

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 (SO₂), a triple cloud chamber scrubber for PM removal, and a Selective Catalytic Reduction (SCR) reactor to reduce oxides of nitrogen (NO_x). 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 1 and 2 in Appendix K).

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

Technical Feasibility

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 NO_x and PM and other pollutants. The 90% estimated emission reductions for NO_x 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 NO_x, HC, and PM in the cost-effectiveness calculation. Oxides of sulfur (SO_x) 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 NO_x tons per year, respectively). Based on these assumptions, staff estimates the ALECS cost-effectiveness is about \$23 per pound of PM and NO_x 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 CO₂ 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 (CO₂), 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 (NO_x), 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 NO_x 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 NO_x) 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 NO_x 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 retrofitted 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 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

Option 24 – Hydrogen Fuel Cells for Locomotives

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.

Option 25 – Hybrid Power Innovations for Locomotives

Efforts to enhance 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"

Option 26 – Alternative Fuel (Ethanol) for Locomotives

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 NO_x and PM reduced, as compared to a pre-Tier 0 switch locomotive (17.4 g/bhp-hr and 0.44 g/bhp-hr with about 20 tons per year of both NO_x 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 NO_x and PM emissions standards of 1.3 g/bhp-hr and 0.03 g/bhp-hr with about 1.5 tons per year of both NO_x and PM emissions. As a result, the cost-effectiveness would range between \$58 and \$117 per pound of NO_x 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 lading 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 be 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.

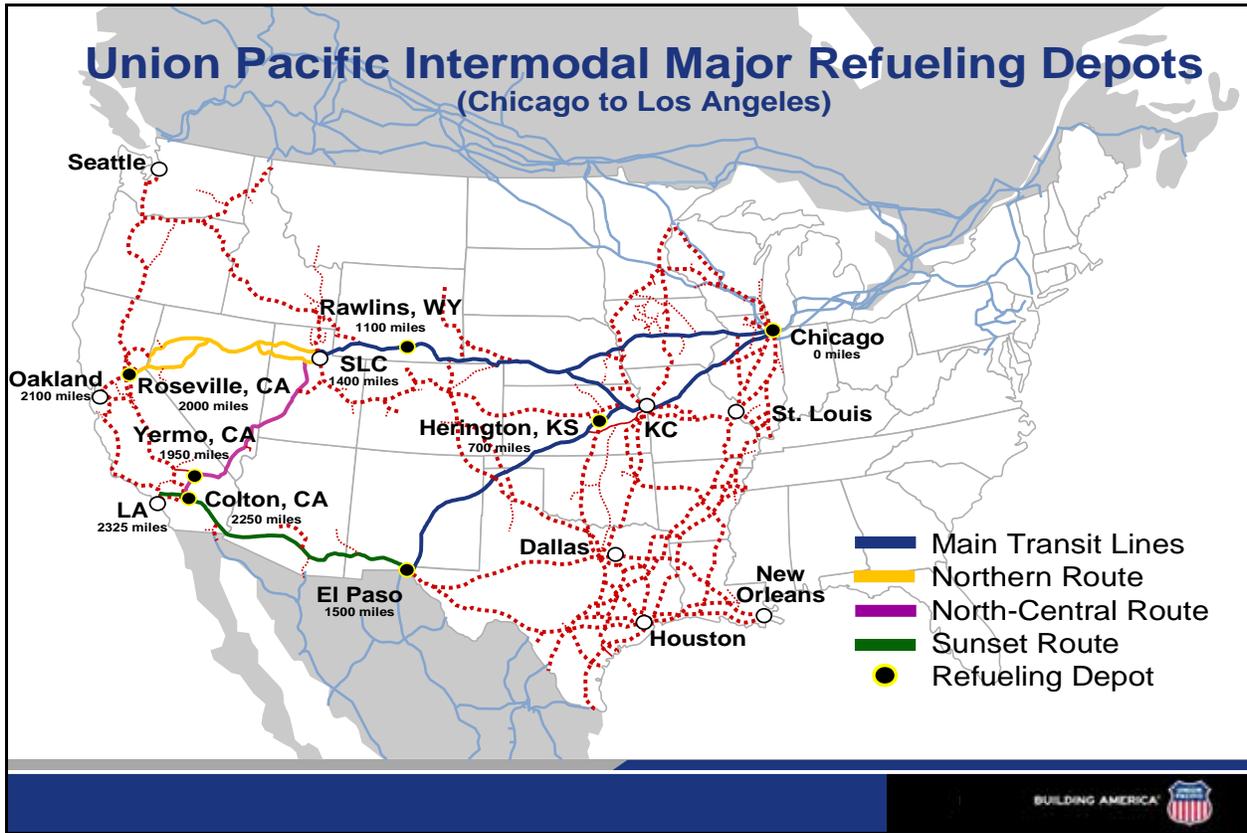
When trains travel on the main open lines, a consist (one or more locomotives – usually three or more) pulls a mile long or so train typically in the highest power settings or in Notches 5-8. Locomotives pulling a long train of railcars, but depending on mountain grades and other variables, will usually 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.

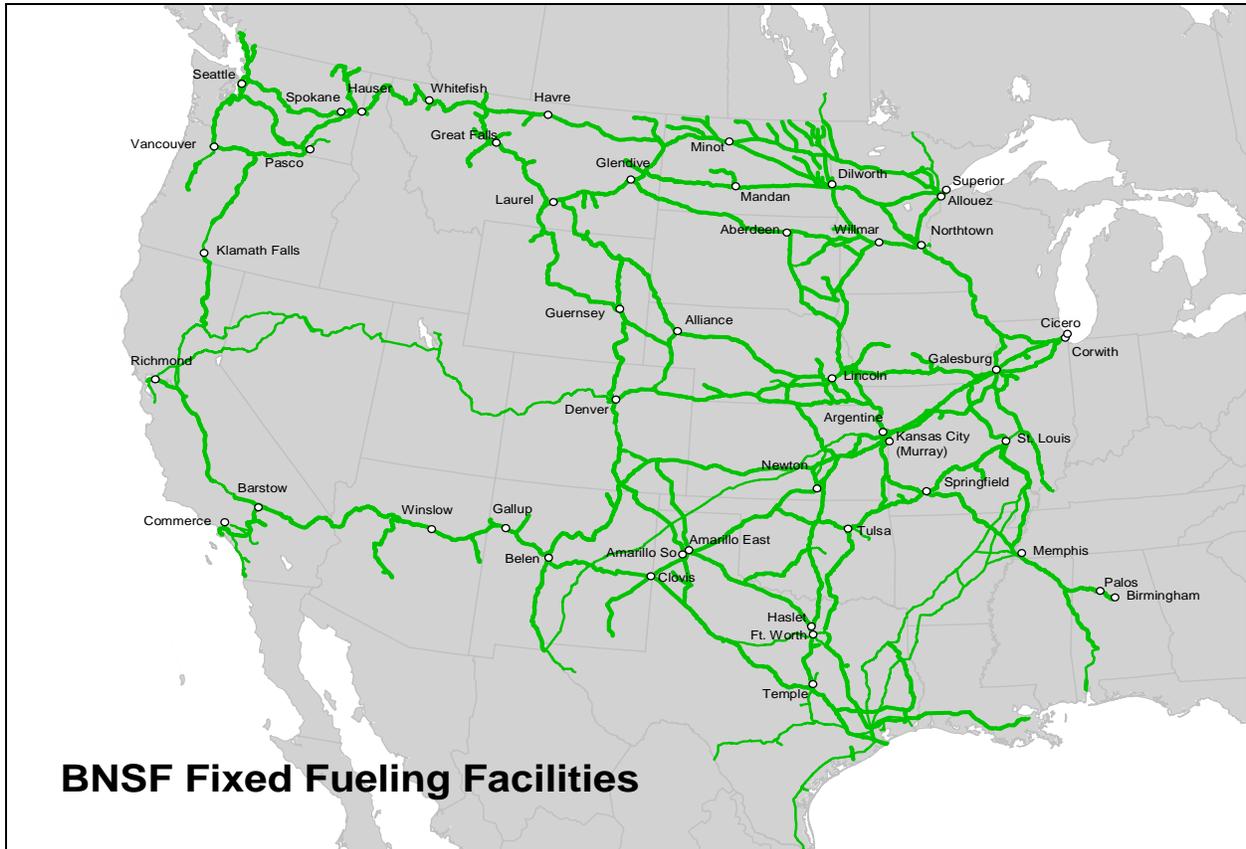
Union Pacific Railroad (UP) – Chicago to California Refueling Patterns

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	Implement- ation 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.

Costs

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 compatibility 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 similar 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 infrastructure 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 inventory¹⁰ forecast, 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.

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 460¹¹ 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 Major 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.