DRAFT WAIRE Menu Technical Report

OVERVIEW

This technical report describes the methodology used to determine how WAIRE Points are attributed to each of the actions on the WAIRE Menu provided in PR 2305. Section 1 of this report presents an overview of how the Points are determined within the Menu, while all subsequent sections presents detailed methodologies for each Menu item.

SECTION 1) WAIRE Points Calculation Methodology

This section describes the general methodology used to determine how WAIRE Points are attributed to each of the actions on the WAIRE Menu. While this methodology is used to determine the value of each WAIRE menu action during the rulemaking process, warehouse operators and/or owners will not need to use this calculation methodology document to determine how to comply with the rule. For compliance, warehouse operators (and in some cases owners if they choose to comply on behalf of their operator) will only need to consult the WAIRE Menu itself to determine how many actions, or how much of each action to complete for compliance.[1]

WAIRE points may be earned in two ways, through the purchase of near-zero and zero emission equipment or equipment that facilitates its use, and through the usage of near-zero and zero emission equipment. WAIRE Points are assigned based on three key parameters, cost, regional emissions reductions, and local emissions reduction. The cost parameter is based on the incrementally higher cost a warehouse operator faces when choosing to purchase NZE/ZE equipment (compared to conventional diesel technology). The regional emissions reduction parameter is based on the reduction in nitrogen oxides (NOx) emissions from using ZE/NZE equipment. The local emissions reduction parameter is based on the reduction in Diesel Particulate Matter (DPM)[2] from using ZE/NZE equipment.

In practice, the actual costs and emission reductions of each implemented action will likely vary for each warehouse operator. Calculating these unique values on a case-by-case basis would impose a considerable administrative burden to both the regulated community and to South Coast AQMD. In order to simplify compliance and administration of PR 2305, WAIRE Points for each Menu action are determined using representative default values described in the calculation methodology summaries that follow.

[1] A draft WAIRE Program User Calculator is available to assist in evaluating compliance scenarios here: www.aqmd.gov/fbmsm

[2] DPM is both a component of the criteria pollutants PM10 and PM2.5, and a toxic air contaminant. Emissions of DPM from warehouse indirect sources can contribute to high-level, localized pollutant concentrations that can significantly affect air quality and public health for populations near warehouses.

Section 1a) WAIRE MENU ANNUALIZED UNITARY METRICS AND BINS

WAIRE Points values in the WAIRE Menu are determined for each action based on a single Annualized Unitary Metric (AUM). The AUM is the default level of implementation used for calculating each WAIRE Menu action's Points. For example, the AUM for the truck acquisition WAIRE Menu action is one truck acquired during the compliance year. The cost and regional and local emissions reductions are calculated for acquiring one truck and used to determine the default WAIRE Point value for that Menu action. Warehouse operators use these default Point values in the WAIRE Menu to determine how many Points they earned in total depending on their level of implementation. For example, the default Point value in the Menu for acquiring one ZE class 8 truck is 126 Points. If a warehouse operator acquired five ZE trucks, they would earn a total of 630 Points (126 Points for each truck acquisition). Similarly, for ZE class 8 truck visits, the AUM of 365 visits per year (one per day on average) yields 27 Points in the WAIRE Menu. If a warehouse operator only has 100 ZE class 8 truck visits during a compliance year, they would earn a total of 7.4 Points[3] $[(100 \div 365) \times 27 = 7.4]$. The AUM's for each WAIRE Menu action are described in the individual calculation methodology summaries that follow.

WAIRE Points are also calculated using a point binning system to simplify the merging of the cost, regional emission reduction, and local emissions reduction parameters. For the AUM, Points are earned for each $25,000 incremental cost, 25-pound NOx regional emission reduction, and 0.25-pound DPM local emission reduction. Once these three parameters are calculated, their binned points are summed to yield the total default WAIRE points earned for that action.

Section 1b) COSTS:

The costs for each WAIRE Menu action are based on the annualized incremental costs difference between the new ZE/NZE technology and the costs of the conventional diesel equivalent. Due to existing statutory or regulatory prohibitions, most state incentive funding programs used to offset the higher purchase price of ZE/NZE vehicles and equipment cannot be used to aid in complying with state or federal law or South Coast AQMD rules or regulations[4], and incentive funds are not considered in these costs. However, WAIRE points may be earned from the usage of incentivized vehicles/equipment. For example, if a warehouse operator owns a fleet of trucks, and they want to purchase a ZE or NZE truck, they will need to decide among two options. First, they could purchase the truck at full price and receive WAIRE Points for that action. Second, they could instead choose to receive incentive funding for that purchase but not earn any WAIRE Points for the truck purchase. In both instances, they would be allowed to receive WAIRE Points for the visits that this truck makes to their warehouse.

[3] WAIRE Points are calculated to no more than one decimal place.

[4] California Health and Safety Codes 44281(b), 44391.4(a), 44271(c), CCR Title 13, Ch. 8.2 Sec. 2353 (c)(4), Moyer Guidelines Ch. 2, CA Beneficiary Mitigation Plan

Section 1c) REGIONAL EMISSION REDUCTIONS:

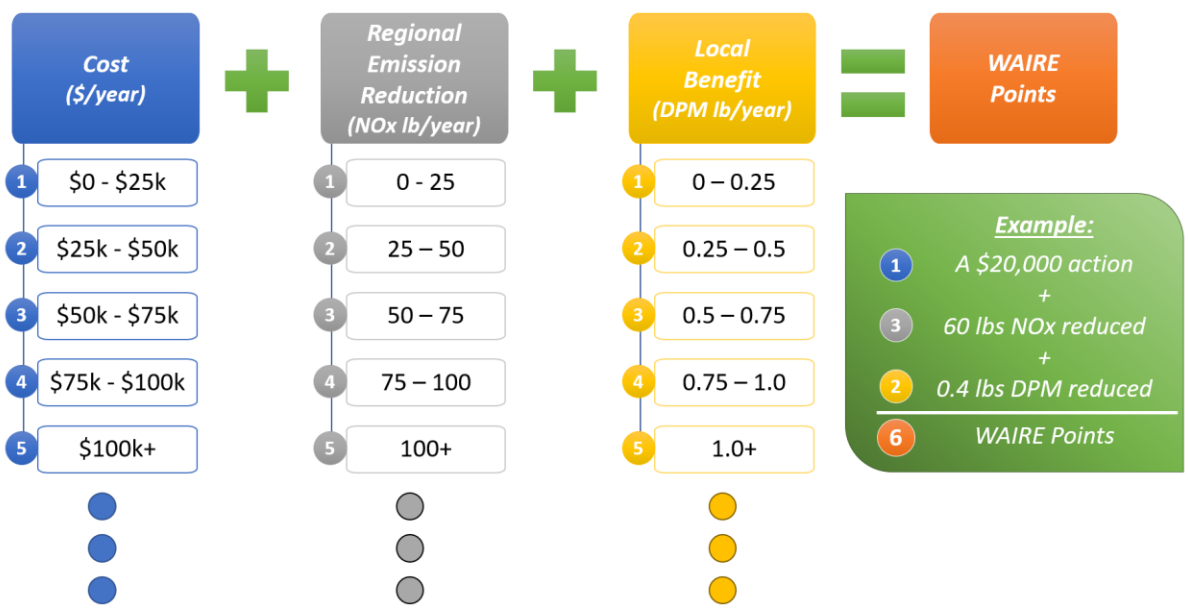
Regional emission reductions are calculated in two ways. First, NOx reductions are calculated from using ZE/NZE vehicles and equipment for activities associated with the warehouse. Second, regional NOx emission reduction Points are calculated for WAIRE Menu items affiliated with the acquisition of ZE/NZE vehicles/equipment at a rate of $100,000 per ton of NOx. This is the cost effectiveness threshold that South Coast AQMD utilizes in its Carl Moyer incentive funding program. These regional emission reduction Points are assigned to these acquisition Menu items because if a facility chose to pay that level of funding as a mitigation fee, South Coast AQMD would likely spend the funds using the same cost effectiveness threshold.

Section 1d) LOCAL EMISSION REDUCTIONS:

Local emission reductions are calculated in a similar manner as regional emission reductions, except that Diesel Particulate Matter (DPM) is used instead of NOx.

Section 1e) EXAMPLE:

The figure below presents one example of how the calculation methods discussed above would yield the total WAIRE Points earned. In this example, an AUM would cost $20,000 and result in a 60 lbs/year NOx reduction, and a 0.4 lbs/year DPM reduction. Combining the three together would result in a total of 6 WAIRE Points. Specific calculations for each WAIRE Menu action are included in the following sections.



SECTION 2) Zero and Near-Zero Emission Truck Visits and Truck Acquisitions

Description: Two key factors affect the analysis of Zero Emission (ZE) and Near Zero Emission (NZE) trucks – the definitions of ZE and NZE, and the truck class. In the context of PR 2305, the definition of a Zero Emission (ZE) truck is the same as CARB's Advanced Clean Trucks Regulation definition. At the time of this writing, CARB's draft definition for ZE truck is one *"with a drivetrain that produces zero exhaust emission of any criteria pollutant (or precursor pollutant) or greenhouse gas under any possible operational modes or conditions."* For PR 2305 a Near Zero Emission (NZE) truck is one in which the engine meets CARB's lowest Optional Low NOx standard of 0.02 g/hp-hr NOx.

In addition to drivetrain technology, trucks are commonly classified based on their Gross Vehicle Weight Rating (GVWR). Throughout this document Class 4-7 refers to heavy duty trucks with GVWR of 14,001 – 33,000 lbs and Class 8 trucks with GVWR of greater than 33,000 lbs. Table 1 below presents truck classifications.

Table 1. Truck Classes

Truck Class	GVWR (lbs)
Class 4	14,001 – 16,000
Class 5	16,001 – 19,500
Class 6	19,501 – 26,000
Class 7	26,001 – 33,000
Class 8	33,001 & over

Commercial Availability: The ZE truck market is beginning to grow rapidly with many models entering the commercial market today and many major manufacturers announcing plans for future commercialization of battery-electric and hydrogen fuel cell electric trucks. Some notable manufacturer announcements include: Daimler Class 8 eCascadia, Navistar battery-electric Class 8, Volvo battery-electric VNR Class 8, Tesla's long range battery-electric tractor, BYD's battery-electric Class 6 and 8, Nikola's and Kenworth (in conjunction with Toyota) hydrogen fuel cell tractors, Sea Electric Class 4-8 battery-electric trucks, Lion Electric's Lion8 Class 8 battery-electric truck, Amazon's order of 100,000 Rivian's battery electric trucks, etc. NZE engines are currently available in two sizes – 11.9 liter and 8.9 liter. Major truck manufacturers offer these engines in different truck classes, including for class 8 regional haul and/or drayage truck operations.

Operation: Trucks that visit warehouses may be owned by the warehouse operator, or by a motor carrier not affiliated with that warehouse. Arrangements for the truck visit to the site to deliver or pick up goods is typically made by the owner of the goods, or someone acting on their behalf. As such, each individual truck visiting a warehouse can have a unique operating profile that may not be shared by any other truck visiting that site. One truck may travel 30 miles on the inbound trip, and only two miles on the outbound trip. Another truck may be loaded with goods from multiple warehouses or stores, and determining what portion of a trip to attribute to each warehouse would be impractical. Finally, trucks may idle their engines for short periods while at the warehouse before or after the trailer is dropped off/picked up. For the emissions and cost analyses presented below, input parameters are meant to be broadly applicable and may not reflect any one individual truck trip or truck acquisition.

SECTION 2a) ZE/NZE Truck Acquisitions[5]

ZE/NZE Truck Purchase Prices: Several key references were consulted to estimate incremental purchase prices for NZE and ZE trucks relative to conventional diesel trucks including: CARB's Advanced Clean Truck Regulation Standardized Regulatory Impact Assessment (SRIA)[6] and Total Cost of Ownership Discussion Documents[7], California Energy Commission's Revised Transportation Demand Forecast[8], the Ports' Feasibility Study[9], ICF's Intensive Literature Review for Medium and Heavy-Duty Electrification in California[10], NACFE's TCO Calculator[11], as well as data from South Coast AQMD's Carl Moyer Grant Program and CARB's HVIP program. While cost estimates vary somewhat among these references, the single point estimates shown in Table 2 below are consistent with these previous analyses.

Table 2. Incremental Costs for NZE and ZE Truck Purchases

WAIRE Menu Item		Annualized Unitary Metric	Incremental Cost ($/metric)
Class 8 Truck	NZE	1 truck purchased	$65,000
Class 4-7 Truck			$30,000
Class 8 Truck	ZE		$150,000
Class 4-7 Truck			$80,000

WAIRE Points for ZE/NZE Truck Acquisitions: Acquisition of NZE Class 8 and Class 4-7 trucks earns 3 and 2 WAIRE points, respectively. Similarly, the acquisition of ZE Class 8 and Class 4-7 trucks earns 6 and 4 WAIRE points, respectively. In addition, using a cost-effectiveness of $100,000 per ton of NOx, WAIRE Points for regional emission reductions for Class 8 and 4-7 NZE truck acquisitions are 52 and 24 WAIRE points, respectively. For ZE truck acquisitions, Class 8 and 4-7 earns 120 and 64 WAIRE points, respectively.

[5] WAIRE Points can be earned from either truck purchases or truck leases. Points are calculated assuming trucks are purchased.
[6] https://ww3.arb.ca.gov/regact/2019/act2019/appc.pdf
[7] https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf
[8] https://efiling.energy.ca.gov/GetDocument.aspx?tn=230885&DocumentContentId=62525
[9] https://cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/
[10] https://caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf
[11] https://nacfe.org/future-technology/medium-duty-electric-trucks-cost-of-ownership/

SECTION 2b) Truck Visits

Regional and Local Emission Reductions from ZE/NZE Truck Visits: Key parameters that can affect the emissions estimate from any one individual trip include: trip length, truck class, vehicle powertrain, and vehicle speed. Collecting all the necessary information to calculate precise emissions estimates for each trip is not feasible as it would require 1) instrumenting all trucks with telematics systems that report uniform data, 2) requiring detailed information reporting about truck loads (e.g., how much of the goods in each truck trailer is being transported to each location), and 3) conducting substantial data analysis to determine the emissions associated with each truck trip. Because of these challenges, various models are used to estimate emissions from trucking activity. In particular, CARB's EMFAC model and SCAG's Heavy-Duty Truck Regional Travel Demand model provide emissions estimates in the South Coast AQMD.

EMFAC2017 provides activity and emission rates for on-road vehicles that operate within California. EMFAC categories[12] and their relationship to truck class are shown in Table 3 below. EMFAC categorizes all truck types that are on the road, however the analysis presented here is limited to those categories that are most likely to deliver goods to and from warehouses.

Table 3. EMFAC Truck Categories

EMFAC Category	Description	Truck Class
T6 CAIRP Small	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR<=26,000 lbs	Class 4-6
T6 Instate Small	Medium-Heavy Duty Diesel Instate Truck with GVWR<=26,000 lbs	
T6 OOS Small	Medium-Heavy Duty Diesel Out-of-State Truck with GVWR<=26,000 lbs	
T6 CAIRP Heavy	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR>26,000 lbs	Class 7
T6 Instate Heavy	Medium-Heavy Duty Diesel Instate Truck with GVWR>26,000 lbs	
T6 OOS Heavy	Medium-Heavy Duty Diesel Out-of-State Truck with GVWR>26,000 lbs	
T7 CAIRP	Heavy-Heavy Duty Diesel CA International Registration Plan Truck with GVWR>33,000 lbs	Class 8
T7 NNOOS	Heavy-Heavy Duty Diesel Non-Neighboring Out-of-State Truck with GVWR>33,000 lbs	
T7 NOOS	Heavy-Heavy Duty Diesel Neighboring Out-of-State Truck with GVWR>33,000 lbs	
T7 POLA	Heavy-Heavy Duty Diesel Drayage Truck in South Coast with GVWR>33,000 lbs	
T7 Tractor	Heavy-Heavy Duty Diesel Tractor Truck with GVWR>33,000 lbs	

[12] https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf (Table 6.1-1)

Baseline weighted averages of NOx and PM10 emission rates[13] for calendar year 2023 for running exhaust (RUNEX), exhaust from engine startups (STREX), and idling exhaust (IDLEX) of the above-mentioned truck categories are presented below.

Table 4. Weighted average emission rates (g/mi for RUNEX, g/trip for STREX, g/vehicle/day for IDLEX)

Truck Class	**NOx**			**DPM**			**Mile/trip[14]**	**Trip/ day/ truck[15]**
	RUNEX	IDLEX	STREX	RUNEX	IDLEX	STREX		
Class 4-7	1.079	2.855	2.117	0.007	0.001	0	14.2	5.9
Class 8	2.372	76.203	2.028	0.020	0.027	0	39.9	5.2

The regional and local emission reductions achieved by switching to ZE trucks relative to baseline emissions are calculated using Equation 1 below. While regional emission reductions from switching to NZE trucks is assumed to equal 90% of the reduction compared to ZE trucks, local emission reductions are assumed to be the same between ZE and NZE as NZE trucks are fueled by natural gas and do not emit DPM.

Equation [1]:

$$Emission\ Reduction\ (\frac{lb}{trip}) = \left[\left(RUNEX\ \left(\frac{g}{mi}\right) \times \frac{mi}{trip}\right) + \left(STREX\ \left(\frac{g}{trip}\right)\right) + \left(\frac{IDLEX\ \left(\frac{g}{day.truck}\right)}{\frac{trip}{day.truck}}\right)\right] \times \frac{1\ lb}{453.592\ g}$$

Results of the calculation for the two truck class categories are presented in Table 5 below.

Table 5. NOx and DPM emission reductions for a single truck trip

Truck Class	**ZE Truck**		**NZE Truck**	
	NOx lb/trip	DPM lb/trip	NOx lb/trip	DPM lb/trip
Class 4-7	0.040	0.0002	0.036	0.0002
Class 8	0.247	0.002	0.222	0.002

Table 6 below illustrates the method used in determining point values based on regional and local emissions reductions using results in Table 5.

[13] VMT-weighted, population-weighted and number of starts-weighted averages were computed to equalize the frequency of the values for RUNEX, IDLEX and STREX emission rates, respectively, in the data set by multiplication of each truck category emission rates to its corresponding VMT, population or number of starts and then dividing by the sum of total VMT, population or number of starts.
[14] SCAG 2016 RTP mileage rates for medium-heavy (Class 4-7) and heavy-heavy trucks (Class 8)
[15] Truck populations from EMFAC and trips/day from SCAG 2016 RTP. A trip is a one-way trip, while a 'visit' to a warehouse includes the incoming trip and the outgoing trip.

Table 6. NOx and DPM emission reductions for the Annualized Unitary Metric

WAIRE Menu Item		Annualized Unitary Metric (AUM)	Annualized Regional Emission Reductions (lb NOx/AUM)	Annualized Local Emission Reductions (lb DPM/AUM)
Class 8 Truck	NZE	365 truck visits	0.9 × 180.3 = 162.3	1.3
Class 4-7 Truck			0.9 × 29.2 = 26.3	0.1
Class 8 Truck	ZE		0.247 × 2 × 365 = 180.3	0.002 × 2 × 365 = 1.3
Class 4-7 Truck			0.040 × 2 × 365 = 29.2	0.0002 × 2 × 365 = 0.1

WAIRE Points from ZE/NZE Truck Visit Emission Reductions: For the annualized regional NOx emission reductions, 365 truck visits from Class 8 ZE and NZE trucks will earn 8 and 7 WAIRE Points. Similarly, Class 4-7 ZE and NZE will earn 2 WAIRE Points. The associated local DPM emission reductions will earn 6 Point for both ZE and NZE Class 8 truck visits and 1 Point for both ZE and NZE Class 4-7 truck visits.

Costs from ZE/NZE Truck Visits: The incremental cost of a truck visit used in the WAIRE Menu is based on the total cost of ownership of a ZE or NZE truck compared to an equivalent conventional diesel truck, taking into account the estimated total number of trips that truck will take in its useful life. The total cost of ownership (TCO), assuming a 12-year life, for Class 6 and 8 conventional diesel, battery electric, and hydrogen fuel cell trucks were obtained from CARB's Advanced Clean Truck Total Cost of Ownership Discussion Documents. The key components of the TCO include:

(1) Capital cost: vehicle capital cost, taxes associated with the vehicle purchase, financing costs for the vehicle
(2) Fuel cost[16]: The cost of the fuel
(3) Other cost: maintenance costs, midlife costs[17], vehicle registration, and residual values at the end of the truck's operating life

Tables 7, 8, and 9 below present the base TCO data used in this analysis for Class 4, 6, and 8 diesel, battery-electric, and hydrogen fuel cell trucks. The total cost of ownership for Class 6 CNG shown in Table 8 was estimated using a similar approach as Table 9, with modifications made to the incremental purchase cost, fuel cost[18] and fuel economy[19,20]. Maintenance cost of natural gas vehicles were assumed to be about one to two cents per mile greater than for diesel vehicles due

[16] Low Carbon Fuel Standard credits were not included in the analysis presented here.
[17] Midlife costs are the cost of rebuilding or replacing major propulsion components due to wear or deterioration. For diesel vehicles, this would be a midlife engine rebuild, for battery-electric vehicles this would be a battery replacement, and for a hydrogen fuel-cell vehicle this would be a fuel cell stack refurbishment.
[18] https://nacfe.org/future-technology/medium-duty-electric-trucks-cost-of-ownership/
[19] https://afdc.energy.gov/files/u/publication/ng_regional_transport_trucks.pdf (Figure 5)
[20] https://www.energy.gov/sites/prod/files/2014/03/f8/deer12_kargul.pdf

to more frequent oil changes and inspections, and higher replacement costs for spark plugs and injectors[21]. A summary of the analyses in Tables 7, 8, and 9 is shown in Table 10.

Table 7. Base TCO data for Class 4 trucks

<table>
<tr><th></th><th>Diesel[22]</th><th>Battery Electric[22]</th><th>Hydrogen Fuel Cell</th><th>Natural Gas NZE</th></tr>
<tr><td>Annual Miles</td><td>15,000</td><td>15,000</td><td rowspan="13">Class 4 H2 trucks are not expected in the near future</td><td rowspan="13">TCO information was not found in the literature</td></tr>
<tr><td>Operating Years</td><td>12</td><td>12</td></tr>
<tr><td>Energy Storage</td><td>-</td><td>120 kWh</td></tr>
<tr><td>Total Capital Cost</td><td>50,000</td><td>100,000</td></tr>
<tr><td>Average Fuel Cost</td><td>$3.74/gal</td><td>$0.17/kWh</td></tr>
<tr><td>Average Fuel Economy</td><td>10 mpg</td><td></td></tr>
<tr><td>Total Fuel Cost</td><td></td><td></td></tr>
<tr><td>Lifetime Maintenance Cost</td><td></td><td></td></tr>
<tr><td>Midlife Cost</td><td></td><td></td></tr>
<tr><td>Registration Fees</td><td></td><td></td></tr>
<tr><td>Residual Values</td><td>$500</td><td>$5,000</td></tr>
<tr><td>Total Other Cost</td><td></td><td></td></tr>
<tr><td>Total</td><td>$124,229</td><td>$177,345</td></tr>
</table>

Table 8. Base TCO data for Class 6 trucks

<table>
<tr><th></th><th>Diesel[23]</th><th>Battery Electric[23]</th><th>Hydrogen Fuel Cell[23]</th><th>Natural Gas NZE</th></tr>
<tr><td>Annual Miles</td><td>24,000</td><td>24,000</td><td>24,000</td><td>24,000</td></tr>
<tr><td>Operating Years</td><td>12</td><td>12</td><td>12</td><td>12</td></tr>
<tr><td>Energy Storage</td><td>-</td><td>104 kWh</td><td>50 kWh/20 kg</td><td>-</td></tr>
<tr><td>Total Capital Cost</td><td>$88,705</td><td>$172,225</td><td>$330,967</td><td>$118,705</td></tr>
<tr><td>Interest Rate</td><td colspan="3">5%</td><td></td></tr>
<tr><td>Financed Period</td><td colspan="3">5 years</td><td></td></tr>
<tr><td>Average Fuel Cost</td><td>$3.74/gal</td><td>$0.17/kWh</td><td>$8.00/kg</td><td>$2.42/GGE</td></tr>
<tr><td>Average Fuel Economy</td><td>7.4 mpg</td><td>1.04 mi/kWh</td><td>14.1 mi/kg</td><td>6.3 mpg</td></tr>
<tr><td>Total Fuel Cost</td><td>$104,349</td><td>$33,472</td><td>$171,398</td><td>$110,629</td></tr>
<tr><td>Lifetime Maintenance Cost</td><td>$49,138</td><td>$36,853</td><td>$49,138</td><td>$54,898</td></tr>
<tr><td>Midlife Cost</td><td>$0</td><td>$0</td><td>$32,237</td><td>$0</td></tr>
<tr><td>Registration Fees</td><td>$11,592</td><td>$10,860</td><td>$15,482</td><td>$11,000</td></tr>
<tr><td>Residual Values</td><td>($10,477)</td><td>($5,239)</td><td>($2,619)</td><td>($10,477)</td></tr>
<tr><td>Total Other Cost</td><td>$50,252</td><td>$42,474</td><td>$94,237</td><td>$55,421</td></tr>
<tr><td>Total</td><td>$243,306</td><td>$248,171</td><td>$596,603</td><td>$340,176</td></tr>
</table>

[21] https://ww3.arb.ca.gov/msprog/tech/techreport/ng_tech_report.pdf
[22] https://nacfe.org/future-technology/medium-duty-electric-trucks-cost-of-ownership/
[23] https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf

Table 9. Base TCO data for Class 8 trucks

	Diesel[23]	Battery Electric[23]	Hydrogen Fuel Cell[23]	Natural Gas NZE[24]
Annual Miles	54,000	54,000	54,000	68,383
Operating Years	12	12	12	12
Energy Storage	-	510 kWh	10 kWh/10 kg	-
Total Capital Cost	**$167,500**	**$593,662**	**$786,486**	**$192,710**
Interest Rate	5%			12.5%
Financed Period	5 years			
Average Fuel Cost	$3.74/gal	$0.15/kWh	$8.00/kg	$2.92/DGE
Average Fuel Economy	5.9 mpg	0.48	11.2 mi/kg	5.1 mi/DGE
Total Fuel Cost	**$296.381**	**$152,074**	**$486.820**	**$469,831**
Lifetime Maintenance Cost	$95,484	$71,613	$95,484	
Midlife Cost	$0	$42,949	$94,023	
Registration Fees	$27,545	$21,472	$26,548	
Residual Values	($15,453)	($7,727)	($3,863)	
Total Other Cost	**$107,576**	**$128,308**	**$212,192**	
Total	***$571,456***	***$874,044***	***$1,485,498***	***$624,925***

Table 10. Summary of TCO Analyses from Literature Review

Truck Class	Ownership period	Annual Mileage	Diesel	Low-NOx CNG	Battery-Electric	Hydrogen Fuel Cell
Class 4	12	15,000	$124,229[1]		$177,345[1]	
Class 6	12	24,000	$243,306[2]	$340,176	$248,171[2]	$596,603[2]
Class 8 (Ports Study)	12	68,383	$598,122[3]	$624,925[3]	$1,063,000[3]	
Class 8 (CARB TCO)	12	54,000	$571,456[2]		$874,044[2]	$1,485,498[2]

1. https://nacfe.org/future-technology/medium-duty-electric-trucks-cost-of-ownership/
2. https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf
3. https://cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/

Using the reported annual mileages shown in Table 10, costs were calculated on a dollar per mile basis, as shown in Equation 2.

Equation [2]:

$$TCO\left(\frac{\$}{mi}\right) = \frac{TCO\ (\$)}{12\ (yr) * Anual\ Mileage\ \left(\frac{mi}{yr}\right)}$$

[24] https://cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/

Table 11. Total Cost of Ownership calculated as $/mi

Truck Class	Diesel	Low-NOx CNG	Battery-Electric	Hydrogen Fuel Cell
Class 4	0.69		0.99	
Class 6	0.84	1.18	0.86	2.07
Class 8 (Ports Study)	0.73	0.76	1.30	
Class 8 (CARB TCO)	0.88		1.35	2.29

SCAG's Heavy-Duty Truck Regional Travel Demand model provides an estimate of heavy-duty truck activities within South Coast Air Basin. TCO values on a dollar per trip basis are estimated using SCAG's VMT and trip rates in Table 12.

Table 12. Truck activity data from SCAG's Heavy-Duty Truck Regional Travel Demand Model

Truck Class	VMT (mi/day)	Trips (trip/day)	Mile/trip
Class 4-7	7,744,000	544,000	14.2
Class 8	12,060,000	302,000	39.9

Equation 3 below illustrates the method used to determine TCOs on a dollar per trip basis using the TCOs ($/mi) in Table 11 and SCAG's mileage rates in Table 12, with results shown in Table 13.

Equation [3]:

$$TCO\left(\frac{\$}{trip}\right) = TCO\left(\frac{\$}{mi}\right) \times \frac{mi}{trip}$$

Table 13. Total Cost of Ownership ($/trip)

Truck Class	Diesel	Low-NOx CNG	Battery-Electric	Hydrogen Fuel Cell
Class 4	9.80		13.99	
Class 6	12.00	16.77	12.24	29.42
Class 8 (Ports Study)	29.08	30.39	51.69	
Class 8 (CARB TCO)	35.19		53.82	91.47

Although the TCO analyses above assume a 12-year useful life for a truck, motor carriers may require shorter periods over which they absorb the incrementally higher costs of ZE or NZE trucks compared to diesel. The analysis here therefore assumes that this incremental cost is absorbed over a 3-year period, instead of the full 12-year useful life. The incremental cost is therefore multiplied by four (12 ÷ 3 = 4) to determine the default cost for truck visits.

Table 15. Annualized Incremental Costs

Truck Class		Annualized Unitary Metric	Annualized Incremental Cost ($/metric)
Class 8	NZE	365 truck visits**	($30.39 - $29.08) × 4 × 2 × 365 = $3,825
Class 4-7*			($16.77 - $12.00) × 4 × 2 × 365 = $13,928
Class 8	ZE		($53.82 - $35.19) × 4 × 2 × 365 = $54,400
Class 4-7*			($12.24 - $12.00) × 4 × 2 × 365 = $701

*In this analysis, Class 6 TCOs were used for the Class 4-7 category in the WAIRE Menu

** One visit equals two one-way trips

WAIRE Points for ZE/NZE Truck Visit Costs: Based on the costs presented in Table 15, the number of WAIRE Points earned for ZE Class 8 and Class 4-7 truck visits are 3 and 1, respectively. One WAIRE Point is earned for both NZE Class 8 and Class 4-7 truck visits.

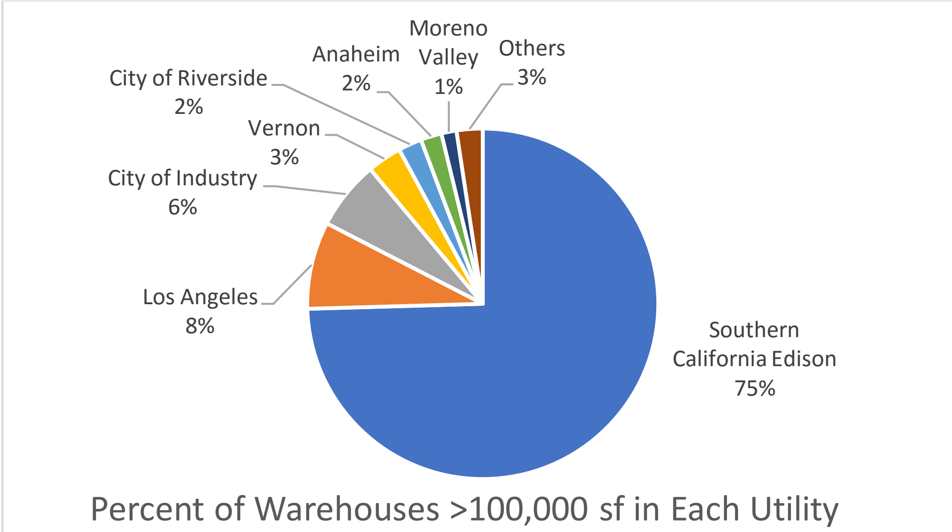
Total WAIRE Points for ZE/NZE Truck Visits: The total WAIRE Points for truck visits includes Points from the cost, regional emission reductions, and local emission reductions. In addition, because most of the emissions associated with warehouses comes from trucks visits, a multiplier of three is applied to the summed Points to encourage operators to choose this option, and to promote a more rapid return on investment for the purchase of ZE/NZE trucks. For example, for 365 class 8 ZE truck visits, a warehouse would earn: 8 Points for regional, 6 Points for Local, and 3 Points for cost, with a sub-total of 17 Points. The final total for this Menu item would by 51 Points (17 × 3).

SECTION 3) **Electric Charger Usage and Installation**

Description: ZE battery electric trucks require specialized charging infrastructure. Installing this infrastructure can require facility electrical upgrades, dedication of space for electrical equipment and vehicle parking, permitting with local authorities, and plans to optimize charger usage. The charging stations themselves range in size and are typically rated based on the amount of kW that can be dispensed. Higher powered charging stations (>=350 kW) are just now entering the market, and may require significant construction. On the usage side, the cost of the electricity can vary depending on the time of day when trucks are charged, the kW charging level, and the level of demand charges. Utilities are introducing new rate structures for the use of these stations to address this new market need. Trucks that would use charging infrastructure at a warehouse are likely to travel to destinations unrelated to the warehouse itself, and providing this infrastructure can facilitate greater usage of ZE trucks.

Commercial Availability: Several different manufacturers sell EVSE at a variety of power levels (e.g., Level 2, Level 3, etc.), including with optional power management software that govern how trucks are charged. At the current early stage of commercialization and demonstration of electric trucks, the higher power chargers used for heavy duty vehicle charging have yet not followed a common standard, and proprietary charging systems are commonly tailored to each vehicle. This is expected to change in the near future with the development of a common High Power Charging for Commercial Vehicles standard by the CharIN[25] organization. In addition, local utilities and land use agencies are developing programs specifically focused on charging infrastructure upgrades. Notable examples include the Charge Ready Transport program from Southern California Edison (SCE)[26], the Commercial EV Charging Station Rebate Program from the Los Angeles Department of Water and Power (LADWP)[27], and permit streamlining efforts from many local permitting agencies[28]. SCE and LADWP collectively provide power to >80% of warehouses that may be included in PR 2305 (see chart).

[25] http://www.charinev.org/hpccv - CharIN members include most major vehicle manufacturers as well as many major energy and charging infrastructure companies.
[26] https://www.sce.com/business/electric-cars/charge-ready-transport
[27] www.ladwp.com/ladwp/faces/ladwp/commercial/c-savemoney/c-sm-rebatesandprograms/c-sm-rp-commevstation
[28] http://www.business.ca.gov/ZEVReadiness



SECTION 3a) Charger Usage

Emissions: While charging infrastructure on its own does not reduce emissions, this equipment does facilitate emissions reductions by providing additional locations for electric vehicles to obtain power and making it possible for their increased use. However, similar to the calculations for truck acquisitions, regional emission WAIRE Points are earned at a $100,000 per ton of NOx cost effectiveness level. Both regional and local emission reductions Points are earned when charging stations are used. The amount of regional NO_x emissions reductions is tied to the total amount of dispensed electricity, using default electric vehicle efficiencies and emission rates. The amount of local DPM emissions reductions is set equal to six miles of travel for every charging event[29]. The Annualized Unitary Metric (AUM) is set at 165,000 kWh, equal to about 450 kWh per day, or enough for five separate two hour-long charging events per day on a 50 kW charger, or to recharge one truck with a 500 kWh battery.

The tables and equations below illustrate the methods used to determine Point values based on regional and local emissions reductions.

Table 16. Electric Vehicle Efficiencies[30], Emission Rates[31], and Emissions Reductions

Truck Category	Efficiency	Emission Rate		Emissions Reductions	
	mile/kWh	NOx g/mile	DPM g/mile	lb NOx/kWh	lb DPM/kWh
Class 4-5	1.26	1.08	0.007	0.003	0.00002
Class 6-7	0.8	1.08	0.007	0.002	0.00001
Class 8	0.62	2.37	0.02	0.003	0.00003

[29] This accounts for three miles of travel each way for the vehicle that accessed the site and used the charger.
[30] CARB Advanced Clean Truck – Draft Standardized Regulatory Impact Assessment (SRIA), 8/8/2019 https://ww3.arb.ca.gov/regact/2019/act2019/appc.pdf
[31] https://www.arb.ca.gov/emfac/2017/, emission rates are from calendar year 2023

Equation [4]: NOx reductions = (mile/kWh) × (g/mile) × 165,000 kWh/yr ÷ 453.59 (g/lb)

Equation 1 (Class 4-5): 1.26 × 1.08 × 165,000 ÷ 453.59 = 495 lb NOx
Equation 1 (Class 6-7): 0.8 × 1.08 × 165,000 ÷ 453.59 = 314 lb NOx
Equation 1 (Class 8): 0.62 × 2.37 × 165,000 ÷ 453.59 = 535 lb NOx

Equation [5]: DPM reductions = (mile/kWh) × (g/mile) × 165,000 kWh/yr ÷ 453.59 (g/lb)

Equation 2 (Class 4-5): 1.26 × 0.007 × 165,000 ÷ *453.59* = 3.2 lb DPM
Equation 2 (Class 6-7): 0.8 × 0.007 × 165,000 ÷ *453.59* = 2.0 lb DPM
Equation 2 (Class 8): 0.62 × 0.02 × 165,000 ÷ *453.59* = 4.5 lb DPM

WAIRE Points from Charging Station Usage Emission Reductions: Emission reductions vary for each class of truck. For the WAIRE Menu, the regional and local emission reductions from class 8 trucks are used. Regional emission reductions therefore result in 22 WAIRE Points, while local emission reductions result in 18 WAIRE Points.

Costs of Using Charging Stations: Over the past year staff worked closely with multiple utilities to understand their new commercial EV charging rate structures and developed estimates of the average cost of electricity per kWh. As noted above, about three quarters of all warehouses potentially subject to the rule are located within SCE's jurisdiction. For this analysis, multiple scenarios were evaluated with different size fleets charging at different times of day, all within SCE territory. The ranges shown below in Table 17 reflect expected charging rates for fleets of between 3 to 20 trucks and all utilizing a Level 4 charger (150 kW) to charge a 450 kWh battery. The average cost assumes an equal amount of charging in each time window.

Table 17. Annual Average Cost of Electricity – Two Key SCE Rate Schedules for Charging Stations South Coast AQMD Staff Analysis*

Charging Window	SCE TOU-EV-9	SCE TOU-8-RTP
	$/kWh	$/kWh
On-Peak	0.29-0.30	0.15-0.18
Mid-peak	0.11-0.13	0.11-0.14
Off-peak	0.08-0.1	0.09-0.12
Average	**0.18**	**0.15**

*These costs do not account for any LCFS revenue that a facility may receive. The LCFS value may vary depending on market conditions but can be more than $0.10/kWh.[32]

Using the $0.18 $/kWh rate above, and AUM of 165,000 kWh per year for a charging station, the total annual cost of electricity for the warehouse is $29,700, equal to two WAIRE Points.

[32] https://ww3.arb.ca.gov/regact/2019/act2019/appc.pdf

SECTION 3b) Charger Installation

Costs to Install Charging Stations: Charging infrastructure costs can vary greatly from site to site. The analysis presented here was informed by staff discussions with charger providers, utilities, other industry stakeholders, data from current South Coast AQMD funded projects, and multiple studies (referenced below). Table 18 presents a summary of the range of costs for purchasing and installing different EVSEs.

Electrification projects require site-specific planning and sometimes can take more than one year to implement. Because of this potentially extended period, the charging infrastructure installation WAIRE Menu item includes project milestones to allow warehouses to earn Points for partial completion of charger installation during a compliance year. Three milestones that are common to all charging station projects include purchasing the Electric Vehicle Supply Equipment (EVSE), construction mobilization, and final permit sign off & charger energization. In order to account for splitting charger installations into two separate milestones, it is assumed that the construction mobilization milestone will require up to $10,000 of the total installation cost, and the remaining cost is incurred during construction and prior to final permit sign-off.

Table 18. Charging Infrastructure Installation Cost Ranges, and Key Incentives/Rebates Programs

Charging Installation Activity	Charger Level	Cost Range [A-D]
		$ per charger
EVSE Purchase	Level 5	60,000 – 140,000
	Level 4	30,000 – 60,000
	Level 3	10,000 – 30,000
	Level 2	3,000 – 5,000
Charger Installation[1]	Level 3, 4, or 5	10,000 – 80,000
	Level 2	5,000 – 10,000

Notes:

1. Installation cost for one charger includes electrical service extension, permitting, labor costs, and trenching to lay cables

References:

A. Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption, Henry Lee and Alex Clark, August 2018
B. Estimating Electric Vehicle Charging Infrastructure Costs across Major U.S. Metropolitan Areas. Michael Nicolas, August 2019
C. Rocky Mountain Institute Report, https://www.greenbiz.com/blog/2014/05/07/rmi-whats-true-cost-ev-charging-stations, 2019
D. CARB Advanced Clean Truck - Standardized Regulatory Impact Assessment (SRIA), August 2019

WAIRE Points from Charging Station Installations: Table 19 below summarizes the Points that a warehouse would earn for purchasing an EVSE and installing it. Similar to truck acquisitions, regional emission Points are assigned at a $100,000 per ton of NOx cost effectiveness.

Table 19. Summary of WAIRE Points Earned for Installing Charging Infrastructure

Charger Installation Activity	Cost Points	Regional Emissions Points	Total WAIRE Points
1 EVSE Purchased	6	112	118
	3	48	51
	2	24	26
	1	4	5
1 construction project	1	8	9
	1	8	9
1 construction project	3	56	59
	1	8	9

SECTION 4) Hydrogen Filling Station Installation and Usage

Description: Hydrogen refueling stations (HRS) are used to supply fuel to vehicles with hydrogen fuel cell drivetrains. An HRS is composed of storage and dispensing units and can sometimes include a production unit if the hydrogen is produced on site. If the hydrogen is produced on site or delivered to the station at an intermediary pressure or in liquid state, intermediary storage is also needed along with a compression system.

Commercial Availability: While construction of hydrogen fueling stations has been increasing, with 43 now operating in the state[33], they are primarily focused on the light duty vehicle market, or in some cases for transit buses. However, some class 8 truck manufacturers are actively pursuing the development and commercialization of hydrogen fuel cell trucks over the next few years, including Toyota, Kenworth, Hyundai, and Nikola. Fueling infrastructure will be a critical component to facilitate these new ZE trucks.

Hydrogen Station Installation Costs: Hydrogen prices are influenced by the cost of production, distribution, and sales, among other factors. In addition to AB 8 and CARB's Scoping Plan, the recently-updated Low Carbon Fuel Standard, Executive Orders B-16-2012 and B-48-18 provide strong policy drivers for accelerating commercialization of fuel cell vehicles and their associated hydrogen fuel station network.

Table 20 below presents a summary of costs associated with developing a hydrogen fueling station from literature review and discussion with stakeholders. In this context, total capital cost includes site design and engineering, permitting, equipment, project management, and labor costs.

[33] www.veloz.org

Table 20. Hydrogen Fueling Station Costs

	Capacity (kg/day)	Cost ($)	$/Capacity ($/kg/day)	Source
			5000-10,000	CARB Total Cost of ownership Discussion Documents[34]
Gaseous H2 LDV fueling system at 700 bar	250	1,725,000	6,900	Moyer Granted Project for Sunline Transit- EPC Design
Gaseous H2 Station- 700 bar Cascade dispensing	700	3,065,724	4,380	Argonne National Lab Heavy Duty Refueling Model, (2016 Dollar)[35]
Gaseous H2 Station- 700 bar Booster compressor	700	3,140,211	4,486	
Gaseous H2 Station- 350 bar Cascade dispensing	700	2,029,488	2,899	
Liquid H2 Station- 700 bar via vaporization/compression	700	2,421,134	3,459	Argonne National Lab Heavy Duty Refueling Station Model, (2016 Dollars)[2]
Liquid H2 Station- 350 bar via vaporization/compression	700	1,430,748	2,044	
Liquid H2 Station- 700 bar via LH2 pump/vaporization	700	1,541,243	2,202	
Liquid H2 Station- 350 bar via LH2 pump/vaporization	700	1,145,634	1,637	
Onsite H2 Production	7257.5	16,500,000	2,274	Industry stakeholder input
Onsite H2 Production	600	5,000,000	8,333	Industry stakeholder input

WAIRE Points for Hydrogen Station Installation: For the WAIRE Menu an onsite hydrogen fueling station with a capacity of 700kg/day with delivered hydrogen was assumed to cost $2 million. This would yield 80 WAIRE Points. At a cost effectiveness of $100,000 per ton of NOx, an additional 1600 Points are earned for regional emissions.

Emission Reductions from Hydrogen Usage: Annualized regional NOx emission reductions and local DPM emission reductions were set to be same as the reductions achieved by usage of onsite electric charger stations at 535 lb NOx/yr and 4.5 lb DPM/yr. Details of the calculation can be found in Section 3 of this report.

Hydrogen Fuel Costs: To determine the annualized unitary metric (AUM) for dispensed hydrogen, a back calculation was conducted based on the amount of regional NOx emissions:

Equation [6]:

$$Total\ kg\ of\ Dispensed\ H_2 = 535\left(\frac{lb}{yr}\right) \times 453.59\,\left(\frac{gr}{lb}\right) \times \frac{1}{2.372\,\left(\frac{g}{mi}\right) \times 16.63\,\left(\frac{mi}{kg\ H_2}\right)} = 6{,}152\,\frac{kg}{yr}$$

Where, 2.372 (g/mi) is the VMT weighted average of NOx running exhaust emission rate of Class 8 trucks considered in this analysis including T7 CAIRP, T7 NNOOS, T7 NOOS, T7 POLA and T7 Tractor. 16.63 (mi/kg) is the reported fuel economy for a class 8 fuel cell truck[36]. Given the

34 https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf
35 https://hdsam.es.anl.gov/index.php?content=hdrsam
36 https://ww3.arb.ca.gov/regact/2019/act2019/appc.pdf

total kg of dispensed hydrogen calculated above and a retail price of $10/kg, the annual cost will be $61,520.

WAIRE Points for Dispensed Hydrogen: Based on the emission reductions stated above, 22 and 18 Points are earned respectively for regional NOx and local DPM. Cost Points would contribute another 3 Points, for a total of 43 Points for 6,152 kg of H_2 dispensed.

SECTION 5) **Zero Emissions Yard Truck Acquisition and Usage**

Description: Yard trucks (also called yard tractors, terminal trucks, hostlers, yard jockeys, or yard goats) move trailers and containers around warehouse facilities. Most yard trucks at warehouse facilities are diesel fueled and emit NOx, DPM, and other pollutants. Duty cycles for yard trucks vary depending on use, with heavier use at railyards and port facilities and lighter use typically at warehouses and manufacturing plants, as defined by hours of use and diesel consumption rates. CARB has limited population data for about 1,100 yard tractors operating statewide through its DOORS reporting program for off-road vehicles, but it is unclear how many of these operate at warehouses in South Coast AQMD. In addition, many yard tractors can be on-road vehicles, which are not required to be reported through the DOORS system. For example, about two thirds of the roughly 1,600 yard tractors at the ports of Los Angeles and Long Beach are on-road vehicles.

Commercial Availability: Many battery-electric yard tractor demonstration projects have taken place in the past several years, including in the South Coast AQMD. Following these efforts, multiple manufacturers have begun offering battery-electric ZE yard trucks for sale commercially including OrangeEV, Kalmar Ottawa, and BYD.

Operation: Operation of yard trucks can be tracked by hours of use, with hourly usage varying from <1,000 hours/year up to 6,000 hours/year. The diesel reductions were calculated by using the horse power, hours of use, the load factor, and the pollutant emission factor.

SECTION 5a) ZE Yard Truck Acquisition

WAIRE Points from ZE Yard Truck Acquisition: ZE yard trucks currently cost about $310,000 while their diesel equivalent costs about $100,000[37]. This incremental cost of $210,000 would earn nine WAIRE Points per ZE yard truck purchased. Similar to the methods used for on-road truck acquisitions, at $100,000 per ton cost effectiveness, a ZE yard truck acquisition would earn 168 Points for regional emission reductions.

SECTION 5b) ZE Yard Truck Usage

Emissions: From the DOORS data, the most common yard trucks operate a 175 hp, Tier 3 engine. Table 21 below shows the emission factors from the Carl Moyer Guidelines[38] for this type of yard truck. Assuming that this type of yard truck operates 1,000 hours per year, and has operated for ten years, the emission reductions from switching to a ZE yard truck are shown in Equation 7 below.

[37] https://cleanairactionplan.org/documents/final-cargo-handling-equipment-che-feasibility-assessment.pdf/
[38] https://ww3.arb.ca.gov/msprog/moyer/guidelines/current.htm

Table 21. Emission Factors for a Tier 3 Yard Truck

Pollutant	Emission Factor (EF) g/hp-hr	Deterioration Rate (DR) g/hp-hr-hr	Load Factor (LF)
NOx	2.32	0.00003	0.39
DPM	0.088	0.0000044	

Equation [7]

$$Emissions = (hp) \times (LF) \times \left[\left((total\ hrs\ of\ use) \times (DR)\right) + (EF)\right] \times (hrs\ of\ use) \div 453.59(\frac{g}{lb})$$

Equation 7 NOx: $175 \times 0.39 \times [((10 \times 1{,}000) \times 0.00003) + 2.32] \times 1{,}000 \div 453.59 = 394$ lbs
Equation 7 DPM: $175 \times 0.39 \times [((10 \times 1{,}000) \times 0.0000044) + 0.088] \times 1{,}000 \div 453.59 = 19.9$ lbs

Costs: Although purchase prices for ZE yard trucks are higher than their diesel equivalent, once purchased the operational costs are expected to be lower. An analysis by the ports of Long Beach and Los Angeles evaluated the Total Cost of Ownership (TCO) for battery-electric ZE yard trucks in comparison to diesel[39]. This analysis found a TCO for ZE yard trucks to be about $450,000 (not including infrastructure costs) while equivalent diesel had a TCO of about $375,000. Assuming a ~12,000 useful life of a yard truck, the annual incremental cost of operating a ZE yard truck for 1,000 hours is shown in Equation 8.

Equation [8]: ($450,000 - $375,000) × 1,000 hrs ÷ 12,000 hrs = $6,250

WAIRE Points from Using ZE Yard Trucks: Following the results from Equation 6, using a ZE yard truck would earn 16 Points for regional emission reductions and 80 Points for local emission reductions. One cost Point would be earned following the results of Equation 7. Similar to the approach for on-road truck visits, a multiplier of three is applied to the sum of cost, regional, and local Points. Therefore the total Points for 1,000 hours of ZE yard truck usage is: (16 + 80 + 1) × 3 = 291 Points.

[39] https://cleanairactionplan.org/documents/final-cargo-handling-equipment-che-feasibility-assessment.pdf/