

March 16, 2021

Preliminary Cost Document for the In-Use Locomotive Regulation



This document was prepared by California Air Resources Board (CARB or Board) staff to document the preliminary cost inputs and assumptions to be used for the economic analysis of the In-Use Locomotive Regulation under development. This document is being released in advance of the Standardized Regulatory Impact Analysis (SRIA) and Initial Statement of Reasons (ISOR) for the In-Use Locomotive Regulation to support stakeholder input and to provide the opportunity for staff to make revisions prior to publication of the SRIA and ISOR.

Please send comments or cost information to the [informal comment docket](#) by April 16, 2021 to be considered prior to completion of the SRIA. Stakeholders can also continue to comment throughout the formal regulatory process.

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Background

CARB staff held a two-day online workshop in October 2020 to discuss advanced locomotive technologies and the concepts in the In-Use Locomotive Regulation under development. This Preliminary Cost Document outlines the preliminary cost inputs and assumptions to be used to develop the cost estimates. The SRIA will assess the economic impact of the formal regulatory proposal for consideration by the Board and will be released prior to the Board hearing. This document is not intended to detail the regulatory requirements nor implementation dates, which can be found in the draft regulatory language on the [In-Use Locomotive Regulation webpage](#).

Summary of Concept Timelines and Calculations

1. In-use locomotive operation reporting would be required under the concepts in order to better understand and quantify emissions within California (CA) beginning in 2023. Locomotive operators would be required to annually report operation details for each locomotive operating in CA.
2. The first year of the Spending Account concept (SA) is 2023. This means that the locomotive operators deposit into the SA for the first time in mid-2023 based on the locomotive usage during 2022. Staff assume that railroads will spend the entire amount deposited in 2023 to purchase the cleanest available locomotives. It is assumed that locomotives purchased in 2023 enter the service in 2024. The same pattern repeats 2024 and onwards.
 - a. The SA funds are proposed to be calculated based on locomotive emissions factors (EF)¹ and yearly activity. Funds would scale in relation to emissions; locomotives with higher emissions pay more per megawatt-hour (MWh).
 - b. Every year, the SA rate would be adjusted from the previous year to account for changes in inflation and population.
3. Idling is currently restricted by the U.S. EPA to 30 minutes, with exemptions for essential functions. CARB would have the ability to enforce these idling limits.
4. The Useful Life Limit concept (ULL) bans locomotives older than 23 years from operating in CA. The ULL begins in 2030. That is, any locomotive can operate in CA regardless of its age in 2029, but in 2030, any locomotive newly manufactured in 2007 or earlier is banned from operating in CA. Each subsequent year, the ban applies to locomotives manufactured more than 23 calendar years prior.

¹ Emission Factors for Locomotives. US EPA. Apr 2009.

Assumptions and Proposed Cost Inputs

CARB staff are utilizing the following assumptions for SRIA development. Please provide comments and supporting data as desired.

1. Locomotive operators will use SA funds to purchase the cleanest available locomotives at any point where funds are sufficient for purchase; funds will not be held unnecessarily.
**Question: What percentage of annual funds deposited in the SA should CARB expect to be used in accordance with Section 2478.4(b)(1)(C, D, and E) of the draft regulatory language?*
2. To comply with the reporting requirements, applicable entities will not be required to install new hardware on the locomotive, but may need to establish or redesign reporting protocols and software.
3. Railroads have ability to alter scheduling algorithms to reduce costs associated with the SA and ULL.
**Question: Following the 1998 MOU, Class I railroads adjusted their operations and increased the proportion of cleaner locomotives (Tier 2) entering the South Coast Air Basin to meet their voluntary commitment to reduce their average emissions. If these regulatory concepts are implemented, how do you expect Class I operations to change on a per Tier basis?*
4. Class I railroads do not operate specific locomotive tiers consistently within a geographic region.
5. Class III/Industrial/Passenger railroads operate specific locomotive tiers consistently within a geographic region.
6. Leasing prices include maintenance costs.
7. Zero-emission (ZE) locomotives will be commercially available starting by no later than 2035. ZE locomotive costs within this document reflect estimates of commercial pricing.
8. Battery Electric (BE) locomotives use batteries as their primary power source propelling the locomotive.
9. Charging station capacity ranges from 400 kilowatt (kW) to 3 mega-watts (MW).
10. New catenary systems are only expected within freight railyards.
11. Hydrogen locomotives use fuel cells as their primary power source propelling the locomotive, and may be paired with either battery or gas turbine as an auxiliary power source to meet peak draw.
12. Hydrogen stations will provide fuel as either gaseous hydrogen at 350 bar or 700 bar gaseous hydrogen or liquid hydrogen, depending on duty cycle of associated locomotives.

Table 1: Scope and Timing of Analysis

Data Input	Value(s)
Years of Cost Analysis	2023-2050
Applicable Operators	<ul style="list-style-type: none"> • Class I • Class III • Industrial • Passenger • Leasing Companies (ULL only)
Assumption of Commercially Available Locomotive Technologies	<p>Locomotive for which the Primary Engine has engine emissions equal to or less than:</p> <ul style="list-style-type: none"> • Prior to 2030 <ul style="list-style-type: none"> ○ 1.3 grams per brake horsepower-hour (g/bhp-hr) oxides of nitrogen (NOx) and 0.03 g/bhp-hr particulate matter (PM) • 2030 to 2035 <ul style="list-style-type: none"> ○ 0.15 g/bhp-hr NOx, 0.006 g/bhp-hr PM, and GHG emissions 15 percent less than Tier 4 • 2035+ <ul style="list-style-type: none"> ○ 0.000 g/bhp-hr NOx, 0.000 g/bhp-hr PM and 0.000 g/bhp-hr GHG emissions
Currency	<p>All costs assumed to be in 2019 U.S. Dollars (2019\$). Staff used the California Consumer Price Index to convert costs to 2019\$ where cost inputs were derived from information provided to CARB in previous year dollars.</p> <p><i>Environment and Climate Change Canada (ECCC) Report</i> costs have been converted to USD</p> <ul style="list-style-type: none"> • CAD to USD conversion (June 1, 2020) = 0.7368 (<i>Bloomberg</i>)
Growth Rates (annual increase in MWh)	<p>Class I: 2.19 % Class III: 0 % Industrial: 0 % Passenger: 0 %</p> <p>See Draft 2020 Update to Emissions Inventory for Locomotives. 2020 Locomotive Emissions Inventory (ca.gov)</p>
Taxes	<p>All costs listed in this document include tax</p> <p>Effective Tax Rate: 28 % (8.85 % CA Corporate Tax-Franchise Tax Board, 21 %-Internal Revenue Service)</p>
Discount rate	0-7 %

Table 2: Pre-Tier 0 to Tier 4 Locomotive Cost Inputs

a. New Purchase Costs

Data Input	Value(s)	Units	Basis
Line Haul-New Tier 4 (4,000+ horsepower (hp))	2,700,000 to 3,300,000	\$/locomotive	Staff analysis of CARB incentive program data and data claimed confidential obtained from industry sources that requested non-attribution
MHP-New Tier 4 (2,301 and 3,999 hp)	2,800,000 to 3,225,000	\$/locomotive	Staff analysis of CARB incentive program data
Switcher-New Tier 4 (2,300 hp or less)	2,150,000 to 2,700,000	\$/locomotive	Staff analysis of CARB incentive program data
Passenger-New Tier 4	7,165,000 to 7,500,000	\$/locomotive	Staff analysis of CARB incentive program data, Caltrans email dated 12/15/2021
Line Haul-New Tier 2	2,000,000	\$/locomotive	CARB Tech Assessment
Line Haul-New Tier 3	2,500,000	\$/locomotive	CARB Tech Assessment

b. Repower, Remanufacture, and Maintenance Costs

Data Input	Value(s)	Units	Basis
Switcher-Repower to Tier 4 (from Pre-Tier 0, 1, 2, or 3 genset)	2,000,000 to 2,500,000	\$/locomotive	Claimed confidential data obtained from industry sources that requested non-attribution
Line Haul and Switcher-Overhaul/Remanufacture Tier 2/Tier 2+	200,000 to 450,000	\$/locomotive	Claimed confidential data obtained from industry sources that requested non-attribution
Line Haul and Switcher-Overhaul/Remanufacture Tier 0/0+ and Tier 1/1+	200,000	\$/locomotive	Based on conversations with manufacturers

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Data Input	Value(s)	Units	Basis
Line Haul and Switcher-Diesel Locomotive Annual/Running Maintenance	50,000 to 75,000	\$/year	Claimed confidential data obtained from industry sources that requested non-attribution
Line Haul and Switcher-End-of-Life Standard Remanufacture/Overhaul	10 to 15	% of original locomotive cost	<i>Total Cost of Ownership for Line Haul, Yard Switchers, and Regional Passenger Locomotives: Preliminary Results (energy.gov).</i> Claimed confidential data obtained from industry sources that requested non-attribution
Passenger-Retrofit Tier 2 to Tier 4	560,000 to 570,000	\$/conversion	Claimed confidential data obtained from industry sources that requested non-attribution
Passenger-Retrofit Tier 0 to Tier 2	970,000 to 1,000,000	\$/conversion	Claimed confidential data obtained from industry sources that requested non-attribution
Passenger-Annual/Running Maintenance	TBD	\$/year	Input Requested
Passenger-Overhaul/Remanufacture	TBD	\$/year	Input Requested

c. Purchase, Lease, and Sale Terms

Data Input	Value(s)	Units	Basis
Class I	16 to 38	% of fleet leased	Range from 2010-2019 in STB R-1, Schedule 710 for Union Pacific (UP) and BNSF railway. UP: AAR and STB Reports. Financial Information BNSF.
Class III/Industrial	5 to 10	% of fleet leased	Staff Assumption
Line Haul (Tier 4)-Lease	1 to 3	Years	Claimed confidential data obtained from industry sources that requested non-attribution
	700	\$/day	
	1	Month(s)	
	800	\$/day	
Line Haul (Tier 3)-Lease	2 to 3	Years	Claimed confidential data obtained from industry sources that requested non-attribution
	700	\$/day	
	1	Month(s)	
	800	\$/day	
Line Haul (Tier 2+)-Lease	2 to 3	Year(s)	Claimed confidential data obtained from industry sources that requested non-attribution
	700	\$/day	
	1	Month(s)	
	800	\$/day	
Passenger (Tier 4)-Lease	1 to 2	Year(s)	Staff analysis based on Metrolink 2016 Lease from BNSF Document
	800	\$/day	
	1	Month(s)	
	900	\$/day	
MHP (Tier 0/1+)-Lease	1 to 5	Year(s)	Claimed confidential data obtained from industry sources that requested non-attribution
	100	\$/day	
	1	Month(s)	
	300	\$/day	
Switcher (Tier 0/Tier 1+)-Lease	1 to 5	Year(s)	Claimed confidential data obtained from industry sources that requested non-attribution
	100 to 130	\$/day	
	1	Month(s)	
	170 to 300	\$/day	
Amortization of New Purchases	11.5	Year(s)	Standard useful life per Federal definition, Average of OMB's Circular A-4 (2003) recommended discount rates.
	5	% interest	

Data Input	Value(s)	Units	Basis
Depreciation-Freight (for tax purposes)	7	Years of Straight-line Depreciation	Modified Accelerated Cost Recovery System (MACRS) Pub 946, 2019
Depreciation-Passenger (for tax purposes)	25 to 30	Years of Straight-line Depreciation	Claimed confidential data obtained from industry sources that requested non-attribution
Sale of Used Freight Locomotive	Original purchase price*(1-Years in Use/25) Minimum value=20%	\$/locomotive	Claimed confidential data obtained from industry sources that requested non-attribution
Salvage Used Freight Locomotive	2 to 5	% of original sale price	U.S. Department of Transportation (2013) Taskload report outline (dot.gov)
Sale of Used Passenger Locomotive	Original purchase price*(1-Years in Use/30) Minimum value = 20%	\$/locomotive	Staff Assumption

Table 3: Advanced Technology Cost Inputs

a. Advanced Equipment Cost and Maintenance

Data Input	Value	Units	Basis
Tier 5 Line Haul	4,000,000	\$/Locomotive	CARB Petition to U.S. EPA
Hydrogen (H2) Line Haul	4,250,000	\$/Locomotive	CARB Tech Assessment
H2 Switcher	2,750,000 to 3,800,000	\$/Locomotive	CARB Tech Assessment, ECCC Report
H2 Passenger Multiple Unit	10,000,000 to 12,000,000	\$/Locomotive	SBCTA Report

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Data Input	Value	Units	Basis
H2 Passenger Locomotive	12,000,000 to 16,000,000	\$/Locomotive	Claimed confidential data obtained from industry sources that requested non-attribution
Retrofit Tier 2 to H2 Passenger	6,000,000 to 8,000,000	\$/Conversion	Claimed confidential data obtained from industry sources that requested non-attribution
H2 Locomotive Annual/Running Maintenance	25	% of Diesel Annual Maintenance Costs	Claimed confidential data obtained from industry sources that requested non-attribution
H2 Overhaul	15 to 20	% of original cost	Claimed confidential data obtained from industry sources that requested non-attribution
BE Line Haul Locomotive	4,500,000 to 8,000,000	\$/locomotive	Claimed confidential data obtained from industry sources that requested non-attribution
BE Switcher Locomotive (1500HP-3000HP equivalent)	3,000,000 to 5,000,000	\$/locomotive	Claimed confidential data obtained from industry sources that requested non-attribution
BE Passenger Multiple Unit (660 kWh)	10,000,000 to 12,000,000	\$/locomotive	SBCTA Report
BE Passenger Locomotive	TBD	\$/locomotive	Input Requested
BE Passenger Tender (meets 70% of duty cycle)	4,000,000 to 5,000,000	\$/tender	Claimed confidential data obtained from industry sources that requested non-attribution
BE Railcar Mover	750,000 to 1,250,000	\$/mover	Staff assumption

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Data Input	Value	Units	Basis
BE Annual Locomotive Maintenance	10	% of Diesel Annual Maintenance baseline	Claimed confidential data obtained from industry sources that requested non-attribution
BE Overhaul	20 to 40	% of original cost	Claimed confidential data obtained from industry sources that requested non-attribution
Catenary Freight	50,000,000	\$/mile	CARB Tech Assessment
Catenary Passenger	25,800,000 to 30,000,000	\$/mile	Caltrain, CARB Tech Assessment

b. Infrastructure and Fuels

Data Input	Value	Units	Basis
H2 Infrastructure with daily Fuel Delivery (75.4 kg/day)	221,000	\$/station	ECCC Report
H2 Electrolysis Generation and Fueling Infrastructure- (831kg/day)	3,700,000 to 5,500,000	\$/station	2019 Annual Evaluation of Fuel Cell Electric Vehicle Deployment & Hydrogen Fuel Station Network Development CARB, ECCC Report
BE Locomotive Charging Equipment	100,000 to 250,000	\$/MW capacity	Claimed confidential data obtained from industry sources that requested non-attribution
BE Locomotive Charging Infrastructure Installation	1,000,000	\$/unit	Staff assumption
Fueling/Charging Infrastructure Finance	20	Year(s)	ECCC Report
	5	Percent	

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Data Input	Value	Units	Basis
H2 Fuel-National (by Steam Methane Reformation)	3.98 (2019) to 4.11 (2050)	\$/kg	Modified Industrial Natural Gas Forecast Energy Information Administration (US EIA) per method on page 68: <i>Prototype Design and Evaluation of Hybrid Solid Oxide Fuel Cell Gas Turbine Systems for use in Locomotives (dot.gov)</i>
H2 Fuel-California	2.75 to 7.56	\$/kg	California Energy Commission (CEC) <i>2019 Integrated Energy Policy Report (ca.gov), Hydrogen Station Network Self-Sufficiency Analysis per Assembly Bill 8 (ca.gov)</i>
Electricity Costs-National	0.06 to 0.07	\$/kWh	<i>U.S. Energy Information Administration-EIA- Independent Statistics and Analysis \$/MMBtu converted to \$/kWh between 2019 and 2050</i>
Electricity Costs-California	0.14 (2019) 0.16 (2050)	\$/kWh	CEC energy price data scaled to 2050 using annual % change from EIA industrial electricity rate

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Data Input	Value	Units	Basis
Diesel Price Class I (National)	2.13 (2019) 2.72 (2050)	\$/gallon	Ex 991 (sec.gov) , staff scaled costs from this document using the annual % change from 2020 EIA Annual Energy Outlook Table 12. Transportation Diesel U.S. Energy Information Administration-EIA-Independent Statistics and Analysis
Diesel Price Class III (California)	2.15 to 3.38	\$/gallon	CEC price data with prices post-2031 scaled using annual percent change from 2020 EIA Annual Energy Outlook Table 12. Transportation Diesel U.S. Energy Information Administration-EIA-Independent Statistics and Analysis
Renewable Diesel (RD) Price	2.63 to 4.18	\$/gallon	Approximate calculation based on Clean Cities Alternative Fuel Price Report, October 2020 (energy.gov) . RD is approximately 50 cents more than national diesel prices and 25 cents less than California diesel Prices.
Low Carbon Fuel Standard (LCFS) Credit-RD	1.00 to 1.49 (2019) 0.84 to 1.23 (2030)	\$/gallon	LCFS Program Staff analysis based on LCFS Credit Prices between 150-218 \$/Metric Ton (MT), 2021 values adjusted to 2019\$.

Table 4: Administrative Costs

Data Input	Value	Units	Basis
Person Year Cost	150,715	\$/Person Year (average)	Staff analysis
Reporting Cost-Class I	1 to 2	Person Years	Staff analysis
Reporting Cost-Class III	0.2 to 0.3	Person Years	Staff analysis
Reporting Cost-Industrial	0.1 to 0.2	Person Years	Staff analysis
Reporting Cost-Passenger	0.2 to 0.3	Person Years	Staff analysis
CARB Registration Fee	175 to 225	\$/locomotive	Staff analysis