,000[1]	Per locomotive
Line-haul retrofit (NC, Tier 0, Tier 0+ to Tier 4)	2.6 million[1]	Per locomotive
Passenger retrofit (Tier 2 to Tier 4)	560,000–570,000[1]	Per locomotive
Switcher retrofit (Tier 0, Tier 1, Tier 2, Tier 3 to Tier 4)	2–2.5 million[1]	Per locomotive
Yard truck (Tier 4)	120,000[2]	Per yard truck

Sources:
[1] (CARB, 2021)
[2] (Ruderman, 2022)

5. Alternative Fuels

This section outlines three fuel options that can be used as alternatives to fossil fuel diesel in internal combustion engines: renewable diesel, natural gas, and hydrogen. Renewable diesel is produced from a blend of plant oils and fats. The chemical formula is similar to petroleum diesel as they are both hydrocarbon fuels. Renewable diesel is considered a drop-in fuel since it can be used in locomotives without mixing it with petroleum or modifying the engine. In contrast, biodiesel is not a hydrocarbon fuel, so it is blended with petroleum diesel or renewable diesel for use.

Natural gas is an alternative fuel option that results in fewer greenhouse gas emissions from combustion than diesel (FRA, n.d.). It can be stored in two forms: compressed natural gas (CNG) and liquified natural gas (LNG). CNG is natural gas stored under high pressure in its gaseous state while LNG is natural gas cooled to its liquid state under atmospheric pressure. Natural gas is primarily composed of methane and can be used by light-, medium-, and heavy-duty vehicles (AFDC, n.d.). Sources of RNG include landfills, wastewater treatment plants, livestock farms, food production operations, and organic waste management facilities (EPA, n.d. **c**). For LNG-fueled locomotives, a port injection system is utilized where diesel is sparked to ignite the natural gas.to ignite the natural gas.

Burning hydrogen in internal combustion engines is another alternative fuel option. While this technology is still being researched, it presents a possible intermediate technology as only slight modifications to locomotives would be necessary (Stephens, 2023). However, similar to LNG, diesel fuel is still needed in the engine to ignite hydrogen. Therefore, while PM emissions would decrease, NOx emissions are not reduced due to combustion. Table C5 outlines some estimated costs associated with alternative fuels.

5.1 Potential Hurdles and Considerations

For potential hurdles and considerations for hydrogen, refer to Section 6.3: Hydrogen Fuel Cells.

- **Cost**: As of April 2024, California, Oregon, and Washington are the only states to provide incentives for renewable diesel use in their clean fuel programs (Troderman & Harris, 2024). These programs result in similar prices for renewable diesel and petroleum diesel. Almost all renewable diesel consumption occurs in California, partially due to the state's renewable diesel rebate program. Rail companies that operate in other states may face higher costs.
- **Natural Gas Infrastructure**: The source and procurement of natural gas pipelines and placement and construction of related refueling infrastructure in railyards must be considered in project costs.
- **Renewable Diesel Infrastructure**: The source and procurement of reliable renewable diesel, and placement and construction of related refueling infrastructure in railyards must be considered in project costs. As of September 2024, only 10 of 638 total renewable diesel fueling stations for all transportation modes in the U.S. exist outside of California, demonstrating the overall lack of infrastructure across the U.S.
- **Safety**: In 2022, a Congressional taskforce determined that transporting liquefied natural gas (LNG) by rail is safe, citing the lack of major safety incidents (Transportation Research Board, 2021). This follows a 2020 Pipeline and Hazardous Materials Safety Administration (PHMSA) ruling that authorized LNG transport with specialized tank cars. However, safety concerns continue to be raised and the task force added that additional research is needed. This finding may be relevant to RNG in regard to emergency response protocols and tenders.

5.2 Current State of the Practice

This section highlights a few examples of promising technologies and recent deployments relevant to railyards and is not meant as a comprehensive list of feasible technology.

- **Amtrak**: Starting in May 2023, trains operating on the Capitol Corridor, Pacific Surfliner, and San Joaquin lines in California use renewable diesel.
- **Argonne National Laboratory**: Scientists at Argonne are researching the performance and challenges of biodiesel and renewable diesel on a single-cylinder locomotive test engine.
- **Cummins Westport and California Clean Energy Commission**: In March 2019, a feasibility study was conducted in the Ports of Los Angeles and Long Beach and demonstrated the daily operations of 20 near-zero emission heavy-duty natural gas drayage trucks, resulting in a TRL rating of 9.
- **Florida East Coast Railway (FECR)**: FECR operates its entire main fleet line, consisting of 24 locomotives, on liquefied natural gas, becoming the first North American railroad to do so.
- **OptiFuel Systems**: In January 2025, OptiFuel will begin testing a prototype line-haul locomotive and tender powered by RNG in Pueblo, Colorado. In 2026, this program will expand to test 10 line-haul locomotives and five tenders over a two-year period with a goal of operating them over one million miles. Production is anticipated to begin in 2028.
- **UP**: UP is running a pilot program in California testing four locomotives using a blend of 80 percent renewable diesel and 20 percent biodiesel.

- **Wabtec**: Wabtec was awarded up to $48,412,512 in FY2023-2024 CRISI funding to conduct research on hydrogen dual-fuel internal combustion engine and liquid hydrogen tender technologies at the Transportation Technology Center in Pueblo, Colorado. The research is aimed at educating rail operators, first responders, and other stakeholders on safely handling hydrogen and developing best practices for these technologies for rail.

Table C5. Costs associated with renewable diesel and natural gas.

Equipment	Cost Estimate (U.S. Dollars)	Cost Unit
Compressed fossil-fuel natural gas	2.92[1]	Per gasoline gallon equivalent
Renewable diesel	5.36[2,a]	Per diesel gallon equivalent
Renewable natural gas line-haul locomotive	5.5 million[3,b]	Per locomotive
Renewable natural gas	Not available	N/a
Hydrogen fuel	2019 = 3.98[4] 2050 = 4.11[4]	Per kg

[a] Price in California only.

[b] Estimated price when production begins in 2028, contingent on successful completion of prototype testing.

Sources:

[1] (Alternative Fuels Data Center, 2024)[2] (Office of Energy Efficiency and Renewable Energy, 2024)

[3] (OptiFuel Systems, 2024)

[4] (CARB, 2021)

Appendix D: Federal Funding Sources for TIEER

The following table was created by FRA and was last updated in November 2023. Note that not all funding sources may be listed here, as new initiatives may become available after the publication of this chart.

Table C3. Climate-Related Funding Opportunities for the Rail Industry (Source: FRA)

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
Consolidated Rail Infrastructure and Safety Improvements (CRISI) - 49 U.S.C. § 22907	Discretionary	DOT/FRA	CRISI provides funding for projects that improve the safety, efficiency, and reliability of intercity passenger and freight rail. See the full list of eligible projects here. Projects eligible for CRISI funding include rehabilitating, remanufacturing, procuring, or overhauling locomotives, provided that such activities result in a significant reduction of emissions.	• State • Group of states; • Interstate Compact; • Public agency or publicly chartered authority established by one or more states; • Political subdivision of a state; • Amtrak or another rail carrier that provides intercity rail passenger transportation; • Class II railroad or Class III railroad or a holding company of a Class II or Class III railroad, or an association representing a Class II or III railroad; • A federally recognized Indian Tribe; • Any rail carrier or rail equipment manufacturer in partnership with at least one of the entities described in (1) through (5); • Transportation Research Board together with any entity with which it contracts in the development of rail-related research, including cooperative research programs; • University transportation center engaged in rail-related research; or • Non-profit labor organization representing a class or craft of employees of rail carriers or rail carrier contractors.

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
Federal-State Partnership for Intercity Passenger Rail Program (Partnership for State of Good Repair) - 49 U.S.C. 24911	Discretionary	DOT/FRA	This program provides funding for capital projects to repair, replace, or rehabilitate qualified railroad assets to reduce the state of good repair backlog and improve intercity passenger rail performance. Eligible projects include those that: • Replace, rehabilitate, or repair infrastructure, equipment, or a facility used for providing intercity passenger rail service to bring such assets into a state of good repair • Improve intercity passenger rail service performance, including reduced trip times, increased train frequencies, higher operating speeds, improved reliability, expanded capacity, reduced congestion, electrification, and other improvements. • Expand or establish new intercity passenger rail service. • Cover the planning, environmental review, and final design of an eligible project or group of projects described above.	• A State (including the District of Columbia) • A group of states • An Interstate Compact • A public agency or publicly chartered authority established by one or more states • A political subdivision of a state • Amtrak, acting on its own behalf or under a cooperative agreement with one or more States • Any combination of the entities described above
Rail Vehicle Replacement Grants (note this program is a set-aside of the State of Good Repair Formula Grants Program, codified at 49 U.S.C. 5337)	Discretionary	DOT/FTA	This program provides funding for replacement of rail rolling stock (revenue service, passenger carrying vehicles, or locomotives). Eligible projects must be reflected in a transit agency's Transit Asset Management (TAM) plan, according to 49 CFR 625.	State and local government authorities in urbanized areas (UZAs)

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
Multimodal Project Discretionary Grant (MPDG); see 49 U.S.C. § 6701 (Mega), 23 U.S.C. § 117 (INFRA), 23 U.S.C. § 173 (Rural)	Discretionary	DOT/OST	The MPDG encompasses three funding opportunities: the National Infrastructure Project Assistance grants program (Mega), Nationally Significant Multimodal Freight and Highway Projects grants program (INFRA), and the Rural Surface Transportation Grant program (Rural). Applicants may apply for one, two, or three of these funding opportunities by submitting only one application. MPDG funds can be used towards highway and bridge, intercity passenger rail, railway-highway grade separation, wildlife crossing, public transportation, marine highway, freight, and multimodal projects.	Varies based on whether applicant is pursuing Mega, INFRA, or Rural grant. All three programs are open to states, units of local government, and tribal governments, among other entities. Mega is specifically open to partnerships between Amtrak and public/tribal authorities.
Port Infrastructure Development Program (PIDP) - 46 U.S.C. 54301	Discretionary	DOT/MARAD	The PIDP supports capital projects that will be used to improve the safety, efficiency, or reliability of the movement of goods through ports and intermodal connections to ports.	• Port authority • Commission or its subdivision or agent under existing authority • State or political subdivision of a state or local government • An Indian Tribe • A public agency or publicly chartered authority established by one or more states • A special purpose district with a transportation function • A multistate or multijurisdictional group of entities • Lead entity described above jointly with a private entity or group of private entities (including the owners or operators of a facility, or collection of facilities, at a port)

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
Capital Investment Grants Program (CIG) - 49 U.S.C. § 5309	Discretionary	DOT/FTA	This grant program funds transit capital investments, including heavy rail, commuter rail, light rail, streetcars, and bus rapid transit. Transit agencies seeking CIG funding are required to complete a series of steps over several years: • For New Starts and Core Capacity projects, agencies must complete two phases in advance of receipt of a construction grant agreement: project development and engineering. • For Small Starts projects, the law requires completion of one phase in advance of receipt of a construction grant agreement: project development.	State and local government agencies, including transit agencies
Diesel Emissions Reduction Act (DERA) Program - 42 USC §16131-16137	Discretionary (National and State)	EPA	DERA provides funding for emissions reductions solutions such as retrofit technologies, alternative fuels and zero emissions engines, idle reduction technologies for diesel vehicles, engines, and equipment. The DERA program generally targets older, dirtier diesel engines that lack modern emission control systems in areas of poor air quality.	• Regional, state, or local agencies; • Tribal governments (or intertribal consortia) and native villages; • Port authorities, which have jurisdiction over transportation or air quality; • Nonprofit organizations or institutions that: ○ represent or provide pollution reduction or educational services to diesel fleets, or ○ have, as their principal purpose, the promotion of transportation or air quality. Although private fleet owners are not eligible to apply directly to EPA for DERA funding, both public and private fleets can benefit from the programs implemented by DERA national grant recipients

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Grants - 49 U.S.C. 6702	Discretionary	DOT/OST	RAISE grants are intended for investments in surface transportation, including road, rail, transit, and port projects, that will have a significant local or regional impact. The eligibility requirements of RAISE allow project sponsors at the state and local levels to obtain funding for multi-modal, multi-jurisdictional projects that are more difficult to support through traditional DOT programs. *RAISE was previously known as the Better Utilizing Investments to Leverage Development (BUILD) and Transportation Investment Generating Economic Recovery (TIGER) Discretionary Grants.*	• States and the District of Columbia • Any territory or possession of the United States • A unit of local government • A public agency or publicly chartered authority established by one or more states • A special purpose district or public authority with a transportation function, including a port authority • A federally recognized Indian Tribe or a consortium of such Indian Tribes • A transit agency • A multi-state or multijurisdictional group of entities that are separately eligible
Railroad Rehabilitation & Improvement Financing (RRIF) - 49 CFR 260	Credit assistance	DOT/OST	Under RRIF, DOT can provide direct loans and loan guarantees to finance development of railroad infrastructure. The funding may be used to: • Acquire, improve, or rehabilitate intermodal or rail equipment or facilities, including track, components of track, bridges, yards, buildings and shops, and includes the installation of positive train control systems • Develop or establish new intermodal or railroad facilities • Reimburse planning and design expenses relating to activities listed above • Refinance outstanding debt incurred for the purposes listed above • Finance transit-oriented development	• Railroads • State and local governments • Government-sponsored authorities and corporations • Limited option freight shippers that intend to construct a new rail connection • Joint ventures that include at least one of the preceding.

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
Transportation Infrastructure Finance and Innovation Act (TIFIA) - 49 CFR part 80	Credit assistance	DOT/OST	TIFIA provides credit assistance in the form of direct loans, loan guarantees, and standby lines of credit (rather than grants) to projects of national or regional significance, including: • Highways and bridges • Intelligent transportation systems • Intermodal connectors • Transit vehicles and facilities • Intercity buses and facilities • Freight transfer facilities • Pedestrian bicycle infrastructure networks • Transit-oriented development • Rural infrastructure projects • Passenger rail vehicles and facilities • Surface transportation elements of port projects • Airports	• State and local governments • Transit agencies • Railroad companies • Special authorities • Special districts • Private entities
Congestion Mitigation and Air Quality (CMAQ) Improvement Program – 23 USC 139	Formula	DOT/FHWA	The CMAQ Program provides funding to states for transportation projects designed to reduce traffic congestion and improve air quality, particularly in areas of the country that do not attain national air quality standards.	• State and local transportation departments • Metropolitan planning organizations • Transit agencies

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Formula Grant Program - 23 U.S.C. 176(c)	Formula	DOT/FHWA	The PROTECT Formula Program was established to help make surface transportation more resilient to natural hazards, including climate change, sea level rise, flooding, extreme weather events, and other natural disasters. Eligible activities include planning activities, resilience improvements, community resilience and evacuation routes, and at-risk costal infrastructure. Funding may go towards development phase activities, preliminary engineering and design work, and construction.	A state may only use its PROTECT Formula Program funds for eligible activities and eligible costs associated with: • highway projects eligible under Title 23, U.S.C. • public transportation facilities or services eligible under chapter 53 of title 49, U.S.C. • port facilities, including facilities that connect ports with other modes of transportation, improve the efficiency of evacuations and disaster relief, or aid transportation. [§ 11405; 23 U.S.C. 176(c)(3)(B)] PROTECT treats every project funded under the program as if it were located on a federal-aid highway.
Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Discretionary Grant Program - 23 U.S.C. 176	Discretionary	DOT/FHWA	PROTECT discretionary grants include resilience improvement grants, community resilience and evacuation route grants, and at-risk coastal infrastructure grants. Highway, transit, and certain port projects are eligible	• State (or political subdivision of a state) • Metropolitan planning organization • Local government • Special purpose district or public authority with a transportation function • Tribe • Federal land management agency (applying jointly with state(s)) Different eligibilities apply for at-risk coastal infrastructure grants.

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
Bridge Investment Program (BIP) - 23 U.S.C. 124	Discretionary	DOT/FHWA	The BIP provides grants to improve bridge condition and the safety, efficiency, and reliability of the movement of people and freight over bridges. Projects eligible for funding under BIP include: • a project (or bundle of projects) to replace, rehabilitate, preserve, or protect a bridge on the National Bridge Inventory (NBI) • project to replace or rehabilitate culverts on the NBI for the purpose of improving flood control and improved habitat connectivity for aquatic species. [§11118(a); 23 U.S.C. 124(a)(1)	• A State or a group of states • A metropolitan planning organization that serves an urbanized area (as designated by the Bureau of the Census) with a population of over 200,000 • A unit of local government or a group of local governments • A political subdivision of a state or local government • A special purpose district or public authority with a transportation function • An FLMA • A Tribal government or a consortium of Tribal governments • A multistate or multijurisdictional group of entities described above
Higher Blends Infrastructure Incentive Program (HBIIP) - 5 U.S.C. 301 and 7 U.S.C. 1989	Discretionary	USDA	The purpose of the HBIIP is to increase significantly the sales and use of higher blends of ethanol and biodiesel by expanding the infrastructure for renewable fuels derived from U.S. agricultural products. To be eligible for this program, a project's sole purpose must be for the installation, and/or retrofitting, and/or otherwise upgrading of fuel dispensers/ pumps, related/attached equipment, underground storage tank (UST) system components, and other infrastructure required at a location to ensure the environmentally safe availability of fuel containing ethanol blends greater than 10 percent or fuel containing biodiesel blends greater than 5 percent.	Owners of transportation fueling and fuel distribution facilities located in the U.S. and its territories may apply for this program. Eligible entities include: • fueling stations, • convenience stores, • hypermarket retailer fueling stations • fleet facilities (including automotive, freight, rail and marine), and • similar entities with equivalent capital investments, as well as fuel/biodiesel terminal operations, midstream operations, and heating oil distribution facilities or equivalent entities.

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
Title 17 Innovative Energy Loan Guarantee Program – 10 CFR part 609	Loan guarantee	DOE	Title 17 helps eliminate gaps in commercial financing for energy projects in the U.S. that utilize innovative technology to reduce, avoid, or sequester greenhouse gas emissions. Eligible projects must: • Employ new or significantly improved technology as compared to commercial technology in service in the U.S. at the time the guarantee is issued • Avoid, reduce, or sequester greenhouse gases • Be located in the U.S. Foreign ownership or sponsorship of the projects is permissible as long as the project is located in one of the fifty states, the District of Columbia, or a U.S. territory • Have a reasonable prospect of repayment	• Private project developers • Investor-owned utilities • Publicly owned utilities • Nonprofits
Regional Clean Hydrogen Hubs (H2Hubs) - 42 USC 16161a	Discretionary, Cooperative Agreement	DOE	H2Hubs will help establish six to ten regional clean hydrogen hubs across the U.S. Funding may be used for projects that demonstrate the production, processing, delivery, storage, and end-use of clean hydrogen through regional clean hydrogen hubs, which are networks of clean hydrogen producers, potential clean hydrogen consumers, and connective infrastructure located in close proximity.	• Technology developers • Industry • Utilities • Universities • National laboratories • Engineering and construction firms • State and local governments • Tribes • Environmental groups • Community based organizations

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
EPA Port Emissions Programs	Discretionary and Rebates	EPA	Projects to: • Purchase or install zero-emission port equipment or technology for use at, or to directly serve, one or more ports • Conduct any relevant planning or permitting in connection with the purchase or installation of such zero-emission port equipment or technology • Develop qualified climate action plans	• A port authority • A state, regional, local, or Tribal agency that has jurisdiction over a port authority or a port • An air pollution control agency • A private entity (including a nonprofit organization) that applies for a grant in partnership with an entity described above and owns, operates, or uses the facilities, cargo-handling equipment, transportation equipment, or related technology of a port. The Clean Air Act defines "state" to mean a state, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, and American Samoa, and includes the Commonwealth of the Northern Mariana Islands

Program	Type of Program	Administering Agency	Program Summary	Eligible Applicants
EPA Climate Pollution Reduction Grants (CPRG) Program	Discretionary and Formula	EPA	Non-competitive Phase I planning grants provide flexible support to states, local governments, tribes, and territories. Phase I grant recipients must use the funding to design Priority Climate Action Plans (PCAPs) that incorporate a variety of measures to reduce GHG emissions. Competitive Phase II implementation grants provide funding to eligible applicants to implement GHG reduction programs, policies, projects, and measures identified in a PCAP.	Non-competitive Phase I planning grants provides flexible support to states, local governments, tribes, and territories. Phase I grant recipients must use the funding to design Priority Climate Action Plans (PCAPs) that incorporate a variety of measures to reduce GHG emissions. Competitive Phase II implementation grants provide funding to eligible applicants to implement GHG reduction programs, policies, projects, and measures identified in a PCAP.

Environmental and Climate Justice Community Change Grants	Discretionary, Cooperative Agreements	EPA	Provides funding for environmental and climate justice activities to benefit disadvantaged communities through projects that reduce pollution, increase community climate resilience, and build community capacity to respond to environmental and climate justice challenges.
			
			Activities may include investments in low- and zero-emission and resilient technologies and related infrastructure.
				• A partnership between at least two community-based non-profit organizations (CBOs).
				• A partnership between a CBO and one or any combination of the following:
				  ○ a federally recognized Tribe
				  ○ a local government
				  ○ an institution of higher education

Appendix E: State Funding Sources for TIEER

The following state funding sources may apply to TIEER projects. Note that not all funding sources may be listed here as new initiatives may become available after the publication of this chart. In addition, other grant programs may not be specifically focused on zero-emission issues but are also available to rail stakeholders.

Table E4. TIEER-Related State Funding Opportunities for the Rail Industry

Program	State	Type of Program	Administering Agency	Program Summary	Eligible Projects	Eligible Applicants
Transit and Intercity Rail Capital Program (TIRCP)	California	Discretionary	California State Transportation Agency	This program provides grants to fund transformative capital improvements to modernize California's intercity, commuter, and urban rail systems, and bus and ferry transit systems, to significantly reduce emissions of greenhouse gases, vehicle miles traveled, and congestion.	• Rail capital projects, including intercity rail, commuter rail, light rail, and other fixed guideway projects. Additionally, the acquisition of rail cars and locomotives, and the facilities to support them. • Intercity, commuter, and urban rail projects, infrastructure access payments to host railroads in lieu of capital investments, efforts to improve existing rail service effectiveness, and minor capital investments, as well as larger scale projects. • Rail, bus, and ferry integration implementation (see program website for more details)	• Public agencies, including joint powers agencies, that operate or have planning responsibility for existing or planned regularly scheduled intercity or commuter passenger rail service, urban rail transit service, or bus or ferry transit service. • Public agencies may include local municipalities. • Private companies may partner with eligible applicants to propose and deliver projects.

Program	State	Type of Program	Administering Agency	Program Summary	Eligible Projects	Eligible Applicants
Carl Moyer Memorial Air Quality Standards Attainment Program	California	Financial incentives	California Air Resources Board	This program provides incentive funding to expedite the replacement of old, higher polluting locomotives with new Tier 4 units. This includes rail equipment that is designed for use on the tracks, such as on-rail vehicles, railcar movers, sweepers, and wheel cranes which have tires, or mounted tracks that replace switcher locomotives.	• Replacements • Repowers • Head End Power Units (HEPs)	• Class 3 • Industrial • Passenger
Volkswagen Environmental Mitigation Trust for California	California	Discretionary	South Coast Air Quality Management District	This program is intended to accelerate the replacement of older, higher polluting engines throughout the state of California, including but not limited to areas that are disproportionately impacted by air pollution, such as freight corridors, ports, and railyards.	Replace/Repower • Class 7 and Class 8 Freight Trucks, Dump Trucks, Waste Haulers, and Concrete Mixers Freight Switcher Locomotives	• Public entities that own and operate eligible equipment anywhere in California • Private entities that own and operate eligible equipment anywhere in California

Program	State	Type of Program	Administering Agency	Program Summary	Eligible Projects	Eligible Applicants
Clean Off-Road Equipment Voucher Incentive Project (CORE)	California	Voucher incentive program	California Air Resources Board	This program encourages California off-road equipment users to purchase or lease currently commercialized zero-emission off-road equipment. This streamlined voucher incentive project helps offset the higher cost of zero-emission technology with a point-of-sale discount. There is no scrappage requirement, and additional funding is available for charging and fueling infrastructure, equipment deployed in disadvantaged communities, and small businesses.	• On- and off-road terminal tractors • Truck- and trailer-mounted TRUs • Large forklifts • Cargo handling equipment • Air cargo loaders • Wide-body aircraft tugs • Railcar movers and freight locomotives • Mobile power units and aircraft ground power units • Commercial harbor craft shore-side electric and hydrogen fueling vessel supply equipment • Construction equipment • Agricultural equipment • Commercial harbor craft	• California purchasers of eligible equipment • California lessees of eligible equipment

Program	State	Type of Program	Administering Agency	Program Summary	Eligible Projects	Eligible Applicants
Locomotive Idle Reduction Grant	Minnesota	Discretionary	Minnesota Pollution Control Agency	This opportunity provides locomotive owners funding to purchase and install U.S. Environmental Protection Agency (EPA) certified SmartWay idle reduction technology and automatic start/stop technology (when not required by rule or statute), and shore connection systems. These systems will reduce diesel emissions while locomotives idle.	• Existing locomotives must idle at least 1,500 hours/year in Minnesota during the previous two years prior to upgrade. The applicant must intend to operate the locomotive in Minnesota for at least five years. The participating fleet owner must currently own and operate the existing locomotive and have owned and operated the locomotive during the two years prior to upgrade. • Unregulated and Tiers 1 to 4 locomotives. • Eligible idle reduction technologies are listed online. To be eligible for funding these technologies must be on EPA's SmartWay Verified Technologies list at the time of acquisition.	• For profit, nonprofit, and public entities — including state, local, and tribal governments — that own and operate locomotives that idle more than 1,500 hours per year. • Grant contractors are eligible under this program. Eligible contractors may request contractor fees up to 10 percent of the equipment cost per piece of equipment with a maximum of $2,000 per project. Contractor fees will be included on a per vehicle/equipment awarded basis and are not included in the maximum project funding.

Program	State	Type of Program	Administering Agency	Program Summary	Eligible Projects	Eligible Applicants
Clean Engine Project (Volkswagen Diesel Emissions Settlement)	Montana	Discretionary	Montana Department of Environmental Quality	This program aims to achieve reductions of mobile NOx emissions in Montana.	Freight Switchers: • Switcher with pre- Tier 4 that operates at least 1,000 hours per year • Repower with new diesel or alternate fueled engine or generator sets • Replace with new diesel or alternate fueled freight switcher certified to meet U.S. EPA emission standards • Repower with all-electric engine (can include charging infrastructure) • Purchase all-new electric freight switcher (can include infrastructure)	• *Applicant information not provided. Refer to Montana DEQ website.*
Rail Freight Assistance Program	New Jersey	Discretionary	New Jersey Department of Transportation	This program supports the preservation, rehabilitation, and enhancement of New Jersey's freight railroad network.	Design, construction, reconstruction, rehabilitation, land acquisition, and environmental mitigation of freight rail projects that: • Are significant to port commerce connectivity • Eliminate rail freight missing links to port facilities • Upgrade freight rail tracks to a 286,000-pound load carrying capacity	• Class I railroads • Class II railroads • Class III railroads • Owners of rail properties • Operators of rail freight service • Responsible public agencies or authorities

Program	State	Type of Program	Administering Agency	Program Summary	Eligible Projects	Eligible Applicants
Passenger and Freight Rail Assistance Program (PFRAP)	New York	Discretionary	New York Department of Transportation	This program is intended to provide funding opportunities for investments in New York state's rail and port infrastructure.	Any capital improvement to freight, intercity passenger, or tourist rail assets with a minimum service life of 10 years or greater, including but not limited to: • track construction and rehabilitation • bridge construction and rehabilitation • elimination of clearance obstructions • yard, terminal and siding construction and rehabilitation • signal and train control systems • rolling stock acquisition and rehabilitation • capital projects that will reduce carbon footprint of railroad facilities	• Any railroad company • Any New York state agency • The federal government • The Canadian government • Any other state or instrumentality thereof • Any public authority of New York or any other state • Any political subdivision or municipality of the state
Mobile Sources Emissions Reductions Grant	North Carolina	Discretionary	North Carolina Division of Air Quality	This program supports significant reductions in diesel emissions, including NOx and GHGs.	• Repowering on-road and nonroad equipment with newer, cleaner engines • Replacing old on-road and nonroad equipment with new, cleaner vehicles • Converting vehicles to run on alternative fuels • Expanding medium and heavy-duty electric vehicle usage throughout the state	• Any private or public sector entity with a physical presence in North Carolina is eligible to apply. All original equipment or vehicles must be operational in the previous two years and the replacement equipment or vehicle must be operated at least 70 percent in North Carolina for the next five years.

Program	State	Type of Program	Administering Agency	Program Summary	Eligible Projects	Eligible Applicants
Ohio Rail Development Commission (ORDC) Grant and Loan Program	Ohio	Discretionary (ongoing basis)	Ohio Rail Development Commission	This program aims to fund projects that support the goals of the ORDC, including economic development, safety, environmental benefits, and efficient railways.	• *Eligible project descriptions not provided. Refer to ORDC website.*	• *Applicant information not provided. Refer to ORDC website.*
Ohio EPA Diesel Mitigation Trust Fund	Ohio	Discretionary	Ohio Environmental Protection Agency	This program aims to help owners of diesel school buses and off-road equipment with all-electric equipment.	Repower or replace diesel equipment with new all-electric equipment, or all-electric or alternative fueled switcher locomotive. • School buses • Cargo handling equipment • Airport ground support equipment • Freight switcher locomotive	• *Applicant information not provided. Refer to Ohio EPA website.*

Program	State	Type of Program	Administering Agency	Program Summary	Eligible Projects	Eligible Applicants
Driving PA Forward – Marine and Rail Freight Movers Grant Program	Pennsylvania	Reimbursement grants	Pennsylvania Department of Environmental Protection	This program is dedicated to improving Pennsylvania's air quality by reducing NOx emissions produced by nonroad equipment like freight switcher locomotives, ferries, and tugboats.	• Repower or replace diesel-powered, pre-Tier 4 freight switcher locomotives that operate 1,000 hours or more per year with any new EPA or CARB-certified diesel, alternative fuel, or all-electric engine • Repower or upgrade unregulated, Tier 1 or Tier 2, diesel-powered marine engines in ferries or tugboats with an EPA Certified Remanufactured system or an EPA Verified Engine Upgrade	Organizations that own or operate eligible ferries or tugboats (including push boats), or eligible freight switcher locomotives, that are based and operate predominately in Pennsylvania. • Businesses • Incorporated nonprofits • State, local, or tribal government agencies • Air quality or transportation organizations • Metropolitan or rural/regional transportation planning organizations • Federal government agencies

Program	State	Type of Program	Administering Agency	Program Summary	Eligible Projects	Eligible Applicants
Freight Rail Enhancement to Increase Goods and Highway Throughput (FREIGHT) Program	Virginia	Discretionary	Virginia Department of Rail and Public Transportation	This program is dedicated to increasing the capacity and improving the functionality of the freight rail network as a vital component of the Commonwealth's multimodal network.	• Railways: mainline, sidings, crossover, yards, terminals, and storage tracks • Railroad equipment • Rolling stock • Right-of-way acquisition • Rail facilities • Signaling • Engineering and design • Environmental • 30 percent design complete	• Freight rail operators • Virginia Port Authority • Local and regional governments • Non-profit organizations • Private companies • Any combination thereof
Emissions Reduction Incentive Grants Program (ERIG)	Texas	Discretionary	Texas Commission on Environmental Quality	This program provides funding to repower or replace older locomotives, marine vessels, stationary equipment, or non-road equipment to reduce NO_X emissions in Texas.	Replace or repower: • select non-road equipment • stationary equipment • marine vessels • locomotives Applicants with eligible projects may request additional funding for on-site refueling infrastructure. Allowable alternative fuels are: • electricity • hydrogen • compressed natural gas (CNG) • liquefied natural gas (LNG) • propane (LPG) • methanol	• Individuals • State and local governments • Corporations • Any other legal entity

Program	State	Type of Program	Administering Agency	Program Summary	Eligible Projects	Eligible Applicants
Defense Economic Adjustment Assistance Grant Program	Texas	Discretionary	Texas Military Preparedness Commission	This is an infrastructure grant program designed to assist defense communities that are responding to or recovering from a reduction or termination of defense contracts, and those that have been positively affected with new or expanded military missions.	Funding can be used for negatively and positively affected communities or for proactive projects that will increase the military value of the installation. Projects can include • The purchase of Department of Defense property • New construction • Rehabilitation of facilities in support of job creation projects and opportunities. Past grant awardees have included projects replacing or repowering locomotives to BE power.	• Local municipalities • Counties • Defense base development authority • Junior college districts and Texas State Technical College campuses • Regional planning commissions
Port Electrification Grant	Washington	Discretionary	Washington State Department of Transportation	This is a competitive grant program that is available to all public port districts in the state of Washington. It is intended to fund either smaller projects or a small part of a larger project where state funds would enable the project to be completed.	• Truck and locomotive replacement with electric vehicles • Electric power upgrades and zero emission charging • Shore power • Other similar projects that will reduce emissions at ports	• All public port districts

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