Technical Options to Achieve Additional Emissions and Risk Reductions from California Locomotives and Railyards

August 2009

California Environmental Protection Agency

Air Resources Board

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State of California
California Environmental Protection Agency
AIR RESOURCES BOARD
Stationary Source Division

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EXECUTIVE SUMMARY

In this report, the Air Resources Board (ARB/Board) staff provides a technical evaluation for public comment of 37 options that may accelerate further statewide locomotive and localized locomotive and non-locomotive railyard emission reductions. This technical evaluation of each option addresses the technical feasibility, potential emission reductions, costs, and relative cost-effectiveness. The purpose of this document is to provide a sound technical basis for the ongoing dialogue on how best to achieve further emissions reductions of oxides of nitrogen (NOx) and diesel particulate matter (PM or diesel PM).

This report is intended to provide an initial technical assessment of various options that are available or may be available in the near future to accelerate and provide additional emissions reductions from locomotives and major railyards in California. It is not intended to serve as an implementation blueprint, as it does not evaluate which agency or agencies may have authority to implement such options. The document also does not evaluate what role, if any, the availability of public funding might play in assuring earlier or further reductions.

Following receipt and evaluation of the public comments on the preliminary draft, ARB staff has developed this revised report on the technical evaluation of the options. ARB staff is now developing a second report that provides recommendations to implement further emission reduction options for locomotives and railyards. This second report also provides possible implementation mechanisms. The range of possible mechanisms includes direct regulation, incentive funds, voluntary actions by the railroads, and enforceable agreements with the railroads.[1] This second report will draw on the results of this technical evaluation. ARB staff will again seek public comments prior to consideration by the Board.

This Executive Summary presents the options evaluated and the results of the technical evaluation. In addition, the Executive Summary highlights several options for consideration. Additional details and background information are presented in the main report and in the Appendices.

A. BACKGROUND

Since the early 1990's, the ARB has worked to develop innovative ways to provide significant emission reductions beyond federal locomotive emissions standards. The ARB has employed a combination of implementation mechanisms such as State regulations, voluntary agreements, and incentive programs to further reduce locomotive and railyard emissions beyond federal requirements. These innovative efforts achieved reductions in spite of specific federal preemptions to regulate locomotive emissions in the federal Clean Air Act and other statutory programs.

[1] The Board adopted Resolution 05-40 on July 21, 2005, concerning any future enforceable agreements. For a copy of the resolution, see http://www.arb.ca.gov/railyard/ryagreement/b-rslution.pdf . For related Board meeting transcript, see http://www.arb.ca.gov/board/mt/mt072105.txt .

The ARB continues to work with affected stakeholders to identify innovative approaches that will build on past efforts to reduce railyard and statewide locomotive emissions. ARB staff is seeking collaborative approaches. To that end, the ARB staff hopes the technical evaluation of options can be used as a basis for discussions with railroads and other stakeholders to accelerate further reductions from locomotives and railyards, or as a blueprint for use of public incentive funding, or for both purposes.

B. Summary of Technical Options Evaluated To Date

The technical evaluation considered 37 options for reducing emissions from locomotives and from non-locomotive sources at railyards. In most cases, there was sufficient information to determine technical feasibility, potential emission reductions, costs, and relative cost-effectiveness. In other options, staff notes where such data do not exist. Staff also acknowledges that the data used in this report represents a snapshot in time. Elements such as locomotive fleet composition data are fluid and are influenced by many factors. In addition, other data used to evaluate technological feasibility, potential emission reductions, and costs are also fluid and subject to change. The staff expects to provide updates as technology developments and demonstration project results warrant.

Staff evaluated technical feasibility based on the state of development of a particular technology or operational measure. Technical feasbility was also evaluated based on the ability to implement a given technology or option within existing or future locomotive or railyard operations. In a number of cases, staff assessed when a technology was developed or could become developed and when the technology could become U.S. EPA certified or ARB verified.

Staff generally calculated potential emissions reductions on a per unit basis. With available data, potential emissions reductions were calculated for regional and statewide benefits. Please note that some options are dependent on the implementation of other options and potential emissions reductions may not be additive when determining emission benefits. Costs were primarily based on capital costs, but in some cases included operational, maintenance, and replacement costs when applicable or where the information was available.

Cost-effectiveness for all options was calculated using ARB Carl Moyer Methodology[2] which is a measure of the dollars provided to a project for each ton of covered emission reductions. As an alternative cost-effectiveness was also calculated by attributing half of the costs of a potential option to PM reductions and the other half to reductions in NOx. The alternative method was only applied to the locomotive options in Table ES-1. The alternative cost-effectiveness was provided as a simplistic means of comparison with other programs with similar costs and reductions. The pollutants reduced were

[2] 2008 Carl Moyer Program Guidelines, Appendix C, Cost-Effectiveness Calculation Methodology at http://www.arb.ca.gov/msprog/moyer/guidelines/current.htm , see Appendix P of this document for an excerpt of Appendix C.

generally both diesel PM and NOx, but there are a few exceptions when information was not available. Staff tried to develop a simple cost-effectiveness range based on pollutants reduced in 2005 versus, in many cases, 2015 or 2020 to show the relative benefits of the various options.

This methodology for cost-effectiveness will ensure consistency when comparing different types of technologies or measures. Tables ES-1 through ES-4 provide an assessment of the 37 options evaluated to further reduce and accelerate locomotive and non-locomotive emissions reductions. The assessments are based on the following criteria: technical feasibility, potential emissions reductions, capital and other costs, and cost-effectiveness. The options are also assessed based on a potential schedule for implementation in California: near-term (within 5 years), mid-term (within 10 years), and long-term (generally within 15 years). Note that the option numbers correspond to the option numbers listed in the main body of the report.

Table ES-1
Options to Accelerate Further
Locomotive Emissions Reductions

Option #	Near-Term Options (up to 5 years)	Emission Reductions Statewide (tons per day)		Cost (Millions)	Cost Effectiveness[1] (Dollars / pound)		
					Alternate Method[4]		Carl Moyer Method
		PM	NOx		PM	NOx	PM + NOx
Locomotive Replacements or Engine Repowers							
1	Replace 152 older switch locomotives with new ULESL ($1.5 million/unit)	0.31	6.6	$228	$25-50/lb	$1-2/lb	$2-3/lb
5	Repower 400[2] older MHP locomotives with new LEL engines ($1 million/unit); or	1.27	22.9	$400	$11-22/lb	$0.6-1/lb	$0.8-1/lb
	subtotal	**1.58**	**29.5**	$628	**$11-50/lb**	**$0.6-2/lb**	**$1-3/lb**
6	A possible alternative to Option #5, replace up to 200 of the 400 older MHP locomotives with new MHP gen-set locomotives ($2 million/unit)	0.63	13.3	$400	$22-44/lb	$1-2/lb	$2-3/lb
Locomotive Remanufacturing Options – Less Expensive Alternatives to Options #1 and #5							
4	Remanufacture 152 older switch locomotives to meet U.S. EPA Tier 0 Plus emission standards 3 ($250,000/unit)	0.22[3]	2.2[3]	$38	$6-12/lb	$0.6-1/lb	$0.6-1/lb
8	Remanufacture 400 older MHP locomotives to meet U.S. EPA Tier 0 Plus emission standards[3] ($250,000/unit)	0.96[3]	12.9[3]	$100	$4-7/lb	$0.3-0.5/lb	$0.3-0.5/lb
	subtotal	**1.18[3]**	**15.1[3]**	**$138**	**$4-12/lb**	**$0.3-1/lb**	**$0.3-1/lb**
	Mid-Term Options (up to 10 years)						
Locomotive Aftertreatment (DPF and SCR) – Enhanced Benefits from Options #1 and #5							
2	Retrofit 244 ULESL with DPF and SCR ($200,000/retrofit)	0.04	1.0	$49	$42-84/lb	$2-3	$3-5/lb
7	Retrofit 400 LEL or gen-set MHP locomotives with DPF and SCR ($500,000/retrofit)	0.18	6.8	$200	$38-76	$1-2	$2-3/lb
	subtotal	**0.22**	**7.8**	**$249**	**$38-76/lb**	**$1-3**	**$2-5/lb**
	TOTALS (Options 1,5,2,7)	**1.80**	**37.3**	$877	$11-76/lb	$0.6-3/lb	$1-5/lb

Table ES-1 (Continued)
Options to Accelerate Further
Locomotive Emissions Reductions

Option #	Long-Term Options (up to 15 years or more)	Emission Reductions Statewide (tons per day)		Cost (Millions)	Cost Effectiveness [1] (Dollars / pound)		
					Alternate Method [4]		Carl Moyer Method
		PM	NOx		PM	NOx	PM + NOx
New Tier 4 Locomotive Replacement or Tier 4 Nonroad Engine Repowers							
3	Repower 244 ULESL with new Tier 4 nonroad engines ($200,000 incremental cost difference)	0.01	0.6	$49	$167-334/lb	$3-6/lb	$6-10/lb
9	Accelerate up to 4,800 Tier 4 interstate line haul locomotives ($3 million/unit) in UP&BNSF national fleet for 1,200 to operate in California (on any given day)	1.28	31.6	$3,600	$96 - 193/lb	$4-8/lb	$7 – 11/lb
	SUBTOTAL	**1.29**	**32.2**	**$3,649**	**$167-334**	**$3-8/lb**	**$6-11/lb**
	TOTALS (1,5,2,7,3,9)	**3.09**	**69.5**	**$4,526**	**$11-334/lb**	**$0.6-8/lb**	**$0.8-11/lb**

1. Cost-effectiveness ranges are based on 10 to 20 years of useful life and may not add up precisely due to rounding.
2. 290 units are freight locomotives and 110 are passenger locomotives.
3. Note: Estimated emissions reductions are highly dependent on whether the railroads choose to remanufacture older locomotives.
4. Cost effectiveness calculated by attributing half the cost to PM and half to NOx.

Table ES-2
Options to Accelerate Further
Non-Locomotive Railyard Emissions Reductions
(Diesel Trucks, Cargo Handling Equipment, TRUs, Off-Road, and Stationary)

Option #	Near-Term Options (up to 5 years)	Emission Reductions Statewide (tons per day)		Cost-Effectiveness (Dollars / pound)	Costs (millions)
		PM	NOx		
CHE - Yard Trucks/Hostlers – (Replace 322 yard hostlers in 8 intermodal railyards)					
10	LNG Yard Hostlers	-	-	-	$39 ($.12/unit 322 units)
11	Electric Yard Hostlers	0.01 [1] (2015)	0.27 [1] (2015)	$29/lb (2015) (8 years)	$68 ($.21/unit 322 units)
12	Hybrid Yard Hostlers [2]	-	-	-	-
CHE – RTG Cranes – (Retrofit/Replace 67 RTGs in 8 intermodal railyards)					
13	Energy Storage Systems	0.0014 (2015)	0.08 (2015)	$8-17/lb (2015) (20 years)	$11-22 ($.16-$.32/ (67 RTGs)
14	Wide Span Gantry Cranes and Non-Locomotive Railyard Electrication Infrastructure Costs	0.023 [2] (2015)	0.79 [2] (2015)	$97/lb (2015) (20 years)	$1,200 (134 WSGs replace 67 RTGs)
Idle Reduction Devices - (Retrofit cargo handling equipment with idle reduction devices similar to those employed on trucks and locomotives)					
15	Idle Reduction Devices (Cargo Handling Equipment)	-	-	-	-
Transport Refrigeration Units (TRUs) (Install at 8 intermodal railyards)					
16	Plug-In Electrification for Transport Refrigeration Units (TRU) – (with necessary non-locomotive railyard electrification)	0.003 (2020)	0.03 (2020)	$561-940/lb (2020)	$500
Drayage Trucks – Ports to Intermodal Railyards (e.g., UP ICTF/BNSF SCIG/UP Oakland)					
17	New 2007 HD Diesel Trucks	NA	NA	NA	$.11/unit
18	LNG HD Drayage Trucks	0.0	0.0002	$62-129/lb [3] (15 years)	$.21/unit
19	CNG HD Drayage Trucks	0.0	0.0005	$2-27/lb [3] (15 years)	$.12/unit
20	Electric HD Drayage Trucks	0.0	0.0006	$20-43/lb [3] (15 years)	$.21/unit

1. Emissions reductions are surplus to the ARB CHE Regulation in 2015.
2. Staff assumes that railyard non-locomotive electrification and replacement with Wide Span Gantry (WSG) Cranes would nearly eliminate all CHE (i.e., Cranes, Yard Hostlers, and related CHE equipment) emissions.
3. Accounting for just cost-differential between new 2007 HD diesel truck cost-effectiveness would be lowered to: LNG - $46/lb, CNG - $2/lb, and Electric - $15/lb.

Note: The 18 railyard HRAs estimated that 2005 CHE railyard diesel PM emissions were 25 tons per year. Staff estimates that the ARB CHE Regulaton will reduce railyard CHE diesel PM emissions by 80 percent by 2015, or to about 5 tons per year.

Note: The 18 railyard HRAs estimated that in 2005 Truck railyard diesel PM emissions were 31 tons per year. Staff estimates that the ARB Port and Intermodal Railyard Drayage Truck regulation may reduce railyard truck diesel PM emissions by up to 90 percent or more by 2015, or to about 3 tons per year.

Note: The 18 railyard HRAs estimated that 2005 TRU railyard diesel PM emissions were 14 tons per year. Staff estimates that the ARB TRU ATCM will reduce railyard TRU diesel PM emissions by 92 percent by 2020, or to about 1 ton per year.

NA – The new 2007 diesel truck PM and NOx emission standards are required in intermodal railyards by 2014 per the CARB Drayage Truck Regulation.

Table ES-3
Options to Accelerate Further
Advanced System Emissions Reductions

Option #	Near-Term Options (up to 5 years)	Emission Reductions Statewide (tons per day)		Cost-Effectiveness (Dollars / pound)	Costs (millions)
		PM	NOx		
21	ALECS or Hood Technology (All 18 railyards service/ maintenance/ fueling diesel PM emissions – 18 tpy. UP Roseville about 1 tpy in one location of railyard).	0.0027	0.05	$23/lb (20 years)	$25/unit
22	Locomotive Remote Sensing	- [1]	- [1]	- [1]	$0.25 [2]
23	Idle Reduction Devices on All Interstate Line Haul Locomotives	- [1]	- [1]	- [1]	$5k-40k/unit
25	GE Electric Hybrid Locomotive	- [1]	- [1]	- [1]	- [1]
27	CARB Diesel Required on All Interstate Line Haul Locomotives Prior to Entering California [3]	0.2	1.0	$15/lb	$0.036/day
28	California Locomotive In-Use Emission Testing	- [1]	- [1]	- [1]	$1 [4]

1. Staff believes these options will not provide emissions reductions beyond current programs.
2. Costs are for one remote sensing device, total costs would depend on number of remote sensing devices procured.
3. Most of these potential CARB diesel emission reductions would occur between state boundaries and major UP and BNSF refueling depots (e.g., Needles to Barstow, Truckee to Roseville, Yuma, AZ to Colton, CA, Las Vegas, NV to Yermo).
4. Costs are annual costs to test 15 locomotives with SWRi mobile lab – which would be equivalent to the federal in-use locomotive emissions testing program. Does not include the costs for California to develop its own locomotive emissions testing facility.

Option #	Mid to Long-Term Options (up to 10 or 15 years or more)	PM (tons per day)	NOx (tons per day)	Cost-Effectiveness (Dollars / pound)	Costs (millions)
24	BNSF Hydrogen Fuel Cell Locomotive	- [1]	- [1]	- [1]	$3.5/ demonstrator
26	Ethanol-Fueled Locomotive	- [1]	- [1]	- [1]	$1.5/unit
~~3~~ 29	Electrification of Major Freight Rail Lines in the South Coast Air Basin	0.7 [2]	18.4 [2]	$15-32/lb (30 years)	$13,000
30	Maglev from Ports of LA/LB to UP ICTF and proposed BNSF SCIG	0.03	- [1]	$56-148/lb (15 years)	$300-$800
31	Linear Induction Motors (LIMs) Retrofit of Major Freight Rail Lines in the South Coast Air Basin	0.7 [2]	14.2 [2]	$29/lb (30 years)	$10,000

1. Insufficient data.
2. Assumes 80 and 70 percent of PM and NOx locomotive emissions are reduced in the South Coast Air Basin.

Table ES-4
Options to Accelerate Further
Individual Railyard Emissions and Risk Reductions

Option #	Near-Term Options	Emission Reductions Statewide (tons per day)		Cost-Effectiveness (Dollars / pound)	Costs (millions)
		PM	NOx		
32	Study potential for walls to serve as barriers to diesel PM emissions	- [1]	- [1]	- [1]	$2.4/mile
33	Study feasibility of trees to filter and create barrier to diesel PM emissions	- [1]	- [1]	- [1]	$.25/mile
34	Install indoor air filtration systems in nearby schools and residents	- [1]	- [1]	- [1]	$1-5k/ central unit
35	Install air monitoring stations near the railyard	- [1]	- [1]	- [1]	$30k/unit $30k annual
36	Enhance state and local locomotive and truck enforcement efforts.	- [1]	- [1]	- [1]	Railyard specific and costs unknown
37	Relocate emissions sources further away from residential receptors	- [1]	- [1]	- [1]	Railyard specific. Costs unknown.

1. Staff has no data to estimate potential diesel PM emissions reductions. Also, when emissions reductions may be possible, they would likely be railyard specific – based on specific railyard operations, location of residents to railyards, etc. Without emissions reductions data, staff was not able to calculate cost-effectiveness.

C. Staff Preliminary Recommendations On Options

After reviewing the results of the technical evaluation, staff has identified several options. These options have the potential to achieve significant emissions reductions in the near term either on a railyard-specific basis or a regional basis, or both. Implementation of these options would not preclude other options being pursued. The options are identified in Table ES-5. Table ES-6 represents similar options for the South Coast Air Basin.

Achieving these results will require future collaboration between all stakeholders to develop an implementation mechanism that assures the reductions are achieved in a timely manner. As discussed in the main report, the technology for Option 1 is available; other options may require the development and demonstration of technology. These demonstrations are in progress and staff believes that the technology transfer has a high probability for success. Even so, it is important to recognize that not all of the options can be implemented immediately.

Table ES-5
Near-Term
Options for the Rest of the State
(Excludes South Coast Air Basin)

Near-Term Options	Technology Demonstrated	Emission Reductions by 2014 (tons per day)		Cost-Effectiveness (Dollars / pound)	Costs (Millions)
		PM	NOx		
Replace 89 older switch locomotives with new ULESL ($1.5 million/unit)	Yes	0.16	3.8	$2-3/lb (10-20 years)	$134
Repower 250 older MHP locomotives with LEL engines ($1 million/unit)or new MHP gen-set locomotives ($2 million/unit)	In Process	0.78	14.4	$0.8-1/lb (10-20 years)	$250 to $500
SUBTOTAL		**0.94**	**18.2**	**$0.8-3/lb**	**$384-$634**
Retrofit DPF and SCR onto 105 ULESL ($200,000/retrofit)	In Process	0.02	0.4	$3-5/lb (10-20 years)	$21
Retrofit DPF and SCR onto 250 MHP LEL engines or new gen-set locomotives ($500,000/retrofit)	In Process	0.11	4.3	$2-3/lb (10-20 years)	$125
SUBTOTAL		**0.13**	**4.7**	**$3-5/lb**	**$146**
TOTALS		**1.07**	**22.9**	**$0.8-5/lb**	**$530-$780**

Note: May not add up precisely due to rounding.

Table ES-6
Options for
Reducing Emissions in the Near Term
in the South Coast Air Basin

Options	Technology Demonstrated	Emission Reductions (tons per day)		Cost-Effectiveness (Dollars / pound)	Costs (Millions)
		PM	NOx		
Replace 63 older switch locomotives with new ULESL ($1.5 million/unit)	Yes	0.14	2.8	$2-3/lb (10-20 years)	$95
Repower 150 older MHP locomotives with LEL engines ($1 million/unit) or new gen-set MHP locomotives ($2 million/unit)	In Process	0.47	8.6	$0.8-1/lb (10-20 years)	$150-$300
Emissions attributable to passenger locomotives (52 Locos)	-	0.16	3.0	-	-
SUBTOTAL		**0.61**	**11.4**	**$0.8-3/lb**	**$245-$395**
Retrofit DPF and SCR onto 139 ULESL ($200,000/retrofit)	In Process	0.02	0.6	$3-5/lb (10-20 years)	$28
Retrofit DPF and SCR onto 150 MHP LEL engines or new gen-set locomotives ($500,000/retrofit)	In Process	0.07	2.5	$2-3/lb (10-20 years)	$75
Emissions attributable to passenger locomotives (52 Locos)	-	0.02	0.9	-	-
SUBTOTAL		**0.09**	**3.1**	**$3-5/lb**	**$103**
Subtotal for passenger locomotives	**-**	0.19	3.8	-	-
TOTALS		**0.7**	**14.5**	**$0.8-5/lb**	**$348-$498**

Note: Numbers may not add up precisely due to rounding.

The proposed locomotive options would provide the largest emissions and risk reductions within railyards, regionally, and statewide. Non-Locomotive railyard electrification, if proven operationally feasible and cost-effective, could potentially nearly eliminate railyard cargo handling equipment emissions. Similarly, were the ALECS or Hood Technology prove to be operationally feasible and cost-effective, it could potentially reduce some stationary locomotive emissions at large locomotive classification and mechanical and servicing railyards. The locomotive options combined could potentially reduce railyard diesel PM risks by up to another 50 percent (e.g., from 100 to 50 in a million).

I. INTRODUCTION

This introduction presents background information on locomotives and railyards, including emissions and efforts taken to reduce emissions. This information forms the basis for the technology evaluation. The technical evaluations of the locomotive and non-locomotive railyard options are based on the following criteria: background, technical and operational feasibility, potential emissions reductions, capital and other costs, and cost-effectiveness.

Chapter 1 is an introduction and background. In Chapter 2, we examine options to reduce locomotive emissions. In Chapter 3, we examine options to reduce non-locomotive railyard emissions (e.g., cargo handling equipment, heavy duty trucks, transport refrigeration units, and offroad equipment). In Chapter 4, we examine options to reduce locomotive and railyard emissions with advanced systems such as the hood technology, remote sensing devices, rail electrification, and magnetic levitation (Maglev). In Chapter 5, we examine options to reduce railyard specific emissions and health risks through operational and physical changes within the railyards such as moving railyard emission sources further away from the closest residents, installing walls and trees, enhanced local enforcement efforts, and installing air monitoring stations near railyards.

All of this information is used to identify and assess each of the options based on technical feasibility, potential emissions reductions, costs, and cost-effectiveness.

A. Emissions from Locomotives and Railyards

In this section, we examine locomotive and railyard emissions to determine which emissions sources generate the most emissions and present the greatest risks to public health today and in the future.

1. Emissions from Locomotives

In 2005, California’s locomotive NOx and PM emissions were about 160 and 4.8 tons per day, respectively. The ARB emission inventory estimates that interstate line haul locomotives contribute to about 90 percent of statewide locomotive NOx and PM emissions. Interstate line haul locomotives typically move across the country (e.g., Los Angeles to Chicago). Switch and passenger locomotives typically operate primarily within the State and are estimated to contribute about 5 percent each towards statewide locomotive NOx and PM emissions. See Table I-1 for more information on statewide locomotive emissions.

2. Emissions at 18 Railyards

Under the 2005 ARB and railroad agreement, the ARB and railroads recently prepared health risk assessments for 18 major railyards in the State. The health risk assessments included detailed railyard and off-site (within a 1 to 2 mile radius of each railyard) diesel PM emission inventories, air dispersion modeling, and estimates of excess cancer risks and non-cancer health effects. The health risk assessments were prepared to identify the localized diesel PM emissions and associated health risks and provide the information necessary to develop railyard diesel PM emission reduction mitigation plans.

In 2005, all mobile sources statewide generated an estimated 172 tons per day of particulate matter (PM). Locomotives statewide contributed nearly 3 percent or about 4.8 tons per day, towards statewide mobile source PM emissions. Of statewide trains, line haul locomotives were responsible for more than 90 percent, or about 4.4 tons per day of PM. Passenger and switch (yard) locomotives also contributed about 4 percent each. See Table I-1 for a summary of statewide mobile source and locomotive PM and NOx emissions.

Table I-1
2005 Statewide Locomotive Contributions to
Statewide Mobile Source PM and NOx Emissions

Statewide Sources	PM (tons per day)	Percent	NOx (tons per day)	Percent
All Sources[1]	3,990	100%	3,635	100%
Mobile Sources	172	4.3%	3,077	84.6%
Contribution to Statewide PM and NOx Mobile Source Emissions				
All Locomotives	4.8	2.8%	158	5%
Contribution to Statewide PM and NOx Locomotive Emissions				
Line Haul Locomotives	4.4	92%	138	88%
Passenger Locomotives	0.2	4%	10.3	6%
Switcher Locomotives	0.2	4%	9.4	6%

1. Stationary, Area, Mobile, and Natural Sources. 2007 Almanac data for year 2005, grown and controlled, annual average.

<u>Diesel PM Emissions at 18 Major Railyards</u>

In 2005, the estimated total diesel PM emissions for 18 major railyards in California were about 0.58 tons per day. Of the total railyard diesel PM emissions in 2005, locomotives were responsible for nearly two-thirds (65 percent), or about 0.38 tons per day. In 2005, the 18 railyards locomotive PM emissions accounted for about 8 percent of statewide locomotive PM emissions. Other non-locomotive railyard diesel PM emissions sources include: heavy-duty diesel trucks, cargo handling equipment, transport refrigeration units (TRUs), offroad equipment, and stationary sources. In 2005, non-locomotive sources were responsible for over one-third (35 percent) of railyard diesel PM emissions, or 0.2 tons per day.

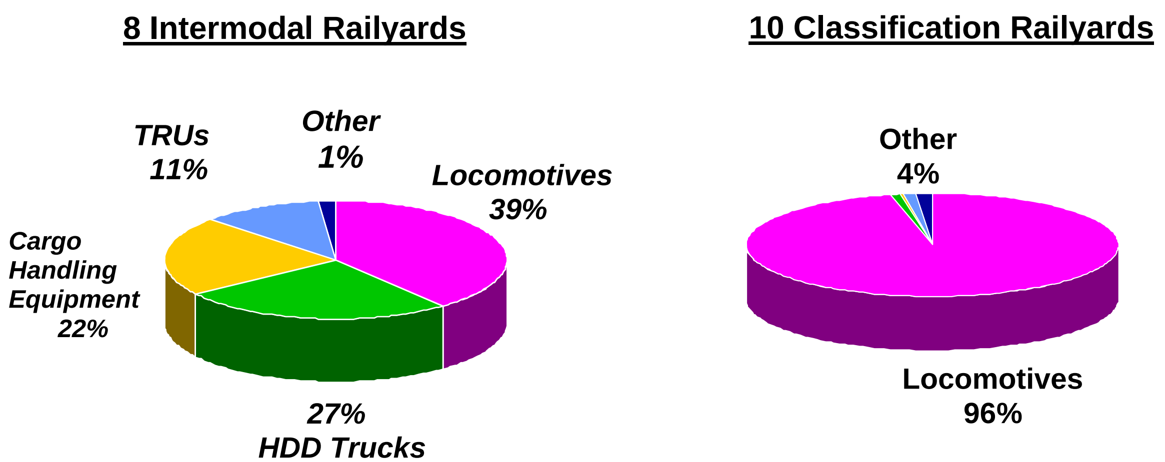
Diesel PM Emissions at Ten Classification Railyards

Ten of the 18 railyards are identified as classification railyards. In classification railyards, locomotives are responsible on average for over 95 percent of railyard diesel PM emissions. In classification railyards, the primary operations are locomotives that power or build trains, are refueled, and are subject to ongoing service and maintenance.

Diesel PM Emissions at Eight Intermodal Railyards

Eight of the 18 railyards are identified as intermodal railyards. In intermodal railyards, goods are moved primarily in containers and trailers from trucks to trains. In an intermodal railyard, railyard diesel PM emissions are distributed more evenly over a number of emission sources: locomotives, heavy-duty diesel trucks, cargo handling and off-road equipment, transport refrigeration units (TRUs), and stationary sources. See Figure I-1 for the distribution of railyard diesel PM emission sources from both intermodal and classification railyards in 2005.

Figure I-1
Distribution of Railyard Diesel PM Emissions Sources in 2005



3. Locomotive Greenhouse Gas Emissions

National Locomotive Fuel Consumption

According to American Association of Railroads (AAR) data for 2007, the nation's seven major railroad companies reported moving 1.8 trillion ton-miles of freight and consuming four billion gallons of diesel fuel for freight trains and trains in switching yards. This gives an average national locomotive fuel efficiency of 436 ton-miles per gallon of diesel fuel in 2007. The 2007 average national locomotive fuel efficiency is the highest on record, and includes a 3.1 percent increase from the 423 ton-miles per gallon reached in 2006.

The railroad industry suggests the factors for the reductions in diesel fuel consumption are:

- Using new and more efficient locomotives.
- Training engineers to conserve fuel.
- Using computers to assemble trains more efficiently in the yard and to plan trips more efficiently to avoid congestion.
- Reducing the amount of time engines are idling.

Tier 2 Interstate Line Haul Locomotives

Both GE and EMD have developed locomotives to meet the U.S. EPA Tier 2 locomotive emissions standards. The new 4,300 horsepower line haul locomotives have advanced engine design and timing, cooling systems, and traction systems that reduce diesel fuel consumption by 3 to 5 percent in comparison with older line haul locomotives (3,000 to 4,000 horsepower)

Over an expected 20 year service life, a Tier 2 line haul locomotive can reduce diesel fuel consumption by up to 300,000 gallons, which is equivalent to about one year's fuel consumption.

Advanced Technology Switcher Locomotives

National Railway Equipment Company (NREC) and Railpower (RP) manufacture gen-set and electric hybrid switcher locomotives (about 2,000 horsepower). These locomotives can provide reductions of 20 to 60 percent in diesel fuel consumption and greenhouse gas emissions. Switcher locomotives typically operate in and around railyards, and consume an average of about 50,000 gallons of diesel fuel annually. With CO2 emissions estimated at 22.4 pounds per gallon of diesel fuel[3], a 20 percent reduction (about 10,000 gallons annually) in diesel fuel consumption would provide more than 100 tons per year of greenhouse gas reductions per switcher locomotive.

Locomotive Fuel Consumption in California

Within California, total annual UP and BNSF locomotive diesel fuel consumption is estimated at about 150 million gallons: approximately 20 million gallons for switcher locomotives, and approximately 130 million gallons for line haul, medium horsepower, and passenger locomotives. The following assumptions are made for diesel fuel savings:

- 3 percent for Tier 2 line haul, medium horsepower, and passenger locomotives

[3] http://www.eia.doe.gov/oiaf/1605/coefficients.html

- 20 percent for advanced technology switcher locomotives

The annual savings in diesel fuel would then be an estimated 7.9 million gallons. With CO2 emissions estimated at 22.2 pounds per gallon of diesel fuel, an annual savings of 7.9 million gallons of diesel fuel corresponds to an annual savings of 87,700 tons of CO2 emissions, or about 240 tons of CO2 per day.

Trains vs. Trucks

Historically, locomotives have compared favorably to trucks in moving goods over long distances. Locomotive fuel efficiency has been two to four times greater.

ARB analyzed trains vs. trucks for movement of intermodal containers. In this comparison, 280 trucks were compared with four interstate line haul locomotives moving a comparable load (i.e., 70 railcars with the equivalent of four 20 ft intermodal containers per railcar).

Under this scenario, the 280 trucks and the four-locomotive train with comparable load move equivalent tons of intermodal containers from Chicago to Los Angeles, for about 2,200 miles. The heavy duty diesel trucks consume about 123,200 gallons of diesel fuel, at 5 miles per gallon. Each of the four locomotives fuels twice: at 4,000 gallons for each fueling, the total amount of diesel fuel for the four locomotives is 32,000 gallons.

In this comparison, the four locomotives would consume about one fourth as much diesel fuel as the 280 trucks. This difference in fuel consumption between trucks and trains provides significant greenhouse gas reductions to California and to the nation as a whole.

B. Efforts to Reduce Locomotive Emissions

In this section, we will examine the existing U.S. EPA and ARB locomotive and non-locomotive regulations and California's railroad agreements. We will begin with locomotive regulations and agreements, and then examine non-locomotive regulations.

1. 1998 U.S. EPA Locomotive Rule

In 1998, the U.S. Environmental Protection Agency (U.S. EPA) promulgated new regulations requiring the phase-in of new locomotive emissions standards.
Table I-2 summarizes the 1998 U.S. EPA locomotive emissions standards.

Table I-2
Summary of the 1998 U.S. EPA Locomotive Emissions Standards

Type	Tier	Date of Original Manufacture	NOx Standard (g/bhp-hr)	Percent Control When Engine is New or Remanufactured*	PM Standard (g/bhp-hr)	Percent Control When Engine is New or Remanufactured*
Line-haul locomotives	Tier 0	1973-2001	9.5	30 percent	0.6	N/A
	Tier 1	2002-2004	7.4	45 percent	0.45	N/A
	Tier 2	2005 and later	5.5	60 percent	0.20	72 percent
Switch locomotives	Tier 0	1973 - 2001	14.0	20 percent	0.72	N/A
	Tier 1	2002 - 2004	11.0	37 percent	0.54	N/A
	Tier 2	2005 and later	8.1	53 percent	0.24	67 percent

* Relative to pre-Tier 0 or unregulated locomotives.

2. ARB Locomotive and Railyard Agreements and Regulations

1998 ARB/UP/BNSF Locomotive NOx Fleet Average Agreement

In 1998, ARB staff and California's two Class I railroads, the Union Pacific Railroad Company (UP) and BNSF Railway Company (BNSF), voluntarily entered into an enforceable agreement to accelerate the introduction of the lowest emitting locomotives into California. The 1998 Agreement requires UP and BNSF to achieve a Tier 2 locomotive NOx fleet average in the South Coast Air Basin by 2010. This is a federally enforceable agreement and an approved measure in California's State Implementation Plan. This agreement requires backstop emission reductions should there be an emissions reduction shortfall by either railroad. The 1998 agreement is estimated to reduce the South Coast Air Basin locomotive NOx and PM emissions by 65 and 50 percent, respectively. UP and BNSF must fully comply with the 1998 Agreement by January 1, 2010.

2005 ARB/UP/BNSF Statewide Railroad Agreement

In 2005, ARB, UP, and BNSF voluntarily entered into another enforceable agreement to reduce diesel particulate matter (PM) emissions by about 20 percent statewide and lower diesel PM health risks in and around railyards. The 2005 Agreement required UP and BNSF to install idle reduction devices on over 400 intrastate locomotives, use at least 80 percent ultra-low sulfur diesel fuel for interstate line haul locomotives, and meet a 99 percent compliance rate for smoking locomotives. Also, the 2005 Agreement called for the preparation of 16 railyard health risk assessments (HRAs) and railyard mitigation plans. The UP Roseville Railyard HRA study was completed in 2004, and the BNSF Sheila Mechanical Railyard in Commerce was added to the 16, bringing the total railyard health risk assessments to 18. All of the 18 railyard HRAs were completed by July 2008.

2004 ARB Regulation Requiring ARB Diesel for Intrastate Locomotives

In 2004, the ARB approved a regulation to extend CARB diesel fuel requirements to over 400 intrastate locomotives. Intrastate locomotives operate 90 percent or more of the time in California. This regulation provides up to 14 and 6 percent reductions in PM and NOx emissions, respectively. The CARB diesel fuel PM and NOx emissions reductions are in excess of the emissions reductions provided by the use of both U.S. EPA onroad ultra low (15 ppmw) and nonroad low sulfur (500 ppmw) diesel fuels. This regulation was fully implemented by January 1, 2007.

Summary of Existing Locomotive Emission Reduction Benefits

California's two agreements with the UP and BNSF railroads, the 1998 U.S. EPA locomotive rulemaking, and the CARB diesel fuel regulation for intrastate locomotives have provided substantial statewide locomotive emission reductions through 2010. See Figures I-2 and I-3 for the estimated NOx and PM emissions reductions, especially through 2010. However, growth in rail activity could potentially erode the statewide locomotive emission reductions from these existing measures beginning soon after 2010.

3. 2008 U.S. EPA Locomotive Rule

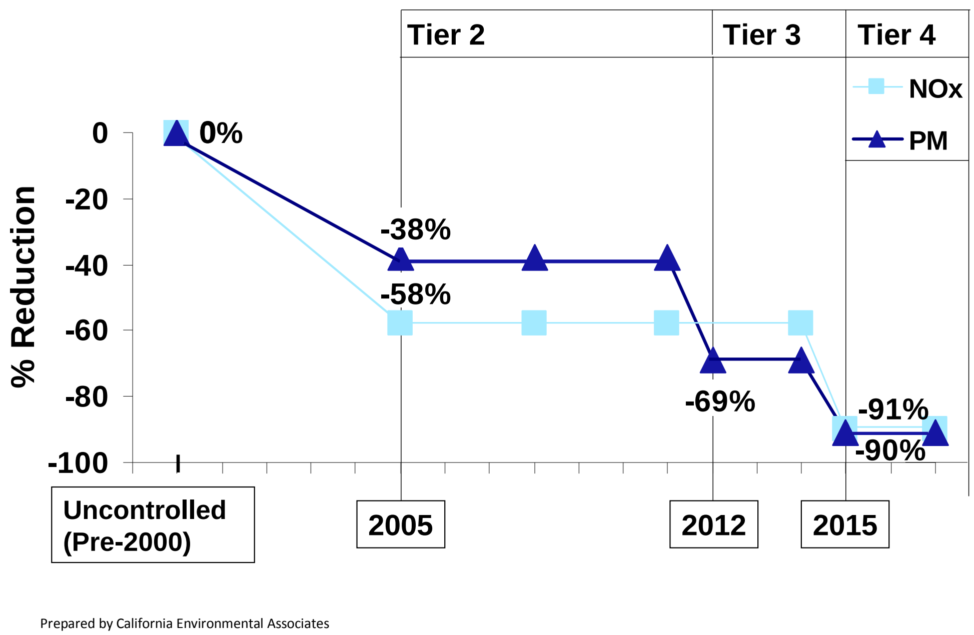
The recent 2008 U.S. EPA locomotive rulemaking will provide NOx and PM emission reductions beyond the existing 1998 U.S. EPA locomotive rulemaking and ARB locomotive regulation and railroad agreements. In the 2008 locomotive rulemaking, U.S. EPA placed particular attention on PM control for existing locomotives.

2008 U.S. EPA Locomotive Remanufacturing Emissions Standards[4]

All existing Tier 0 through Tier 2 line haul locomotives will be required to meet Tier "plus" emissions standards upon remanufacture (about every 7 to 10 years). The U.S. EPA remanufacturing standards will reduce PM emissions on average by up to 50 percent. NOx control, however, was limited to about a 20 percent reduction from the remanufacturing of only Tier 0 locomotives. The U.S. EPA locomotive remanufacturing emission standards will begin as soon as certified remanufacture kits are available (as early as 2009). Locomotive remanufacturing will occur gradually over the next ten years. In 2012, new Tier 3 line haul locomotives will be required to meet what are equivalent to the Tier 2 "plus" PM emissions standards. Figure 1-2 summarizes the U.S. EPA standards and their percent reduction since calendar year 2000.

[4] See Appendix B for details on U.S. EPA locomotive emission standards.

Figure I – 2
EPA Line Haul Locomotive Standards
(% Reduction from Uncontrolled Levels)



U.S. EPA New Tier 4 Line Haul Locomotive Emissions Standards

In 2015, new Tier 4 line haul locomotives will be required to meet NOx and PM emissions standards that will go beyond Tier 2 levels by 76 and 85 percent, respectively. However, due to the long operational lives of locomotives, a national Tier 4 locomotive fleet turnover will occur gradually over 30 years, or from 2015 to 2045. Turnover in California's locomotive fleets would be expected to occur more quickly, even without additional actions, given the significance and importance of the goods movement freight market.

Summary of Locomotive Emissions Reductions Benefits

In California, the U.S. EPA locomotive remanufacturing standards for existing locomotives, and the gradual introduction of new Tier 4 locomotives between 2015 and 2045, will provide an estimated 60 and 2 tons per day, respectively, of NOx and PM reductions by 2025.

Figures I-2 and I-3 graphically illustrate statewide locomotive NOx and PM emissions and the 2008 U.S. EPA locomotive rulemaking emissions reductions through 2025.

Figure I - 3
Estimated Statewide Locomotive NOx Emissions and Emission Reductions
(Tons/Day – Assumes 1 percent Annual Growth Rate)

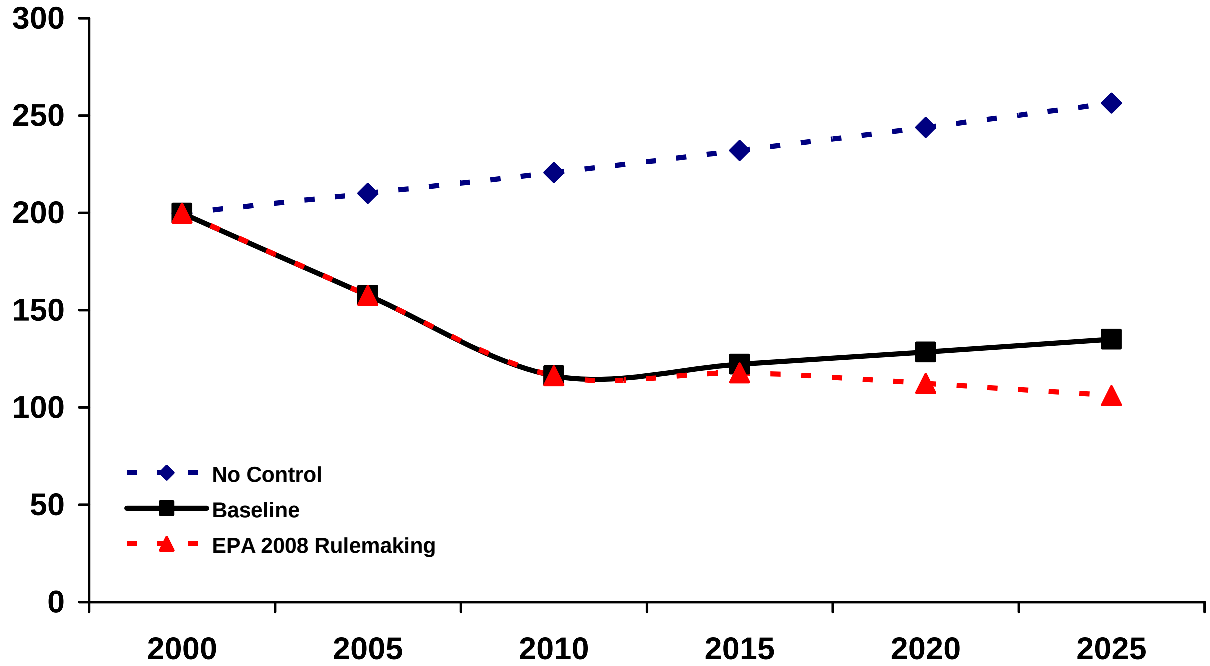
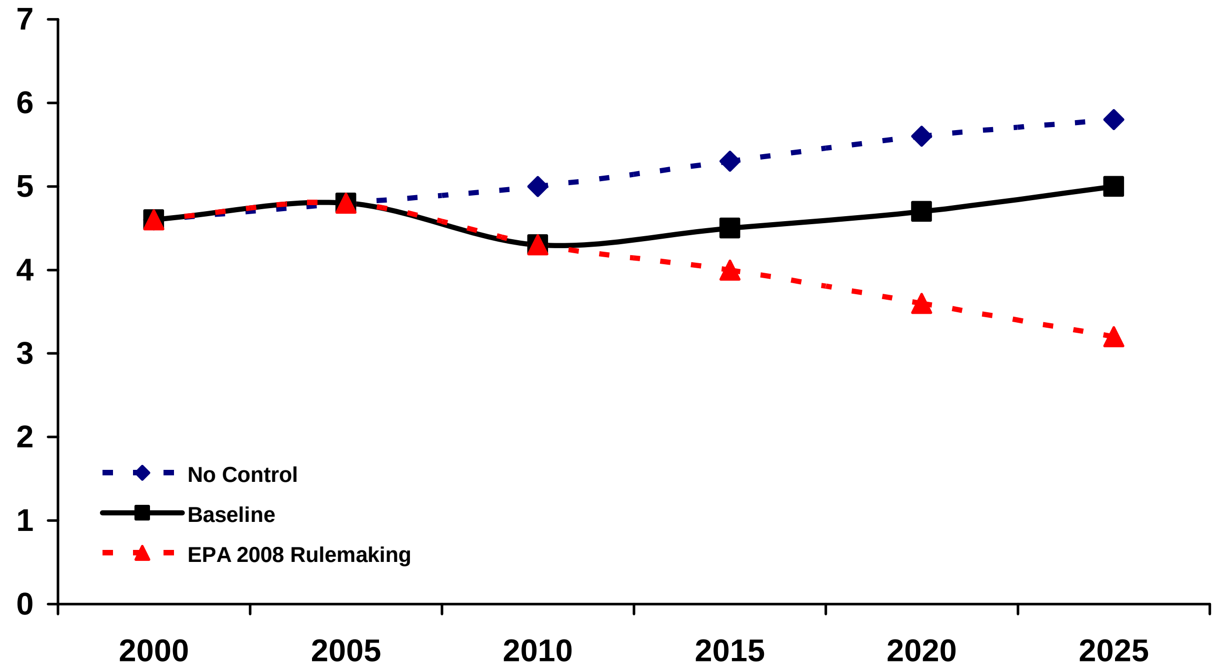


Figure I - 4
Estimated Statewide Locomotive PM Emissions and Emissions Reductions
(Tons/Day – Assumes 1 percent Annual Growth Rate)



C. Summary of Efforts to Reduce Non-Locomotive Railyard Emissions

1. Heavy-Duty Diesel Trucks

The ARB has approved three regulations to reduce new and existing heavy-duty diesel truck emissions. In 2005, the 18 major railyard HRAs estimated heavy-duty diesel truck emissions within the railyards at about 31 tons per year. By 2020, the three ARB truck regulations discussed below are estimated to reduce the 18 major railyards heavy-duty diesel trucks emissions on average by up to 90 percent or more. Below are brief summaries of the federal and ARB new and existing heavy-duty diesel truck regulations.

New ARB and U.S. EPA Heavy-Duty Diesel Truck Regulations

Both ARB and U.S. EPA have adopted emission standards for new 2007-2010 and subsequent model year on-road heavy-duty diesel truck engines. These standards represent a 90 percent reduction of NOx emissions, 72 percent reduction of non-methane hydrocarbon emissions, and a 90 percent reduction of PM emissions compared to the 2004 emission standards. DPFs are required on new heavy-duty diesel trucks beginning in 2007, and SCR or equivalent aftertreatment is required on new heavy-duty diesel trucks beginning in 2010.

ARB Regulation for Port and Intermodal Railyard Drayage Diesel Trucks

In 2007, the Board approved a port and intermodal railyard drayage truck fleet modernization program that will reduce existing heavy-duty truck diesel PM emissions by 86 percent by January 1, 2010 and up to 90 percent or more by January 1, 2014, and NOx emissions by nearly 56 percent by January 1, 2014. There are an estimated 20,000 heavy-duty diesel trucks operating regularly at ports and intermodal railyards.

ARB Statewide Diesel Truck and Bus Regulation

The Board approved a statewide regulation for existing diesel trucks and buses on December 12, 2008. The proposed regulation would reduce diesel PM and NOx emissions from existing statewide on-road heavy-duty diesel-fueled vehicles that are not covered by the U.S. EPA/ARB new diesel truck regulation or the ARB port and intermodal existing drayage truck regulation. The goals of the approved regulation are:

- By 2014, PM emissions are to be no higher than a 2007 model year engine with a diesel particulate filter.
- By 2023, NOx emissions are to be no higher than a 2010 model year engine.

2. ARB Regulation for Cargo Handling Equipment (CHE) Emissions

In 2005, the Board approved a regulation that requires the control of emissions from more than 4,000 pieces of mobile cargo handling equipment, such as yard trucks, cranes, and forklifts that operate at ports and intermodal railyards. The ARB CHE regulation took effect on January 1, 2007. This regulation is expected to reduce diesel CHE PM and NOx emissions by up to 80 percent by 2020.

3. ARB Regulation for Transport Refrigeration Units (TRUs) Emissions

The Board approved a regulation applicable to refrigeration systems powered by integral internal combustion engines used on trucks, trailers, railcars, and shipping containers. The regulation became effective on December 10, 2004, and implementation will be phased-in beginning on December 31, 2008. The ARB regulation is estimated to reduce TRU diesel PM emissions by about 65 percent in 2010 and up to 92 percent by 2020.

4. ARB Regulation for Tier 4 Off-Road New Engine Emission Standards

In 2004, the ARB and U.S. EPA adopted a fourth phase of emission standards (Tier 4). New off-road engines are now required to meet aftertreatment-based exhaust standards for PM and NOx starting in 2011. The new Tier 4 offroad engine standards will achieve a reduction of more than 90 percent over current levels by 2020, putting off-road engines on a virtual emissions par with on-road heavy duty engines.

D. Railyard Mitigation Plans

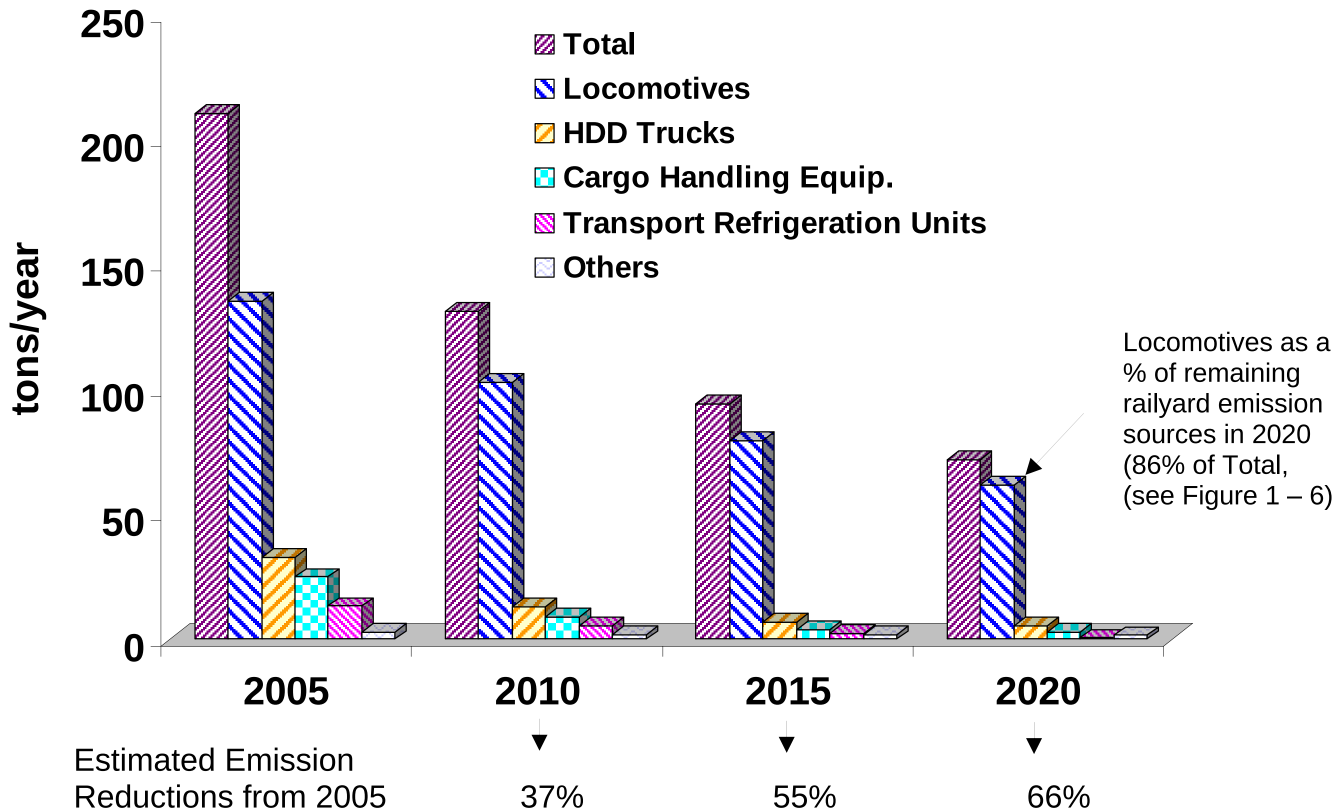
Under the 2005 Statewide Railroad Agreement, UP and BNSF are responsible for developing mitigation plans to reduce railyard diesel PM emissions. The mitigation plans identify required and voluntary measures to reduce diesel PM emissions and public health impacts to surrounding communities.

Based on a technical assessment of UP and BNSF railyard mitigation plans, staff estimates that both existing regulatory and voluntary railroad measures for the 18 railyards will provide an average reduction of over 37 percent in railyard diesel PM emissions by as early as 2010, 55 percent by 2015, and 66 percent by 2020.

1. Estimated Railyard Diesel PM Emissions 2005 to 2015

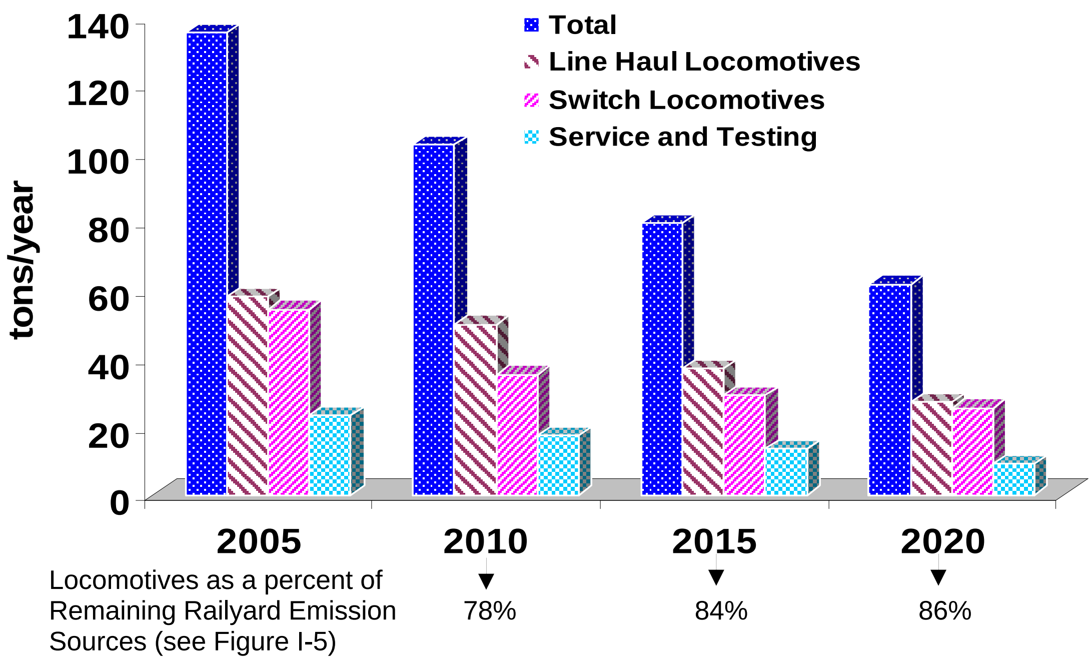
Staff estimates that existing regulatory and voluntary railroad measures will reduce railyard diesel PM emissions from 210 tons per year in 2005 to 94 tons per year in 2015. In 2015, locomotives would continue to represent the largest source of remaining railyard diesel PM emissions at about 80 tons per year or about 84 percent. Non-locomotive sources (i.e., trucks, cargo handling equipment, TRUs, and others) would contribute to the remaining 14 tons per year or about 16 percent. See Figure I - 5 and 6 for the 2005 railyard estimated diesel PM emissions and estimated railyard mitigation plan reductions.

Figure I - 5
Estimated Diesel PM Emissions for 18 Major Railyards* from 2005 to 2020



* BNSF Hobart, UP/ICTF Dolores, BNSF San Bernardino, UP Colton, UP Commerce, UP City of Industry, UP LATC, UP Mira Loma, BNSF Commerce Eastern, BNSF Sheila, BNSF Watson, UP Oakland, BNSF Richmond, UP Stockton, BNSF Stockton, BNSF San Diego, BNSF Barstow, and UP Roseville railyards. For UP Roseville railyard, ARB staff assumed that between 2010 and 2020 there is 50% reduction in diesel PM emissions due to fleet turn over and the remanufacturing PM reductions prescribed in the 2008 U.S.EPA locomotive rulemaking.

Figure I - 6
Projected Locomotive Diesel PM Emissions* for 18 Major Railyards from 2005 to 2020



* ARB staff assumed that 55% of the service and testing emissions are from line haul locomotives and 45% are from switch locomotives.

2. Estimated Railyard Cancer Risks in 2005

Based on the 18 railyard health risk assessments, staff determined that railyard diesel PM emissions resulted in significant local and regional excess cancer risks. Maximum individual cancer risks (MICRs) were as high as a 500 to 2,500 in a million for four railyards, 250 to 500 in a million for six railyards, and 40 to 250 in a million for eight railyards. The four Commerce railyards combined were estimated to be responsible for cancer risks in excess of 10 in a million for a population of nearly 1.3 million. The railyard diesel PM cancer and non-cancer health effects are considered significant, and will require accelerated and aggressive actions to reduce public exposure expeditiously.

3. Estimated Railyard Diesel PM Cancer Risks in 2015

Staff estimates that railyard mitigation plan diesel PM emission reductions will lower maximum individual cancer risks (MICR), in nearly all of the 18 railyards, from a range between 40 to 2,500 in a million to between 10 and 300 in a million by as early as 2015. Further, there would also be corresponding reductions in the population exposure to greater than 10 in a million cancer risks.

E. Key Terms

Baseline: A characterization of current conditions.

BNSF Railway (BNSF): One of two Class I railroads that operate within California. BNSF has over 6,000 locomotives (about ¼ of national locomotives) that operate within 28 states, predominately west of Chicago, Ilinois.

Brake horsepower (bhp-hr): Means the sum of the alternator/generator input horsepower and the mechanical accessory horsepower, excluding any power used to circulate engine coolant, circulate engine lubricant, or to supply fuel to the engine.

CARB Diesel: Diesel fuel formulated to meet the specification adopted in 2005 by the Air Resources Board (Sulfur: <15 ppmw; Aromatics: 10% by volume). CARB diesel is estimated to provide 14 percent PM and 6 percent NOx emission reductions beyond U.S. EPA ultra low sulfur (15 pmmw) and nonroad (500 ppmw) diesel fuels.

Cargo Handling Equipment (CHE): Container cargo, which is the most common type of cargo at ports and intermodal rail yards, requires equipment such as yard trucks, rubber-tired gantry (RTG) cranes, top picks, side picks, forklifts, and straddle carriers.

Classes or Categories of Railroads: A revenue-based definition of categories of railroads found in the regulations of the Surface Transportation Board (STB). The STB's accounting regulations group rail carriers into three classes for purposes of accounting and reporting (49 CFR Part 1201 Subpart A). See Appendix D for publication “Railroad Service” and “Freight Railroads” Operating in California.

- **Class I Railroads**: As determined annually by the Surface Transportation Board, a Class I railroad has annual gross operating revenues greater than about $319 million (2006). There are currently seven Class I railroads operating in North America: UP, BNSF, Canadian Northern (CN), Canadian Pacific (CP), CSX, Norfolk Southern (NS), and Kansas City Southern (KCS).

- **Class II Railroads**: As determined annually by the Surface Transportation Board, a Class II railroad has annual gross operating revenues between about $25 and $319 million (2006). There are two Class II railroads that operate on a regular basis in California, but are headquartered outside the state: Central Oregon and Pacific Railroad (CORP) and Arizona and California Railroad (ARCZ).

- **Class III Railroads**: As determined annually by the Surface Transportation Board, a Class III railroad has annual gross operating revenues less than about $25 million (2006). There are more than twenty Class III railroads that include, but are not limited to: Pacific Harbor Lines (PHL), San Joaquin Valley Railroad (SJVRR), California Northern Railroad (CFNR), Sierra Northern Railroad (SNR), Central California Traction (CCT), Modesto Empire Traction (MET), McCloud Railway, etc.

Cost-Effectiveness: Cost-effectiveness is a measure of the dollars provided to a project for each ton of covered emission reductions. In general, it is determined by dividing the annual cost of the project by the annual surplus emission reductions that will be achieved by the project. The calculation methodology used in this document is cosistent with the ARB Carl Moyer Program. For locomotive options, an additional calculation methodology is presented that splits the cost between NOx and PM, and presents the results as dollars per pound of NOx or PM, as appropriate. See appendices..

Diesel Particulate Matter (Diesel PM): The particles found in the exhaust of diesel fueled compression ignition engines. Diesel PM may agglomerate and adsorb other species to form structures of complex physical and chemical properties. In 1998, the Board identified diesel PM as a toxic air contaminant (TAC)

Diesel exhaust is a complex mixture of thousands of gases and fine particles that contain more than 40 identified toxic air contaminants (TACs). These include many known or suspected cancer-causing substances, such as benzene, arsenic and formaldehyde.

Diesel Particulate Filter (DPF): An emission control technology that reduces diesel PM emissions by directing the exhaust through a filter that physically captures particles but permits gases to flow through. Periodically, the collected particles are either physically removed or oxidized (burned off) in a process called regeneration.

Drayage Truck: Diesel-fueled, heavy-duty trucks with a gross vehicle weight rating (GVWR) of 33,000 pounds or greater. Drayage trucks transport containers, bulk, and break-bulk goods to and from ports and intermodal rail yards to other locations. ARB staff estimates that there are approximately 100,000 drayage trucks statewide, and nearly 20,000 of them frequently service ports and rail yards.

Forklifts: Used at both container facilities and bulk cargo facilities, forklifts are industrial trucks used to hoist and transport materials by means of one or more steel forks inserted under (or in the case of steel coils, in the middle of) the load. Forklifts are extremely diverse in both their size and custom cargo handling abilities. While they are designed to move and/or lift empty cargo containers or stacked or palletized cargo, they can also be designed to move or rotate (flip) truck chassis.

Forklift engines can be powered by either electric motors or internal combustion engines, such as compression ignition (i.e., diesel or natural gas) or spark ignition (i.e., gasoline or propane) engines. Compression ignition forklifts are usually designed for higher lift capacity than their electric or spark ignited counterparts, and are therefore more likely to be used in cargo handling operations. The cargo handling forklifts used at ports and intermodal rail yards have a horsepower range of about 45 to 280 horsepower. There are approximately 460 forklifts at California's ports and intermodal railyards.

Gen-Set Switch Locomotive: A locomotive that has been certified by U.S. EPA and verified by ARB as an ultra-low emitting switch locomotive (ULESL). A gen-set locomotive, to date, is powered by one or more nonroad engines of less than 1,006 horsepower, instead of one large diesel fuel powered locomotive engine. They are locomotives designed or used solely for the primary purpose of propelling railroad cars a short distance, and are presently built up to 2,100 horsepower utilizing three nonroad 700 horsepower engines.

Green Goat (Electric Hybrid) Switch Locomotive: An advanced technology battery hybrid switch locomotive that has been certified by U.S. EPA and verified by ARB as a ULESL. A Green Goat is a battery-dominant hybrid switch locomotive powered by a small generator set diesel engine of 90 to 350 horsepower. The Green Goat generator produces energy that is stored in a large bank of up to 330 lead acid batteries. This energy can be used to produce the equivalent of 1,000 to 2,000 tractive horsepower for switch locomotive operations, primarily within a railyard.

High Horsepower Locomotives: Locomotives powered by engines greater than 3,800-horsepower. Electromotive Diesel (EMD) and General Electric (GE) both build interstate line haul locomotives 4,000 horsepower or greater.

Hump Yard: A railroad classification yard in which the classification of cars is accomplished by pushing them over a summit, known as a "hump," beyond which they run by gravity, into a group of tracks below in a bowl. Each track in the bowl has been designated as a particular track for the formation of a specific train. Once the requisite number of cars are accumulated on the specific track, the locomotives are brought to couple with the line of railcars to form a completed train at the end of the bowl, or the Trim Yard.

Hybrid: The use of two or more distinct power sources to do work.

Interstate Line Haul Locomotive: Generally newer (built 1995 and later) high horsepower (greater than 4,000 horsepower) locomotives that typically operate over long distances and many states. Staff believes most interstate line haul locomotives typically operate significantly less than 50 percent of annual fuel consumption, annual hours of operation, or annual rail miles traveled within California. An interstate line haul locomotive can be designated to regional and local service, but this is the exception rather than typical practice. On a typical trip between Chicago and Los Angeles, an interstate line haul locomotive may operate in California only about 10 to 20 percent of the trip.

Intrastate Locomotives: Locomotives that operate within California for which at least 90 percent of annual fuel consumption, annual hours of operation, or annual rail miles traveled occur within California. Intrastate locomotives are typically switch locomotives (1,006-2,300 horsepower), but a number of smaller medium horsepower locomotives (2,301 to 4,000 horsepower) locomotives can meet this definition.

Locomotive: Pursuant to 40 CFR Part 92, 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. The following other equipment are not locomotives (see 40 CFR parts 86 and 89 for this equipment):

(1) Equipment designed for operation both on highways and rails are not locomotives.

(2) Specialized railroad equipment for maintenance, construction, post accident recovery of equipment, and repairs; and other similar equipment, are not locomotives.

(3) Vehicles propelled by engines with total rated horsepower of less than 750 kW (1006 hp) are not locomotives (see 40 CFR parts 86 and 89 for this equipment), unless the owner (including manufacturers) chooses to have the equipment certified under the requirements of this part. Where equipment is certified as a locomotive pursuant to this paragraph (3), it shall be subject to the requirements of this part for the remainder of its service life. For locomotives propelled by two or more engines, the total rated horsepower is the sum of the rated horsepowers of each engine.

Low Emitting Locomotive (LEL) MHP Locomotive Engines: LEL MHP locomotive engines are advanced new four or two stroke diesel powered MHP engines that are smaller but have equivalent horsepower and are significantly less emitting, with equal or better than Tier 2 locomotive emissions levels. LEL engines have NOx and PM emissions levels when tested pursuant to 40 CFR Parts 92 and 1033 as low as 4.0 g/bhphr and 0.1 g/bhphr, respectively. Being smaller and less emitting, LEL MHP engines may potentially enable the use of DPF and SCR retrofits in the future.

Low Horsepower Locomotives: Locomotives powered by engines less than 1,006-horsepower and subject to 40 CFR Part 89 offroad engine emissions standards. Within the rail industry, these smaller locomotives are sometimes referred to as “industrial” or “critters”.

Maximum Individual Cancer Risk (MICR): MICR is the estimated probability of a potential maximally exposed individual contracting cancer as a result of residential exposure to toxic air contaminants over a duration of 70 years.

Medium Horsepower (MHP) Locomotives: Typically, older locomotives powered by a single medium speed diesel fueled engine rated between 2,301 and 4,000 horsepower. Staff believes there are three subcategories of MHP locomotives: 1) 2,301 to 2,999 horsepower - typically large switchers and local road service, 2) 3,000 to 3,299 horsepower – typically helpers and short haulers, and 3) 3,300 to 4,000 horsepower – typically intrastate line haul locomotives. Many of the 3,000 or greater horsepower locomotives may have served as interstate line haul locomotives when they were initially built. This category of locomotives is not necessarily consistent with railroad terminology or how locomotives are used, but it is functional for the purposes of this document.

Option: A technological, operational, or physical measure that can potentially reduce locomotive and railyard emissions.

Passenger Locomotive: Means a locomotive designed and constructed for the primary purpose of propelling passenger trains. In California, passenger locomotives main propulsion engine averages about 3,000 horsepower. Most passenger locomotives are also equipped with head end power (HEP) or hotel power, about a 500 horsepower onboard generator, to provide power to the passenger cars of the train for such functions as heating, lighting and air conditioning.

Power Assembly (Locomotive): Means the components of an engine in which combustion of fuel occurs, and consists of the cylinder, piston and piston rings, valves and ports for admission of charge air and discharge of exhaust gases, fuel injection components and controls, cylinder head and associated components.

Railyard: A system of tracks within defined limits provided for the making up of trains, storing of cars, and other purposes. A system of tracks branching from a common track.

Rated (Locomotive) Horsepower: Means the maximum horsepower output of a locomotive engine in use.

Reefer Racks: Are electrified refrigerated cargo container racks. Containers are stacked and plugged in. The racks provide power and monitor refrigerated containers.

Remanufacture: Pursuant to 40 CFR Part 92.2, means:

(1)(i) To replace, or inspect and qualify, each and every power assembly of a locomotive or locomotive engine, whether during a single maintenance event or cumulatively within a five year period; or

(ii) To upgrade a locomotive or locomotive engine; or

(iii) To convert a locomotive or locomotive engine to enable it to operate using a fuel other than it was originally manufactured to use; or

(iv) To install a remanufactured engine or a freshly manufactured engine into a previously used locomotive.

Repowered Locomotive: Means a locomotive that has been repowered with a freshly manufactured engine (Pursuant to 40 CFR Part 92.2).

Retrofit: In this document, an engine "retrofit" includes (but is not limited to) the addition of new and better pollution control aftertreatment equipment to diesel fueled or alternative fueled (e.g., LNG) engines.

Rubber-tired gantry cranes (RTG): Very large cargo container handlers that have a lifting mechanism mounted on a cross-beam supported on vertical legs which run on rubber tires. While the propulsion of the crane is very slow (about three miles per hour), the lifting mechanism can move quickly, and is therefore able to load and unload containers from yard trucks or from stacks at a very fast pace. RTG cranes typically have a horsepower range of about 200 to 1,000 horsepower. There are approximately 300 RTG cranes at California's ports and intermodal rail yards. UP and BNSF have about 67 RTGs at the eight largest intermodal railyards in California.

Selective Catalytic Reduction: A control technology that can convert nitrogen oxides (NOx), with the aid of a catalyst, into diatomic nitrogen, (N_2), and water (H_2O). An SCR injects urea (32% of an aqueous solution) into the engine exhaust as ammonia (NH_3) to react with with and reduce NOx emissions to N_2 and H_20.

Side Handler: Like the top handler, side handlers (or side picks) are used to lift and stack cargo containers. A side handler looks very similar to a top pick, but instead of grabbing the containers from the top, the boom arm extends the width of a container to lift it from the front face (or side). Side handlers are most often used to lift empty containers; however, some are manufactured to lift loaded containers. Side handlers have a horsepower range of about 120 to 400 horsepower, with most being between 160 and 250 horsepower.

Switching: Switching service consists of moving railcars from one track to another track or to different positions on the same track. Switching includes the moving of railcars in the make-up and break-up of trains, moving of railcars on industrial switching tracks or interchange tracks, and the general movement of railcars within terminals or at junctions.

Switch (Yard) Locomotive: Based on the 1998 and 2008 U.S. EPA locomotive rulemakings definitions, locomotives with engines that produce between 1,006 and 2,300 horsepower. Switch locomotives are typically four axle, for a tighter turning radius within railyard tracks, but some can be six axle. Switch locomotives are typically used to push railcars together to form trains within railyards, but can also be used to power local and regional service trains.

Technical Feasibility: Means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social, and technological factors.

Tiers – U.S. EPA Locomotive and Nonroad Engine Emission Standards:

- **Exempt Locomotives (U.S. EPA):** Pursuant to 40 CFR Part 92, any locomotive built prior to 1973, less than 1,006, horsepower, any locomotive operated by a Class 3 railroad or small business, and all electric or historic steam locomotives.

- **Pre-Tier 0 Locomotives:** Locomotives that are expressly exempt under U.S. EPA locomotive regulations (i.e., built before 1973, less than 1,006 horsepower, owned and operated by a small business, steam, or historic) or were built between 1973 and 1999 but have not been remanufactured yet to meet U.S. EPA Tier 0 locomotive emissions standards. This definition is an ARB created category of locomotives not formally recognized in U.S. EPA's locomotive rule.

- **Tier 0 Locomotives:** Built new in 2000 and 2001 model years or remanufactured (typically locomotives built from 1973-1999) to meet U.S. EPA locomotive Tier 0 emission standards. U.S. EPA Tier 0 locomotive NOx and PM emissions standards are: Line haul locomotives: NOx: 9.5 g/bhp-hr. PM: 0.60 g/bhp-hr. Switch locomotives: NOx: 14.0 g/bhp-hr PM: 0.72 g/bhp-hr.

- **Tier 1 Locomotives:** Built new in 2002 to 2004 to meet U.S. EPA Tier 1 locomotive emission standards. U.S. EPA Tier 1 locomotive NOx and PM emissions standards are: Line Haul Locomotives: NOx: 7.4 g/bhp-hr. PM: 0.22 g/bhp-hr. Switch Locomotives: NOx: 11.0 g/bhp-hr. PM: 0.54 g/bhp-hr.

- **Tier 2 Locomotives:** Built new in 2005 to 2012 model years to meet U.S. EPA Tier 2 locomotive emissions standards. U.S. EPA Tier 2 locomotive NOx and PM emissions standards are: Line Haul Locomotives: NOx: 5.5 g/bhp-hr. PM: 0.20 g/bhp-hr. Switch Locomotives: NOx: 8.1 g/bhp-hr. PM: 0.24 g/bhp-hr.

- **Tier 3 Locomotives:** Built new in 2012 to 2014 model years to meet U.S. EPA Tier 3 locomotive emissions standards. U.S. EPA Tier 3 locomotive NOx and PM emissions standards are: Line Haul Locomotives: NOx: 5.5 g/bhp-hr. PM: 0.10 g/bhp-hr. Switch Locomotives: NOx: 5.0 g/bhp-hr. PM: 0.10 g/bhp-hr.

- **Tier 4 Locomotives:** Built new in 2015 and later model years to meet U.S. EPA Tier 4 locomotive emission standards. U.S. EPA Tier 4 locomotive NOx and PM emissions standards are: Line Haul Locomotives: NOx: 1.3 g/bhp-hr. PM: 0.03 g/bhp-hr. Switch Locomotives: NOx: 1.3 g/bhp-hr. PM: 0.03 g/bhp-hr.

- **Tier 3 Nonroad Engines:** Pursuant to 40 CFR Part 89.112 requirements. Tier 3 nonroad engines between 600 and 750 horsepower are required to meet a NOx standard of 3.0 g/bhp-hr and a PM standard of 0.15 g/bhp-hr by 2006.

- **Tier 4 Nonroad Engines:** Pursuant to 40 CFR Part 89.112 requirements. Tier 4 nonroad engines between 175 and 750 horsepower are required to meet a NOx standard of 0.3 g/bhp-hr phased-in between 2011 and 2014, and a PM standard of 0.01 g/bhp-hr by 2011.

Top Handler: Another very common type of container handling equipment

is the top handler. Also known as top picks, top handlers are large truck-like vehicles with an overhead boom which locks onto the top of containers in a single stack. They are used within a terminal to stack containers for temporary storage and load containers onto and off of yard trucks. Top handlers are capable of lifting loaded cargo containers weighing as much as 45,000 pounds. Top handlers have a horsepower range of about 250 to 400 horespower, with most being between 250 and 350 horsepower.

Transport Refrigeration Unit (TRU): means refrigeration systems powered by integral internal combustion engines designed to control the environment of temperature sensitive products that are transported in trucks, trailers, railcars, and shipping containers. TRUs may be capable of both cooling and heating.

Ultra Low Emitting Locomotive (ULEL): Pursuant to the 1998 Agreement between ARB and UP and BNSF regarding the "Locomotive NOx Fleet Average Emissions Program for the South Coast Basin", through 2011 means a locomotive (based on the line haul locomotive duty cycle) with a NOx emission level of less than 4.0 g/bhp-hr, and for 2012 through 2014 means a locomotive (based on the line haul locomotive duty cycle) with a NOx emission level less than 3.0 g/bhp-hr.

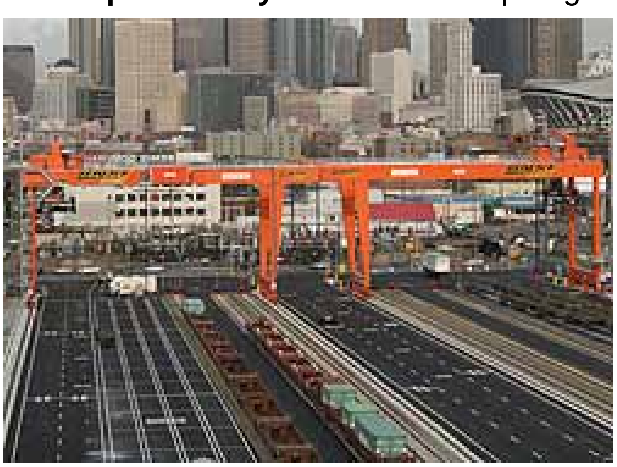
Ultra Low Emitting Switch Locomotive (ULESL): An advanced technology switch locomotive certified by U.S. EPA and verified by ARB, pursuant to 40 CFR Part 92 to meet or exceed 3.0 g/bhphr NOx and 0.1 g/bhphr PM. As of October 2008, a ULESL includes: gen-set, diesel battery electric (Green Goat), or LNG switch locomotives.

Union Pacific Railroad (UP): One of two Class I railroads that operates within California. UP operates over 8,000 locomotives (about one-third of the 25,000 national locomotives) within a 23 state system, predominately west of Chicago, Ilinois.

VDECS: **V**erified **D**iesel **E**mission **C**ontrol **S**ystem

- A Level 1 VDECS is a verification is for those technologies achieving at least 25 percent or greater reduction in particulate matter.
- A LEVEL 2 VDECS is a verification is for those technologies achieving at least 50 percent or greater reduction in particulate matter.
- A Level 3 VDECS is a verification is for those technologies achieving at least an 85 percent or greater reduction in particulate matter or less than 0.01 g/bhp-hr emission level.

Wide Span Gantry Crane: Wide span gantry (WSG) cranes travel on rails to lift and stack container cargo. Compared to rubber tired gantry cranes, WSG cranes are wider, are driven by electrical power, and have a higher traveling speed while handling cargo. WSG cranes are not only larger but also faster than rubber tired gantry cranes which allows them to process more container cargo faster and gives container handling facilities (like intermodal railyards) higher stacking densities and greater lift capacities. As WSG cranes are driven by electrical power



they are typically much more quiet than rubber tired gantry cranes, but they also have no direct on-site emissions.

Yard Trucks and Hostlers: Yard trucks are also known as yard goats, utility tractor rigs (UTRs), hustlers, yard hostlers, and yard tractors. Yard trucks are very similar to heavy-duty on-road truck tractors, but the majority are equipped with off-road engines. Yard trucks are designed for moving cargo containers. They are used at container ports and intermodal rail yards as well as distribution centers and other intermodal facilities. Containers are loaded onto the yard trucks by other container handling equipment, such as rubber-tired gantry cranes, top picks, or side picks, and they are unloaded the same way. In addition to loading and unloading operations, yard trucks are used to move containers around a facility (yard) for stacking and storing purposes.

II. LOCOMOTIVE OPTIONS

This chapter discusses the potential options to accelerate further emission reductions from locomotives. These emissions reductions could also provide reductions in risk from exposure to diesel PM, particularly around railyards. For purposes of this analysis, we have divided locomotives into three groups: switch locomotives, medium horsepower (MHP) locomotives, and interstate line haul locomotives. The groupings represent three generally different uses for locomotives within California. The following sections describe each type of locomotive and the potential options to accelerate further locomotive emissions reductions.

There are three major categories of locomotives UP and BNSF operate in California. The first category is switch (or yard) locomotives with between 1,006 and 2,300 horsepower. The second category is medium horsepower (MHP) locomotives with between 2,301 and 3,800 horsepower. The third category is interstate line haul locomotives with between 3,801 and 6,000 horsepower.

Switch locomotives typically meet ARB's CARB diesel fuel regulation definition of an "intrastate" locomotive by operating 90 percent or more of the time in California. Many of the MHP locomotives meet the "intrastate" definition, especially smaller MHP freight and passenger locomotives. The remaining MHP locomotives typically operate between 50 and 90 percent of the time within California. Finally, interstate line haul locomotives typically operate less than 50 percent of the time within California. An interstate line haul locomotive on a typical run from Chicago to Los Angeles may operate within California only about 15 percent of the trip. There are examples where a few interstate line haul locomotives have been assigned to operate in a particular area within California, but this is the exception rather than the norm.

A. Switch Locomotives

Switch locomotives are primarily used to put rail cars together to form trains within or around a railyard. They are also referred to as "yard" locomotives or "switchers." Switchers primarily have four axles to allow for a tight-turning radius within railyards. However, larger switchers that put larger trains together can employ up to six axles (e.g., hump and trim switchers).

1. Types of Switch Locomotives

U.S. EPA defines a switch locomotive as having between 1,006 and 2,300 horsepower. Larger switch locomotives that typically range between 2,000 and 2,300 horsepower in California may also be used, to a certain extent, for local short haul service. Switch locomotives less than 1,006 horsepower are referred to as "industrial" or "critters" and are expressly exempt from U.S. EPA locomotive emissions standards. Industrial locomotives are not addressed in this document as there only about 100 operating in operation within the state, and consume on average less than 25,000 gallons of diesel fuel annually.

There are generally four distinct types of switch locomotives operating in California. There are the traditional large single engine diesel switch locomotives, multi-engine gen-set locomotives, liquefied natural gas (LNG) locomotives, and battery electric hybrid locomotives. The three latter types of locomotives are referred to as ultra low-emitting switch locomotives (ULESL). [5]

In 2008, staff estimates that there are about 244 intrastate UP and BNSF switch locomotives operating in California, with about 139 operating in the South Coast Air Basin. The switch locomotive estimates are based on documentation provided by both UP and BNSF for the intrastate locomotive inventories, health risk assessment emission inventories, and ARB diesel fuel regulation for intrastate locomotives. Primarily as a result of the 1998 ARB/Railroad Agreement, 76 of the 92 intrastate ULESLs are operating in the South Coast Air Basin.

The four types of switch locomotives are described in the following subsections.

Single Engine Diesel Switch Locomotives

Historically, a switch locomotive has been powered by a large single diesel engine manufactured by either EMD or General Electric. In California, the average age of a UP and BNSF conventional single engine switch diesel-electric locomotive is about 40 years old. In 1998, U.S. EPA established national emission standards for 1973 and later locomotives. Tier 0 standards applied to locomotives originally manufactured between 1973 and 2001. The Tier 0 standards apply upon the remanufacturing of the locomotives built between 1973 and 1999. These locomotives were built prior to the new Tier 0 locomotive emission standards for 2000 and 2001 model years. However, there was no explicit requirement that 1973 to 1999 locomotive engines be remanufactured on any defined schedule. In addition, U.S. EPA emission standards do not apply to locomotives manufactured before 1973.

As shown in Table II-1, UP and BNSF operate about 152 intrastate older switch locomotives in California. Of these 152 older switchers, UP and BNSF have remanufactured 49 to meet U.S. EPA Tier 0 emissions standards and 103 are pre-Tier 0 or unregulated switch locomotives. Of the 103 unregulated switch locomotives, about 40 were built before 1973 (which are exempt from U.S. EPA regulations) and 63 were built between 1973 and 1999, the latter mostly built between 1973 and 1980. Staff believes that due to the cost of remanufacturing, and the low residual value of older switch locomotives, it is unlikely that many of these remaining 103 older UP and BNSF

[5] ARB staff defines an ultra low emitting switch locomotive (ULESL) as a locomotive that meets or exceeds a NOx emissions limit of 3.0 g/bhp-hr and a PM emissions limit of 0.1 g/bhp-hr. For comparison, older pre-Tier 0 switch locomotives can emit up to or more than 17.4 g/bhp-hr of NOx and 0.7 g/bhp-hr of PM.

switch locomotives will be remanufactured to meet the U.S. EPA Tier 0 emissions standards.

Compared to pre-Tier 0 or unregulated switch locomotives, Tier 0 engines are approximately 20 percent cleaner for NOx emissions, but were allowed under the 1998 U.S. EPA locomotive regulations to have higher PM emissions as a tradeoff for the NOx benefits. While an improvement over pre-Tier 0 switch locomotives, Tier 0 locomotives are still considerably dirtier than currently available options as discussed below.

Gen-Set Switch Locomotives

In recent years, a new switch locomotive technology has been pioneered by the railroads in California and Texas that involves the use of two or three smaller offroad engines mounted on the same chassis to replace a single diesel engine. These new switch locomotives are referred to as gen-set switch locomotives and are much lower emitting than existing older switch locomotives.

UP currently operates 70 intrastate gen-set ULESLs, of which 61 are operating in the South Coast Air Basin, 5 in the San Joaquin Valley, and 4 at UP Roseville. BNSF currently operates 6 intrastate gen-set ULESLs, which are assigned to the Bay Area.

Manufacturers build gen-set switch locomotives with Cummins, Deutz, or Caterpillar Tier 3 nonroad engines. National Railway Equipment Company (NREC) and Railpower (RP) combined have built over 250 new gen-set switch locomotives since 2005. In addition, Motive Power Inc. (MPI), Caterpillar/Progress Rail (PR), and Brookville Corporation have all recently built prototypes of three engine gen-set switch locomotives. The three engine gen-set switch locomotive prototypes are currently being evaluated in field testing.

Gen-set switch locomotives can incur initial additional operational costs. As with the transition to most new technologies, there can be a reduction in operational times versus existing switch locomotives. The operational costs should be reduced as manufacturers and railroad personnel gain more experience with gen-set locomotives.

Gen-set switch locomotives can also provide cost-savings. Gen-set switch locomotives can reduce diesel fuel consumption, as compared to older switch locomotives, by 20 to 40 percent. The fuel savings can potentially offset a portion of the initial capital costs over a 30 year life. The cost-savings would not offset the need for new nonroad engine repowers, estimated to occur about every 15 years.

Liquefied Natural Gas Switch Locomotives

Morrison Knudsen, now Motive Power, built four liquefied natural gas (LNG) switch locomotives in the early 1990s. UP owned two of the LNG switch locomotives, but transferred ownership to BNSF in the mid-1990s. As a result, all four of the LNG switch locomotives are operated by BNSF in the Los Angeles area. BNSF's four LNG switch locomotives are the only active operating LNG switch locomotives in the United States.

Battery Electric Hybrid Switch Locomotives (Green Goats)

Railpower built more than 65 Green Goats, or diesel charged battery-electric hybrids, over the past three years. The Green Goats are being operated in different parts of the country, but primarily in California and Texas. Recently, UP and BNSF shifted predominately to the purchase of gen-set switch locomotives over the battery-electric hybrid switch locomotives, largely due to the greater gen-set operational capabilities and flexibility. The Green Goats are primarily limited to light-duty applications due to the relatively quick draw down of battery stored power under heavier workloads, and the time needed to recharge the Green Goat's 330 lead acid batteries. With a recent set of Green Goat battery fires (five of the 65 units), some railroads chose to convert some of the Green Goats to gen-set switch locomotives. Railpower repaired all of the remaining Green Goats, and have returned all of them to their former service (e.g., UP returned all 11 Green Goats to service in California). There are twelve Green Goats operating in California. UP has ten operating in the South Coast Air Basin and one in the San Joaquin Valley; BNSF has one operating in the South Coast Air Basin. A summary of the types of switch locomotives operating in California and the South Coast Air Basin in 2008 is presented in Table II-1.

Table II-1
Summary of the Types of Switch Locomotives Operating in California and the South Coast Air Basin in 2008

Type of Locomotives	**Number of Locomotives**	
	California	**South Coast Air Basin**
Existing Switch Locomotives		
Pre-Tier 0 Manufactured Before 1973	40	19
Pre-Tier 0 Manufactured 1973 or Later	63	15
Pre-Tier 0 Remanufactured to Tier 0	49	29
Subtotal	**152**	**63**
Ultra Low-Emitting Switch Locomotives		
Gen-Set Diesel	76	61
LNG-Powered	4	4
Battery Electric	12	11
Subtotal	**92**	**76**
Total	**244**	**139**

2. *Switch Locomotive Duty Cycle*

The U.S. EPA locomotive duty cycle assumes switch locomotives idle about 60 percent of the time. This rate of idling does not account for the benefits of idle reduction devices. Some studies suggest that idle reduction devices can reduce switch locomotive idling times by 10 percent or more and line haul locomotive idling times by 3 percent or more. Under the 2005 ARB/Railroad Agreement, idle reduction devices are required to be installed on greater than 99 percent of the intrastate locomotive fleet.

Beyond idling, the U.S. EPA duty cycle assumes switch locomotives primarily operate in the lower locomotive power (notch) settings (i.e., Notch 1-4) for most of the operating times. This duty cycle also reflects the distribution of diesel fuel consumption for a switch locomotive over a range of eight power (notch) settings. On average, UP and BNSF switch locomotives consume up to 140 gallons per day, or up to 50,000 gallons of diesel fuel annually.

3. *Emissions from Switch Locomotives*

In 2005, ARB staff estimated that switch locomotive emissions were responsible for about 5 percent of statewide locomotive PM and NOx emissions, respectively, or about 0.2 tons per day of PM and 9.3 tons per day of NOx. In the South Coast Air Basin, switch locomotive emissions accounted for about 0.1 tons per day of PM and 4.6 tons per day of NOx. Switch locomotive emissions are summarized in Tables II-2 and II-3.

In 2005, diesel PM emissions from the 18 designated railyards were about 0.58 tons per day. Railyard emissions occur from locomotive and non-locomotive diesel emissions sources. The railyard non-locomotive emissions occur primarily from diesel trucks, cargo handling equipment, and transport refrigeration units. In comparison to the total railyard diesel PM emissions of 0.58 tons per day, locomotives generated about 0.38 tons per day or about 65 percent of total railyard diesel PM emissions. Switch locomotives generated about half of the 18 railyard locomotive diesel PM emissions, at about 0.18 tons per day.

Based on the current ARB locomotive emission inventory and the railyard health risk assessments, over 90 percent of the switch locomotive PM emissions occur at the 18 major railyards in California. Many of the 18 major railyards are also located in highly urbanized areas where railyard diesel PM emissions can create significant public health risks.

Table II-2
Summary of the Emissions from Switch Locomotives Operating in California in 2008

Type of Switcher Locomotives	Number of Locomotives	Emissions (tons per day)	
		PM	NOx
Existing Switch Locomotives			
Pre-Tier 0 Manufactured Before 1973	40	0.09	2.2
Pre-Tier 0 Manufactured 1973 or Later	63	0.14	3.4
Pre-Tier 0 Remanufactured to Tier 0	49	0.11	2.2
Subtotal	**152**	**0.34**	**7.8**
Ultra Low-Emitting Switch Locomotives			
Gen-Set Diesel	76	0.018	0.570
LNG-Powered	4	0.001	0.090
Battery Electric	12	0.003	0.037
Subtotal	**92**	**0.022**	**0.7**
Totals	**244**	**0.36 ***	**8.5 ***

* May not add up precisely due to rounding.

Table II-3
Summary of Emissions from Switch Locomotives Operating in the South Coast Air Basin in 2008

Type of Switcher Locomotives	Number of Locomotives	Emissions (tons per day)	
		PM	NOx
Existing Switch Locomotives			
Pre-Tier 0 Manufactured Before 1973	19	0.043	1.04
Pre-Tier 0 Manufactured 1973 or Later	15	0.034	0.82
Pre-Tier 0 Remanufactured to Tier 0	29	0.066	1.27
Subtotal	**63**	**0.14 ***	**3.13 ***
Ultra Low-Emitting Switch Locomotives			
Gen-Set Diesel	61	0.0147	0.456
LNG-Powered	4	0.0012	0.037
Battery Electric	11	0.0027	0.082
Subtotal	**76**	**0.019 ***	**0.58 ***
Totals	**139**	**0.16 ***	**3.7 ***

* May not add up precisely due to rounding.

4. Summary of Options to Reduce Emissions from Switch Locomotives

Staff has identified four potential options to reduce emissions from switch locomotives. These options are summarized below and described in more detail in the following sections.

Option 1: Replace Existing Switch Locomotives with ULESLs

The first option would be to replace the 152 older existing intrastate switch locomotives with ULESLs. The gen-set, battery-dominant electric hybrid (Green Goats), and LNG ULESLs (yard) are technically feasible, thoroughly tested in-use, and commercially available. However, this evaluation is based on using gen-set ULESLs due to their current market dominance and efficacy in California's Class I railroad operations. Upon completion of this option, UP and BNSF would have an estimated 244 ULESLs. Of the 244 ULESLs, 228 would be gen-sets, 12 would be electric hybrids or Green Goats, and 4 would be LNG switchers.

Option 2: Retrofit Gen-Set Switchers with NOx and PM Emission Controls[6]

The second option builds upon the first option. In this option, the 244 ULESLs would be retrofitted with emission control devices to reduce the emissions of NOx and PM at the time of engine overhaul. The emission control devices would be either diesel particulate filters (DPF) for PM and selective catalytic reduction (SCR) for NOx, or both. The DPF and SCR retrofit emissions reductions would be in addition to the ULESL emissions reductions in option 1 above.

Staff estimates that the ULESLs will need engine overhauls about every seven years. A DPF and SCR could be retrofitted onto the ULESL when it comes in to the mechanical shop for an engine overhaul. The DPF and SCR would need to be ARB verified for ULESLs, and also be commercially available. Both DPF and SCR ARB verification and commercial availability could potentially occur within the next seven years. The DPF and SCR retrofits could enable the 244 ULESLs to approach or meet the U.S. EPA Tier 4 switch locomotive emissions standards.

Option 3: Upgrade Tier 3 Nonroad Gen-Set Switchers to Tier 4 Nonroad Engines

The third option would be to replace the 244 Tier 3 nonroad engine ULESLs that had also been retrofitted with both DPF and SCR, with a new Tier 4 nonroad engine. By 2015, a Tier 4 nonroad engine would come built and equipped with both DPF and SCR. Staff estimates that switch locomotive Tier 3 nonroad engine repowers may be needed about every 15 years. In this option, the 244 ULESLs may need to have the Tier 3 nonroad engines repowered for the gen-sets, Green Goats, and LNGs. Rather than repower the Tier 3 nonroad engine ULESLs with new Tier 3 nonroad engines, and DPF and SCR retrofits, the ULESLs could be upgraded to cleaner new Tier 4 nonroad

[6] DPF and SCR technology for gen-set switch locomotives has not demonstrated or ARB verified.

engines. Tier 4 nonroad engines may be able meet emissions levels significantly below the U.S. EPA Tier 4 switch locomotive emissions standards.

Option 4: Remanufacture Older Switch Locomotives to Meet New U.S. EPA Tier 0 "Plus" Locomotive Emissions Standards

In this option, the remanufacture of the 152 older UP and BNSF switch locomotives would be accelerated and expanded to meet U.S. EPA Tier 0 "plus" remanufacture emission standards (See Table II-4). In 2008, staff estimates that UP and BNSF have 103 pre-Tier 0 and 49 Tier 0 switch locomotives. This would be a less aggressive and less costly approach.

Table II-4
2008 U.S. EPA Switch Locomotive NOx Emission Standards

Type	Tier	Date of Original Manufacture	Existing NOx Standard (g/bhp-hr)	New "Plus" NOx Standards New and Remanufactured (g/bhp-hr)	Percent Control When Engine is New or Remanufactured
Switcher locomotives	*Pre-Tier 0*	*Pre-1973 and 1973-1999***	*17.4 **	***N/A***	*32 percent (vs. Tier 0 plus)*
	Tier 0	*2000-2001 and 1973-1999 ***	*14.0*	***11.8***	*16 percent*
	Tier 1	2002 – 2004	11.0	**11.0**	0 percent
	Tier 2	2005-2011	8.1	**8.1**	0 percent
	Tier 3	*2011*	*N/A*	***5.0***	*48 percent (vs. Tier 2)*
	Tier 4	*2015*	*N/A*	***1.3***	*84 percent (vs. Tier 2)*

Note: In most cases, gen-set and electric hybrid switchers have been U.S. EPA NOx emissions certified at levels below 3.0 g/bhphr, without aftertreatment. The LNG units have certification test data below 3.0.
* This is estimated average in-use NOx emissions levels by U.S. EPA in 1998. In-use NOx emissions were estimated to range from 11 to 33 g/bhp-hr.
** 1973-1999 were not built as Tier 0, but can be remanufactured to Tier 0.

Table II-5
2008 U.S. EPA Switch Locomotive PM Emission Standards

Type	Tier	Date of Original Manufacture	Existing PM Standards (g/bhp-hr)	New "Plus" PM Standards Remanufactured or New (g/bhp-hr)	Percent Control When Engine is New or Remanufactured
Switcher locomotives	*Pre-Tier 0*	*Pre-1973 and 1973-1999 ***	*0.41**	***N/A***	*37 percent*
	Tier 0	*2000-2001 and 1973-1999 ***	*0.72*	***0.26***	*64 percent*
	Tier 1	*2002-2004*	*0.54*	***0.26***	*48 percent*
	Tier 2	*2005-2010*	*0.24*	***0.13***	*54 percent*
	Tier 3	*2011*	*N/A*	***0.10***	*58 percent (vs. Tier 2)*
	Tier 4	*2015*	*N/A*	***0.03***	*87 percent (vs. Tier 2)*

Note: In most cases, gen-set, electric hybrid, and LNG switchers have certification test data at levels below 0.15 g/bhphr, without aftertreatment.
* This is estimated average in-use PM emissions levels by U.S. EPA in 1998. In-use emissions PM emissions were estimated to range from 0.2 to 1.0 g/bhp-hr.
** 1973-1999 were not built as Tier 0, but can be remanufactured to Tier 0.

Table II-6 summarizes the four switch locomotive options based on technical feasibility, potential emissions reductions, costs, and cost-effectiveness. The following sections provide the basis for the information in this table.

Table II-6
Options to Further Reduce Emissions from Switch Locomotives

Options	Switch Locomotive Options	Timeframe	NOx (tons/day)	PM (tons/day)	Cost-Effectiveness (NOx+PM)	Capital Costs (millions)
1	Replace 152 older switchers with new ULESLs ($1.5m/unit)	Near Term (up to 5 years)	6.6	0.31	$2-3/lb	$228
2	Retrofit 244 ULESLs with DPF and SCR ($200k/unit)	Mid Term (up to 10 years)	1.0	0.04	$3-5/lb	$49
3	Repower 244 ULESLs new Tier 4 nonroad engines ($200k additional costs vs Tier 3)	Long Term (up to 15 years or more)	0.6	0.01	$6-10/lb	$49
	SUBTOTAL		**8.2**	**0.36**	**$2-10/lb**	**$326**
4	Accelerate the remanufacture 152 pre-Tier 0 (103) and Tier 0 (49) switchers to meet Tier 0 plus standards *	Near Term (up to 5 years)	2.2**	0.22**	$0.6-1/lb	$38

* May take up to 20 years for a older switch locomotive to be remanufactured versus a gen-set switcher remanufacture of about every seven to ten years. ** Assume Tier 0 switchers will be remanufactured to Tier 0 plus standards upon remanufacture and there would not be any accelerated or surplus emissions reductions. This would reduce potential emissions reductions by at least one-third.

5. Analysis of Option 1 – Replacement of Existing Switch Locomotives with Tier 3 Nonroad Gen-Set Switch Locomotives

Technical Feasibility

Manufacturers currently build gen-set switch locomotives with new Tier 3 nonroad engines either from Cummins, Deutz, or Caterpillar. Since 2005, National Railway Equipment Company (NREC) and Railpower (RP) combined have built over 250 new multiple nonroad engine gen-set switch locomotives nationally. Currently, UP and BNSF operate about 76 gen-set switch locomotives in California, as well as a large number in Texas and other states.

Most new gen-set switch locomotives are three nonroad engine packages, but there are also a small number of two and single engine packages. The smaller engine packages are primarily designed for lighter-duty applications and smaller Class 3 and military and industrial railroads.

Motive Power Inc. (MPI), Caterpillar/Progress Rail (PR), and Brookville Corporation also recently built Tier 3 nonroad engine (three) gen-set switch locomotive prototypes. The gen-set switch locomotive prototypes are currently being evaluated in field testing.

Also, efforts are underway to develop a single medium speed engine for switch locomotives that could also achieve ULESL emission levels.

The gen-set, electric hybrid, and LNG ULESLs (yard) are technically feasible, thoroughly tested in-use, and commercially available. However, we will focus this evaluation on gen-set ULESLs due to their current market dominance and efficacy in California's Class I railroad operations.

To date, there have been significant reductions from the ULESLs that have already replaced existing switch locomotives. Table II-7 presents the emission reductions that have already been achieved from the 92 ULESLs.

Table II-7
Estimated Emission Reductions Already Achieved from the Existing 92 ULESLs

Location	ULESL* Switchers	Emission Reductions (tons per day)		Costs (millions)
		NOx	PM	
South Coast	76	3.6	0.17	$114
Rest of State	16	0.7	0.03	$24
Statewide	**92**	**4.3**	**0.20**	**$138**

* ULESLs: 80 gen-sets, 12 electric hybrids, and 4 LNG locomotives.

Potential Emission Reductions

New Tier 3 nonroad engine gen-set switch locomotives are at or below existing ULESL NOx emission levels of 3.0 g/bhp-hr. In addition, gen-set ULESLs meet or exceed PM emission levels of 0.1 g/bhp-hr. Gen-set switch locomotives also consume 20 to 40 percent less diesel fuel than older medium speed single-engine switch locomotives, providing greenhouse gas emissions reductions. With the use of CARB diesel, the ULESLs provide a reduction in both PM and NOx emissions, respectively, over pre-Tier 0 switch locomotive emissions of about 85 percent.

Potential emission reductions are calculated based on a change in the expected emission factors for gen-set locomotives versus pre-Tier 0 locomotives, or Tier 0 locomotives. These emission factors are presented in Table II-8.

Table II-8
Emission Factors Used to Determine
Potential Emission Reductions for Option 1

Type of Locomotive	Number of Locomotives	Emission Factors (g/bhp-hr) NOx	PM
Pre-1973 Switchers	41	17.4	0.72
Pre-Tier 0 Switchers	62	17.4	0.72
Pre-Tier 0 Switchers Remanufactured to Tier 0	49	14.0	0.72
Subtotal	152		
ULESL (Tier 3 Nonroad Engine)	152	3.0	0.10

The potential emission reductions can be determined using the U.S. EPA emission factors. As Table II-9 shows, replacement of the 152 remaining older intrastate UP and BNSF switch locomotives, with new Tier 3 nonroad engine gen-set ULESLs, could provide additional statewide NOx and PM reductions of about 6.6 and 0.31 tons per day, respectively, beyond current UP and BNSF switch locomotive emissions levels.

Table II - 9
Estimated Potential Emission Reductions From Replacement of
152 Remaining Older UP and BNSF Switch Locomotives
With New Gen-Set Switch Locomotives
(Option 1)

Location	Total # of Older Switcher	Pre-1973 Switcher (Exempt)	Pre-Tier 0 Switcher (1973-1999)	Tier 0 Switcher (1973-1999) *	Emission Reductions NOx (tons/day)	PM (tons/day)
South Coast	63	19	15	29	2.8	0.14
Rest of State	89	21	48	20	3.8	0.16
Statewide	**152 ****	**40**	**63**	**49**	**6.6**	**0.30**

* There are three pre-1973 switch locomotives that have been remanufactured to Tier 0.
** At up to $1.5 million per ULESL, total capital costs estimated to be up to $228 million.

Costs

A new Tier 3 nonroad engine gen-set switch locomotive (i.e., ULESL) can reach total costs of up to $1.5 million. Therefore, to replace 152 existing switch locomotives with gen-set switchers could cost as much as $230 million. Details on the costs are presented below.

A single Tier 3 nonroad engine can cost about $50,000. However, adding a new generator, auxiliary generator, cooling system, and other key parts to complete a total "skid mounted engine package" can cost up to $200,000. As a result, a "three engine" gen-set skid mounted package, to provide the propulsion power for a three engine gen-set switch locomotive, can cost between $500,000 and $600,000.

There are additional costs beyond the three engine gen-set package. For example, a control system is needed to serve as the brain to alternate the work evenly over the three engines in the gen-set package. The engine control system can cost between $100,000 and $150,000. A new locomotive cab to meet federal safety standards can cost about $100,000. New traction motors and wheels can cost about $100,000. Onboard equipment such as a GPS, event recorder, and data loggers can also add to the costs. Depending on whether an existing switch locomotive chassis is used, or a new one is built, costs can vary by up to $200,000 or more. All of these costs above combined can add up to as much as $1.5 million for a new gen-set switch locomotive.

With nonroad engine gen-set switch locomotives, railroads can incur significant future engine repower costs. High speed nonroad engines, being worked under the rigors of a locomotive duty cycle, are not designed or built with the life-time durability of a single medium speed locomotive engine. Currently, manufacturers and railroads mechanical staff estimate that the gen-set switch locomotives powered by Tier 3 nonroad engines may need to be completely overhauled in 10 to 15 years.

A medium speed locomotive engine can operate for 50 years or longer. However, a medium speed engine will need to be remanufactured or rebuilt with new fuel injectors, power assemblies, and other components about every seven to ten years at a cost of about $150,000 to $200,000 per remanufacture.

Cost Effectiveness

Cost-effectiveness to replace an older pre-Tier 0 or Tier 0 switch locomotive, with a new gen-set switch locomotive (ULESL) ranges from $2 to $3 per pound. This assumes the gen-set switch locomotive engines operate for at least ten years, and possibly up to 20 years, before there is a need for complete engine repower. A new ULESL gen-set switch locomotive replacement is very cost-effective when compared to other ARB control measures or options. Details of the cost-effectiveness calculations are presented in Appendix E.

6. Analysis of Option 2 – Retrofit of Gen-Set Switchers with NOx and PM Emission Controls

<u>Technical Feasibility</u>

Technical feasibility is an issue for this option. Neither the ARB nor the U.S. EPA has verified any aftertreatment control technologies for PM or NOx on switch locomotives. These control technologies include diesel particulate filters (DPF) for PM or selective catalytic reduction (SCR) for NOx. However, as a mid-term option, DPF and SCR aftertreatment retrofits for use on nonroad engines should be available by as early as 2011. Appendix C summarizes the status of research efforts on locomotive aftertreatment emission controls.

Nonroad engine manufacturers such as Cummins, Deutz, and Caterpillar are already designing and testing aftertreatment systems to meet the future Tier 4 nonroad engine standards. The emphasis is being placed on DPFs, as the federal Tier 4 nonroad PM standard, and the need for DPFs, becomes effective in 2011. SCR NOx control is more technically challenging, but there is also more time to address the Tier 4 nonroad standard for NOx, with the latter being phased-in between 2011 and 2014. However, existing nonroad engine aftertreatment retrofit systems, like DPF and SCR on Tier 3 nonroad engines, will most likely take a lower priority to designing aftertreatment systems for the new Tier 4 nonroad engines.

Staff believes that retrofitting aftertreatment systems onto Tier 3 nonroad engines could potentially affect engine performance, and the aftertreatment could be subject to ongoing operational and maintenance problems. However, in spite of these potential technical challenges, DPF and SCR retrofits may be able to achieve significant potential cost-effective emissions reductions on ULESLs. As a result, it is important to explore this option to provide interim emissions reductions until new Tier 4 nonroad engines, equipped with DPF and SCR, become commercially available by about 2015.

Based on discussions with engine manufacturers and the railroads, staff estimates that gen-set switch locomotives will need engine overhauls in 10 to 15 years. This would provide a potential opportunity to retrofit DPF or SCR, or both, onto Tier 3 nonroad engines in gen-set switch locomotives as part of a normal locomotive maintenance schedule.

Staff believes ARB verification and commercial production of both DPF and SCR retrofits could potentially be achieved for ULESLs within the next couple of years. Based on discussions with ULESL manufacturers and ARB research efforts, staff believes DPF retrofits for ULESLs could receive ARB verification and become commercially available as early as 2010. SCR retrofits for ULESLs would probably not be ARB verified and commercially available until 2012 or later.

Potential Emissions Reductions

Table II-10 presents the staff estimates of the changes in emission factors that would be achieved by retrofitting gen-set switch locomotives with DPF and SCR emission controls.

Table II-10
Emission Factors Used to Determine
Potential Emission Reductions
(Option 2)

Type of Locomotive	Number of Locomotives	Emission Factors (g/bhp-hr)	
		NOx	PM
ULESL (Tier 3 Nonroad Engine)	244	3.0	0.10
ULESL (with DPF and SCR)	244	1.3	0.03

The retrofit of both DPF and SCR onto ULESLs could approach or meet Tier 4 emissions levels. As shown in Table II-11, Option 2 could provide an additional 1.0 and 0.04 tons per day of NOx and PM statewide, respectively, beyond ULESL replacement of 152 switch locomotives. Of the potential statewide emissions reductions, over half would be achieved in the South Coast Air Basin.

Table II-11
Estimated Emission Reductions from
Retrofit of DPF and SCR onto 228 Gen-Set, 12 Electric Hybrid,
and 4 LNG ULESLs
(Option 2)

Location	Retrofit DPF & SCR to ULESL	Emission Reductions (tons per day)		Costs (millions)
		NOx	PM	
South Coast	139	0.6	0.02	$28 *
Rest of State	105	0.4	0.02	$21
Statewide	**244**	**1.0**	**0.04**	**$50 ***

* May not add up precisely due to rounding.

Costs

A DPF and SCR retrofit of a gen-set switch locomotive powered by a Tier 3 nonroad engine is estimated to cost about $200,000. Retrofitting 244 ULESLs with DPF and SCR could cost about $50 million. Details on the derivation of the $200,000 retrofit costs are presented below.

Retrofit of both DPF and SCR onto Tier 3 nonroad engine gen-set or electric hybrid switch locomotives (ULESL) would cost about $200,000 per three engine gen-set switch locomotive. These initial estimates are based on conversations with nonroad engine and gen-set locomotive manufacturers.

Cost-Effectiveness

A UP and BNSF gen-set switch locomotive fleet (ULESL), powered with Tier 3 nonroad engines, as compared to 152 pre-Tier 0 or Tier 0 switch locomotives, could provide NOx and PM emissions reductions of up to 6.6 and 0.31 tons per day, respectively. In comparison, retrofitting a Tier 3 nonroad engine switch locomotive (ULESL), with both DPF and SCR, could provide additional NOx and PM emissions reductions of only up to 1.0 and 0.04 tons per day, respectively.

Replacement of pre-Tier 0 switch locomotives with Tier 3 nonroad engines provides an incremental reduction in mass emissions that is nearly ten times higher than retrofits of Tier 3 nonroad engines both DPF and SCR. However, the *incremental* cost differences are substantially lower for the retrofit of both DPF and SCR on the Tier 3 nonroad engine, at about an estimated additional $200,000, versus a new Tier 3 nonroad engine gen-set switch locomotive that could cost up to $1.5 million.

Both DPF and SCR retrofitted to an existing three engine Tier 3 nonroad package may cost an additional or incremental cost difference of about $200,000. We estimate the cost-effectiveness for a retrofit of both DPF and SCR onto a Tier 3 nonroad three engine package, to be between $3 and $5 per pound, depending on a 10 to 20 year range of useful life.

7. Analysis of Option 3 – Upgrade Gen-Set Switchers to Tier 4 Nonroad Engines

Technical Feasibility

Initial estimates indicate that new gen-set ULESLs built with Tier 3 nonroad engines will require repowers with new nonroad engines in 10 to 15 years, depending on individual locomotive workloads. The frequency of engine repowers is anticipated because nonroad engines are high speed (about 1,800 rpm) and are not designed or built with the durability of a medium speed (about 1,000 rpm) engine. Medium speed engines can operate in a locomotive for up to 50 years or more.

New gen-set ULESLs are predominately powered by three Tier 3 nonroad engines, with each engine rated at less than 750 horsepower, and the total three engine package roughly equivalent to about 2,000 horsepower.

UP ordered and assigned 61 gen-set switch locomotives to the South Coast Air Basin in 2007; in 2008 four more were assigned to UP Roseville and five to the San Joaquin Valley. Also, BNSF ordered and assigned 6 gen-sets to the Bay Area in 2008. All of the 76 UP and BNSF gen-set switch locomotives may be due for complete nonroad engine repowers in 10 to 15 years. In addition, the 12 electric hybrids are powered by Tier 2 or 3 nonroad engines, usually between 90 and 300 horsepower, that could be upgraded to Tier 4 nonroad engines.

The U.S. EPA and ARB Tier 4 nonroad engine standards should be fully implemented for NOx and PM by 2015. U.S. EPA and ARB require Tier 4 nonroad engines to be phased in between 2011 and 2015. Tier 4 nonroad engines of less than 750 horsepower are expected to be built with diesel particulate filters (DPF) by 2011, and selective catalytic reduction (SCR) between 2011 and 2014. New Tier 4 nonroad engine repowers, when the Tier 3 nonroad gen-set switch locomotives engines need to be repowered, should be technically feasible, thoroughly tested, and commercially available as early as 2015.

Potential Emission Reductions

Tier 4 nonroad engine repowers could provide greater emissions reductions than Tier 3 nonroad gen-set switch and electric hybrid locomotive (ULESLs) engines retrofitted with both DPF and SCR. The latter would be equivalent to U.S. EPA Tier 4 locomotive emissions levels of 1.3 g/bhp-hr NOx and 0.03 g/bhp-hr PM. Tier 4 nonroad engine emission standards are even more stringent at 0.3 g/bhp-hr NOx and 0.01 g/bhp-hr PM.

As shown in Table II-12, a Tier 3 nonroad engine retrofitted with DPF and SCR could approach or equal U.S. EPA Tier 4 locomotive emissions standards. New Tier 4 nonroad engine repowers could lower these emissions levels further, as Tier 4 nonroad emissions standards represent a reduction of about 77 percent for NOx and about 65 percent for PM over Tier 4 locomotive emission levels. As shown in Table II-13, however, the actual mass emission reductions are substantially less than those achieved with Option 1 – switch locomotive (ULESL) replacements.

The Tier 4 nonroad engine repowers, with Tier 4 nonroad emissions levels applied to 244 ULESLs powered with Tier 3 nonroad engines and retrofitted with DPF and SCR, could provide additional NOx and PM statewide emissions reductions of up to 0.6 and 0.01 tons per day, respectively. See Table II-13 for further details on the Tier 4 nonroad engine repowers that could potentially provide additional emissions reductions beyond a gen-set switch locomotive retrofitted with both SCR and DPF.

Table II-12
Emission Factors Used to Determine
Potential Emission Reductions
(Option 3)

Type of Locomotive	Number of ULESLs	Emission Factors (g/bhp-hr)	
		NOx	PM
ULESL (retrofitted with DPF and SCR)	244	1.3	0.03
ULESL (repowered with Tier 4 nonroad engines and equipped with DPF and SCR)	244	0.3	0.01

Table II-13
Estimated Emission Reductions from Repowering ULESL
with Tier 4 Nonroad Engines Equipped with DPF and SCR
(Option 3)

Location	Repower ULESLs with Tier 4 Nonroad Engines	Emission Reductions (tons per day)		Incremental Costs (millions)
		NOx	PM	
South Coast	139	0.3	0.006	$28 *
Rest of State	105	0.3	0.004	$21 *
Statewide	**244**	**0.6**	**0.01**	**$50 ***

* May not add up precisely due to rounding.

Costs

Repowering a Tier 3 nonroad engine, with a new Tier 4 nonroad engine equipped with DPF and SCR, is estimated to be about $200,000. This cost would only be an incremental cost increase over the cost of a new Tier 3 nonroad engine repower. Therefore, repowering 244 ULESLs with Tier 4 nonroad engines, built with DPF and SCR, could cost about $50 million. Details on the derivation of the $200,000 incremental costs are presented below.

Gen-set locomotive manufacturers have indicated that a skid mounted Tier 3 nonroad engine package would include a single Tier 3 nonroad engine, new generators, new cooling systems, and other components which could cost up to $200,000. For a “three engine” skid mounted package, these costs could add up to $600,000. Staff assumes that the railroads would be replacing the Tier 3 nonroad engines upon repower in 10 to 15 years.

This option evaluates the incremental cost difference between a required repower with a new Tier 3 nonroad engine versus a repower with a new Tier 4 nonroad engine, the latter equipped and built with DPF and SCR.

Due to the easy design, configuration, and installation of Tier 3 nonroad engines on an existing locomotive platform, gen-set engine manufacturers believe similarly (even with DPF and SCR) that future Tier 4 nonroad engine repowers could potentially be completed within two to three workdays. This approach would significantly minimize locomotive downtime and labor costs to perform engine repowers. Staff has spoken to gen-set locomotive manufacturers who indicate they plan to be able to incorporate future Tier 4 nonroad engines onto the existing gen-set switch locomotive platforms.

Initial estimates to retrofit DPF and SCR onto Tier 3 nonroad gen-set switch locomotive engines are about $65,000 per engine, or about $200,000 for a three engine gen-set switch locomotive. This assumes $200,000 per skid mounted engine package (i.e., engine plus generator package) for a three engine gen-set locomotive that would total about $600,000. We assume adding DPF and SCR would bring the total costs to about $800,000, or about a $200,000 incremental cost difference.

New Tier 4 nonroad engines designed with DPF and SCR could cost less than a retrofitted aftertreatment system, but the base Tier 4 nonroad engine might be more expensive than a Tier 3 nonroad engine. To address these potentially offsetting costs, we chose to use the higher aftertreatment cost number of $200,000. The incremental cost differential between a repower with a new Tier 4 versus new Tier 3 nonroad engine gen-set in a three engine package, is estimated to be about $200,000.

Cost-Effectiveness

A 244 gen-set ULESL fleet powered with three Tier 3 nonroad engines, as compared to 152 pre-Tier 0 or remanufactured Tier 0 switch locomotives and 92 existing ULESLs, could provide NOx and PM emissions reductions of up to 6.6 and 0.31 tons per day, respectively. Retrofits of the 244 ULESLs with both DPF and SCR could provide an additional 1.0 and 0.04 tons per day of NOx and PM emissions reductions, respectively. Beyond both repowering 244 old switchers with new Tier 3 nonroad engine ULESLs, and retrofitting the 244 ULESLs with both DPF and SCR, new Tier 4 nonroad engines could provide additional NOx and PM emissions reductions of 0.6 and 0.01 tons per day, respectively.

A new Tier 3 nonroad three engine skid mounted package would cost about $600,000. A retrofit of both DPF and SCR on to a three engine gen-set package may cost an additional $200,000. A new Tier 4 nonroad three engine package, built with DPF and SCR, may cost about $800,000. There would be no cost difference between a new Tier 3 nonroad engine gen-set package that has been retrofitted with DPF and SCR and a new Tier 4 nonroad engine. The incremental cost difference would be limited to the difference between only a repower of new Tier 3 versus new Tier 4 nonroad engine, which would be about $200,000.

Based on the assumptions above, staff estimates the cost-effectiveness for a Tier 3 to new Tier 4 nonroad three engine package upgrade, based on the new engine cost differences, to be between $6 and $10 per pound, depending on a range of useful life between 10 and 20 years. Also, a case could be made that with no cost differential between an ULESL, retrofitted with both DPF and SCR, and a new Tier 4 nonroad engine, the cost-effectiveness would be zero. Staff has chosen to be conservative in this particular cost-effectiveness calculation.

8. *Analysis of Option 4 – Remanufacture Existing Switch Locomotives to Meet U.S. EPA Tier 0 Plus Emission Standards*

Technical Feasibility

There are a couple of key issues with applying the Tier 0 plus remanufacture approach to switch locomotives. Switch locomotives are not remanufactured as often as interstate line haul locomotives (the latter about every 7 to 10 years). Switch locomotives work predominately in the lower power settings, work fewer hours, and place significantly less stress and work on their engines. As a result, switch locomotives may only be remanufactured about every 10 to 20 years.

Another issue is that the U.S. EPA switch locomotive Tier 0 plus emissions standards are applicable only to switch locomotives remanufactured to meet existing Tier 0 standards. Of UP and BNSF's 152 older switch locomotives, a majority (103) have not been remanufactured to meet U.S. EPA Tier 0 locomotive emissions standards.

Staff believes there may be little economic incentive for railroads to remanufacture older pre-Tier 0 switch locomotives to meet U.S. EPA Tier 0 and subsequently Tier 0 plus locomotive emissions standards. Staff is concerned that older pre-Tier 0 switch locomotives may have little, if any, residual value. As a result, it may be cost prohibitive for railroads to incur switch locomotive remanufacture costs that could potentially exceed the value of the switch locomotive. These same concerns may also apply to switch locomotives remanufactured to Tier 0.

Staff does believe that U.S. EPA Tier 0 plus locomotive emission reduction kits could be adapted or commercially produced for pre-Tier 0 older switch locomotives if there were a sufficient market size. Further, there are about 49 older switch locomotives that have been remanufactured to meet U.S. EPA Tier 0 emissions standards and will be subject to the U.S. EPA Tier 0 plus requirements. Staff assumes the railroads will spend the necessary funds to remanufacture older Tier 0 switch locomotives.

U.S. EPA recently promulgated new switch locomotive emission standards as part of the 2008 rulemaking: older locomotives that had been remanufactured to meet existing Tier 0 emission standards, and new Tier 0 units built between 2000 and 2001, are required to meet new Tier 0 plus emission standards. Under the Tier 0 plus standards, PM emissions could be lowered potentially from 0.72 g/bhphr to 0.26 g/bhphr, a 64 percent reduction, and NOx from 17.4 g/bhphr to 11.8 g/bhphr, a 32 percent reduction.

Staff and U.S. EPA believe the Tier 0 plus remanufacture kits could be available much earlier than the required date of 2010, perhaps in early 2009. However, according to U.S. EPA, the Tier 0 plus emission standards were not intended to apply to pre-Tier 0 locomotives. U.S. EPA believed most pre-Tier 0 locomotives would be significantly reduced in numbers in the near future, primarily due to retirement. Therefore, U.S. EPA intended the Tier 0 plus locomotive emission standards to apply only to locomotives built or remanufactured to meet U.S. EPA locomotive Tier 0 emission standards.

Two-thirds (103) of UP and BNSF's 152 older switch locomotives are either expressly exempt (built prior to 1973) or have not been remanufactured yet (built 1973-1999) to meet U.S. EPA Tier 0 emission standards. Staff still believes Tier 0 plus emission kits could be adapted or produced for exempt or pre-Tier 0 switch locomotives in the near future. Further, staff believes many of these older locomotives will continue to operate for the foreseeable future, potentially up to another 10 to 15 years.

Older switch locomotives may be remanufactured only about every 10 to 15 years, or up to 20 years in some cases. Due to remanufacturing costs, railroads may delay remanufacturing older switch locomotives until they are retired from service and not remanufacture them at all.

Potential Emissions Reductions

As discussed above, the Tier 0 plus remanufacture kits could lower pre-Tier 0 and Tier 0 switch locomotive emissions by up to 64 and 32 percent for PM and NOx, respectively. Emission factors are presented in Table II-14.

Table II - 14
Emission Factors Used to Determine
Potential Emission Reductions for Option 4

Type of Locomotive	**Number of Locomotives**	**Emission Factors** (g/bhp-hr)	
		NOx	**PM**
Pre-1973 Switchers	41	17.4	0.72
Pre-Tier 0 Switchers	62	17.4	0.72
Pre-Tier 0 Remanufactured to Tier 0	49	14.0	0.72
Subtotal	152		
Remanufactured Switch Locomotives to Tier 0 "Plus"	**152**	**11.8**	**0.26**

As shown in Table II-15, remanufacturing 152 UP and BNSF switch locomotives (103 pre-Tier 0 and 49 Tier 0) to meet Tier 0 plus emissions standards would provide NOx and PM emissions reductions of about 2.2 and 0.22 tons per day, respectively. However, these potential emissions reductions could be lowered significantly if railroads decide that older switch locomotives will continue to work, via ongoing maintenance and overhauls, and to avoid the expense of remanufacturing to Tier 0 plus emissions standards.

Table II - 15
Estimated Emission Reductions from Remanufacturing 152 Pre-Tier 0 and Tier 0 Switch Locomotives to Tier 0 "Plus" Emission Standards
(Option 4)

Location	Remanufacture pre-Tier 0 and Tier 0 Switchers to Tier 0 Plus	Emission Reductions (tons per day)		Capital Costs (millions)
		NOx	PM	
South Coast	63	0.8	0.09	$16
Rest of State	89	1.4	0.13	$22
Statewide	**152**	**2.2 ***	**0.22**	**$38**

* May not add up precisely due to rounding.

<u>Costs</u>

Remanufacturing older switch locomotives to Tier 0 plus emission standards would cost about $250,000 per remanufacture to meet Tier 0 plus emissions standards. Therefore, the total cost for 152 pre-Tier 0 and Tier 0 switch locomotives would be about $38 million. Details on the derivation of the $250,000 remanufacture costs are presented below.

The estimated cost to remanufacture an existing pre-Tier 0 older switch locomotive to meet Tier 0 emission levels is up to $200,000, based on actual cost estimates provided by UP and BNSF. U.S. EPA estimated that the Tier 0 plus kits would be less than $50,000, but these costs do not account for labor and testing costs, locomotive downtime, and necessary related parts. Staff expects that the Tier 0 plus remanufacture kit would be about the same price or slightly higher than a Tier 0 kit. Staff estimated the costs of a Tier 0 plus remanufacture kit at a slightly higher level than a Tier 0 kit, or about $250,000.

Cost-Effectiveness

Cost-effectiveness for NOx and PM emissions reductions to remanufacture an older pre-Tier 0 or Tier 0 switch locomotive with a Tier 0 "plus" switch locomotive kit is between $0.5 and $1 per pound, depending on the range of useful life of between 10 to 20 years.

B. Medium Horsepower Locomotives

Medium horsepower (MHP) locomotives are used both in freight and passenger locomotive operations. The different MHP locomotive applications are discussed below.

1. Types of MHP Locomotives

MHP Freight Locomotives

MHP freight locomotives range from 2,301 to 4,000 horsepower. Staff identified three distinct subgroups of freight MHP locomotives. Smaller freight MHP locomotives range from 2,301 to 2,999 horsepower and can serve as large switch (yard) locomotives and also perform local service. A second set of freight MHP locomotives range from 3,000 to 3,300 horsepower. This mid-size group of freight MHP locomotives generally serves as helpers by assisting trains over mountain grades or performing as local and regional short haulers. The third subgroup of freight MHP locomotives is intrastate or regional line haul locomotives. This latter category of locomotives typically moves freight up to 500 miles and ranges from 3,301 to 4,000 horsepower. For comparison, today's interstate freight line haul locomotives (e.g., Chicago to Los Angeles) are typically 4,000 horsepower or greater.

MHP freight locomotives are typically powered by six axles, though some units may be powered with 4 axles. Nearly all freight MHP locomotives were originally built within a wide range of 10 to 50 years ago. Many were originally interstate line haul locomotives (e.g., Chicago to Los Angeles) that over time were cascaded down to shorter routes and local and regional operations. The UP and BNSF freight MHP locomotive fleet operating in California is on average about 40 years old.

UP and BNSF's California MHP freight locomotives are predominately pre-Tier 0 and have not been remanufactured to meet U.S. EPA Tier 0 locomotive emissions standards. Many of these locomotives are also expressly exempt from U.S. EPA locomotive emission standards by being built before the 1973 model year. About 10 percent or about 40 of these older MHP line haul locomotives, especially the relatively newer ones (1985-1999 model years), may have recently been remanufactured to meet U.S. EPA Tier 0 locomotive emission standards.

MHP Passenger Locomotives

Another group of MHP locomotives move passengers. California has about 110 intrastate passenger locomotives that average about 3,000 horsepower, with some up to 3,600 horsepower, and use the same or similar engine families as MHP freight locomotives. California's 110 intrastate passenger locomotives on average are about 15 years old. Intrastate passenger operators include Amtrak, Metrolink, California Department of Transportation, Caltrain, Altamont Commuter Express, and North County Transit District in San Diego.

Intrastate passenger locomotives operate predominately in idle or the higher power (Notch 5-8) settings, and on average consume nearly 200,000 gallons of diesel fuel annually. Some of the intrastate passenger locomotives have been documented to consume up to 300,000 gallons or more of diesel fuel annually. Passenger locomotives also typically have large stationary generators of about 500 horsepower or more onboard to provide hotel power, such as lighting, air conditioning, etc., for passenger cars and can operate for up to 24 hours per day.

Estimates of UP and BNSF Intrastate MHP Locomotives

Table II-16 presents staff estimates of the number of intrastate UP and BNSF freight and passenger MHP locomotives operating statewide and within the South Coast Air Basin. These estimates are based on documentation provided by both UP and BNSF for the intrastate locomotive inventories and health risk assessment emission inventories. Also, the estimates are based on the CARB diesel fuel regulation for intrastate UP and BNSF freight and passenger locomotives. For this evaluation, the estimates of UP and BNSF freight and intrastate passenger MHP locomotives were based on an engine power range of between 2,301 and 4,000 horsepower.

Table II - 16
Estimates of Intrastate
UP and BNSF Freight and Passenger MHP Locomotives

Area of State	Intrastate Freight (2,301-2,999 HP)	Intrastate Freight * (3,000-3,300 HP)	Intrastate Regional Freight** (3,301-4,000 HP)	Intrastate Passenger (3,000-3,600 HP)	Total
South Coast	20	12 ‡	~65 ‡	52	~150
Rest of State	83	55	~55 ‡	58	~250
Statewide	**103**	**67**	**~120** ‡	**110**	**~400**

* EMD GP40's, SD39/40's.
** EMD GP50/GP60 (4 axle) and SD50/SD60/SD70 (6 axle).
‡ Preliminary data that still needs to be confirmed with UP and BNSF.

2. *MHP Locomotive Duty Cycles*

MHP Freight Locomotives

The U.S. EPA freight locomotive duty cycle assumes line haul locomotives idle about 40 percent of the time. This rate of idling does not account for the benefits of idle reduction devices, which, under the 2005 Agreement, have been installed on greater than 99 percent of the intrastate UP and BNSF freight locomotive fleet of which about 150 are MHP freight locomotives. Intrastate passenger locomotives are not required to comply with the 2005 ARB/Railroad Agreement.

Beyond idling about 40 percent of the time, the U.S. EPA duty cycle assumes line haul locomotives primarily operate in the higher locomotive power (notch) settings (i.e., Notch 5-8) for the rest of the operating times. Helpers and larger intrastate line haul freight locomotives operate closer to a line haul locomotive duty cycle. However, intrastate MHP line haul locomotives typically operate fewer hours, travel fewer miles, and consume less diesel fuel annually than interstate line haul locomotives. In contrast to interstate line haul locomotives that may consume only about 15 percent of annual diesel fuel consumption within the state, MHP intrastate locomotives consume at least half of the annual diesel fuel burned annually within the state.

On average statewide, UP and BNSF freight MHP locomotives may consume a wide range of diesel fuel annually. Smaller freight MHP such as helpers and short haulers may consume between 50,000 and 150,000 gallons per year. Larger intrastate line haul locomotives may consume from 100,000 to 300,000 gallons annually. In comparison, a 4,000 horsepower freight interstate line haul locomotive (e.g., Chicago to Los Angeles) operates for significantly more time in the higher power settings (Notch 5-8).

A freight interstate line haul locomotive can consume up to 1,000 gallons per day, or about 360,000 gallons of diesel fuel annually. Some interstate line haul locomotives may consume up to 500,000 gallons or more of diesel fuel annually. However, an interstate line haul locomotive may only consume up to 20 percent of its annual diesel fuel within California, based on a trip between Chicago and Los Angeles.

MHP Passenger Locomotives

U.S. EPA has passenger locomotives perform the same duty cycle for emission testing as line haul locomotives. However, passenger locomotives actually operate on a much different duty cycle than freight locomotives. Typically, passenger locomotives operate predominately in idle for extended periods, or they operate at the other extreme – the higher power settings ranging from Notch 5 to 8. Intrastate passenger locomotives also do not need the tractive effort of a freight line haul locomotive, the latter needs to pull trains up to a mile or longer in length.

3. Medium Horsepower Locomotives: Statewide and Railyard Emissions

Most intrastate MHP freight and passenger locomotives are pre-Tier 0. A significant portion of these older freight locomotives are exempt from federal locomotive emissions standards by being built prior to 1973. Staff has only been able to identify about ten percent, or about 40, of the intrastate UP and BNSF MHP freight and intrastate passenger locomotives that have been remanufactured to meet Tier 0 emissions levels. Freight MHP locomotives also comprise nearly one-third of UP and BNSF's 15,000 locomotive national fleet. UP and BNSF combined may operate up to 290 or more intrastate freight MHP locomotives statewide.

Intrastate passenger locomotives add an additional 110 MHP locomotives to the statewide MHP locomotive fleet. About 52 operate in the South Coast and 58 in the rest of the state. All of the freight and passenger MHP locomotives may add up to a total of up to as much as 400 MHP locomotives statewide or more. Staff believes intrastate freight and passenger MHP locomotives may contribute up to one-third of the total statewide locomotive NOx and PM emission inventory.

4. Summary of Potential Options to Reduce Emissions from Medium Horsepower Locomotives

Staff has identified four possible options to reduce medium horsepower freight and passenger locomotive emissions. These options are referred to as options 5, 6, 7 and 8. In this evaluation, medium horsepower (MHP) locomotives are defined as between 2,301 and 4,000 horsepower. Based on available data, ARB staff identified only about 10 percent of the MHP freight and passenger locomotives that have been remanufactured to meet U.S. EPA Tier 0 locomotive emission standards.

<u>Option 5: Repower Older Locomotives with Low-emitting Engines</u>

The first option is to repower about 400 older pre-Tier 0 (~360) and Tier 0 (~40) MHP freight and passenger locomotives with new LEL engines. A new low emitting locomotive (LEL) engine is defined as a locomotive engine repower with new four or two stroke MHP engines that meets or exceeds 4.0 g/bhphr NOx and 0.1 g/bhphr PM. Staff estimates that UP and BNSF have about 290 intrastate MHP freight locomotives and that there are about 110 intrastate MHP passenger locomotives.

<u>Option 6: Replace Older MHP Locomotives with New MHP Gen-Set Locomotives</u>

An alternative to the first option is to replace up to 200 of the approximately 290 MHP freight locomotives with new gen-set MHP locomotives powered with four 700 horsepower nonroad engines, or about 2,800 horsepower. A four engine gen-set locomotive has not been U.S. EPA certified or ARB verified as of December 2008.

However, gen-set manufacturers have informed ARB staff they are in the process of building four engine MHP gen-set locomotives.

A MHP gen-set locomotive would potentially have as much tractive effort (pulling force exerted) as an EMD SD-40 with 3,000 horsepower. Staff estimates that UP and BNSF have up to 200 of the 290 MHP freight locomotives that could potentially be replaced with MHP gen-set locomotives, depending on the individual duty cycle and horsepower/tractive effort needs of the locomotive being replaced.

<u>Option 7: Retrofit Low-Emitting MHP Locomotives with NOx and PM Emission Controls</u>

The third option builds upon the first two options. This option involves retrofitting the 400 MHP LEL freight and passenger locomotives, and potentially MHP gen-set freight locomotives, with both DPFs and SCRs. The second option would be an option only after ARB has verified DPF and/or SCR for retrofit onto a MHP freight and passenger locomotive powered by an LEL or gen-set engines. The combination of an LEL engine repower, or MHP gen-set engine, and DPF and SCR retrofits could approach or meet U.S. EPA Tier 4 locomotive NOx and PM emissions levels.

<u>Option 8: Remanufacture MHP Locomotives to U.S. EPA Tier 0 Plus Standards</u>

The fourth option, though less aggressive and costly, would be to accelerate the remanufacture of 400 pre-Tier 0 (~360) or Tier 0 (~40) freight and passenger MHP locomotives to meet U.S. EPA Tier 0 plus locomotive emissions standards. U.S. EPA requires the Tier 0 plus emission standards upon remanufacture of existing built or remanufactured Tier 0 locomotives, but not for pre-Tier 0 locomotives.

Table II-17 summarizes the four MHP locomotive options based on technical feasibility, potential emissions reductions, costs, and cost-effectiveness. Option 6 is a partial alternative to Option 5. Option 7 can complement both Options 5 and 6. Option 8 is a less expensive alternative to Options 5,6, and 7. The following sections provide the basis for the information in this table.

Table II - 17
Options to Reduce Medium Horsepower (MHP) Locomotive Emissions

Option	Medium Horsepower Locomotive Strategies	Timeframe	NOx (tons/day)	PM (tons/day)	Cost-Effectiveness ($/lb)	Capital Costs (millions)
5	Repower 400 older MHP locomotives with new LEL engines	Near Term (up to 5 years)	22.9	1.27	$0.8-1 (10-20 years)	$400
6	Replace 200 older MHP locomotives with new gen-set MHP locomotives	Near Term (up to 5 years)	13.3	0.63	$2-3 (10-20 years)	$400
7	Retrofit DPF and SCR onto MHP locomotives with repowered LEL engines or gen-sets	Mid Term (up to 10 years)	6.8	0.18	$1-2 (10-20 years)	$200
	SUBTOTAL (Options 5 and 7)	**Near-Mid Term**	**29.8**	**1.45**	**$0.8-2/lb**	**$600**
8	Remanufacture* 400 older MHP locomotives to meet U.S. EPA Tier 0 plus emission standards.	Near Term (up to 5 years)	12.9 **	0.96 **	$0.3-0.5 (10-20 years)	$100

Note: Numbers may not add up precisely due to rounding.
* May take up to 15 years for a remanufacture of an older medium speed engine MHP locomotive. Also, about 40 Tier 0 locomotives will be required to meet Tier 0 plus standards upon remanufacture.
** Assumes all existing older MHP locomotives are pre-Tier 0.

5. Analysis of Option 5 - Repower 400 Older MHP Locomotives with LEL Engines

Technical Feasibility

Intrastate older MHP locomotive engines provide an opportunity to achieve significant additional emission reductions by repowering them with new four or two stroke engines. The new advanced MHP locomotive engines are less emitting, smaller in size but just as powerful, and more combustion and fuel efficient than the older two stroke locomotive engines. The new advanced MHP locomotive engines emit at levels that can meet or significantly exceed the current and most stringent U.S. EPA Tier 2 locomotive NOx and PM emissions standards.

We refer to the new MHP locomotive engine repowers with NOx levels at or below 4.0 g/bhp-hr and PM at or below 0.1 g/bhp-hr as low emitting locomotive (LEL) engines. LEL engine NOx and PM emissions levels represent a 70 and 85 percent reduction, respectively, when compared to pre-Tier 0 NOx and PM emission levels. Staff believes LEL engines are technically feasible and expect them to be commercially available for locomotives in the next two years. Staff expects that some LEL locomotive engine repowers could be in California operation as early as January 1, 2010.

Potential Emission Reductions

LEL engine repowers can significantly reduce existing pre-Tier 0 intrastate MHP freight and passenger locomotive NOx and PM emissions by about 70 and 85 percent, respectively. MHP locomotives consume an estimated 50,000 to 300,000 gallons of diesel fuel annually. In our estimates, we assumed intrastate MHP freight and passenger locomotives consume on average about 100,000 gallons of diesel fuel annually. Staff believes this to be a conservative fuel consumption level, since passenger and larger intrastate MHP line haul locomotives have been documented to consume 200,000 to 300,000 gallons of diesel fuel annually.

Based on the estimated annual activity and fuel consumption levels of 400 freight and passenger MHP locomotives, staff estimated statewide NOx and PM reductions of up to 22.9 and 1.27 tons per day, respectively. Also, note that the new LEL engine may potentially reduce fuel consumption by up to 3 percent, which could mean up to 36 tons per day of greenhouse gas emissions reductions.

Table II-18
Estimated NOx and PM Emissions Reductions
LEL Repowers of 400 Intrastate
Freight and Passenger MHP Locomotives

Location	Number of MHP Locomotives	NOx* (tons per day)	PM* (tons per day)	Cost-Effectiveness ($/lb)	Capital Costs (millions)
South Coast	150	8.6	0.48	$0.8-1	$150
Rest of State	250	14.4	0.79	$0.8-1	$250
Statewide	**~ 400**	**22.9**	**1.27**	**$0.8-1**	**$400**

* May not add up precisely due to rounding.

Costs

A new LEL engine repower of an older MHP locomotive, between 3,000 and 4,000 horsepower, would cost on average about an estimated $1,000,000. Some engine repowers could be as low as $500,000 and some as high as $1,500,000. Therefore, to repower 400 locomotives would be about $400 million.

Cost-Effectiveness

Cost-effectiveness to repower an older pre-Tier 0 or Tier 0 MHP intrastate freight or passenger line haul locomotive with a new LEL engine would be about $1 per pound, depending on the range of useful life of between 10 and 20 years. A MHP locomotive repower, with a new LEL engine, is very cost-effective when compared to most current ARB control measures or options.

6. Analysis of Option 6 - Replace Up to 200 Older MHP Locomotives with New MHP Gen-Set Locomotives

Technical Feasibility

Intrastate older MHP locomotive engines provide an opportunity to achieve significant additional emission reductions by replacing them with new MHP gen-set locomotives. New MHP gen-set locomotives, powered by four nonroad engines, of less than 750 horsepower each, may be able to approach, meet, or exceed ultra low emitting locomotive (ULEL) emissions levels of 3.0 g/bhp-hr NOx and 0.1 g/bhp-hr PM. Current three engine gen-set switch locomotives are able meet and exceed ULESL emissions levels. ARB staff believes a four engine MHP gen-set locomotive would perform in similar duty cycles and may achieve similar levels of emissions.

We refer to a new four engine (roughly equivalent to about 3,000 horsepower) gen-set locomotive, with certified emissions at or below 3.0 g/bhp-hr and PM at or below 0.1 g/bhp-hr, as a MHP gen-set locomotive. A MHP gen-set locomotive NOx and PM emissions levels represent about an 80 percent reduction when compared to pre-Tier 0 line haul locomotive NOx and PM emission levels. Staff believes MHP gen-set locomotives are technically feasible and expects four engine gen-set locomotives to be commercially available within the next one to two years. Staff expects that some MHP gen-set locomotives could be in California operation as early as 2010.

Potential Emission Reductions

New MHP gen-set locomotives could significantly reduce existing pre-Tier 0 MHP freight line haul locomotive NOx and PM emissions by about 80 percent. MHP freight locomotives consume an estimated 50,000 to 300,000 gallons of diesel fuel annually. In our estimates, we assumed MHP freight locomotives consume on average about 100,000 gallons of diesel fuel annually. Staff believes this to be a conservative fuel consumption level, since larger intrastate MHP line haul locomotives have been documented to consume 200,000 to 300,000 gallons of diesel fuel annually.

Based on the estimated annual activity and fuel consumption levels of 200 intrastate freight MHP locomotives, staff estimated statewide NOx and PM reductions of up to 13.3 and 0.63 tons per day, respectively. Also, note that a new MHP gen-set locomotive may also potentially reduce fuel consumption by up to 20 percent or more.

Table II – 19
Estimated NOx and PM Emissions Reductions
Replacement of 200 Freight MHP Locomotives
With New MHP Gen-Set Locomotives
(2,301 to 4,000 horsepower)

Location	Number of MHP Gen-Set Freight Locomotives	NOx (tons per day)	PM (tons per day)	Cost-Effectiveness ($/lb)	Capital Costs (millions)
South Coast	100	6.6	0.32	$2-4	$200
Rest of State	100	6.6	0.32	$2-4	$200
Statewide	**~200**	**13.3**	**0.63**	**$2-4**	**$400**

* Numbers may not add up precisely due to rounding.

Costs

A new MHP gen-set freight locomotive, between 2,500 and 3,500 horsepower, could cost up to an estimated $2,000,000. This cost estimate is based on the cost of a new three engine gen-set switch locomotive at about $1.5 million, with a new engine and related parts, to derive a conservative estimate of $2 million. In 2008 dollars, actual costs might be about $1.8 million. Staff chose to be more conservative on costs, as there is currently no commercial production of a four engine gen-set locomotive. Therefore, the total estimated costs would be about $400 million.

Cost-Effectiveness

Cost-effectiveness to replace an older pre-Tier 0 or Tier 0 MHP intrastate freight line haul locomotive with a new MHP gen-set locomotive could range between $2 and $3 per pound, depending on the range of useful life of between 10 and 20 years. A new MHP gen-set locomotive replacement of an older MHP locomotive is very cost-effective when compared to most current ARB control measures or options.

7. Analysis of Option 7 - Retrofit of DPF and SCR onto 400 MHP Freight and Passenger Locomotives Repowered with LEL Engines or Replaced with New MHP Gen-Set Locomotives

Technical Feasibility

Intrastate MHP freight and passenger locomotives that have been repowered with new LEL engines, or new MHP gen-set locomotives, may be potential candidates for retrofits with DPF and SCR. LEL engines and new MHP gen-set locomotives that are retrofitted with DPF and SCR may be able to approach or meet Tier 4 locomotive NOx and PM emissions levels. The new LEL engines and MHP gen-set locomotives are expected to be more combustion efficient and smaller in size. In addition, with significantly less engine emissions, an LEL engine and new MHP gen-set locomotive can potentially reduce the size needed for DPF and SCR aftertreatment.

Major concerns with locomotive aftertreatment devices are their size and weight. DPFs retrofitted onto UP and BNSF switch locomotives are the size of two pianos (2 x 1,100 pounds or more). An SCR retrofitted onto a locomotive engine has been estimated to weigh over 4,000 pounds. The SCR will also need a urea tank (about 250 gallons or more) and a urea dosing control unit to fit within the locomotive carbody. Another concern is the locomotive carbody space available to accommodate such large aftertreatment devices, and the necessary aftertreatment support equipment, is limited. The combination of a smaller, but equally powerful engine and significantly less emissions, could allow for significant aftertreatment downsizing. A smaller DOC, SCR, and DPF aftertreatment system may be able to fit within the limited locomotive carbody space.

Research is currently underway by the ARB, railroads, and locomotive and engine manufacturers to assess the technical feasibility of retrofits of LEL engines with DPF and SCR. Staff is also working on a research effort to demonstrate DPFs on gen-set locomotives. Staff believes that a DPF and SCR retrofit system for either a MHP locomotive, with an LEL engine repower or gen-set technology, could be ARB verified and commercially available by as early as 2012.

Potential Emission Reductions

UP and BNSF combined may operate about 290 older MHP two stroke engine locomotives. Staff estimates about 70 older UP and BNSF MHP locomotives in the South Coast Air Basin and an additional 230 or more statewide. California also has about 110 intrastate passenger locomotives with typically two stroke Electro-Motive Diesel (EMD) engines of about 3,000 horsepower. Combined, freight and passenger MHP locomotives may total up to 400 statewide.

Intrastate freight and passenger MHP locomotives consume an estimated 50,000 to 300,000 gallons of diesel fuel annually. In our calculations, we assumed intrastate MHP freight and passenger locomotives consume an average of about 100,000 gallons of diesel fuel annually. Staff believes this to be a conservative fuel consumption level, since intrastate passenger and larger freight MHP line haul locomotives have been documented as consuming 200,000 to 300,000 gallons of diesel fuel annually.

Based on the estimated annual activity and fuel consumption levels, staff estimates that 400 intrastate MHP freight and passenger locomotives powered by new LEL engines, or new MHP gen-set locomotives, could provide additional emissions reductions if also retrofitted with DPF and SCR. The additional NOx and PM reductions from the DPF and SCR retrofits could be up to 6.8 and 0.18 tons per day, respectively.
See Table II-20 for estimated emissions reductions.

Table II - 20
Estimates of NOx and PM Emissions Reductions
Retrofit of DPF and SCR onto 400 Intrastate MHP Locomotives
With LEL Engine Repowers or Gen-Set Replacements
(2,301 to 4,000 horsepower)

Location	Number of MHP Freight and Passenger LEL or Gen-Set Locomotives	SCR NOx (tons per day)	DPF PM (tons per day)	Capital Costs (millions)
South Coast	150	2.6	0.07	$75
Rest of State	250	4.2	0.11	$125
Statewide	**400**	**6.8**	**0.18**	**$200**

* Numbers may not add up precisely due to rounding.

Assuming 400 intrastate MHP freight and passenger locomotives are repowered with LEL engines, or replaced with new MHP gen-set locomotives, and also retrofitted with DPF and SCR, both options combined could provide up to 29.8 and 1.45 tons per day of NOx and PM statewide, respectively. See Table II-21 for the estimates of the combined NOx and PM emissions reductions.

Table II - 21
Estimates of NOx and PM Emissions Reductions
Combination of LEL Engine Repowers and Retrofit of DPF and SCR
400 Intrastate MHP Locomotives
(2,301 to 3,800 horsepower)

Location	Number of Locomotives	Emission Reductions (tons/day)					
		LEL NOx	LEL PM	SCR NOx	DPF PM	Total NOx	Total PM
Freight							
South Coast	98	5.6	0.32	1.7	0.04	7.3	0.35
Rest of State	192	11.0	0.60	3.3	0.09	14.3	0.68
Passenger							
South Coast	52	3.0	0.17	0.9	0.02	3.9	0.19
Rest of State	58	3.3	0.18	1.0	0.03	4.3	0.21
Statewide *	**400**	**22.9**	**1.27**	**6.8**	**0.18**	**29.8**	**1.43**

* Numbers may not add up precisely due to rounding.

Costs

Initial estimates of the costs to retrofit SCR and DPF onto an existing older freight or passenger MHP locomotive, that has been repowered with a LEL engine or replaced with a new MHP gen-set locomotive, is up to $500,000. The DPF and SCR retrofit costs of $500,000, would be in addition to the cost of a new LEL engine repower of about $1 million, or replacement with a new MHP gen-set locomotive at about $2 million.

Cost-Effectiveness

The cost-effectiveness of a retrofit of a DPF and SCR system onto an older intrastate MHP locomotive, that has also been repowered with a LEL engine or replaced with a new MHP gen-set locomotive, is between $2 and $3 per pound, depending on a range of useful life of between 10 and 20 years. A retrofit of DPF and SCR onto an intrastate or MHP locomotive, after a LEL engine repower or replacement with new MHP gen-set locomotive, is cost-effective when compared to most current ARB control measures or options.

8. Analysis of Option 8 - Accelerate Remanufacture of 400 Pre-Tier 0 (~350) or Tier 0 (~50) Freight and Passenger Locomotives to Meet U.S. EPA Tier 0 Plus Emissions Levels

Technical Feasibility

In 2008, U.S. EPA promulgated new locomotive emission standards. The new U.S. EPA locomotive remanufacture emission standards require new and remanufactured Tier 0 locomotives to meet the more stringent Tier 0 plus emission standards. The Tier 0 plus PM line haul locomotive emission standards were lowered from 0.6 g/bhphr to 0.22 g/bhphr, a 63 percent reduction, and NOx from 13.5 g/bhphr (pre-Tier 0 NOx) or 9.5 g/bhphr (Tier 0 NOx) to 8.0 g/bhphr or 7.4 g/bhphr (Tier 0 plus NOx), or up to a 49 percent reduction. U.S. EPA and ARB staff believes certified Tier 0 plus emissions standards remanufacture kits could be commercially available by as early as 2009.

The Tier 0 plus option is already required by the 2008 U.S. EPA locomotive rulemaking for existing Tier 0 locomotives. However, the requirements do not apply to pre-Tier 0 line haul locomotives. This option would primarily provide benefits if Tier 0 plus emission kits become available for California's large number of pre-Tier 0 MHP locomotives. According to available data, UP and BNSF and intrastate passenger operators only have about ten percent (or about 40) of intrastate MHP freight and passenger locomotives that have been remanufactured to meet the U.S. EPA Tier 0 emission standards.

The extent of implementation may be dependent on how often older two stroke MHP locomotives come in for complete remanufactures. Interstate line haul locomotives are typically remanufactured every five to seven years due to the higher hours of operation, especially in the higher power settings (i.e., Notch 5-8). However, older medium speed engine MHP locomotives usually are remanufactured at a much slower pace, due to lower hours of operation and the predominate use of lower and mid power settings. Older MHP locomotives may only be remanufactured about every 10 to 15 years. Also, due to the costs of remanufacturing, which can equal or exceed the residual value of older locomotives, railroads may decide to avoid remanufacturing until the units are retired.

Potential Emissions Reductions

As discussed above, the Tier 0 plus remanufacture kits could lower pre-Tier 0 and Tier 0 MHP locomotive emissions by up to 63 and 49 percent for PM and NOx, respectively. Remanufacturing 400 pre-Tier 0 and Tier 0 MHP locomotives to Tier 0 plus emissions standards would provide NOx and PM emissions reductions of up to about 13 and 1 tons per day, respectively, depending on the number of MHP locomotives not already subject to the federal Tier 0 plus requirements (about ten percent of California's MHP locomotives) and the rate of remanufactures for MHP locomotives in California.

Costs

The remanufacture of an existing pre-Tier 0 older MHP locomotive to Tier 0 plus emission levels could cost up to $250,000. This estimate is based on prior costs for Tier 0 remanufacturing kits of up to $200,000. U.S. EPA estimated that the Tier 0 plus kits would be less than $50,000, but these costs do not account for labor and testing costs and other related parts. Staff expects that the Tier 0 plus remanufacture kits would be about the same price or slightly higher than actual Tier 0 remanufacturing costs. Therefore, we have estimated the costs of a Tier 0 plus remanufacture kit at a slightly higher level than a Tier 0 remanufacture or about $250,000.

Cost-Effectiveness

Cost-effectiveness to remanufacture an older pre-Tier 0 or Tier 0 MHP freight or passenger locomotive, with a U.S. EPA Tier 0 plus package, is estimated to be between $0.3 and $0.5 per pound, depending on the range of useful life between 10 and 20 years.

C. Interstate Line Haul Locomotives

1. Types of Line Haul Locomotives

Freight interstate line haul locomotives typically have large diesel-electric engines of greater than 4,000 horsepower and operate on 6 axles. UP and BNSF's interstate line haul locomotives are on average about 15 years old or so. Interstate line haul locomotives are typically the newest and highest horsepower locomotives available to railroads. Interstate line haul locomotives can move the most volume of freight, most efficiently and reliably, and over the greatest distances. Interstate line haul locomotives in a consist, usually three or more locomotives, pull trains with railcars as long as one to two miles long. Interstate line haul locomotives traverse mountains, desert, and other challenging terrains as they cross the country from destinations like Chicago to Los Angeles.

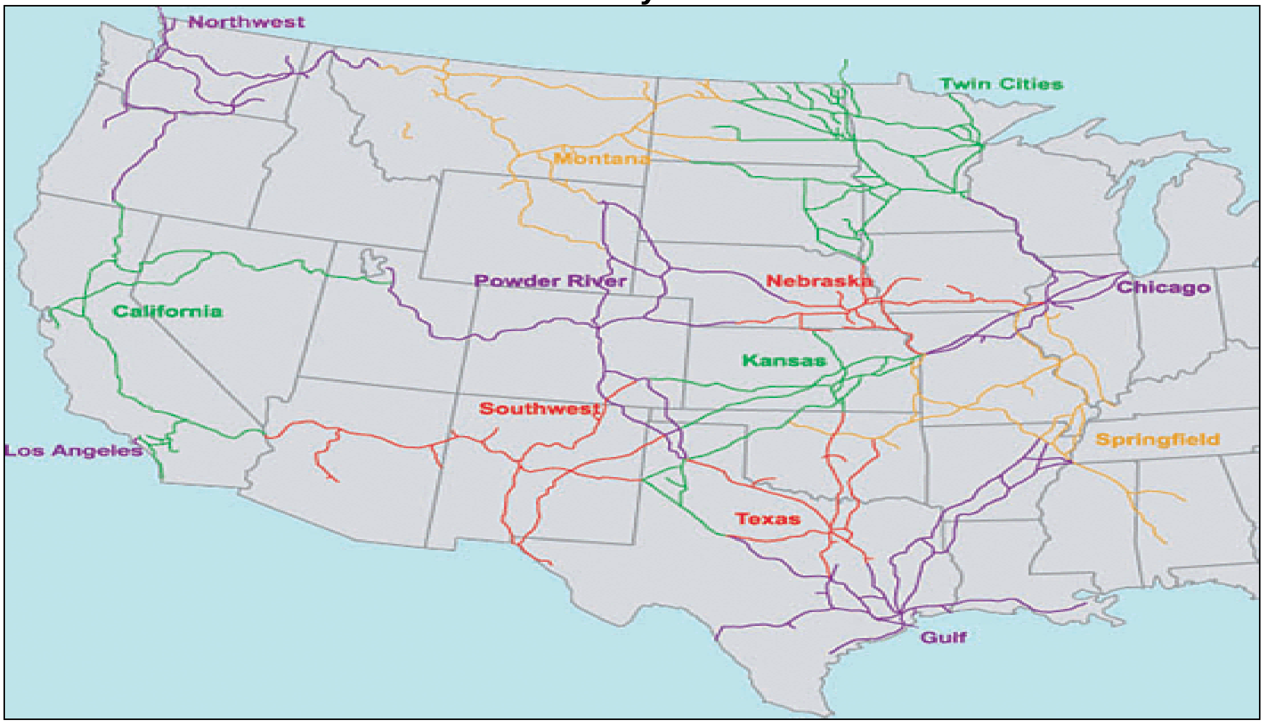
2. BNSF and UP Major Cross-Country Rail Line Routes

The predominant California UP and BNSF interstate line haul locomotive routes are from the Ports of Los Angeles and Long Beach and Port of Oakland both to Chicago. BNSF's major southern route is from the Port of Los Angeles and Long Beach via San Bernardino and north over the Cajon Pass towards Barstow and then east to Needles, California. From Needles, the BNSF route goes north towards Winslow, Arizona and then east to Belen, New Mexico which is a major BNSF refueling depot. Ultimately, the route runs north via through Texas and to Kansas City and to as far east as Chicago. This BNSF transcontinental route is referred to as the Transcon.

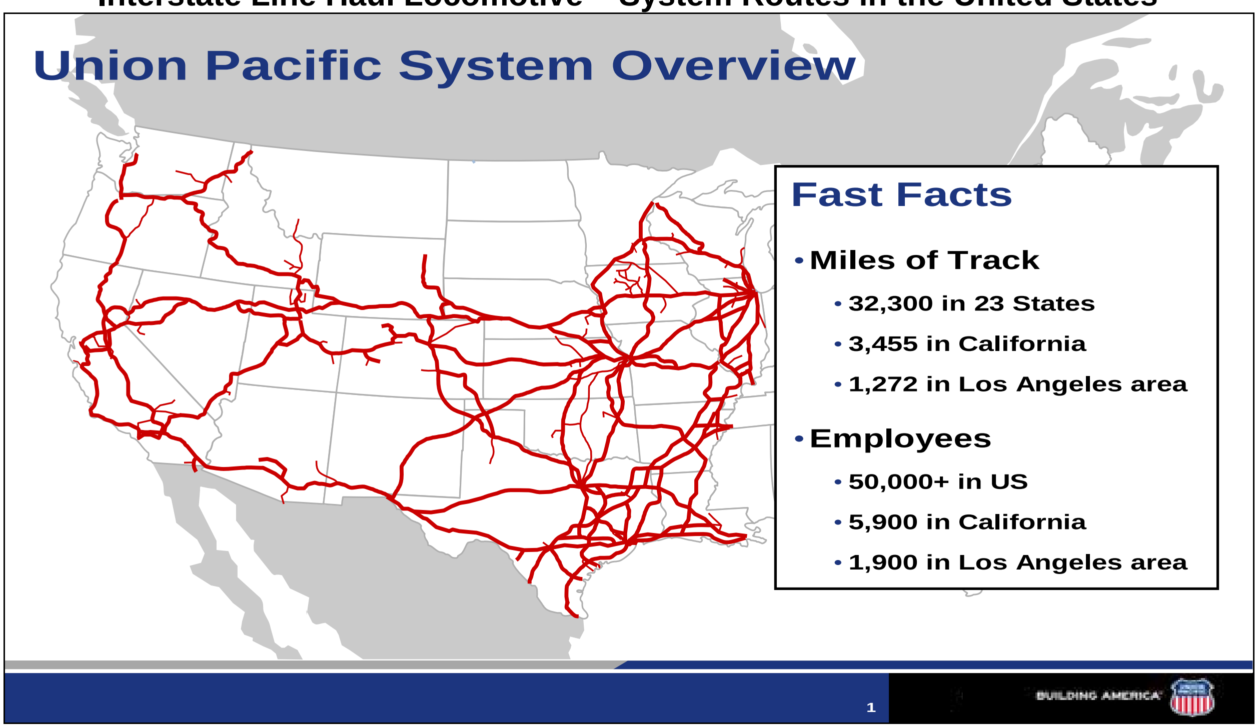
UP also has a similar route which is from the Los Angeles ports via Colton, then north over the Cajon Pass and through Barstow to Yermo, California. From Yermo, the UP line runs northeast through Las Vegas and Salt Lake City. From Salt Lake City the route runs east through Rawlins, Wyoming – a major refueling depot for UP – and east past the UP Bailey Yard in Nebraska and ultimately east to Chicago. UP's southern route from the Los Angeles Ports via Colton, but then turns south to Yuma, Arizona and then east to El Paso, Texas, and can then continue through the south or can go north to Chicago. This UP southern line is referred to as the Sunset Route.

From the Port of Oakland, BNSF trains typically route through the San Joaquin Valley to Barstow, and then to Needles, and then onto the Transcon. UP trains typically use the route from the Port of Oakland east towards UP Roseville and east through Nevada and ultimately east to Chicago. UP, also to a lesser extent than BNSF, uses the San Joaquin Valley route towards Southern California.

BNSF Railway's
Interstate Line Haul Locomotive – System Routes in the United States



Union Pacific Railroad's
Interstate Line Haul Locomotive – System Routes in the United States



3. Interstate Line Haul Locomotive Operational Duty Cycles

The operational duty cycles of newer high horsepower interstate line haul locomotives are dominated by higher power (notch) settings (i.e., Notch 5-8) when traveling cross country on main rail lines. When interstate line haul locomotives do operate within railyards (e.g., to trim with railcars to form trains or receive fuel, service, or maintenance) they typically operate in idle or lower power settings, which is about 40 percent of their total operational time. As a comparison, the effects of line haul locomotive power settings on diesel fuel consumption are significant. In idle or power setting Notch 1 a line haul locomotive may consume about 5 to 10 gallons per hour, whereas in Notch 8 a line haul locomotive may consume up to 200 gallons per hour.

A typical interstate line haul locomotive may consume 250,000 to 500,000 gallons or more of diesel fuel annually. However, interstate line haul locomotives might spend only about 15 percent (e.g., 600 miles round trip – Needles to the Ports of Los Angles/Long Beach and back) of a cross-country 4,200 mile round trip operating in California. Under the latter assumption, interstate line haul locomotives would consume about 50,000 to 75,000 gallons of diesel fuel annually within the state.

4. Interstate Line Haul Locomotives: Statewide and Railyard Emissions

The ARB emission inventory estimates that interstate line haul locomotives (e.g., Los Angeles to Chicago) contribute about 90 percent of the statewide locomotive NOx and PM emissions. Interstate line haul locomotives emissions do not concentrate their operations in specific local or regional areas like many switchers and medium horsepower locomotives. Instead, interstate line haul locomotive operations are distributed over many areas of the state.

Between 2015 and 2020, California should have nearly a statewide Tier 2 locomotive fleet average, largely due to the 1998 Locomotive NOx Fleet Average Agreement in the South Coast Air Basin (required by January 1, 2010) and normal locomotive fleet turnover in UP and BNSF national fleets that would benefit the rest of the state. Under this latter assumption, the primary difference in interstate line haul locomotive emissions would be the difference between Tier 2 and Tier 4 new interstate line haul locomotives. That difference would be about a 76 and 85 percent reduction in NOx and PM emissions, respectively, between Tier 2 and Tier 4 interstate line haul locomotives.

5. Analysis of Option 9 – Accelerated Replacement of Line Haul Locomotives

Based on prior experience, it may take more than 30 years for national fleets to turnover (or from 2015 to 2045) to the new Tier 4 interstate line haul locomotives and to fully realize the Tier 4 emission benefits. This option would evaluate the accelerated use of new Tier 4 interstate line haul locomotives in California after 2015.

If the options to replace switchers and repower and replace MHP locomotives were fully implemented, there would be no other California locomotives left to provide the flexibility for a California Tier 4 interstate line haul locomotive fleet average. Hence, this option would simply accelerate the number of Tier 4 interstate line haul locomotives directed by UP and BNSF to operate in California, without any averaging elements.

<u>Technical Feasibility</u>

GE and EMD are currently on schedule to commercially produce new Tier 4 interstate line haul locomotives by 2015. Prototypes of Tier 4 interstate line haul locomotives should be built by about 2013, which would allow two years for field testing prior to commercial production.

Note that U.S. EPA included compliance flexibility provisions as an option for locomotive manufacturers in complying with the Tier 4 emission standards. One option allows locomotive manufacturers to meet a 2.6 g/bhphr NOx standard in-use for three model years (i.e., 2015/2016/2017). The other option allows locomotive manufacturers to meet a 1.9 g/bhphr NOx standard in-use for seven model years (i.e., 2015-2022). GE and EMD may not seek the compliance flexibility. However, if GE and EMD do seek the compliance flexibility, it could reduce the actual emissions reductions provided by early models of Tier 4 locomotives over the operational life of the Tier 4 locomotive.

<u>Potential Emissions Reductions</u>

The ARB emission inventory estimates that 1,200 interstate line haul locomotives will operate in California on any given day by 2020. We have assumed only the emissions differences between Tier 2 and Tier 4 locomotives in California by 2020. With these assumptions, a statewide Tier 4 interstate line haul locomotive fleet of 1,200 could provide up to 31.62 tons per day of NOx and 1.28 tons per day of PM emission reductions, respectively.

<u>Costs</u>

Interstate line haul locomotives are manufactured either by General Electric (GE) or Electro-Motive Diesel (EMD). Currently, new Tier 2 locomotives can cost from $1.8 million to $2.2 million, depending on accessories and options. With new Tier 4 line haul locomotives, DPF and SCR aftertreatment may increase new locomotive capital costs by up to $500,000. As a result, a new Tier 4 interstate line haul locomotive, with advanced engine design and upgrades, may cost between $2.5 to $3.0 million with GE and EMD commercial production of Tier 4 locomotives in 2015. Staff has assumed the upper end capital costs of $3.0 million per Tier 4 line haul locomotive.

A UP and BNSF Tier 4 fleet available to operate in California would require at least 1,200 Tier 4 interstate line haul locomotives operating in California on any given day by 2020. At up to $3 million per Tier 4 interstate line haul locomotive, UP and BNSF would need to spend about $3.6 billion for a 1,200 Tier 4 locomotive fleet dedicated to California only.

UP and BNSF argue, however, that up to a national pool of 4,800 UP and BNSF Tier 4 interstate line haul locomotives would be needed to ensure 1,200 of them were operating in California on any given day. See Table II-22 for an illustration.

Table II - 22
Estimated Number of UP and BNSF National Fleet Tier 4 Locomotives Needed to Ensure 600 in California on Any Given Day in 2020

UP Tier 4 Locomotives	BNSF Tier 4 Locomotives	Total UP and BNSF Tier 4 Locomotives	California (Number On Any Given Day) Tier 4 Locomotives
2,880	1,920	4,800	1,200 [1]

[1] Estimate by ARB staff using available railroad data.

A national pool of 4,800 UP and BNSF Tier 4 interstate line haul locomotives directed to operate towards California would cost an estimated $14.4 billion. It should be noted, that as the interstate line haul locomotives move from primarily Chicago to California, a number of other states would be receiving the Tier 4 emission reductions benefits, too. Therefore, a case could be made that potential costs should be shared proportionally over the other states enroute to California in the UP and BNSF operating systems. California's share would be $3.6 billion for 1,200 Tier 4 dedicated interstate line haul locomotives.

Cost-Effectiveness

By 2015, staff estimates UP and BNSF may pay up to $3.0 million for each new Tier 4 interstate line haul locomotive. The cost-effectiveness of a Tier 4 interstate line haul locomotives, consuming 500,000 gallons per year, would be within a range $3-$8 per pound NOx and PM reduced nationally. Assuming operations of only 20 percent within California, and consuming 100,000 gallon per year in California, the cost-effectiveness might range between $6 and $11 per pound or more of NOx and PM reduced within the state.

III. RAILYARD OPTIONS

This chapter provides evaluations of potential options to enhance and accelerate non-locomotive emission reductions within railyards. These options would primarily apply to intermodal railyards where operations include the use of non-locomotive sources such as: cargo handling equipment (CHE), heavy-duty (HD) diesel trucks, transport refrigeration units (TRUs), off-road equipment, and stationary sources. The evaluations are based on the following criteria: technical feasibility, potential emission reductions, costs, and cost-effectiveness.

A. Cargo Handling Equipment

1. Background

Cargo Handling Equipment is used to stack and move cargo containers and trailers, the most common type of cargo at intermodal railyards. This equipment includes: yard trucks, rubber-tired gantry cranes, top picks, side picks, forklifts, and straddle carriers. Cargo handling equipment is typically powered by off-road compression-ignition diesel engines, however, there is some equipment powered by on-road compression-ignition diesel engines. In 2004, the U.S. E.P.A promulgated new emission standards for off-road and on-road engines. Table III-1 lists these standards.

Table III-1: Cargo Handling Equipment
U.S. EPA On-Road and Off-Road Emissions Standards

Class	NOx (g/bhp-hr)	PM (g/bhp-hr)
On-Road		
2004 -2006	2.0	0.10
2007+	0.2	0.01
Off-Road		
Tier 1	6.9	0.40
Tier 2	4.3	0.15
Tier 3	2.6	0.15
Tier 4	0.3	0.015

Emission Standards for off-road engines rated between 175 hp and 750 hp

The following paragraphs describe three types of cargo handling equipment: yard trucks or hostlers, rubber tired gantry (RTG) cranes, and wide span gantry cranes.

Yard Trucks:

Yard trucks, also known as yard goats, utility tractor rigs, hustlers, yard trucks, and yard tractors, are the most common type of cargo handling equipment. Yard trucks are typically equipped with off-road engines but are very similar to heavy-duty on-road truck tractors. Cargo handling equipment, such as RTG cranes, load container cargo to and from yard trucks and trains. Yard trucks then move the container cargo around the railyard for stacking and storing purposes.

Yard Truck

Rubber Tired Gantry Cranes:

RTG cranes are very large cargo container handlers that have a lifting mechanism mounted on a cross-beam supported on vertical legs which run on rubber tires. While the propulsion of the crane is very slow (about three miles per hour), the lifting mechanism can move quickly, and is therefore able to load and unload containers from yard trucks or from stacks at a very fast pace. RTG cranes used in railyard intermodal yards typically range from 200 to 350 horse power compared to RTG cranes used in ports that have a horsepower range of about 200 to 1,000 horsepower, with the average being around 600 horsepower. There are approximately 300 RTG cranes at California's ports and intermodal rail yards. Based on the 18 railyard HRAs, there are about 67 RTGs in eight intermodal railyards.

Rubber Tired Gantry (RTG) Cranes

Rail Mounted Gantry or Wide Span Gantry Cranes:

Wide span gantry (WSG) cranes travel on rails to lift and stack container cargo. Compared to RTG cranes, WSG cranes are wider, are driven by electrical power, and have a higher traveling speed while handling cargo. WSG cranes are not only larger but also faster than RTG cranes which allows them to process more container cargo faster and gives container handling facilities (like intermodal railyards) higher stacking densities and greater lift capacities. As WSG cranes are driven by electrical power, they are quieter than RTG cranes and also have no direct on-site emissions.

Wide Span Gantry (WSG) Cranes

U.S. EPA Tier 4 Non-Road Engine Regulation and the ARB Regulation for Mobile Cargo Handling Equipment at Ports and Intermodal Railyards

In 2004, the U.S. EPA promulgated final emission standards for Tier 4 off-road diesel engines which are estimated to result in a 95 percent reduction in particulate matter emissions (PM) and a 90 percent reduction in oxides of nitrogen (NOx). The rulemaking affects engines manufactured after 2007 and uses a seven year phase-in period to implement the new emission standards. The new U.S. EPA emission standards are based on the use of advanced exhaust emission control devices such as diesel oxidation catalysts (DOC), selective catalytic reduction (SCR), and diesel particulate filters (DPF).

In 2005, the ARB took aggressive steps to mitigate emissions beyond the U.S. EPA off-road diesel emissions standards by approving a regulation for “Mobile Cargo Handling Equipment at Port and Intermodal Railyards.” This regulation takes a two pronged approach to reduce emissions and breaks up cargo handling equipment into two basic categories: Yard Trucks (e.g., hostlers) and Non-Yard Trucks (e.g., cranes). Both categories are required to comply with the regulation through the best available control technology (BACT).

Yard trucks can contribute up to 70 percent of railyard CHE emissions. Non-yard truck equipment such as RTGs cranes and other types of container cranes can contribute up to 20 percent or more of railyard CHE emissions. Other CHE such as top picks, forklifts, and loaders contribute to the rest of railyard CHE emissions.

Older yard trucks or hostlers will meet this performance standard primarily by accelerated turnover to new yard trucks equipped with on-road engines meeting the 2007+ emission standards. Non-yard truck equipment will meet BACT performance standards either through new on-road, or off-road engines or through the use of engine retrofit and a second compliance step (Tier 4 off-road engine or Level 3 VDECS). The ARB regulation is estimated to reduce diesel PM and NOx emissions from all cargo handling equipment by up to 80 percent by 2020. The ARB regulation became effective on January 1, 2007. Table III-2 shows the estimated emission reductions from the ARB regulation relative to the estimated emissions for 2004.

Table III-2
Estimated NOx and PM Emission Reductions
(ARB Regulation for Mobile Cargo Handling Equipment at Port and Intermodal Railyards)

Pollutant	2010	2015	2020
NOx	35%	47%	77%
PM	52%	66%	82%

2. Summary of Potential Options to Reduce Emissions from Cargo Handling Equipment

For this assessment, ARB staff assessed six potential options to reduce emissions from yard trucks and RTG cranes. These options are summarized in Table III-3 and are referred to as options 9 through 14.

Table III-3: Potential Options to Reduce Emissions from Cargo Handling Equipment

No.	Options	PM (tons per day)	NOx (tons per day)	Cost-Effectiveness (NOx+PM)	Costs (millions)
Yard Trucks/Hostlers – (Replace 322 yard trucks in 8 intermodal railyards)					
10	LNG Yard Trucks	-	-	-	$39 ($.12/unit 322 units)
11	Electric Yard Trucks	0.01[1] (2015)	0.27[1] (2015)	$29/lb (2015) (8 years)	$68 ($.21/unit 322 units)
12	Hybrid Yard Trucks	-	-	-	-
RTG Cranes – (Retrofit/Replace 67 RTGs in 8 intermodal railyards)					
13	Energy Storage Systems	0.0014 (2015)	0.08 (2015)	$10-$20/lb (2015) (20 years)	$11-22 ($.16-$.32/ 67 RTG Cranes)
14	Wide Span Gantry Cranes and Non-Locomotive Railyard Electrication	0.023 (2015)	0.79 (2015)	$97/lb (2015) (20 years)	$1,200 (134 WSGs replace 67 RTGs)
Idle Reduction Devices - (Retrofit cargo handling equipment with idle reduction devices similar to those employed on trucks and locomotives)					
15	Idle Reduction (Cargo Handling Equipment)	-	-	-	-

1. Emission benefits are based on emission inventories for 18 railyard health risk assessments finalized in 2007 and 2008. Estimated emission reductions are surplus to the ARB Regulation for Mobile Cargo Handling Equipment at Ports and Intermodal Railyards in 2015.

Each option could provide further and earlier emission reductions than required by the ARB's existing cargo handling equipment regulation.

3. Analysis of Option 10 - LNG Yard Trucks at Railyards

Background

Alternative fuels are one of the many strategies that the ARB has employed to control emissions and reduce health risks from diesel engines. In heavy-duty diesel engines, liquefied natural gas (LNG) is one alternative to diesel fuel. LNG is a cryogenic liquid (boiling point: -260°F) and a form of natural gas that is not only denser, but also contains more energy per volume than most alternative fuels. However, compared with diesel fuel, the energy content of LNG is less (diesel is rated at about 130,000 Btu per gallon and LNG is rated at about 75,000 Btu per gallon). This a key consideration with LNG because LNG fueled vehicles can incur up to a 40 percent loss in energy content, as well as a potential loss in fuel efficiency, as compared to diesel on a gallon equivalent basis.

In order to transport and store LNG, with such a low boiling point, on-board fuel tanks require a double wall design with high grade insulation and vacuum inter-tank space.

These requirements make LNG tanks more complex and heavier than traditional diesel fuel tanks. Accordingly, LNG fueled yard trucks carry a weight penalty absent in conventional diesel-fueled yard trucks.

Heavy-duty engines can either be originally manufactured to run on LNG or converted from diesel. Diesel engines can be converted to run on LNG fuel because they share many of the same components as heavy-duty LNG engines. The biggest differences between LNG and diesel engines are the compression ratio, fuel delivery, and ignition systems.

There are several conversion kits available which allow heavy duty diesel engines to be adapted to use LNG fuel, but the conversion usually comes with a tradeoff of derated power which avoids pre-ignition detonation of the gaseous fuel.

Technical Feasibility

LNG yard trucks are being evaluated through demonstration programs sponsored by the U.S. EPA, South Coast Air Quality Management District (SCAQMD), the Ports of Los Angeles and Long Beach, and others. In 2008, Sound Energy Solutions (SES) and the Port of Long Beach released a report detailing the findings of a joint project to determine performance, emissions, and business impacts of LNG yard trucks.

One potential issue surrounding the use of LNG fuel is the NOx emissions from LNG engines. Previous studies comparing on-road diesel to on-road LNG yard trucks, one conducted by ARB (2006) and one by the Port of Long Beach (2007), showed significantly higher NOx emissions from the LNG engines in comparison to the on-road diesel engines[7]. Emission testing conducted as part of the Port of Long Beach and SES LNG yard truck study also found that the LNG engines produced more NOx than the

on-road diesel engines. The SES report also noted a decrease in fuel efficiency in comparison to the diesel-fueled yard trucks. ARB plans to conduct in-use emissions testing in 2009, comparing a diesel-fueled yard truck certified to 2007 on-road standards to an LNG-fueled yard truck certified to 2010 on-road standards.

The lack of an LNG fueling infrastructure also remains a challenge to LNG. In the SES study, the refueling station consisted of a 3,450 gallon ORCA™ mobile LNG refueling truck. The truck was inspected to verify conformance to local permitting and safety requirements and, for the study, treated as a permanent structure. Applied LNG Technologies was contracted to provide fuel deliveries for the project.

[7] Source: "Cargo Handling Equipment Yard Truck Emissions Testing", CARB, September 2006; "Liquefied Natural Gas (LNG) Yard Hostler Demonstration and Commercialization Project – Prepared for the Port of Long Beach," West Start-CALSTART, 2007

Potential Emission Reductions

The SES report compared three LNG-fueled yard trucks to a representative sample of diesel-fueled yard trucks powered by off-road and on-road engines meeting standards illustrated in Table III-1.

One key aspect to the ARB CHE Regulation is its fuel neutrality. New yard trucks must meet the 2007+ on-road or Tier 4 off-road engine standards for PM and NOx regardless of fuel type. Therefore, if LNG fueled yard trucks are compared to diesel fueled yard trucks powered by 2007+ on-road or Tier 4 off-road engines, they provide no surplus emission reductions to the ARB CHE regulation in 2015.

Costs

According to 2008 SES and the Port of Long Beach report, the estimated cost of an LNG yard truck is about $120,000 per unit. The SES report also estimated that the cost of a LNG fueling station at around $700,000, but ARB staff did not include the fueling infrastructure costs as it was not clear how many LNG trucks could be supported by an individual LNG fueling station. In comparison, diesel fueled yard trucks are estimated to cost between $50,000 and $60,000 per unit.

Cost-Effectiveness

Cost-effectiveness for LNG yard trucks was not calculated because staff was not able to identify emission reductions that are surplus to the ARB CHE regulation in 2015.

4. Analysis of Option 11 - Electric Yard Trucks in Railyards

Background

Electric yard trucks use onboard batteries which produce electricity to run an electric motor. Electric yard trucks have zero emissions onsite, but need an external charging station to recharge their batteries. This technology has been demonstrated on vehicle platforms ranging from passenger vehicles to trucks. Electric yard trucks are currently being tested at the Port of Los Angeles to demonstrate the technical feasibility of this technology in port applications.

Technical Feasibility

Electric yard trucks are being evaluated through demonstration programs sponsored by the U.S. EPA, SCAQMD, the Ports of Los Angeles and Long Beach, and others. In 2008 the Port of Los Angeles began testing and demonstrating an electric yard truck for several parameters critical to port applications, including payload and range. As a result of this demonstration effort, the Los Angeles Harbor Commission recently approved an order for the production of 20 electric yard trucks, pending the successful completion of cargo terminal tests. According to the manufacturer, Balqon, these electric yard trucks are capable of towing up to 30 tons, have a maximum speed of 25 miles per hour, and a range of 30 miles when under full load.

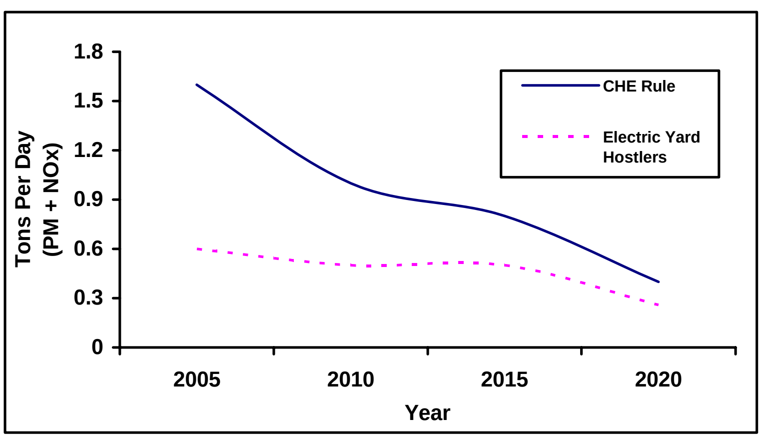
Potential Emission Reductions

ARB staff compared the individual emissions of an electric yard truck to a conventional yard truck powered by a 2007+ on-road diesel engine (PM: 0.01 g/bhp-hr, NOx: 0.3 g/bhp-hr). ARB staff estimated that on a per unit basis, electric yard trucks provide potential diesel PM and NOx emission reductions of 0.000005 and 0.00016 tons per day, respectively.

According to the 18 railyard HRAs, in 2005, the 322 yard trucks operated at eight intermodal railyards generated an estimated 0.041 and 0.90 tons per day of diesel PM and NOx emissions, respectively. As a result of the ARB CHE regulation, staff estimates that by 2020 diesel PM and NOX emissions, associated with yard trucks, could be as low as 0.005 and 0.082 tons per day respectively.

Staff estimates that electric yard trucks could reduce railyard diesel PM and NOx emissions from yard trucks by up to 100 percent. These emission reductions would be surplus to the to the ARB CHE regulation, as well as the U.S. EPA/ARB Tier 4 non-road engine regulation and result in diesel PM and NOx reductions of up to 0.015 and 0.46 tons per day, in 2010, respectively. In 2015, as diesel engines become cleaner, the level of diesel PM and NOx reductions that electric yard trucks could achieve drops to 0.01 and 0.27 tons per day, respectively. Figure III-4 shows the projected railyard CHE emission reductions from electric yard trucks.

Figure III – 4: CHE Railyard Emissions –
Projected Emission Benefits of Electric Yard Trucks



Costs

According the Port of Los Angeles Electric Truck Demonstration Fact Sheet, electric yard trucks cost approximately $189,950 per unit. The fact sheet also states that the price of one charging station (which simultaneously charges four trucks) is about $75,000. It is not clear whether the charging station cost also includes the cost of construction or additional infrastructure needed to support this technology. Allocating the cost of the charging station to an electric yard truck increases the cost to about $209,000 per piece of equipment. In comparison, diesel fueled yard trucks are estimated to cost between $50,000 and $60,000 per unit.

Cost-Effectiveness

Staff has calculated cost-effectiveness for electric yard trucks to be about $29 per pound of NOx and PM emissions reduced. This is based on the estimated railyard yard truck emission levels of diesel PM and NOx in 2015, as a result of the ARB cargo handling regulation. As stated previously, this estimate does not account for the cost of the electric infrastructure.

5. Analysis of Option 12 - Hybrid Yard Trucks in Railyards

Background

Hydraulic hybrid yard trucks are vehicles that, in addition to their main engines, have a drive train that can recover, store, and reuse energy. In a hydraulic hybrid, the hydraulic drive system uses hydraulic accumulators and converts stored energy with hydraulic pump motors. This hydraulic drive system replaces a conventional drive train and eliminates the need for a conventional transmission.

The hydraulic hybrid system increases vehicle fuel economy in three ways by:
1) permitting the recovery of energy that is otherwise wasted in vehicle braking,
2) allowing the engine to be operated at much more efficient modes, and 3) enabling the engine to be shut-off during many operating conditions, such as when the vehicle is decelerating and momentarily stopped.

Technical Feasibility

Hybrid yard trucks are being evaluated through demonstration programs sponsored by the U.S. EPA, the Ports of Los Angeles and Long Beach, and others. In 2005, the U.S. EPA and United Parcel Service (UPS) unveiled a demonstration delivery van with a hydraulic hybrid drive-train. The demonstration van uses a series hydraulic hybrid system which transmits power directly to the wheels rather than through a conventional transmission or drive shaft. Early test results show a potential for up to a 45 to 50 percent improvement in fuel economy in city driving.

Based on the results of the early tests, U.S. EPA and the Port of Long Beach commenced a hydraulic hybrid yard truck demonstration project. The goal of this demonstration program is to build a prototype so that common requirements could be established for a hybrid yard truck duty cycle. The results of this demonstration are still pending. ARB is planning to support this demonstration project through in-use comparison emissions testing with a 2007+ conventional diesel yard truck. Testing is expected to occur in 2009.

Potential Emission Reductions

Staff was unable to develop estimates of hybrid yard trucks potential emission reductions. Any emission reductions would most likely result from increases in fuel economy indicated throughout initial testing. During ARB's planned emissions testing next year, in-use data logging will be performed on the hybrid engine and an appropriate duty cycle will be developed and used for the comparison tests.

Costs

Staff does not currently have cost information for hybrid yard trucks. However, following the UPS demonstration, U.S. EPA estimated that in high-volume production (20,000 to 30,000 units per year), the incremental cost difference would be about $10,000 compared to a conventional diesel truck for the same application.

Cost-Effectiveness

Staff did not calculate cost-effectiveness for hybrid yard trucks due to the lack of costs and emissions reductions data.

6. Analysis of Option 13 - Energy Storage Systems on Railyard RTG Cranes

Background

Energy Storage Systems (ESS) capture regenerated energy from energy that would otherwise be dissipated and lost from crane braking, deceleration, etc. In crane applications, an ESS is integrated with a hoist motor, and the dissipated (lost) energy is captured (regenerated) from the hoist cycle. As the crane lowers a container, the hoist motor acts as a generator (through regenerative braking energy, a result of deceleration). Typically, this energy is routed to dissipating resistor banks and wasted as heat. The ESS captures this energy and uses it to reduce the load of an engine throughout the duty cycle.

Technical Feasibility

ESS systems are currently available for several off-road engines. These systems are considered a Level 1 VDECS for RTG crane applications. A level 1 VDECS reduces diesel PM by up to 25 percent, however, ESS can also reduce NOx emissions by 25 percent as well[8].

[8] http://www.arb.ca.gov/diesel/verdev/vt/cvt.htm

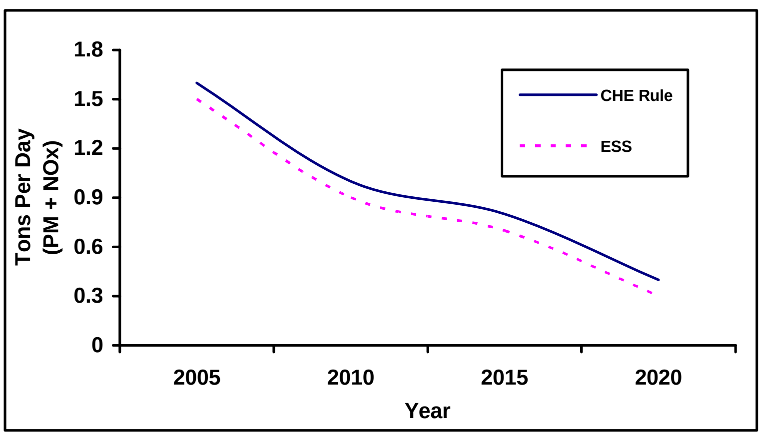
Potential Emission Reductions

ARB staff calculated the emission benefits of an ESS retrofit on a RTG crane powered by a Tier 4 off-road diesel engine (PM: 0.01 g/bhp-hr, NOx: 0.3 g/bhp-hr). ARB staff estimated that an individual ESS unit can provide diesel PM and NOx emission reductions of up to 0.002 and 0.04 tons per year, respectively.

According to the 18 railyard HRAs, in 2005, the 67 RTG cranes operated at eight intermodal railyards generated an estimated 0.014 and 0.40 tons per day of diesel PM and NOx emissions, respectively. As a result of the ARB CHE regulation, staff estimates that by 2020 diesel PM and NOX emissions, associated with RTG cranes, could be as low as 0.005 and 0.27 tons per day respectively.

Staff estimates that ESS could reduce railyard diesel PM and NOx emissions from RTG cranes by up to 25 percent. These emission reductions would be surplus to the ARB CHE regulation as well as the U.S. EPA/ARB Tier 4 non-road engine regulation. In 2010, the ESS could provide diesel PM and NOx reductions of up to 0.002 and 0.093 tons per day respectively. In 2015, as diesel engines become cleaner, the level of diesel PM and NOx reductions that ESS could achieve drops to 0.001 and 0.082 tons per day, respectively. Figure III-5 shows the resulting railyard CHE emission benefits from retrofitting RTG cranes with ESS.

Figure III - 5: CHE Railyard Emissions – Projected Emissions Reduction of ESS on RTG Cranes



Costs

An ESS is estimated to cost between $160,000 and $320,000 per crane[9]. For the eight intermodal railyards with 67 RTG cranes, the total costs would range between $11 and $22 million.

[5] Source: "Proposition 1B: Goods Movement Emission Reduction Program, Final Guidelines for Implementation" – February, 2008.

Cost-Effectiveness

Cost-effectiveness for ESS ranges between an estimated $10 and $20 per pound of NOx and PM emissions reduced. Cost effectiveness is based primarily upon the estimated cost range for ESS, and the estimated railyard RTG crane emission levels of diesel PM and NOx in 2015, as a result of the ARB cargo handling regulation.

7. Analysis of Option 14 – Use of Railyard Wide Span Gantry Cranes and Non-Locomotive Railyard Electrification

Background

One alternative to traditional RTG cranes are wide span gantry (WSG) cranes and installation of the necessary electrific infrastructure to support WSG cranes. Railyard electrification and the installation of WSG cranes could nearly eliminate all RTG crane and yard truck railyard-related emissions.

WSG cranes are powered by electricity generated by the electrical grid (rather than a diesel engine). WSG cranes are twice as wide as conventional RTG cranes and are rail mounted. In contrast to RTG cranes, WSG cranes can be semi-automated because they employ advanced computer and GPS systems.

Technical Feasibility

Generally, WSG crane systems are implemented at brand new or key port and railyard facilities designed to handle a large volume of containers (i.e, more than 750,000 per year). WSG cranes have been installed at the Port of Seattle and are proposed for other key facilities in Memphis, Kansas City and Long Beach.

Union Pacific has proposed to modernize the Intermodal Container Facility (ICTF) in Long Beach, California. UP has proposed to install 39 WSG cranes in three phases over three years. The proposed expansion would replace 10 existing RTGs, with 20 WSG cranes. In addition, UP has proposed to install an additional 19 WSG cranes to accommodate the proposed doubling of container handling, which would increase from the current 750,000 to 1,500,000 lifts.

Installation of WSG cranes carry widely varying costs associated with planning and construction and the operational needs of an individual facility. Installing WSG cranes may require an extensive redesign and reconstruction of an entire yard as the flow of goods and equipment completely changes. There is no one route to electrification at a railyard and construction at an existing facility is extremely difficult. Every facility is different, and projects of this magnitude require extensive planning; there are extensive structural foundations to be constructed in addition to the work for handling the electrical demand. The type of electric equipment which may be operationally feasible at one yard may not be operationally feasible at another railyard. Furthermore, electrification may not necessarily result in zero emissions. Some facilities may still need to use diesel-fueled CHE, such as side loaders, top picks, and forklifts, to complement the all-electric equipment.

Potential Emission Reductions

According to the 18 railyard HRAs, in 2005 the 322 yard trucks and 67 RTG cranes operated at eight intermodal railyards generated nearly all of the 0.07 and 1.49 tons per day of railyard CHE diesel PM and NOx emissions, respectively. As a result of the ARB CHE regulation, staff estimates that by 2020 diesel PM and NOX emissions, associated with railyard CHE, could be as low as 0.014 and 0.30 tons per day, respectively. Table III-4 compares diesel PM and NOx emissions for eight intermodal railyards in 2005 and 2020.

Table III-4
Eight Intermodal Railyards - 2005 and 2020 CHE Emissions

Railyard	2005 CHE Emissions (tons per day)		Estimated 2020 CHE Emissions (tons per day)	
	PM	NOx	PM	NOx
UP Commerce	0.013	0.13	0.003	0.026
UP ICTF	0.012	0.33	0.0024	0.066
BNSF Hobart	0.011	0.34	0.0023	0.068
BNSF San Bernardino	0.01	0.32	0.002	0.065
UP City of Industry	0.008	0.1	0.0015	0.02
UP LATC	0.007	0.16	0.0014	0.032
UP Oakland	0.005	0.06	0.0011	0.013
BNSF Commerce Eastern	0.001	0.04	0.0002	0.008
Total	**0.067**	**1.48**	**0.0139**	**0.298**

Staff has assumed a best case scenario, that the electrification of a railyard and the installation of WSG cranes would eliminate all CHE emissions in the eight intermodal railyards. Emission reductions resulting from this option would be surplus to the ARB CHE regulation and the U.S. EPA/ARB Tier 4 non-road engine regulation. This option could result in diesel PM and NOx reductions of up to 0.033 and 0.97 tons per day in 2010, respectively. In 2015, as diesel engines become cleaner, the level of diesel PM and NOx reductions that WSG cranes and railyard electrification could achieve drops to 0.023 and 0.79 tons per day, respectively.

Costs

WSG cranes can cost between $4 and $8 million per crane (depending on size, configuration, application, etc.). However, as was stated previously, WSG cranes, along with their base costs, can incur other costs (i.e., planning and construction) that can vary widely. Electric infrastructure and related construction costs needed to support WSG cranes can be more than double the costs of the WSG cranes. Table III-5 lists cost estimates of WSG crane and railyard electrification for eight intermodal railyards.

Table III-5
Estimated Railyard Electrification and Wide Span Gantry Costs For Eight Intermodal Railyards

Eight Intermodal Railyards	Estimated 2005 Container Lifts	Estimated RY Electrification* and WSG Costs ($ million)
BNSF Hobart	1,340,00	400
UP ICTF	750,000	200
BNSF San Bernardino	550,000	150
UP Commerce	350,000	100
UP LATC	350,000	100
UP Oakland	350,000	100
UP City of Industry	350,000	100
BNSF Commerce/East.	130,000	40
Totals	4,280,000	1,190

*Non-Locomotive

As Table III-4 shows, in 2005 eight intermodal railyards performed 4,280,000 container lifts. In order to perform comparable work, nearly 134 WSG cranes would need to be installed across the eight railyards. Staff has estimated that the cumulative costs of the WSG cranes at eight intermodal railyards as well as the necessary electric infrastructure could approach $1.2 billion.

Cost-Effectiveness

Staff has calculated cost-effectiveness for non-locomotive railyard electrification and WSG cranes to be about $97 per pound of diesel PM and NOx emissions reduced. Cost effectiveness is based on the estimated railyard CHE emission levels of diesel PM and NOx in 2015, as a result of the ARB cargo handling regulation.

7. Analysis of Option 15 – Reducing Idling for Railyard CHE

Background

Idle reduction technologies were initially developed to mitigate emissions associated with non-essential idling from locomotive and truck engines. Most idle reduction systems are passive and automate shutdown/restart sequences by monitoring and maintaining essential parameters that are needed for the operational or safety purposes (i.e., powering heating units in cold climates) of this equipment without any input from the operator. Currently, there are several idle reduction technologies available for locomotives and heavy duty diesel trucks. These technologies include: automatic shutdown/ startup systems, auxiliary power units, fuel operated heaters, and battery air conditioning.

Automatic shutdown/startup systems (referred to as AESS) for locomotives work by managing the shutdown and restart sequences of a locomotive engine while the locomotive is stopped. The system monitors the existing condition of several essential criteria (i.e. brake cylinder pressure, battery voltage, throttle position, etc.) against preset standards and determines whether the engine can be shut down or if it needs to be restarted. In trucks, the AESS system works in a similar fashion.

Auxiliary power units (APU) are small engines that work to reduce engine idle by shutting down the main (larger) engines of locomotives and trucks. As with automatic shutdown/startup systems, these units also monitor essential engine systems against set criteria. APUs, however, can also provide power for the heating and air conditioning units in the locomotive or truck cab.

Fuel operated heaters (FOH) and battery air conditioning (BAC) both work to reduce engine idle by providing power to a cab's heating and air conditioning system, allowing the main engine to be shut-down.

Most idle reduction technologies were not initially designed for cargo handling equipment. While shutdown/startup systems have been effective at reducing emissions from idling trucks and locomotives, it is not clear what, if any, emission reductions these systems can provide from cargo handling equipment.

Anti-idling policies at intermodal railyards may also effectively reduce emissions from CHE. Limiting unnecessary idling will result in reduced fuel usage, a reduction of criteria pollutants, and a fuel cost savings.

<u>Technical Feasibility</u>

Idle reduction device technology for cargo handling equipment is not currently available nor is it being demonstrated. Additionally, there is currently no regulation prohibiting unnecessary idling from CHE. It has not yet been determined to what extent CHE may idle unnecessarily. Further research is needed to address CHE adaptability with idle reduction devices, to identify potential opportunities for emission reductions (i.e., extended idling periods within the duty cycle), and analyze railyard cost-effectiveness and operational and business technical feasibility. Safety issues related to turning engines off while equipment is awaiting use also needs to be thoroughly studied.

<u>Potential Emission Reductions</u>

At this time there is no proven idle reduction technology for cargo handling equipment. However, the emission reductions achieved would depend on the amount of unnecessary idling that exists and is reduced. Any emission reductions would be surplus to the ARB CHE regulation.

Costs

At this time staff does not have any actual costs for idle reduction devices on CHE.

Cost-Effectiveness

ARB staff does not currently have actual emission reductions and costs data for idle reduction devices on CHE. As a result, staff has not calculated cost-effectiveness.

B. Transportation Refrigeration Unit (TRU) – Plug-In Electrification

1. Background

TRUs are typically powered by small nonroad diesel engines of usually less than 50 horsepower. TRU diesel engines power compressors that regulate the temperature inside a cargo container or refrigerated railcar. They are primarily used to ensure that temperature sensitive cargo, such as food, is kept at an acceptably low temperature while in transit.

In February 2004, the Board approved a regulation for "In-Use Diesel Fueled Transport Refrigeration Units" (TRU) and TRU generator (gen) sets, and facilities where TRUs operate. The existing TRU regulation was approved by the Office of Administrative Law on December 10, 2004. Implementation was scheduled to begin December 31, 2008, but has been delayed to January 1, 2010. The TRU regulation applies to both owners and operators of diesel fueled TRUs. The goal of the TRU regulation is to reduce diesel particulate matter from TRUs that operate in California by about 92 percent by 2020.

In 2005, the ARB emission inventory estimated that statewide TRUs accounted for about 2.5 tons per day (or 913 tons per year) of diesel PM and 24 tons per day of NOx. According to the ARB railyard HRAs, TRU diesel PM emissions were an estimated 0.04 tons per day, or about 14 tons per year, within California's 18 designated railyards in 2005. Within the eight intermodal railyards, TRUs accounted for about 13 tons per year in 2005. Total railyard TRU diesel PM emissions represent nearly 2 percent of statewide TRU diesel PM emissions.

Staff has prepared a technical assessment of an option that would be in addition to the ARB TRU regulation. This option is to include plug-in electrification for TRUs, to further reduce diesel PM emissions from TRUs at railyards.

2. *Analysis of Option 16 – Plug-In Electrification for Transport Refrigeration Units (TRUs)*

Technical Feasibility

Plug-in electric power is currently technically feasible and commercially available. For example, plug-in TRU electrification has been installed in the Port of Oakland. Land must be dedicated for this equipment and electrical infrastructure must be installed to utilize plug-in TRU electrification. For the Port of Oakland, the plug-in electrification equipment are located at either a parking lot where containers are placed on chassis and serviced by dedicated electrical outlets, or on a structure called a reefer rack where containers are stacked and plugged in. In all applications, there is a time component in racking and de-racking the units when a truck or train is ready for the container. In addition, added vehicle activity may be required to ferry containers around the yard to the racks.

Reefer Rack

Currently, there are about 160 reeferplugs at ICTF (TRU plug-in electric power). In order to incorporate plug-in electric power for TRUs, railyards would have to dedicate areas within the railyards, like the Port of Oakland, and install the necessary reefer racks and electrical infrastructure. Installation of electrical infrastructure would be necessary due to the high power draw of the TRUs when plugged in, especially during peak shipping periods such as the summer harvest. TRU plug-in electrification would likely be most effective if included as part of a larger railyard electrification project.

Plug-in electric power would have the greatest impact in the railyards with the highest TRU diesel PM emissions. Note that electric plug-in for TRUs would be compatible with TRU standalone containers, but not with refrigerated railcars.

Potential Emissions Reductions

In 2005, the eight intermodal railyards generated about 13 of the 14 tons per year of diesel PM emissions associated with TRUs. The eight intermodal railyards include: BNSF Hobart, BNSF San Bernardino, BNSF Commerce Eastern, UP ICTF, UP Oakland, UP Commerce, UP City of Industry, and UP LATC.

The ARB TRU regulation is expected to reduce TRU emissions by 92 percent by 2020 in the 8 intermodal railyards (accounting for growth) or to about 0.003 tons per day, or about 1 ton per year, of railyard TRU diesel PM emissions. Therefore, the maximum possible emissions reductions in the four largest railyards would be about 0.003 tons per day of diesel PM by 2020.

TRU NOx is generally emitted at a factor of 10 times higher than PM emissions. To estimate the NOx emission reductions, the PM emission reductions were multiplied by 10. The maximum mitigated NOx would therefore be about 0.03 tons per day by 2020 using this method.

Due to the increased usage of yard trucks to transport the TRUs from rail to racks and back, there is a possibility that this option could also lead to no emission reductions or possibly lead to emissions increases. The amount of increased emissions is not known. Further study would be necessary before implementation of this option to assess all of the potential impacts. However, accelerated implementation of this option would increase the emission benefits.

Costs

Costs of the refrigerated or reefer racks have been estimated to be about $120,000 to $216,000 per rack, based on bids received at the Port of Oakland. Based on these estimates, staff assumed total costs of $1 million to install racks at eight intermodal railyards. The installation of reefer racks would necessitate installation of additional electrical infrastructure which could cost up to $500 million. However, non-locomotive railyard electrification costs for eight intermodal railyards would cost an estimated $1.2 billion to be able to support the TRU plug-in electrification. The $500 million dollar value for infrastructure was determined by taking the electrification cost of 1.2 billion for eight intermodal railyards (see Table III-5), and subtracting an estimated WSG equipment cost of 700 million (close to the $804 million figure determined using an average cost of $6 million per crane).

Cost-Effectiveness

This option assumes that 100 percent of the remaining 0.003 tons per day of diesel PM emissions and 0.03 tons per day of NOx in 2020 are completely eliminated. The costs have been amortized over 10 years. Based on these assumptions, the cost-effectiveness for this option would be about $940 per pound of PM and NOx reduced.

C. Port and Intermodal Railyard Drayage Trucks

1. Background

A heavy-duty drayage truck is any on-road diesel-fueled vehicle with a gross vehicle weight rating (GVWR) of 33,001 pounds or greater. Drayage trucks operate primarily in and around ports and intermodal railyards. Drayage trucks transport cargo, such as containerized, bulk or break–bulk goods. Staff estimates that approximately 20,000 drayage trucks annually operate on a regular basis at California’s ports and intermodal railyards. Of that total, approximately 16,800 drayage trucks frequently operate at the Ports of Los Angeles and Long Beach.

Drayage trucks are a significant source of air pollution. In 2007, drayage trucks generated an estimated 3 and 61 tons per day of diesel PM and NOx, respectively. Drayage trucks also often operate in close proximity to communities. In December 2007, the ARB Board approved a port truck fleet modernization program that, as compared to the 2007 emission inventory baseline, will reduce diesel PM by nearly 86 percent by 2010, and NOx by nearly 56 percent by 2014. The ARB port and intermodal railyard drayage truck regulation will result in significant reductions in exposure and potential cancer risks to residents that live near ports, railyards, and the major roadways that service the ports and intermodal railyards.

ARB staff has assumed, for both emissions reductions and cost-effectiveness calculations, all intermodal railyards will meet the ARB drayage truck regulation requirements by January 1, 2014. This would result in all intermodal railyard drayage trucks meeting a 1.2 g/bhphr for NOx and 0.01 g/bhp-hr for PM by at least 2015. ARB staff assumes that the ARB drayage truck regulation will serve as the emissions baseline to compare with LNG, CNG, and electric drayage trucks in 2015.

Health risk assessments were prepared for 18 major railyards, with 8 of those railyards identified as intermodal. In 2005, within the boundaries of the 8 intermodal railyards drayage trucks generated about 0.085 tons per day (31 tons per year) of diesel PM emissions. The eight intermodal railyard drayage truck diesel PM emissions account for about 3 percent of statewide drayage truck PM emissions. The ARB drayage truck regulation is estimated to reduce intermodal railyard drayage truck diesel PM emissions by up to 90 percent by 2015, or to about 0.0085 tons per day (3.1 tons per year) of diesel PM emissions.

ARB staff estimates that the emerging alternative fuel technologies for drayage trucks (e.g., CNG, LNG, and electric), may potentially provide additional emission reductions for intermodal railyards beyond those required by the ARB port and intermodal railyard drayage truck regulation by 2015.

2. *Analysis of Option 17 – New 2007 Diesel Fueled Drayage Trucks Within Intermodal Railyards*

Background

The ARB port and intermodal railyard drayage truck regulation has been approved by Office of Administrative Law and will go into effect by January 1, 2009. Drayage trucks entering ports and intermodal railyards will be required to generally meet new 2007 PM truck standards (i.e., built with or retrofitted with a diesel particulate filter) and meet 0.01 g/bhp-hr, except for a smaller group of newer trucks, by January 1, 2010.   On a fleet average basis, ARB staff estimated an 86 percent reduction in drayage truck PM emissions by January 2010, and up to a 90 percent reduction in PM emissions by 2014.

Similarly, port and intermodal railyard drayage truck NOx emissions will be limited to the new 2007 truck emissions levels of 1.2 g/bhp-hr (average) by January 1, 2014. The ARB drayage truck regulation NOx requirement will result in about a 56 percent NOx reduction on a fleet average basis by 2014. The intermodal railyards will also benefit from any new 2010 trucks (NOx at 0.2 g/bhp-hr) that enter the intermodal railyards as well.

Potential Emissions Reductions

Health risk assessments were prepared for 18 major railyards, with eight of those railyards identified as intermodal. In 2005, within the boundaries of the eight intermodal railyards drayage trucks generated about 0.085 tons per day, or 31 tons per year, of diesel PM emissions. The eight intermodal railyard drayage truck diesel PM emissions account for about 3 percent of statewide drayage truck PM emissions. The ARB drayage truck regulation is estimated to reduce intermodal railyard drayage truck diesel PM emissions by up to 90 percent by 2015, or to about 0.0085 tons per day (3.1 tons per year) of diesel PM emissions.

Table III - 6
Older Existing HD Diesel Truck and New HD Diesel Truck
NOx and PM Emissions Standards

Existing Older Heavy-Duty (HD) Diesel and LNG Truck Model-Year	**NOx (g/bhp-hr)**	**PM (g/bhp-hr)**	**NOx Reduced from 1995 MY**	**PM Reduced from 1995 MY**
1995 Trucks	5.0	0.1	-	-
New 2007 HD Diesel Trucks	1.2	0.01	76%	90%
New 2010 HD Diesel Trucks	0.2	0.01	96%	90%
ARB Drayage Truck Regulation * (2010 PM/2014 NOx)	**1.2**	**0.01**	**76%**	**90%**

* Between 2007 and 2009 U.S. EPA requires 50 percent of the heavy-duty diesel engine family certifications to meet the 0.20 g/bhp-hr NOx standard. Averaging is allowed and it is expected that most engines will conform to the fleet NOx average of approximately1.2 g/bhp-hr.

The Port of Los Angeles (white paper) assumed that the average port drayage truck is a 1995 model year. The ARB Goods Movement Calculation assumes 1995 model year port drayage trucks travel about 40,000 miles per year. A 1995 model year HD diesel truck has NOx and PM grams per mile emissions rates of about 21 and 0.7, respectively, or about 1 ton per year for both NOx and PM.

ARB staff has assumed a new 2007 truck NOx and PM emissions levels (i.e., 5 grams/mile NOx and 0.07 grams/ mile PM) as the baseline for 2014, based on the ARB drayage truck regulation. A new 2007 HD diesel truck would generate about 446 pounds of NOx (440 lbs) and PM (6 lbs) per year. Therefore, a 2007 diesel drayage truck replacement, as required by the ARB drayage truck regulation by 2015, would provide no surplus NOx and PM emissions reductions beyond existing ARB truck regulations applicable to intermodal railyards.

Costs

The Port of Los Angeles (white paper) estimated the cost of a new 2007/2010 HD diesel truck to be about $110,000.

Cost-Effectiveness

Assuming there are no emissions reductions when comparing 2007 HD diesel trucks with new 2007 HD diesel trucks, as required by the ARB drayage truck regulation by 2014. Therefore, there is no cost-effectiveness calculation for new 2007 HD diesel trucks.

3. Analysis of Option 18 – Liquefied Natural Gas (LNG) Fueled Drayage Trucks Within Intermodal Railyards

Background

The ARB port and intermodal drayage regulation defines “Liquid Natural Gas (LNG) Fueled Trucks” as drayage trucks that utilize a heavy-duty pilot ignition engine that is designed to operate using an alternative fuel, such as LNG, except that diesel fuel is used for pilot ignition at an average ratio of no more than one part diesel fuel to ten parts total fuel on any energy equivalent basis. An engine that can operate or idle solely on diesel fuel at any time does not meet this definition.

ARB staff examines the scenario of possibly replacing 2007 compliant diesel drayage trucks with new LNG fueled drayage trucks that will operate primarily from the ports to near dock intermodal railyards.

Technical Feasibility

LNG drayage trucks are being evaluated through various demonstration programs and projects sponsored by the U.S. EPA, South Coast Air Quality Management District (SCAQMD), the Ports of Los Angeles and Long Beach, and others. The Ports of Los Angeles and Long Beach, in collaboration with SCAQMD, California Energy Commission, Clean Energy, Kenworth Truck Company and Westport are working on the development and certification of a 2007 LNG high-pressure direct-injection engine. This effort will work to determine performance, emissions and business case impacts of the LNG truck engine. LNG drayage trucks are technically feasible, thoroughly tested, and are commercially available through the Kenworth Truck Company.

Figure III - 6. LNG Drayage Truck by Kenworth Truck Company

Potential Emission Reductions

In 2005, within the eight intermodal railyards boundaries (with railyard HRAs), heavy-duty (HD) diesel trucks were responsible for an estimated 31 tons per year of diesel PM emissions. The ARB has three statewide diesel truck regulations for new, drayage, and private fleet trucks. However, the ARB drayage truck regulation will have the largest impacts in the near-term at intermodal railyards. ARB staff estimates that the ARB port and intermodal railyard drayage truck regulation will reduce diesel PM emissions by up to 90 percent by 2015, or to about 3.1 tons per year. New LNG heavy duty (HD) trucks could potentially provide earlier and greater emissions reductions beyond the emissions reductions provided by the ARB drayage truck regulation in 2015.

The Ports or Los Angeles and Long Beach have about 16,800 drayage trucks operating at their facilities. On average, the port's drayage trucks are 1995 model year trucks emitting at about 5.0 g/bhp-hr NOx and 0.1 g/bhp-hr PM. However, under the ARB drayage truck regulation, the older diesel trucks will be replaced or required to meet the 2007 new truck PM emissions standard of 0.01 g/bhp-hr (90% reduction) by January 1, 2010, and the 2007 new truck NOx emissions standard of 1.2 g/bhp-hr (75% reduction) by January 1, 2014. See the applicable truck emission standards below in Table III-7. With an average 90 percent reduction, the eight intermodal railyards diesel drayage truck diesel PM emissions could be reduced from 31 to about 3.1 tons per year by 2020.

As a result, the new 2007 HD diesel trucks, required by the ARB drayage truck regulation by 2010 and 2014, provide about the same level of PM and nearly the same levels of NOx emissions reductions as LNG HD trucks. With a reasonable compliance margin below the NOx standard, new 2007 HD diesel trucks may provide about equivalent NOx emissions reductions as current LNG HD trucks. However, staff has assumed that LNG HD trucks will provide a NOx benefit of about 33 percent.

Table III - 7
HD Diesel Truck and LNG Truck
NOx and PM Emissions Standards

HD Diesel and LNG Truck Model-Year	NOx (g/bhp-hr)	PM (g/bhp-hr)	NOx Reduced 1995 MY	PM Reduced 1995 MY
1995 Trucks	5.0	0.1	-	-
New 2007 Trucks	1.2 **	0.01	76%	90%
New 2010 Trucks	0.2	0.01	96%	90%
ARB Drayage Truck Regulation (2010 PM/2014 NOx)	**1.2**	**0.01**	**76%**	**90%**
LNG	0.8*	0.01*	84%	90%

* LNG certified emission rates.
** Diesel in-use and actual NOx emissions may be equivalent to LNG.

The Port of Los Angeles (white paper) assumed that the average port drayage truck is a 1995 model year. The ARB Goods Movement Calculation assumes 1995 model year port drayage trucks travel about 40,000 miles per year. A 1995 model year HD diesel truck has NOx and PM grams per mile emissions rates of about 21 and 0.7, respectively, or about 1 ton per year for both NOx and PM.

ARB staff has assumed a new 2007 HD diesel truck NOx and PM emissions levels (i.e., 5 grams/mile NOx and 0.07 grams/ mile PM) as the baseline for 2014, based on the ARB drayage truck regulation. A new 2007 HD diesel truck would generate about 446 pounds of NOx (440 lbs) and PM (6 lbs) per year.

An LNG HD replacement would provide emissions reductions, beyond those required by the ARB drayage truck regulation by 2015, for NOx only at about 33 percent. A 33 percent NOx reduction would provide about 146 pounds per year of NOx emissions reductions, beyond the current ARB drayage truck regulation by 2015.

Costs

The Port of Los Angeles (white paper) estimated the cost of a new LNG HD drayage truck to be about $210,000. A new 2007/2010 HD truck was estimated to cost about $110,000. The estimated additional cost for a new HD diesel truck to be built with a LNG fuel system (Cummins Westport, 2007) is estimated to be about $80,000.

The Port of Los Angeles estimated the cost for new LNG fueling tanks to be $5 million each. ARB staff has estimated that capital costs for a LNG fuel dispensing station are an estimated $800,000. Staff was advised that approximately 4 stations are needed to fuel 1,000 trucks, which is equivalent to a cost of $3,200,000 per 1,000 trucks, or about $3,200 per truck. ARB staff chose not to include LNG fueling infrastructure costs for this analysis.

Cost-Effectiveness

With capital costs of about $210,000, and assuming a 15-year useful life, the LNG HD truck replacement cost-effectiveness would be about $129 per pound of NOx reduced. Assuming only the cost difference between a new HD diesel drayage and LNG HD truck of about $100,000 (i.e., $210,000-$110,000), the cost-effectiveness would lower to about $62 per pound of NOx reduced.

4. Analysis of Option 19 – Compressed Natural Gas (CNG) Fueled Drayage Trucks Within Intermodal Railyards

Background

CNG trucks are powered by compressed natural gas. To provide adequate driving range, CNG must be stored onboard a vehicle in tanks at high pressure—up to 3,600 – 4,000 psi (pounds per square inch). A CNG-powered vehicle gets about the same fuel economy as a conventional gasoline vehicle on a gasoline gallon equivalent (GGE) basis.

Unlike diesel-powered trucks, CNG trucks have a shorter driving range due to fuel storage limitations. This option examines replacing the current average drayage truck fleet (1995 model year fleet) with new CNG fueled drayage trucks that will operate primarily from the ports to near dock intermodal railyards.

This option would have the greatest potential impacts at near dock railyards, such as UP ICTF, proposed BNSF SCIG, UP Oakland, and BNSF Oakland International Gateway (OIG). CNG trucks may also have potential range to operate to regional inland areas – such as the Inland Empire.

Technical Feasibility

The ports of Los Angeles-Long Beach recently launched a 12-month demonstration of CNG-fueled drayage trucks in December 2008 (see Figure III-7). The CNG HD drayage trucks are certified at 0.1 g/bhp-hr for NOx, which meets and exceeds the stringent 2010 NOx on-road truck emission standards of 0.2 g/bhp-hr. However, it is possible with a reasonable compliance margin, new 2010 HD diesel trucks may have actual in-use NOx emissions levels of about 0.01 g/bhp-hr similar to the CNG drayage trucks. The CNG drayage trucks also meet the new 2007-2010 on-onroad truck PM emissions standards of 0.01 g/bhp-hr.

Four heavy-duty CNG trucks (powered by Cummins Westport ISL G engines) were recently introduced at the Ports of Los Angles and Long Beach to demonstrate CNG HD drayage trucks abilities to move containers between the San Pedro Bay ports and nearby freight-consolidation yards. CNG trucks would be expected to be commercially available if the technology is successful during the demonstration project.

Figure III – 7
Demonstrated CNG-powered Heavy Duty Truck

The CNG HD port drayage truck project proponents ultimately hope to transition the CNG drayage truck technology to a CNG/hydrogen fuel blend technology. Project proponents believe a CNG/hydrogen fuel blend may be able to provide an additional 30 to 50 percent in NOx emissions reductions.

Potential Emission Reductions

In 2005, within the eight intermodal railyards boundaries (with railyard HRAs), heavy-duty (HD) diesel trucks were responsible for an estimated 31 tons per year of diesel PM emissions. The ARB has three statewide diesel truck regulations for new, drayage, and private fleet trucks. However, the ARB drayage truck regulation will have the largest impacts in the near-term at intermodal railyards. ARB staff estimates that the ARB port and intermodal railyard drayage truck regulation will reduce diesel PM emissions by up to 90 percent by 2015, or to about 3.1 tons per year. New CNG heavy duty (HD) trucks could potentially provide earlier and greater emissions reductions beyond the emissions reductions provided by the ARB drayage truck regulation in 2015.

The Ports of Los Angeles and Long Beach have about 16,800 drayage trucks operating at their facilities. On average, the port's drayage trucks are 1995 model year trucks emitting at about 5.0 g/bhp-hr NOx and 0.1 g/bhp-hr PM. However, under the ARB drayage truck regulation, the older diesel trucks will be replaced or required to meet the 2007 new truck PM emissions standard of 0.01 g/bhp-hr (90% reduction) by January 1, 2010, and the 2007 new truck NOx emissions standard of 1.2 g/bhp-hr (75% reduction) by January 1, 2014. See the applicable truck emission standards below in Table III-8. With an average 90 percent reduction, the eight intermodal railyards diesel drayage truck diesel PM emissions could be reduced from 31 to about 3.1 tons per year by 2020.

As a result, the new 2007 HD diesel trucks or equivalent, required by the ARB drayage truck regulation by 2010 and 2014, provide about the same level of PM emissions reductions as CNG HD trucks. With a reasonable compliance margin below the NOx standard, new 2010 HD diesel trucks may provide about equivalent NOx emissions reductions as current CNG HD trucks. However, staff has assumed that CNG HD trucks will provide a NOx benefit of about 90 percent, as compared to new 2007 HD diesel truck emissions standards, and which is required by the ARB drayage truck regulation by 2015.

Table III - 8
HD Diesel Truck and CNG Truck
NOx and PM Emissions Standards

HD Diesel and LNG Truck Model-Year	NOx (g/bhp-hr)	PM (g/bhp-hr)	NOx Reduced 1995 MY	PM Reduced 1995 MY
1995 Trucks	5.0	0.1	-	-
New 2007 Trucks	1.2	0.01	76%	90%
New 2010 Trucks	0.2 **	0.01	96%	90%
ARB Drayage Truck Regulation (2010 PM/2014 NOx)	**1.2**	**0.01**	**76%**	**90%**
CNG	0.1*	0.01*	98%	90%

* CNG certified emission rates.
** 2010 diesel in-use and actual NOx emissions may be equivalent to CNG.

The Port of Los Angeles (white paper) assumed that the average port drayage truck is a 1995 model year. The ARB Goods Movement Calculation assumes 1995 model year port drayage trucks travel about 40,000 miles per year. A 1995 model year HD diesel truck has NOx and PM grams per mile emissions rates of about 21 and 0.7, respectively, or about 1 ton per year for both NOx and PM.

ARB staff has assumed a new 2007 truck NOx and PM emissions levels (i.e., 5 grams/mile NOx and 0.07 grams/ mile PM) as the baseline for 2014, based on the ARB drayage truck regulation. This would amount to about 446 pounds of NOx (440 lbs) and PM (6 lbs) per year as required for diesel drayage trucks by 2015.

A CNG HD replacement would provide emissions reductions, beyond those required by the ARB drayage truck regulation by 2015, for NOx only at about 90 percent. A 90 percent NOx reduction would provide about 400 pounds per year of NOx emissions reductions beyond the current ARB drayage truck regulation by 2015.

Costs

The cost of a new CNG HD drayage truck is estimated to be about $150,000. A tax credit equivalent to $32,000 would lower the costs to about $120,000. However, the CNG fuel and the CNG fueling infrastructure costs are excluded from this analysis.

Cost-Effectiveness

With capital costs of about $150,000, but allowing for a $32,000 tax credit, capital costs are estimated at about $120,000. Assuming a 15-year useful life, the CNG HD truck replacement cost-effectiveness would be about $27 per pound of NOx reduced. Assuming only the cost difference between a new HD diesel drayage and CNG HD truck of about $10,000 (i.e., $120,000-$110,000), the cost-effectiveness would lower to less than $2 per pound of NOx reduced. Staff assumed no PM emissions reductions, as both CNG and 2007 trucks must meet the same PM emission standard.

5. Analysis of Option 20 - Electric Drayage Trucks Within Intermodal Railyards

Background

Electric drayage trucks use onboard batteries which store and provide electricity to run an electric motor. This technology produces zero emissions from the vehicle, but needs an external charging station to recharge the batteries. This technology has been demonstrated on vehicle platforms ranging from passenger vehicles to trucks.

Technical Feasibility

Electric drayage trucks are currently being evaluated through demonstration programs sponsored by the South Coast Air Quality Management District, U.S. EPA, the Ports of Los Angeles and Long Beach, and others. In 2008, the Port of Los Angeles began demonstration testing of an electric truck for several parameters critical to port applications, including maximum range when full and empty, maximum speed, payload, and charging capabilities.

As a result of the demonstration testing, the Los Angeles Harbor Commission recently approved an order for six electric drayage trucks with Balqon Corporation. Electric drayage trucks should be technical feasible, thoroughly tested, and are commercially available from Balqon Corporation.

Potential Emission Reductions

According to the Port of Los Angeles fact sheet (electric truck demonstration project), an overall calculation of net emissions reductions still needs to be performed in order to take into account the emissions created in the generation of electric power used to charge the truck's batteries. However, for this analysis, staff has assumed there would no direct truck emissions within railyards from electric drayage trucks.

In 2005, within the eight intermodal railyards boundaries (with railyard HRAs), heavy-duty (HD) diesel trucks were responsible for an estimated 31 tons per year of diesel PM emissions. The ARB has three statewide diesel truck regulations for new, drayage, and private fleet trucks. However, the ARB drayage truck regulation will have the largest impacts in the near-term at intermodal railyards. ARB staff estimates that the ARB port and intermodal railyard drayage truck regulation will reduce diesel PM emissions by up to 90 percent by 2015, or to about 3.1 tons per year. New electric HD drayage trucks could potentially provide earlier and greater emissions reductions beyond the emissions reductions provided by the ARB drayage truck regulation.

The Ports or Los Angeles and Long Beach have about 16,800 drayage trucks operating at their facilities. On average, the port's drayage trucks are 1995 model year trucks emitting at about 5.0 g/bhp-hr NOx and 0.1 g/bhp-hr PM. However, under the ARB drayage truck regulation, the older diesel trucks will be replaced or required to meet the 2007 new truck PM emissions standard of 0.01 g/bhp-hr (90% reduction) by January 1, 2010, and the 2007 new truck NOx emissions standard of 1.2 g/bhp-hr (75% reduction) by January 1, 2014. See the applicable truck emission standards below in Table III-9. With an average 90 percent reduction in the eight intermodal railyards, diesel truck intermodal railyard diesel PM emissions could be reduced from 31 to about 3.1 tons per year by 2020.

Table III - 9
HD Diesel Truck and Electric Truck
NOx and PM Emissions Standards

HD Diesel and Electric Truck Model-Year	NOx (g/bhp-hr)	PM (g/bhp-hr)	NOx Reduced 1995 MY	PM Reduced 1995 MY
1995 Trucks	5.0	0.1	-	-
New 2007 Trucks	1.2	0.01	76%	90%
New 2010 Trucks	0.2	0.01	96%	90%
ARB Drayage Truck Regulation (2010 PM/2014 NOx)	**1.2**	**0.01**	**76%**	**90%**
Electric	0	0	100%	100%

The Port of Los Angeles (white paper) assumed that the average port drayage truck is a 1995 model year. The ARB Goods Movement Calculation assumes 1995 model year port drayage trucks travel about 40,000 miles per year. A 1995 model year HD diesel truck has NOx and PM grams per mile emissions rates of about 21 and 0.7, respectively, or about 1 ton per year for both NOx and PM.

ARB staff has assumed a new 2007 truck NOx and PM emissions levels (i.e., 5 grams/mile NOx and 0.07 grams/ mile PM) as the baseline for 2014 based on the ARB drayage truck regulation. This would amount to about 446 pounds of NOx (440 lbs) and PM (6 lbs) per year as required for diesel drayage trucks by 2015.
An electric HD truck replacement would provide emissions reductions beyond those required by the ARB drayage truck regulation by 2015, for both NOx and PM, at about 100 percent. A 100 percent NOx and PM reduction would provide about 440 pounds per year of NOx and PM emissions reductions, beyond the current ARB drayage truck regulation by 2015.

Costs

According to the Port of Los Angeles fact sheet, an electric drayage truck cost is approximately $208,500. The estimated cost of one charging station, which simultaneously charges four trucks, is about $75,000. However, this does not include the cost of construction or additional infrastructure needed to support this technology.

The costs above do not include costs for battery replacement, which based on light duty electric vehicles, is about ten years. An electric drayage capital costs are more than two times higher than a comparable new 2007-2010 HD diesel truck which costs about $110,000.

Cost-Effectiveness

With capital costs of about $210,000 and assuming a 15-year useful life, the electric HD truck replacement cost-effectiveness would be about $43 per pound of NOx and PM reduced. Assuming only the cost difference between a new HD diesel drayage and electric HD truck of about $100,000 (i.e., $210,000-$110,000), the cost-effectiveness would be about $20 per pound of NOx and PM reduced.

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IV. ADVANCED SYSTEMS OPTIONS FOR LOCOMOTIVES AND RAILYARDS

In this chapter, the staff presents an evaluation of potential options to achieve additional emissions reductions from locomotives and railyards using advanced systems and technologies. These options would primarily apply to railyards to reduce both locomotive and non-locomotive emissions.

Some options include system-wide approaches such as the electrification of major freight rail lines in the South Coast Air Basin and use of Maglev as alternative to moving container by drayage trucks from ports to near-dock intermodal railyards. The evaluations are based on the following criteria: technical feasibility, potential emissions reductions, costs, and cost-effectiveness.

A. Advanced Locomotive Emission Control System (ALECS)

1. Background

In concept, the Advanced Locomotive Emission Control System (ALECS), otherwise known as the “hood project”, is a set of stationary emissions control equipment connected to an articulated bonnet. The bonnet is designed to capture or extract locomotive exhaust air pollutants and deliver the pollutants to a ground-based emission control system via ducting. The bonnet hood would remain attached via ducting to the stationary system, but would have the flexibility to move with the locomotive as it moves slowly for short distances. The preliminary design discussions revealed that the bonnet movements would be limited by the length of the full system ducting, or about 400 to 1,200 feet in length, depending on the system configuration.

The future full scale deployment concept of ALECS was designed (for costing purposes) to be a versatile system that can be arranged to accommodate many railyard configurations using common components. These components could be used to tailor a system to an area of the railyard with varying numbers of parallel tracks of different lengths. For the economic analysis, staff assumed the ALECS would cover an estimated 1,200 feet length of track. The track could be three 400 foot sections side-by side, two 600 foot sections side-by-side, or one continuous track at 1,200 feet in length, servicing up to 12 locomotives. (TIAX Report April 2007)

The ALECS stationary emissions treatment system (ETS) equipment is comprised of a sodium hydroxide wash to remove sulfur dioxide (SO_2), a triple cloud chamber scrubber for PM removal, and a Selective Catalytic Reduction (SCR) reactor to reduce oxides of nitrogen (NOx). The ETS (emission treatment system) is designed to treat exhaust flows between 2,000 and 12,000 standard cubic feet per minute (scfm). The former is approximately the exhaust flow from a locomotive at idle, while the latter is approximately the exhaust flow from a line-haul locomotive at throttle Notch 8 (i.e., full power).

The most likely application of ALECS is in areas of the railyard where the utilization rate (emission capture) can be maximized. This potentially would include railyard service, maintenance, and refueling locations (See Figures 1and 2 in Appendix K).

2. Analysis of Option 21 – Advanced Locomotive Emissions Control Systems (ALECS

<u>Technical Feasibility</u>

The ETS portion of ALECS would employ stationary emission control elements (e.g., scrubbers, SCR, etc.) that have been tested extensively and are commercially available for use with stationary sources. The UP Roseville Railyard preliminary locomotive testing demonstrated that ALECS has potential control efficiencies of up to 90 percent or more for NOx and PM and other pollutants. The 90% estimated emission reductions for NOx and PM attributed to ALECS do not reflect the emissions associated with the substantial energy consumption associated with operation of the control system: an estimated 328 kw continuous electrical demand, and 2.6 MMbtu/hr for a natural gas burner for each 12.000 scfm system. (TIAX Report, P., 4-5).

The emissions capture system (ECS) portion of ALECS was initially tested on a limited basis, with a small number of locomotives on an isolated and separate track, as part of a pilot program at the UP Roseville Railyard in the summer of 2007. The ECS has not yet been tested on a large scale to demonstrate ability to effectively capture and convey locomotive emissions to the ETS over a period of time (i.e. – 6 months) sufficient to demonstrate its durability and effectiveness.

ALECS has not been subject to full-scale railyard demonstration testing. Full-scale railyard demonstration testing is needed to determine the potential utilization rates and emissions reductions within actual railyard operations. Another reason for the demonstration testing is to determine what effects, if any, the ALECS system would have on the timeliness and effectiveness of railyard operations (i.e., moving locomotives in and out of the railyard). A full-scale demonstration of the ECS is also needed to assess ALECS multiple bonnet system options to determine which can best be utilized between the locomotives and the stationary control equipment. A full scale demonstration project is contemplated for the UP Roseville railyard, but has not been scheduled.

The ALECS demonstration testing will primarily focus on the potential to reduce railyard service and maintenance diesel PM emissions. Service and maintenance areas are where the greatest numbers of locomotives operate in idle or are stationary for diagnostic testing purposes for the greatest periods of time. The ALECS bonnet system is designed to move with rolling locomotives, but would be limited to a total system length of about 1,200 feet or 1/5 of a mile or so. ALECS is a stationary system that is not designed to move on rail tracks alongside locomotives. This is a system limitation in railyards, as locomotives move throughout different parts of railyards that are usually 2 miles long or longer. As a result, ALECS needs to be installed in areas of railyards where the greatest number of locomotives congregate, and are generally stationary, while locomotive engines are operational.

Potential Emission Reductions

As mentioned above, ALECS can reduce stationary locomotive emissions by up to 90 percent or greater, based on UP Roseville Railyard pilot program testing. The potential emissions reductions that may result from the use of ALECS will vary by individual railyard and location within the yard. ALECS potential emission reductions will be highly dependent on the specific operations conducted at the individual location and the emissions available for capture and treatment (i.e., where locomotives are idling or maintenance personnel perform engine diagnostics for extended periods of times).

The ARB HRA Study 2004, based on 2000 year baseline emissions at the UP Roseville Railyard found that service and testing related diesel PM emissions accounted for about one-third, or about 6 tons per year, of the total railyard emissions. Those emissions emanated from various sub areas such as: 1) the “ready tracks” area, 2) the east side of the “maintenance facility” area, 3) west side of the “maintenance facility” area, 4) “modsearch building” area, and 5) “service tracks” area or inspection pit area. (See Figures 1 and 2 in Appendix K).

Though staff assumed ECS would serve a track of up to 1,200 feet in length, the ETS is a stationary system that is limited to operate in one specific area of a railyard. For example, one stationary ALECS bonnet system would not be able to cover the entire UP Roseville railyard, which is about 7 miles in length and about ½ mile wide. As a result, a separate ALECS unit would be needed for each area as shown in Figure 1 and Figure 2. Thus, one unit would be needed for the east side of the maintenance facility, one unit for west side, etc.

The UP Roseville railyard ECS demonstration testing is planned on the west side of the maintenance shop (See Appendix K). At that location, locomotives are diagnostically tested after mechanical repairs, and as part of the diagnostic testing, the locomotives operate in different notch (power) settings from notch 5 through notch 8. Locomotives have eight power or notch settings. In idle or Notch 1, locomotives consume about 5 gallons per hour of diesel fuel. In comparison, in Notch 8 locomotives can consume up to 200 gallons per hour. Therefore, which power setting a locomotive operates in can have a significant effect on locomotive railyard emissions and the potential emissions could be available for ALECS to capture and treat.

The UP Roseville railyard’s west side of the maintenance track is approximately 600 feet in length. In 2000, the diesel PM emissions at the UP Roseville railyard west side maintenance track area were estimated to be about 0.81 tons per year. Of that total (0.81 tons per year), pre- and post-test emissions accounted for about 0.53 tons per year, locomotive idling about 0.23 tons per year, and locomotive movements about 0.05 tons per year. (See figure 2 in Appendix K). Staff has assumed the diesel PM emissions are as high as 1 ton per year at the west side of the maintenance track.

Costs

The initial capital costs of a single ALECS unit, with an estimated 12 bonnet system, are about $8.7 million. Annual operational costs for an ALECS unit are estimated to be about $900,000. As a result, the total capital and operational costs of a single ALECS unit for a 20 year period is about $25 million. These capital costs include the purchase cost, 20 years of operational and maintenance costs, and on average $64,000 every five years for the catalyst replacement. (Source: TIAX Report)

Cost-Effectiveness

Preliminary cost-effectiveness data was developed in the TIAX Report, based on the experience with the ALECS pilot program in 2007. TIAX estimated ALECS would be in full operation 96 percent of the time, or 23 out of 24 hours per day. This may be an unrealistic expectation for use of ALECS in California's railyards. The railyards can and do operate up to 24 hours per day. However, staff believes that most locomotive intermodal and classification railyard peak activities occur between 6 am and 6 pm. There are also numerous hours each day from 6 am to 6 pm, where there is significantly less activity occurring than during key peak periods.

TIAX included NOx, HC, and PM in the cost-effectiveness calculation. Oxides of sulfur (SOx) emissions reduced were not included in the cost-effectiveness calculation. TIAX also weighted the PM emissions reduced by a factor of 20, based on the Carl Moyer Incentive Program guidelines. This weighting was used in calculating cost-effectiveness because of the toxicity level of PM. According to TIAX, and based on the assumptions above, TIAX estimated the cost-effectiveness for ALECS to range between $3.60 and $9 per pound of weighted pollutant reduced. This range of cost-effectiveness was largely dependent on the mode of locomotive operations (i.e., power setting), a Tier 0 versus Tier 2 locomotive, and the 96 percent utilization rate. (TIAX April 2007)

The UP Roseville Railyard ECS full-scale demonstration project has not yet been scheduled. The west side of the UP Roseville Railyard maintenance facility was chosen as the area of the railyard for the demonstration. At this location in the railyard, the estimated diesel PM emissions are about 0.80 tons per year (See figure 1 and 2 in Appendix K).

In this cost-effectiveness calculation, staff assumed that the total emissions reductions for the west side of the maintenance facility area are about 40 tons per year (i.e., 1.0 and 20 - PM and NOx tons per year, respectively). Based on these assumptions, staff estimates the ALECS cost-effectiveness is about $23 per pound of PM and NOx reduced for this scenario. Detailed calculations and scenarios are described in Appendix K. Note that service, idling and movement DPM emissions at the Roseville Railyard declined from the 6 ton per year level cited in the report (from the ARB 2004 HRA) to 2.6 tons per year in 2007,as shown in the June 3, 2008 inventory update submitted by Union Pacific to the Placer County APCD. Similarly, shop idling emissions are estimated to be 0.6 tons per year in 2007, and load testing is now performed at a variety of locations through the railyard, rather than being concentrated near the maintenance shop as was the case in 1999-2000. These changes in operating practices and activity levels will make it more difficult to apply ALECS to the Roseville railyard, and will adversely affect cost-effectiveness.

B. Use of Remote Sensing Devices to Measure Locomotive Emissions

1. Background

Remote sensing technology, or remote sensing devices (RSD), provide readings of pollutants from locomotive exhaust from a distance. Locomotives moving past a reading site have a portion of the locomotive exhaust plume either read or extracted to calculate a reading. The RSD technology uses infrared and ultraviolet light beams to pass through locomotive exhaust plumes, and largely based on CO_2 signatures, extrapolates and develops RSD emissions readings.

When the infrared and ultraviolet light (as invisible beams) pass through the locomotive exhaust gases, the changes in the transmitted light are an indication of the concentrations of the pollutants. The light is partially absorbed by the carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxide (NO) present in the vehicle's exhaust gases, and is partially blocked and scattered by particulate matter (PM) in the exhaust. Readings on the effects of the exhaust on the light beams are correlated, based on assumptions and emissions factors, to provide estimated emission levels at the instant the exhaust gases pass the RSD reading site. The opacity of the exhaust (i.e., how much smoke particles in the exhaust block and scatter light) are also monitored.

On October 6, 2005, Governor Schwarzenegger signed Assembly Bill 1222 (AB 1222, Health and Safety Code Sections 39940 – 39944). This bill, which was authored by Assemblyman Jones, required the Air Resources Board (ARB) to implement a pilot program to determine emissions from locomotives, using a wayside RSD. The objectives of the pilot program were to determine whether an RSD could accurately and replicably determine, with a reasonable level of precision:

- The levels of nitrogen oxides (NOx), particulate matter (PM), and CO emissions from locomotives;
- Whether a locomotive is subject to Tier 0, 1, or 2 federal certification emission standards; and
- Whether the measured results could be calibrated to determine whether the locomotive is above or below the applicable federal certification standards.

AB 1222 required that the pilot program be developed and implemented in consultation with an Advisory Group comprised of a total of 14 members from the Union Pacific Railroad (UP), BNSF Railway (BNSF), South Coast Air Quality Management District (SCAQMD), Sacramento Metropolitan Air Quality Management District (SMAQMD), citizen groups, and remote sensing and locomotive technology experts. AB 1222 also required that the remote sensing testing for the pilot program include data from a sufficient number of locomotives that would be representative of the locomotive fleet operating in California.

A final report to the legislature is being prepared by ARB staff, with the review of the Advisory Group, regarding the results of the test program.

2. Analysis of Option 22 – Remote Sensing Devices

Technical Feasibility

The technological feasibility for remote sensing devices is currently being evaluated by ARB staff and the Advisory Group.

Potential Emissions Reductions

At this time, there is insufficient data available to determine whether RSD readings could result in locomotive emissions reductions.

Costs

The estimated cost of one remote sensing device is about $250,000. In addition, based on the AB 1222 experience, personnel are needed to operate and monitor the RSD devices.

Cost-Effectiveness

At this time, there is insufficient data available to determine whether RSD readings could result in locomotive emissions reductions. Therefore, staff is currently unable to calculate cost-effectiveness for the use of RSD to read locomotive emissions.

C. Retrofit Intrastate Locomotives with Idle Reduction Devices

1. Background

Intrastate Locomotives

Intrastate locomotives are defined by ARB regulation as operating 90 percent or more of the time in California, based on vehicle miles traveled, hours of operation, and fuel consumption. The 2005 ARB/Railroad Agreement requires that 99 percent of intrastate locomotives be retrofitted with idle reduction devices by June 30, 2008. Both UP and BNSF met the requirement by retrofitting more than 400 UP and BNSF intrastate switch and medium horsepower locomotives with idle reduction devices by June 30, 2008.

UP and BNSF intrastate locomotives, and all interstate line haul locomotives equipped or retrofitted with idle reduction devices, are programmed by UP and BNSF to limit non-essential idling to 15 minutes or less.

Interstate Line Haul Locomotives

Interstate line haul locomotives are typically 4,000 horsepower and greater and travel cross-country (e.g., Chicago to Los Angeles). Interstate line haul locomotives tend to be the newest equipment owned by UP and BNSF. This approach provides the railroads with the fuel, horsepower, and reliability efficiencies needed when moving the most profitable freight the greatest distances.

UP and BNSF began to order new interstate locomotives with idle reduction devices partially with the 2000 model year, which was the first model year for new Tier 0 locomotives. UP and BNSF ordered most model year 2000 and all 2001 model year (Tier 0) and newer (Tier 1 and 2 – 2002 to the present) interstate line haul locomotives equipped with automatic engine start/stop (AESS) idle reduction devices. Nearly all UP and BNSF post-2000 model year line haul locomotives were ordered with idle reduction devices, referred to as automatic engine start/stop systems or AESS.

Over the past five years, UP and BNSF have also established programs to retrofit pre-2000 model year interstate line haul locomotives. UP and BNSF combined have national locomotive fleets of about 15,000 locomotives. The UP and BNSF national locomotive fleets combined are approaching 50 percent equipped or retrofitted with idle reduction devices.

In 1998, the ARB and UP and BNSF entered into the Locomotive NOx Fleet Average Agreement applicable to all locomotives operating in the South Coast Air Basin. This Agreement requires UP and BNSF to achieve a Tier 2 locomotive fleet average (i.e., 5.5 g/bhp-hr NOx) by January 1, 2010. Due to this agreement, UP and BNSF will typically operate mostly Tier 2 interstate line haul locomotives, but to a lesser extent Tier 1 and Tier 0 line haul locomotives, in the South Coast Air Basin.

As discussed above, pursuant to the 2005 ARB/Railroad Agreement, all intrastate locomotives have been retrofitted with idle reduction devices. Due to 1998 Locomotive NOx Fleet Average Agreement, nearly all of the interstate line haul locomotives (new Tier 0 through Tier 2) that will operate in the South Coast Air Basin by January 1, 2010 will have been built or retrofitted with idle reduction devices. As a result, staff expects very few interstate line haul, and no intrastate locomotives, to operate in the South Coast Air Basin without idle reduction devices by January 1, 2010.

Any remaining UP and BNSF interstate line haul locomotives (pre-2000 model year) without idle reduction devices, will be subject to the 2008 U.S. EPA locomotive rulemaking. The 2008 U.S. EPA locomotive rulemaking requires all new Tier 3 (beginning in 2012) and new Tier 4 (beginning in 2015) locomotives to be built and equipped with idle reduction devices. In addition, U.S. EPA requires all existing locomotives that have been remanufactured to meet Tier 0 through Tier 2 plus emissions standards, to be retrofitted with idle reduction devices. Both the U.S. EPA new Tier 3 and 4 and existing locomotive remanufacturing idle reduction device requirements are delineated in 40 CFR Part 1033.115(g).

With the 2008 U.S. EPA locomotive rulemaking idle control requirements, staff expects that eventually nearly all Class I railroad interstate line haul locomotives nationally to be equipped with idle reductions devices. These requirements are contingent upon the remanufacture schedule and remanufacturing kit availability for older locomotives. Staff expects UP and BNSF to also program all of their locomotives with idle reduction devices to be able to meet the 15 minute idle limit and ensure that all of their locomotives can operate, and meet the 2005 ARB/Railroad agreement requirements, within California.

2. Analysis of Option 23 – Idle Reduction Devices for All Interstate Line Haul Locomotives

Technical Feasibility

Idle reduction devices are technically feasible, thoroughly proven in-use, and commercially available.

Pursuant to the 2005 ARB/Railroad Agreement, over 99 percent or over 400 of the UP and BNSF intrastate locomotives have been retroffited with idle reduction devices as of June 30, 2008. Staff anticipates that by 2010, nearly all UP and BNSF interstate line haul locomotives will come equipped with idle reduction devices and be programmed to limit non-essential idling to 15 minutes within the South Coast Air Basin. This is largely due to UP and BNSF directing mostly newer Tier 2 and Tier 1 interstate line haul locomotives toward California to meet the 1998 Locomotive NOx Fleet Average Agreement for the South Coast Air Basin.

All UP and BNSF Tier 2 and Tier 1 interstate line haul locomotives were ordered and equipped with idle reduction devices. In addition, a significant portion of new Tier 0 locomotives (2000 and 2001 model years) were ordered and equipped with idle reduction devices. Further, UP and BNSF began efforts five years ago to retrofit pre-2000 model year locomotives with idle reduction devices. As a result, most of the locomotives directed to operate in the South Coast Air Basin primarily, and also to a large extent the rest of the state, will be equipped or retrofitted with idle reduction devices by 2010.

Any locomotives UP and BNSF operate nationally without idle reduction devices will most likely be subject to the 2008 U.S. EPA locomotive requirements to retrofit an idle reduction device upon remanufacture. As a result of the U.S. EPA requirements, staff expects that eventually there will be very few locomotives operating without idle reduction devices nationally.

Potential Emissions Reductions

Idle reduction devices are estimated to provide about 10 percent reduction in fuel and emissions from switch locomotives and about a 3 percent reduction in fuel and emissions from line haul locomotives. Actual levels of idle reduction device emissions reductions vary widely by individual locomotive. However, on average, staff estimated that idle reduction devices provide up to a ten percent or more reduction in diesel PM emissions in and around railyards.

Staff, however, anticipates nearly all interstate line haul locomotives operating in South Coast Air Basin will be equipped or retrofitted with an idle reduction device by 2010, and within the rest of California, will be built or retrofitted with idle reduction devices by 2012. Therefore, staff has concluded there will be would be little or no additional emissions reductions from this option.

Costs

Locomotive idle reduction device capital costs can cost up to $40,000. UP and BNSF have retrofitted all of their intrastate locomotives with ZTR idle control devices that have capital costs of about $15,000 per locomotive. These estimated costs were for retrofit of locomotives that were not OEM equipped with idle reduction devices. Staff assumed on average the capital costs for ZTR retrofits and installation costs was about $10,000. In some cases, idle reduction devices can pay for themselves within 2 to 3 years, depending on locomotive use and diesel fuel costs.

Other expenses incurred during a retrofit is the time taken to put a locomotive into a maintenance shop for idle reduction device installation. In a number of cases, there has been a need to customize the installation of an idle reduction device onto older locomotives, especially those without computerized locomotive operating systems. This latter cost should be reduced if performed when the locomotive comes in for a remanufacture. In addition, concerns have been raised by the railroads regarding increased operation and maintenance costs associated with idle reduction devices due to the increased number of startup/shutdown cycles and its impact on engine parts.

Cost-Effectiveness

Locomotive idle reduction devices are cost-effective based on the potential emissions reductions and relatively low capital costs. Fuel savings can offset the capital costs of idle reduction devices within as little as 2 to 3 years. On a conservative per switch locomotive basis, 1,250 pounds per year of NOx and PM are reduced. Assuming only a ten year life for the idle reduction device, and an average $10,000 capital cost for the idle reduction device, the cost-effectiveness on an annualized basis would be about $1 per pound or less of NOx and PM reduced.

ARB staff assumes nearly all locomotives operating in the South Coast Air Basin will either be equipped or retrofitted with idle reduction devices by 2010. In addition, staff assumed that all locomotives operating in California will either be equipped or retrofitted with idle reduction devices by 2012. Therefore, staff has not calculated potential additional emissions reductions or cost-effectiveness for this option.

D. Alternative Power Sources and Innovative Technologies for Locomotives

1. Background

The first steam powered locomotives appeared in the early 1800's. Movement of people and goods by steam powered locomotives introduced the first practical forms of land transport and they remained the primary form of mechanized land transport for the next 100 or so years. Replacement of steam powered locomotives with diesel-electric locomotives (generally referred to as a diesel locomotive) began in the 1930s. Steam powered locomotives were quickly superseded by diesel and electric locomotives largely because of the reduction in operating costs.

Even though electric locomotives shared some of the diesel locomotive's advantages of over steam, the cost of building and maintaining the power supply infrastructure, which had always worked to discourage new installations, brought on the elimination of most mainline electrification outside the Northeast. Today, diesel powered locomotives dominate the freight and passenger rail system. Recent developments in locomotive power sources have led to innovations that reduced emissions and improved overall efficiency.

2. Summary of Alternative Power Sources and Innovative Technologies for Locomotives

<u>Option 24 – Hydrogen Fuel Cells for Locomotives</u>

Among the various types of fuel cells under research and development, the Department of Defense has funded a fuel cell locomotive for demonstration. The locomotive is powered by a low temperature Polymer Exchange Membrane fuel cell (PEMFC) that uses hydrogen as a fuel and is coupled to a large battery system for energy storage. This fuel cell locomotive is the first of its kind under development for freight applications. BNSF has provided the locomotive and other support for this project.

<u>Option 25 – Hybrid Power Innovations for Locomotives</u>

Efforts to ehance lower emissions and energy recovery efforts to improve overall operating efficiency have recently resulted in the development of the "Green Goat" and the "GE Evolution Series Hybrid"

<u>Option 26 – Alternative Fuel (Ethanol) for Locomotives</u>

The project involves a completely new locomotive engine technology being developed by Alternative Hybrid Locomotive Technologies (AHL-TECH). This hybrid design locomotive combines internal combustion engines with battery technology. The engine is spark-ignited, fueled by bioethanol.

3. Analysis of Option 24 – Hydrogen Fuel Cells for Locomotives

Background

Fuel cell technologies are generally regarded as clean, quiet, and efficient. Fuel cells are electrochemical devices that convert a fuel's (typically hydrogen) chemical energy to electrical energy with high efficiency. Fuel cells can produce electricity continuously as long as fuel and air are supplied.

Fuel cell technology is currently under development using a BNSF donated switch locomotive. Vehicle Projects LLC is managing the development of the fuel cell switch locomotive in a collaborative effort. BNSF Railway has provided the locomotive and other support for this project and is collaborating with an industry-government consortium that includes numerous members.

The fuel cell powered hybrid switch locomotive technology is being assessed for a variety of positive environmental characteristics which include: zero locomotive emissions, low noise, and higher overall efficiency when compared to conventional diesel-electric locomotives. The project objectives are to reduce noise and air pollution in urban areas and sea ports.

BNSF Railway and the consortium plan to have this technology demonstrated in the Los Angeles basin or one of its ports. This technology can also serve as mobile back up power (power to grid) for military bases and civilian disaster relief efforts.

Technical Feasibility

There are various types of fuel cells under research and development. The fuel cell locomotive is powered by a low temperature Polymer Exchange Membrane fuel cell (PEMFC) that uses hydrogen as a fuel and is coupled to a large battery system for energy storage. The fuel cell locomotive is the first of its kind under development for freight applications. The PEMFC is considered a prime candidate for vehicle and other mobile applications of all sizes. Fabrication, assembly, and testing of the fuel cell powered switch locomotive are underway at BNSF Railway's Topeka, Kansas, rail shop. Staff has no schedule for when the fuel cell locomotive will start demonstration testing.

Potential Emission Reductions

Assuming zero locomotive emissions, the fuel cell locomotive emission reductions are essentially 100 percent for criteria pollutants. In 2005, locomotive diesel PM emissions within the 18 major railyards were an estimated 0.38 tons per day. By 2020, U.S. EPA locomotive rulemakings and ARB railroad agreements are estimated to reduce the 18 major railyard diesel PM emissions to about 0.082 tons per day. Fuel cell locomotives could potentially be employed to further reduce railyard and statewide locomotive emissions.

Costs

The demonstrator fuel cell locomotive capital cost is estimated to be about $3.5 million. Hydrogen fueling infrastructure cost data are needed.

Cost-Effectiveness

Based on the fuel cell switch locomotive demonstration, staff estimates the cost-effectiveness range to be between $4 and $8 per pound of NOx and PM reduced, as compared to a pre-Tier 0 switch locomotive (17.4 g/bhphr-hr and 0.44 g/bhp-hr with about 20 tons per year of both NOx and PM), with a range of 10 to 20 years of useful life. The emissions differences may be limited to Tier 4 switch locomotives by 2020.

A Tier 4 switch locomotive would have NOx and PM emissions standards of 1.3 g/bhphr-hr and 0.03 g/bhp-hr with about 1.5 tons per year of both NOx and PM emissions. As a result, the cost-effectiveness would range between $58 and $117 per pound of NOx and PM reduced, with a range of 10 to 20 years for useful life. Also, fueling infrastructure cost data are needed.

4. Analysis of Option 25 – GE Hybrid Locomotive Use of Regenerative Braking

Background

Virtually all American freight locomotives are hybrids. A large diesel engine turns a generator (DC Locomotive) or alternator (AC Locomotive) which creates electric current to power electric traction motors between the wheels. The diesel engine and generator or alternator combination is generally referred to as a diesel generator set. This configuration eliminates the need for a traditional transmission and enhances efficiency. A battery electric hybrid locomotive, like the Green Goat, is one hybrid approach which is discussed in much greater detail in Chapter II for locomotives.

In one hybrid approach, locomotives supplement their airbrakes with dynamic braking, or regenerative braking, by using the traction motors as generators. Normally, the current generated by dynamic braking is dissipated as heat through resistor grids at the top of the locomotive. General Electric (GE) has been conducting research to design a new hybrid locomotive to capture this otherwise wasted electrical energy.

GE's Evolution Series Hybrid is a new type of hybrid line haul locomotive. GE developed this locomotive concept to use the "dissipated" electric current from dynamic braking to charge a battery bank. This captured power can be used in three ways. "Dual Power Mode" allows the locomotive to use the stored energy in the batteries to supplement the diesel-electric engine. This allows the locomotive to conserve fuel by reducing the amount of output required from the diesel-electric engine. “Power boost Mode” allows for the batteries to be used in conjunction with the full 4,400 horsepower of the diesel-electric engine. “Primary Power Mode” allows the power stored in the batteries as the primary source of power reducing emissions and fuel consumption.

Technical Feasibility

The GE Evolution Series hybrid is currently in a demonstration and field validation phase. The first demonstrator or prototype was available for public viewing during the Union Pacific/GE Technology Tour which occurred in California in 2007. Numerous challenges still remain with its development (e.g., regenerative braking, battery technology, system hardening for rail service, protocols and procedures to handle high voltage batteries, process for recognizing emission benefits). GE anticipates that final product launch will occur sometime in 2010.

Potential Emission Reductions

A GE Hybrid locomotive is expected to have 5 to 10 percent improvement in fuel efficiency and emissions, depending on route topography and type of train service.

Costs

Cost data are needed for GE Evolution Series Hybrid interstate line haul locomotive.

Cost-Effectiveness

At this time, staff does not have actual emissions reductions and cost data to be able to calculate cost-effectiveness.

5. Analysis of Option 26 – Ethanol-Fueled Locomotive

Background

The project involves a completely new locomotive engine technology, developed by Alternative Hybrid Locomotive Technologies (AHL-TECH). This hybrid design locomotive combines internal combustion engines with battery technology. The engines are spark-ignited, specifically designed to operate on ethanol. The ethanol-hybrid stores electricity when the generator produces more power than is being used to move the locomotive. This allows the locomotive’s control software (known as Predictive Power Management Control – PPMC) the option of powering the axles by running the engines alone, using battery power only, or any combination of engine and battery power (engine dominant hybrid or battery dominant hybrid). The GPS enabled software can also be configured to give dominance to battery power when the locomotive is working in high pollution areas, such as within the confines of a industrial park, or within a locomotive service facility in the railyard. This hybrid technology also allows for regenerative braking, i.e., capturing energy dissipated when the locomotive is brought to a halt.

The ethanol-hybrid locomotive could potentially replace smaller locomotives (up to 2,500 hp), such as switchers. AHL-TECH is also designing a line of 3,000 to 4,300 hp ethanol-electric hybrid locomotives for heavy haul, helper, and mainline freight service.

AHL-TECH has partnered with Power-Tec Engineering to provide design and development services for the ethanol generator sets.

This technology approach would be the first locomotive with an ethanol-powered generator (eGenSet). Also, it would also be the first use of a higher-horsepower (> 500 hp) ethanol-optimized engine. The AHL-TECH locomotives will be multi-genset locomotives. The locomotives will use anywhere from one to six eGenSets to produce 500hp to 3,000hp of continuous power. Coupled with the hybrid energy storage, the overall horsepower potential of an AHL-TECH locomotive is 1,000hp up to 4,400hp.

Technical Feasibility

The prototype ethanol-hybrid locomotive is currently under development. Initial dynamometer testing of the 500hp ethanol engines is expected to be completed by early summer 2009. The first prototype locomotive, a three eGenSet hybrid, will use an existing switcher frame, cab, and trucks. The prototype MHP locomotives will use an all new frame and cab, but will use existing four- or six-axle trucks.

AHL-TECH expects to have its first commercial ethanol-electric hybrid locomotives available for purchase in 2010.

Potential Emission Reductions

By fueling with ethanol rather than diesel, the ethanol-hybrid system proposed by AHL-TECH offers a completely new prevention technology for locomotives. AHL-TECH's ethanol-hybrid system, if successful, could be applied to switcher locomotives, which are a significant source of railyard PM and NO_x emissions in California. By combining a higher number of generator sets with a larger battery storage system, a MHP locomotive for heavy haul, heavy switching, and transfer work is also possible.

In addition to reducing PM and NO_x, the AHL-TECH ethanol-electric hybrid locomotive could also reduce greenhouse gas emissions.

Costs

AHL-TECH estimates the ethanol-electric hybrid locomotive cost to be about $1.5 million for a new four-axle switcher or road switcher, and $1.8 to $2 million for a six-axle MHP locomotive.

Cost-Effectiveness

At this time, staff does not have actual emissions data to be able to calculate cost-effectiveness.

E. Use CARB Diesel for All Interstate Line Haul Locomotives

1. Background

An intrastate locomotive is defined in ARB's regulation as operating within California for at least 90 percent of its annual fuel consumption, annual hours of operation, or annual miles traveled within California. California Code of Regulations (CCR) Sections 2281, 2282, 2284, and 2299 require intrastate locomotives to be refueled with CARB diesel beginning on January 1, 2007.

Recent detailed surveys and bills of ladings determined that UP and BNSF may be approaching 100 percent CARB diesel fuel dispensed to both intrastate and interstate locomotives within California. As a result, California and adjacent states (e.g., Oregon, Nevada, Arizona, Utah, and New Mexico) may be receiving significant levels of additional emissions reductions than anticipated under the original CARB diesel fuel regulation for intrastate locomotives.

2. Analysis of Option 27 – Use CARB Diesel for All Interstate Line Haul Locomotives

Technical Feasibility

CARB diesel fuel is technically feasible, thoroughly validated in-use, and commercially available in California. However, to comply with this option CARB diesel would need to be supplied to the UP and BNSF major out-of-state refueling depots (e.g., Rawlins, WY, Belen, NM, and El Paso, TX). The last UP and BNSF major refueling depots before entering California are about 800 miles from the next major California refueling depots. To supply UP and BNSF out-of-state refueling depots with CARB diesel would require movements of large amounts of CARB diesel fuel. Under this option, CARB diesel fuel would have to be moved from California refiners and pipelines/terminals via trucks or trains to UP and BNSF''s out-of-state refueling depots (e.g., Rawlins, WY, Belen, NM, and El Paso, TX).

Trains would be the most fuel efficient method for transporting large volumes of CARB diesel fuel to other states (excluding pipelines). However, there would be significant emissions impacts to California and other states as a result of transporting the CARB diesel fuel. In addition, there would a significant cost premium to transport CARB diesel fuel via train or truck to other states.

Interstate line haul locomotives are typically greater than 4,000 horsepower and can consume within a wide range of diesel fuel depending on power or notch settings employed on cross-country trains. For example, in idle or Notch 1, the lowest power (notch) settings a locomotive may consume about 3 to 5 gallons per, whereas in Notch 8, the highest power setting, a locomotive can consume up to 200 gallons per hour.

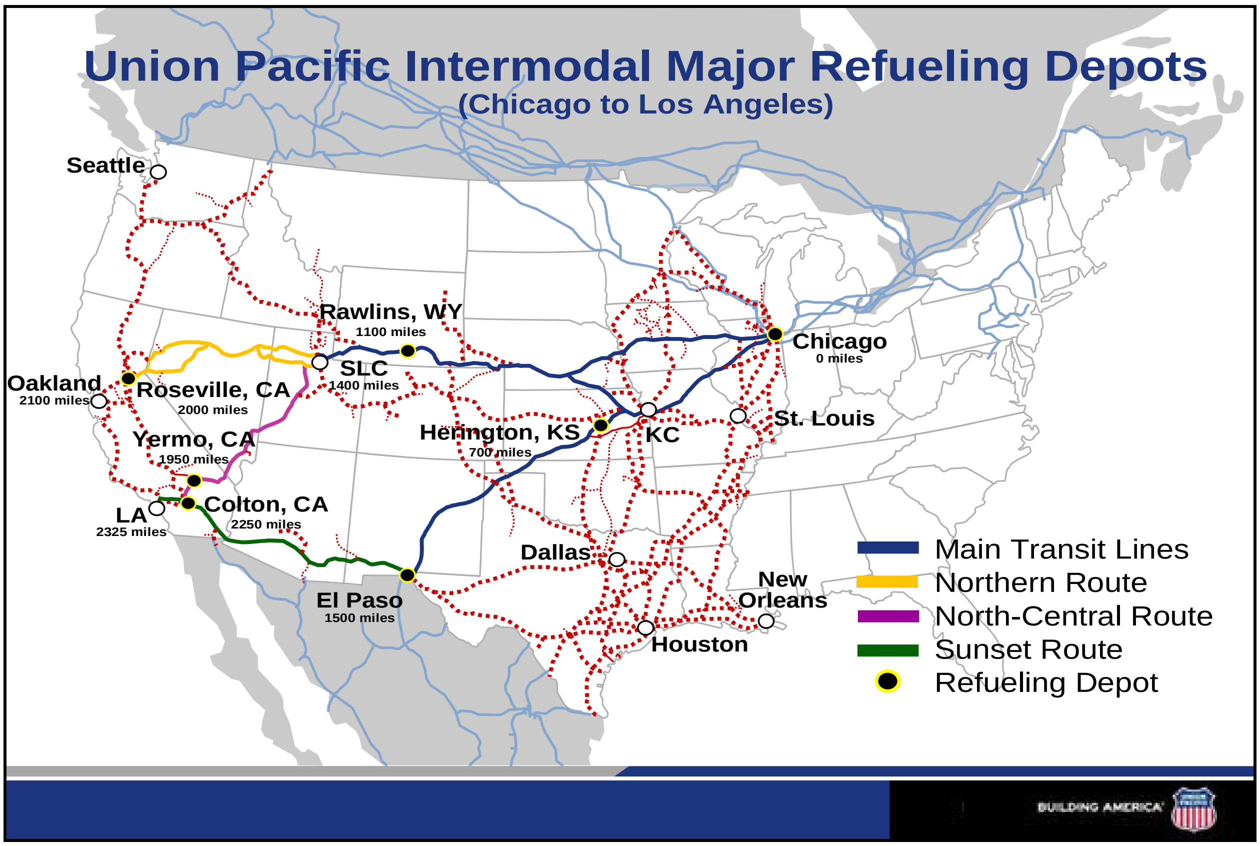
When trains travel on the main open lines, a consist (one or more locomotives – usually three or more) pulls a mile long or so train typically in the highest power settings or in Notches 5-8. Locomotives pulling a long train of railcars, but depending on mountain grades and other variables, will usually have a fuel range of about 700 to 1,200 miles. An oversimplified and generalized diesel fuel consumption rate for an interstate line haul locomotive might be about 0.25 miles per gallon with a 5,000 gallon fuel tank capacity.

Interstate line haul locomotives typically have fuel tanks with about a 5,000 gallon capacity. In many cases, interstate line haul locomotives will refuel with about a 10 to 20 percent margin of safety of diesel fuel remaining in the fuel tank. This fuel level would mean about 500 to 1,000 or so of the 5,000 gallons remains in the fuel tank. Based on these estimates, and the primary fuel depots for UP and BNSF across the UP and BNSF major western corridors, we have developed probable scenarios for fuel rates and routes (see below).

UP and BNSF both have major refueling depots on the Chicago to California corridors. The routes illustrated on the next two pages may represent typical and predominate fueling practices. However, note that there can be numerous exceptions and differences to this oversimplified illustration of cross-country refueling practices for both UP and BNSF.

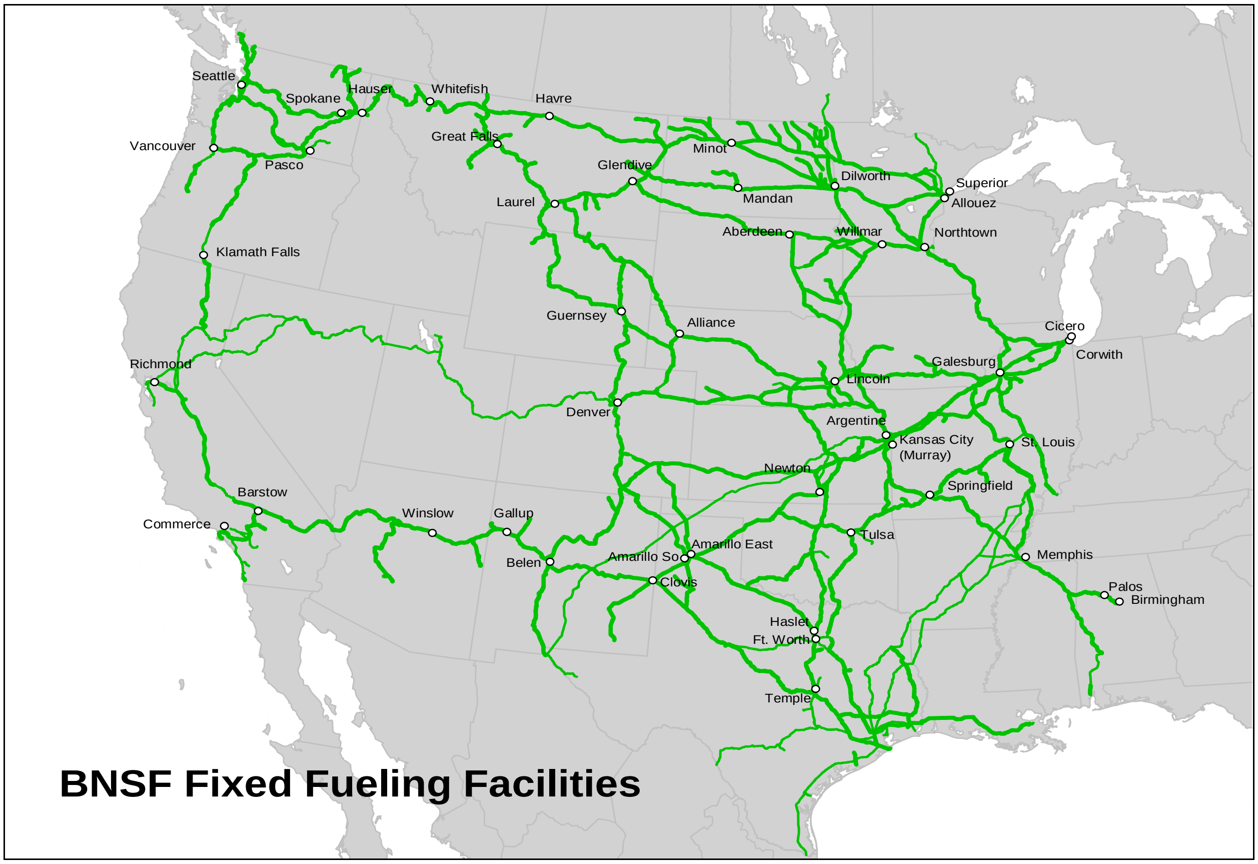
Union Pacific Railroad (UP) – Chicago to California Refueling Patterns

UP Route	Start	Refueling Stop 1	Refueling Stop 2	Refueling Stop 3	End
Northern Miles from start	Chicago, IL 0	Rawlins, WY 1,100	Salt Lake City, UT 1,400	Roseville, CA 2,000	Oakland, CA 2,100
North Central Miles from start	Chicago, IL 0	Rawlins, WY 1,100	Salt Lake City, UT 1,400	Yermo, CA 1,950	Colton, CA 2,050
Southern Miles from start	Chicago, IL 0	Herington, KS 700	El Paso, TX 1.500	-	Colton, CA 2,250



BNSF Railway (BNSF) – Chicago to California Refueling Patterns

BNSF Route	Start	Refueling Stop 1	Refueling Stop 2	Refueling Stop 3	End
Transcon Southern Miles from start	Chicago, IL 0	Kansas City, KS 730	Belen, NM 1,400	Barstow, CA 2,100	San Pedro, CA 2,200
Transcon Northern Miles from start	Chicago, IL 0	Kansas City, KS 730	Belen, NM 1,400	Barstow, CA 2,100	Richmond, CA 2,500



As illustrated above, the last major refueling depots for interstate line haul locomotives are about 700 to 800 miles before the next refuelings in California. At this time, the out-of-state railroad refueling depots have a choice of two types of diesel fuels to dispense: 1) U.S. EPA nonroad diesel fuel (500 ppmw sulfur); or 2) U.S. EPA onroad diesel fuel (15 ppmw).

U.S. EPA diesel fuel regulations are already beginning to phase out the use of low (500 ppmw) sulfur diesel fuel. U.S. EPA regulations will lower nonroad diesel fuel levels from 500 ppmw to 15 ppmw in 2010 for offroad equipment and to 15 ppmw for locomotives and marine vessels by 2012. In most cases, UP and BNSF will probably be dispensing ultra low sulfur (15 ppmw) diesel fuel in most out-of-state locations as early as 2010. Also, note U.S. EPA nonroad diesel fuel in-use sulfur levels, on average, are about 350 ppmw versus the maximum of 500 ppmw.

When UP and BNSF trains arrive to California, nearly 100 percent of refueling is with CARB diesel. At a minimum, UP and BNSF locomotives will refuel in California with U.S. EPA onroad ultra low (15 ppmw) sulfur diesel fuel. Ultra low sulfur (15 ppmw) diesel fuel is only allowed in California. This is because Kinder Morgan and the major refiners only allow ultra low (15 ppmw) sulfur diesel fuel to be moved through the state's pipelines. These same pipelines also supply California's neighboring states of Nevada (nearly 100 percent of state's fuel – Reno and Las Vegas), Arizona (about 66 percent of state's fuel), and southern Oregon (about 33 percent of state's fuel).

At this time, CARB diesel fuel supply is limited to California borders, but under this option would be trucked or moved via trains to UP and BNSF out-of-state major refueling depots in Wyoming and New Mexico. However, truck and train emissions from transporting CARB diesel fuel to the UP and BNSF out-of-state refueling depots could potentially offset part or all of emissions reductions from this option.

Potential Emissions Reductions

CARB diesel is estimated to provide a 14 and 6 percent reduction in particulate matter (PM) and oxides of nitrogen (NOx) emissions, respectively, as compared to both U.S. EPA ultra low sulfur (15 ppmw) onroad and low (500 ppmw) sulfur nonroad diesel fuels. See the table below for explanation of the different types of diesel fuels available in the United States and the key diesel fuel specifications.

Table IV – 1
ARB and U.S. EPA Diesel Fuels – Key Standards and Implementation Dates

Type of Diesel Fuel	Implemen-tation Date	Maximum Sulfur (ppmw)	Maximum Aromatics (% by Volume)	Minimum Cetane Index
CARB	2006	15	10 *	40 *
EPA Onroad	2006	15	35	40
EPA Nonroad	2007	500 **	35	40
EPA Nonroad (Offroad)	2010	15	35	40
EPA Nonroad (Locomotives and Marine Vessels)	2012	15	35	40

* Or meet an alternative formulation that provides equivalent emissions reductions to that obtained with a 10 percent aromatic flat limit. In California, that can mean on average about 20% aromatics and about a 50 cetane index.

** On average, in-use sulfur levels are about 350 ppmw.

Based on the ARB staff report (Extension of CARB Diesel Requirements to Intrastate Locomotives, October 1, 2004), staff estimates that CARB diesel is providing up to 3 and 0.3 tons per day of NOx and PM statewide emissions reductions from the use of CARB diesel dispensed to both intrastate and interstate line haul locomotives within California.

Under this option, locomotives would refuel with CARB diesel in Wyoming, New Mexico, and Texas. The potential locomotive CARB diesel emissions reductions would benefit many of the states that the locomotives would operate in prior to entering California. However, the CARB diesel fuel emissions reductions within California would be limited to those areas between the states borders and the next California refueling depot. For example, for UP from about Truckee to Roseville California, from Las Vegas Nevada border to Yermo, California, and west of Tucson Arizona to Colton, California. For BNSF, from Needles to Barstow, California.

Staff assumed there were about 300 locomotives per day inbound to California on the UP and BNSF interstate line haul locomotive routes. The potential CARB diesel fuel emissions reductions for this option would be for about 100 miles from California boundaries to the nearest California refueling depots. At about 450 gallons consumed per locomotive per 100 miles, the 300 locomotives would consume about 135,000 gallons of diesel fuel per day. Assuming on average the UP and BNSF operate Tier 0 line haul locomotives on these routes, the locomotives emissions would be about 29.5 and 1.9 tons per day of NOx and PM, respectively. The use of CARB diesel fuel (6% NOx and 14% PM) would provide about 1.8 and 0.26 tons per day of NOx and PM emissions reductions, respectively.

Staff has assumed trains would supply the CARB diesel fuel to Rawlins, WY, Belen, NM, and El Paso, TX – which would be the most fuel and emissions efficient. A CARB diesel fuel unit train (moving only one type of commodity) with 100 tanker cars could carry up to a maximum 2.5 million gallons of CARB diesel fuel. Assuming the 300 locomotives are refueled with 4,000 gallons at the major refueling depots, there would be a need for 1.2 million gallons of diesel fuel per day. At this rate, a CARB diesel fuel unit train would be needed every other day.

Assuming one unit train could deliver the CARB diesel to each refueling depot, the unit train would emit about 3.5 and 0.22 tons per day of NOx and PM, respectively. Heavy-duty diesel trucks operating at higher speeds and traveling similar levels of miles would produce similar levels of emissions. Staff assumes the unit train would emit about 15 percent of those emissions within California borders or about 0.5 and 0.03 tons per day. As a result, the net statewide emissions benefit might be as much as about 1 and 0.2 tons per day of NOx and PM, respectively, for the areas between state boundaries and the next California refueling depot.

<u>Costs</u>

ARB staff estimated (Extension of CARB Diesel Requirements to Intrastate Locomotives, October 1, 2004) that CARB diesel would increase diesel fuel production costs for California refiners by 3 cents per gallon as compared to non-CARB diesel fuels. Staff estimates that all statewide locomotive diesel fuel *consumption* (i.e., UP and BNSF, intrastate passenger locomotives, and Class III and military/industrial railroads) is up to 220 million gallons annually (Extension of CARB Diesel Requirements to Intrastate Locomotives, October 1, 2004). At 3 cents per gallon production costs, this would equate to about $6.6 million additional annual diesel fuel production costs. Note these costs do not take into account retail diesel fuel costs paid by railroads.

Cost-Effectiveness

Staff estimated 1.2 tons per day of NOx and PM of CARB diesel statewide emissions reductions. Staff estimated a minimum of $36,000 per day increase in fuel costs, and not accounting for transportation costs. Based on these assumptions, the annualized cost-effectiveness would be about $15 per pound of NOx and PM reduced.

F. Locomotive Emissions In-use Testing

1. Background

Federal locomotive emissions in-use testing requires railroads to test a small but representative sample of the national locomotive fleet to ensure that locomotives continue to meet federal emission standards over locomotive operational lifetimes. The U.S. EPA test procedures used for locomotive in-use testing are the same test procedures (i.e., 40 CFR Part 92) used for certification. Performing annual in-use testing is critical to the overall success and integrity of the federal locomotive emission program. A California locomotive emissions in-use testing program would mirror the federal program, but test a random sample of locomotives operating in California.

2. Analysis of Option 28 – California Locomotive In-Use Testing Programs

Technical Feasibility

A California specific in-use locomotive emission testing program is technologically feasible. The federal locomotive emissions in-use testing program is ongoing and has been in place since 1998. In 2007, 15 locomotives representing the national fleet for pre-Tier 0 (unregulated), Tier 0, Tier 1, and Tier 2 locomotives have been tested annually since 2005. All fifteen locomotives tested were in compliance and measures with emissions levels well below applicable U.S. EPA locomotive not-to-exceed locomotive emission standards. The federal test procedure (FTP) locomotive emission tests were all conducted at Southwest Research Institutes (SwRI's) facility in San Antonio, Texas at a cost of about $30,000+ per locomotive. The in-use testing can also be done at other locations such as Boise, ID and at both EMD's and GE's facilities.

Potential Emissions Reductions

There are no data currently available to determine if a California in-use locomotive emissions testing program would provide additional emissions reductions beyond the federal in-use locomotive emissions testing program. Locomotive emissions could potentially increase by performing additional emission testing of complying locomotives at California facilities. A California locomotive in-use testing program would be a complement, and possibly be redundant, to the federal locomotive in-use emission testing program. The federal in-use locomotive emissions testing is currently performed outside of California and is considered by U.S. EPA to be the most comprehensive for any of the emissions source categories.

Pursuant to the 2005 ARB/Railroad Agreement, ARB staff has inspected over 4,000 locomotives in 32 designated and covered railyards and statewide over the past three years. ARB inspectors have not issued a single Notice of Violation for any locomotive exceeding federal locomotive emission opacity standards. In addition, the SwRi federal locomotive in-use emission testing program has not found any locomotives to date that have exceeded federal locomotive emissions standards.

The U.S. EPA locomotive emissions standards require locomotives "not-to-exceed" the emissions standards over the operating life of the locomotive. As a result, most of the SwRi in-use locomotive emission tests have measured emissions levels up to 20 percent below U.S. EPA locomotive emissions standards. Based on the ARB inspections and U.S. EPA in-use locomotive emission testing results, there may be little, if any, locomotives that would have been identified as exceeding U.S. EPA locomotive emissions standards with a California locomotive in-use emissions testing program.

Costs

Currently, there are no California facilities designed or built with the necessary dynamic brake load banks and fully U.S. EPA certified testing equipment to perform 40 CFR Part 92 in-use locomotive emission testing. Based on the costs for the SwRi locomotive emissions testing facilities, a California dedicated locomotive emissions testing facility could cost millions. As an alternative to a dedicated California facility, California could contract out the locomotive in-use emission testing to SwRI's mobile lab. SwRi could come to California annually to perform the testing, and with the SWRi mobile lab, it would cost about $50,000 per locomotive emissions test.

In 2005 to 2007, SwRi conducted the federal in-use locomotive emissions testing program for 15 locomotives. These 15 locomotives were a representative sample of the national locomotive fleet with pre-Tier 0, Tier 0, Tier 1, and Tier 2 locomotives. If a similar number of locomotives were tested in California, the costs would be estimated to be about $750,000 dollars annually.

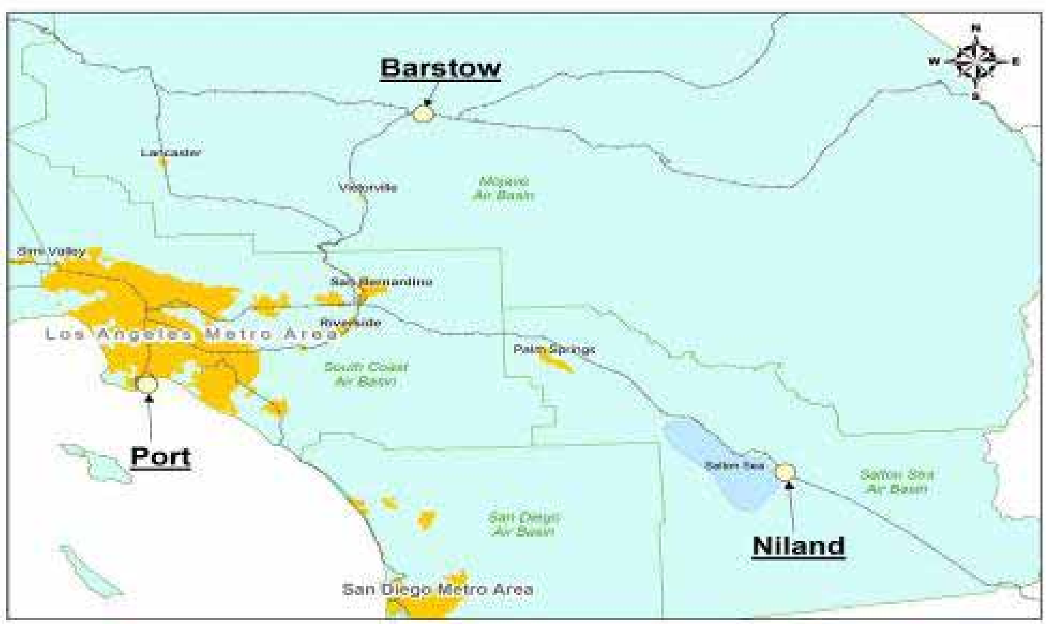
Cost-Effectiveness

At this time, there are insufficient data to estimate potential emissions reductions for this option. Ongoing federal annual in-use testing of existing locomotives demonstrates that locomotives tested typically comply, and in many cases, are well below U.S. EPA locomotive emissions standards. In some cases, in-use locomotive emissions levels can be up to 20 percent below U.S. EPA locomotive emissions standards. There are currently no data to suggest additional California in-use locomotive emission testing would provide additional emissions reductions within the state. As a result, staff has not calculated cost-effectiveness for this option.

G. Electrify Major Freight Rail Lines in the South Coast Air Basin

1. Background

In this option, staff assesses the potential to electrify two main rail lines from the Ports of Los Angeles and Long Beach to BNSF Barstow/UP Yermo and UP Niland. The current rail infrastructure is used exclusively by diesel-electric locomotives on traditional rail ties. Electrification would involve the installation of high voltage overhead power lines to supply power to fully electric locomotives. This option would require the purchase of all new electric locomotives and significant changes to the current infrastructure. Staff's analysis of this option is not intended to be comprehensive, but merely attempts to convey the general magnitude of cost and technological feasibility relative to other options presented in this document. Addressing complex issues such as electrification infrastructure, funding requirements and opportunities, electric freight locomotive design, and operational combatibility with the existing United States rail system are beyond the scope of this analysis.



2. *Analysis of Option 29 - Electrify Major Freight Lines in the SCAB to BNSF Barstow/UP Yermo and UP Niland*

Technical Feasibility

The Southern California Association of Governments (SCAG) and the Southern California Regional Rail Authority (SCRRA) have examined the economic and operational feasibility of electrification of freight and passenger rail since 1992. From a technological standpoint, electrification is feasible, but the most recent SCAG proposals and previous studies of electrification in southern California raise operational and cost-effectiveness issues that are not easily addressed. Electrified rail is an existing technology currently utilized for passenger and container freight transport in other countries, notably countries in Europe. In addition, some passenger lines in the United States are currently electrified. Even with these examples of electrified rail significant differences exist between electric railroad systems in other countries and the diesel-propelled North American heavy haul freight system. For example, assuming a simlar horse power level, the average North American freight train hauls about 10 times the weight encountered in Europe (e.g., 6,000 vs 600 tons).

Europe has seen a dramatic shift in moving freight with rail to moving freight with trucks over the past ten years. One of the key reasons for this dramatic shift has been the incompatibility of electric rail infrastructure between multiple countries and the differences in needs for higher electric voltage for freight versus passenger rail. In the United States, if a uniform federal standard was adopted for electric rail infrastructure, we could avoid some of the electric infrastructure incompatibility issues experienced in Europe. Also, electric rail infrastrasture would need to have higher voltage levels for freight trains as compared to passenger trains. Freight trains pull mile long or so densely weighted railcars (e.g., about 6,000 tons) whereas passenger locomotives may pull only passengers housed in a relatively few passenger cars (e.g., about 300 to 600 tons).

Both UP and BNSF operate national systems which will continue to run on diesel-electric locomotives, even if rail electrification were to be implemented in the South Coast Air Basin. This would create a problem of interface between the electrified geographical areas and the areas running on diesel-electric. There are two potential ways in which this problem could be addressed: 1) the use of dual mode locomotives, or 2) the use of a switchout or interchange point. Both would need to be demonstrated for United States heavy freight applications.

Dual mode locomotives are made to run on both diesel and electricity. Dual mode locomotives are available for passenger rail; however they tend to be about 5 times as expensive ($10 million) as comparable diesel-electric locomotives ($2 million). Dual mode locomotives also have a significantly reduced range in a diesel mode. Under the dual mode approach, all locomotives on routes entering the South Coast Air Basin would have to be dual mode. In order to ensure that there is a large enough pool to constantly supply the South Coast Air Basin with dual mode locomotives, on any given day, the railroads (UP and BNSF) would likely have to purchase about 2,000 dual mode locomotives. At $10 million per locomotive, that would equate to about $2 billion.

The use of a switchout point would serve as an interface between the electrified areas and the areas in which diesel-electric locomotives are utilized. This would involve an unknown increase in shipping time as changing locomotives involves the checking of air brakes and, likely, a crew change. The amount of increased time may be anywhere between a few hours to nearly an extra day. Also, additional tracks would have to be installed at the interchange facilities to accommodate the large number of changes between the different types of locomotives. This could create an adverse impact on the movement of interstate commerce and potentially be subject to litigation.

There are currently no all electric or dual mode freight locomotives being produced or available for purchase on the open market in the United States. Creation of customer demand could help spur production and commercial availability. Passenger electric locomotives are available. However, passenger electric locomotives have significantly lower horsepower, and perform a much lighter duty cycle, than the diesel-electric locomotives currently used for interstate freight transport.

The technology for installation of high voltage overhead power lines is currently available. Freight rail electrification would need more robust and higher power ratings to handle heavier US freight trains which would result in added cost. Based on the experience in Europe, it is likely that electrification would only be applied on the main lines, and not in the switching and cargo handling areas of railyards. In railyards, complications may arise with cargo handling equipment, such as Rubber Tired Gantry (RTGs) cranes, which are tall enough to interfere with overhead electric lines. This limited application of electrification would only impede current efficiency levels and argues a comprehensive approach that goes beyond the South Coast Air Basin which again would result in added cost.

This option would not affect emissions from passenger locomotives, but could be expanded to include passenger rail (e.g., for those lines where passenger and freight locomotives share track).

Potential Emission Reductions

ARB staff acknowledges that any large scale electrification infrastructure effort in Southern California would not likely be implemented earlier than 2020. Also assuming continued fleet turnover to newer lower emitting locomotives between 2008 and 2020, (i.e., 2008 U.S. EPA Locomotive Rulemaking) it is anticipated that the emission reductions identified in this analysis would be less. As a result, using the 2008 ARB emission inventory for trains is not applicable to this analysis. According to the 2020 ARB emission inventory[10] forcast, all locomotive diesel PM and NOx emissions in the

[10] Source: ARB Emission Inventory, Other Mobile Sources – Trains, 2009 Almanac Data, Base Year 2008, South Coast Air Basin, Grown & Controlled, Annual Average. Note - This ARB inventory does

South Coast Air Basin (SCAB) are about 0.9 and 26 tons per day, respectively. Interstate line haul locomotives account for about 83 and 71 percent, respectively, of the SCAB locomotive diesel PM and NOx emissions.

Staff's analysis assumes emissions from electrical generation units in the South Coast Air Basin are controlled effectively through the use of natural gas fuel and selective catalytic reduction for NOx controls. Further, staff's analysis did not account for all possible electricity generation sources. As a result of staff's general assumption, rail electrification could result in large net emission reductions of particulate matter (PM) and NOx, and total elimination of diesel PM emissions. If interstate line haul freight lines in the South Coast Air Basin were electrified, diesel PM and NOx emissions from the locomotives themselves would be reduced by 83 and 71 percent to about 0.13 and 7.43 tons per day, respectively. The net emissions reductions for the South Coast Air Basin would be 18.4 and 0.7 tons per day of NOx and PM, respectively. There may be additional spillover emissions benefits in both the Mojave and Salton Sea air basins as well.

Electrification of smaller segments (e.g. as an initial step in a regional system) would have correspondingly lower regional emissions benefits, but reduced diesel PM emissions near such segments could assist in reducing significant localized health risks. For example, as was noted above, the Alameda Corridor (approximately 22 miles long) was constructed (with dedicated track from ports to downtown Los Angeles) to more easily accommodate electrification. ARB railyard health risk assessments for railyards at either end of the South Coast Air Basin rail corridors found significant diesel PM cancer risks.

Finally, rail electrification would provide significant reductions of greenhouse gas emissions and assist the state in meeting its goals under AB 32, particularly as greater portions of electricity generation is based on renewable sources.

Costs

As part of its 2008 Regional Transportation Plan, SCAG utilized a cost estimate of $9 million per mile to electrify existing rail lines. ARB staff has found some estimates as high as $50 million per mile. Actual costs would depend on the configuration of existing infrastructure and its ability to accommodate electrification. Segments such as the Alameda Corridor that have been constructed in a manner that will accommodate rail electrification would, presumably, have electrification costs that would not be at the higher end of these estimates.

In addition, proposals have been made to substantially expand the current rail system by double or triple tracking substantial segments through the SCAB. The incremental costs to build electrification into such new segments would presumably be less than the cost to retrofit existing lines.

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not include emissions benefits from the 2008 U.S. EPA Locomotive Rulemaking.

A new electric freight locomotive is estimated to cost between $4 million and $10 million. SCAG's analyses, which included the renovation of 460[11] miles of track and the purchase of 775 electric freight locomotives, estimated total costs of $6.4 billion. ARB staff has done an analysis using the same miles of track and locomotives, and estimated that costs could approach $13 billion. Some estimates are even higher.

The overall costs will depend on the amount of rail miles electrified. Short term proposals could start with electrification from the ports to the nearest intermodal facilities, followed by the Alameda Corridor.

Cost-Effectiveness

Assuming a lifetime of 30 years, the annualized cost would be about $32 per pound of NOx and PM reduced.

H. Maglev Electrification from the Ports of Los Angeles/Long Beach to BNSF SCIG (Proposed) and UP ICTF

1. Background

This option would be an alternative to moving goods with drayage trucks from the Ports of Los Angeles and Long Beach to the near-dock railyards (proposed) BNSF SCIG and UP ICTF railyards. This alternative would propose to employ Magnetic Levitation or Maglev to move containers from the ports to near-dock railyards.

Maglev generally does not use steel wheels but instead uses permanent magnets or electromagnets to suspend the vehicle up to an inch above a track. There is no motor on a Maglev vehicle; movement is achieved by varying electricity in cables within the track to create magnetic fields, or by creating magnetic fields on the vehicle, in such a way that the vehicle is propelled along the track.

Maglev track would likely be fully grade separated because of the electricity running through the active portions of the track. The ports of Los Angeles and Long Beach are considering proposals for Maglev transport of containers between the two ports and the near-dock railyards which includes the proposed BNSF Southern California International Gateway (SCIG) and the UP Intermodal Container Transport Facility (ICTF), a distance of approximately 4.7 miles. The Port of Long Beach is considering construction of a Maglev demonstration system and is reported to be in the process of issuing an RFP for a pilot Maglev system as part of a long term project to develop an electric container movement system (ECMS) to carry containers from the docks to distribution centers as far as 200 miles inland.

[11] SCAG 2007 – Freight Rail Emission Reduction Strategy to Help Meet Air Quality Standards for PM 2.5.

2. Analysis of Option 30 - Maglev Electrification from the Ports of Los Angeles/Long Beach to UP ICTF/BNSF SCIG

Technical Feasibility

Maglev is currently in use for a few short passenger lines and is being investigated for use in longer lines and freight applications. Movement of freight using Maglev technology is currently under research. Existing Maglev technology and infrastructure is incompatible with current rail lines, and containers bound out of the region by rail would thus have to be transferred to traditional trains at some point. If Maglev were to be implemented from the Ports of Los Angeles and Long Beach to BNSF SCIG and UP ICTF, it may be capable of displacing some or all of the truck traffic along that route. There may be issue with some cargo being carried by Maglev, as more dense freight may be too heavy for sustained levitation.

Potential Emission Reductions

The emission benefits of implementing Maglev from the Ports of Los Angeles and Long Beach to BNSF SCIG and UP ICTF would be equal to the drayage truck emissions from traveling from the ports to the railyards and within the railyards. Increased emissions associated with the additional container moves by hostlers at ports and railyards necessitated by the maglev approach were not quantified.

In 2016, the truck emissions from ICTF are expected to be about 2.5 tons per year of diesel PM. The UP ICTF estimates are based on the proposed ICTF expansion from 750,000 to 1.5 million lifts. The proposed BNSF SCIG railyard is expected to process up to 1.5 million lifts each year by about 2015, and staff assumed BNSF SCIG would have similar levels of drayage truck emissions as UP ICTF. UP ICTF and BNSF SCIG combined then would have railyard diesel PM emissions of about 5 tons per year in 2016.

Staff estimates that the drayage truck diesel PM emissions from movement of containers from the Ports of Los Angeles and Long Beach to the BNSF SCIG and UP ICTF railyards would be about 7.1 tons per year in 2016 for about 3 million lifts. Under these assumptions, Maglev could potentially reduce total drayage truck diesel PM emissions by up to about 12 tons per year in 2016. NOx emissions were not estimated due to insufficient data.

Costs

The estimated costs for Maglev projects have ranged from $65 million to $100 million per mile. At these rates, Maglev capital costs for 4.7 miles of track would range between $306 million and $470 million. One Maglev proposal from the Ports of Los Angeles and Long Beach to BNSF SCIG and UP ICTF estimated costs as high as $575 million. These costs do not include those associated with additional land needs and additional lifts to transfer containers onto the Maglev system.

Cost-Effectiveness

Assuming a project lifetime of 15 years, and 12 tons per year of drayage truck diesel PM emissions reduced per year, the cost effectiveness could range from about $57 to $148 per pound of diesel PM reduced. The cost-effectiveness would largely depend on the capital costs that staff estimated would range between $300 and $800 million.

I. Retrofit of Existing Major Rail Infrastructure with Linear Induction Motors (LIMs) in the South Coast Air Basin

1. Background

Linear Induction Motors (LIMs) are a method of train propulsion that has not yet been applied to freight applications. The key aspect of LIMs, which differentiates them from traditional rail propulsion, is that the motor does not turn the wheels, but rather it pushes the train along the track. LIMs use a varying electrical current running along a line in the track or on the train to create a magnetic field which repels a coil, or other inductive mechanism, and pushes the train along the track. LIMs can be used in conjunction with maglev or with steel wheel on steel rail systems. This option focuses on the application of LIMs to steel wheel on steel rail.

There are at least 10 current implementations of LIMs to passenger systems. They tend to be short in length, with the majority less than 15 miles long. The longest line currently using LIMs is Vancouver's SkyTrain system which is 31 miles long and has been in operation since 1985. There are two major manufacturers of LIMs passenger systems: Bombardier and Kawasaki Heavy Industries. Existing LIMs systems make use of an onboard linear induction motor powered by an external electric source, and an inductive mechanism in the tracks such as a coil or a plate.

This option would include the retrofit of existing diesel-electric locomotives and rail cars with inductive devices and installation of the linear motor in the track, opposite of how LIMs has been implemented in existing rail service. This option would also include the installation of the corresponding electric infrastructure along existing rail track. . A pool of about 2,000 UP and BNSF locomotives operating in the South Coast Air Basin would need to be retrofitted with LIMs technology. A train equipped with LIMs can either be powered solely by the retrofit of locomotives with a plate or coil, or all of the railcars can be equipped with a plate or coil which reduces the need for high power linear motors in the track.

2. Analysis of Option 31 - Retrofit of Existing Majojr Rail Infrastructure with Linear Induction Motors (LIMs) in the South Coast Air Basin

Technical Feasibility

The economic and operational feasibility of this option are under evaluation. Although

LIMs has been applied to passenger rail systems with success, the difference in method of operation as well as loads and distances makes the implementation of LIMs to freight rail uncertain. There are no existing freight LIMs systems in place; however General Atomics has a 100 foot long test track, which uses the same motor in track setup, to test freight maglev.

Potential Emission Reductions

If LIMs were to be implemented throughout the SCAB, the emission reductions would be similar to those of electrifying the rail. As shown in Table IV-2 this would result in emission reductions of about 81% and 72% for diesel PM and NOx respectively. This reduction only considers the emissions from the locomotive, not including power plant emissions which are assumed to be well controlled in the SCAB and would yield a net decrease in emissions. The net emissions reductions for the South Coast Air Basin would be 14.2 and 0.7 tons per day of NOx and PM, respectively.

Table IV-2
Emission Reductions due to LIMs in the SCAB

Pollutant	2010	LIMS	% Reduced
PM (tons/day)			
Main Line	0.69	0	100%
Total	0.85	0.16	81%
NOx (tons/day)			
Main Line	14.24	0	100%
Total	19.69	5.45	72%

Costs

The cost to retrofit existing track with LIMs is estimated between $10 million/mile and $20 million/mile. The cost to retrofit locomotives and railcars with LIMs is currently under evaluation. Assuming that 460 miles of track were to be retrofitted with LIMs, the cost would be about $7.4 billion. The retrofit of the locomotive pool and railcars would be in addition to this cost. The retrofit of the UP and BNSF locomotive pool and/or railcars would be in addition to this cost and could approach $2 to $3 billion.

Cost Effectiveness

Including costs to retrofit locomotives, and using a 30 year project life, the cost effectiveness of this option is about $29 per pound of NOx and PM reduced.

V. RAILYARD OPERATIONAL AND PHYSICAL CHANGES

There are opportunities to reduce railyard diesel PM emissions and associated health risks to nearby residents through the design and implementation of railyard specific operational and physical changes. Total railyard diesel PM emissions have a more direct effect on health risks in downwind areas. Other source diesel PM emissions characteristics such as density or strength, allocation, and proximity to residents also play a critical role in the level of public health risks that occur near a railyard. Individual railyard operational and physical changes could potentially reduce both diesel PM emissions and downwind exposure levels.

In this chapter, there is an evaluation of potential options to enhance and accelerate efforts to reduce railyard emissions. Two of these options include the installation of walls and trees to provide a barrier, redirect, or filter railyard diesel PM emissions away from nearby residents. Other options include the installation of ambient air monitoring stations and remote sensing devices to more accurately measure and track railyard diesel PM emissions. Another option is to create an enhanced state and local enforcement task force to ensure air quality levels are preserved and protected. There is also an option to install indoor air filters at nearby schools and homes to potentially reduce indoor exposure to railyard diesel PM emissions. Another key option is to move emissions sources further away from exposed residents to reduce Maximum Individual Cancer Risk (MICR) levels near railyards. All of these options represent potential operational and physical changes to the railyards that would typically be implemented as unique and individual to each railyard.

The evaluations for the railyard operational and physical change options are based on the following criteria: technical feasibility, potential emissions reductions, costs, and cost-effectiveness.

A. Install Railyard Perimeter Walls

1. Background

In this option, staff assessed the potential for concrete walls, built around the perimeter of railyards, to serve as a barrier or to redirect railyard diesel PM emissions away from nearby residents.

Currently, there are no published studies indicating whether walls can impede or reduce diesel PM exposure to residents living near railyards. Unlike air filtration effects from trees or vegetation, walls have a low surface density as compared to the breadth and height of tree branches. The barricade effect from railyard perimeter walls may theoretically result in an enhanced air dispersion on the emissions close to the installed walls. However, the potential of the barricade effect to impede, reduce, or redirect diesel PM emissions away from nearby residents may be limited, if there are any benefits at all. There may be potential reductions in diesel PM exposure if railyard emission sources, with low exhaust heights (i.e., lower than the wall height), operate relatively close to the walls under certain ambient conditions. Because of the characteristic of emission plume rise, the benefits of enhanced air dispersion will be apparent only within about 10-20 feet wall heights downwind of the wall; therefore, while perimeter walls might be effective, in some cases, in reducing exposure levels at locations close to railyard boundaries, they would have little or no impact in reducing overall population exposures.

2. Analysis of Option 32 - Install Railyard Perimeter Walls

Technical Feasibility

Building perimeter walls around a railyard facility is technically feasible. Similar types of walls are built by the California Department of Transportation (CalTrans) next to freeways for visual aethetics and sound reduction. However, when building walls around the perimeter of a railyard there will need to be an analysis of any potential effects on individual railyard operations and safety. At this time, staff has been unable to identify any studies or data to suggest that walls can create a barrier or redirection effect on diesel PM emissions to reduce diesel PM exposure to nearby residents.

Potential Emission Reductions

There are no potential diesel PM emissions reductions associated with the installation of walls around the perimeter of railyards. Staff theorizes that there might be limited potential for walls to serve as a barrier to impede or redirect diesel PM emissions, but only for low exhaust stack emissions sources, such as low-height stationary diesel generators. The low exhaust emissions sources would have to also operate primarily in areas right next to or near the walls to have any potential benefits. However, at this time, staff has no data to support this theory.

Costs

Based on building a Caltrans-style[12] wall (similar to a sound wall built along highways) that is about 16 feet high, staff estimates the costs to on average about $450 per lineal foot or $2.4 million per mile.

Cost-Effectiveness

Staff has been unable to identify studies or data to quantify the potential diesel PM emissions reductions from the installation of walls around the perimeter of railyards. As a result, staff has not calculated cost-effectiveness for this option.

[12] Source: http://www.dot.ca.gov/dist07/resources/soundwalls/

B. Plant Trees Around the Perimeter of Railyards

1. Background

This option assesses the potential for trees, planted around the perimeter of railyards, to possibly filter and capture airborne railyard diesel PM emissions, and thereby reduce diesel PM exposure to nearby residents. The trees would be planted to filter and capture, via particulate dry deposition or falling onto the vegetation surfaces, airborne railyard diesel PM emissions on tree branches and leaves.

Airborne particulate matter (PM) can travel a long distance before falling onto or depositing onto surfaces such as the ground, water, or vegetation (e.g., trees, bushes, etc.). What happens to PM in the air depends on many variables such as: atmospheric conditions, wind speed, wind direction, air mixing, local turbulent eddies, terrain characteristics, and emission stack heights.

A recent study (Cahill et al., 2008[13]) preliminarily concluded that as diesel PM moved through the air some of the particles would fall out of the air and settle (i.e., deposition) onto tree leaves and branches. Also, as airbone diesel PM moved through the air, and passed through tree branches and leaves, the trees could collect particles through filtration. The Cahill study confirmed that airborne particles can be collected on various types of surfaces, and also indicated that the rate of deposition and filtration of airborne particles onto trees can be influenced by a number of factors.

The Cahill study is similar to many other studies that have been conducted on this subject. The Cahill study experiments were conducted in a confined and well-controlled wind tunnel and vegetation chamber. The vegetation chamber was about 8 feet long and 3 feet by 3 feet in width and height with tree branches inside the chamber (see Figure VI-1).

For the Cahill study experiments, a PM emission source was simulated by flare smoke being blown into the wind tunnel and the vegetation chamber. The study indicated that, under the designed configuration, the trees did collect between a range of 30 to 85 percent of the smoke that passed by branches under a low wind speed condition of 1 to 2 meters per second. However, the study also indicated that the location of a tree and its branches and leaves, relative to the emission sources, can substantially affect the rate of PM collection by the tree leaf surfaces.

[13] Cahill, T.A. et al., *Removal Rates of Particulate Matter onto Vegetation as a Function of Particle Size*, Final Report to Breathe California of Sacramento-Emigrant Trail's Health Effects Task Force and Sacramento Metropolitan Air Quality Management District, April 30, 2008.

Figure VI-1
Cahill Study: Wind Chamber

Figure VI-1: Wind chamber with filled redwood tree branches used by Cahill et al. study. Image source: Adapted from *Removal Rates of Particulate Matter onto Vegetation as a Function of Particle Size*, Cahill et al. (2008).

The Cahill study determined that the greatest PM collection rate was found in a configuration where the trees are located very close to the emission sources. Among several tree species tested in the study, redwood trees were found to have higher particulate capturing efficiency due to a large surface ratio per unit biomass. The Cahill test chamber was designed so that PM emissions flowed into tree branches in the chamber at low wind speeds. As may be expected, the spatial differences in pollutant flows played a key role in the deposition and filtering effectiveness provided by the tree branches and leaves.

Based on results from the Cahill study, plants that are located nearest to emissions sources, such as trees and tall bushes planted next to highways, would remove more PM than plants that are located at greater distances from emissions sources. Tree deposition and filtering rates, based on the distances of emission sources from the trees or vegetation planted at the perimeter of railyards, are difficult to quantify. Relative to railyard emissions sources, locomotive emissions can generally be concentrated in the middle of railyard tracks, which can be up to one half mile from the nearest railyard perimeter.

Another important consideration, along with distance of the trees from the emissions sources, is tree height. A typical locomotive engine exhaust height is about 15 feet from ground. Locomotive exhaust temperatures, when operating in railyards can range from 150 to 250 ^{o}C, in the lower locomotive power settings of idle to Notch 3. With these exhaust temperatures, a locomotive exhaust plume quickly elevate high into the ambient air (see Figure VI-2).

Once the diesel PM emissions are mixed in the higher air mass, the plume can be transported to a height that exceeds 100 foot trees, the latter influenced by how far the trees are located from the emissions sources. This is also true for other types of diesel PM emission sources, such as Rubber Tired Gantry (RTG) cranes, that have exhaust stacks with greater heights. The Cahill study may not have taken into account tree deposition and filtration rates when considering: 1) railyard diesel PM emissions that could elevate to levels of 100 feet or higher, and 2) where locomotives may emit up to one half mile away from the where the trees are located (in this case along a railyard perimeter).

Figure VI-2
Example of Locomotive Exhaust Plume Rise

Figure VI-2. An example of locomotive exhaust effluence and plume rise with a 16.4 foot exhaust stack height. **Note: The Image was altered (darkened) to better illustrate exhaust plume rise. Under normal engine operating conditions the exhaust plume is difficult to observe.** The opacity of the locomotive engine exhaust plume shown is not necessarily representative of most locomotives, but the plume rise is typical for general locomotives under low wind speed conditions.

The railyards in California range from large classification and intermodal railyards to small mechanical and servicing facilities. In many cases, locomotive emissions are emitted along the tracks located in the middle of a railyard. Railroad tracks are not generally located in small confined areas and next to railyard boundaries and perimeters, where trees could realize the greatest deposition and filtration rates. One exception may be mechanical shops, where locomotives can aggregate in confined areas, and potentially be located near a railyard perimeter.

One case is the UP Roseville Railyard, a major classification facility located in northern California. Most of UP Roseville's locomotive emissions occur on the tracks located in the center portion of the railyard. Within the UP Roseville Railyard, the distance between the main classification train tracks (located in the middle of the railyard) to the east or west fence lines is about 1,600 feet, or about one-third of a mile. With UP Roseville, taking into account locomotive exhaust stack heights and a one-third mile distance to the railyard perimeter, a significant amount of the locomotive emissions could potentially rise into the upper air mass and travel up and over most trees located on the railyard perimeter.

Trees can potentially provide benefits other than diesel PM emissions reductions. For example, trees planted at railyard perimeters may provide neighbors with a visual barrier from railyard operations. Trees may provide for better neighborhood aesthetics around railyards. Also, trees may dampen noise from railyard operations, and the shade they provide may potentially help to reduce nearby summer temperatures.

2. Analysis of Option 33 - Plant Trees Around the Perimeter of Railyards

Technical Feasibility

Over the past decade, there have been a number of research efforts to study potential tree and vegetation deposition and filtration rates of air pollutants. However, staff has not been able to identify any studies with experiments or modeling of the diesel PM deposition or filtration rates from planting trees near the perimeter of railyards or similar types of facilities. Some prior studies have assessed the efficacy of trees for capturing airborne particulate through particle dry deposition on a regional scale, but with a particular focus on urbanized areas. These studies typically employed air flow models or a wind tunnel (or chamber) for the assessments.

Extrapolating regional or urban modeling studies to actual field conditions can be challenging. The applicability and technical feasibility of these macro-level study findings to an actual local or micro facility (like a railyard) are unclear. As mentioned above, a number of factors would need to be considered at a particular railyard beyond the issues of exhaust stack heights, the distances between the railyard emissions sources, and the distances from trees planted on a railyard perimeter. For example, there would be a need to consider operational (e.g., movement of cargo handling equipment within the railyard, sight lines for engineers operating locomotives) and safety (e.g., visual obstructions that may not meet homeland security requirements) concerns within railyards.

Trees planted on railyard perimeters may potentially be able to filter diesel PM emissions that are generated near-ground (e.g., low exhaust from yard hostlers and trucks) and that operate close to a railyard perimeter. Trees may also provide filtering effects from regional diesel PM and other criteria and toxic air contaminants. However, each individual railyard would need to be evaluated to determine which particular operations may benefit from tree deposition and filtration diesel PM emissions.

Staff is not aware of monitoring devices or techniques available to speciate between regional and localized (facility) diesel PM emissions. Regional and facility diesel PM speciation would be critical in order to estimate the diesel PM emissions reductions derived from tree filtration at a particular facility. Staff believes there would need to be a study at an actual railyard, with measurement systems that could differentiate between regional and facility-specific diesel PM emissions, to determine the technical feasibility and potential emissions reductions from planting trees at railyards. While tree planting may have a barricade effect on the railyard emissions, it would substantially create sight line concerns and may cause safety issues, such as crossing, to impede railyard operations.

Potential Emission Reductions

The potential diesel PM emissions reductions from planting trees and vegetation on the perimeter of a railyard are unclear at this time. A pilot study of an individual railyard may be needed to quantify the potential deposition and filtration rates of diesel PM from planting trees and vegetation at railyard perimeters.

Costs

Tree planting option shares some technical limitations with perimeter wall installation. There are no potential diesel PM emissions reductions from planting trees and vegetation on the perimeter of a railyard. Railyard activities are different from facilities to facilities depending upon the individual operations. However, a pilot study of an individual railyard may be needed to quantify the potential deposition and filtration rates of diesel PM from planting trees and vegetation at railyard perimeters in order to quantify the potential benefits, if there is any, from reducing exposures.

Cost-Effectiveness

Currently, there are no studies that have measured the effectiveness of tree deposition and filtration rates for diesel PM at the perimeter of railyards. Without emissions data, staff is currently unable to calculate the cost-effectiveness for this option.

C. Install Indoor Air Filters in Schools and Homes Nearby Railyards

1. Background

Air cleaning devices are usually sold as filters or cleaners in a central air system or as portable, stand-alone appliances. Portable units can usually help clean the air in a single room, while central air units may improve the air throughout the house.

Central air filters are rated based on their removal efficiency for different particle sizes. Based on test results for ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) Standard 52.2-2007, filters are assigned a Minimum Efficiency

Reporting Value (MERV) rating. Typical filters in homes are made of coarse fiberglass mesh, and cost $2-3. They have very low removal efficiencies, usually below MERV 4, i.e., less than 20% efficiency for 3-10 micron particle sizes (a micron is one millionth of a meter). There are a number of HVAC[14]-based air filtration products available in market with upgraded filters (e.g., polypropylene/fiberglass filters). However, availability of on site applications or demonstration studies for different environments is limited in order to fully understand the effectiveness of particulate matter removal and the durability of filtration mechanism. Most portable air cleaners in market are rated for their removal of tobacco smoke, road dust, and pollen. Based on a test developed by the Association of Home Appliance Manufacturers, portable air cleaners are assigned a Clean Air Delivery Rate (CADR) and an appropriate room size for operation.

The health benefits of air cleaning devices are not clear, based on the very limited scientific evidence that is currently available. However, air cleaners that deliberately produce ozone (ozone generators) should never be used in occupied spaces. Ozone generators also indirectly produce UFPs and formaldehyde, and do not clean the air. ARB will limit ozone emissions from portable indoor air cleaners, starting in 2010; additional information on air cleaners and the new ARB regulation can be found at ARB's website[15].

2. Analysis of Option 34 - Install Indoor Air Filters in Schools and Homes Nearby Railyards

Technical Feasibility

Central air filters can be upgraded to improve indoor air quality in a home. Medium-efficiency filters typically are made of pleated, woven material, and have a one-inch depth. They have MERV 6-8 ratings with 35-70% efficiency for removing particles of 3 to 10 microns. Their removal efficiencies for particle sizes less than 3 microns are not tested, but results from modeling and a one-home study indicate particle removal efficiency decreases from 3 to 0.1 microns and then increases for sizes below 0.1 micron. These filters are easily installed in place of the typical fiberglass mesh filter, and should have a minimal effect on air flow and energy use by the central air system.

Even higher efficiency filters may be installed on some central air systems. Filters with MERV 9-12 have even better efficiencies: 70-85% for 3-10 microns, and 50-80% for 1-3 microns[16,17]. These filters are two inches deep, so a new holding rack may need to be installed. In addition, these filters have much higher air resistance, so professional inspection is necessary to avoid air flow problems when exceeding the rated pressures

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14 Heating, ventilating, and air conditioning.

15 ARB, 2008. "Hazardous Ozone-Generating "Air Purifiers." http://www.arb.ca.gov/research/indoor/ozone.htm.

16 Kowalski WJ and Bahnfleth WP, 2002. MERV Filter Models For Aerobiological Applications. Aerosol Media, Summer Issue, 2002. http://www.nafahq.org/LibaryFiles/Articles/Article015.htm.

17 Wallace LA, Emmerich SJ, and Howard-Reed C, 2004. Effect of central fans and in-duct filters on deposition rates of ultrafine and fine particles in an occupied townhouse. Atmospheric Environment Volume 38 (3): 405-413. http://fire.nist.gov/bfrlpubs/build04/PDF/b04008.pdf.

for the system. Upgraded filters such as near-HEPA (i.e., high MERV ratings) or HEPA filters, and electrostatic precipitator (ESP) devices, can be installed in a central air system, but they require professional installation to modify the ductwork and may require a more powerful fan.

Portable air cleaners or some stand-alone filtration systems can reduce indoor particle levels in small rooms. Models with HEPA filter media or ESP devices can remove 40-60% of particles above 0.050 microns[18]. However, their removal efficiencies can decrease markedly below 0.030 microns, and significant filter by-pass may reduce the HEPA's efficiency. In addition, the energy and maintenance costs of portable air cleaners can be substantial. The expected lifetime of these devices is not known, but under constant use the fan motors may only operate for 10 years or less. Ionizing air cleaners are less effective at reducing UFPs and can also produce ozone, which can increase UFP levels[19].

Finally, the actual removal efficiency of central air filters and portable air cleaners in occupied homes is expected to be less than the rated efficiency for several reasons. Particle buildup (loading) and ionizing wire deposits can quickly reduce the efficiency of the device. Filters usually are not changed very often and have significant air bypass around the edges. In addition, central air filters only remove particles when the central air system is operating, which is usually only intermittently for parts of the year when heating or cooling is needed. To conserve energy, a two-speed or variable speed fan is recommended for central systems that operate continuously, but such systems are not readily available for retrofit applications. For new homes in California, energy standards will require outdoor air ventilation systems that operate throughout the day and year, starting in mid-2009; some types of ventilation systems appear to be more effective in removing outdoor PM[20].

Recently, a pilot study of air purifier system has been conducted at elementary schools in Cities of Wilmington and Carson in South Coast Air Basin, but the findings are still under evaluation and the details are not available at this time.

Potential Emission Reductions

Staff believes there are no potential diesel PM emission reductions associated with central air filters or portable air cleaners discussed above, but these devices do generally reduce indoor particle levels when the central air system or portable air cleaner is running. The efficiency of new air filtration cleaners to remove excess air particles (fine particulates typically) can range from about 70% by a HEPA-similar type filter to 99.97% by a true certified HEPA filter. The effectiveness of portable air

[18] Waring MS, Siegel JA, and Corsi RL, 2008. Ultrafine particle removal and generation by portable air cleaners. Atmospheric Environment 42: 5003–5014. http://www.ce.utexas.edu/prof/siegel/papers/waring_2008_aircleaner_ae.pdf.

[19] Ibid.

[20] Bowser D and Fugler D, 2004. Preventing Particle Penetration. Home Energy: March/April 2004. http://www.homeenergy.org/article_full.php?id=181&article_title=Preventing_Particle_Penetration.

cleaners, especially for UFPs, is not well known. As mentioned above, both central air filters and portable air cleaners generally require continuous operation to be effective.

Costs

Central air filters with a MERV 6-8 cost about $5 to $20, and both disposable and washable models are available. MERV 9-11 filters cost about $20 to $130, depending on whether they are disposable or washable. Installation of a HEPA or ESP unit in the central air system can cost from about $1,000 to $5,000. Continuous operation of the system fan can add $200 or more per year in energy costs[21]. Portable air cleaners range in cost between $50 and $200 for smaller units, and $300 or more for larger or more effective models. The energy and maintenance costs can be substantial for portable air cleaners. At least two portable air cleaners would be needed to filter the air in a bedroom and a living room of a typical home.

Cost Effectiveness

While the central air filters and portable air cleaners can provide benefits to improve indoor air quality, the cost effectiveness in reducing indoor particle levels and health risks over time is unclear due to insufficient data.

D. Install Ambient Diesel PM Monitoring Stations

1. Background

Diesel engines emit a complex mixture of inorganic and organic compounds that exist in gaseous, liquid, and solid phases. The composition of this mixture will vary depending on engine type, engine age and horsepower, operating conditions, fuel, lubricating oil, and whether or not an emission control system is present. The primary gas or vapor phase components of diesel exhaust include typical combustion gases and vapors such as carbon monoxide (CO), carbon dioxide, sulfur dioxide, NOx, reactive organic gases (ROG), water, and excess air (nitrogen and oxygen).

Diesel exhaust contains over 40 substances that have been listed as TACs (toxic air contaminants) by the state of California and as hazardous air pollutants by U.S. EPA. Diesel PM is either directly emitted from diesel powered engines (primary particulate matter) or is formed from the gaseous compounds emitted by a diesel engine (secondary particulate matter). Diesel PM consists of both solid and liquid material and can be divided into three primary constituents: the elemental carbon fraction; the soluble organic fraction, and the sulfate fraction.

Currently, there is no approved specific measurement technique for directly monitoring diesel PM emissions in the ambient air. A PM monitor is designed to collect all types of

[21] Bowser D, 1999. Evaluation of Residential Furnace Filters. Prepared for CMHC. http://www.cmhc-schl.gc.ca/odpub/pdf/61607.pdf.

air particulates on the site, regardless of the differences among the sources. The speciation from the samples can face many technical limitations. More often than not, a monitoring site is also heavily impacted by other surrounding diesel PM sources, such as diesel trucks on the major roadways nearby a facility.

A source apportionment from different diesel PM emissions cannot be done without an approved technique, a surrogate methodology, or a source tagging method. The readings from an upwind-downwind monitoring configuration could be strongly influenced by the high background air diesel PM concentrations in many urban areas. Air monitor measurements would not necessarily be accurate in singling out the emissions from a local facility. A PM monitor can serve as a tool to track the trend of ambient particulate concentrations, or for relative comparison of one location's readings with another's. However, a PM monitor is not designed to differentiate individual diesel PM emission contributions from various regional and local emissions sources.

Recently, the Roseville Railyard Air Monitoring Project study (RRAMP study) (Campbell et al., 2008[22]) concluded that there was a substantial increase in particulate concentrations at the sites downwind of the railyard relative to the sites upwind of the railyard. However, it is difficult to use this observed increase to quantify the diesel PM emissions specifically from the UP Roseville Railyard and not take into account regional particulate matter emission sources.

The Aethalometer™ is a device that can provide real-time measurements of the concentration of an aerosol component that is specific to combustion emissions, such as traffic emissions and wood burning. The technique was developed in the late 1970s, and manufactured in the late 1980s. It has been used for measuring ambient black carbon, a surrogate for elemental carbon, which is a ubiquitous component of traffic and industrial combustion emissions. This is a tool, through a surrogate, that can potentially assess diesel PM levels at a single area or location. However, the tool is not designed to speciate diesel PM emissions and assign those emissions to a particular facility or emissions source.

2. Analysis of Option 35 - Install Ambient Monitoring Stations to Measure Railyard Diesel PM Emissions

Technical Feasibility

A PM monitoring system has been widely used for measuring and tracking ambient PM levels to evaluate trends on a regional basis. A PM monitoring system is not designed to quantify and speciate individual facility diesel PM emission sources. This applies even with a possible source tagging method, like elemental carbon, which would provide only anecdotal data instead of emission source apportioned measurements.

[22] Reference: Campbell, D.E.; Fujita, E.M., *Roseville Railyard Air Monitoring Project*, Third Annual Report to Placer County Air Pollution Control District, Auburn, California, July, 2008.

A PM monitor is designed for qualitative emissions monitoring (i.e., measuring and tracking ambient levels) to evaluate emissions trends over a region, with specific measurement levels for a particular area of a region.

Potential Emission Reductions

An ambient PM monitoring station would measure long-term emissions trends for a location within a region. There are no diesel PM emissions reductions associated with the installation of a PM monitoring system.

Costs

The cost of an Aethalometer™ ranges from $25,000 to $35,000, with all of the options possible. ARB staff estimates the operation, data analysis, and maintenance costs at about $30,000 - $35,000 annually.

Cost-Effectiveness

Staff has not calculated cost-effectiveness for this option. Ambient air monitors are emissions measurement systems and are not designed to provide diesel PM emission reductions.

E. Implement an Enhanced Truck and Locomotive Inspection Program

1. Background

In this option, staff assesses the potential to enhance existing state and locale enforcement programs. This option would provide more frequent state enforcement inspections, and provide more coordination with local air districts and local community law enforcement.

2. Analysis of Option 36 - Implement an Enhanced Truck and Locomotive Inspection Program

Technical Feasibility

This proposed option could apply statewide for all 31 UP and BNSF designated and covered railyards.

ARB staff peform locomotive inspections at the 31 UP and BNSF covered railyards on a semi-annual basis. With increased enforcement staffing and funding, this option would propose to increase the frequency of inspections to quarterly or monthly, depending on the need. ARB staff conduct periodic inspections of diesel trucks operating at intermodal railyards to ensure there are no exceedances of the five minute idling regulations. With increased enforcement staffing and funding, this option would propose to increase the frequency of truck inspections. In addition, all of these efforts could be coordinated with local air pollution control districts to enhance these efforts.

Also, local communities have offered to coordinate with ARB inspectors during inspections to issue tickets to truckers parked illegally in and around railyards.

This option is technologically and operationally feasible. The ability to implement this option would largely depend on finding the resources (i.e., staffing and funding) necessary to implement the program.

Potential Emission Reductions

The potential emissions reductions that could be provided by a proposed ARB and local community truck and locomotive enhanced enforcement program are difficult to quantify at this time. Field inspection data over a period of time would be necessary to attempt to quantify emissions reductions from enhanced inspections of railyards.

Costs

Costs are difficult to quantify due to lack of available data and the details of the scope of an enhanced program for individual railyards.

Cost-Effectiveness

Cost-effectiveness cannot be quantified due to the lack of available emissions reductions and costs data.

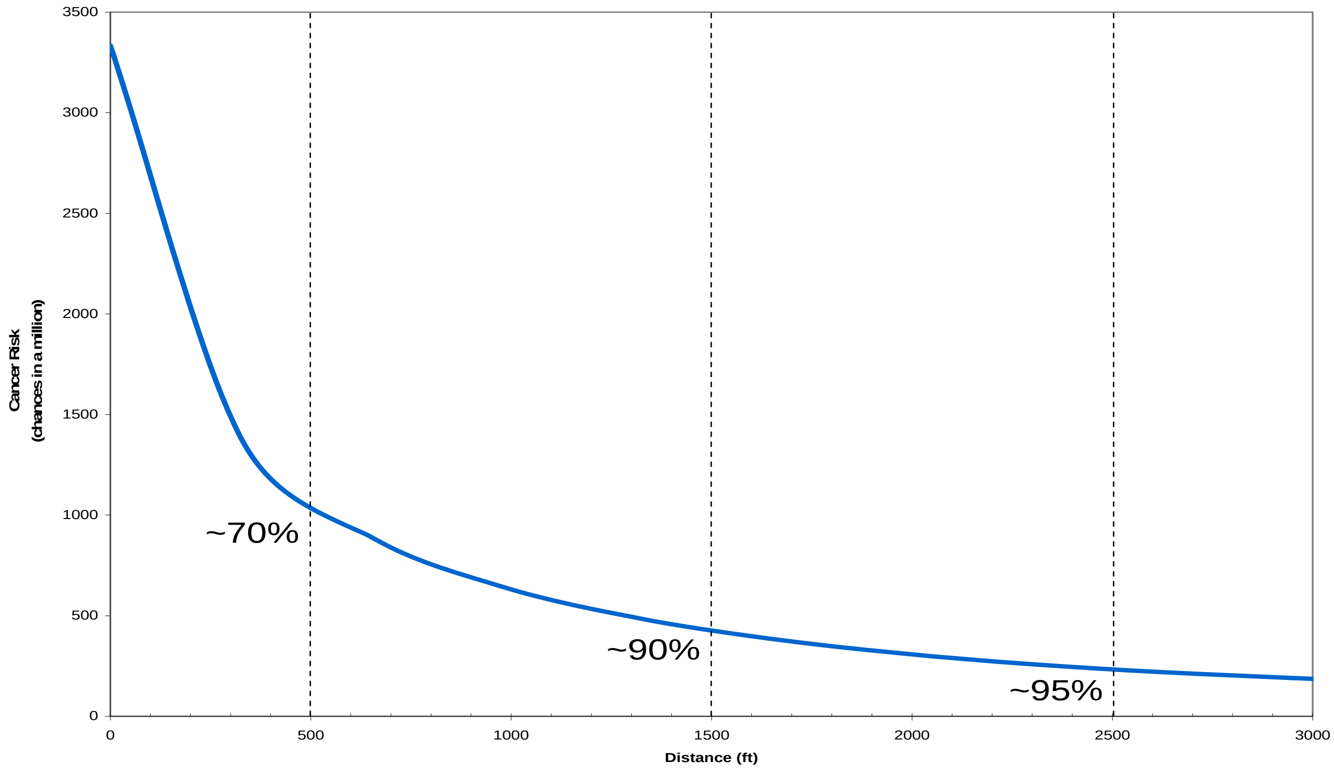
F. Move Railyard Emission Sources Further Away from Nearby Residents

1. Background

In this option, staff assesses the potential public health benefits from moving railyard emissions sources further away from nearby residents. Most health studies indicate that diesel PM cancer risks decrease significantly the further away emissions sources are from the populations exposed. These studies indicate that up to a 90 percent reduction can occur when diesel PM emissions sources are greater distances from populations exposed of more than 1,500 feet. There are also significant benefits are distances less than 1,500 feet. Each railyard has different operational dynamics, and the location and population density of nearby residents can vary widely. Therefore, this option would need to be designed on an individual railyard basis.

The proximity of railyard emission sources to nearby residents can have a significant effect the level of cancer and non-cancer health effects from railyard diesel PM emissions. Health risks increase significantly when railyard diesel PM emissions occur closer to nearby residents.

The figure below presents an example that shows the estimated cancer risks versus the distance from the railyard boundary along north direction at a major emission source for the BNSF San Bernardino railyard. As indicated, the estimated health risks decrease significantly within 500 feet from the yard boundary, about a 70 percent reduction.



2. Analysis of Option 37 - Move Railyard Emission Sources Further Away from Nearby Residents

<u>Technical Feasibility</u>

The technical feasibility of the option is only limited by individual railyard operational constraints. This option could provide significant reductions in diesel PM health risks at hot spot areas or locations near a railyard diesel PM emissions sources.

<u>Potential Emission Reductions</u>

The potential diesel PM emissions reductions associated with a change in the proximity of a railyard diesel PM emissions source may range from zero reduction (i.e., increase source-receptor distance) to a certain degree of increase due to operational changes. Potential health benefits would need to be evaluated through a health impact modeling assessment and a sensitivity analyses.

Costs

The costs of reducing the proximity from emission sources to receptors would be railyard and source specific and driven by specific railyard operations. To evaluate the costs of this option would require individual railyard measures and cost estimates.

Cost-Effectiveness

Emissions, costs, and cost-effectiveness would have to be determined based on the specific changes made at individual railyards. The potential benefits and costs would depend on the unique operations and specific operational and physical changes made at each individual railyards.

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APPENDIX A:

Diesel PM Emissions from Eighteen Major California Railyards

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Table A-1
Diesel PM Emissions from Eighteen Major California Railyards
2005

(tons per year)

Railyard	Locomotive	Cargo Handling Equipment	On-Road Trucks	Others (Off-road, TRUs, Stationary, etc.)	Total§
South Coast Air Quality Management District					
BNSF Hobart	5.9	4.2	10.1	3.7	**23.9**
UP ICTF/Dolores	9.8	4.4	7.5	2.0	**23.7**
BNSF San Bernardino	10.6	3.7	4.4	3.4	**22.0**
UP Colton	16.3	N/A	0.2	0.05	**16.5**
UP Commerce	4.9	4.8	2.0	0.4	**12.1**
UP City of Industry	5.9	2.8	2.0	0.3	**10.9**
UP LATC	3.2	2.7	1.0	0.5	**7.3**
UP Mira Loma	4.4	N/A	0.2	0.2	**4.9**
BNSF Commerce Eastern	0.6	0.4	1.1	1.0	**3.1**
BNSF Sheila	2.2	N/A	N/A	0.4	**2.7**
BNSF Watson	1.9	N/A	<0.01	0.04	**1.9**
Bay Area Air Quality Management District					
UP Oakland	3.9	2.0	1.9	3.4	**11.2**
BNSF Richmond	3.3	0.3	0.5	0.6	**4.7**
San Joaquin Valley Unified Air Pollution Control District					
UP Stockton	6.5	N/A	0.2	0.2	**6.9**
BNSF Stockton	3.6	N/A	N/A	0.02	**3.6**
San Diego Air Pollution Control District					
BNSF San Diego	1.6	N/A	0.007	0.04	**1.7**
Mojave Desert Air Quality Management District					
BNSF Barstow	27.1	0.03	0.04	0.75	**27.9**
Placer County Air District/Sac Metro AQMD					
UP Roseville	25.1	N/A	N/A	N/A	**25.1**
TOTAL	136.8	25.33	31.15	17.0	**210.1§**
Percentage	*65*	*12*	*15*	*8*	***100***

N/A : Not applicable.

§ : Numbers may not add up due to rounding.

Table A-2
Diesel PM Emissions from 18 Major Railyards Summarized by Source Categories in 2005

18 Major Railyards	Diesel PM Emissions (tons per year)	Percent of Railyard Diesel PM Emissions
Locomotives	136	65%
- Line Hauls	58.1	43%
- Switchers	54.3	40%
- MechanicalService/Testing	23.1	17%
Diesel Trucks	33	16%
Cargo Equipment	26	12%
TRUs/Other	13	7%
Total	**210**	**100%**

Table A-3
Estimated Railyard Diesel PM Emissions and Reductions from 2005 to 2020
(tons per year)

YEAR	TOTAL*	Percent Reduction from 2005	Line Haul Locomotives **	Switch Locomotives ***	Service/ Test Locomotives	HDD Trucks	Cargo (CHE)	TRUs	Other (Stationary)
2005	210	-	58	54	23	33	26	13	2.7
2010	131	37%	50	35	17	13	9	5	2
2015	94	55%	37	29	13	8	4	2	1.6
2020	72	66%	27	25	9	5	2.6	0.4	1.5

* Assumes an average of 80 percent diesel PM emission reductions for 18 classification and intermodal railyards.
** Assumes full implementation of 1998 and 2008 U.S. EPA rulemakings, 1998 and 2005 ARB/Railroad Agreements, CARB or ULSD for all California locomotives, and beginning of introduction of Tier 4 locomotives nationally between 2015 and 2020.
*** Assumes statewide replacement with advanced technology switch locomotives at 90% PM control with use of CARB diesel.

Table A-4 below provides an estimate of diesel PM emissions and reductions for 18 railyards through 2020. These estimates are based on the UP and BNSF railyard mitigation plans submitted to date. The estimates include commitments UP and BNSF have made since the release of the railyard mitigation plans.

Table A-4
Estimated Railyard Diesel PM Emissions and Reductions for Eight Railyards
(tons per year)

Railyard	2005	2010	2015	2020
BNSF Hobart (MICR = 500) [2]	24.7	10.5	7.9	5.9
	Reduction	58%	68%	76%
BNSF Barstow (MICR = 450) [2]	28.0	24.5	17.7	13.6
	Reduction	1%	28%	45%
UP ICTF (MICR = 800) [3]	23.7	14.4	7.9	6.6
	Reduction	42%	68%	73%
UP Roseville (MICR = 645) [2]	23.4	19.3	14.3	9.6
	Reduction	22%	42%	61%
BNSF San Bernardino (MICR = 2,500) [2]	22.4	13.2	9.0	6.0
	Reduction	46%	63%	76%
UP Colton (MICR = 150) [2]	16.5	19.5	16.9	14.2
	Reduction	21%	32%	42%
UP Commerce (MICR = 500) [2]	12.1	11.1	7.7	5.9
	Reduction	55%	69%	76%
UP Oakland (MICR = 460) [2]	11.2	13.0	8.8	7.1
	Reduction	47%	64%	71%
UP City of Industry (MICR = 450) [2]	10.9	10.9	7.5	5.9
	Reduction	56%	70%	76%
UP LATC (MICR = 250) [2]	7.3	15.6	10.8	9.1
	Reduction	37%	56%	63%
UP Stockton (MICR = 150) [2]	6.9	10.1	8.2	6.9
	Reduction	59%	67%	72%
UP Mira Loma (MICR = 100) [2]	4.9	13.6	10.1	8.2
	Reduction	45%	59%	67%
BNSF Richmond (MICR = 100) [2]	4.6	14.1	9.0	6.7
	Reduction	43%	63%	73%
BNSF Stockton (MICR = 120) [2]	3.6	22.7	15.5	13.5
	Reduction	8%	37%	46%
BNSF Commerce Eastern (MICR = 100) [2]	3.0	8.5	6.8	4.7
	Reduction	66%	73%	81%
BNSF Watson (MICR = 175) [2]	1.9	16.2	12.1	8.9
	Reduction	34%	51%	64%
BNSF San Diego (MICR = 70) [2]	1.7	22.8	14.3	9.1
	Reduction	8%	42%	63%

1. Potentially achieved through additional locomotive emission reductions and site specific options to the 25 in a million cancer risk level.
2. 2005 MICR (Maximum Individual Cancer Risks) estimate.

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APPENDIX B:

U.S EPA Locomotive Emission Standards

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In 1998, U.S. EPA established national emission standards for 1973 and later locomotives (see Table B-1). The applicability of these emission standards is based on the original manufacture date for the locomotive, and follows a tiered system. The most stringent existing standards (Tier 2) provided a significant reduction in locomotive emissions.

Table B-1
1998 U.S. EPA Locomotive
NOx and PM Emission Standards

Type	Tier	Date of Original Manufacture	NOx Standard (g/bhp-hr)	Percent Control When Engine is New or Remanufactured *	PM Standard (g/bhp-hr)	Percent Control When Engine is New or Remanufactured *
Line-haul locomotives	exempt	Pre - 1973	NA	NA	NA	NA
	Tier 0 **	1973-2001	9.5	30 %	0.6	N/A
	Tier 1	2002-2004	7.4	45 %	0.45	N/A
	Tier 2	2005 and later	5.5	60 %	0.20	59 %
Switcher locomotives	exempt	Pre - 1973	NA	NA	NA	NA
	Tier 0 **	1973 - 2001	14.0	29 %	0.72	N/A
	Tier 1	2002 - 2004	11.0	44 %	0.54	N/A
	Tier 2	2005 and later	8.1	59 %	0.24	59 %

* Relative to pre-Tier 0 locomotives.

** New Tier 0 locomotives model years 2000 and 2001. Also, existing 1973 to 1999 model year locomotives remanufactured to meet Tier 0 locomotive emissions standards.

In 2008, U.S. EPA released a new federal locomotive rulemaking. A particular emphasis was placed on reducing PM emissions from existing locomotives and the introduction of new Tier 4 locomotives by 2015. Tier 4 locomotives with DPF and SCR are expected to reduce locomotive emissions, beyond Tier 2 NOx and PM emissions levels, by up to 76 and 85 percent, respectively. See next two tables for NOx and PM standards.

Table B-2
2008 U.S. EPA Locomotive NOx Emission Standards

Type	Tier	Date of Original Manufacture	Existing NOx Standard (g/bhp-hr)	New NOx Standard New and Remanufactured (g/bhp-hr)	Percent Control When Engine is New or Remanufactured*
Line-haul locomotives	*exempt*	*Pre - 1973*	*NA*	*NA*	*NA*
	*Tier 0 **	*1973 – 2001*	*9.5*	*8.0 or 7.4*	*16 or 22 %*
	Tier 1	2002 – 2004	7.4	7.4	0 %
	Tier 2	2005-2012	5.5	5.5	0 %
	Tier 3	2012	N/A	5.5	0 %
	Tier 4	*2015-2017*	*N/A*	*1.3*	*76* % *(vs. Tier 2)*
Switcher locomotives	*exempt*	*Pre - 1973*	*NA*	*NA*	*NA*
	Tier 0	*1973 – 2001*	*14.0*	*11.8*	*16* %
	Tier 1	2002 – 2004	11.0	11.0	0 %
	Tier 2	2005-2011	8.1	8.1	0 %
	Tier 3	*2011*	*N/A*	*5.0*	*48* % *(vs. Tier 2)*
	Tier 4	*2015*	*N/A*	*1.3*	*84* % *(vs. Tier 2)*

Note: In most cases, gen-set and electric hybrid switchers have been U.S. EPA NOx emissions certified at levels below 3.0 g/bhphr, without aftertreatment. The LNG units have certification test data below 3.0.

* In most cases, except for Tier 4, as compared to pre-Tier 0 emissions levels.

Table B-3
2008 U.S. EPA Locomotive PM Emission Standards

Type	Tier	Date of Original Manufacture	Existing PM Standards (g/bhp-hr)	New PM Standards Remanufactured or New (g/bhp-hr)	Percent Control When Engine is New or Remanufactured*
Line-haul locomotives	*exempt*	*Pre-1973*	*NA*	*NA*	*NA*
	Tier 0	*1973 - 2001*	*0.60*	*0.22*	*63 %*
	Tier 1	*2002 - 2004*	*0.45*	*0.22*	*49 %*
	Tier 2	*2005-2011*	*0.20*	*0.10*	*50 %*
	Tier 3	*2012*	*N/A*	*0.10*	*50 %* *(vs. Tier 2)*
	Tier 4	*2014*	*N/A*	*0.03*	*85 %* *(vs. Tier 2)*
	exempt	*Pre - 1973*	*NA*	*NA*	*NA*
Switcher locomotives	*Tier 0*	*1973 - 2001*	*0.72*	*0.26*	*64 %*
	Tier 1	*2002 - 2004*	*0.54*	*0.26*	*48 %*
	Tier 2	*2005-2010*	*0.24*	*0.13*	*54 %*
	Tier 3	*2011*	*N/A*	*0.10*	*58 %* *(vs. Tier 2)*
	Tier 4	*2015*	*N/A*	*0.03*	*87 %* *(vs. Tier 2)*

Note: In most cases, gen-set, electric hybrid, and LNG switchers have certification test data at levels below 0.15 g/bhphr, without aftertreatment.
* In most cases, except for Tier 4, as compared to pre-Tier 0 emissions levels.
New federal rule diesel fuel requirements will bring non-road diesel fuel sulfur content from 500 ppmv to 15 ppmv in 2012.

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APPENDIX C:

Current Status of Aftertreatment for Existing Locomotives

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CURRENT STATUS OF AFTERTREATMENT FOR EXISTING LOCOMOTIVES

We have been working with U.S. EPA, SCAQMD, and UP and BNSF to develop and demonstrate aftertreatment for existing (pre-Tier 0 through Tier 2) interstate line haul, medium horsepower (MHP), and switch locomotives. In this section we will examine the status of the locomotive aftertreatment efforts to date.

A. Background on Aftertreatment

Two aftertreatment options that could be retrofitted to existing locomotives to reduce PM emissions are diesel particulate filters (DPFs) and diesel oxidation catalysts (DOCs). Selective catalytic reduction (SCR) could be retrofitted to existing locomotives to reduce NOx emissions. A key question to be addressed is whether the filters can maintain the anticipated level of control and necessary durability over time, particularly in interstate line haul operations. In addition, it is critical that aftertreatment not adversely affect engine exhaust flows and combustion efficiencies and can fit into the limited areas available within a locomotive carbody space. The latter is critical due to considerations of locomotive serviceability and reliability; and such that they are able to travel through tunnels across the nation. Finally, after the aftertreatment has been demonstrated successfully on a single locomotive, the ARB verification process will need to be completed. The final step would be for a manufacturer to make the ARB verified aftertreatment commercially available.

1. Diesel Oxidation Catalysts (DOCs)

Diesel oxidation catalysts (DOCs) use a catalyst material and oxygen in the air to trigger a chemical reaction that converts a portion of diesel PM and ROG into carbon dioxide and water. These catalysts have been shown to reduce diesel PM emissions by 20 to 50 percent and ROG emissions by up to 38 percent. While diesel particulate filters typically need a low-sulfur content fuel to operate effectively, DOCs are tolerant of higher fuel sulfur contents. DOCs can be effective in controlling soluble organic fraction (SOF – oil and diesel fuel combustion related) emissions from locomotives, but is not as effective as DPFs in controlling fine particulates.

A DOC may be the first line control system needed to enhance the effectiveness of both a DPF and an SCR on locomotives. A DOC can enhance the efficiency of a DPF. A DOC can also increase NO_2 generation to improve SCR control efficiencies.

2. Diesel Particulate Filters (DPFs)

DPFs contain a semi-porous material that permits gases in the exhaust to pass through while trapping the diesel soot, with a PM control efficiency of 85 percent or more. They have been successfully demonstrated in the laboratory and demonstrated on two U.S. switch locomotives (UP and BNSF), where they reduced diesel PM emissions by up to about 80 percent.

Diesel PM is mainly composed of elemental carbon (soot), ash and volatile compounds derived from unburned and partially burned fuel and lubricating oil and sulfate. These volatile compounds are also known as the soluble organic fraction or wet portion of diesel PM. Soot particles are formed in the combustion chamber, while volatile organic compounds transform from the gas phase to particle phase as the exhaust cools and dilutes with ambient air after exiting the engine exhaust pipe into the atmosphere. A concern with the use of DPFs with locomotive engines are the high levels of the soluble organic fraction of PM that are emitted from locomotive~~s~~ engines (e.g., EMD two stroke) and can potentially clog a DPF, thereby requiring extensive cleaning and maintenance. Current approaches to reduce the concern of clogging are with the use of a DOC installed before the engine exhaust enters the DPF. Over time soot and ash will accumulate in DPF. A process to manage soot build-up is through the use of “Passive” and “Active” DPF regeneration. Regeneration uses high heat levels to burn off accumulated soot which converts the carbon portion into ash.

A passive DPF regeneration system relies on locomotive exhaust temperatures to burn away soot accumulation in the DPF. However, locomotives can operate a substantial part of their operating cycle in idle and lower notch (i.e., power) settings, where locomotive exhaust temperatures are typically not high enough to burn off soot build up in the DPF. With an active DPF regeneration system relies on auxiliary heat introduced into the exhaust to burn off soot buildup in the DPF. Eventually, even with passive or active regeneration, ash will accumulate in the DPF and must be removed by special cleaning equipment.

2. Selective Catalytic Reduction (SCR)

Another control option for existing locomotives is to retrofit selective catalytic reduction (SCR). SCR is a means of converting NOx with the aid of a catalyst into diatomic nitrogen, N_2, and water, H_2O. A gaseous reductant, typically anhydrous ammonia, aqueous ammonia, or urea, is added to a stream of flue or exhaust gas and is absorbed onto a catalyst. CO_2 is a reaction product when urea is used as the reductant. SCR catalysts are manufactured from various ceramic materials used as a carrier, such as titanium oxide, and active catalytic components are usually either oxides of base metals (such as vanadium and tungsten), zeolites, and various precious metals. SCR has been used on stationary sources (e.g., boilers) and has been shown to reduce NOx emissions by 70 to 95 percent.

One of the key challenges with SCR on an interstate line haul locomotive is being able to design a system that precisely meters urea to approach a one to one conversion ratio between urea to NOx and to minimize potentially toxic emissions from ammonia slip. Further, the lower locomotive engine exhaust temperatures in lower notch settings (i.e., idle to Notch 3) significantly reduce the levels of control from SCR.

B. Demonstration of DPFs on a Gen-Set Switch Locomotive

Brookville Equipment Company recently installed a passive DPF system on a prototype three engine gen-set switch locomotive built with three Cummins QSK19 Tier 3 nonroad engines. Brookville employed a passive DPF system that relied on locomotive exhaust temperatures to burn away ash and carbon buildup on the DPF. During field testing, Brookville began to experience ongoing ash buildup and cleaning problems with the passive DPF system. As the DPF is not required by any regulation, Brookville chose for the time being to remove the passive DPF system from the prototype gen-set switch locomotive during field testing.

C. Demonstration of Experimental DPFs on Older Switch Locomotives

ARB and the UP and BNSF entered into the California Emissions Program (CEP) in 2001. The two railroads funded this effort with $5 million, and as of April 2008 about $4 million or more has been expended. The CEP's primary objective was to demonstrate the use of DPFs on older switch locomotives. UP and BNSF each provided an older (both over 25 years old) switch locomotive of about 1,500 horsepower for this program.

After five years of research and bench testing, the UP and BNSF switch locomotives were retrofitted with very large DPFs (two on each locomotive, each about piano size – 1,100 pounds) in front of the cabs of UPY 1378 and BNSF 3703. Baseline emission testing indicates that these switchers can provide up to an 80 percent reduction in particulate matter and 30 percent reduction in hydrocarbon emissions.

UPY 1378 is a Tier 0 EMD MP15DC locomotive and was released into demonstration service in December 2006 to the UP Oakland yard, and then recently transferred to the UP Roseville yard. UPY 1378 has been operating over the past year with only minor mechanical and aftertreatment adjustments. BNSF 3703 was retrofitted with the same DPF technology in late 2006, but for nearly two years remained at the Southwest Research Institute (SWRi) facility in San Antonio, Texas due to ongoing technical challenges in improving the DPF system efficiency. In April 2008, BNSF 3703 arrived in Southern California for demonstration testing.

An important consideration with DPF retrofits on switch locomotives is the recent advances in switch locomotive technology (i.e., gen-set and electric hybrid) since the CEP program was initiated over 7 years ago. Gen-set and electric hybrid switch locomotives can provide up to a 90 percent reduction in both particulate matter and NOx emissions without aftertreatment. These switch locomotives also significantly reduce diesel fuel consumption by 20 to 40 percent.

Due to the DPF and engine rebuild (Tier 0) capital costs ($300,000 to $500,000 or more) and ongoing maintenance costs of DPFs, the new advanced technology switch locomotives may make the retrofitting of older (20-50 year old) switch locomotives with DPFs less cost competitive with the new switch technologies. In California, an important question would be whether to invest limited capital into aftertreatment retrofits of 25 to 50 year old switch locomotives, or whether to purchase new gen-set switch locomotives instead. The gen-set engines provide ongoing fuel savings and these engines can easily be changed (in a few days) for upgrades to future nonroad engines with even more stringent emission standards.

D. Demonstration of an Experimental Diesel Oxidation Catalyst (DOC) on an Older Freight Line Haul Locomotive

U.S. EPA and UP initiated a demonstration program, in April 2006, on an existing freight line haul locomotive (UP 2368). UP 2368 is an EMD SD60M model interstate freight line haul locomotive built in 1989 and powered by an EMD 16-710-G3A cylinder engine. UP 2368's engine was rebuilt from uncontrolled levels to a Tier 0 level and then retrofitted with a Miratech DOC. UP 2368 was then placed into service in California in October 2006.

UP 2368 baseline emission testing indicated that the DOC could reduce DPM by up to 50 percent. However, during in-field demonstrations in 2007, there were three separate incidents of DOC aftertreatment and DOC support structure failures. The most recent failure resulted in broken catalysts panels and supports. Fortunately, this failure was caught early enough to prevent serious engine damage. Generally, these three DOC related failures have been attributed to the large two-stroke medium speed EMD engine with extreme exhaust pulsations. Miratech worked on a new DOC design and support frames to protect the integrity of the DOC catalysts under locomotive vibration and stresses, and UP 2368 was returned to service in Southern California in May 2008. UP 2368 has performed successfully for over the past six months, and the same DOCs used on UP 2368 have been retrofitted on two Canadian passenger locomotives.

E. SwRI Bench Test of a Compact SCR on a Locomotive Engine

ARB recently funded a $200,000 research effort with the SwRI. This research consisted of a bench test program of a compact SCR system offered by Engine Fuel and Emissions Engineering, Inc. (EF&EE) (via Haldor Topsoe – a Danish Catalyst Company) and funded by the SCAQMD for use on a MHP Metrolink passenger locomotives. The SWRi bench tests were conducted on an EMD 710 – 12 cylinder engine, which is the same engine family commonly used on pre-2000 freight line haul locomotives (~75 percent), passenger locomotives (most in California), and some marine vessels. The EMD 3000 hp 12-710 G3 engine was retrofitted with the compact SCR device for performance and emission testing. During the performance testing, significant issues occurred with the SCR system's ability to dose the urea properly. Part of this urea dosing imbalance was caused by the un-uniform engine exhaust flows within the turbocharger outlet of the EMD 710 engine and the challenge for the compact SCR system to be able to adjust urea dosing precisely. The poor mixing resulted in large amounts of ammonia slip. EF&EE is currently working to redesign the compact SCR and urea dosing system to try to address these issues. SWRi completed the report for this research effort in March 2008.

Summary of the Status of Locomotive Aftertreatment

As of November 2008, ARB staff has not verified any locomotive aftertreatment system. Staff is optimistic that candidates for locomotive aftertreatment systems will be submitted for ARB verification sometime in 2009.

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APPENDIX D:

AAR publication on
“Railroad Service” and “Freight Railroads Operating”
in California

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Railroad Service in

California

2006

Railroad Service and Employment

Facilities	Number of Freight Railroads	24
	Miles Operated (Excluding Trackage Rights)	5,352
Traffic	Total Carloads of Freight Carried	7,578,456
	Total Tons of Freight Carried	177,907,810
Employment and Earnings	Rail Employees Living in State	15,268
	Freight Employees Only	10,478
	Total Wages of Rail Employees	$1,042,945,000
	Freight Employees Only	$726,479,000
	Average Per Freight Rail Employee:	
	Wages	$69,300
	Fringe Benefits	$26,900
	Total Compensation	$96,300
Railroad Retirement	Railroad Retirement Beneficiaries	29,196
	Railroad Retirement Benefits Paid	$445,149,000

Freight Railroad Traffic in California

Tons Originated 2006

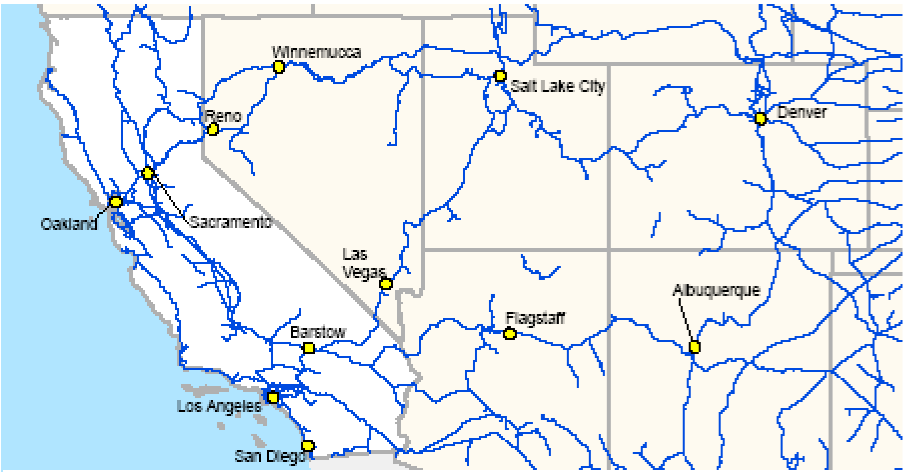
	Tons	%
Mixed Freight*	37,794,104	54%
Food Products	6,250,236	9
Primary Metal Products	3,727,429	5
Glass & Stone Products	3,697,956	5
Chemicals	3,616,449	5
All Other	14,980,922	21
Total	70,067,096	100%

*Predominantly Intermodal

Tons Terminated 2006

	Tons	%
Mixed Freight*	28,407,880	26%
Farm Products	13,696,924	12
Food Products	11,616,124	11
Chemicals	10,977,633	10
Lumber & Wood Prod.	6,843,232	6
All Other	38,575,378	35
Total	110,117,171	100%

Railroad Map of California



Rail network based upon 2006 National Transportation Atlas Database published by the U.S. DOT, Bureau of Transportation Statistics.

Freight Railroads Operating in

California

2006

	Miles of Railroad Operated in California
Class I Railroads	
BNSF Railway Company	2,130
Union Pacific Railroad Co.	3,358
	5,488
Regional Railroads	
Central Oregon & Pacific Railroad	52
San Joaquin Valley Railroad Co.	351
	403
Local Railroads	
Arizona & California Railroad Co.	133
Carrizo Gorge Railway Inc.	80
McCloud Railway Co.	100
Modoc Northern Railroad Company	96
San Diego & Imperial Valley Railroad	41
Santa Maria Valley Railroad	14
Sierra Northern Railway	99
Stockton Terminal & Eastern Railroad	30
Trona Railway Co.	31
Ventura County Railroad Company	13
West Isle Line, Inc.	5
Yreka Western Railroad	12
	654
Switching & Terminal Railroads	
California Northern Railroad	247
Modesto & Empire Traction Co.	34
Napa Valley Railroad Co.	21
Oakland Terminal Railway	6
Pacific Harbor Line, Inc.	21
Quincy Railroad	3
Richmond Pacific Railroad Corp.	10
Santa Cruz, Big Trees & Pacific Railway	10
	352

California Totals	Number of Freight Railroads	Miles Operated: Excluding Trackage Rights	Miles Operated: Including Trackage Rights
Class I	2	3,990	5,488
Regional	2	403	403
Local	12	640	654
Switching & Terminal	8	319	352
Total	24	5,352	6,897

Rail network based upon 2006 National Transportation Atlas Database published by the U.S. DOT, Bureau of Transportation Statistics.

Class I Railroad - As defined by the Surface Transportation Board, a railroad with 2006 operating revenues of at least $346.7 million.
Regional Railroad - A non-Class I line-haul railroad operating 350 or more miles of road and/or with revenues of at least $40 million.
Local Railroad - A railroad which is neither a Class I nor a Regional Railroad and is engaged primarily in line-haul service.
Switching & Terminal Railroad - A non-Class I railroad engaged primarily in switching and/or terminal services for other railroads.
Note: Railroads operating are as of December 31, 2006. Some mileage figures may be estimated.

 June 2008

APPENDIX E:

Options 1 thru 4 -
Calculations for Switch Locomotives

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Calculations of Switch Locomotive NOx and PM Emissions:

(Source: U.S. EPA Fact Sheet – Emission Factors for Locomotives – U.S. EPA420-F-97-051 – December 1997)

http://www.U.S. EPA.gov/otaq/regs/nonroad/locomotv/frm/42097051.pdf

Switch Locomotive Emission Factors (EF)

Tier	NOx EF *(g/bhp-hr)*	PM EF *(g/bhp-hr)*
Pre Tier 0	17.4	0.72
Tier 0	14.0	0.72
Tier 0+	11.8	0.26
ULESL	**3.0**	**0.10**
Tier 3	3.0	0.10
Tier 4	**1.3**	**0.03**
Tier 4 Nonroad	**0.3**	**0.01**

Conversion Factors

bhp-hr/gallon
20.8

tons/g
1.10E-06

UP and BNSF Switch Locomotive Fleet Composition (2008)

Switchers	# Locos	Pre Tier 0	Tier 0	ULESL
Statewide	244	103	49	92
South Coast	139	34	29	76
Rest of State	105	69	20	16

<u>Other Key Assumptions</u>:

Pre-Tier 0 and Tier 0 switch locomotives are assumed to consume 50,000 gallons of diesel fuel per year. ULESLs, Tier 3, and Tier 4 switch locomotives are assumed to consume 40,000 gallons of diesel fuel per year due to 20% reduction with ULESLs: gen-sets, electric hybrids, and LNGs.

Option 1 - Replace 152 older UP/BNSF switchers with new ULESL

Emission Reduction (TPD)	NOx	PM
Statewide	6.6	0.30
South Coast	2.8	0.14
Rest of State	3.8	0.16

NOx:

NOx Baseline Emissions – 17.4 g/bhp-hr x 20.8 = 362 grams/gallon.
103 pre-Tier 0 UP and BNSF Switch Locomotives
50,000 gallons/yr x 362 grams/gallon=18,100,000 grams/yr/454 g/lb=39,867.84 lbs/yr/2,000 lbs/ton=19.93 tons/yr/365 days/yr=0.0546 tons/day NOx x 103 pre-Tier 0 switchers = 5.625 tons/day NOx emissions.

NOx Baseline Emissions – 14.0 g/bhp-hr x 20.8 = 291 grams/gallon.
49 Tier 0 UP and BNSF Switch Locomotives
50,000 gallons/yr x 291 grams/gallon=14,550,000 grams/yr/454 g/lb=32,048.46 lbs/yr/2,000 lbs/ton=16.0 tons/yr/365 days/yr=0.0439 tons/day NOx x 49 Tier 0 switch locomotives = 2.15 tons/day NOx emissions.

103 pre-Tier 0 UP/BNSF switch locomotives + 49 Tier 0 UP/BNSF switch locomotives=
(5.625 tons/day) + (2.15 tons/day) = 7.776 tons/day NOx or 7.8 tons/day.
NOx baseline emissions for 152 older UP/BNSF switchers= 7.8 tons/day.

NOx Control Emissions – 3.0 g/bhp-hr x 20.8 = 62 grams/gallon.
152 ULESL UP and BNSF Switch Locomotives (20% Diesel Fuel Reduction)
40,000 gallons/year x 62 grams/gallon = 2,480,000 grams/yr/454 g/lb=5,462.55 lbs/yr/2,000 lbs/ton=2.73 tons/yr/365 days/yr=0.00748 tons/day NOx x 152 ULESLs = 1.1374 tons/day **NOx controlled emissions or 1.14 tons/day NOx controlled**.

NOx baseline emissions (7.776 tons/day) – NOx control emissions (1.1374 tons/day) = 6.6386 tons/day NOx reduced or 6.64 or **6.6 tons/day NOx reduced**.

PM:

PM Baseline Emissions – 0,72 g/bhp-hr x 20.8 = 15 grams/gallon.
152 pre-Tier 0 and Tier 0 UP and BNSF Switch Locomotives
50,000 gallons/yr x 15 grams/gallon=750,000 grams/yr/454 g/lb=1,651.98 lbs/yr/2,000 lbs/ton=0.826 tons/yr/365 days/yr=.002263 tons/day PM x 152 pre-Tier and Tier 0 switchers =**0.344 tons/day PM baseline emissions**.

PM Control Emissions – 0.1 g/bhp-hr x 20.8 = 2 grams/gallon.
152 ULESL UP and BNSF Switch Locomotives (20% Diesel Fuel Reduction)
40,000 gallons/year x 2 grams/gallon = 80,000 grams/yr/454 g/lb=176.21 lbs/yr/2,000 lbs/ton=0.088 tons/yr/365 days/yr=0.00024 tons/day PM x 152 ULESLs = 0.03669 tons/day PM controlled emissions or **0.037 tons/day PM controlled**.

PM baseline emissions (0.344 tons/day) – PM control emissions (0.037 tons/day) = 0.307 tons/day PM reduced or 0.31 or **0.3 tons/day PM reduced**.

Cost-Effectiveness Calculations:
Annual emission reductions for NOx and PM: (NOx+PM) x (2,000 lbs/ton) x (365 days/yr) =
(6.64+0.31) x (2,000 lbs/ton) x (365 days/yr) = 5,735,000 lbs/yr.
Capital or Project Cost: $1,500,000 x 152 gen-sets or ULESLs = $228,000,000

Cost-Effectiveness by attributing half the project cost to PM and half the project cost to NOx:

PM
10 yr project life = (Project Cost x 0.5) / (PM tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($228,000,000 x 0.5) / (0.31 x 2000 x 365 x 10) = $50.38 / lb
20 yr project life = ($228,000,000 x 0.5) / (0.31 x 2000 x 365 x 20) = $25.19 / lb

NOx
10 yr project life = (Project Cost x 0.5) / (NOx tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($228,000,000 x 0.5) / (6.64 x 2000 x 365 x 10) = $2.35 / lb
20 yr project life = ($228,000,000 x 0.5) / (6.64 x 2000 x 365 x 20) = $1.18 / lb

Carl Moyer Cost-Effectiveness = (Capital Recovery Factor[1] x Project Cost) / (ROG + NOx + PM10x20):

(10 yrs) = (0.1233 x $228,000,000) / 9,373,200 lbs) = $3.00 / lb
(20 yrs) = (0.0736 x $228,000,000) / 9,373,200 lbs) = $1.79 / lb

1. Capital Recovery factor assumes a four percent discount rate.

Option 2 - DPF and SCR Retrofits of 244 UP/BNSF ULESLs:

Emission Reduction(TPD)	NOx	PM
Statewide	1.0	0.04
South Coast	0.6	0.02
Rest of State	0.4	0.02

NOx:

NOx Baseline Emissions – 3.0 g/bhp-hr x 20.8 = 62 grams/gallon.
244 UP and BNSF ULESLs (20% Diesel Fuel Reduction)
40,000 gallons/yr x 62 grams/gallon = 2,480,000 grams/yr/454 g/lb=5,462.55 lbs/yr/2,000 lbs/ton=2.73 tons/yr/365 days/yr=0.00748 tons/day NOx x 244 ULESLs = 1.825 tons/day NOx baseline emissions or **1.8 tons/day NOx baseline emissions**.

NOx Control Emissions – 1.3 g/bhp-hr x 20.8 = 27 grams/gallon.
244 UP and BNSF ULESLs Retrofitted with SCR (20% Diesel Fuel Reduction)
40,000 gallons/yr x 27 grams/gallon = 1,080,000 g/yr/454 g/lb=2,378.85 lbs/yr/2,000 lbs/ton=1.1894 tons/yr/365 days/yr=0.003258 tons/day NOx x 244 ULESLs retrofitted with SCR =
0.795 tons/day NOx controlled.

NOx baseline emissions (1.8 tons/day) – NOx control emissions (0.795 tons/day) =
1.0 tons/day NOx reduced.

PM:

PM Baseline Emissions – 0.1 g/bhp-hr x 20.8 = 2 grams/gallon.
244 UP and BNSF ULESLs (20% Diesel Fuel Reduction)
40,000 gallons/year x 2 grams/gallon = 80,000 grams/yr/454 g/lb=176.21 lbs/yr/2,000 lbs/ton=0.088 tons/yr/365 days/yr=0.00024 tons/day PM x 244 ULESLs = 0.05856 tons/day PM baseline emissions or **0.059 tons/day PM baseline emissions**.

PM Control Emissions – 0.03 g/bhp-hr x 20.8 = 0.624 grams/gallon.
244 UP and BNSF ULESLs Retrofitted with DPFs (20% Diesel Fuel Reduction)
40,000 gallons/yr x 0.624 grams/gallon = 24,960 g/yr/454 g/lb=54.98 lbs/yr/2,000 lbs/ton=0.0275 tons/yr/365 days/yr=0.0000753 tons/day PM x 244 ULESLs retrofitted with DPFs =
0.018 tons/day NOx control emissions

PM baseline emissions (0.059 tons/day) – PM control emissions (0.018 tons/day) = 0.041 tons/day PM reduced or **0.04 tons/day PM reduced**.

Cost-Effectiveness Calculations:

Annual emission reductions for NOx and PM: (NOx+PM) x (2,000 lbs/ton) x (365 days/yr) =
(1.0+0.04) x (2,000 lbs/ton) x (365 days/yr) x (1 yr) = 759,200 lbs/yr.
Capital or Project Cost: $200,000 x 244 ULESLs = $48,800,000.

Cost-Effectiveness by attributing half the project cost to PM and half the project cost to NOx:

PM
10 yr project life = (Project Cost x 0.5) / (PM tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($48,800,000 x 0.5) / (0.04 x 2000 x 365 x 10) = $41.78 / lb
20 yr project life = ($48,800,000 x 0.5) / (0.04 x 2000 x 365 x 20) = $83.56 / lb

NOx
10 yr project life = (Project Cost x 0.5) / (NOx tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($48,800,000 x 0.5) / (1.0 x 2000 x 365 x 10) = $1.67 / lb
20 yr project life = ($48,800,000 x 0.5) / (1.0 x 2000 x 365 x 20) = $3.34 / lb

Carl Moyer Cost-Effectiveness = (Capital Recovery Factor[1] x Project Cost) / (ROG + NOx + PM10x20):

(10 yrs) = (0.1233 x $48,800,000) / 1,314,000 lbs) = $4.58 / lb
(20 yrs) = (0.0736 x $48,800,000) / 1,314,000 lbs) = $2.73 / lb

1. Capital Recovery factor assumes a four percent discount rate.

Option 3 - Repower 244 ULESLs, that had been retrofitted with DPF and SCR, with new Tier 4 nonroad engines

(Emissions Reductions beyond ULESL and DPF/SCR Retrofit)

Emission Reduction(TPD)	NOx	PM
Statewide	0.60	0.01
South Coast	0.35	0.007
Rest of State	0.25	0.005

NOx:

NOx Baseline Emissions – 1.3 g/bhp-hr x 20.8 = 27 grams/gallon.
244 UP and BNSF ULESLs Retrofitted with SCR (20% Diesel Fuel Reduction)
40,000 gallons/yr x 27 grams/gallon = 1,080,000 g/yr/454 g/lb=2,378.85 lbs/yr/2,000 lbs/ton=1.1894 tons/yr/365 days/yr=0.003258 tons/day NOx x 244 ULESLs retrofitted with SCR =
0.795 tons/day NOx controlled.

NOx Control Emissions – 0.3 g/bhp-hr x 20.8 = 6.24 grams/gallon.
244 UP and BNSF ULESLs Tier 4 Nonroad Engines (20% Diesel Fuel Reduction)
40,000 gallons/yr x 6.24 grams/gallon = 249,600 grams/yr/454 g/lb=549.78 lbs/yr/2,000 lbs/ton=0.2749 tons/yr/365 days/yr=0.000753 tons/day NOx x 244 ULESLs with Tier 4 Nonroad engines = 0.18376 tons/day NOx baseline emissions or **0.184 tons/day NOx control emissions**.

NOx baseline emissions (0.795 tons/day) – NOx control emissions (0.184 tons/day) =
0.61 tons/day NOx reduced.

PM:

PM Baseline Emissions – 0.03 g/bhp-hr x 20.8 = 0.624 grams/gallon.
244 UP and BNSF ULESLs Retrofitted with DPFs (20% Diesel Fuel Reduction)
40,000 gallons/yr x 0.624 grams/gallon = 24,960 g/yr/454 g/lb=54.98 lbs/yr/2,000 lbs/ton=0.0275 tons/yr/365 days/yr=0.0000753 tons/day PM x 244 ULESLs retrofitted with DPFs =
0.018 tons/day NOx control emissions

PM Control Emissions – 0.01 g/bhp-hr x 20.8 = 0.208 grams/gallon.
244 UP and BNSF ULESLs with Tier 4 Nonroad Engines (20% Diesel Fuel Reduction)
40,000 gallons/year x 0.208 grams/gallon = 8,320 grams/yr/454 g/lb=18.33 lbs/yr/2,000 lbs/ton=0.0092 tons/yr/365 days/yr=0.000025 tons/day PM x 244 ULESLs with Tier 4 Nonroad Engines =
0.006 tons/day PM baseline emissions.

PM baseline emissions (0.018 tons/day) – PM control emissions (0.006 tons/day) = 0.012 tons/day PM reduced or **0.01 tons/day PM reduced**.

Cost-Effectiveness Calculations:

Annual emission reductions for NOx and PM: (NOx+PM) x (2,000 lbs/ton) x (365 days/yr) =
(0.61+0.01) x (2,000 lbs/ton) x (365 days/yr) = 452,600 lbs/yr.
Capital or Project Cost: $200,000 x 244 ULESLs = $48,800,000.

Cost-Effectiveness by attributing half the project cost to PM and half the project cost to NOx:

PM
10 yr project life = (Project Cost x 0.5) / (PM tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($48,800,000 x 0.5) / (0.01 x 2000 x 365 x 10) = $334.25 / lb
20 yr project life = ($48,800,000 x 0.5) / (0.01 x 2000 x 365 x 20) = $167.12 / lb

NOx
10 yr project life = (Project Cost x 0.5) / (NOx tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($48,800,000 x 0.5) / (0.61 x 2000 x 365 x 10) = $5.48 / lb
20 yr project life = ($48,800,000 x 0.5) / (0.61 x 2000 x 365 x 20) = $2.74 / lb

Carl Moyer Cost-Effectiveness = (Capital Recovery Factor[1] x Project Cost) / (ROG + NOx + PM10x20):

(10 yrs) = (0.1233 x $48,800,000) / 620,500 lbs) = $9.70 / lb
(20 yrs) = (0.0736 x $48,800,000) / 620,500 lbs) = $5.79 / lb

1. Capital Recovery factor assumes a four percent discount rate.

Option 4 - Remanufacture 152 older UP and BNSF switch locomotives to meet the U.S. EPA Tier 0 Plus emission standards

Emission Reduction(TPD)	**NOx**	**PM**
Statewide	2.2	0.22
South Coast	0.8	0.09
Rest of State	1.4	0.13

NOx:

<u>NOx Baseline Emissions – 17.4 g/bhp-hr x 20.8 = 362 grams/gallon.</u>
<u>103 pre-Tier 0 UP and BNSF Switch Locomotives</u>
50,000 gallons/yr x 362 grams/gallon=18,100,000 grams/yr/454 g/lb=39,867.84 lbs/yr/2,000 lbs/ton=19.93 tons/yr/365 days/yr=0.0546 tons/day NOx x 103 pre-Tier 0 switchers = 5.625 tons/day NOx emissions.

<u>NOx Baseline Emissions – 14.0 g/bhp-hr x 20.8 = 291 grams/gallon.</u>
<u>49 Tier 0 UP and BNSF Switch Locomotives</u>
50,000 gallons/yr x 291 grams/gallon=14,550,000 grams/yr/454 g/lb=32,048.46 lbs/yr/2,000 lbs/ton=16.0 tons/yr/365 days/yr=0.0439 tons/day NOx x 49 Tier 0 switch locomotives = 2.15 tons/day NOx emissions.

<u>103 pre-Tier 0 UP/BNSF switch locomotives + 49 Tier 0 UP/BNSF switch locomotives</u>=
(5.625 tons/day) + (2.15 tons/day) = 7.776 tons/day NOx or 7.8 tons/day.
<u>NOx baseline emissions for 152 older UP/BNSF switchers=</u> <u>7.8 tons/day.</u>

NOx Control Emissions – 11.8 g/bhp-hr x 20.8 = 245 grams/gallon.
<u>152 Tier 0 Plus UP and BNSF Switch Locomotives</u>
50,000 gallons/year x 245 grams/gallon = 12,250,000 grams/yr/454 g/lb=26,982.4 lbs/yr/2,000 lbs/ton=13.49 tons/yr/365 days/yr=0.03696 tons/day NOx x 152 Tier 0 Plus switch locomotives = 5.618 tons/day **<u>NOx controlled emissions or 5.6 tons/day NOx controlled</u>**.

NOx baseline emissions (7.776 tons/day) – NOx control emissions (5.618 tons/day) = 2.15775 tons/day NOx reduced or 2.16 or **<u>2.2 tons/day NOx reduced</u>**.

PM:

<u>PM Baseline Emissions – 0,72 g/bhp-hr x 20.8 = 15 grams/gallon.</u>
<u>152 pre-Tier 0 and Tier 0 UP and BNSF Switch Locomotives</u>
50,000 gallons/yr x 15 grams/gallon=750,000 grams/yr/454 g/lb=1,651.98 lbs/yr/2,000 lbs/ton=0.826 tons/yr/365 days/yr=0.002263 tons/day PM x 152 pre-Tier and Tier 0 switchers =
<u>0.344 tons/day PM baseline emissions</u>.

PM Control Emissions – 0.26 g/bhp-hr x 20.8 = 5.408 or 5.4 grams/gallon.
<u>152 Tier 0 Plus UP and BNSF Switch Locomotives</u>
50,000 gallons/year x 5.4 grams/gallon = 270,000 grams/yr/454 g/lb=594.7 lbs/yr/2,000 lbs/ton=0.297 tons/yr/365 days/yr=0.0008147 tons/day PM x 152 Tier 0 Plus = 0.12383 tons/day PM controlled emissions or **<u>0.12 tons/day PM controlled</u>**.
PM baseline emissions (0.344 tons/day) – PM control emissions (0.12 tons/day) = 0.224 tons/day PM reduced or **<u>0.22 tons/day PM reduced</u>**.

Cost-Effectiveness Calculations:

Annual emission reductions for NOx and PM: (NOx+PM) x (2,000 lbs/ton) x (365 days/yr) =
(2.16+0.22) x (2,000 lbs/ton) x (365 days/yr) = 1,737,400 lbs/yr.
Capital or Project Cost: $250,000 x 152 locos = $38,000,000

Cost-Effectiveness by attributing half the project cost to PM and half the project cost to NOx:

PM
10 yr project life = (Project Cost x 0.5) / (PM tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($38,000,000 x 0.5) / (0.22 x 2000 x 365 x 10) = $11.83 / lb
20 yr project life = ($38,000,000 x 0.5) / (0.22 x 2000 x 365 x 20) = $5.92 / lb

NOx
10 yr project life = (Project Cost x 0.5) / (NOx tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($38,000,000 x 0.5) / (2.16 x 2000 x 365 x 10) = $1.20 / lb
20 yr project life = ($38,000,000 x 0.5) / (2.16 x 2000 x 365 x 20) = $0.60 / lb

Carl Moyer Cost-Effectiveness = (Capital Recovery Factor[1] x Project Cost) / (ROG + NOx + PM10x20):

(10 yrs) = (0.1233 x $38,000,000) / 4,788,800 lbs) = $0.98 / lb
(20 yrs) = (0.0736 x $38,000,000) / 4,788,800 lbs) = $0.58 / lb

1. Capital Recovery factor assumes a four percent discount rate.

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APPENDIX F:

Options 5 thru 8 -
Calculations for Medium Horsepower Locomotives

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Calculations for Medium Horsepower Locomotives

(Source: EPA Fact Sheet – Emission Factors for Locomotives – EPA420-F-97-051 – December 1997)
http://www.epa.gov/otaq/regs/nonroad/locomotv/frm/42097051.pdf

Medium Horsepower Locomotive Emission Factors (EF)

Tier	NOx EF *(g/bhp-hr)*	PM EF *(g/bhp-hr)*
Pre Tier 0	13.5	0.60
Tier 0	9.5	0.60
Tier 0+	8.0	0.22
LEL	4.0	0.10
ULESL	3.0	0.10
Tier 3	3.0	0.10
Tier 4	1.3	0.03

Conversion Factors

bhp-hr/gallon
20.8

tons/g
1.10E-06

UP/BNSF/Passenger Medium Horsepower Locomotive Fleet Composition

Medium HP	# Locos	Pre-Tier 0	Tier 0
Statewide	400	360	40
South Coast	150	130	20
Rest of State	250	230	20

<u>Other Key Assumptions</u>:

All medium horsepower locomotives are assumed to consume 100,000 gallons of fuel per year.

Option 5 - Repower of 400 older Freight and Passenger MHP locomotives with new LEL engines:

Emission Reduction(TPD)	NOx	PM
Statewide	23	1.25
South Coast	8.6	0.47
Rest of State	14.4	0.78

NOx:

NOx Baseline Emissions – 13.5 g/bhp-hr x 20.8 = 281 grams/gallon.
360 UP/BNSF/Passenger Pre-Tier 0 MHP Locomotives
100,000 gallons/yr x 281 grams/gallon=28,100,000 grams/yr/454 g/lb=61,894.27 lbs/yr/2,000 lbs/ton=30.95 tons/yr/365 days/yr=0.08478 tons/day NOx x 360 pre-Tier 0 MHP locomotives = 30.52 tons/day or **30.5 tons/day** NOx baseline emissions.

NOx Baseline Emissions – 9.5 g/bhp-hr x 20.8 = 198 grams/gallon.
40 UP/BNSF/Passenger Tier 0 MHP Locomotives
100,000 gallons/yr x 198 grams/gallon=19,800,000 grams/yr/454 g/lb=43,612.33 lbs/yr/2,000 lbs/ton=21.81 tons/yr/365 days/yr=0.0597 tons/day NOx x 40 Tier 0 MHP locomotives = 2.3897 tons/day or **2.4 tons/day** NOx baseline emissions.

360 pre-Tier 0 UP/BNSF/Passenger MHP locomotives + 40 Tier 0 UP/BNSF/Passenger MHP locomotives=
(30.5 tons/day) + (2.4 tons/day) = **32.9 tons/day NOx baseline emissions for 400 older UP/BNSF/Passenger MHP Locomotives.**

NOx Control Emissions – 4.0 g/bhp-hr x 20.8 = 83 grams/gallon.
400 UP/BNSF/Passenger MHP LEL Engine Repower Locomotives
100,000 gallons/year x 83 grams/gallon = 8,300,000 grams/yr/454 g/lb=18,281.94 lbs/yr/2,000 lbs/ton=9.14 tons/yr/365 days/yr=0.025 tons/day NOx x 400 MHP LEL Engine Repower Locomotives = 10.0175 tons/day **NOx controlled emissions or 10.0 tons/day NOx controlled**.

NOx baseline emissions (32.9 tons/day) – NOx control emissions (10.0 tons/day) =
22.9 or 23 tons/day NOx reduced.

PM:

PM Baseline Emissions – 0,6 g/bhp-hr x 20.8 = 12.5 grams/gallon.
400 pre-Tier 0 and Tier 0 UP/BNSF/Passenger MHP Locomotives
100,000 gallons/yr x 12.5 grams/gallon=1,250,000 grams/yr/454 g/lb=2,753.3 lbs/yr/2,000 lbs/ton=1.377 tons/yr/365 days/yr=0.00377 tons/day PM x 400 pre-Tier and Tier 0 MHP Locomotives =
1.509 tons/day PM baseline emissions.

PM Control Emissions – 0.1 g/bhp-hr x 20.8 = 2 grams/gallon.
400 UP/BNSF/Passenger MHP Locomotives with LEL Engine Repowers
100,000 gallons/year x 2 grams/gallon = 200,000 grams/yr/454 g/lb=440.53 lbs/yr/2,000 lbs/ton=0.22 tons/yr/365 days/yr=0.0006 tons/day PM x 400 MHP Locomotives with LEL Engine Repowers = **0.241 tons/day PM controlled**.

PM baseline emissions (1.51 tons/day) – PM control emissions (0.24 tons/day) = 1.27 tons/day PM reduced or **1.25 tons/day PM reduced**.

Cost-Effectiveness Calculations:

Annual emission reductions for NOx and PM: (NOx+PM) x (2,000 lbs/ton) x (365 days/yr) =
(22.9+1.27) x (2,000 lbs/ton) x (365 days/yr) = 17,644,100 lbs/yr.
Capital or Project Cost: $1,000,000/ x 400 MHP LEL locomotives = $400,000,000

Cost-Effectiveness by attributing half the project cost to PM and half the project cost to NOx:

<u>PM</u>
10 yr project life = (Project Cost x 0.5) / (PM tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($400,000,000 x 0.5) / (1.27 x 2000 x 365 x 10) = $21.57 / lb
20 yr project life = ($400,000,000 x 0.5) / (1.27 x 2000 x 365 x 20) = $10.79 / lb

<u>NOx</u>
10 yr project life = (Project Cost x 0.5) / (NOx tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($400,000,000 x 0.5) / (22.9 x 2000 x 365 x 10) = $1.20 / lb
20 yr project life = ($400,000,000 x 0.5) / (22.9 x 2000 x 365 x 20) = $0.60 / lb

Carl Moyer Cost-Effectiveness = (Capital Recovery Factor[1] x Project Cost) / (ROG + NOx + PM10x20):

(10 yrs) = (0.1233 x$400,000,000) / 35,259,000 lbs) = $1.34 / lb
(20 yrs) = (0.0736 x$400,000,000) / 35,259,000 lbs) = $0.80 / lb

1. Capital Recovery factor assumes a four percent discount rate.

Option 6 - Replace up to 200 of the 400 older MHP locomotives with new MHP gen-set locomotives *(Complement and Alternative to MHP LEL Engine Repowers)*

Emission Reduction(TPD)	NOx	PM
Statewide	13.3	0.63
South Coast	6.65	0.315
Rest of State	6.65	0.315

NOx:

NOx Baseline Emissions – 13.5 g/bhp-hr x 20.8 = 281 grams/gallon.
200 UP/BNSF/Passenger Pre-Tier 0 MHP Locomotives
100,000 gallons/yr x 281 grams/gallon=28,100,000 grams/yr/454 g/lb=61,894.27 lbs/yr/2,000 lbs/ton=30.95 tons/yr/365 days/yr=0.084786676 tons/day NOx x 200 pre-Tier 0 MHP locomotives = 16.957 tons/day or **17 tons/day** NOx baseline emissions.

NOx Control Emissions – 3.0 g/bhp-hr x 20.8 = 62 grams/gallon.
200 UP/BNSF/ MHP Gen-Set Replacement Locomotives
100,000 gallons/year x 62 grams/gallon = 6,200,000 grams/yr/454 g/lb=13,656.4 lbs/yr/2,000 lbs/ton=6.83 tons/yr/365 days/yr=0.0187 tons/day NOx x 200 MHP Gen-Set Locomotives =
3.7415 tons/day or **3.74 tons/day NOx controlled emissions**.

NOx baseline emissions (17 tons/day) – NOx control emissions (3.74 tons/day) =
13.26 or 13.3 tons/day NOx reduced.

PM:

PM Baseline Emissions – 0,6 g/bhp-hr x 20.8 = 12.5 grams/gallon.
200 pre-Tier 0 and Tier 0 UP/BNSF/Passenger MHP Locomotives
100,000 gallons/yr x 12.5 grams/gallon=1,250,000 grams/yr/454 g/lb=2,753.3 lbs/yr/2,000 lbs/ton=1.377 tons/yr/365 days/yr=0.00377 tons/day PM x 200 pre-Tier and Tier 0 MHP Locomotives =
0.754 tons/day PM baseline emissions.

PM Control Emissions – 0.1 g/bhp-hr x 20.8 = 2 grams/gallon.
200 UP/BNSF/Passenger MHP Locomotives with Gen-Set Replacement Locomotives
100,000 gallons/year x 2 grams/gallon = 200,000 grams/yr/454 g/lb=440.53 lbs/yr/2,000 lbs/ton=0.22 tons/yr/365 days/yr=0.0006 tons/day PM x 200 MHP Gen-Set Locomotives = **0.12 tons/day PM controlled**.

PM baseline emissions (0.754 tons/day) – PM control emissions (0.12 tons/day) = 0.634 tons/day PM reduced or
0.63 tons/day PM reduced.

Cost-Effectiveness Calculations:

Annual emission reductions for NOx and PM: (NOx+PM) x (2,000 lbs/ton) x (365 days/yr) =
(13.26+0.63) x (2,000 lbs/ton) x (365 days/yr) = 10,139,700 lbs/yr.
Capital or Project Cost: $1,000,000 x 400 MHP LEL locomotives = $400,000,000

Cost-Effectiveness by attributing half the project cost to PM and half the project cost to NOx:

PM
10 yr project life = (Project Cost x 0.5) / (PM tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($400,000,000 x 0.5) / (0.63 x 2000 x 365 x 10) = $43.49 / lb
20 yr project life = ($400,000,000 x 0.5) / (0.63 x 2000 x 365 x 20) = $21.74 / lb

NOx
10 yr project life = (Project Cost x 0.5) / (NOx tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($400,000,000 x 0.5) / (13.26 x 2000 x 365 x 10) = $2.07 / lb
20 yr project life = ($400,000,000 x 0.5) / (13.26 x 2000 x 365 x 20) = $1.03 / lb

Carl Moyer Cost-Effectiveness = (Capital Recovery Factor[1] x Project Cost) / (ROG + NOx + PM10x20):

(10 yrs) = (0.1233 x$400,000,000) / 18,877,800 lbs) = $2.61 / lb
(20 yrs) = (0.0736 x$400,000,000) / 18,877,800 lbs) = $1.56 / lb

1. Capital Recovery factor assumes a four percent discount rate.

Option 7 - Retrofit 400 LEL or gen-set MHP locomotives with DPF and SCR

Emission Reduction(TPD)	NOx	PM
Statewide	6.8	0.18
South Coast	2.55	0.07
Rest of State	4.25	0.11

NOx:

NOx Baseline Emissions – 4.0 g/bhp-hr x 20.8 = 83.2 grams/gallon.
400 UP/BNSF/Passenger MHP LEL Engine Repower Locomotives
100,000 gallons/year x 83.2 grams/gallon = 8,320,000 grams/yr/454 g/lb=18,325.99 lbs/yr/2,000 lbs/ton=9.163 tons/yr/365 days/yr=0.0251 tons/day NOx x 400 MHP LEL Engine Repower Locomotives = 10.042 tons/day or **10.042 tons/day NOx baseline emissions**.

NOx Control Emissions – 1.3 g/bhp-hr x 20.8 = 27 grams/gallon.
400 UP/BNSF/Passenger MHP LEL Engine Repower Locomotives Retrofitted with SCR
100,000 gallons/yr x 27 grams/gallon=2,700,000 grams/yr/454 g/lb=5,947.17 lbs/yr/2,000 lbs/ton=2.97 tons/yr/365 days/yr=0.0081468 tons/day NOx x 400 MHP LEL Engine Repowered Locomotives with SCR = 3.2587 tons/day or **3.26 tons/day** NOx control emissions.

NOx baseline emissions (10.042 tons/day) – NOx control emissions (3.2583 tons/day) = 6.784 or **6.8 tons/day NOx reduced**.

PM:

PM Baseline Emissions – 0.1 g/bhp-hr x 20.8 = 2.08 grams/gallon.
400 UP/BNSF/Passenger MHP Locomotives with LEL Engine Repowers
100,000 gallons/year x 2.08 grams/gallon = 208,000 grams/yr/454 g/lb=458.15 lbs/yr/2,000 lbs/ton=0.229 tons/yr/365 days/yr=0.0006276 tons/day PM x 400 MHP Locomotives with LEL Engine Repowers = **0.251 tons/day PM baseline emissions.**

PM Control Emissions – 0,03 g/bhp-hr x 20.8 = 0.624 grams/gallon.
400 UP/BNSF/Passenger MHP Locomotives with LEL Engine Repowers Retrofitted with DPFs
100,000 gallons/yr x 0.624 grams/gallon=62,400 grams/yr/454 g/lb=137.45 lbs/yr/2,000 lbs/ton=0.06872 tons/yr/365 days/yr= 0.000188281 tons/day PM x 400 MHP Locomotives with LEL Engine Repowers and Retrofitted with DPFs =**0.0753 tons per day PM controlled emissions**.

PM baseline emissions (0.251 tons/day) – PM control emissions (0.0753 tons/day) = 0.1757 tons/day PM reduced or **0.18 tons/day PM reduced**.

Cost-Effectiveness Calculations:

Annual emission reductions for NOx and PM: (NOx+PM) x (2,000 lbs/ton) x (365 days/yr) =
(6.78+0.18) x (2,000 lbs/ton) x (365 days/yr) = 5,080,800 lbs/yr.
Capital or Project Cost: $500,000 x 400 MHP LEL locomotives retrofitted with SCR and DPF =
$200,000,000

Cost-Effectiveness by attributing half the project cost to PM and half the project cost to NOx:

<u>PM</u>
10 yr project life = (Project Cost x 0.5) / (PM tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($200,000,000 x 0.5) / (0.18 x 2000 x 365 x 10) = $76.10 / lb
20 yr project life = ($200,000,000 x 0.5) / (0.18 x 2000 x 365 x 20) = $38.05 / lb

<u>NOx</u>
10 yr project life = (Project Cost x 0.5) / (NOx tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($200,000,000 x 0.5) / (6.78 x 2000 x 365 x 10) = $2.02 / lb
20 yr project life = ($200,000,000 x 0.5) / (6.78 x 2000 x 365 x 20) = $1.01 / lb

Carl Moyer Cost-Effectiveness = (Capital Recovery Factor[1] x Project Cost) / (ROG + NOx + PM10x20):

(10 yrs) = (0.1233 x $200,000,000) / 7,577,400 lbs) = $3.25 / lb
(20 yrs) = (0.0736 x $200,000,000) / 7,577,400 lbs) = $1.94 / lb

1. Capital Recovery factor assumes a four percent discount rate.

Option 8 - Remanufacture 400 older MHP locomotives to meet U.S. EPA Tier 0 Plus Emission Standards *(Less Expensive Alternative to LEL and Gen-Set Options)*

Emission Reduction(TPD)	NOx	PM
Statewide	13	1.0
South Coast	4.9	0.37
Rest of State	8.1	0.63

NOx:
NOx Baseline Emissions – 13.5 g/bhp-hr x 20.8 = 281 grams/gallon.
360 UP/BNSF/Passenger Pre-Tier 0 MHP Locomotives
100,000 gallons/yr x 281 grams/gallon=28,100,000 grams/yr/454 g/lb=61,894.27 lbs/yr/2,000 lbs/ton=30.95 tons/yr/365 days/yr=0.08478 tons/day NOx x 360 pre-Tier 0 MHP locomotives = 30.52 tons/day or
30.5 tons/day NOx baseline emissions.

NOx Baseline Emissions – 9.5 g/bhp-hr x 20.8 = 198 grams/gallon.
40 UP/BNSF/Passenger Tier 0 MHP Locomotives
100,000 gallons/yr x 198 grams/gallon=19,800,000 grams/yr/454 g/lb=43,612.33 lbs/yr/2,000 lbs/ton=21.81 tons/yr/365 days/yr=0.0597 tons/day NOx x 40 Tier 0 MHP locomotives = 2.3897 tons/day or **2.4 tons/day** NOx baseline emissions.

360 pre-Tier 0 UP/BNSF/Passenger MHP locomotives + 40 Tier 0 UP/BNSF/Passenger MHP locomotives=
(30.5 tons/day) + (2.4 tons/day) = 32.9 tons/day
NOx baseline emissions for 400 older UP/BNSF/Passenger MHP Locomotives = 32.9 tons/day.

NOx Control Emissions – 8.0 g/bhp-hr x 20.8 = 166 grams/gallon.
400 UP/BNSF/Passenger MHP Locomotives Remanufactured to Tier 0 Plus NOx
100,000 gallons/year x 166 grams/gallon = 16,600,000 grams/yr/454 g/lb=36,563.87 lbs/yr/2,000 lbs/ton=18.28 tons/yr/365 days/yr=0.05 tons/day NOx x 400 MHP Locomotives Remanufactured to Tier 0 Plus NOx = 20.035 tons/day **or 20.0 tons/day NOx controlled emissions**.

NOx baseline emissions (32.9 tons/day) – NOx control emissions (20.0 tons/day) =
12.9 or 13 tons/day NOx reduced.

PM:
PM Baseline Emissions – 0,6 g/bhp-hr x 20.8 = 12.5 grams/gallon.
400 pre-Tier 0 and Tier 0 UP/BNSF/Passenger MHP Locomotives
100,000 gallons/yr x 12.5 grams/gallon=1,250,000 grams/yr/454 g/lb=2,753.3 lbs/yr/2,000 lbs/ton=1.377 tons/yr/365 days/yr=0.00377 tons/day PM x 400 pre-Tier and Tier 0 MHP Locomotives =
1.509 or 1.51 tons/day PM baseline emissions.

PM Control Emissions – 0.22 g/bhp-hr x 20.8 = 4.576 or 4.6 grams/gallon.
400 UP/BNSF/Passenger MHP Locomotives Remanufactured to Tier 0 Plus PM Standards
100,000 gallons/year x 4.6 grams/gallon = 460,000 grams/yr/454 g/lb=1,013.21 lbs/yr/2,000 lbs/ton=0.5066 tons/yr/365 days/yr=0.001388 tons/day PM x 400 MHP Locomotives Remanufactured to Tier 0 Plus Standards = **0.55518 tons per day or 0.555 tons per day PM controlled**.

PM baseline emissions (1.51 tons/day) – PM control emissions (0.555 tons/day) = 0.955 or 0.96 tons/day PM reduced or **1.0 tons/day PM reduced**.

Cost-effectiveness:

Annual emission reductions for NOx and PM: (NOx+PM) x (2,000 lbs/ton) x (365 days/yr) =
(12.9+0.96) x (2,000 lbs/ton) x (365 days/yr) = 10,117,800 lbs/yr.
Capital or Project Cost: $250,000 x 400 MHP locomotives = $100,000,000

Cost-Effectiveness by attributing half the project cost to PM and half the project cost to NOx:

PM
10 yr project life = (Project Cost x 0.5) / (PM tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($100,000,000 x 0.5) / (0.96 x 2000 x 365 x 10) = $7.13 / lb
20 yr project life = ($100,000,000 x 0.5) / (0.96 x 2000 x 365 x 20) = $3.57 / lb

NOx
10 yr project life = (Project Cost x 0.5) / (NOx tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($100,000,000 x 0.5) / (12.9 x 2000 x 365 x 10) = $0.53 / lb
20 yr project life = ($100,000,000 x 0.5) / (12.9 x 2000 x 365 x 20) = $0.27 / lb

Carl Moyer Cost-Effectiveness = (Capital Recovery Factor[1] x Project Cost) / (ROG + NOx + PM10x20):

(10 yrs) = (0.1233 x $100,000,000) / 23,433,000 lbs) = $0.53 / lb
(20 yrs) = (0.0736 x $100,000,000) / 23,433,000 lbs) = $0.31 / lb

1. Capital Recovery factor assumes a four percent discount rate.

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APPENDIX G:

Option 9 -
Calculations for Interstate Line Haul Locomotives

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Line Haul Locomotive Emission Factors (EF)

Tier	NOx EF *(g/bhp-hr)*	PM EF *(g/bhp-hr)*
Tier 2	5.5	0.20
Tier 4	1.3	0.03

Conversion Factors

bhp-hr/gallon
20.8

tons/g
1.10E-06

Projected UP and BNSF Interstate Line Haul Locomotive Fleet Composition in 2020

Interstate Line Hauls	# Locos	Tier 2
Statewide	1,200	1,200
South Coast	600	600
Rest of State	600	600

Other Key Assumptions:

All line haul locomotives are assumed to consume 100,000 gallons of fuel per year. This assumes an interstate line haul locomotive consumes up to 500,000 gallons per year, traveling across county (e.g., Chicago to Los Angeles), and only 20 percent of annual consumption is within the state of California.

Assumes UP and BNSF interstate line haul locomotive fleet in California will be a Tier 2 fleet average by 2020. Net emissions reductions would be only difference between a Tier 2 and Tier 4 interstate line haul locomotive emissions (76% NOx and 85% PM).

Option 9 - Accelerate UP and BNSF national Tier 4 interstate line haul locomotive fleet with orders for up to 4,800 to ensure 1,200 operate in California on any given day in 2020:

Emission Reduction(TPD)	NOx	PM
Statewide	32	1.3
South Coast	16	0.65
Rest of State	16	0.65

NOx:

NOx Baseline Emissions – 5.5 g/bhp-hr x 20.8 = 114.4 grams/gallon.
1,200 UP and BNSF Tier 2 Interstate Line Haul Locomotives in 2020
100,000 gallons/year x 114.4 grams/gallon = 11,440,000 grams/yr/454 g/lb=25,198.24 lbs/yr/2,000 lbs/ton=12.599 tons/yr/365 days/yr=0.034518 tons/day NOx x 1,200 UP and BNSF Tier 2 Interstate Line Haul Locomotives = 41.4 tons/day NOx baseline emissions.

NOx Control Emissions – 1.3 g/bhp-hr x 20.8 = 27 grams/gallon.
1,200 UP and BNSF Tier 4 Interstate Line Haul Locomotives in 2020
100,000 gallons/yr x 27 grams/gallon=2,700,000 grams/yr/454 g/lb=5,947.17 lbs/yr/2,000 lbs/ton=2.97 tons/yr/365 days/yr=0.0081468 tons/day NOx x 1,200 UP and BNSF Tier 4 Interstate Line Haul Locomotives with SCR = 9.78 tons/day NOx controlled emissions.

NOx baseline emissions (41.1 tons/day) – NOx control emissions (9.78 tons/day) = 31.62 tons/day NOx reduced.

PM:

PM Baseline Emissions – 0.2 g/bhp-hr x 20.8 = 4.16 grams/gallon.
1,200 UP and BNSF Tier 2 Interstate Line Haul Locomotives in 2020
100,000 gallons/year x 4.16 grams/gallon = 416,000 grams/yr/454 g/lb=916.3 lbs/yr/2,000 lbs/ton=0.458 tons/yr/365 days/yr=0.0012552 tons/day PM x 600 1,200 UP and BNSF Tier 2 Interstate Line Haul Locomotives in 2020 = 1.51 tons/day PM baseline emissions

PM Control Emissions – 0,03 g/bhp-hr x 20.8 = 0.624 grams/gallon.
1,200 UP and BNSF Tier 4 Interstate Line Haul Locomotives in 2020
100,000 gallons/yr x 0.624 grams/gallon=62,400 grams/yr/454 g/lb=137.45 lbs/yr/2,000 lbs/ton=0.06872 tons/yr/365 days/yr= 0.000188281 tons/day PM x 1,200 UP and BNSF Tier 4 Interstate Line Haul Locomotives with DPFs = 0.23 tons per day PM controlled emissions.

PM baseline emissions (1.51 tons/day) – PM control emissions (0.23 tons/day) = 1.28 tons/day PM reduced.

Cost-Effectiveness Calculations:

Annual emission reductions for NOx and PM: (NOx+PM) x (2,000 lbs/ton) x (365 days/yr) =
(31.62+1.28) x (2,000 lbs/ton) x (365 days/yr) = 24,017,000 lbs/yr.
Capital or Project Cost (National): $3,000,000 x 4,800 Tier 4 Line Haul locomotives = $14,400,000,000
Capital or Project Cost (California): $3,000,000 x 1,200 Tier 4 Line Haul locomotives = $3,600,000,000

Cost-Effectiveness by attributing half the project cost to PM and half the project cost to NOx:

PM
10 yr project life = (Project Cost x 0.5) / (PM tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($3,600,000,000 x 0.5) / (1.28 x 2000 x 365 x 10) = $192.64 / lb
20 yr project life = ($3,600,000,000 x 0.5) / (1.28 x 2000 x 365 x 20) = $96.32 / lb

NOx
10 yr project life = (Project Cost x 0.5) / (NOx tons/day x 2000 lbs/ton x 365 days/yr x 10 yrs)
= ($3,600,000,000 x 0.5) / (31.62 x 2000 x 365 x 10) = $7.80 / lb
20 yr project life = ($3,600,000,000 x 0.5) / (31.62 x 2000 x 365 x 20) = $3.90 / lb

Carl Moyer Cost-Effectiveness = (Capital Recovery Factor[1] x Project Cost) / (ROG + NOx + PM10x20):

(10 yrs) = (0.1233 x $3,600,000,000) / 41,770,600 lbs) = $10.63 / lb
(20 yrs) = (0.0736 x $3,600,000,000) / 41,770,600 lbs) = $6.34 / lb

1. Capital Recovery factor assumes a four percent discount rate.

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APPENDIX H:

Options 10 thru 15 -
Calculations for Cargo Handling Equipment (CHE)

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Calculations of Cargo Handling Equipment NOx and PM Emissions and Cost-Effectiveness

(Source: ARB Staff Report – Initial Statement of Reasons for Proposed Rulemaking – Regulation for Mobile Cargo Handling Equipment at Ports and Intermodal Rail Yards – October 2005
ARB Staff Report – Carl Moyer Program Guidelines – Part IV, Appendices – November 2005
CALSTART – LNG Yard Hostler Demonstration and Commercialization Project, Final Report - August 2008
Port of Los Angeles – Electric Truck Demonstration Project Fact Sheet – May 2008
National Renewable Energy Laboratory – "Using LNG as fuel in Heavy-Duty Tractors" – July, 1999)

This section provides a discussion of the methodology used to develop emission estimates and cost-effectiveness of potential options to enhance and accelerate non-locomotive emission reductions related to cargo handling equipment within railyards.

Estimating Emissions

The approach used to develop the cargo handling equipment emission estimates entailed determining the average annual emissions per engine and then multiplying it by the total number of engines in that group.

$$E_{y,t} = pop_x \times HP \times \%\ Load_t \times EF_x \times hrs_t$$

where:
- *E = Pollutant specific emissions*
- *HP = Horsepower*
- *pop = Cargo handling equipment type-specific population*
- *% Load = Average Engine Load (Load Factor)*
- *EF = Emission factor*
- *hrs = Annual use in hours*
- *y = Inventory year*
- *t = Equipment type*
- *x = Horsepower range*

Each of these elements and how they are incorporated in to the cargo handling equipment emission estimates is discussed below.

Population

Cargo handling equipment populations were developed using information gathered in an effort to develop facility-wide emission inventories for 18 California railyards. The information collected includes equipment type, engine specific information, and annual activity.

Horsepower

Average horsepower was estimated by equipment using information gathered to develop emission inventories for 18 California railyards.

Activity

Annual use (hours of operation) values for specific equipment was provided by emission inventories developed for 18 California railyards.

Engine Load Factor

This number represents engine load under normal operating conditions. Engine load factors were taken from ARB's OFFROAD model for the specific type of cargo handling equipment.

Emission Factors

Emission factors were taken from ARB's OFFROAD model and are based on the engines rated horsepower. Emission factors for this report do not incorporate deterioration rates associated with zero hour (i.e. brand new) emissions and equipment age.

Surplus Emission Reductions

Surplus emission reductions are estimated by taking the sum of all annual surplus pollutant reductions.

$$NOx\ Reductions\ (tons) + [20 \times PM\ Reductions\ (tons)] + ROG\ Reductions\ (tons)$$

To determine surplus emission reductions, annual emissions by pollutant must be estimated for both the baseline technology (technology applied under normal business practices) and the reduced technology (newer technology). The annual baseline technology emissions and the annual reduced technology emissions are compared. All pollutants are given an equal weight except for PM which has been identified as a toxic air and carries a greater weight.

If the reduced technology is an engine repower or replacement (i.e. new purchase) then estimated annual emissions for the reduced technology are subtracted from the estimated annual emissions for the baseline technology.

$$Annual\ Emissions\ for\ the\ Baseline\ Technology - Annual\ Emissions\ for\ the\ Reduced\ Technology$$

If the reduced technology is an engine retrofit then the annual baseline technology pollutant emissions are multiplied by the verified percent of emission reductions for the technology.

$$Annual\ Emissions\ for\ the\ Baseline\ Technology \times Reduced\ Technology\ Verification\ Percent$$

Annualized Cost

Annualized cost is calculated by multiplying the total cost of the project by the capital recovery factor (CRF).

$$Total\ Cost \times CRF$$

The CRF uses an interest rate and project life to calculate the rate at which earnings could reasonably be expected if the same funds were invested over the entire project life. For this report staff assumed an interest rate of 4 percent, the prevailing earnings potential for state funds expected by investing in various financial instruments.

$$[(1+i)^n (i)] / [(1+i)^n - 1]$$

Where:
i = discount rate
n = project life

Cost Effectiveness

The cost effectiveness for each potential option in this report was determined by dividing the annualized cost of the project by the total amount of surplus emission reductions.

$$Annualized\ Cost / Surplus\ Emission\ Reductions$$

Option 10 - LNG Yard Truck

Annual Baseline Emissions:

Yard Truck w/ 2007+ On-road Diesel Engine:

PM Emissions$_{Baseline}$:

[(0.01 g/bhp-hr x 170hp x 0.39 x 3,196 hr/yr) x (1 ton/907,200g)] = 0.002 ton/yr

NOx Emissions$_{Baseline}$:

[(0.27 g/bhp-hr x 170hp x 0.39 x 3,196 hr/yr) x (1 ton/907,200g)] = 0.06 ton/yr

Total Annual Baseline Emissions$_{PM + NOx}$ = **0.062 ton/yr**

8 Intermodal Railyards:

PM Emissions$_{2005}$: 14.80 ton/yr
NOx Emissions$_{2005}$: 328 ton/yr
342.8 ton/yr

PM Emissions$_{2010}$: 14.80 ton/yr x 0.36 = 5.3 ton/yr
NOx Emissions$_{2010}$: 328 ton/yr x 0.51 = 167 ton/yr
172.3 ton/yr

PM Emissions$_{2015}$: 14.80 ton/yr x 0.24 = 3.6 ton/yr
NOx Emissions$_{2015}$: 328 ton/yr x 0.30 = 98.4 ton/yr
102 ton/yr

PM Emissions$_{2020}$: 14.80 ton/yr x 0.12 = 1.78 ton/yr
NOx Emissions$_{2020}$: 328 ton/yr x 0.09 = 29.5 ton/yr
31.3 ton/yr

Based on emission inventories for 18 railyard health risk assessments finalized in 2007 and 2008. Estimated emission reductions are surplus to the ARB Regulation for Mobile Cargo Handling Equipment at Ports and Intermodal Railyards.

Annual Reduced Technology Emissions:

LNG Yard Truck:

PM Emissions$_{reduced}$:

N/A

NOx Emissions$_{reduced}$:

[(2.68 g/bhp-hr x 170hp x 0.39 x 3196 hr/yr) x (1 ton/907,200g)] = 0.63 ton/yr

Total Annual Reduced Technology Emissions$_{PM + NOx}$ = **0.63 ton/yr**

Annual Surplus Emission Reductions:

Total Annual Baseline Emissions$_{PM + NOx}$ + Total Annual Reduced Technology Emissions$_{PM + NOx}$

(0.06 ton/yr – 0.63 ton/yr)$_{NOx}$ + (0.002 ton/yr – 0 ton/yr)$_{PM}$ = ***-0.57 ton/yr*** (2007+ on-road engine)

Cost Estimates:

LNG Yard Truck: $120,000
8 Intermodal Railyards: $120,000 x 322 = **$38,640,000**

Cost Effectiveness: N/A

Option 11 - Electric Yard Truck

Annual Baseline Emissions:

Yard Truck w/ 2007+ On-road Diesel Engine:

PM Emissions$_{Baseline}$:
[(0.01 g/bhp-hr x 170hp x 0.39 x 3,196 hr/yr) x (1 ton/907,200g)] = 0.002 ton/yr

NOx Emissions$_{Baseline}$:
[(0.27 g/bhp-hr x 170hp x 0.39 x 3,196 hr/yr) x (1 ton/907,200g)] = 0.06 ton/yr

Total Annual Baseline Emissions$_{PM + NOx}$ = **0.062 ton/yr**

8 Intermodal Railyards:

PM Emissions$_{2010}$: 14.80 ton/yr x 0.36 = 5.3 ton/yr
NOx Emissions$_{2010}$: 328 ton/yr x 0.51 = 167 ton/yr
172.3 ton/yr

PM Emissions$_{2015}$: 14.80 ton/yr x 0.24 = 3.6 ton/yr
NOx Emissions$_{2015}$: 328 ton/yr x 0.30 = 98.4 ton/yr
102 ton/yr

PM Emissions$_{2020}$: 14.80 ton/yr x 0.12 = 1.78 ton/yr
NOx Emissions$_{2020}$: 328 ton/yr x 0.09 = 29.5 ton/yr
31.3 ton/yr

Based on emission inventories for 18 railyard health risk assessments finalized in 2007 and 2008. Estimated emission reductions are surplus to the ARB Regulation for Mobile Cargo Handling Equipment at Ports and Intermodal Railyards.

Annual Reduced Technology Emissions:

Electric Yard Truck:

PM Emissions$_{reduced}$:
N/A

NOx Emissions$_{reduced}$:
N/A

Total Annual Reduced Technology Emissions$_{PM + NOx}$ = **0 ton/yr**

8 Intermodal Railyards

PM Emissions$_{2010}$: 0 ton/yr
NOx Emissions$_{2010}$: 0 ton/yr

PM Emissions$_{2015}$: 0 ton/yr
NOx Emissions$_{2015}$: 0 ton/yr

PM Emissions$_{2020}$: 0 ton/yr
NOx Emissions$_{2020}$: 0 ton/yr

Annual Surplus Emission Reductions:

Total Annual Baseline Emissions$_{PM + NOx}$ - Total Annual Reduced Technology Emissions$_{PM + NOx}$
[(0.06 ton/yr)$_{NOx}$ + (0.002 ton/yr)$_{PM}$] - 0 ton/yr = **0.062 ton/yr** (2007+on-road engine)

Total Annual Baseline $Emissions_{PM + NOx}$ - Total Annual Reduced Technology $Emissions_{PM + NOx}$
$[(167\ ton/yr)_{NOx} + (5.3\ ton/yr)_{PM}]$ - 0 ton/yr = **172.3 ton/yr** (2010 Railyard Emissions)

Total Annual Baseline $Emissions_{PM + NOx}$ - Total Annual Reduced Technology $Emissions_{PM + NOx}$
$[(98.4\ ton/yr)_{NOx} + (3.6\ ton/yr)_{PM}]$- 0 ton/yr = **102 ton/yr** (2015 Railyard Emissions)

Total Annual Baseline $Emissions_{PM + NOx}$ - Total Annual Reduced Technology $Emissions_{PM + NOx}$
$[(29.5\ ton/yr)_{NOx} + (1.78\ ton/yr)_{PM}]$ - 0 ton/yr = **31.3 ton/yr** (2020 Railyard Emissions)

Annual Weighted Surplus Emission Reductions:

Total Annual Baseline $Emissions_{PM + NOx}$ - Total Annual Reduced Technology $Emissions_{PM + NOx}$
$[(0.06\ ton/yr)_{NOx} + 20(0.002\ ton/yr)_{PM}]$ - 0 ton/yr = **0.1 ton/yr** (2007+on-road engine)

Total Annual Baseline $Emissions_{PM + NOx}$ - Total Annual Reduced Technology $Emissions_{PM + NOx}$
$[(167\ ton/yr)_{NOx} + 20(5.3\ ton/yr)_{PM}]$ - 0 ton/yr = **273 ton/yr** (2010 Railyard Emissions)

Total Annual Baseline $Emissions_{PM + NOx}$ - Total Annual Reduced Technology $Emissions_{PM + NOx}$
$[(98.4\ ton/yr)_{NOx} + 20(3.6\ ton/yr)_{PM}]$- 0 ton/yr = **170.4 ton/yr** (2015 Railyard Emissions)

Total Annual Baseline $Emissions_{PM + NOx}$ - Total Annual Reduced Technology $Emissions_{PM + NOx}$
$[(29.5\ ton/yr)_{NOx} + 20(1.78\ ton/yr)_{PM}]$ - 0 ton/yr = **65.1 ton/yr** (2020 Railyard Emissions)

Cost Estimates:

Electric Yard Truck: $208,700
8 Intermodal Railyards: $208,700 x 322 = $67,201,400

Annualized Cost:

Electric Yard Truck: $208,700 x 0.149 = $31,096
8 Intermodal Railyards: = $67,201,400 x 0.149 = $10,013,008

Cost Effectiveness:

($31,096 ÷ 200 lbs) = **$155/lb** (2007+on-road engine)

($10,013,008 ÷ 546,000 lbs) = **$18.33/lb** (8 Intermodal $Railyards_{2010\ Emissions}$)
($10,013,008 ÷ 340,800 lbs) = **$29.38/lb** (8 Intermodal $Railyards_{2015\ Emissions}$)
($10,013,008 ÷ 130,200 lbs) = **$76.90/lb** (8 Intermodal $Railyards_{2020\ Emissions}$)

Option 12 – Hybrid Yard Hostlers

No calculations.

Staff assumes that railyard non-locomotive electrification and replacement with Wide Span Gantry (WSG) Cranes would nearly eliminate all CHE (i.e., Cranes, Yard Hostlers, and related CHE equipment) emissions.

Option 13 - Energy Storage Systems

Annual Baseline Emissions:

RTG Crane w/ Tier 4 Off-road Diesel Engine:
PM Emissions$_{Baseline}$:
[(0.01 g/bhp-hr x 300hp x 0.43 x 4,380 hr/yr) x (1 ton/907,200g)] = 0.006 ton/yr

NOx Emissions$_{Baseline}$:
[(0.27 g/bhp-hr x 300hp x 0.43 x 4,380 hr/yr) x (1 ton/907,200g)] = 0.168 ton/yr

Total Annual Baseline Emissions$_{PM + NOx}$ = **<u>0.174 ton/yr</u>**

8 Intermodal Railyards

PM Emissions$_{2005}$: 4.95 ton/yr
NOx Emissions$_{2005}$: 147.3 ton/yr
<u>152.5 ton/yr</u>

PM Emissions$_{2010}$: 4.95 ton/yr x 0.58 = 2.9 ton/yr
NOx Emissions$_{2010}$: 147.3 ton/yr x 0.91 = 134 ton/yr
<u>136.9 ton/yr</u>

PM Emissions$_{2015}$: 4.95 ton/yr x 0.43 = 2.1 ton/yr
NOx Emissions$_{2015}$: 147.3 ton/yr x 0.79 = 116.4 ton/yr
<u>118.5 ton/yr</u>

PM Emissions$_{2020}$: 4.95 ton/yr x 0.43 = 1.45 ton/yr
NOx Emissions$_{2020}$: 147.3 ton/yr x 0.79 = 100.16 ton/yr
<u>101.6 ton/yr</u>

Based on emission inventories for 18 railyard health risk assessments finalized in 2007 and 2008. Estimated emission reductions are surplus to the ARB Regulation for Mobile Cargo Handling Equipment at Ports and Intermodal Railyards.

Annual Reduced Technology Emissions:

Energy Storage System:
PM Emissions$_{reduced}$:
0.006 ton/yr x 0.25 = 0.0045 ton/yr

NOx Emissions$_{reduced}$:
0.168 ton/yr x 0.25 = 0.126 ton/yr

Total Annual Reduced Technology Emissions$_{PM + NOx}$ = **<u>0.131 ton/yr</u>**

8 Intermodal Railyards

PM Emissions$_{2010}$: 2.9 ton/yr x 0.75 = 2.2 ton/yr
NOx Emissions$_{2010}$: 134 ton/yr x 0.75 = 100.5 ton/yr
<u>102.7 ton/yr</u>

PM Emissions$_{2015}$: 2.1 ton/yr x 0.75 = 1.6 ton/yr
NOx Emissions$_{2015}$: 116.4 ton/yr x 0.75 = 87.3 ton/yr
<u>88.9 ton/yr</u>

PM Emissions$_{2020}$: 1.45 ton/yr x 0.75 = 1.08 ton/yr

NOx Emissions$_{2020}$: 100.16 ton/yr x 0.75 = 76.2 ton/yr
77.3 ton/yr

Annual Surplus Emission:

Total Annual Baseline Emissions$_{PM + NOx}$ - *Total Annual Reduced Technology Emissions*$_{PM + NOx}$ =

$(0.168$ ton/yr – $0.126)_{NOx}$ + $(0.006$ ton/yr – $0.0045)_{PM}$ = **0.043 ton/yr** (Tier 4 Off-road Diesel Engine)
$(134$ ton/yr – $100.5)_{NOx}$ + $(2.9$ ton/yr – $2.2)_{PM}$ = **34.2 ton/ yr** (8 Intermodal Railyards$_{2010\ Emissions}$)
$(116.4$ ton/yr – $87.3)_{NOx}$ + $(2.1$ ton/yr – $1.6)_{PM}$ = **29.6 ton/yr** (8 Intermodal Railyards$_{2015\ Emissions}$)
$(100.16$ ton/yr – $76.2)_{NOx}$ + $(1.45$ ton/yr – $1.08)_{PM}$ = **24.3 ton/yr** (8 Intermodal Railyards$_{2020\ Emissions}$)

Annual Weighted Surplus Emission:

$(0.168$ ton/yr – $0.126)_{NOx}$ + $20(0.006$ ton/yr – $0.0045)_{PM}$ = **0.072 ton/yr** (Tier 4 Off-road Diesel Engine)
$(134$ ton/yr – $100.5)_{NOx}$ + $20(2.9$ ton/yr – $2.2)_{PM}$ = **47.5 ton/ yr** (8 Intermodal Railyards$_{2010\ Emissions}$)
$(116.4$ ton/yr – $87.3)_{NOx}$ + $20(2.1$ ton/yr – $1.6)_{PM}$ = **39.1 ton/yr** (8 Intermodal Railyards$_{2015\ Emissions}$)
$(100.16$ ton/yr – $76.2)_{NOx}$ + $20(1.45$ ton/yr – $1.08)_{PM}$ = **31.36 ton/yr** (8 Intermodal Railyards$_{2020\ Emissions}$)

Cost Estimates:

Energy Storage System: $160,000 - $320,000
Eight Intermodal Railyards: $10,720,000 - $21,440,000

Annualized Cost:

Energy Storage System: $160,000 x 0.074 = **$11,840**
$320,000 x 0.074 = **$23,680**
Eight Intermodal Railyards: $10,720,000 x 0.074 = **$793,280**
$21,440,000 x 0.074 = **$1,586,560**

Cost Effectiveness:

($11,840 ÷ 144 lbs) = **$82.22/lb** (Tier 4 Off-road engine)
($23,680 ÷ 144 lbs) = **$164.44/lb** (Tier 4 Off-road engine)

($793,280 ÷ 95,000 lbs) = **$8.35/lb** (8 Intermodal Railyards$_{2010\ Emissions}$)
($1,586,560 ÷ 95,000 lbs) = **$16.70/lb** (8 Intermodal Railyards$_{2010\ Emissions}$)

($793,280 ÷ 78,200 lbs) = **$10.14/lb** (8 Intermodal Railyards$_{2015\ Emissions}$)
($1,586,560 ÷ 78,200 lbs) = **$20.29/lb** (8 Intermodal Railyards$_{2015\ Emissions}$)

($793,280 ÷ 62,720 lbs) = **$12.65/lb** (8 Intermodal Railyards$_{2020\ Emissions}$)
($1,586,560 ÷ 62,720 lbs) = **$25.29/lb** (8 Intermodal Railyards$_{2020\ Emissions}$)

Option 14 - Railyard Wide Span Gantry Cranes and Railyard Electrification

Annual Baseline Emissions:

CHE Equipment at 8 intermodal Railyards:
PM Emissions$_{2005}$: 25 tons/yr
NOx Emissions$_{2005}$: 543 tons/yr
568 tons/yr

PM Emissions$_{2010}$: 25 tons/yr x 0.48 = 12 tons/yr
NOx Emissions$_{2010}$: 543 tons/yr x 0.65 = 353 tons/yr
365 tons/yr

PM Emissions$_{2015}$: 25 tons/yr x 0.34 = 8.5 tons/yr
NOx Emissions$_{2015}$: 543 tons/yr x 0.53 = 287.8 tons/yr
296.3 tons/yr

PM Emissions$_{2020}$: 25 tons/yr x 0.2 = 5 tons/yr
NOx Emissions$_{2020}$: 543 tons/yr x 0.2 = 108.6 tons/yr
113.6 ton/yr

Based on emission inventories for 18 railyard health risk assessments finalized in 2007 and 2008. Estimated emission reductions are surplus to the ARB Regulation for Mobile Cargo Handling Equipment at Ports and Intermodal Railyards.

Annual Reduced Technology Emissions:

WSG Crane at 8 intermodal Railyards:
PM Emissions$_{reduced}$:
N/A

NOx Emissions$_{reduced}$:
N/A

Total Annual Reduced Technology Emissions$_{PM + NOx}$ = **0 ton/yr**

Annual Surplus Emission Reduction:

Total Annual Baseline Emissions$_{PM + NOx}$ - Total Annual Reduced Technology Emissions$_{PM + NOx}$

[(353 ton/yr)$_{NOx}$ + (12 ton/yr)$_{PM}$] – 0 ton/yr = **365 ton/yr** (2010 Emissions)
[(287.8 ton/yr)$_{NOx}$ + (8.5 ton/yr)$_{PM}$] – 0 ton/yr = **296.3 ton/yr** (2015 Emissions)
[(108.6 ton/yr)$_{NOx}$ + (5 ton/yr)$_{PM}$] – 0 ton/yr = **113.6 ton/yr** (2020 Emissions)

Annual Weighted Surplus Emission Reduction:

[(353 ton/yr)$_{NOx}$ + 20(12 ton/yr)$_{PM}$] – 0 ton/yr = **593 ton/yr** (2010 Emissions)
[(287.8 ton/yr)$_{NOx}$ + 20(8.5 ton/yr)$_{PM}$] – 0 ton/yr = **457.8 ton/yr** (2015 Emissions)
[(108.6 ton/yr)$_{NOx}$ + 20(5 ton/yr)$_{PM}$] – 0 ton/yr = **208.6 ton/yr** (2020 Emissions)

Cost Estimates:

WSG Crane Installations at 8 intermodal Railyards: $1,200,000,000

Annualized Cost:

WSG Crane Installations at 8 intermodal Railyards: $1,200,000,000 x 0.074 = **$88,800,000**

Cost Effectiveness:

(\$88,800,000 ÷ 1,186,000 lbs) = **$\underline{\$74.87/lb}$** (8 Intermodal Railyards$_{2010\ Emissions}$)
(\$88,800,000 ÷ 915,600 lbs) = **$\underline{\$96.98/lb}$** (8 Intermodal Railyards$_{2015\ Emissions}$)
(\$88,800,000 ÷ 417,200 lbs) = **$\underline{\$212.84/lb}$** (8 Intermodal Railyards$_{2020\ Emissions}$)

Option 15 – Idle Reduction Devices For Cargo Handling Equipment (CHE)

ARB staff does not currently have actual emission reductions and costs data for idle reduction devices on CHE. As a result, staff has not calculated emissions or cost-effectiveness.

APPENDIX I:

Option 16 -
Calculations for Transport Refrigeration Unit (TRU) Plug In Electrification

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Option 16 - TRU PLUG-IN ELECTRIFICATION EMISSION CALCULATIONS

PM Emission Reductions if installed at BNSF BNSF Hobart, BNSF San Bernardino, UP ICTF, UP Oakland, UP Commerce, UP City of Industry, UP LATC and BNSF Commerce Eastern assuming 100% mitigation:
PM Emission Reductions = Emissions x Emission Reduction Factor
PM Emission Reductions = 13.5 TPY x 0.08 = <u>**1.08 TPY or 0.003 TPD**</u>

NOx Emission Reductions if installed at BNSF BNSF Hobart, BNSF San Bernardino, UP ICTF, UP Oakland, UP Commerce, UP City of Industry, UP LATC and BNSF Commerce Eastern assuming 100% mitigation:
NOx Emission Reduction = PM Emission Reductions * 10
NOx Emission Reduction = 1.08 TPY x 10 = <u>**10.8 TPY or 0.03 TPD**</u>

<u>COST-EFFECTIVENESS CALCULATIONS</u>

<u>TRU plug-in electrification Cost-Effectiveness Estimates</u>
New reefer racks and associated electric infrastructure
Cost for reefer racks for 8 railyards= $1,000,000 ($1 million)
Cost for electric infrastructure for 8 railyards = $500,000,000 ($500 million)
Total Costs = $501,000,000 ($501 million)

<u>(1) Cost-Effectiveness Calculation for New TRU plug-in electrification of 8 intermodal railyards</u>
Cost for 8 New Reefer Racks and associated electric infrastructure $ 1,000,000

$$\text{Carl Moyer Cost-Effectiveness} = \frac{\text{(Project Cost x CRF)}}{\text{(ROG + NOx + PMx20) x 365 days/yr x 2000 lbs/ton}}$$

Cost Effectiveness (10 years) = ($501,000,000 x 0.1233) / (0.03 + 0.003x20)x365x2000
= $940.23 / lb

Cost Effectiveness (20 years) = ($501,000,000 x 0.1233) / (0.03 + 0.003x20)x365x2000
= $561.24 / lb

Electric infrastructure costs:
The $500 million dollar value for infrastructure was determined by taking the electrification cost of 1.2 billion for eight intermodal railyards (see Table III-5), and subtracting an estimated WSG equipment cost of 700 million (close to the $804 million figure determined using an average cost of $6 million per crane).

References:

(1) Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate (2004 ARB)

(2) Email Communication with Tim Leong at the Port of Oakland (2008)

(3) Railyard HRAs (2008 ARB)

(4) Intermodal Container Transfer Facility (ICTF) Modernization Project (2007 UP)

(5) Staff Report: Initial Statement of Reasons for Proposed Rulemaking: Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate (2003 ARB)

APPENDIX J:

Options 17 thru 20 - Calculations for Port and Intermodal Railyard Drayage Trucks

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Option 17 – New 2007 HD Diesel Trucks

The new 2007 diesel truck PM and NOx emission standards are required in intermodal railyards by 2014 per the CARB Drayage Truck Regulation.

Assuming there are no emissions reductions when comparing 2007 HD diesel trucks with new 2007 HD diesel trucks, as required by the ARB drayage truck regulation by 2014. Therefore, there is no cost-effectiveness calculation for new 2007 HD diesel trucks.

Option 18 - LNG HD trucks

2007 HD truck NOx emission level = 5 g/mile
Average VMT = 40,000 miles/year (fleet average VMT by ARB Goods Movement Plan)
LNG HD truck NOx emissions compared to 2007 models = approximately 67%
NOx emission reduction from LNG HD trucks = (5 g/mile) x (40,000 miles/yr) X (1-67%)
= 146lb/yr

Carl Moyer Cost-Effectiveness = $\frac{\text{Capital Cost x Capital recovery factor}}{\text{(NOx+20PM+ROG)}}$

Capital cost = $210,000/unit
Cost-effectiveness (15 years) = ($210,000 x 0.08994)/[(146lb/yr) = $129 / lb

Capital cost = $100,000/unit
Cost-effectiveness (15 years) = ($100,000 x 0.08994)/[(146lb/yr) = $61.6 / lb

Option 19 - CNG HD trucks

2007 HD truck NOx emission level = 5 g/mile
Average VMT = 40,000 miles/year (fleet average VMT by ARB Goods Movement Plan)
CNG HD trucks NOx emissions compared to 2007 models = approximately 10%
NOx emission reduction from CNG HD trucks = (5 g/mile) x (40,000 miles/yr) X (1- 10%)
= 397 lb/yr

Carl Moyer Cost-Effectiveness = $\frac{\text{Capital Cost x Capital recovery factor}}{\text{(NOx+20PM+ROG)}}$

Capital cost = \$120,000/unit
Cost-effectiveness (15 years) = (\$120,000 x 0.08994)/[(397 lb/yr) = \$27.19 / lb

Capital cost = \$10,000/unit
Cost-effectiveness (15 years) = (\$10,000 x 0.08994)/[(397 lb/yr) = \$2.27 / lb

Option 20 - Electric HD trucks

2007 HD truck NOx emission level = 5 g/mile
Average VMT = 40,000 miles/year (fleet average VMT by ARB Goods Movement Plan)
NOx reduction from electric HD trucks = (5 g/mile) x (40,000 miles/yr) X (100%)
= 441 lb/yr

Carl Moyer Cost-Effectiveness = $\frac{\text{Capital Cost x Capital recovery factor}}{\text{(NOx+20PM+ROG)}}$

Capital cost = $210,000/unit
Cost-effectiveness (15 years) = ($210,000 x 0.08994) / (441 lb/yr) = $42.83 / lb

Capital cost = $100,000/unit
Cost-effectiveness (15 years) = ($100,000 x 0.08994) / (441 lb/yr) = $20.39/lb

APPENDIX K:

Option 21 -
Calculations for Advanced Locomotive Emission Control System (ALECS)

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Cost-Effectiveness

DPM reduction from the UP Roseville maintenance facility = ~1 ton/year (about 0.8 tpy)
NOx reduction (a factor of 20 from DPM reduction) = 20 tons/year
Capital cost = $25,000,000
Cost-effectiveness (20 years) =

= (Funded Amount x Capital recovery factor) / (Nox+20PM+ROG)
= ($25,000,000 x 0.07358) / (20*1+20 ton/yr x 2000lb/ton)
= $23/lb

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Calculations for Total Diesel PM Emissions for Service and Maintenance Area for UP Roseville Railyard

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TOTAL TPY FOR SERVICE AND MAINTENANCE FOR UP ROSEVILLE RAILYARD				
IDLING LOCOMOTIVES AT SERVICE TRACKS, MODSEARCH BUILDING, MAINTENANCE SHOP, AND READY TRACKS				
YARD LOCATION	**ANNUAL NUMBER OF LOCOMOTIVES**	**DURATION OF EACH EVENT (mins)**	**ANNUAL AVERAGE HOURLY EMISSIONS RATE (g/hr)**	**ANNUAL DIESEL PM EMISSIONS (tpy)**
Service Tracks				
Inspection pits	19,380.00	120.00	168.42	1.62
SUB-TOTAL	19,380.00	120.00	168.42	1.62
Modsearch Building				
Idling	7,200.00	120.00	15.67	0.15
SUB-TOTAL	7,200.00		15.67	0.15
Maintenance Shop				
East side Idling	5,400.00	120.00	47.02	0.454
West-side Idling	same as above	60.00	23.51	0.227
SUB-TOTAL	5,400.00		70.53	0.68
Ready Tracks				
Idling	21,547.49	120.00	148.15	1.43
SUB-TOTAL	21,547.49		148.15	1.43
GRAND-TOTAL				**3.88**
Source: UP Roseville Railyard Study (emission estimation baseline year 2000)				

MOVEMENT OF LOCOMOTIVES AT SERVICE TRACKS AND MAINTENANCE SHOP				
YARD LOCATION TO YARD LOCATION	**ANNUAL NUMBER OF LOCOMOTIVES**	**DURATION OF EACH EVENT (mins)**	**ANNUAL AVERAGE HOURLY EMISSIONS RATE (g/hr)**	**ANNUAL DIESEL PM EMISSIONS (tpy)**
SERVICE TRACKS Area				
In-bound to Wash Racks	19,380.49	5.00	10.3 - 14.4	0.10 - 0.14
Wash Racks to Service Trks	19,380.49	5.00	10.3 - 14.4	0.10 - 0.14
Service Trks to Ready Trks	14,251.47	5.00	7.54 - 10.60	0.073 - 0.102
Service Trks to Modsearch	7,200.00	15.00	8.13 - 12.80	0.08 - 0.12
SUB-TOTAL	19,380.49		36.27 - 52.2	0.35 - 0.50
AVERAGE TOTAL			**44.24**	**0.43**
Maintenance Shop Area				
Modsearch Buildings				
To East-side Maint. Shop	5,400.00	30.00	12.20 - 19.20	0.12 - 0.19
To Ready Tracks	1,800.00	10.00	1.35 - 2.13	0.013 - 0.021
Maintenance Shop				
West-side to Ready Tracks	5,400.00	10.00	4.06 - 6.40	0.039 - 0.062
SUB-TOTAL	5,400.00		17.61 - 27.73	0.039 - 0.062
GRAND-TOTAL	**21,451.47**		**53.81 - 80.02**	**0.52 - 0.77**
AVERAGE GRAND TOTAL			**66.92**	**0.645**

Source: UP Roseville Railyard Study (emission estimation baseline year 2000)

LOCOMOTIVE TESTING AT SERVICE TRACKS, MODSEARCH BUILDING,AND MAINTENANCE SHOP				
YARD LOCATION	**ANNUAL NUMBER OF TESTS**	**DURATION OF EACH EVENT (mins)**	**ANNUAL AVERAGE HOURLY EMISSIONS RATE (g/hr)**	**ANNUAL DIESEL PM EMISSIONS (tpy)**
Service Tracks				
Pre-test emissions	1,354.00	*	19.47	0.19
Post test emissions	1,525.00	**	21.13	0.20
SUB-TOTAL	2,879.00		40.6	0.39
Modsearch Building				
Pre-test emissions	4,508.00	*	62.95	0.61
Post test emissions	none	**	none	none
SUB-TOTAL	4,508.00		62.95	0.61
Maintenance Shop				
East-side				
Pre-test emissions	799.00	*	9.25	0.089
Post test emissions	none	**	none	none
SUB-TOTAL	799.00		9.25	0.09
West-side				
Pre-test emissions	none	*	none	
Post test emissions	3,581.00	**	55.39	0.534
SUB-TOTAL	3,581.00		55.39	0.53
GRAND-TOTAL FOR TABLE 2.3	**11,767.00**			**1.62**
GRAND TOTAL FOR ALL TABLES			682.12	**6.15 TPY**
Grand total for Service and Testing is 6.15 tons per year according to Roseville Railyard study emissions estimation baseline year 2000.				

Note1- The length of the ready tracks is approximately 600 yards or 1800 feet.
The length of the of the inspection pit Area (part of the service track is) approximately 250 yards or about 750 feet.
The length of the Area on the east and west side of the maintenance shop is approximately 200 yards each side or about 600 feet.
Note 2-The emission estimation source is UP Roseville railyard Report.

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Figures of UP Roseville Service and Maintenance Area

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Figure K-1: Aerial Picture of Roseville Railyard with Description of different Areas

Figure K-2: Descriptions of the Different Areas of the UP Roseville Railyard

Service Track Area
Idling at Inspection pits=1.62
Pre and post test emissions=0.39
Movement in service Area=0.43
Total=2.44 tpy
Note4*

Ready Tracks
Idling Emissions=1.43tpy

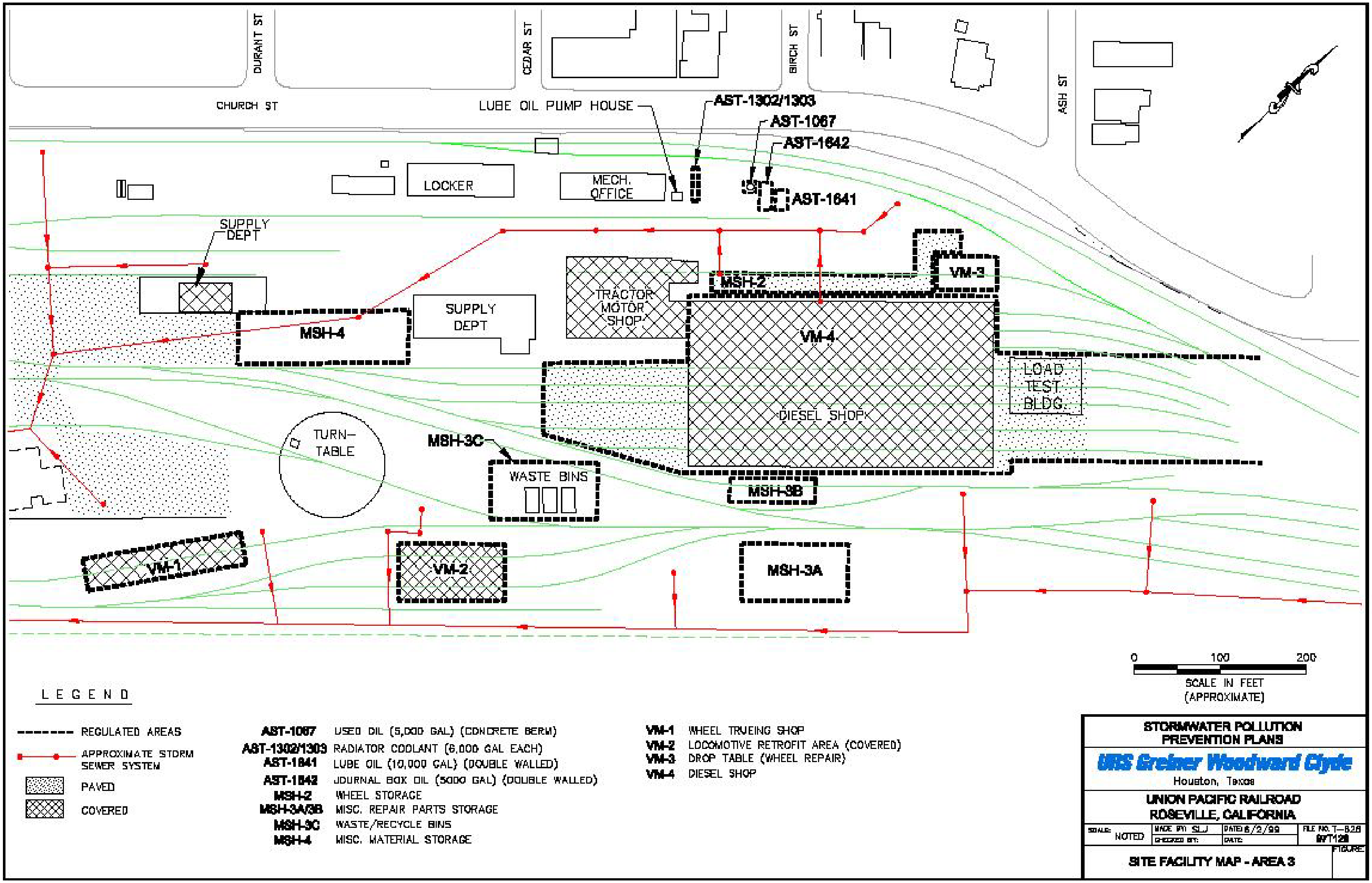
Modsearch Building
Idling Emissions=0.15tpy
Movement to ready track=0.017
Pre-& post Test missions=0.61 tpy
Total=0.78tpy

West side of the Maintenance Facility
Idling Emissions=0.23 tpy
Movement at west side=0.05 tpy
Pre-& post Test emissions=0.53 tpy
Total=0.81tpy

East side of the Maintenance Facility
Idling Emissions=0.45 tpy
Movement at east side=0.16tpy
Pre-& post Test missions=0.09 tpy
Total=0.69tpy

Note 1-These emission estimates are based on the emissions for baseline year 2000
Note 2- Service Track Emissions Occur over the whole length of the service tracks.
Note 3-Idling Emissions may have been significantly reduced since 2000 due to installation of Idle reduction Devices and Idling reduction requirements under the 2005ARB/Railroad MOU.
*Note 4=Movement in service Area emissions are further divided into 4 different areas as follows In-bound to Wash Racks=0.12tpy, Wash Racks to Service Trks=0.12tpy, Service Tracks to Ready Tracks=0.09tpy, Service Tracks to Modsearch=0.1tpy.

Figure K-3 Schematic Diagram of the Service and Maintenance Area of the UP Roseville Railyard.



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Photos of Service and Maintenance Area at UP Roseville Railyard

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Figure K-4: Near-Source Picture of the Service Track Area as Shown in Figure 2

Figure K-5: Picture of the East Side of the Maintenance Shop as Mentioned in Figure K-2.

Figure K-6: Picture of the Service and maintenance area as shown in Figure K-1.

Figure K-7: Near- Source Picture of maintenance Area as Shown in Figure K-1 and K-2.

Figure K-8: Near-Source Picture of East side of the Maintenance Area

Cost Elements for Cost Effectiveness of ALECS

Cost elements are broken down into Initial Capital Costs, Operating and Maintenance Costs including Utility/Energy Costs, Repair and Replacement Costs, Downtime Costs, Environmental Costs, and Salvage Value.

A) Initial Capital Costs include engineering and design (drawings and regulatory issues), bidding process, purchase order administration, hardware capital costs, testing and inspection, inventory of spare parts, foundations (design, preparation, concrete and reinforcing), installation of equipment, connection of process piping, connection of electrical wiring and instrumentation, one-time licensing/permitting fees, and the start up (check out) costs.
B) Operating and Maintenance Costs include items such as labor costs of operators, inspections, insurance, warranties, recurring licensing/permitting fees, and all maintenance (corrective and preventive maintenance). Also included are yearly costs of consumables such as the utility/energy costs (electricity, natural gas, and water) and chemical costs (such as sodium hydroxide and urea).

C) Repair and Replacement Costs are the costs of repairing and replacing equipment over the life of the ALECS. This would also include catalyst material replacement.

D) Environmental Costs are associated with the disposal of wastewater, solid waste, used chemicals, and used parts.

E) The Salvage Value of the system would be the net worth of the ALECS in its final year of the life cycle period. If the system can be moved and salvaged for useful parts/purposes, there would be a reduction in life cycle costs.

F) Rail yard impact costs include estimates of costs incurred by the Union Pacific Railroad. An example would be if the ALECS was shut down for repairs and locomotives that normally would be serviced or stored in a specific area needed to be relocated and serviced/stored elsewhere. Rail yard impact costs would also include the costs to change rail yard operations that are different from what is practiced today (including structural changes, if needed, to accommodate ALECS). For example, the additional time and costs (including labor) of rerouting locomotives to the ALECS area if the locomotives may not have been normally required to be moved. Locomotive downtimes can be very expensive to the rail yard and may result in loss of revenue. Costs may also be negative (a benefit to the rail yard) if the implementation of ALECS produced increased efficiencies such as decreased dwell time (time a locomotive is in the rail yard). At the current time, Union Pacific Railroad does not have an estimate (positive or negative) as to the effect ALECS would have on rail yard operations. This cost is not included in the Analysis.

APPENDIX L:

Option 23
Calculations for Interstate Line Haul Locomotives Operating with Idle Reduction Devices

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Assuming on a conservative basis for a switch (yard) locomotive (assumed 10% idle reduction device benefits - some studies suggest up to 50% idle reduction benefits):

CONSERVATIVE CALCULATION OF IDLING REDUCTION EMISSION REDUCTION BENEFITS

KEY ASSUMPTIONS

• Total Hours in a Calendar Year (365 x 24):	8,760 hours per year.
• Industry Standard for Locomotive Availability:	90 percent (10% maintenance/shutdown)
• Net Potential Hours Locomotive Available Per Year:	up to 7,884 hours

SWITCH LOCOMOTIVES

Average Hours Work Per Day:	15 hours/day
Number of Days Available Per Year (90%)	329 day/year
Annual Hours Worked Per Year	4,935 hours/year work
U.S. EPA Duty Cycle – Idle Time (60%)	2,961 hours per year idle (~9 hours/day).

Hours per year idle mode	2,961 hours/year
Gallons per hour in idle mode	x 5 gallons/hour
Gallons/Year Burned in Idle Mode	14,805 gallons/year
Idle Reduction Device	10% idle reduction
Gallons Diesel Fuel Unburned Due Idle Device	~1,500 gallons/year

NOx Emissions Calculations: 17.4 g/bhp-hr NOx (switch pre-Tier 0) x U.S. EPA bhp-hr conversion 20.8=362 grams/gallon.

~1,500 gallons/year x 362 grams/gallon = 543,000 grams/year/454 g/lb=**1,196.0 lbs/year**/2,000 lbs/ton=0.6 tons/year/365 days/year=0.0016 tons/day NOx reduced.

PM Emissions Calculations: 0.72 g/bhp-hr PM (switch pre-Tier 0) x U.S. EPA bhp-hr conversion 20.8=15 grams/gallon.

~1,500 gallons/year x 15 grams/gallon = 22,500 grams/year/454 g/lb=**49.6 lbs/year**/2,000 lbs/ton=0.025 tons/year/365 days/year=0.00007 tons/year PM reduced.

NOx (1,200 lbs/year) + PM (50 lbs/year) = 1,250 lbs/year of NOx and PM reduced.

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APPENDIX M:

Option 29 -
Calculations to Electrify Major Freight Lines in the SCAB to Barstow and Niland

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FREIGHT ELECTRIFICATION EMISSION CALCULATIONS:

ARB Emission Inventory Forcast for NOx [1]:

Source Category	Pollutant – Oxides of Nitrogen "NOx" (Tons per Day) Year			
	2008	2010	2020	% of 2020
Line Haul	21.264	14.241	18.389	71
Switch	4.314	2.597	2.588	10
Passenger	3.371	2.847	4.839	19
Total	28.949	19.686	25.816	100

ARB Emission Inventory Forcast for PM [1]:

Source Category	Pollutant – Particulate Matter "PM" (Tons per Day) Year			
	2008	2010	2020	% of 2020
Line Haul	0.688	0.685	0.733	83.4
Switch	0.090	0.082	0.076	8.7
Passenger	0.079	0.079	0.070	7.9
Total	0.857	0.846	0.878	100

1. Source: ARB Emission Inventory, Other Mobile Sources – Trains, 2009 Almanac Data, Base Year 2008, South Coast Air Basin, Grown & Controlled, Annual Average. Note: This ARB inventory does not include emissions benefits from 2008 U.S. EPA Locomotive Rulemaking.

NOx Emissions in the SCAB:
Emissions = Total Emissions – Emissions from line haul Locomotives
Emissions = 25.82 TPD – 18.39 TPD = 7.43 TPD

Diesel PM Emissions in the SCAB:
Emissions = Total Emissions – Emissions from line line Locos
Emissions = 0.86 TPD – 0.73 TPD = 0.13 TPD

COST EFFECTIVENESS CALCULATIONS:

Freight Electrification Cost Estimates:
ARB Analysis:
New Electric Freight Locomotive
Cost = approx $8,000,000 (8 million)
Number of Locomotives = 775

Electric Retrofit of Existing Track
Cost = approx $15,000,000/mile (15 million per mile)
Miles of Track = 460

Cost of Locomotives	$8,000,000/loco x 775 locos = $6,200,000,000
Cost of Track	$15,000,000/mile x 460 miles = $6,900,000,000
Total Project Cost	$6,200,000,000 + 6,900,000,000 = $13,100,000,000
Carl Moyer Cost-Effectiveness	= (Project Cost x CRF) / (ROG + NOx + PM10x20)
	= ($13,100,000,000 x 0.0578) / (18.39 + 0.73x20)
	= $31.54 / lb

Note:
Cost Effectiveness assumes a project life of 30 years.

SCAG Analysis:
Renovation and purchase of electric locomotives:
Cost = approx $6,400,000,000 (6.4 billion)

Carl Moyer Cost-Effectiveness	= (Project Cost x CRF) / (ROG + NOx + PM10x20)
	= ($6,400,000,000 x 0.0578) / (18.39 + 0.73x20)
	= $15.36 / lb

Note:
Cost Effectiveness assumes a project life of 30 years.

References:

(1) ARB Emission Inventory (2007 ARB)

(2) Caltrain Electrification Program Environmental Assessment/ Draft Environmental Impact Report (Peninsula Corridor Joint Powers Board, 2004)

(3) Final Program EIR/EIS for the Proposed California High-Speed Train System (California High Speed Rail Authority, 2005)

(4) Freight Rail Emission Reduction Strategy to Help Meet 2014 Air Quality Standards for PM 2.5. (SCAG, 2007)

(5) Letter to SCAG from Kirk Markwald of The California Railroad Industry (CRI, 2008)

(6) Analysis of Good Movement Emission Reduction Strategies (SCAG, 2007)

(7) Comments on LA Times Article re Railway Electrification (M. Iden - Union Pacific, 2008)

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APPENDIX N:

Option 30 -

Calculations for Maglev Electrification From the Port of LA/LB to ICTF/SCIG

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MAGLEV ELECTRIFICATION EMISSION CALCULATIONS:

Off Facility PM Emissions = (Trips/day) x (Trip Length) x (# Facilities) x (grams DPM/mile) x (tons/g) x (365 days/year)
Off Facility PM Emissions = (6300 trips/day) x (4.7 miles) x 2 x (0.3 g/mile) x (1.1×10^{-6} tons/g) x (365 days/year) = 7.1 TPY

On Facility PM Emissions = (Emissions from ICTF) x 2 Facilities
On Facility PM Emissions = 2.5 TPY x 2 = 5.0 TPY

Total PM Emissions = Off Facility Emissions + On Facility Emissions
Total PM Emissions = **12.1 TPY**

COST EFFECTIVENESS CALCULATIONS:

1. Cost Effectiveness of Maglev Electrification (Low)

Installation of Maglev from Ports to ICTF/SCIG
Cost = approx $65,000,000/mile (65 million)
Miles of Track = 4.7 miles

Cost	$65,000,000/mile x 4.7 miles = $305,500,000
Carl Moyer Cost-Effectiveness	= (Project Cost x CRF) / (ROG + NOx + PM10x20)
	= ($305,500,000 x 0.0899) / (484,000 lbs)
	= $56.74 / lb

Note:
Cost Effectiveness assumes a project life of 15 years.

2. Cost Effectiveness of Maglev Electrification (High)

Installation of Maglev from Ports to ICTF/SCIG
Cost = approx $170,000,000/mile (170 million)
Miles of Track = 4.7 miles

Cost	$170,000,000/mile x 4.7 miles = $799,000,000
Carl Moyer Cost-Effectiveness	= (Project Cost x CRF) / (ROG + NOx + PM10x20)
	= ($799,000,000 x 0.0899) / (484,000 lbs)
	= $148.41 / lb

Note:
Cost Effectiveness assumes a project life of 15 years.

References:

(1) Press Release of Shanghai Maglev Gets Official Approval (China Daily, 2006)

(2) Nagoya builds Maglev Metro (International Railway Journal, 2004)

(3) Intermodal Container Transfer Facility (ICTF) Modernization Project (UPRR, 2007)

(4) The Evaluation and Implementation Plan for Southern California Maglev Freight System (CCDTT, 2007)

(5) Proceedings of the Federal Transit Administrations Urban Maglev Workshop (DOT, 2005)

Shanghai maglev gets official approval

By Miao Qing (China Daily)
Updated: 2006-04-27 06:11

After two years of operation, China's first magnetic levitation line has formally passed State examination and appraisal.

Yesterday's announcement augurs well for the proposed construction of a line connecting Shanghai and Hangzhou.

The existing line was started in March 2001 and completed 22 months later. The 30-kilometre track connects Shanghai's Pudong Airport with the city, and is largely based on German magnetic levitation (maglev) technology.

Maglev trains can travel at a speed of up to 430 kilometres per hour, whizzing passengers to their planes in less than eight minutes.

According to the National Development and Reform Commission (NDRC), which carried out the examination, the maglev trains had carried 6.23 million passengers by the end of March this year, both for transportation and sightseeing.

The cost of line was revealed to be 9.93 billion yuan (US$1.2 billion), slightly below budget.

The successful construction and operation of the Shanghai maglev line is regarded by many as a good prelude to the construction of 175-kilometre line connecting Shanghai with Hangzhou, provincial capital of East China's Zhejiang Province.

Technology will remain a big concern in the construction of the new line, officials said. The Shanghai-Hangzhou maglev line will in part use German technology, but the State Council is encouraging engineers "to learn and absorb foreign advanced technologies while making further innovations."

Since accomplishing the first maglev line, China has mastered the core technology required to build maglev rail tracks, one of four major systems supporting the advanced mode of transportation, and gained 20 patents in the field.

"Lowering the cost of a maglev system is a significant issue in the study and construction of the Shanghai-Hangzhou maglev railway we are now confident we can achieve that," said Zhang Xiaoqiang, vice-minister of the NDRC.

"Our aim is to limit the cost of each kilometre of maglev line to approximately 200 million yuan (US$24.6 million)." This means that the unit cost will be cut by one third.

The government also suggests the Shanghai maglev line operator could improve its operating management and efficiency, extend operation hours and attract more passengers.

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APPENDIX O:

Option 31 -
Calculations to Retrofit Existing Rail Infrastructure with LIMs in the SCAB

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Option 31 - RETROFIT OF EXISTING RAIL WITH LIMS EMISSION CALCULATIONS

PM	TPY (ton/year)		TPD (ton/day)	
Source	2010*	Electrification	2010*	Electrification
Main Line	252	0	0.69	0
Passenger	29	29	0.08	0.08
Switching	29	29	0.08	0.08
Total	310	58	0.85	0.16
				81%

NOx	TPY (ton/year)		TPD (ton/day)	
Source	2010*	Electrification	2010*	Electrification
Main Line	5198	0	14.24	0
Passenger	949	949	2.6	2.6
Switching	1040	1040	2.85	2.85
Total	7187	1989	19.69	5.45
				72%

* ARB Emission Inventory Data 2010 for South Coast Air Basin

NOx Emissions in the SCAB:
Emissions = Total Emissions – Emissions from Main line Locos
Emissions = 19.69 TPD – 14.24 TPD = **5.45 TPD**

Diesel PM Emissions in the SCAB:
Emissions = Total Emissions – Emissions from Main line Locos
Emissions = 0.85 TPD – 0.69 TPD = **0.16 TPD**

COST EFFECTIVENESS CALCULATIONS

Retrofit of existing rail with LIMs
Cost / mile = $16,000,000/mile
Miles of track = 460 miles
Cost to retrofit locomotives: $3,000,000,000 ($3 billion)

Track Cost	$16,000,000/mile x 460 miles = $7,360,000,000
Retrofit Cost	$3,000,000,000
Total Cost	$7,360,000,000 + $3,000,000,000 = $10,360,000,000
Carl Moyer Cost-Effectiveness	= (Project Cost x CRF) / (ROG + NOx + PM10x20)
	= ($10,360,000,000 x 0.0578) / (20,469,200 lbs)
	= $29.25 / lb

Note:
Cost Effectiveness assumes a project life of 30 years.

References:

(1) Alternative Container Transportation Technology Evaluation and Comparison (Ports of Long Beach and Los Angeles, 2008)

(2) ARB Emission Inventory (Air Resources Board, 2008)

(3) Maglev and Linear Motors for Goods Movement (SCAQMD, 2007)

APPENDIX P:

Cost-Effectiveness Calculation Methodology

Note: The following was excerpted from the 2008 Carl Moyer Program Guidelines, Appendix C, Cost-Effectiveness Calculation Methodology. For further detail see http://www.arb.ca.gov/msprog/moyer/guidelines/current.htm.

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I. Introduction

To receive Carl Moyer Program funding, each project must meet the maximum cost-effectiveness limit of $16,000 per weighted ton of surplus NOx, ROG, and PM10 (PM10 means combustion PM) emissions reduced. Only Carl Moyer Program funding, funding under the district's fiduciary budget authority, or funding provided by a port authority (to meet the match fund requirement) are included in determining the cost-effectiveness of surplus emission reductions. For more details see Part IV, Administration of the Carl Moyer Program.

II. General Cost-Effectiveness Calculations

The cost-effectiveness of a project is determined by dividing the annual cost of the potential project by the annual weighted surplus emission reductions that will be achieved by the project as shown in formula C-1 below.

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton):

$$\frac{\text{Annualized Cost (\$/yr)}}{\text{Annual Weighted Surplus Emission Reductions (tons/yr)}}$$

Descriptions on how to calculate annual emission reductions and annualized cost are provided in the following sections.

A. Calculating the Annual Weighted Surplus Emission Reductions

Annual weighted emission reductions are estimated by taking the sum of the project's annual surplus pollutant reductions following formula C-2 below. This will allow projects that reduce one, two, or all three of the covered pollutants to be evaluated for eligibility to receive Carl Moyer Program funding. While NOx and ROG emissions are given equal weight; emissions of combustion PM10 (such as diesel exhaust PM10 emissions) have been identified as a toxic air contaminant and thus carry a greater weight in the calculation.

Formula C-2: Annual Weighted Surplus Emission Reductions:

NOx reductions (tons/yr) + ROG reductions (tons/yr) + [20 * (PM10 reductions (tons/yr)]

The result of formula C-2 is used to complete formula C-1 to determine the cost effectiveness of surplus emission reductions.

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