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.

Diesel PM Emissions at 18 Major Railyards

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.

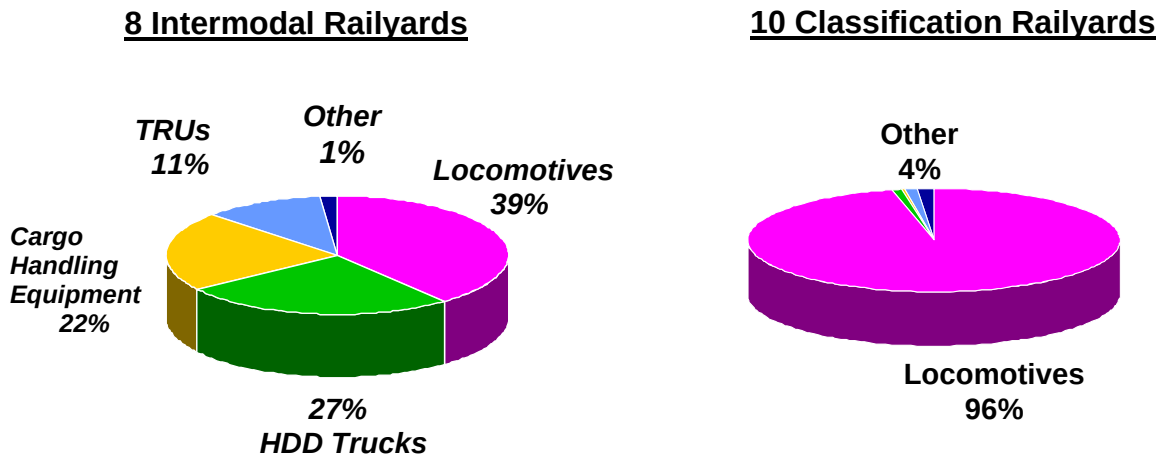
Diesel PM Emissions at Ten Classification Railyards

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

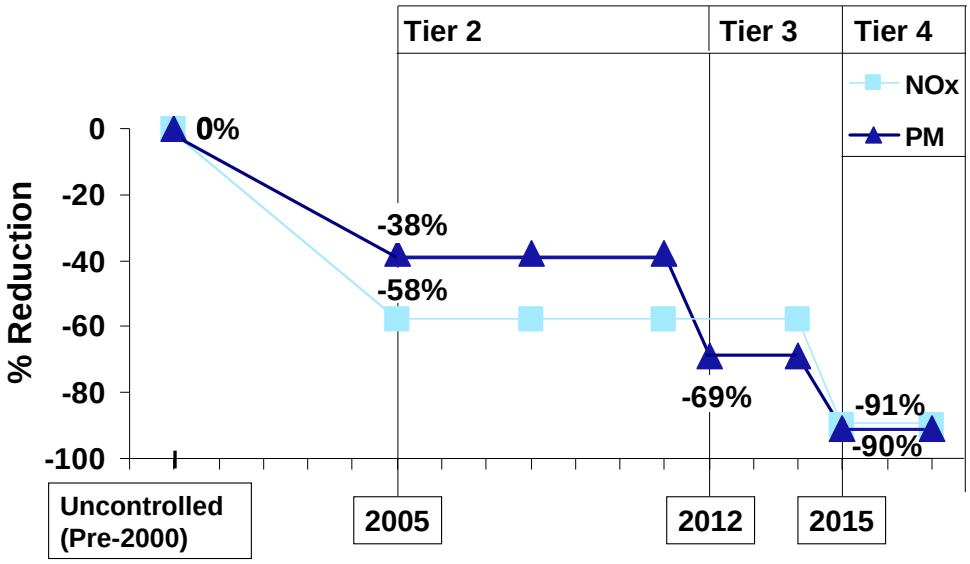
The recent 2008 U.S. EPA locomotive rulemaking will provide NOx and PM emission reductions beyond the existing 1998 U.S. EPA locomotive rulemaking and ARB locomotive regulation and railroad agreements. In the 2008 locomotive rulemaking, U.S. EPA placed particular attention on PM control for existing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



Prepared by California Environmental Associates

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)

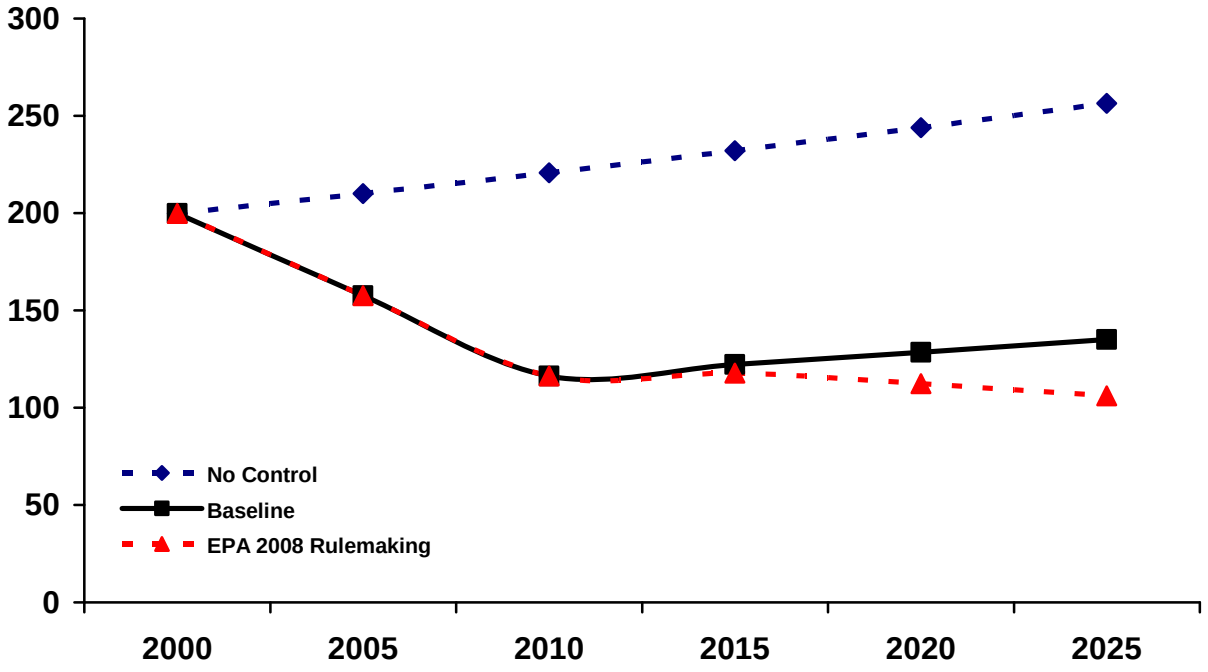
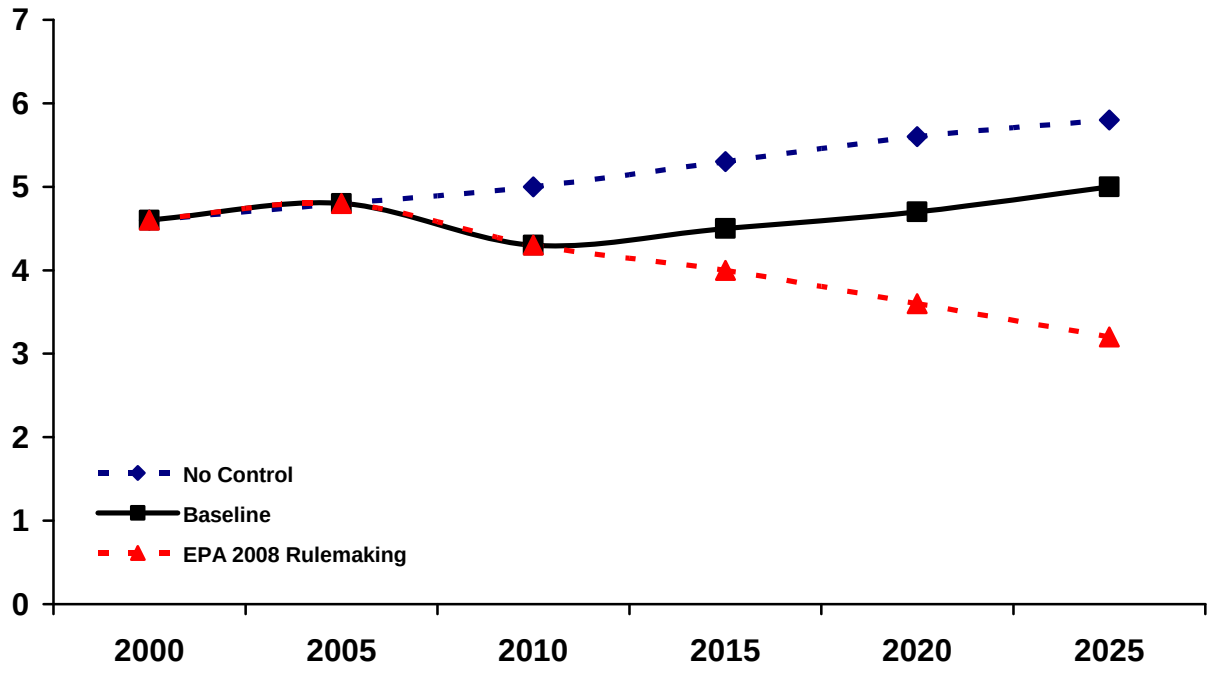


Figure I - 4
Estimated Statewide Locomotive PM Emissions and Emissions Reductions
(Tons/Day – Assumes 1 percent Annual Growth Rate)



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

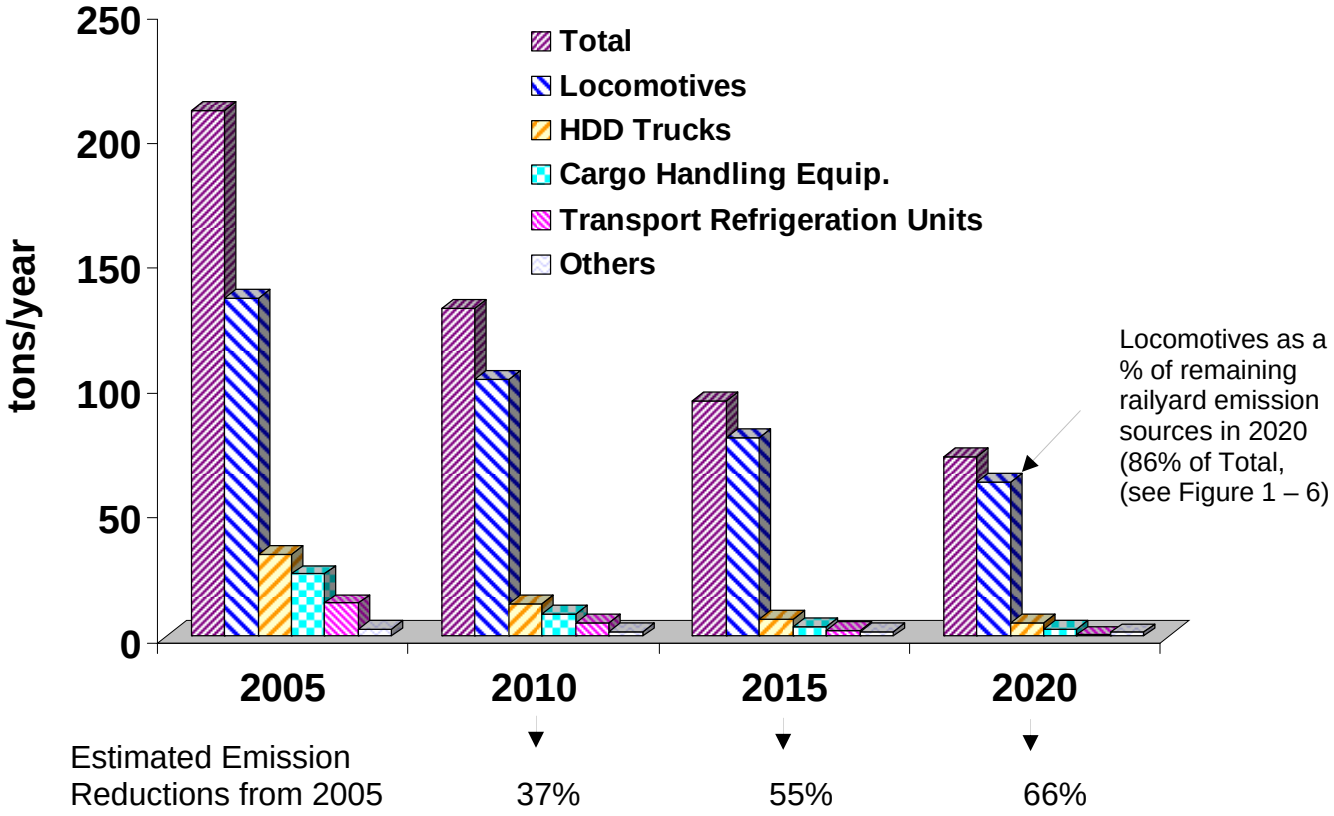
Under the 2005 Statewide Railroad Agreement, UP and BNSF are responsible for developing mitigation plans to reduce railyard diesel PM emissions. The mitigation plans identify required and voluntary measures to reduce diesel PM emissions and public health impacts to surrounding communities.

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

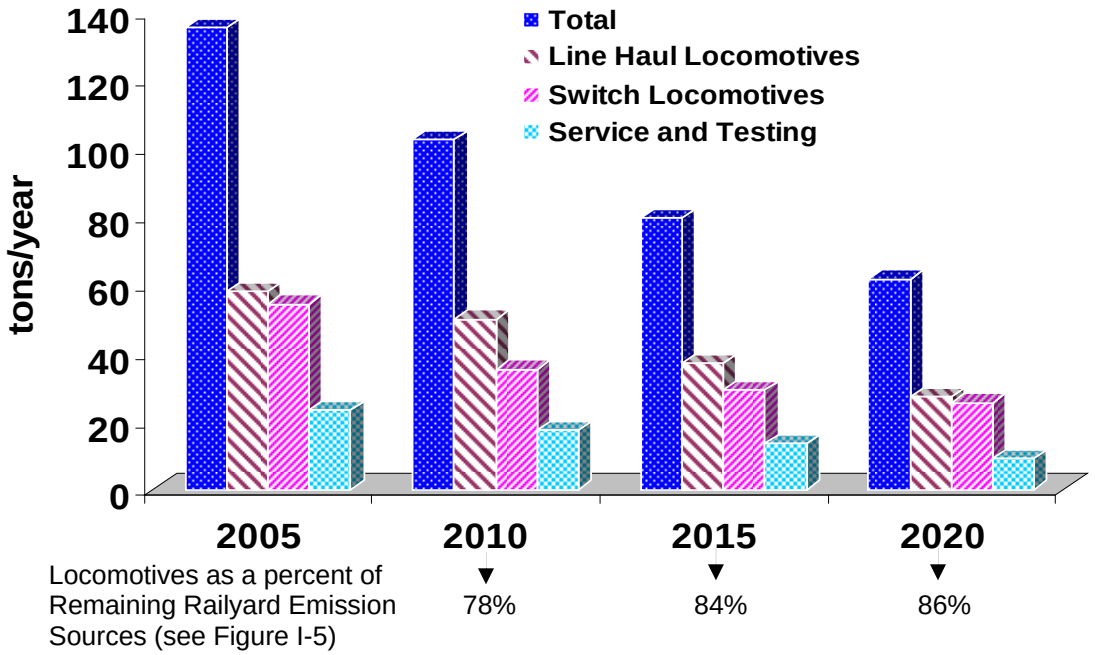
Staff estimates that existing regulatory and voluntary railroad measures will reduce railyard diesel PM emissions from 210 tons per year in 2005 to 94 tons per year in 2015. In 2015, locomotives would continue to represent the largest source of remaining railyard diesel PM emissions at about 80 tons 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.