5.3.2 Truck Emissions Regulations

A wide range of regulatory strategies to control emissions from heavy-duty vehicles operating in California have been proposed for the period between 1987 and 2010. Strategies focus on both further controlling the emissions of newly sold vehicles and on controlling emissions of in-use vehicles. The following exemplifies the range of control strategies that have either been implemented since 1987 or are under consideration by the ARB for future implementation.

- *1988 New Heavy-Duty Truck PM Standard of 0.6 Grams per Horsepower-Hour* — which requires all newly sold trucks beginning with the 1988 model year to meet this PM standard. The ARB has estimated the cost of this program to be an additional $115 per vehicle. Because fuel savings would be achieved, there would be a lifetime savings on the cost of the engine.

- *1990 Heavy-Duty Gasoline Biennial Inspection Program* — which requires that all 1990 and beyond model year heavy-duty gasoline trucks be inspected on a biennial basis for emissions. The inspection includes visual, functional control, and tailpipe tests. Tailpipe emissions criteria are for hydrocarbons and carbon monoxide and vary by the age of the vehicle. The California Bureau of Automotive Repair estimates the costs of the inspection to average $33.45 per vehicle inspected.

- *1991 Roadside Smoke and Emissions Control System Inspection Program for All In-Use Heavy-Duty Diesel and Gasoline Powered Vehicles Operating in California* — In 1988, the California Legislature passed Senate Bill 1997 to establish a program to reduce the number of heavy-duty diesel vehicles that emit excessive smoke and that exhibit forms of emissions control tampering and mal-maintenance. The ARB adopted the program in 1990. Prior to adoption of this program, a pilot program was implemented to provide information on the cost of repairs for vehicles that failed the smoke test cutpoint. The pilot program showed the average repair cost to be $693. In addition, vehicles cited are required to pay a penalty ranging from $300 to $1,800, depending on prior citations.

- *1991 New Heavy-Duty Truck Engine PM Standard of 0.25 Grams/Bhp-hr* — This control strategy requires that all newly sold heavy-duty trucks be certified to the revised PM standard, beginning with the 1991 model year. The ARB estimates an additional $458 per vehicle as compared with 1988 costs.

- *1993 Fuel Specifications for Sulfur and Aromatic Content for Diesel Fuel* — This strategy proposed changes to the content of diesel fuel sold in California. The ARB estimated an associated increase of $0.06 per gallon prior to the introduction of the new fuel. However, wholesale prices increased by 11 to 15 cents per gallon after implementation of the strategy. Another cost associated with the introduction of "clean diesel" may be increases in needed engine repairs and maintenance. The California Trucking Association has stated publicly that the costs of the "clean diesel" program have been dramatically underestimated by the ARB. The "clean diesel" program is currently under review by the ARB.

- *1994 New Heavy-Duty Truck PM Standard Revised to 0.10 Grams/Bhp-hr* — The ARB estimates the additional cost of the revised standard to be $163 per new vehicle sold in addition to the incremental cost of the 1991 standard.

- *1995 Regulation Requiring Periodic Smoke Self-Inspection Program for Heavy-Duty Diesel Powered Vehicle Fleets of Two or More Vehicles* — This program complements the roadside inspection program discussed above by requiring that owners of vehicles of 6,001 pounds GVW or more test their vehicles annually for excessive smoke emissions. The estimated annual cost estimated by the ARB for the self-test program is $243 per vehicle inspected for small fleets (5 vehicles or less) and $93 per vehicle inspected for larger fleets (6 or more vehicles).

The strategies listed above exemplify the wide range of regulations that heavy-duty vehicles must currently, or will have to, comply with if they are to operate in California. These strategies will undoubtedly result in increases in the cost of operating and maintaining heavy-duty vehicles in the state. However, the evaluation of each of these strategies on mode shift and NO_x emissions is beyond the scope of this study. First, the strategies listed above do not specifically focus on reducing NO_x. Second, if the strategies impact truck freight rates, the impact will occur over time, and diversion would need to be calculated independently for each year. Third, program cost data were not available for this study. Fourth, truck and/or rail ton-mileage data were not available for those years when the strategies would come into effect. Finally, the strategies impact both new trucks and in-use trucks, thereby requiring the use of a vehicle stock model to fully assess the impact of each strategy.

Since the focus of this study is on the impact of NO_x emissions regulations on mode shift and truck and rail emissions in 2010, future regulations that may be implemented to control truck NO_x emissions should be considered in this analysis. Section 43013 (b) of the California Health and Safety Code requires that the ARB adopt standards and regulations for heavy-duty vehicles on or before December 31, 1993. While the ARB was not able to meet that deadline, it has conducted preliminary studies to determine the types of control technologies that will be able to reduce NO_x emissions to needed levels for ozone attainment by 2010. This study draws on those studies to identify the control strategies for heavy-heavy-duty diesel trucks that may prevail by 2010.

In a study conducted for the ARB, Acurex Environmental Corporation concluded that it is currently possible to achieve low NO_x and PM emissions with alternatively-fueled heavy-duty engines, and that diesel engines will be able to achieve low NO_x and PM emissions in the future as well. Existing methanol and natural gas engines can now meet emissions rates of less than 2.0 grams/Bhp-hr of NO_x and 0.05 grams/Bhp-hr of PM. Acurex identified the following approaches for reducing emissions of heavy-heavy-duty diesel trucks to levels as low as 2.0 to 2.5 grams/Bhp-hr of NO_x.[27]

[27] Op. cit.

Fuel	Vehicle/Technology	Cost (1992 $) (Cents/Mile)	
		Low	High
1993 Diesel	Baseline DI diesel	40	42
Diesel	DI Diesel w/EGR & Catalytic Trap	44	47
Diesel	DI Diesel w/NO_x Catalyst	43	46
M100	DI Compression-Ignition 2-Stroke	44	48
M100	DI Glow-Plug-Ignition 4-Stroke	44	47
CNG	Lean-Burn Spark-Ignition	42	46
LNG	Lean-Burn Spark-Ignition	44	50
LPG	Lean-Burn Spark-Ignition	45	47

For the purpose of developing scenarios to estimate the mode shift and corresponding emissions impacts of rail and truck regulations, this study investigates only two of these strategies: CNG/Lean-Burn SI using the estimated cost of 42 cents/mile, or an incremental cost of 2 cents/mile from the baseline DI diesel scenario developed by Acurex; and LNG/Lean-Burn SI using the estimated cost of 44 cents/mile, or an incremental cost of 4 cents/mile from the baseline. For each truck scenario, this analysis assumes the following:

- in 2010, all heavy-heavy-duty diesel trucks will be either powered by CNG/Lean-Burn SI or LNG/Lean-Burn SI; and
- the impact on truck freight rates only will reflect the additional cost per mile above the baseline DI diesel baseline scenario developed by Acurex.

The low end of the corresponding incremental cost for these two mitigation strategies was selected to minimize increases in truck freight rates and thus maximize the shift from rail to trucking resulting from locomotive emissions regulations. This ensures that conservative estimates of mode shifts are developed in this study.[28]

Exhibit 5-8 demonstrates the effect of each strategy on the cost/ton-mile of heavy-heavy-duty diesel truck movements. The incremental costs per mile of each strategy are translated to a ton-mile basis using data on the population of heavy-heavy-duty diesel vehicles and average yearly vehicle miles travelled (VMT). These data are used to derive the total cost for each strategy, which when divided by total ton-mileage results in estimates of strategy cost per ton-mile. As

[28]Also, note that the incremental costs developed by Acurex are expressed in 1992 dollars. However, because of rounding, conversion to 1987 dollars or 1993 dollars (see Exhibit 5-8) does not change the incremental costs associated with each strategy of 2 and 4 cents.

Exhibit 5-8

Cost of Heavy-Heavy-Duty Diesel Truck Regulations

	CNG/Lean-Burn SI	LNG/Lean-Burn SI
Heavy-Heavy Diesel Truck Pop.(1) Average VMT (1993) (2) Total VMT in millions (1993)	102,400 40,000 4,096	102,400 40,000 4,096
Strategy Cost ($/Mile) (2)	0.02	0.04
Strategy Cost (1993$)	81,920,000	163,840,000
Strategy Cost (1987$)	80,117,760	160,235,520
1987 Ton-Miles in millions	32,717	32,717
Cost/Ton-Mile in Cents (1987$)	0.24	0.49
Cost/Ton-Mile in Cents (1977$)	0.21	0.41

Source: (1) California Energy Commission (CEC) DMV-Derived Registration Data (1993)
(2) Acurex Environmental Corporation, "Technical Feasibility of Reducing NO_x and Particulate Emissions from Heavy-Duty Engines", 1993.

shown in Exhibit 5-8, CNG/Lean-Burn SI is expected to increase trucking cost by 0.24 cents/ton-mile, while LNG/Lean-Burn SI is expected to increase this cost by 0.49 cents/ton-mile (1987 dollars).

5.3.3 Regulatory Scenarios for Diversion and Emissions Analysis

Exhibit 5-9 describes the regulatory strategy scenarios for which diversion and emissions impacts will be estimated in this study. Since the focus of this study is on the impacts of locomotive emissions, the first four scenarios isolate the effects of Dual-Fuel, LNG-SI, DF+SCR, and SCR independently. The last two scenarios have been designed to capture the range of possible mode shift given combined locomotive and truck control strategies. Scenario 5 assumes that locomotives operating in California will be powered by dual-fuel engines, while heavy-heavy-duty diesel trucks will be powered by LNG/lean-burn spark-ignition engines. Dual-Fuel is the least expensive strategy for locomotives investigated in this study. LNG/Lean-Burn SI is the most expensive strategy for trucks investigated in this study. Consequently, this scenario has been designed to represent the high-end of diversion from truck to rail. Likewise, Scenario 6 has been designed to represent the high-end of diversion from rail to truck, since it includes the most expensive locomotive regulation (SCR) and the least expensive truck regulation (CNG/Lean-Burn SI). The six scenarios are summarized below.

- *Scenario 1* — assumes that locomotives operating in California in 2010 will be powered by engines that use either natural gas or diesel (i.e., dual-fuel), while heavy-heavy-duty diesel trucks will experience no further control beyond that of the current NO_x standard of 5 grams/Bhp-hr.[29]

- *Scenario 2* — assumes that locomotives operating in California in 2010 will be powered by LNG-SI engines, while heavy-heavy-duty diesel trucks will experience no further control beyond that of the current NO_x standard of 5 grams/Bhp-hr.

- *Scenario 3* — assumes that locomotives operating in California in 2010 will be powered by Dual-Fuel engines with SCR devices, while heavy-heavy-duty diesel trucks will experience no further control beyond that of the current NO_x standard of 5 grams/Bhp-hr.

- *Scenario 4* — assumes that locomotives operating in California in 2010 will be powered by engines with SCR devices, while heavy-heavy-duty diesel trucks will experience no further control beyond that of the current NO_x standard of 5 grams/Bhp-hr.

[29]As discussed in Section 3.2.4 of this report, this analysis assumes that trucks will emit (on average) 0.006 pounds of NO_x per ton-mile in 2010 under the no-further-control-scenario, a 36 percent decrease from the contribution that prevailed in 1987 (see Exhibit 3-5). The 0.006 lbs/ton-mile estimate reflects the current NO_x standard of 5 g/Bhp-hr, while the 1987 estimate of 0.009 lbs/ton-mile reflects a fleet average of 7.83 g/Bhp-hr developed using EMFAC7.

Exhibit 5-9

Regulatory Scenarios for Diversion and NO_x Emissions Analysis

	New Rail Freight Rate (in Cents/ Ton-Mile, 1987$)	New Truck Freight Rate (in Cents/ Ton-Mile, 1987$)	Change in the Cost Advantage of Rail (in Cents/ Ton-Mile, 1987$)	Change in the Cost Advantage of Rail (in Cents/ Ton-Mile, 1977$)
Scenario 1 - Dual-Fuel for Rail no Further Control for Trucks	2.82	22.48	-0.09	-0.08
Scenario 2 - LNG-SI for Rail no Further Control for Trucks	2.90	22.48	-0.17	-0.15
Scenario 3 - DF+SCR for Rail no Further Control For Trucks	3.00	22.48	-0.27	-0.23
Scenario 4 - SCR for Rail no Further Control for Trucks	3.13	22.48	-0.38	-0.31
Scenario 5 - Dual-Fuel for Rail LNG/Lean-Burn SI for Trucks	2.82	22.97	0.41	0.34
Scenario 6 - SCR for Rail CNG/Lean-Burn SI for Trucks	3.13	22.72	-0.13	-0.11

- *Scenario 5* — assumes that locomotives operating in California in 2010 will be powered by engines that use either natural gas or diesel (i.e., dual-fuel), while heavy-heavy-duty diesel trucks will be powered by LNG/lean-burn SI engines, reducing NO_x from 5 grams/Bhp-hr to 2.0 grams/Bhp-hr in 2010.

- *Scenario 6* — assumes that locomotives operating in California in 2010 will be powered by engines with SCR devices, while heavy-heavy-duty diesel trucks will be powered by CNG/lean-burn SI engines, reducing NO_x from 5 grams/Bhp-hr to 2.0 grams/Bhp-hr in 2010.

As reported in Exhibit 5-9, the change in the cost advantage of rail ranges from -0.08 to -0.31 cents (1977 dollars) for those scenarios that isolate the impacts of locomotive regulations (i.e., Scenario 1 to 4). The change in the cost advantage of rail for Scenario 5 is 0.34, signaling a shift from truck to rail. While that for Scenario 6 is -0.11, signaling a shift from rail to truck. These changes in the cost advantage of rail are employed to calculate mode shifts using the CALFED sensitivity parameters discussed in Section 5.1.

5.4 Modal Diversion and Emissions Impacts by Scenario

This section describes the diversion and NO_x emissions impacts of each of the six regulatory scenarios discussed above. Diversion impacts are derived by employing the change in the cost advantage of rail (1977 dollars) shown in Exhibit 5-9 and the CALFED modal sensitivity parameters presented in Exhibit 5-1. Specifically, the change in rail ton-miles resulting from a change in the rail cost advantage is estimated via the following equation:

$$NRS_{i,j} = ORS_j + (\Delta RCA_i * MSP_j)$$

where $NRS_{i,j}$ is the new rail share in 2010 for scenario *i* and commodity group *j*;
ORS_j is the old rail share in 2010 for commodity *j*;
ΔRCA_i is the change in the rail cost advantage for scenario *i*; and
MSP_j is the modal sensitivity parameter for commodity *j*.

In this manner, new rail ton-mile flows are estimated by applying the new rail shares to the total flows estimated for 2010 (see Section 2). The new truck ton-mile flows are simply the difference between the total flows and the new rail flows.

The resulting NO_x emissions impacts for rail are calculated using the emissions spreadsheet model developed for this study and described in Section 3. Specifically, for each scenario, the population of locomotives expected to be operating in California in 2010 is adjusted to reflect the percentage change in rail ton-miles resulting from diversion, as estimated via the CALFED sensitivity parameters. This assumes that the change in the share of rail ton-miles will affect proportionally the population of locomotives needed to transport the new rail ton-miles after diversion. This proportionality approach is discussed in detail in Appendix A.

As discussed in Section 3, in 1987 emissions from heavy-heavy-duty diesel trucks on a pounds per ton-mile basis are estimated to be 0.009. This "emissions factor" is expected to decrease to 0.006 lbs/ton-mile by 2010 under the no-control scenario. However, the implementation of regulations that require CNG/Lean-Burn SI or LNG/Lean-Burn SI technology by 2010 will directly impact the emissions rate of trucks. As discussed in Section 5.3, the deployment of these technologies is expected to reduce NO_x emissions from 5 grams/Bhp-hr to 2 grams/Bhp-hr by the forecast year of 2010. Assuming that the resulting percentage decrease holds on a ton-mile basis, the effect of Scenarios 5 and 6 on heavy-heavy-duty diesel truck emissions can be expected to be a decrease in the "emissions factor" from 0.006 pounds/ton-mile to 0.002 pounds/ton-mile.

The following sub-sections present the results of the diversion and subsequent emissions impact analysis by regulatory scenario.

5.4.1 Diversion Impacts by Regulatory Scenario

Exhibit 5-10 presents the results of the diversion analysis for each of the six regulatory scenarios. Scenario 1, *Dual-Fuel for Rail and No Further Control for Trucks*, is expected to reduce rail ton-miles by 406 million in 2010, or by 1.1 percent. Consequently, in 2010 heavy-heavy-duty diesel truck ton-miles are expected to increase to 52,554 million from 52,148 million. The estimated diversion impact of Scenario 2, *LNG-SI for Rail and No Further Control for Trucks*, is a decrease in rail ton-miles and a corresponding increase in truck ton-miles of 762 million, representing a drop in rail ton-miles of 2.1 percent. Likewise, Scenario 3, *DF+SCR for Rail and No Further Control for Trucks*, is expected to reduce rail ton-miles by 1,168 million, or by 3.2 percent, while Scenario 4, *SCR for Rail and No Further Control for Trucks*, is expected to reduce rail ton-miles by 1,625 million in 2010, or by 4.4 percent. The diversion impact of Scenario 5, *SCR for Rail and CNG/Lean-Burn SI for Trucks*, is estimated to be an increase in rail ton-miles of 1,727 million, since the rail cost advantage increases for this scenario. In contrast, Scenario 6, *Dual-Fuel for Rail and LNG/Lean-Burn SI for Trucks*, is expected to decrease rail ton-miles by 610 million.

This analysis shows the importance of developing emissions control strategies that account for the full economic impacts of regulation. Diversion can result in increases in the activity of higher polluting sources that may negate some of the expected emissions benefits of the regulatory initiative. A system-wide approach is necessary to fully account for the indirect economic and emissions impacts. Depending on the mix of regulations promulgated for each source, or mode, the diversion impact may either increase or decrease the activity of a given source. For example, Scenario 5 resulted in increased rail activity relative to truck, while Scenario 6 resulted in decreased rail activity relative to truck. As a result, regulations that impact competition between modes must be analyzed in conjunction to one another to ensure that

Exhibit 5-10

Modal Diversion by Regulatory Scenario (2010)

Scenario	Δ in Rail Ton-Miles (Millions)	% Δ in Rail Ton-Miles	New Rail Ton-Miles (Millions)	New Truck Ton-Miles (Millions)
No Control 2010 Baseline	--	--	36,541	52,148
Scenario 1 - Dual-Fuel for Rail no Further Control for Trucks	-406	-1.1%	36,135	52,554
Scenario 2 - LNG-SI for Rail no Further Control for Trucks	-762	-2.1%	35,780	52,910
Scenario 3 - DF+SCR for Rail no Further Control For Trucks	-1,168	-3.2%	35,373	53,316
Scenario 4 - SCR for Rail no Further Control for Trucks	-1,625	-4.4%	34,916	53,774
Scenario 5 - Dual-Fuel for Rail LNG/Lean-Burn SI for Trucks	+1,727	+4.7%	38,269	50,421
Scenario 6 - SCR for Rail CNG/Lean-Burn SI for Trucks	-610	-1.7%	35,932	52,758

Note: Numbers may not add up exactly because of rounding.

the net emissions consequences are accounted for in the promulgation process. With this in mind, the following sub-section presents the emissions consequences of each scenario.

5.4.2 NO_x Emissions Impacts by Regulatory Scenario

Exhibit 5-11 presents the corresponding NO_x emissions impacts of each scenario that result from changes in the NO_x emissions factors of locomotives and trucks and of modal diversion. For each scenario, combined truck and rail 2010 NO_x emissions are significantly lower when compared to the 2010 no-control scenario. Scenarios 5 and 6 provide the largest combined truck and rail NO_x emissions reductions. This is because under Scenarios 1 to 4 no further emissions controls from those prevalent in 1987 are assumed for heavy-heavy-duty diesel vehicles. Consequently, increases in truck activity, resulting mostly from economic and demographic growth, offset benefits accrued from locomotive emissions control strategies.

The results presented in Exhibits 5-10 and 5-11 highlight the relative importance of diversion versus changes in emissions factors resulting from the regulatory strategies examined in this study. In Scenarios 1 to 4, emissions reductions are mostly driven by changes in the emissions rate of locomotives—since significant emissions reductions are achieved from the 2010 no-control baseline even though only small reductions in rail activity occur as a result of decreases in the rail cost advantage (see Exhibit 5-10). For example, 2010 locomotive NO_x emissions under the no control scenario are 158 tons/day. Rail NO_x emissions under Scenario 3 are estimated to be 21 tons/day in 2010, a decrease of 87 percent from the 2010 no control level. However, rail ton-miles under Scenario 3 only decrease by 3.2 percent. Consequently, most of the emissions reductions are associated with the effectiveness of control strategies rather than with modal diversion.

The emissions consequences of the regulatory scenarios investigated in this study are encouraging. Diversion by itself is not expected to have a major impact on emissions by mode. Rather, emissions reductions are mostly driven by changes in the emissions rates of locomotives and heavy-heavy-duty diesel trucks that result from technology deployment. Nevertheless, it is useful to conduct a sensitivity analysis to determine the possible ranges of diversion impacts. This is the subject of the next section.

5.5 Sensitivity Analysis — Changes in the Modal Sensitivity Parameters

In the section of this report that discusses the selection of the CALFED model to perform modal diversion calculations, several shortcomings of the model were noted. One of the most significant shortcomings is that the model parameters were estimated using 1977 data. As already mentioned, freight transportation markets have undergone significant changes since 1977. What is most important in this analysis is isolating those changes which would cause the modal cost sensitivity parameters in CALFED to change; since in this analysis, cost of service is the

Exhibit 5-11

Resulting NO_x Emissions Impacts by Regulatory Scenario (2010, in Tons/Day)

Scenario	Truck NO_x	Rail NO_x	Total NO_x	Difference From 2010 No-Control
No Control 2010 Baseline	410	158	568	--
Scenario 1 - Dual-Fuel for Rail no Further Control for Trucks	413	39	452	-116
Scenario 2 - LNG-SI for Rail no Further Control for Trucks	416	23	439	-129
Scenario 3 - DF+SCR for Rail no Further Control For Trucks	419	21	440	-128
Scenario 4 - SCR for Rail no Further Control for Trucks	423	41	464	-104
Scenario 5 - Dual-Fuel for Rail LNG/Lean-Burn SI for Trucks	159	41	200	-368
Scenario 6 - SCR for Rail CNG/Lean-Burn SI for Trucks	166	42	208	-360

Note: Results may not add up exactly because of rounding.

only variable which is directly influenced by the proposed emissions regulations. Since 1977, trucking has gained market share at the expense of rail, rail and trucking costs have changed relative to each other, and the types of service offered by rail and trucking have changed. But these changes do not clearly indicate that specific commodity groups have become more or less responsive to changes in cost when making mode choice decisions.

One of the biggest changes that has occurred since 1977, and which would have an impact on shippers' responsiveness to relative cost changes, was the deregulation of shipping rates for both trucking and rail. When rates were regulated, competition often occurred on the basis of differences in levels of service and these differences were not reflected in costs of service. Today's rates incorporate much more information about the services offered than did those of the past, making shippers' choices more likely to be responsive to cost changes. Changes in truck size and weight limits allowed trucking to compete in long-haul markets in which they were previously less competitive. This made shippers in these markets more responsive to price as a determinant of mode choice. The product mix in each of the major commodity groups has also shifted since 1977. Different products within a broad commodity group could have significantly different sensitivities to modal costs and the changing mix within a group could significantly affect the aggregate modal cost sensitivity parameter. Lastly, emphasis on "just-in-time" inventory requirements has made some industries less responsive to cost changes and more responsive to service levels.

There is a general consensus that the net effect of all of these changes is to that broad segments of the market have become more sensitive to cost changes than they were before deregulation. In this sensitivity analysis, an assessment is conducted of how much of an impact these changes might have on conclusions drawn from this report. The approach used is to selectively vary the modal cost sensitivity parameters in CALFED to see how this affects the results of the analysis.

There is no clear cut way to determine how much to vary the parameters. Since the data necessary to re-compute the parameters are not available, some reasonable judgements need to be made in selecting alternative parameter values for sensitivity analysis. One point of reference is the comparative analysis of CALFED results and results from the AAR's Intermodal Competition Model described in Section 4 of this report. In that comparison it was shown that CALFED predicts that a one percent reduction in <u>truck</u> costs would result in 0.39 percent reduction in <u>rail</u> ton miles. If the same analysis were conducted using the ICM, the result would be 33 percent greater diversion from rail to trucking (i.e., a 0.52 percent reduction in rail ton-miles for a one percent reduction in trucking costs). Using this as a basis for determining the magnitude of the underestimation of modal diversion which results from using CALFED, the modal cost sensitivity parameters in CALFED are increased by 100 percent for the sensitivity analysis. In other words, the sensitivity analysis assumes that twice as much traffic will shift away from rail per unit increase in rail costs today as was the case when the CALFED parameters were originally estimated. Given the comparison with ICM alluded to above, this appears to be a worst case magnitude for how much more diversion there might be as a result of locomotive regulations as compared to the estimates from CALFED, and allows for the development of an estimate of a range within which the results are most likely to fall.

Some commodity groups are unlikely to have experienced a change in responsiveness to modal cost changes and this should be accounted for in the sensitivity analysis. These are commodity groups that have not experienced major changes in the mix of products shipped and whose rail and truck shares are determined largely by commodity characteristics which cause one mode or the other to dominate the market. One such commodity group is fruits and vegetables. These perishable commodities are very service sensitive, and while the precise mix of specific fruits and vegetables may change over time, their relative shipping characteristics remain the same. Comparisons of modal split in 1977 and 1987 also shows that trucking has held over 80% of this market with little change over the ten year period. The second such commodity group is timber and lumber which is largely a bulk shipment type commodity that has been shipped predominantly by rail (approximately 70% of the market with little change between 1977 and 1987). Therefore, in the sensitivity analysis, the modal cost sensitivity parameters for these commodity groups have not been changed. The modal cost sensitivity parameters used in the sensitivity analysis are shown in Exhibit 5-12.

To determine the range of impacts associated with these changes in modal cost sensitivity parameters, the analysis that follows considers three scenarios. The first scenario assumes no additional truck emissions regulations beyond those already incorporated and assumes that locomotive emissions standards will be met with dual-fuel engine technology (i.e., Scenario 1, as defined above). This was found to be the most cost-effective rail control strategy and it results in the least diversion from rail to trucking.

The second and third scenarios are equivalent to Scenarios 5 and 6, as described above, and assume adoption of more stringent emissions regulations for trucking as are currently being considered by the ARB. This takes into account that if there is pressure to reduce emissions from rail, there may be similar pressure for further reductions in other freight modes. The second scenario assumes that the truck emissions control strategy will be LNG with lean burn in spark ignition engines and the rail control strategy will be dual-fuel. This combination of strategies actually results in a significant diversion of traffic from truck to rail. The third scenario combines the least cost control strategy for trucking investigated in this study (i.e., CNG/Lean-Burn SI) with the highest cost rail control strategy (SCR).

Exhibit 5-13 presents the results of the sensitivity analysis for Scenarios 1, 5, and 6. The discussion presented below compares the diversion and NO_x emissions impacts of the sensitivity analysis with those of the original analysis presented in Section 5.4. Increasing the modal sensitivity parameters by 100 percent for the selected commodities does not result in proportional increases in diversion. Under Scenario 1, rail ton-miles decrease by 751 million, compared to a 406 million decrease in the earlier analysis (see Exhibit 5-10)—a difference of 85 percent. The increase in diversion, however, only increases combined truck and rail emissions by 2 tons/day. Under Scenario 5, rail ton-miles increase by 85 percent, from 1,727 million more ton-miles to 3,194 million, resulting in a decrease in NO_x emissions of 3 tons/day. Finally, under Scenario 6, rail ton-miles decrease by 1,127 million as compared to a decrease of 610 million in the original analysis, also representing a change of 85 percent. Combined rail and truck emissions increase by 1 ton/day under Scenario 6. As a result, although the sensitivity analysis shows significant changes in the amount of diversion, the impact on NO_x is small. This again suggests

Exhibit 5-12

Cost Sensitivity Parameters for Sensitivity Analysis

Commodity Group	Parameter
Fruits and Vegetables	0.0268
Other Agricultural Products	0.2402
Minerals and Construction Materials	0.2224
Timber and Lumber	0.0837
Food Products	0.0522
Paper Products	0.1574
Chemicals	0.1136
Primary Metals	0.0526
Machinery	0.0538
Other Manufactured Products	0.0536

Exhibit 5-13

Results of the Sensitivity Analysis (2010)

Scenario	Δ in Rail Ton-Miles (Millions)	% Δ in Rail Ton-Miles	New Rail Ton-Miles (Millions)	New Truck Ton-Miles (Millions)	Truck NO_x (Tons/Day)	Rail NO_x (Tons/Day)
Scenario 1 - Dual-Fuel for Rail no Further Control for Trucks	-751	-2.1%	35,790	52,900	416	38
Scenario 5 - Dual-Fuel for Rail LNG/Lean-Burn SI for Trucks	+3,194	+8.7%	39,735	48,955	154	43
Scenario 6 - SCR for Rail CNG/Lean-Burn SI for Trucks	-1,127	-3.1%	35,414	53,275	168	41

Note: Numbers may not add up exactly because of rounding.

that NO_x reductions are mostly driven by changes in the emissions rates of locomotives and heavy-heavy-duty diesel trucks resulting from the deployment of advanced technology needed to comply with regulation.

6. Markets for Locomotive Emissions — Marketability Review

The discussion of markets for locomotive emissions consists of two parts. This section reviews issues related to the applicability of markets to the regulation of NO_x emissions from locomotives in California. Section 7 presents three market designs and JFA's recommended approach.

This section reviews issues related to the applicability of markets to the regulation of NO_x emissions from locomotives operating in California. It consists of five parts: an introduction, an overview of emissions credit programs, a discussion of emissions trading programs for mobile sources, a discussion of economic factors affecting locomotive emissions market design, and conclusions and preliminary recommendations.

6.1 Introduction

The objective of this sub-section is to review emissions trading concepts relevant to markets for locomotive emissions. Specifically, the objective is to uncover information pertinent to the development of emissions trading programs which are capable of implementing the concepts outlined by the ARB, especially as related to the use of caps for the phased reduction of NO_x emissions from locomotives operating in California. Such emissions trading programs could be used for NO_x, PM, or any other pollutant emitted by locomotives. They would be applicable in nonattainment areas for each affected pollutant as well as in attainment areas where growth of emissions is of concern.

The analytical approach that was taken to achieve this goal was to conduct a literature review supplemented by consideration of existing and proposed emissions trading systems and by observations based on JFA's extensive experience in dealing with emissions trading concepts. Sources used included papers from the economic literature and descriptions and discussions of programs promulgated or proposed by state and local governments and by the U.S. Environmental Protection Agency (U.S. EPA).

The subsequent parts of this section present the results of this review and analysis. Section 6.2 provides an overview of emissions credit programs. This includes existing programs such as the RECLAIM program for the South Coast Air Quality Management District (SCAQMD) and the programs for emissions averaging discussed in the Federal Implementation Plan for California recently withdrawn by the U.S. EPA. Section 6.3 describes special considerations related to the design of mobile source emissions credit programs. Section 6.4 assesses factors affecting the design of markets for emissions from locomotives. Section 6.5 discusses general conclusions and preliminary recommendations.

6.2 Overview of Emissions Credit Programs

Emissions trading is a concept developed by economists in the 1970s to allocate emissions reductions more cost-effectively than the "command and control" approach, once the reduction target is determined. Emissions trading is one of two economic incentive approaches, the other being emissions fees, that have optimal efficiency properties. Another economic incentive approach, based on subsidies to those who reduce emissions, does not share the efficiency properties of emissions trading and emissions fees.

Emissions trading can take many forms, based on the pollution control objective. Three basic approaches to emissions trading are discussed below.

1. ***The Emissions Budget Approach.*** This approach bases emissions trading on the rule that the sum of all emissions released within a jurisdiction shall not exceed a predetermined limit. The limit is often referred to as an emissions budget. The emissions increase allowed to one party of the trade would equal the emissions decrease guaranteed by the other.

2. ***The Ambient Air Quality Approach.*** In this approach, emissions trading is based on the rule that the ambient air quality after the trade be no worse than it was before the trade. This approach accounts for the pollution impact of each source at each location.[30] It assumes that air quality was acceptable before the trade. If it was not, the ambient limit required after the trade may become the limiting criterion for the trade. The criterion for the ambient air quality approach is more complicated to apply than the one for the emissions budget approach because it requires use of some form of air quality modeling.

3. ***The Damages Approach.*** This approach requires an additional step beyond the ambient air quality approach. The step is to measure the economic impacts on health, crops, materials, and the environment due to changes in emissions patterns resulting from a trade. The decision rule associated with this approach would state that net damages be zero or that there be no negative impacts. The requirement to measure the economic effects of the trade adds a great deal of complexity to trading.

Obviously, the emissions budget approach is the easiest approach to implement, because neither economic nor air quality modeling must be performed in conjunction with the trade. The emissions budget can be based on cost and air quality considerations, and the boundaries of the trading area can be set to ensure that the impacts of the emissions involved in the trade are similar. Moreover, most of the emissions trading programs being implemented or proposed follow the emissions budget approach. The rest of this sub-section focuses on the emissions

[30] Krupnick, Alan J.; Oates, Wallace E.; and Van De Verg, Eric. *On Marketable Air-Pollution Permits: The Case for a System of Pollution Offsets*. Journal of Environmental Economics and Management, 1983, 10(3), pp. 233-247.

budget approach to emissions trading.

There are three basic formats for emissions trading and two institutional settings. The three formats are as follows.

- *Emissions Reduction Credit (ERC) Trading* which is a form of emissions trading in which an ERC is approved by the regulatory agency based on emissions reductions already attained. Before the ERC is approved, the agency has assessed the amount by which the altered control technologies and operating procedures have reduced the level of emissions of a source below its emissions limit. ERCs can then be sold to other emissions sources to be used to meet their emissions control requirements.

- *Emissions Allowance (EA) Trading* involves the assignment of a certain number of emissions allowances to each source. Sources must install controls or institute programs to meet those limits. If emissions are less than the limit, sources may sell their surplus EAs. If emissions are in excess of the limit, sources must obtain additional Eas or are deemed to be out of compliance with the limit.

- *Emissions Averaging* is a form of emissions trading in which no specific limit is placed on a source's total emissions. Rather, a limit is placed on the emissions rate of each piece of equipment. If the emissions rate of a given piece of equipment is lowered below its limit, then the rate for another piece of equipment may be increased. The allowable increase in the rate is determined using a weighting system in which the expected rates of utilization for the various pieces of equipment are used as the weights.

The design of an emissions trading system depends on which formats and institutional settings prevail. The two pertinent institutional settings for these forms of emissions trading can be summarized as follows.

- Constant emissions limits have been set for the foreseeable future. The limits may be in the form of emissions caps on each source or emissions rates per unit of activity for each source.

- Baseline emissions limits for each source have been set and the limits are then reduced according to a schedule—referred to as declining caps.

6.2.1 Examples of Existing Emissions Trading Programs

The first major application of emissions trading was the emissions offset program developed as part of the new source review (NSR) program included in the Clean Air Act of 1977. The NSR program required that major new sources (i.e., those that would emit, or have the potential to emit, over 100 tons per year of an air pollutant) in a nonattainment area undergo a close review of their design and operating plans, install the most advanced form of pollution control equipment available to them, and induce other sources to lower emissions by at least as much as the new source's expected emissions (known as the offset requirement). Major new sources had to obtain an offset unless the region had required existing sources to reduce emissions by an extra amount in order to create an allowance for growth. Growth allowances were abandoned by the 1990 Clean Air Act Amendments (1990 CAAA).

The offset program has been in effect since the late 1970s. During this time, each nonattainment area in each state has had to develop a state implementation plan (SIP) to implement emissions offsets if it is to accommodate the location of a facility that would be classified as a major new source. SIPs for offset trading are the source of most currently available information on the practical workings of emissions trading. Offset trading traditionally has focused on industrial sources of emissions.

The offset trading conducted under NSR and implemented though the SIP process in various states is a special case of emissions trading. Specifically, it does not encompass previously existing sources or smaller sources, except as sources of emissions reductions. Emissions trading programs to reduce the costs to existing sources subject to emissions reduction retrofits have also been proposed and some have been implemented. A recent example is the RECLAIM program implemented by the SCAQMD. This program implements a "declining cap" on emissions of NO_x and SO_2 from a universe of both new and existing sources. The cap declines by three percent per year from a pre-established baseline. Emissions reductions at existing sources must exceed emissions increases due to growth by this amount.

The U.S. EPA is involved in emissions trading in several ways. In addition to its role in the NSR program, the U.S. EPA has released guidelines for emissions trading on two occasions. In 1986, the agency released its Emissions Trading Policy Statement (ETPS). On March 15, 1994, the U.S. EPA released its Economic Incentive Program (EIP) Rules. These rules establish guidelines to states for the development of emissions trading programs, emissions fee programs, and other economic incentive programs that will be subject to approval as part of a SIP.

Concurrently, the U.S. EPA published its proposed Federal Implementation Plan (FIP) for California. After a comment period, the FIP was revised and published in final form on February 14, 1995. The FIP used several concepts (such as emissions averaging) from the EIP and addressed specific issues relevant to the control of railroad and truck emissions. Although the FIP has since been withdrawn, it serves as a statement of programs that were acceptable to EPA as of February 1995.

The U.S. EPA's EIP Rules define nine issues relevant to the development of any economic incentive program that will function as part of a SIP. They also constitute guidelines applicable in most trading situations that may arise with respect to criteria air pollutants (CAPs)—including attainment areas when maintenance of air quality is an issue. These issues are discussed below.

1. <u>*Program Goals:*</u> For discretionary programs, such as locomotive emissions trading, no specific requirement exists, except that the overall SIP "ensure expeditious attainment of the national ambient air quality standards (NAAQS)" regardless of the nature of the proposed program.

2. *Interface With Reasonably Available Control Technology (RACT) Requirements:* RACT is the set of control standards developed for certain types of existing stationary sources by the U.S. EPA in response to the Clean Air Act Amendments (CAAA). The EIP Rule allows emissions trading involving RACT and non-RACT sources. Nothing in the final EIP Rule limits the design of an expanded trading universe incorporating stationary sources and mobile sources.

3. *Program Baseline:* The importance of this issue is to eliminate double counting in SIP demonstrations. The rule requires that in a nonattainment area for ozone, the choice of a baseline cannot interfere with meeting "reasonable further progress" requirements for actual emissions. One baseline rule that meets this criterion is the "lower-of-actuals-or-allowables" baseline. This means that the baseline emissions are less than or equal to emissions measured in recent years and less than or equal to what emissions would be under any regulation applicable to the source but not yet implemented. Regions are free to develop baselines as they see fit as long as "reasonable further progress" requirements are met.

4. *Emissions Quantification:* Two issues concerning emissions quantification are discussed in the EIP Rule:

    a) *Criteria for Adequacy of Approach:* The methods used to quantify emissions should be credible, workable, and replicable. The methods will necessarily vary between source categories depending on the nature of a specific source. The proposed FIP suggested a computational methodology for calculating emissions from locomotives and from trucks based on fuel use. The same methodological approach is applied to both. In the final FIP, EPA did not finalize its proposed fee-enforced fleet averaging programs for heavy-duty vehicles. For the emissions averaging applicable to railroads in the SCAQMD that have an increase in traffic, the final FIP states that "such railroads will be required to demonstrate that their fleet average emissions do not exceed national Tier I or Tier II operating emissions levels based on the methodology established in the national locomotive rule for calculating emissions from locomotives." The national locomotive rule is under development.

    b) *Extended Averaging Times:* Air quality models use a source's emissions for a typical summer day as input. If sources state their emissions limits in terms of a longer-term average, such as annually or monthly, they are required to also place a cap on daily emissions. The EIP Rule considers approaches that would allow longer-term averaging in defining the emissions allocation that would be traded. In the proposed FIP for California, although RECLAIM uses annual averages in its trading program, the U.S. EPA proposed monthly averages. The additional flexibility of the proposed rule is required for either of these approaches to be used effectively.

5. <u>*Monitoring, Record Keeping, and Reporting:*</u> The U.S. EPA has developed guidance regarding monitoring, record keeping, and reporting. It is important to develop a reliable system for monitoring emissions—or monitoring the data that will be used to calculate emissions—in an emissions allowance trading system (such as declining caps), because monitoring is the key mechanism for determining compliance. In such a system, no specific controls are required. The U.S. EPA recognizes that optimal systems for monitoring, record keeping, and reporting emissions will vary across source types. Monitoring, record keeping, and emissions reporting comprise a cost item that may be increased by emissions trading. The proposed FIP recommended that locomotive emissions be calculated by multiplying fuel usage for each locomotive by the appropriate emissions factor.. The final FIP proposed using a rule to be developed as part of the national locomotive rule.

6. <u>*SIP Creditability:*</u> This issue concerns methods for predicting the expected emissions reductions attributable to an EIP. The method must account for emissions reductions due to incomplete compliance with previous emissions reduction programs. In addition, the method must account for the likelihood of noncompliance and for any uncertainty inherent in the program. According to the EIP Rule, in a cap program such as that proposed for locomotive emissions, the only uncertainty is due to problems in measuring the true emissions levels. The effects of a program such as capping locomotive emissions on the emissions of another source, such as trucks, may need to be considered in the context of SIP creditability. Note that the issue of SIP creditability is valid in attainment areas as well as nonattainment areas. In attainment areas, air pollution officials have to implement plans for prevention of significant deterioration.

7. <u>*Audit/Reconciliation Procedures:*</u> Audits and reconciliations must occur frequently enough to provide input in assessing milestones for the "reasonable further progress" requirements of the 1990 CAAA. The U.S. EPA has solicited comments on how audits should be performed for mobile sources.

8. <u>*Penalties for Noncompliance:*</u> If the state submits an EIP that is not specified on a per day-per source basis, then the state must develop a procedure for assessing the number of days of violation and for identifying the responsible parties. The procedure must not dilute the incentive to comply.

9. <u>*Interface With Existing Emissions Trading Policies:*</u> The U.S. EPA reiterates its fundamental rule for emissions trading as follows: "... SIP credited trading activity must be quantifiable, enforceable, surplus, permanent within the time frame specified by the program, and consistent with all other statutory and Federal regulatory requirements." It specifies that although the ETPS can be used to devise an EIP that can be approved, it is not <u>necessary</u> to use the guidance of the ETPS in devising an EIP. The EIP Rule is more general and applies to a broader range of possible programs than the ETPS.

Attention to these nine requirements will ensure that the trading program developed by the ARB will conform to the U.S. EPA's guidance, thereby facilitating the SIP approval process.

It should be noted that emissions trading concepts have also been established for situations other than the nonattainment of ambient standards for criteria air pollutants. For example, a market for lead levels in gasoline during the lead phase out period illustrates the best potential for the emissions trading concept. Most of the potential trading opportunities were realized and trading proceeded smoothly.[31] In contrast, little use of emissions trading was made by owners of emissions sources in an effort to reduce control costs under the ETPS.

6.2.2 Special Consideration for Mobile Source Emissions Trading

In general, emissions trading programs involving mobile sources must meet the same criteria as programs for stationary sources. Emissions reduction credits must be quantifiable, enforceable, surplus, permanent within the time frame specified by the program, and consistent with all other statutory and Federal regulatory requirements. The only significant differences between emissions trading for stationary sources and emissions trading for mobile sources is that in some cases mobile source emissions are more difficult to quantify and the location and ownership of specific sources is highly variable. This is especially true of private automobiles. As a result, many proposals for the trading of mobile source emissions deal with fleets of vehicles under common ownership. In such cases, the emissions are likely to be easier to quantify and one owner has the ability to reduce larger quantities of emissions by his/her decisions regarding emissions controls, fuel use, maintenance programs, and vehicle miles traveled. The following section discusses emissions trading programs for mobile sources.

6.3 Emissions Trading Programs for Mobile Sources

In this sub-section, emissions trading programs that are specifically designed for mobile sources are discussed. Because emissions trading has been applied to mobile sources only recently, few systems have actually been in place long enough to assess relevant execution processes and impacts. Accelerated vehicle retirement programs constitute the majority of emissions trading schemes implemented to date for mobile sources. However, "vehicle scrappage programs" are not investigated in this study for controlling locomotive emissions.

The most relevant issues for mobile source emissions trading addressed by the EIP Rule include the requirement for a satisfactory method for monitoring emissions and SIP creditability. A method for satisfying the emissions monitoring requirements for mobile sources, based on applying emissions factors to the amount of fuel used, was suggested in the FIP, as discussed above. However, this proposed method was subsequently withdrawn by EPA. In this analysis, SIP creditability involves the impact of a locomotive emissions trading market on truck

[31] Stavins, Robert N., *Transaction Costs and the Performance of Markets for Pollution Control*. Presented at the American Economics Association Meeting, Boston, MA, January 1994.

emissions.

Furthermore, all of the emissions trading concepts discussed in the previous sub-section apply to mobile sources. These include:

- emissions reduction credits,
- emissions allocations,
- declining caps, and
- emissions averaging.

A critique of mobile source emissions trading programs that have actually been implemented, if only briefly, is conducted below, followed by a description of mobile source trading concepts being considered in California. Finally, analyses of how trading issues have been addressed by the U.S. EPA and of possible refinements that could improve the currently accepted approach are performed.

6.3.1 Critique of a Current Mobile Source Emissions Trading Program and Recent Trial Programs

Two important demonstrations of mobile source emissions trading—the UNOCAL accelerated vehicle retirement demonstration program and the Delaware Vehicle Retirement Program—have been completed and the results examined.[32] In addition, the SCAQMD (and other jurisdictions) has included mobile source emissions trading for NO_x and oxides of sulfur (SO_x) in its RECLAIM program. These three programs are discussed below.

The Union Oil Company (UNOCAL) conducted a demonstration project in 1990 in which it purchased over 8,000 pre-1971 vehicles in the Los Angeles basin. The program required that automobiles be operated in the region for a minimum of six months and that they be driven to the scrap yard by the registered owner. UNOCAL paid $700 for each vehicle.

The focus of UNOCAL's program was to determine how much regional emissions were reduced by scrapping older vehicles. First, UNOCAL had to estimate the emissions that the vehicles would have emitted under a no-scrappage scenario. This was accomplished via the execution of surveys to obtain data on the driving habits of 800 of the motorists that participated in the program and by the subsequent execution of the Federal Test Procedure on 74 of the 8,000

[32] Alberini, Anna; Edelstein, David; Harrington, Winston; and McConnell, Virginia. *Reducing Emissions From Old Cars: The Economics of the Delaware Vehicle Retirement Program.* Resources for the Future, Washington, DC, 1994.

vehicles purchased by UNOCAL. Second, UNOCAL estimated the emissions related to the mode of transportation used by participants after the sale of their vehicles. By relying on fleet averages for this calculation, UNOCAL estimated that reductions of hydrocarbon emissions, the emissions of concern for this program, cost between $2,200 and $2,900 per ton. The emissions reductions were not accepted in an emissions trading program, but were accepted in lieu of an employee ridesharing program.

The Delaware Vehicle Retirement Program was a demonstration program similar to the UNOCAL program. It was designed as an experiment, so certain vehicles thought to have exceptionally high emissions were targeted and follow-up surveys were conducted. Since the major concerns of the program were the calculation of regional emissions reductions due to the program and its acceptability in providing emissions reduction credits, great attention was paid to examining the emissions characteristics of the automobiles that participated in this program. The Delaware Vehicle Retirement Program also focused on hydrocarbon emissions.

In 1993, the SCAQMD released Rule 1610 establishing guidelines for allowing trading between mobile and stationary sources. Emissions are calculated by a simple rule incorporating generalized assumptions about the miles an automobile is driven annually and its expected remaining life—based on its year and model. UNOCAL has applied for emissions reduction credits under this rule.

The accelerated vehicle retirement programs discussed above highlight a more complex issue related to the estimation of emissions reductions than do most stationary source emissions reduction programs. Vehicle retirement programs require estimation of data that can never be observed (i.e., a retired vehicle's emissions profile). In contrast, most stationary source emissions trading programs can measure the actual emissions that occur once the controls are in place and compare them to an emissions limit that has been placed on the source. The emissions trading program proposed in Section 7 of this study for locomotive emissions is more like the stationary source programs than the accelerated vehicle retirement programs in this respect.

6.3.2 Programs That Have Been Proposed for Trading of Mobile Source Emissions in California

James Boyd—the executive officer of the California Air Resources Board—recently presented a paper on mobile source emissions trading.[33] After discussing the advantages and challenges of "market controls" relative to more traditional approaches to reducing pollution, Boyd listed three categories of mobile source emissions reduction credits (MSC), including:

[33]Boyd, James D. *Mobile Source Emissions Reduction Credits as a Cost Effective Measure for Controlling Urban Air Pollution*. in Cost Effective Control of Urban Smog, (papers presented at a conference sponsored by Workshop on Market-Based Approaches to Environmental Policy, Federal Reserve Bank of Chicago, and Chicago Council on Foreign Relations), Federal Reserve Bank of Chicago, November 1993, pp. 149-157.

- manufacturer credits;
- low emissions, heavy-duty vehicle credits for industrial/utility use; and
- credits derived from existing light-duty cars and trucks.

Manufacturer credits represent a form of emissions averaging in which the number of motor vehicles sold in California per year by vehicle class (five major classes and numerous subclasses) are tallied and used to determine the fleet average vehicle emissions for hydrocarbons. The fleet average is compared to the fleet average vehicle limits. Boyd described this as a "fleet bubble." The specific mix of vehicles produced and sold is left to the discretion of the manufacturers. Fleet averages below the limits are available for trading or may be banked for use against limits in future years.

Low emissions, heavy-duty vehicle credits for industrial/utility use is a concept aimed at reducing NO_x emissions. The credits may be used by local air quality districts after developing specific rules. For example, if low emissions buses are purchased, the difference in their emissions and those of buses just meeting the standards may be used as the basis for an emissions reduction credit that could be used by industrial or utility sources to facilitate economic growth.

Vehicle retirement programs (such as the "cash for clunkers" programs that have been demonstrated in Delaware and written into RECLAIM) represent approaches for reducing automotive hydrocarbon emissions below the levels required by regulations. The credits generated by these programs have been used by industrial or utility sources.

Each of these concepts allows emissions trading between different types of mobile sources or between mobile and stationary sources. Boyd stated, "To be recognized for credit, any emissions reduction project must meet two basic criteria: (1) the reductions are real, measurable, and enforceable, and (2) the reductions are 'surplus,' meaning they are not required by or credited to any other programs."

Although positive about the promise offered by these approaches, Boyd cautioned that challenges are to be met in implementing them. These challenges include the calculation of credits (many factors in the calculations must be estimated), and the possibility of developing a "green book" of emissions values for each type of vehicle. This book will determine the type(s) of vehicle(s) creating the most pollution; and therefore, target it (them) first to maximize cost-effectiveness. Boyd also cautioned that no region should be allowed to suffer adverse air quality impacts. He closed by stating that numerous efforts exist to develop similar concepts which will increase the opportunities to provide incentives for reducing emissions from categories of mobile sources not currently being regulated.

Boyd's discussion touched on the most widely discussed concepts for involvement of mobile sources in emissions trading programs and made it clear (as does the U.S. EPA) that the opportunity for emissions trading among mobile sources and between mobile and stationary sources is available as long as the criteria in the EIP Rule are met.

6.3.3 Issues to be Addressed in Market Design for Railroad Emissions Trading

The two primary issues for the design of mobile source emissions trading programs, emissions monitoring and SIP creditability, have been the focus of this sub-section. For locomotive emissions, SIP creditability for an emissions capping approach depends on whether the regulatory treatment of truck emissions constitutes a cap. This issue is discussed in Section 6.4.

The issue of emissions measurement was temporarily resolved by the U.S. EPA's proposal to multiply emissions factors by fuel use. The merit of this approach is that it can be applied to all mobile sources. Issues of mode of operation (which affects the emissions per gallon of fuel) and location of use are not resolved in this study. However, relatively simple refinements, applicable to both trucks and trains, are feasible. For example, a log book showing the hours a vehicle was in motion, as opposed to idling, would improve emissions estimates and allow estimation of the emissions released in each jurisdiction. The solution suggested by EF&EE, in which computer logs show the mode of operation of locomotives in real time may be feasible, especially if the necessary computer equipment has been installed previously for other purposes. However, unless all truck operators also install similar computer systems, a uniform approach to measuring emissions from rail and trucking activities would not prevail. The most interesting conclusion regarding emissions monitoring is that the U.S. EPA seems willing to accept a simple method that provides only a first-order approximation of emissions. This is a much less stringent method than they have required for stationary sources.

In addition to the regulatory criteria presented in the EIP Rule, other critical economic issues affecting the design of emissions trading programs for locomotives must be addressed. These are discussed in the following sub-section.

6.4 Economic Factors Affecting Locomotive Emissions Market Design

In this sub-section, four issues are discussed that are vital to the successful application of emissions trading programs to rail operations and to achieving the goal of reducing NO_x emissions to desired levels. These issues are as follows:

- capping locomotive NO_x emissions,
- ensuring the viability of long-term markets;
- reducing transactions costs, and
- overlapping jurisdictions.

6.4.1 Capping Locomotive NO_x Emissions

As shown in Section 5, the relative change in the marginal cost of reducing NO_x emissions from trucks and trains will determine mode shifts which, in turn, affect emissions from freight transport. The mode shift and emissions analyses presented in that section demonstrate that reductions gained from reducing rail emissions more than offset any increase in truck emissions, even if trucks are not subject to any further controls. The analyses formulated in Section 5 are based on "command and control" approaches to mitigating freight related emissions (i.e., emission standards that newly sold locomotives or trucks must adhere to). However, the ARB is considering market-based mitigation strategies that strive to allocate emissions reductions more cost-effectively across polluters. One approach is to cap locomotive emissions.

A cap on locomotive emissions means that total NO_x emissions within a given geographic area may not go above a prescribed level. The caps envisioned by the ARB would limit emissions from each rail line's operation within each nonattainment area in California. Railroads could trade emissions within each air shed to meet the cap at the least cost. However, before locomotive emissions caps are considered, an important regulatory issue must be addressed--whether or not similar caps will be placed on truck emissions. This discussion will show that in some circumstances, depending on how truck emissions are treated, a cap on locomotive emissions may be detrimental to the achievement of air quality goals.

A cap that fluctuates with the number of rail ton-miles was considered by the ARB. The concern expressed by the ARB that led to consideration of a flexible cap is that if the cap on locomotive emissions becomes too tight to accommodate increased freight demand, particularly for rail services, increases in freight transport demand will be accommodated by trucks. Since trucks emit more than rail on a ton-mile basis (see Section 3), a binding cap may be detrimental to achieving regional air quality goals. The proposed remedy under consideration by the ARB is to adjust the cap to accommodate increases in the demand for rail services.

The concern that a non-adjusted cap on rail emissions would increase emissions from trucks is certainly valid.[34] If the cap is placed on emissions from locomotives only, and the only recourse is to trade emissions between locomotives, increased shipping activity will be difficult to accommodate. At some future point, the only options for railroads will be to refuse shipping of additional freight or to invest in major technological changes such as electrification of the rail lines. If trucks are not subject to a similar cap, they will be available to take up the slack. The cost of shipping by truck will impose an upper limit on the cost of economically viable investments in abatement technology by the railroads.

However, two problems exist with the flexible cap approach. First, the air quality management districts need to know the emissions budgets for locomotives so that they can allocate emissions reduction requirements to other pollution sources, such as area and stationary sources. An

[34]Oates, Wallace E. and Schwab, Robert N. *Market Incentives for Integrated Environmental Management: The Problem of Cross-Media Pollution*. Unpublished paper.

increase in locomotive emissions for a future year will cause an air quality violation, unless another source is required to further reduce emissions. Second, the flexible cap does not put pressure on the railroads to reduce the mileage involved in moving a shipment from point A to point B. To minimize this problem, the program should provide incentives to ship goods via the shortest route, unless another route provides advantages, such as fewer grades. Incentives to reduce traffic in switch yards, or to redesign and/or relocate switch yards, also contribute to the most efficient emissions control strategy. In general, the economic incentives created by the market based controls should be designed to apply uniformly to all factors affecting locomotive emissions.

Likewise, the regulatory system should treat emissions from all freight modes (i.e., rail, truck, air, and marine) uniformly. Obviously, this does not imply that if one mode is required to reduce its emissions rates (e.g., in terms of grams of NO_x per Bhp-hr), other modes should be required to meet the same emissions rate. If an emissions rate strategy is chosen, it should entail differential emissions rates between modes such that control costs are balanced, or it should be specified in terms of emissions per ton-mile of goods.

Uniformity means applying uniform pressure on all modes to reduce emissions. If emissions rate strategies are chosen, modes should be allowed to use emissions averaging to allow greater flexibility and reduce costs. However, the best way to achieve uniformity is to subject all modes to emissions caps and allow trading of emissions within and between the caps.[35] If all transportation systems are subject to caps, mode shifts will be economically efficient and total emissions will be limited by the caps. The greatest benefit will be realized when trading systems embrace all transportation emissions, as well as emissions from stationary sources.

This analysis recognizes the difficulty in capping truck emissions of NO_x due to the large number of trucks on the road that would have to be monitored in order to keep track of total NO_x emissions. Other factors to consider include the following: 1) the difficulty of recording all the accelerations, decelerations, and loads on the engines experienced in a trip and the emissions released in each situation; and 2) the problem of asserting regulatory authority over all trucks, especially those registered outside of California. However, with the advent of Intelligent Transportation Systems, specifically advanced vehicle identification, location, and monitoring systems, trucks based-plated out-of-state can be identified. For example, the Heavy Vehicle Electronic License Plate (HELP)/Crescent Project, which affixes transponders to trucks and monitors their locations, has shown these systems to be effective. A number of trucks are now participating voluntarily and the project hopes to include all trucks operating in a crescent of states from Texas to Washington within the next two decades. Once these technologies are deployed on a wide-scale basis, data on truck populations, usage, and activity patterns can be improved upon for emissions forecasting purposes.

[35]As discussed in Section 7, this approach is recommended in this study.

Another factor that advances the issue of the treatment of truck emissions is the proposed FIP, signed in February 1994 by the U.S. EPA.[36] Although it has since been withdrawn in favor of local planning processes for meeting air quality goals, the proposed FIP envisioned major restrictions on the emissions rates of new and in-use California heavy-duty trucks, limited stops by non-California trucks to two per trip in California and just one in the SCAQMD, established statewide emissions averaging for truck fleets, and established emissions averaging for locomotives operating in the SCAQMD. The proposed emissions averaging program would have collected data necessary for the demonstration of compliance under an emissions cap scenario. In the final FIP, the U.S. EPA withdrew emissions averaging for trucks and the one stop-two stop program for trucks. The U.S. EPA predicated this change on a national truck rule that would reduce truck emissions to levels similar to those originally proposed.

The U.S. EPA's conformity rules[37] (i.e., transportation conformity and general conformity) issued in November, 1993, also could be used in the development of a program that caps truck emissions. These rules require that the emissions budgets used in demonstrating that the SIP will bring the region into compliance with ambient air quality standards are either met or formally amended so that regional transportation plans conform to regional air quality plans. Since truck emissions are implicitly or explicitly budgeted in all SIPs for ozone, air pollution districts and air quality management districts will be responsible for ensuring that truck emissions meet the cap implicit in the emissions budget. However, localities only need be concerned with the effect of transportation projects on regional air quality. Increases in emissions due to increases in truck traffic are not necessarily an issue in conformity assessments. In any case, capping truck emissions would assist localities in demonstrating that road improvement plans would not cause increased emissions while, concurrently, the emissions budgets developed by localities would provide useful inputs in the development of caps for truck emissions.

However, Federal requirements currently are not sufficient to place implicit caps on trucks. Truck emissions remain a concern when considering the capping of locomotive emissions, or any other approach which addresses locomotive emissions without specific attention to the impact on mode choice. For example, an emissions averaging approach to locomotive emissions could cause modal diversion from rail to truck if the marginal cost of reducing locomotive emissions is increased by a larger amount than the marginal increase in the cost of reducing truck emissions. A cap that reduces locomotive emissions by a modest amount could have a smaller

[36] U.S. EPA. *Approval and Promulgation of Implementation Plans; California--Sacramento and Ventura Ozone Federal Implementation Plans; South Coast Ozone and Carbon Monoxide State and Federal Implementation Plans; California Motor Vehicle and Fuels Program; California Nonroad Engine Program; California Consumer Product Rules; California Pesticides Rule; California Architectural Coatings Rule; Sacramento Ozone Area Reclassification*, Federal Computer Bulletin Board, February 15, 1994. This will be referred to as "the proposed FIP."

[37] U.S. EPA, *Determining Conformity of General Federal Actions to State or Federal Implementation Plans*, Federal Register, Vol. 58 No. 228, Tuesday, November 30, 1993 and U.S. EPA, *Air Quality: Transportation Plans, Programs, and Projects; Federal or State Implementation Plan Conformity; Rule*, Federal Register, Vol. 58 No. 225, Wednesday, November 24, 1993.

impact on truck emissions than an emissions averaging requirement that requires the most stringent controls on locomotives.

6.4.2 Ensuring the Viability of Long-Term Markets

Emissions trades may be made in spot, short-term, or long-term markets. In a **spot market**, emissions traders are interested in immediate concerns. In terms of rail operations, suppose the clean locomotive malfunctions and emissions from the substitute locomotive exceed the planned amount of available allowances by 5 percent. The railroad would look to the spot market to supply allowances to make up the difference. In a **short-term market**, emissions credits would be purchased or sold to accommodate operational adjustments affecting emissions. These adjustments are low cost and generally reversible. They do not represent a grand investment strategy. In a **long-term market**, emissions credits are purchased and sold based on a railroad's capital investment strategy. Such a strategy may include electrifying a segment of track or purchasing a fleet of alternatively fueled locomotives. Of the spot, short-term, and long-term markets, the one most likely to contribute to market inefficiency, thereby stifling trading activity, is the long-term market.

Long-term markets are the most vulnerable to design inefficiency because long-term investment strategies will require the purchase or sale of streams of emissions allowances. The railroads must project their emissions needs in each year of the strategy and consider how they can obtain allowances to cover them. They would need to be able to purchase or sell streams of emissions allowances for future years (or for perpetuity) to implement this planning. Long-run planning is needed to accommodate new business. Some long-run plans could be accommodated by purchasing allowances on the spot market each year, but this would involve increased risk. Lack of well-defined market instruments far into the future will motivate railroads to place less reliance on emissions markets.

Three types of government activity introduce uncertainty into long-term markets:[38]

- the manner in which emissions trading would be treated in regulated industries,
- the possibility that various levels of government may enact environmental laws limiting or revoking emissions allowances, or move in the opposite direction and repeal existing laws, and
- the reluctance of some factions at the U.S. EPA to let go of the "command and control" approach.

[38]Hausker, Karl. *The Politics and Economics of Auction Design in the Market for Sulfur Dioxide Pollution.* Journal of Policy Analysis and Management, 1992, 11(4), pp. 553-572.

The third type is manifested in the regulations to implement Title IV of the 1990 CAAA. For instance, sources holding allowances to emit SO_2—having installed continuous monitors and subject to large fines if their emissions are in excess of their allowances—are also required to submit detailed compliance plans for the U.S. EPA's approval. This requirement means that firms cannot respond quickly to trading opportunities or to rapidly changing market conditions. The command and control overlay effectively eliminates the flexibility granted to firms in meeting emissions limits, over riding a key virtue of market incentives.

To ensure efficiency in long-term NO_x markets, Federal, state, and local governments must ensure the long-term stability of the regulatory structure. This does not necessarily mean that they need to determine, once and for all, the emissions allocations for the next several centuries. But it does mean that, should they establish a market mechanism, the rules of the market should not be altered indifferently.

Some economists question government's long-term commitment to economic incentives. For example, R. W. Hahn and Robert Stavins question whether governments are capable of "making the type of long-term credible commitments under markets that would be required to encourage affected firms to adopt new and improved technologies."[39]

6.4.3 Reducing Transaction Costs

Transaction costs are the costs to individual firms and government agencies that are related to completion of an exchange of emissions allocations. They include the following: search costs, payments to brokers, negotiating costs, costs of demonstrating compliance, documentation and filing costs, fees (in money or in kind—such as an offset ratio), and costs of enforcement.

In the brief history of emissions trading, transaction costs have varied greatly from one trading system to another.[40] The magnitude of transaction costs is thought to be a primary determinant of the success of a trading system. For example, the market for lead rights, in effect between 1982 and 1987, is thought to have had relatively low transaction costs. The trading unit and trading universe were well defined, with the trading universe consisting of gasoline refiners who were in the habit of frequent transactions with each other in other markets. Over half of all lead rights were involved in market activity, and half of eligible firms participated. Transactions in this market consisted of external trades (i.e., trades between firms).

[39]Hahn, R. W. and Stavins, R. N. *Economic Incentives for Environmental Protection: Integrating Theory and Practice*, American Economic Review, May 1992, 82(2), pp. 464-468.

[40]Stavins, Robert N., *Transaction Costs and the Performance of Markets for Pollution Control*. Presented at the American Economics Association Meeting, Boston, MA, January 1994. Stavins reviews several papers that depict the link between transactions costs and the performance of emissions trading systems and then develops a model to illustrate how transactions costs affect the optimal control levels of a pollutant. This paragraph is based on his review.

The level of trading activity in the lead market contrasts with that under the U.S. EPA's ETPS program, which was characterized by a low level of external trades—less than one percent of possible situations—and a high level of internal trades (i.e., trades between sources owned by the same firm). Differences between the number of external and internal trades in the ETPS program partly are attributable to differences in transactio costs. Under the ETPS program, transaction costs of internal trades are thought to be substantially lower than those of external trades.

Transaction costs may be felt in many ways. They may be experienced as the amount of time the firm's employees spend on executing a trade rather than on some other task. Also, the elapsed time required for the firm's employees or agency personnel to complete the transaction may cost the firm in terms of lost business opportunities. There is evidence of the magnitude of monetary transaction costs as well. As an example of the magnitude of costs that occur in some trading systems, AER*X, an emissions brokerage firm, has reported that when emissions offsets were purchased in Los Angeles for new sources, the fixed fee was $3,000 per trade with $10,000 to $25,000 for administrative costs, such as documentation and filing costs.[41]

The nature of each type of transaction cost must be discerned in order to ascertain how or if it can be reduced. The evidence concerning transaction costs is drawn from the NSR program, which concerns new or expanding firms requiring an offset. As will be seen, NSR is not necessarily a good example for determining the costs of trading locomotive emissions. A firm subject to NSR must first develop the design specifications of the plant to be constructed, then project emissions based on the specifications and expected operating parameters. Projected emissions are then included in air models to determine their ambient impacts. Based on these projections, the location and quantities of emissions reductions needed to offset the new emissions are estimated.

Once the firm's emissions permit needs are determined, it must search for other firms with emissions profiles capable of providing the required reductions, purchase the emissions credits, and register them with the agency. Costs associated with these steps are discussed below.

- Search costs are the costs of finding a firm that will reduce emissions to provide the offset. The search frequently consists of a broker developing a list of firms with potential to provide the offset and then contacting each firm to explore offers, often keeping the name of the prospective purchaser anonymous. The firm will have to make a payment to the broker for its expenses, which may run from $20,000 to $85,000 per trade.[42]

---

[41]Stavins, Op. Cit.

[42]AER*X, Inc. in conjunction with Jack Faucett Associates, Analysis of the nature and costs of Emission Offsets, Prepared for U.S. EPA, Ambient Standards Branch, Air Quality Management Division, December 1992.

- Negotiation costs are incurred once a candidate firm is located. The firms' lawyers will discuss terms and contractual conditions for the development and sale of the offset.

- Costs of demonstrating compliance of the offset with all requirements are incurred when the firms take the proposed offset to the pollution control agency.

- Costs of filing all required documents, and paying fees are the next category of costs the firm encounters. Fees may be a dollar amount or they may be in the form of an offset ratio—an extra reduction beyond the amount needed to maintain current ambient levels of pollution. Determining the trading ratio between emissions increases and offsetting emissions decreases requires a balanced approach.[43] Too low a ratio between the increase and the decrease stymies interest in trading participation. Too high a ratio jeopardizes air quality. Uncertainties concerning the effects of altered emissions on air quality provide a rationale for discounting an ERC. Discounting the ERC adds a "margin of safety," but simultaneously decreases the cost-effectiveness of the program.

- Costs of enforcement are additional cost items that are sometimes included under transaction costs. They should only be included if the enforcement costs for a firm involved in trading are higher than for a firm not involved in trading.

It should be noted that the transaction costs involved for pollution offsets (i.e., the relevant type of trading) are higher than they would be in most other cases. First, the purchasers of offsets are major new sources. By the definitions prevailing until recently, major sources emitted over 100 tons per year of a pollutant. These sources constitute a captive market, whereby the cost is a required cost of entry or expansion. As long as the projected scale of the operation is sufficient to qualify the facility as a major new source, its options regarding the purchase of an offset are to do so, to find an alternative production technology, or to abandon the project. A major new source seeking an offset is different from an existing source whose options are to trade, to reduce production levels, or to install more pollution control equipment. The major new source has a higher upper limit on the total costs it would pay for an offset, including transaction costs. The firm will pay for an offset as long as the cost is less than the cost of not constructing or modifying the facility. Second, the search for offsets is complicated by the need to determine the potential emissions reductions from firms that would not have to reduce emissions otherwise. Hence, part of the search cost consists of preliminary engineering studies of potential emissions controls by potential sources. Third, the offset is a one time expense and its costs are amortized over the life of the facility.

Because offsets have been purchased since the late 1970s, more information is available about them than about other forms of emissions trading. The remaining discussion will consider how

[43] Tom Tietenberg, *Discussion*. in Cost Effective Control of Urban Smog, (papers presented at a conference sponsored by Workshop on Market-Based Approaches to Environmental Policy, Federal Reserve Bank of Chicago, and Chicago Council on Foreign Relations), Federal Reserve Bank of Chicago, November 1993, pp. 158-165.

the transaction costs experienced by major sources purchasing offsets may be reduced, as well as how costs for different trading systems are likely to be lower.

Search costs are lowered significantly in an emissions trading system in which all participants are identified in advance and are required to reduce emissions. Such programs are referred to in the U.S. EPA's FIP and EIP Rules as "declining caps." In a system of declining caps with trading, all participants must consider their options for reducing emissions in both the short run and long run. This knowledge will be developed by all participants regardless of their propensity to trade. Search costs for the participants can be lowered further if the agency establishes a clearing house for trading. Any party seeking to initiate a sale or purchase of emissions allotments needs to only provide basic information regarding the proposed number of allotments and prices. All others will be informed of these prices and quantities and may then determine if they can make use of them.

As part of the establishment of the clearing house, specific rules are developed. Trades of emissions allocations are credited immediately upon agreement between the participants. This system reduces the major components of search costs because engineering studies are no longer a cost factor for trading and because information on the prices and quantities of allocations offered for sale are public. The clearing house need not publish the identity of those making offers, but it may, through established procedures, bring offerers and purchasers together.

Negotiation costs will also be reduced in such a system because the only negotiable items would be price and quantity. All other issues will be determined by the air quality regulations and clearing house rules. Because each firm would be required to meet its emissions limit, whether or not the limit was altered by trading, enforcement costs would not be affected by trading.

The only other form of transaction costs, filing costs and fees, is in the control of the governing agency. Filing costs are influenced by the amount of detail requested in the filing. These costs are trivial if the only information filed with respect to a trade is the identity of the purchaser and seller, the price per unit of trade, and the number of units exchanged. If fees are charged to all sources subjected to declining caps whether they trade or not, then fees will not be a transaction cost for trading. The basis for the fee would then be independent of trading and the fee would cover all aspects of regulatory costs, not just trading. Alternatively, the expenses of the agency could be supported by general funds.

6.4.4 Overlapping Jurisdictions

The ARB's rulemaking on locomotive emissions is being developed in a complex regulatory setting. The rule will interface with: 1) regions such as the SCAQMD that must develop SIPs for ozone and that will need large percentage reductions of NO_x from locomotives and all other sources; 2) regions such as Santa Barbara that will not need as large a reduction; 3) the California Clean Air Act; and 4) Federal standards for new locomotive emissions. Part of the difficulty is in the timing. The ARB may not know the U.S. EPA's final rule on locomotive emissions before setting its own rule. Similarly, the regions developing SIPs may not know details of relevant rules set by others.

Besides timing, when a higher jurisdiction sets a rule, it may reduce the flexibility of the lower jurisdictions. Thus, the U.S. EPA's decision on the definition of new locomotives and a single, national set of emissions limits for new locomotives, preempts the ARB's authority to set limits for new locomotives. Similarly, the ARB's rule may limit the flexibility of air quality districts in developing their SIPs.

A related issue is what criterion should be used to set the level of reduction of locomotive emissions. From the perspective of the SCAQMD, the rule should allow them to reduce NO_x emissions from any source by as much as they need to reach attainment. This would be similar for other jurisdictions, except that they will not need as large a reduction. The U.S. EPA may be looking for the largest emissions reduction that can be achieved at a reasonable cost. Meanwhile the railroads (who are not a jurisdiction) would prefer that their expenditures on controls not be increased beyond the amount that can easily be accommodated for by their rate structure. In addition, the railroads would prefer equipment requirements that do not inhibit their plans to upgrade the speed and dependability of their service.

Given these conflicting goals and concerns, it may be well to return to the bottom line: what emissions reductions are required to meet the NAAQS and the California ambient air quality standards. Thus, the ARB's best option may be to develop its own rule, independent of the U.S. EPA, keeping in mind the assistance it provides to nonattainment areas and attainment areas in applying declining caps—with reductions of a magnitude needed for conditions prevailing in the local jurisdiction—in the preparation of their SIPs. The flexibility of emissions caps or emissions averages will mitigate the uncertainty of not knowing the precise rule that the U.S. EPA will promulgate with respect to locomotive emissions. The U.S. EPA has endorsed such an approach in its EIP and its FIP, even though the percentage emissions reductions required for railroads may be larger than the percentage emissions reductions for new locomotives.

Since the locomotives which railroads would have to place in service in the SCAQMD may be cleaner than those required in other jurisdictions, such as Ventura and Santa Barbara, railroads may have credits to sell to other emissions sources (such as stationary sources) in non-SCAQMD markets. Thus, factories or power plants may, in the final analysis, assist railroads in paying for cleaner equipment.

6.4.5 Summary of Issues and Implications

The following four issues have been discussed in this section of the report: capping locomotive NO_x emissions, ensuring the viability of long-term markets, reducing transactions costs, and overlapping jurisdictions.

First, the overall regulatory structure is not sufficiently strict with respect to truck emissions as to constitute a cap on them. If a cap or any other method is used to reduce locomotive NO_x emissions, care should be taken so that the resulting marginal pollution reduction costs do not trigger an increase in truck mileage and emissions. A cap is still the least costly way of obtaining a reduction in locomotive emissions and would result in the least amount of additional truck emissions.

Second, it is very important to ensure the long-term viability of emissions markets by developing a stable set of rules conducive to planning long-term investment strategies. Governments at all levels must make long-term commitments to these rules.

Third, declining caps is a form of emissions trading for which transactions costs are intrinsically low, as long as government sets fees at levels consistent with the low level of costs actually incurred for necessary activities such as recording the prices for and quantities of emissions trades and providing a clearing house.

Fourth, the complexities of the regulatory environment can be mitigated by establishing rules for emissions trading based on declining caps within nonattainment areas and attainment areas where maintenance of the ambient air quality is an issue. Each nonattainment area would set its cap based on the amount of reduction needed to meet its ambient air quality limits.

These considerations demonstrate that declining emissions caps set in advance will provide a stable environment for emissions trading and the development of long-term investment strategies, provided government makes a commitment to the long-term stability of the rules and works to keep fees at a level that just covers the costs associated with the efficient provision of basic services in the market.

6.5 Conclusions and Preliminary Recommendations

The conclusion of this analysis is that emissions caps are a viable option, because they will provide a given decrease in rail emissions at the lowest cost, and recommends that specific details be developed to implement them. However, care should be taken that the stringency of the cap or of any other method adopted for reducing locomotive emissions does not promote increases in truck activity. The rules adopted to implement an emissions cap should provide a uniform framework for individual air pollution control districts to apply once the magnitude of emissions reductions required from railroads in the district is determined.

The design of the trading program should incorporate the following elements:

- the trading goal, that is, the emissions limit or ambient air quality goal to be met by the trading system;
- the universe of sources of NO_x emissions;
- baseline emissions for each source;
- the unit of trade; and

- the trading rule.

Section 7 develops a trading rule for NO_x emissions from locomotives in California nonattainment areas based on the declining cap concept. The rule is designed to allow interface between emissions allocations for locomotives, other transportation sources, and stationary sources.

7. Markets for Locomotive Emissions — Market Design

In Section 6, various issues related to the application of markets to the regulation of NO_x emissions from locomotives operating in California were reviewed. In this section, three market designs are developed for using economic incentive approaches in conjunction with a statewide cap on NO_x emissions from locomotives operating in California. Although the discussion focuses on NO_x emissions, emissions of other pollutants (especially criteria air pollutants) could be regulated in the same manner.

The discussion is organized as follows. Section 7.1 presents the analytic assumptions used in the development of a market for locomotive emissions. Section 7.2 discusses issues relevant to the evaluation of alternative market designs. Section 7.3 defines three candidate market designs and evaluates differences among them. Section 7.4 presents the recommended market design (i.e., emissions allocation trading) which includes locomotive emissions in a total emissions allocation trading program that also includes stationary, area source, and other mobile source emissions. Finally, Section 7.5 summarizes the conclusions of the analysis.

7.1 Analytic Assumptions

In this study, the following assumptions govern the development of candidate market designs:

- that declining statewide caps are placed on locomotive emissions;
- that a simplified approach for emissions calculations is developed by the U.S. EPA in its proposed national locomotive rule, or that alternative approaches based on current methodologies developed by the ARB (e.g., methodologies developed by Booz•Allen or EF&EE) are employed; and
- that air quality goals are developed in terms of either a SIP for a nonattainment area or an air quality maintenance plan for a "prevention of significant deterioration" area (i.e., emissions limits for locomotives and other sources are developed with respect to local environmental conditions).

These three assumptions are discussed below.

7.1.1 Caps on Locomotive Emissions

This analysis assumes that declining statewide caps will be placed on locomotive NO_x emissions. These statewide caps will serve as the baseline for determining emissions limits for each railroad operating in each jurisdiction.

A rigid cap is recommended for this purpose, as opposed to a flexible cap that accounts for growth in the demand for freight transport services. Rigid caps allow for more precise emissions budgeting by air pollution control districts and air quality management districts. From an equity standpoint, most jurisdictions employing emissions trading programs (especially the SCAQMD) are placing rigid, declining caps on those area, stationary, and mobile sources involved in emissions trading. Although participating sources have growth plans, their plans must now be predicated on developing strategies for reducing emissions sufficiently to accommodate growth. In the case of rail operations, however, the stringency of the emissions cap is an integral issue since highly stringent caps may cause mode shifts from rail to trucks, and thereby possibly increase combined emissions. Measured in terms of marginal abatement costs, stringency is also the most important determinant of equity under a trading system characterized by rigid emissions caps.

Initial statewide caps should be based on current equipment usage. To ensure this, actual emissions from locomotives operating in each jurisdiction (e.g., during the last three years) must be estimated. Initial statewide caps must, therefore, reflect the emissions that would result from each railroad's typical operations in each jurisdiction.

Initial statewide caps should then be followed by an across-the-board rollback of NO_x emissions from locomotives. The basis for determining the percentage rollback should reflect the needs of the air pollution control districts and air quality management districts in terms of emissions abatement to reach air quality goals. Each region would prepare its SIP or air quality management plan allocating emissions among various sources. The emissions allocated to railroads operating within the jurisdiction in subsequent years would be compared to the emissions baseline to determine the total percentage reduction required from this source. From this calculation, the necessary annual reduction to meet the overall goal by the target date can be determined.

It will not be necessary to require that the statewide rollback be large enough to meet the emissions reduction needs of the most polluted jurisdiction. That is, the statewide percentage rollback need not be as large as would be required to meet the emissions reduction needs of the SCAQMD. The statewide cap can accommodate different percentage emissions reductions in each jurisdiction as long as statewide emissions reduction goals are achieved. Thus, in some jurisdictions the statewide cap could result in larger percentage reductions, while in other jurisdictions smaller reductions could be applied.

7.1.2 Emissions Calculations

This analysis further assumes that emissions calculations will be performed using the approach proposed by the U.S. EPA in its pending national locomotive rule, or via an appropriate alternative such as methodologies developed by Booz•Allen or EF&EE. The U.S. EPA approach is likely to be a simple method in light of recent proposals that estimate locomotive emissions by multiplying fuel usage for each locomotive by the appropriate emissions factor. Methodologies based on the duty cycle of locomotives (e.g., time-in-notch) would provide more realistic emissions estimates, while the collection of real time data on route and mileage using transponders potentially could provide the basis for yet another approach. More sophisticated (and possibly more costly) methodologies are available and could be used if associated development costs are not too great. Nevertheless, to achieve economies of scale and reduce the number of agencies dealing with the railroads, it is assumed that state pollution control officials will perform the calculations and provide them to local jurisdictions.

7.1.3 Local Responsibility for Air Quality Plans

Finally, this analysis assumes that two jurisdictional levels will be involved in economic incentives programs for locomotive emissions: air pollution control districts (or air quality management districts) and the state. While state involvement is necessary to coordinate the activities of local jurisdictions and to certify locomotive emissions attributable to each railroad, local jurisdictions will have to determine what level of locomotive emissions reductions are required as part of their SIPs or air quality management plans. If emissions trading is to take place, it must be part of a local emissions trading system based on coordinated plans for meeting and maintaining air quality goals. The state should provide guidelines to ensure consistency in emissions trading rules across jurisdictions.

7.2 Issues in Evaluating Alternative Market Designs

The evaluation of market designs for mitigating locomotive emissions must address the following issues:

- direct and indirect economic impacts,
- environmental impacts, and
- participation levels in proposed emissions markets.

These issues are discussed below.

7.2.1 Economic Gains Associated with Emissions Markets

The purpose of economic incentives is to minimize the economic cost of environmental regulation subject to environmental goals. This is accomplished when marginal costs of emissions reduction are equal across sources contributing to air pollution in a region and when total emissions are consistent with stated emissions targets. To achieve this objective, it is necessary to include as many sources as possible in well designed emissions markets. When sources are excluded from market participation, there is no mechanism for equating marginal costs.

Market designs based on emissions trading potentially can maximize the number of sources participating in emissions markets. For example, the SCAQMD's RECLAIM program for NO_x and SO_x addresses NO_x emissions from power plants and other major sources. As RECLAIM is expanded to include smaller sources, its economic efficiency will increase.

In contrast, a market design based on emissions averaging isolates emissions from a specific source, thereby resulting in only small economic efficiency gains arising from compliance flexibility. It is unlikely that the marginal costs associated with emissions control will approach optimal levels under an emissions averaging market design.

7.2.2 Environmental Impacts

The primary purpose of implementing declining caps is to reduce emissions to a desired level. The discussion of declining caps thus far has been sensitive to the emissions control needs of the individual air pollution control districts and air quality management districts in California, since a statewide emissions cap on a particular source is an amalgamation of local caps. When economic incentives are introduced, it is desirable that the emissions limits defined by the caps are adhered to.

Market designs based on emissions trading preserve the emissions caps within each jurisdiction. This is especially true if caps concurrently are placed on all relevant sources of emissions. In some cases, emissions trading schemes may result in actual emissions being below the governing cap. However, emissions averaging does not resolve this potential problem since it offers no guarantee that emissions will be below the cap.

7.2.3 Market Activity and Transactions Costs

A major concern about the functioning of emissions markets is the level of market activity. In the past, some environmental markets have not performed well due to lack of participation. Economic incentives based on declining caps such as the one used in the RECLAIM program, however, have positive implications for market activity. Declining caps force sources to consider participation in the market. For example, if a source's cap declines by 3 percent each year, the source must always be evaluating measures to meet each year's cap. For instance, the source may decide to implement process changes designed to meet the cap ten years into the future, although such changes can be completed in two years. For the remaining eight years, the source will have surplus emissions reductions and is likely to consider participation in the emissions market where surplus emissions have economic value. By dating emissions allocations, a source can purchase or sell allocations just for the years of projected need. A source planning a major revamping of its equipment to meet future emissions requirements can cover the temporary short fall with purchased allocations. Consequently, a market design based on emissions allocation trading fosters participation by creating many opportunities for small, medium, and large trades. Sources can learn to use the market while concurrently minimizing risk.

However, participation depends on the magnitude of transaction costs. Transaction costs include two major components: recording costs and search costs. Recording costs are similar to closing costs incurred in a real estate transaction. They include the costs of activities undertaken by pollution control authorities to verify and record information about a trade. Emissions allocation trading, for example, is characterized by low recording costs. A document is prepared transferring the allocation and the resulting allocations for each source are recorded in a database. Search costs are the costs of identifying a trading partner and negotiating a trade.

Both recording and search costs can be influenced by governing agencies. For instance, California can develop, or encourage local air pollution control districts to develop emissions clearing houses. Clearing houses would provide information on ownership of emissions allocations and on the asking and/or offer price and quantity of proposed transactions. The clearing house could be designed to conceal the identity of parties offering to buy or sell emissions allocations. Clearing houses, therefore, reduce search costs.

Another determinant of the magnitude of transaction costs is the number of regional markets necessary for achieving air quality goals. The total number of regional markets could simply be constrained by the number of nonattainment areas. Although attainment areas may use a cap to maintain air quality levels, such areas probably will not have to establish emissions markets to accommodate locomotive emissions. Emissions from locomotives will be constrained by the railroads' responses to emissions limits promulgated by air quality management districts in the most highly polluted region. For example, a railroad that meets requirements in the SCAQMD likely will have surplus allocations in the attainment regions it traverses since it will have lowered its emissions from a level consistent with meeting or maintaining the ambient air quality standard in attainment regions. Emissions markets in attainment areas will be needed only if other types of NO_x sources seek to increase activity in an attainment area, or if a railroad wishes to increase the number of locomotives operating in an attainment area.

7.3 Three Alternative Market Designs

In this sub-section, three market designs are introduced: emissions allocation trading, emissions reduction credit (ERC) trading, and emissions averaging.

- *Emissions Allocation Trading* — emissions allocations are distributed to emissions sources within a jurisdiction and the allocations may then be bought and sold in an emissions market. The source (e.g., a railroad) must keep its total emissions in the jurisdiction beneath the level set by its emissions allocation. The jurisdiction may be the state or an air pollution control district.

- *ERC Trading* — emissions reductions are certified prior to the issuance of ERCs by pollution control officials. The ERCs may then be traded. A source creating ERCs must keep its emissions below the new limit approved by officials in granting the ERCs. A source purchasing ERCs may increase its emissions by the amount of the ERC.

- ***Emissions Averaging*** — no specific limit is placed on a source's total emissions. Rather, a limit is placed on the emissions rate of each piece of equipment. If the emissions rate of a given piece of equipment is lowered below its limit, then the rate for another piece of equipment may be increased. The allowable increase in the emissions rate is determined using a weighting system in which the expected rates of utilization for each piece of equipment are used as the weights. Emissions averaging may be conducted at the state or local level. In the case of locomotives, averaged emissions may reflect one railroad or several railroads.

Exhibit 7-1 shows how the basic components of an economic incentive program are handled for each of the three candidate market designs. Components include the trading goal, the universe of NO_x sources to be involved in trading, the baseline emissions for each source, the unit of trade, and the enforceable trading rule. For each of the market designs presented in Exhibit 7-1, it is assumed that allocations, caps, credits, or averages would be replaced annually to reflect the percentage decrease from the previous year. The result of this process is referred to as "dated permits." For example, if the rate of emissions decrease in a jurisdiction is 3 percent each year for twenty years, the first year's permit would be for 100 percent of the baseline emissions calculation. The second year's permit would be three percent less than the first year's permit, the third year's permit three percent less than the second year's permit, and so on for the twenty years. Permits for subsequent years could be issued for the emissions level reached in the twentieth year. The jurisdiction could issue permits for as many years in advance as are necessary. The jurisdiction would retain the option of readjusting the permit in future years. The method for making such an adjustment, if it becomes necessary, should be part of the initial plan. An equal percentage rollback of all allocations, caps, ERCs, and averages for all sources participating in the system is recommended.

Market designs based on emissions allocation and ERC trading are identical with respect to the first three components presented in Exhibit 7-1. However, they differ with respect to the unit of trade. In ERC trading, the source providing the ERC must demonstrate to pollution control officials that proposed equipment modifications and/or process changes will reduce emissions by a predetermined amount. The cap for the firm is then reduced by that amount. This approach, which is more stringent than that used in emissions allocation trading, is also more burdensome for both the source and the pollution control agency. However, both systems provide pollution control officials the means by which compliance can be ensured.

For the purpose of developing a locomotive emissions market, certifying ERCs is a cumbersome extra step requiring effort by both the pollution control agency and a railroad to design and evaluate a control process. ERC trading was first proposed in the late 1970s and early 1980s in a climate in which pollution control officials were distrustful of the emissions trading concept.

Exhibit 7-1
Components of Three Economic Incentive Programs
Applicable to NO_x Emissions from Locomotives Operating in California

Component	Emissions Allocation Trading	Emissions Reduction Credit Trading	Emissions Averaging
Trading Goal	Meet emissions limits established to attain ambient air quality standards for ozone or NO_x in air pollution control districts (APCD) or air quality management districts (AQMD).	Meet emissions limits established to attain ambient air quality standards for ozone or NO_x in APCD or AQMD.	To maintain average NO_x emissions per unit of activity for each railroad or grouping of railroads at a predetermined level. Average could be a statewide or regional average.
Universe of NO_x Sources to be Involved in Trading	All railroad controlled NO_x sources and other NO_x emissions sources included in SIP or Air Quality Maintenance Plan.	All railroad controlled NO_x sources and other NO_x emissions sources included in SIP or Air Quality Maintenance Plan.	Locomotives owned by the participating railroad or railroads and other equipment as long as the emissions rate measure is uniform.
Baseline Emissions for Each Source	Initially, the lowest of actual or allowable emissions during previous N years. Then decline at a predetermined rate (say 3 % per year) until total desired reduction (say 50%) is achieved.	Initially, the lowest of actual or allowable emissions during previous N years. Then decline at a predetermined rate (say 3 % per year) until total desired reduction (say 50%) is achieved.	Initially, the lowest of actual or allowable emissions during previous N years. Then decline at a predetermined rate (say 3 % per year) until total desired reduction (say 50%) is achieved.
Unit of Trade	An "Emissions Allocation," defined as the number of tons (pounds) of NO_x allocated to an emissions source by the jurisdiction. Specified in terms of pounds per hour or tons per year.	"Emissions Reduction Credits," defined as a credit earned by a source when it demonstrates to authorities that it has put into effect the means to keep its NO_x emissions below a lower cap than it originally was assigned. Specified in terms of pounds per hour or tons per year.	Emissions per unit of activity (e.g., pounds of NO_x per ton mile).
Enforceable Trading Rule	The parties trading the Emissions Allocation must register the trade with state and local authorities. This could be accomplished with a notarized form submitted locally. Any source having emitted more than the amount permitted by the allocations in its possession at the end of the allocation period would be in violation.	The sale of an ERC must be recorded with state and local authorities. Any firm violating its current cap is in violation.	Total NO_x emissions from a group of equipment divided by total units of activity of the group of equipment should be less than or equal to the average emissions rate assigned to that group of equipment.

By certifying the emissions reduction and lowering the source's emissions cap prior to trading, officials could be assured that emissions would not increase as the result of trading. However, experience with Title IV of the Clean Air Act Amendments, which established a national market in emissions allocations for SO_2 and the operation of the SCAQMD's RECLAIM program for NO_x and SO_2 has helped to alter attitudes about emissions trading. The stringent step of certifying ERCs—which increases transactions costs and reduces market activity—is no longer necessary. Therefore, ERC trading is not the recommended approach for developing a locomotive emissions market.

With the exception of baseline emissions determinations, emissions averaging is different than emissions allocation and ERC trading. First, the trading goal is more vague since caps are not set under emissions averaging. Second, emissions rates are rolled back, but total emissions may vary from the expected level without triggering a violation. Third, the unit of trade for emissions averaging is emissions per unit of activity. Each piece of equipment would be assigned an emissions rate and the rates could be altered as long as their average rate per unit of activity does not increase. Fourth, in the case of railroad operations the trading universe under an emissions averaging scheme is limited to locomotives. But, it is conceptually possible to include trucks if the unit used to measure emissions and activity is consistent (e.g., ton-miles). In contrast, the two emissions trading programs are highly adaptable to large numbers of sources regardless of the type of activity for which they are used.

Under an emissions averaging scheme for controlling emissions from locomotives, the trading goal is to maintain an average emissions rate that accounts for activity (e.g., tons of NO_x per ton-mile). However, such a goal does not satisfy the first assumption described in Section 7.1 (i.e., maintenance of a statewide emissions cap) because ton-miles (and emissions) could increase as long as the average emissions rate of the fleet is maintained at predetermined levels. Concurrently, the nature of emissions averaging constrains the types of sources that are able to participate in the program, since an emissions averaging scheme relies on emissions limits that are expressed in tons of emissions per unit of activity. Therefore, stationary sources would not be able to participate, while trucks could be included. Furthermore, under emissions averaging two issues must be monitored: emissions from rail operations and ton-miles. The introduction of ton-miles complicates the ability of railroads and pollution control agencies to implement, monitor, and execute market initiatives. Each would have to track the weight of the cargo—or possibly the train—and calculate ton-miles for each segment of the run.

In sum, emissions averaging is incompatible with caps, is lax in meeting environmental goals, and provides only limited economic benefits.

7.4 The Recommended Market Design—Emissions Allocation Trading

Emissions allocation trading is the recommended market design for mitigating locomotive emissions via the use of market-based economic incentives. Emissions allocation trading is the best suited strategy when combined with a rigid, declining, statewide cap on locomotive emissions, as proposed in this study.

Under the recommended market design, the statewide cap will be used to determine yearly emissions allocations for each railroad operating in the state's air pollution control district or air quality management district. Allocations should be based on the relative, historical contributions of specific polluters (e.g., railroads, power plants, trucking firms, etc.) to emissions in a given air pollution control district. Once allocations have been prescribed to each polluter participating in the recommended emissions allocation scheme, emissions trading will be possible internally within railroads, between railroads, or between railroads and other emissions sources located in a particular district. The suggested unit of trade is tons of emissions per year. Annual emissions limits could be translated to daily limits to accommodate air quality modeling. The duties of a pollution control agency under the recommended market design include the following: assignment of emissions allocations, recording of trades of emissions allocations, monitoring of emissions, and enforcement of emissions limits. Information on the contribution of emissions by source (i.e., stationary sources, rail operations, trucking, etc.) available from SIPs and air quality management plans can serve as the basis from which rigid caps and emissions allocation strategies can be developed.

Under the recommended emissions allocation trading scheme, the state would collect and certify locomotive emissions data from railroad operations in each district and disseminate these data to each air quality district. There are a number of methods for accomplishing this state function. This analysis, however, assumes that a simplified approach for estimating the contribution of locomotives to emissions in each district based on methodologies developed by the U.S. EPA in its proposed national locomotive rule, or that an alternative approach based on methodologies previously developed for the ARB, will be employed by California. If measures taken by a given railroad increase the railroad's contribution to emissions in a given district to levels that exceed the prescribed allocation, the railroad must either 1) reduce emissions from the other sources that it operates within the district, 2) obtain additional allocations from another railroad operating in the given district, or 3) obtain emissions allocations from another source (e.g., a stationary source located in the district). Conversely, if a railroad institutes measures that decrease its contribution to emissions in a particular district to levels below its prescribed allocation, the railroad would be able to trade surplus allocations to other railroads or sources.

In sum, emissions allocation trading is the preferred option. The following attributes of emissions allocation trading exemplify its inherent advantages over ERC trading and emissions averaging.

- Emissions allocation trading affords the greatest economic benefit since it provides the largest trading universe (i.e., it provides the greatest opportunity to reduce costs associated with NO_x emissions control).

- Emissions allocation trading preserves the emissions cap, thereby maintaining the desired level of environmental protection.

- Emissions allocation trading results in the lowest transactions costs, thereby maximizing the level of market participation.

- Emissions allocation trading will provide railroads with the easiest method for reducing cost burdens associated with the implementation of rigid, declining statewide emissions caps.

However, to maximize the potential benefits of emissions allocation trading, it is necessary to establish emissions trading systems in all jurisdictions of the state where there is likely to be a demand for emissions allocations, and to ensure that, at least with respect to railroads, emissions allocation programs across jurisdictions operate in a uniform manner. An example highlights the importance of a comprehensive, uniform trading system. Suppose that a railroad over-controls the emissions from a locomotive that moves across several jurisdictions in the state, with the attendant goal of being able to sell or use the surplus reductions under a trading scheme. The associated emissions reductions will occur in each jurisdiction that is traversed by the specific locomotive, and to receive benefit for 100 percent of its surplus emissions, the railroad would have to complete emissions trades in each jurisdiction. If it cannot find trading partners in some jurisdictions, then the cost per ton of the emissions reduction surpluses it does trade will be greater than the cost per ton of those that are not traded. For instance, if it costs $100,000 to reduce the locomotive's emissions by 25 tons/year, the yearly cost of the emissions reduction is $4,000/ton. If only 80 percent of those emissions can be traded because the rest are emitted in a region where there is no demand for emissions allocations, the cost of producing the 20 tons/year of tradable emissions is $5,000 per ton/year. Therefore, implementing a trading scheme that maximizes the opportunity for trades provides significant economic benefits to market participants. However, even when comprehensive and uniform schemes are developed there will still be the added burden of identifying trading partners in each jurisdiction. State and local emissions clearing houses will ease this burden.

7.5 Conclusions

This analysis has developed and described three economic incentive programs for use in conjunction with rigid, declining statewide caps on locomotive emissions. The proposed method for setting the caps takes account of each region's environmental needs and emissions reduction priorities. Emissions data collection was assigned to the state to reduce the number of agencies the railroads must deal with. The method for calculating emissions is yet to be determined, but could be based on current methodologies adopted by the ARB.

The recommended market design, emissions allocation trading, adds little administrative burden to that prevailing under a statewide cap. It provides railroads with the opportunity to minimize compliance costs associated with an emissions cap by allowing for the purchase (sale) of emissions allocations from (to) any other emissions source participating in local emissions markets while concurrently ensuring that emissions levels will not exceed the cap. The only major cost associated with the recommended emissions allocation trading market is the cost of identifying trading partners. This cost can be minimized by ensuring that as many sources as possible participate in emissions markets and by establishing information clearing houses.

Other market designs do not have the same attributes of emissions allocation trading. ERC trading adds a costly step that inhibits market participation (i.e., certifying a proposed ERC increases transaction costs). Emissions averaging does not result with significant economic benefits nor does it ensure adherence to the statewide emissions cap.

Appendix A

Statement of Methodology

Jack Faucett Associates

4550 Montgomery Avenue•Suite 300 North•Bethesda, Maryland 20814
Telephone (301)961-8800•Facsimile (301)469-3001

Memorandum

To: Members of the Steering Committee

From: Jack Faucett Associates, Inc. (M. Fischer, S. Ostria, E. Van De Verg)

Subject: ARB study entitled *Assessment of the Effects of Proposed Locomotive Regulations on Goods Transport Modes and Locomotive Emissions*, Statement of Methodologies

The purpose of this memorandum is to present the proposed methodology for conducting the various tasks of the study. The study is divided into two general tasks. Task 1, ***Goods Transport***, basically involves the analysis of the effects of emissions regulations on mode diversion and emissions. It includes three subtasks: Task 1A, *Intermodal Shift Analyses*, Task 1B, *Emissions Assessments*, and Task 1C, *Emissions Comparisons*. Task 2, ***Market Development***, involves the design of an emissions credit trading program in which the railroad industry can be active. This task includes two subtasks: Task 2A, *Marketability Review* and Task 2B, *Market Design*. The Steering Committee is asked to please review our proposed approaches and comment accordingly by no later than April 4, 1994.

Task 1A — Intermodal Shift Analyses

The principal objective of the study of the economic impacts of proposed locomotive emission regulations in California is to determine how increased costs of rail freight transportation due to emission regulations would impact freight movement patterns in the state. Ultimately, impacts on the amount of cargo shipped through California, the modal choice for these shipments, and the relative emissions characteristics of each mode are the significant issues which must be addressed in the study. In order to address the objectives of the study, the following issues are the most important:

- the extent to which increased rail costs or decreased levels of service would cause modal diversion from rail to other modes (primarily trucking);
- the extent to which increased rail costs or decreased level of service would cause diversion of international trade from California ports to other West Coast ports;

- the extent to which increased rail costs could change intermodal shipment patterns by displacing truck-rail transfer points to locations out of state; and
- the extent to which increased rail costs could cause substitution of non-transport factors for transportation.

The last issue is linked directly to the cross-price elasticities of demand for transportation services with respect to other factor inputs. Many of these substitution possibilities are long-term phenomena, especially location decisions and the use of equipment capital, which are outside the scope of this study. Changes in the makeup of intermodal moves, while potentially significant, are difficult to capture in existing models and data bases and must therefore be handled through ad hoc methods outside of the modeling framework. While port diversion could potentially be handled in a port traffic model, this not the principal focus of the study and will be discussed qualitatively rather than in a modeling framework. Thus, the primary focus of the study is on modal diversion impacts. Modal diversion consequences of locomotive emission regulations are critical to this analysis, especially if parallel regulations on trucking are not implemented, since diversion will result in an increase in trucking emissions which could more than offset the decrease in rail emissions anticipated to result from regulation.

In developing the approach for the intermodal shift analysis, JFA's objective was to identify an appropriate modal diversion analysis methodology with the ability to analyze the effects of changes in key variables on mode choice (e.g., the relative transport cost of rail as compared to other modes). In addition, in order to limit bias in the diversion analysis, the methodology needs to include model parameters which reflect data relevant to California shipment characteristics in the base year (1987) and forecast year (2010). Finally, the methodology needs to employ data which is readily available given the limited resources of the study.

JFA conducted a detailed review of the literature to identify previous modal diversion analyses and mode choice models with relevance to the current study. Both aggregate and disaggregate mode choice models were reviewed. In a disaggregate model, changes in costs and service characteristics determine whether a sample of shipments will move by rail or by truck. Once the mode split for the sample has been determined (typically employing probability models), suitable expansion factors can be applied to determine modal diversion for the universe of shipments which were sampled. Given the lack of good disaggregate models, a number of researchers have developed techniques for modeling mode choice which utilize more aggregate data sets. Typically, these models use aggregate data on total commodity flows and mode shares for industries, sectors, and/or regions. Data is often available disaggregated by commodity group but not necessarily by origin-destination pair. The results of JFA's literature search is contained in a draft chapter for Task 1A of this project (see Section 1.2 of the draft Task 1A chapter).

The literature review raised several important issues which were considered in the selection of a modal diversion analysis methodology. First, while disaggregate models are generally preferred for mode choice analysis, they require very detailed data bases which are generally not available in the public domain. The last comprehensive survey of shipments conducted at the national level was the 1977 Commodity Transportation Survey (CTS). This survey did not include shipments from all economic sectors and all modes. In addition to the type of data contained in the CTS, disaggregate models also require detailed information on logistics costs and service characteristics which are only available in proprietary data bases. Aggregate models, on the other hand, use aggregate data on commodity flows which is available in the public domain for most modes. We believe that aggregate models are both appropriate and sufficient for the modal diversion analysis which will be conducted in this study.

Unfortunately, aggregate models estimated to-date suffer from some of the same data deficiencies mentioned above for disaggregate models. The main short-coming is that most of these models are estimated with 1977 U.S. or foreign data. Re-estimating these models with current freight flow data would be costly and outside the scope of this project.

As a result, JFA selected the modal diversion algorithms from the California Energy Commission's (CEC) Freight Energy Demand Model (CALFED) to conduct the modal diversion analysis. CALFED was developed in 1983 for the CEC by JFA. The model incorporates an aggregate modal diversion analysis methodology which calculates changes in rail market share as a function of rail-truck relative costs for each commodity group and a set of regional origin-destination pairs. CALFED offers several important advantages over other alternative choices. CALFED is the only model that we reviewed which is estimated specifically with California shipment data. It also provides O-D and commodity detail, and it implicitly incorporates length of haul and shipment size effects.

In CALFED, 10 commodity classes are identified as competitive traffic, with rail and truck modes able to compete for a share of the transportation market. The ten commodity classes include agricultural commodities, construction and mining, timber and lumber, and all manufacturing commodities. The change in the rail share of transport (in ton-miles) is calculated for each commodity and O-D region combination. The O-D regions include intrastate freight, Arizona, Nevada and Utah, Oregon and Idaho, Washington and Montana, and the remaining 40 contiguous states. For each commodity/O-D region combination, the change in rail share is computed by multiplying a modal sensitivity to the cost of service parameter for each commodity by the change in the rail cost advantage per ton-mile for transport of each commodity to or from each O-D region. This product is adjusted by taking into account the previous year's rail share. Thus, commodity traffic for a particular O-D region which was evenly split between rail and truck in the previous year appears to the model as highly competitive, and the modal sensitivity to cost of service parameter and the change in relative cost advantage of rail tend to dominate the modal share equation. In cases in which one mode was dominant in the previous year, modal costs and sensitivities to changes in these costs are a less significant determinant of mode choice. The modal sensitivity to cost of service parameter for each commodity group is calculated taking into account the distribution of all shipments in California by length of haul and the cost of rail service as a function of length of haul.[1] The data used to determine the distribution of shipments by length of haul was developed from the 1977 CTS. The data used to determine the cost of rail service as a function of length of haul was obtained from the 1977

[1]*California Freight Energy Demand Model*, Jack Faucett Associates, prepared for the California Energy Commission, Sacramento, CA, June 1983.

ICC Carload Waybill Sample.

In order to implement the modal diversion methodology from CALFED several additional pieces of information are necessary. First, it is important to have a forecast of modal shares (in ton-miles) for each commodity group in each O-D region. Second, it is necessary to have a forecast of modal costs of service for each commodity group in each O-D region. These two forecasts will be based on the latest available economic data and economic forecasts for California and up-to-date modal cost data obtained from the 1990 ICC Carload Waybill Sample (revenue per ton-mile data for rail) and from a 1990 working paper on truck costs prepared by JFA for the Federal Highway Administration.[2] In the analysis of modal diversion effects associated with locomotive emission regulations, rail costs will be adjusted to take account of the effects of emission control technologies using data drawn primarily from *Controlling Locomotive Emissions in California: Technology, Cost-Effectiveness, and Regulatory Strategy* by Engine, Fuel, and Emissions Engineering, Inc. (October 1993). To the extent that there is some controversy surrounding the cost estimates for emissions reduction strategies contained in the EF&EE report, JFA proposes to conduct sensitivity analyses using a range of costs for each emission reduction technology, assuming that alternative cost data acceptable to the ARB can be obtained from industry sources. While the data used to calculate the modal sensitivity to cost of service parameters used in CALFED is drawn from 1977 sources, the use of more up-to-date data on modal shares and modal costs of service should provide more accurate estimates of modal diversion which reflect current goods movement patterns in California.

In light of the foregoing discussion, there are some clear advantages of the CALFED model for application in this study. These include:

- it is based on actual California shipment data;
- modal cost sensitivities are developed by commodity group and thus reflect the unique commodity characteristics which would favor one mode over another irrespective of modal costs (e.g., commodity value, use rate, shelf life, etc.);
- modal diversion is calculated for O-D pairs which reflects the actual production and consumption patterns of California economic regions and trade relationships with the rest of the nation; and
- it uses aggregate shipment data which is the only data readily available without additional survey work.

There are two principal disadvantages of CALFED. First, the modal cost sensitivity parameters are estimated using 1977 data. Given changes in the regulatory environment facing trucking and rail, the change in commodity characteristics, and the changes in rail and truck pricing practices, the use of the 1977 modal cost sensitivity parameters is likely to bias the results of the analysis

[2]Jack Faucett Associates, "The Effect of Size and Weight Limits on Truck Costs: Working Paper," prepared for the U.S. Department of Transportation, Federal Highway Administration, Washington, DC, June 1990.

to some extent. We believe that CALFED may have a tendency to slightly underestimate diversion. Second, CALFED only incorporates modal costs as the sole explanatory variable for modal diversion. To the extent that emission regulations impact other level of service variables, this could be a shortcoming. However, we believe that the principal effect of locomotive emission regulations which will impact mode choice is to raise rail costs. Thus, this last shortcoming of CALFED may be of limited significance for the current study.

The only other model identified in the literature review with any potential for overcoming the above-mentioned shortcomings was the AAR's Intermodal Competition Model (ICM). The ICM is a proprietary disaggregate model which has been maintained with data revisions over the last 15 years. When JFA approached AAR about using the ICM in this study, we were told that the model is not available for use by outside contractors and that the AAR would be unable to make the model available for use in this study. While the two models (CALFED and ICM) have very different theoretical approaches, we believe that the results which would be obtained using these models may not be too dissimilar. During a previous truck size and weight study for the Federal Highway Administration, JFA compared cross-elasticities of rail ton-miles with respect to trucking costs calculated from CALFED with results from ICM runs. These cross-elasticities show the percentage change in rail ton-miles which would result from a given change in trucking costs. In this comparison it was shown that for scenarios involving across the board reductions in rail-competitive trucking costs, cross elasticities computed with CALFED were less than 33% lower than those obtained with ICM. While the effects to be examined in this study are associated with increases in rail costs rather than decreases in trucking costs, we believe that the cross-elasticity comparisons made for the truck size and weight study provide an indication of how changes in the relative costs of rail vs. trucking might affect modal diversion calculations that are conducted with each model. These comparisons lead us to believe analyses conducted with CALFED should provide a good "ballpark" estimate of modal diversion effects as compared to ICM.

As stated above, in order to use CALFED, JFA will need to develop a reasonable estimate of baseline and forecasted modal shares in the absence of any regulations. Our approach to developing baseline commodity flows and modal shares is described in detail in Section 1.5 of the Task 1A draft chapter. In summary, base year economic data will be used to develop estimates of production and consumption of each commodity in each region. Data from the ICC Carload Waybill Sample, the Corps of Engineers Waterborne Commerce Statistics, and Census data for air cargo will be used to determine baseline flows for these modes. The residual production and consumption in each region will then be used to develop trucking flows among the regions (this is necessary due to the lack of good data on trucking flows available from public sources). Trucking flows will be developed using gravity model techniques. Forecasts of production and consumption by region will be developed from OBERS projections and other economic forecasts for the state as appropriate. Flows will be developed among the regions using a Frater model. Initially these flows will be allocated to modes using the base year modal shares. These will be adjusted for diversion which would have taken place in the absence of regulations by using the CALFED modal diversion algorithms and the modal cost data developed by JFA for the truck size and weight study described above.

Task 1B - Emissions Assessment

The underlying objective of this subtask is to develop a methodology that can be employed to evaluate the emission repercussions of modal shifts. Diversion will directly influence both truck and rail emissions in the state. From the perspective of railroad operations, diversion away from rail may change the number of trains that operate in the state at any given point in time, the average horsepower of the consist, the average trailing tons of the train, duty cycles, and other emission parameters. Moreover, changes in activity that result from diversion probably will not be evenly distributed across all locomotive types, nor across all segments or corridors. Similarly, significant levels of diversion from rail to truck may increase the number of trucks operating in the state and/or the average cargo weight per truck. Changes in any of these parameters will alter the emission profiles of these goods transport modes.

In addition to the effects of changes in relative activity on emissions, emission control regulations will change the emission factors of locomotives and trucks. For example, regulations that require the conversion of locomotives to LNG will directly impact the emission rate of a consist or train. Therefore, it is important to account for both the emission consequences of modal diversion and the emission consequences of control regulations when constructing emission forecasts under dynamic scenarios.

In order to answer the underlying question of how will freight mode-specific emissions change as a result of regulations and diversion, the following preliminary steps must be performed.

- First, a base year emissions inventory must be gathered for each freight mode. These base year inventories will be the basis from which changes in emissions will be calculated.
- Second, the reliability of the base year emission inventories must be assessed, and if necessary the base year inventories must be adjusted to account for inherent biases.
- Third, emission factors must be altered to reflect emission control strategies.
- Fourth, a methodology to assess the impacts of diversion on emissions by mode must be developed.

The base year for this study will be 1987 since emission inventories have been developed by ARB for that year. The base year inventories will be drawn from a variety of sources (see briefing package for JFA's Progress Meeting with ARB, February 16, 1994, page 17). For truck emissions, ARB's *Emission Inventory, 1987* (Emission Inventory Branch, March 1990) will be used. To be useful for this study, truck emission inventories presented in this ARB publication will need to be adjusted. Adjustments are needed because ARB's vehicle classification scheme includes all vehicles above 8,501 GVW as heavy-duty. This implies that ARB's HDV emission inventories include emissions from non-freight vehicles (such as passenger trucks and buses) and from vehicles that do not compete with rail (such as urban delivery trucks and trash trucks). Since the focus of this study will be on comparing emissions from line-haul freight modes, from a freight transport perspective the current inventories for heavy-duty vehicles published by ARB overstate the truck contribution. HDV emissions should only reflect those trucks that directly compete with rail (line-haul combination trucks). In order to perform these adjustments, JFA has contacted ARB's emissions inventory branch for guidance. They have agreed to provide us with revised inventories that only reflect the heavy-heavy duty component of the HDV fleet. Heavy-heavy is the classification for vehicles above 33,000 GVW. Although an adjustment based on this classification helps to resolve the problem, bias will still remain since line-haul combination trucks typically scale at 60,000 GVW and above.

Base year locomotive emissions will be drawn from ARB's *Locomotive Emissions Study* (Booz•Allen & Hamilton, March 1991). The inventories presented in this report are the official ARB estimates and, thus, should be the basis for this study. In any event, Booz•Allen's throttle notch analysis probably results in the most representative emission estimates given available data.

Base year inventories for the other goods transport modes, air and water, have been collected and are reported in the accompanying briefing package. However, the focus of the analysis in this study will be on truck and rail emissions.

The recalculation of emission factors to reflect regulatory initiatives will be conducted from data provided by the ARB, from data available in the Engine, Fuel, and Emissions Engineering, Inc. (EF&EE) report entitled *Controlling Locomotive Emissions in California*, and from data provided in Booz•Allen & Hamilton's report to ARB entitled *Locomotive Emissions Study* (including appendix and addendum).

ARB's Emissions Inventory Branch will provide emission factors for heavy-heavy duty vehicles. HDV emission factors will be provided on a grams/mile basis. Preliminary data has been provided that demonstrates the potential impacts of various regulatory programs to control heavy-duty vehicle (HDV) emissions. For example, the ARB has estimated the emission reductions due to cleaner diesel fuels to be as follows:

	NO_x	PM
Pre MY 91 Vehicles	7%	25%
MY 91 to 93 Vehicles	10%	45%

For the purpose of this study, one approach may be to adjust the base year emission factors for HDVs by percentage reductions estimated for the various regulatory initiatives that will be considered.

In any event, to forecast HDV emissions under diversion, we will need to convert the adjusted emission factors to a grams/revenue ton-mile basis. We will employ California specific information from the 1987 Truck Inventory and Use Survey (TIUS) on average payload or cargo weight to achieve this objective. The following equation reflects the general relationship that will allow for this conversion:

$$\text{grams/mile} \times 1/\text{revenue ton} = \text{grams/revenue ton-mile}$$

The forecast of truck emissions under diversity then becomes a simple exercise since the modal diversion model will provide forecasts on total revenue ton-miles by mode. Moreover, we will be able to distinguish between diversion effects and impacts attributable to increased activity irrespective of mode shifts.

The process for locomotives is more involved. We have reviewed the approaches that were used by EF&EE and Booz•Allen to estimate locomotive emissions. This review has identified key issues that ultimately constrain the level of accuracy that will be imbedded in our analysis. First, the EF&EE report contains some limitations that may not be possible to overcome. The most important of these is the lack of tons/year emission reduction estimates for **all** the locomotives that are expected to be operating across California in the future. EF&EE restricts their emission reduction analyses to a select number of locomotive types. Yet, as was mentioned in the February 16, 1994 workshop, the penetration of more efficient locomotives has been evident for years, and there is no reason to suspect that this will not continue. Therefore, limiting the analysis to older models may create bias in the results. However, we do not have emission reduction estimates for all the locomotives that likely are to be operating in California in the year 2010 (our proposed forecast year).

Booz•Allen & Hamilton recognizes the need to change the mix of locomotives in the fleet for its forecast of emissions. They change the mix by assuming a constant percentage increase in the penetration of newer, more efficient models. However, Booz•Allen's report does not provide emission forecasts under an emissions control regulatory scenario. So, it is not possible to use their estimates.

As a result of these constraints, we have developed an approach that relies on data from both reports and that makes various necessary simplifying assumptions. (It is important to keep in mind the scope of this project and the budget, approximately $84,000 for the entire project, that we have to work with in evaluating this approach and in providing comments and alternative methods.) Our proposed approach basically employs the more aggregate emissions calculation process that was used by EF&EE. It is centered on the assumption that locomotive-hours will scale **proportionally** to changes in revenue ton-miles. We will forecast locomotive emissions by calculating the sum of the following products:

- the adjusted notch-specific average NO_x emission factors for each locomotive type that is expected to be in-use in the forecast year;

- the notch-specific average duty cycles by type of service found in the EF&EE report; and

- the annual number of locomotive-hours by locomotive type and type of service adjusted to reflect diversion, growth in activity, and/or the penetration of newer, more efficient locomotives as suggested by the Booz●Allen study.

For the locomotive types that are included in the EF&EE report, we plan to adjust the notch-specific NO_x emission factors by the EF&EE tons/year emission reduction estimates (in percentage terms) to derive the emission factors for the regulatory scenarios that will be considered in this study. For those locomotives not included in the EF&EE report, we plan to adjust the emission factors presented in the Booz●Allen report by the EF&EE's average notch-specific emission reduction percentages. These notch-specific emission reductions will be averaged across all locomotive types included in the EF&EE report by type of service. We realize that this is not an accurate approach, but there currently does not exist another alternative that is within the scope and budget of this study. We are, however, open to suggestions from the Steering Committee, and we urge the Committee to provide us with alternatives.

The average notch-specific duty cycles used by EF&EE will be directly incorporated into this emissions forecasting approach. Given the lack of readily available information on the types and degrees of operational effects that can arise as a result of diversion (such as changes in average horsepower, average trailing tons, etc.), we are forced to make the simplifying assumption that duty cycles will not change in the future as a result of increased activity and/or diversion. For those locomotives not included in the EF&EE report, we will use the duty cycles presented in the Booz●Allen report. Therefore, we will be accounting for differences in duty cycles between older locomotives and newer, more efficient models.

The annual number of locomotive-hours by locomotive type and type of service will be proportionally scaled to reflect growth in revenue ton-miles without diversion and changes in revenue ton-miles that result from diversion. We will also alter the mix of locomotive-hours to reflect Booz●Allen's estimates of the penetration rates attributable to the newer locomotive models. The proportionality approach implies that if our diversion model estimates a 10% decrease in rail revenue ton-miles from a particular regulatory initiative, then the locomotive-hours for all locomotive types will be reduced by that 10%. We recognize that changes in activity levels are not likely to be distributed proportionally across all locomotive types. However, we do not expect this to create significant bias, especially when considered at the aggregate level. The magnitude of the bias is, therefore, expected to be small.

In this manner, we will forecast locomotive emissions that account for both changes in emission factors resulting from regulation and changes in activity that result from diversion and/or growth.

Task 1C — Emissions Comparison

The underlying objective of this subtask is to estimate the changes in relative emissions that result from regulatory initiatives to control emissions from the freight transport modes, especially trucks and rail. Therefore, the implementation of the methodologies that are outlined above for subtasks 1A and 1B will occur under this subtask.

Before this implementation takes place, however, we will need to conduct various preliminary analyses related to emission control regulations and strategies. Specifically, a prerequisite to the implementation process is the development of the regulatory scenarios to be included in this study for both locomotives and line-haul trucks and the estimation of changes in freight rates (rail and truck) for each scenario. The rate changes will drive the degree of diversion that is calculated by the CALFED model and ultimately the emission effects. As a result, the first activities that will be conducted under this subtask will be to evaluate proposed emission control regulations for each mode and define the regulatory bundles that will be analyzed. Second, for each regulatory strategy in a bundle, the estimated emission reductions must be identified. These reductions can then be used to adjust the emission factors. Finally, for each regulatory bundle, associated costs must be calculated and spread to the California portion of freight movements.

JFA has begun the review of the regulatory initiatives that are being considered by ARB for trucks and locomotives. There are a number of initiatives on the table for heavy-duty vehicles operating in California. These are outlined in the accompanying briefing package on pages 26 through 27. The costs associated with various HDV emission control strategies are also outlined in the briefing package. We are currently investigating approaches to translating these costs to a program level and eventually to a freight rate change level. For locomotives, we will select from the proposed strategies that EF&EE has outlined in their report. Similarly, the costs attributable to the programs specified by EF&EE are outlined in detailed in that report. Costs are provided at the program level and must also be translated to the freight rate change level. We are currently investigating approaches to conduct this translation and are open to suggestion by the Steering Committee. A special concern is the distribution of program level costs to the California portions of hauls.

Once we have defined the regulatory bundles for the analysis, the corresponding emission impacts, and the freight rate impacts, we will implement the methodologies discussed under subtasks 1A and 1B.

Task 2A — Marketability Review

JFA is reviewing the literature relevant to the marketing of emission allowances and other closely related economic incentives including emission reduction credits, emissions averaging, and declining emission caps. JFA's review covers three types of information:

- Documents and reports prepared by or for ARB.
- Papers appearing in the economics literature on emissions trading.
- Regulations prepared by federal, state, and local governmental agencies. These regulations include the federal implementation plan (FIP) prepared by the U.S. EPA for the Sacramento, Ventura, and South Coast air basins; U.S. EPA's Economic Incentive Programs Rule; U.S. EPA's conformance rules; the mobile to stationary source emission reduction credit trading program prepared by SMAQMD; and the RECLAIM program prepared by SCAQMD.

ARB Memoranda and Consultant Reports

To identify the issues of concern to ARB, JFA reviewed ARB memoranda and consultant reports on the control of locomotive exhaust emissions. ARB's deliberations show steady movement towards a rational plan for emission trading of NO_x from locomotives.[3] The ARB has recognized the need for and benefits of:

- a flexible cap on NO_x emissions from locomotives in each air district that may be applied in each air basin's State Implementation Plan (SIP) or Federal Implementation Plan (FIP) — the cap would adjust based on changes in activity;
- trading of intra-basin emission limits between various operations within individual railroads and between railroads;
- a mechanism to allow for the growth of rail traffic; and
- the consideration of the potential impact on truck and marine emissions when developing a regulatory strategy for locomotive emissions.

In addition, ARB has entertained the possibility of extending trading beyond locomotive emissions to include other transportation emissions and stationary source emissions. Complicating ARB's considerations are: the intersecting roles of air quality management districts, which must develop SIPs; the ARB, which is developing regulations for NO_x reductions from locomotives; the U.S. EPA, which is developing emission trading and is preparing FIPs for several AQMDs in California; and the preemption by the U.S. Clean Air Act Amendments of 1990, which place the authority for setting standards for emissions from new locomotives with the U.S. EPA.

These documents raised the following three issues:

- how to accommodate economic growth, given that locomotive emissions are capped;
- how to diminish the tendency of stringent regulations on locomotives, or caps on locomotive emissions, to increase the share of shipments by truck; and
- how to integrate the roles of the ARB in developing an emission trading system

[3] ARB Mailout No. 91-34. *Notice of Public Meeting to Consider Approval of the Final Report of the Locomotive Emission Advisory Committee Regarding the Feasibility and Cost-Effectiveness of Controlling Emissions from Locomotives Operated in California*. August 1991; ARB Mailout No. 91-36 *Notice of Public Meeting to Consider a Regulatory Plan for the Control of Locomotive Exhaust Emissions*. August 1991; ARB Mailout No. 92-55. *Regulatory Measures to Control Locomotive Exhaust Emissions in the State of California*. December 1992; ARB Mailout No. 93-48. *Notice of Public Meeting to Consider a Report to the Legislature on Emission Reductions from Locomotives Operating in California*. November 1993.

with the roles of the air quality management districts and U.S. EPA.

Economic Literature

The economic literature does not directly address trading of NO_x emissions from locomotives. However, the following relevant issues were identified:

- how differential environmental regulations (for example, differences in treatment of rail emissions and truck emissions) can distort the regulatory outcome, possibly leading to emissions increases rather than decreases;
- how to ensure that long-term markets for NO_x emissions are sufficiently efficient and free of risk that government will change the rules to support major decisions affecting capital investments by the railroads;
- how to keep transactions costs at a level that supports frequent spot market and short-term market transactions; and
- widespread concern among economists that the degree of uncertainty in the operation of trading programs will not support costly long-term investment programs.

Recent Regulatory Developments

New regulations, rules, and guidelines are currently being prepared and other recently developed regulatory programs are breaking new ground. These regulatory materials raise numerous issues related to emissions trading and propose new forms of emissions trading. Therefore, it is vital that JFA keep abreast of the issues raised in these documents.

For example, the U.S. EPA signed off on the FIP for the Sacramento, Ventura, and South Coast regions on February 15, 1994. The FIP includes comments directly applicable to the trading of locomotive emissions, such as:

- emission averaging of locomotive emissions in the South Coast region;
- emission limits on freshly manufactured locomotives;
- a standard for remanufactured engines — average 8 g/hp-hr or less;
- emission limits on all heavy duty trucks registered in California;
- restricted access to California for heavy duty trucks not certified to meet California standards; and

- a one month averaging time for sources involved in emissions trading as compared to the one year averaging time envisioned in RECLAIM.

In addition, the U.S. EPA obtained a delay until March 15, 1994 for releasing its Economic Incentive Programs Rule. The reason for the delay is to consider whether too much of the benefits of trading are going to industry. This leads us to believe that the new rule will have features such as high offset ratios that work against emission trading similar to the emission trading guidelines published in the mid-1980s.

The U.S. EPA's conformance rules place a requirement on SIP developers and transportation planners to maintain the emission budgets they use in their SIP demonstrations. This may imply that truck and rail emissions are already capped and that SIP planners will have to closely consider how projections of truck emissions are affected by regulations on locomotive emissions.

At the state level, the SMAQMD has implemented a mobile to stationary credit trading program and will soon implement a mobile to mobile program. Under this program, mobile credit values determined using ARB guidance and credits established on a vehicle-by-vehicle basis. The program requires enactment of fleet rules for effectiveness — or an active spot market. Moreover, the SMAQMD is currently investigating the incorporation of locomotives by focusing on passenger trains.

In addition, the SCAQMD's RECLAIM program provides some relevant background on emission credit programs in California. Literature on the program describes their NO_x trading program for stationary sources and discusses general rules for allowing emission trades. An example of the level of detail required in the measurement of emissions to be traded is also provided. Although SCAQMD's program establishes NO_x trading for stationary sources, RECLAIM offers a possible vehicle for trades between stationary and mobile sources. It will be necessary to consider how any locomotive emission trading program can be incorporated with RECLAIM.

Discussion of Key Issues

Based on the documents discussed above, JFA has identified five key issues that must be resolved in order to design a declining cap on locomotive emissions.

1) Whether or not to Place a Flexible Cap on Locomotive NO_x Emissions — Because trucks and trains are such close substitutes, capping emissions from trains but not from trucks could aggravate the emissions problem. The problem is to identify the conditions under which capping locomotive emissions is part of a cost-effective program for reducing NO_x emissions.

2) Ensuring the Viability of Long-term Markets — In order to encourage railroads to make long term investments based on emissions trading transactions, the durability and stability of the trading system must be guaranteed.

3) *Reducing Transactions Costs* — High transactions costs will limit the use of emissions trading. Ways of keeping the transactions costs of an emissions trading system need to be investigated.

4) *Averaging Times and Other Technical Issues* — The FIP suggests that averaging times for sources involved in emissions trading be one month rather than one year as specified in RECLAIM. The pros and cons of this and other technical issues must be considered.

5) *Overlapping Jurisdictions* — The U.S. EPA, ARB, and local AQMDs are all involved in regulating locomotive emissions. In addition to the potential for conflicting regulations, there are already conflicting time tables. The emission trading systems to be considered should be adaptable to these circumstances.

JFA is in the process of finalizing a draft chapter for this subtask that will review and analyze these issues and adapt them to the setting of locomotive emissions in California.

Task 2B: Market Design

Once the underlying issues have been characterized, JFA will develop emission trading schemes. The underlying objective is to identify specific emission trading programs applicable to NO_x emissions from locomotives in California. The approach employed by JFA includes the following steps. First, in consultation with ARB, JFA will develop options for defining each element of the emission trading system. These elements include the trading goal, the trading universe, the emission baseline, the unit of trade, and the trading rule. Second, JFA will define, describe, and assess three internally consistent trading systems and prepare recommendations.

We envision that the systems we will suggest will include the following central feature: declining caps on NO_x emissions from locomotives, line-haul trucks, and major stationary sources, with emission trading allowed among all three types of sources. The ARB will enact the cap on locomotive emissions, but it must address concerns that truck emissions do not increase as a result. As an example, some local AQMDs have already placed declining caps on major stationary sources of NO_x. But we believe that placing a flexible cap on truck emissions will be much more difficult (conformity rules seem to require that it be done, however).

Other features of the systems that we envision include:

- a system of "dated" emission allocations showing each firm's allocation of NO_x emissions by year for the next twenty years, including clear rules as to how emission allocations beyond that time frame will be determined;

- an allowance for the trade of any number of emissions allocations in any year (current or future), where a trade becomes valid as soon as it is duly submitted to ARB;

- a criterion that no increases in total NO_x emissions in any air shed occur as the basis of ARB's administration of emissions trading; and

- a rule that no extra emission reduction be required to make up for uncertainty in the measurement of locomotive emissions.

Appendix B

Mileage Estimates From BEA Area to State Border by Interstate Route

APPENDIX B

Highway Mileage Estimates Between California BEA Areas

REDDING

Origin/Destination	Interstate I5	I8	I10	I15	I40	I80	Total
Alabama	672	168	0	0	0	0	840
Alaska	117	0	0	0	0	0	117
Arizona	442	0	0	0	277	0	719
Arkansas	442	0	0	0	277	0	719
Colorado	163	0	0	0	0	133	296
Connecticut	163	0	0	0	0	133	296
Delaware	163	0	0	0	0	133	296
District of Columbia	163	0	0	0	0	133	296
Florida	672	168	0	0	0	0	840
Georgia	442	0	0	0	277	0	719
Hawaii	0	0	0	0	0	0	0
Idaho	163	0	0	0	0	133	296
Illinois	163	0	0	0	0	133	296
Indiana	163	0	0	0	0	133	296
Iowa	163	0	0	0	0	133	296
Kansas	163	0	0	0	0	133	296
Kentucky	442	0	0	0	277	0	719
Louisiana	672	168	0	0	0	0	840
Maine	163	0	0	0	0	133	296
Maryland	163	0	0	0	0	133	296
Massachusetts	163	0	0	0	0	133	296
Michigan	163	0	0	0	0	133	296
Minnesota	163	0	0	0	0	133	296
Mississippi	672	168	0	0	0	0	840
Missouri	163	0	0	0	0	133	296
Montana	163	0	0	0	0	133	296
Nebraska	163	0	0	0	0	133	296
Nevada	163	0	0	0	0	133	296
New Hampshire	163	0	0	0	0	133	296
New Jersey	163	0	0	0	0	133	296
New Mexico	442	0	0	0	277	0	719
New York	163	0	0	0	0	133	296
North Carolina	442	0	0	0	277	0	719
North Dakota	163	0	0	0	0	133	296
Ohio	163	0	0	0	0	133	296
Oklahoma	442	0	0	0	277	0	719
Oregon	117	0	0	0	0	0	117
Pennsylvania	163	0	0	0	0	133	296
Rhode Island	163	0	0	0	0	133	296
South Carolina	442	0	0	0	277	0	719
South Dakota	163	0	0	0	0	133	296
Tennessee	442	0	0	0	277	0	719
Texas	672	168	0	0	0	0	840
Utah	163	0	0	0	0	133	296
Vermont	163	0	0	0	0	133	296
Virginia	163	0	0	0	0	133	296
Washington	117	0	0	0	0	0	117
West Virginia	163	0	0	0	0	133	296
Wisconsin	163	0	0	0	0	133	296
Wyoming	163	0	0	0	0	133	296

APPENDIX B
Highway Mileage Estimates Between California BEA Areas

EUREKA

Origin/Destination	Interstate I5	I8	I10	I15	I40	I80	Total
Alabama	672	168	0	0	0	0	840
Alaska	117	0	0	0	0	0	117
Arizona	442	0	0	0	277	0	719
Arkansas	442	0	0	0	277	0	719
Colorado	163	0	0	0	0	133	296
Connecticut	163	0	0	0	0	133	296
Delaware	163	0	0	0	0	133	296
District of Columbia	163	0	0	0	0	133	296
Florida	672	168	0	0	0	0	840
Georgia	442	0	0	0	277	0	719
Hawaii	0	0	0	0	0	0	0
Idaho	163	0	0	0	0	133	296
Illinois	163	0	0	0	0	133	296
Indiana	163	0	0	0	0	133	296
Iowa	163	0	0	0	0	133	296
Kansas	163	0	0	0	0	133	296
Kentucky	442	0	0	0	277	0	719
Louisiana	672	168	0	0	0	0	840
Maine	163	0	0	0	0	133	296
Maryland	163	0	0	0	0	133	296
Massachusetts	163	0	0	0	0	133	296
Michigan	163	0	0	0	0	133	296
Minnesota	163	0	0	0	0	133	296
Mississippi	672	168	0	0	0	0	840
Missouri	163	0	0	0	0	133	296
Montana	163	0	0	0	0	133	296
Nebraska	163	0	0	0	0	133	296
Nevada	163	0	0	0	0	133	296
New Hampshire	163	0	0	0	0	133	296
New Jersey	163	0	0	0	0	133	296
New Mexico	442	0	0	0	277	0	719
New York	163	0	0	0	0	133	296
North Carolina	442	0	0	0	277	0	719
North Dakota	163	0	0	0	0	133	296
Ohio	163	0	0	0	0	133	296
Oklahoma	442	0	0	0	277	0	719
Oregon	117	0	0	0	0	0	117
Pennsylvania	163	0	0	0	0	133	296
Rhode Island	163	0	0	0	0	133	296
South Carolina	442	0	0	0	277	0	719
South Dakota	163	0	0	0	0	133	296
Tennessee	442	0	0	0	277	0	719
Texas	672	168	0	0	0	0	840
Utah	163	0	0	0	0	133	296
Vermont	163	0	0	0	0	133	296
Virginia	163	0	0	0	0	133	296
Washington	117	0	0	0	0	0	117
West Virginia	163	0	0	0	0	133	296
Wisconsin	163	0	0	0	0	133	296
Wyoming	163	0	0	0	0	133	296

APPENDIX B
Highway Mileage Estimates Between California BEA Areas

SAN FRANCISCO

Origin/Destination	Interstate I5	I8	I10	I15	I40	I80	Total
Alabama	387	0	228	0	0	0	615
Alaska	335	0	0	0	0	0	335
Arizona	284	0	0	0	277	0	561
Arkansas	284	0	0	0	277	0	561
Colorado	0	0	0	0	0	226	226
Connecticut	0	0	0	0	0	226	226
Delaware	0	0	0	0	0	226	226
District of Columbia	0	0	0	0	0	226	226
Florida	387	0	228	0	0	0	615
Georgia	284	0	0	0	277	0	561
Hawaii	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	226	226
Illinois	0	0	0	0	0	226	226
Indiana	0	0	0	0	0	226	226
Iowa	0	0	0	0	0	226	226
Kansas	0	0	0	0	0	226	226
Kentucky	0	0	0	0	0	226	226
Louisiana	387	0	228	0	0	0	615
Maine	0	0	0	0	0	226	226
Maryland	0	0	0	0	0	226	226
Massachusetts	0	0	0	0	0	226	226
Michigan	0	0	0	0	0	226	226
Minnesota	0	0	0	0	0	226	226
Mississippi	387	0	228	0	0	0	615
Missouri	0	0	0	0	0	226	226
Montana	0	0	0	0	0	226	226
Nebraska	0	0	0	0	0	226	226
Nevada	0	0	0	0	0	226	226
New Hampshire	0	0	0	0	0	226	226
New Jersey	0	0	0	0	0	226	226
New Mexico	284	0	0	0	277	0	561
New York	0	0	0	0	0	226	226
North Carolina	284	0	0	0	277	0	561
North Dakota	0	0	0	0	0	226	226
Ohio	0	0	0	0	0	226	226
Oklahoma	284	0	0	0	277	0	561
Oregon	335	0	0	0	0	0	335
Pennsylvania	0	0	0	0	0	226	226
Rhode Island	0	0	0	0	0	226	226
South Carolina	284	0	0	0	277	0	561
South Dakota	0	0	0	0	0	226	226
Tennessee	284	0	0	0	277	0	561
Texas	387	0	228	0	0	0	615
Utah	0	0	0	0	0	226	226
Vermont	0	0	0	0	0	226	226
Virginia	0	0	0	0	0	226	226
Washington	335	0	0	0	0	0	335
West Virginia	0	0	0	0	0	226	226
Wisconsin	0	0	0	0	0	226	226
Wyoming	0	0	0	0	0	226	226

APPENDIX B
Highway Mileage Estimates Between California BEA Areas

SACRAMENTO

Origin/Destination	Interstate I5	I8	I10	I15	I40	I80	Total
Alabama	387	0	228	0	0	0	615
Alaska	335	0	0	0	0	0	335
Arizona	284	0	0	0	277	0	561
Arkansas	284	0	0	0	277	0	561
Colorado	0	0	0	0	0	226	226
Connecticut	0	0	0	0	0	226	226
Delaware	0	0	0	0	0	226	226
District of Columbia	0	0	0	0	0	226	226
Florida	387	0	228	0	0	0	615
Georgia	284	0	0	0	277	0	561
Hawaii	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	226	226
Illinois	0	0	0	0	0	226	226
Indiana	0	0	0	0	0	226	226
Iowa	0	0	0	0	0	226	226
Kansas	0	0	0	0	0	226	226
Kentucky	0	0	0	0	0	226	226
Louisiana	387	0	228	0	0	0	615
Maine	0	0	0	0	0	226	226
Maryland	0	0	0	0	0	226	226
Massachusetts	0	0	0	0	0	226	226
Michigan	0	0	0	0	0	226	226
Minnesota	0	0	0	0	0	226	226
Mississippi	387	0	228	0	0	0	615
Missouri	0	0	0	0	0	226	226
Montana	0	0	0	0	0	226	226
Nebraska	0	0	0	0	0	226	226
Nevada	0	0	0	0	0	226	226
New Hampshire	0	0	0	0	0	226	226
New Jersey	0	0	0	0	0	226	226
New Mexico	284	0	0	0	277	0	561
New York	0	0	0	0	0	226	226
North Carolina	284	0	0	0	277	0	561
North Dakota	0	0	0	0	0	226	226
Ohio	0	0	0	0	0	226	226
Oklahoma	284	0	0	0	277	0	561
Oregon	335	0	0	0	0	0	335
Pennsylvania	0	0	0	0	0	226	226
Rhode Island	0	0	0	0	0	226	226
South Carolina	284	0	0	0	277	0	561
South Dakota	0	0	0	0	0	226	226
Tennessee	284	0	0	0	277	0	561
Texas	387	0	228	0	0	0	615
Utah	0	0	0	0	0	226	226
Vermont	0	0	0	0	0	226	226
Virginia	0	0	0	0	0	226	226
Washington	335	0	0	0	0	0	335
West Virginia	0	0	0	0	0	226	226
Wisconsin	0	0	0	0	0	226	226
Wyoming	0	0	0	0	0	226	226

APPENDIX B
Highway Mileage Estimates Between California BEA Areas

STOCKTON

Origin/Destination	Interstate I5	I8	I10	I15	I40	I80	Total
Alabama	387	0	228	0	0	0	615
Alaska	335	0	0	0	0	0	335
Arizona	284	0	0	0	277	0	561
Arkansas	284	0	0	0	277	0	561
Colorado	0	0	0	0	0	226	226
Connecticut	0	0	0	0	0	226	226
Delaware	0	0	0	0	0	226	226
District of Columbia	0	0	0	0	0	226	226
Florida	387	0	228	0	0	0	615
Georgia	284	0	0	0	277	0	561
Hawaii	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	226	226
Illinois	0	0	0	0	0	226	226
Indiana	0	0	0	0	0	226	226
Iowa	0	0	0	0	0	226	226
Kansas	0	0	0	0	0	226	226
Kentucky	0	0	0	0	0	226	226
Louisiana	387	0	228	0	0	0	615
Maine	0	0	0	0	0	226	226
Maryland	0	0	0	0	0	226	226
Massachusetts	0	0	0	0	0	226	226
Michigan	0	0	0	0	0	226	226
Minnesota	0	0	0	0	0	226	226
Mississippi	387	0	228	0	0	0	615
Missouri	0	0	0	0	0	226	226
Montana	0	0	0	0	0	226	226
Nebraska	0	0	0	0	0	226	226
Nevada	0	0	0	0	0	226	226
New Hampshire	0	0	0	0	0	226	226
New Jersey	0	0	0	0	0	226	226
New Mexico	284	0	0	0	277	0	561
New York	0	0	0	0	0	226	226
North Carolina	284	0	0	0	277	0	561
North Dakota	0	0	0	0	0	226	226
Ohio	0	0	0	0	0	226	226
Oklahoma	284	0	0	0	277	0	561
Oregon	335	0	0	0	0	0	335
Pennsylvania	0	0	0	0	0	226	226
Rhode Island	0	0	0	0	0	226	226
South Carolina	284	0	0	0	277	0	561
South Dakota	0	0	0	0	0	226	226
Tennessee	284	0	0	0	277	0	561
Texas	387	0	228	0	0	0	615
Utah	0	0	0	0	0	226	226
Vermont	0	0	0	0	0	226	226
Virginia	0	0	0	0	0	226	226
Washington	335	0	0	0	0	0	335
West Virginia	0	0	0	0	0	226	226
Wisconsin	0	0	0	0	0	226	226
Wyoming	0	0	0	0	0	226	226

APPENDIX B
Highway Mileage Estimates Between California BEA Areas

FRESNO

Origin/Destination	Interstate I5	I8	I10	I15	I40	I80	Total
Alabama	387	0	228	0	0	0	615
Alaska	335	0	0	0	0	0	335
Arizona	284	0	0	0	277	0	561
Arkansas	284	0	0	0	277	0	561
Colorado	0	0	0	0	0	226	226
Connecticut	0	0	0	0	0	226	226
Delaware	0	0	0	0	0	226	226
District of Columbia	0	0	0	0	0	226	226
Florida	387	0	228	0	0	0	615
Georgia	284	0	0	0	277	0	561
Hawaii	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	226	226
Illinois	0	0	0	0	0	226	226
Indiana	0	0	0	0	0	226	226
Iowa	0	0	0	0	0	226	226
Kansas	0	0	0	0	0	226	226
Kentucky	0	0	0	0	0	226	226
Louisiana	387	0	228	0	0	0	615
Maine	0	0	0	0	0	226	226
Maryland	0	0	0	0	0	226	226
Massachusetts	0	0	0	0	0	226	226
Michigan	0	0	0	0	0	226	226
Minnesota	0	0	0	0	0	226	226
Mississippi	387	0	228	0	0	0	615
Missouri	0	0	0	0	0	226	226
Montana	0	0	0	0	0	226	226
Nebraska	0	0	0	0	0	226	226
Nevada	0	0	0	0	0	226	226
New Hampshire	0	0	0	0	0	226	226
New Jersey	0	0	0	0	0	226	226
New Mexico	284	0	0	0	277	0	561
New York	0	0	0	0	0	226	226
North Carolina	284	0	0	0	277	0	561
North Dakota	0	0	0	0	0	226	226
Ohio	0	0	0	0	0	226	226
Oklahoma	284	0	0	0	277	0	561
Oregon	335	0	0	0	0	0	335
Pennsylvania	0	0	0	0	0	226	226
Rhode Island	0	0	0	0	0	226	226
South Carolina	284	0	0	0	277	0	561
South Dakota	0	0	0	0	0	226	226
Tennessee	284	0	0	0	277	0	561
Texas	387	0	228	0	0	0	615
Utah	0	0	0	0	0	226	226
Vermont	0	0	0	0	0	226	226
Virginia	0	0	0	0	0	226	226
Washington	335	0	0	0	0	0	335
West Virginia	0	0	0	0	0	226	226
Wisconsin	0	0	0	0	0	226	226
Wyoming	0	0	0	0	0	226	226

APPENDIX B
Highway Mileage Estimates Between California BEA Areas

LOS ANGELES

Origin/Destination	Interstate I5	I8	I10	I15	I40	I80	Total
Alabama	0	0	238	0	0	0	238
Alaska	660	0	0	0	0	0	660
Arizona	0	0	238	0	0	0	238
Arkansas	0	0	0	0	285	0	285
Colorado	0	0	0	237	0	0	237
Connecticut	0	0	0	0	285	0	285
Delaware	0	0	0	0	285	0	285
District of Columbia	0	0	0	0	285	0	285
Florida	0	0	238	0	0	0	238
Georgia	0	0	238	0	0	0	238
Hawaii	0	0	0	0	0	0	0
Idaho	0	0	0	237	0	0	237
Illinois	0	0	0	0	285	0	285
Indiana	0	0	0	0	285	0	285
Iowa	0	0	0	237	0	0	237
Kansas	0	0	0	0	285	0	285
Kentucky	0	0	0	0	285	0	285
Louisiana	0	0	238	0	0	0	238
Maine	0	0	0	0	285	0	285
Maryland	0	0	0	0	285	0	285
Massachusetts	0	0	0	0	285	0	285
Michigan	0	0	0	0	285	0	285
Minnesota	0	0	0	237	0	0	237
Mississippi	0	0	238	0	0	0	238
Missouri	0	0	0	0	285	0	285
Montana	0	0	0	237	0	0	237
Nebraska	0	0	0	237	0	0	237
Nevada	0	0	0	237	0	0	237
New Hampshire	0	0	0	0	285	0	285
New Jersey	0	0	0	0	285	0	285
New Mexico	0	0	0	0	285	0	285
New York	0	0	0	0	285	0	285
North Carolina	0	0	0	0	285	0	285
North Dakota	0	0	0	237	0	0	237
Ohio	0	0	0	0	285	0	285
Oklahoma	0	0	0	0	285	0	285
Oregon	660	0	0	0	0	0	660
Pennsylvania	0	0	0	0	285	0	285
Rhode Island	0	0	0	0	285	0	285
South Carolina	0	0	0	0	285	0	285
South Dakota	0	0	0	237	0	0	237
Tennessee	0	0	0	0	285	0	285
Texas	0	0	238	0	0	0	238
Utah	0	0	0	237	0	0	237
Vermont	0	0	0	0	285	0	285
Virginia	0	0	0	0	285	0	285
Washington	660	0	0	0	0	0	660
West Virginia	0	0	0	0	285	0	285
Wisconsin	0	0	0	237	0	0	237
Wyoming	0	0	0	237	0	0	237

APPENDIX B
Highway Mileage Estimates Between California BEA Areas

SAN DIEGO

Origin/Destination	I5	I8	I10	I15	I40	I80	Total
	Interstate						
Alabama	0	168	0	0	0	0	168
Alaska	789	0	0	0	0	0	789
Arizona	0	168	0	0	0	0	168
Arkansas	0	168	0	0	0	0	168
Colorado	0	0	0	339	0	0	339
Connecticut	0	0	0	339	0	0	339
Delaware	0	0	0	339	0	0	339
District of Columbia	0	0	0	339	0	0	339
Florida	0	168	0	0	0	0	168
Georgia	0	168	0	0	0	0	168
Hawaii	0	0	0	0	0	0	0
Idaho	0	0	0	339	0	0	339
Illinois	0	0	0	339	0	0	339
Indiana	0	0	0	339	0	0	339
Iowa	0	0	0	339	0	0	339
Kansas	0	0	0	339	0	0	339
Kentucky	0	168	0	0	0	0	168
Louisiana	0	168	0	0	0	0	168
Maine	0	0	0	339	0	0	339
Maryland	0	0	0	339	0	0	339
Massachusetts	0	0	0	339	0	0	339
Michigan	0	0	0	339	0	0	339
Minnesota	0	0	0	339	0	0	339
Mississippi	0	168	0	0	0	0	168
Missouri	0	0	0	339	0	0	339
Montana	0	0	0	339	0	0	339
Nebraska	0	0	0	339	0	0	339
Nevada	0	0	0	339	0	0	339
New Hampshire	0	0	0	339	0	0	339
New Jersey	0	0	0	339	0	0	339
New Mexico	0	168	0	0	0	0	168
New York	0	0	0	339	0	0	339
North Carolina	0	168	0	0	0	0	168
North Dakota	0	0	0	339	0	0	339
Ohio	0	0	0	339	0	0	339
Oklahoma	0	168	0	0	0	0	168
Oregon	789	0	0	0	0	0	789
Pennsylvania	0	0	0	339	0	0	339
Rhode Island	0	0	0	339	0	0	339
South Carolina	0	168	0	0	0	0	168
South Dakota	0	0	0	339	0	0	339
Tennessee	0	168	0	0	0	0	168
Texas	0	168	0	0	0	0	168
Utah	0	0	0	339	0	0	339
Vermont	0	0	0	339	0	0	339
Virginia	0	0	0	339	0	0	339
Washington	789	0	0	0	0	0	789
West Virginia	0	168	0	0	0	0	168
Wisconsin	0	0	0	339	0	0	339
Wyoming	0	0	0	339	0	0	339

APPENDIX B

Highway Mileage Estimates Between California BEA Areas

	Redding	Eureka	San Francisco	Sacramento	Stockton	Fresno	Los Angeles	San Diego
Redding	68	154	215	163	214	327	545	672
Eureka	154	40	281	298	332	462	680	807
San Francisco	215	281	81	95	82	183	387	514
Sacramento	163	298	95	75	51	164	382	509
Stockton	214	332	82	51	68	124	335	459
Fresno	327	462	183	164	124	80	211	336
Los Angeles	545	680	387	382	335	211	95	124
San Diego	672	807	514	509	459	336	124	80

Appendix C

Average Mileage Estimates From BEA Area to State Border for Interstate Rail Movements

APPENDIX C
Average Mileage From BEA Area to State Border for Interstate Rail Movements

REDDING

Origin/Destination	Entry/Exit Route					Total
	Klamath	Reno	Williams	Yuma	Las Vegas	
Alabama	0	181	0	0	0	181
Alaska	150	0	0	0	0	150
Arizona	0	0	0	800	0	800
Arkansas	0	181	0	0	0	181
Colorado	0	181	0	0	0	181
Connecticut	0	181	0	0	0	181
Delaware	0	181	0	0	0	181
District of Columbia	0	181	0	0	0	181
Florida	0	181	0	0	0	181
Georgia	0	181	0	0	0	181
Hawaii	0	0	0	0	0	0
Idaho	151	0	0	0	0	151
Illinois	0	181	0	0	0	181
Indiana	0	181	0	0	0	181
Iowa	0	181	0	0	0	181
Kansas	0	181	0	0	0	181
Kentucky	0	181	0	0	0	181
Louisiana	0	181	0	0	0	181
Maine	0	181	0	0	0	181
Maryland	0	181	0	0	0	181
Massachusetts	0	181	0	0	0	181
Michigan	0	181	0	0	0	181
Minnesota	0	181	0	0	0	181
Mississippi	0	181	0	0	0	181
Missouri	0	181	0	0	0	181
Montana	150	0	0	0	0	150
Nebraska	0	181	0	0	0	181
Nevada	0	181	0	0	0	181
New Hampshire	0	181	0	0	0	181
New Jersey	0	181	0	0	0	181
New Mexico	0	0	0	800	0	800
New York	0	181	0	0	0	181
North Carolina	0	181	0	0	0	181
North Dakota	0	181	0	0	0	181
Ohio	0	181	0	0	0	181
Oklahoma	0	181	0	0	0	181
Oregon	150	0	0	0	0	150
Pennsylvania	0	181	0	0	0	181
Rhode Island	0	181	0	0	0	181
South Carolina	0	181	0	0	0	181
South Dakota	0	181	0	0	0	181
Tennessee	0	181	0	0	0	181
Texas	0	181	0	0	0	181
Utah	0	181	0	0	0	181
Vermont	0	181	0	0	0	181
Virginia	0	181	0	0	0	181
Washington	150	0	0	0	0	150
West Virginia	0	181	0	0	0	181
Wisconsin	0	181	0	0	0	181
Wyoming	0	181	0	0	0	181

APPENDIX C

Average Mileage From BEA Area to State Border for Interstate Rail Movements

EUREKA

Origin/Destination	Entry/Exit Route					Total
	Klamath	Reno	Williams	Yuma	Las Vegas	
Alabama	0	0	870	0	0	870
Alaska	445	0	0	0	0	445
Arizona	0	0	870	0	0	870
Arkansas	0	0	870	0	0	870
Colorado	0	490	0	0	0	490
Connecticut	0	490	0	0	0	490
Delaware	0	490	0	0	0	490
District of Columbia	0	490	0	0	0	490
Florida	0	0	870	0	0	870
Georgia	0	0	870	0	0	870
Hawaii	0	0	0	0	0	0
Idaho	445	0	0	0	0	445
Illinois	0	490	0	0	0	490
Indiana	0	490	0	0	0	490
Iowa	0	490	0	0	0	490
Kansas	0	490	0	0	0	490
Kentucky	0	490	0	0	0	490
Louisiana	0	0	870	0	0	870
Maine	0	490	0	0	0	490
Maryland	0	490	0	0	0	490
Massachusetts	0	490	0	0	0	490
Michigan	0	490	0	0	0	490
Minnesota	0	490	0	0	0	490
Mississippi	0	0	870	0	0	870
Missouri	0	490	0	0	0	490
Montana	445	0	0	0	0	445
Nebraska	0	490	0	0	0	490
Nevada	0	490	0	0	0	490
New Hampshire	0	490	0	0	0	490
New Jersey	0	490	0	0	0	490
New Mexico	0	0	870	0	0	870
New York	0	490	0	0	0	490
North Carolina	0		870	0	0	870
North Dakota	0	490	0	0	0	490
Ohio	0	490	0	0	0	490
Oklahoma	0	0	870	0	0	870
Oregon	445	0	0	0	0	445
Pennsylvania	0	490	0	0	0	490
Rhode Island	0	490	0	0	0	490
South Carolina	0	0	870	0	0	870
South Dakota	0	490	0	0	0	490
Tennessee	0	0	870	0	0	870
Texas	0	0	870	0	0	870
Utah	0	490	0	0	0	490
Vermont	0	490	0	0	0	490
Virginia	0	490	0	0	0	490
Washington	445	0	0	0	0	445
West Virginia	0	490	0	0	0	490
Wisconsin	0	490	0	0	0	490
Wyoming	0	490	0	0	0	490

APPENDIX C
Average Mileage From BEA Area to State Border for Interstate Rail Movements

SAN FRANCISCO

Origin/Destination	Klamath	Reno	Williams	Yuma	Las Vegas	Total
	Entry/Exit Route					
Alabama	0	0	636	0	0	636
Alaska	400	0	0	0	0	400
Arizona	0	0	636	0	0	636
Arkansas	0	0	636	0	0	636
Colorado	0	282	0	0	0	282
Connecticut	0	282	0	0	0	282
Delaware	0	282	0	0	0	282
District of Columbia	0	282	0	0	0	282
Florida	0	0	636	0	0	636
Georgia	0	0	636	0	0	636
Hawaii	0	0	0	0	0	0
Idaho	0	282	0	0	0	282
Illinois	0	282	0	0	0	282
Indiana	0	282	0	0	0	282
Iowa	0	282	0	0	0	282
Kansas	0	282	0	0	0	282
Kentucky	0	282	0	0	0	282
Louisiana	0	0	636	0	0	636
Maine	0	282	0	0	0	282
Maryland	0	282	0	0	0	282
Massachusetts	0	282	0	0	0	282
Michigan	0	282	0	0	0	282
Minnesota	0	282	0	0	0	282
Mississippi	0	0	636	0	0	636
Missouri	0	282	0	0	0	282
Montana	0	282	0	0	0	282
Nebraska	0	282	0	0	0	282
Nevada	0	282	0	0	0	282
New Hampshire	0	282	0	0	0	282
New Jersey	0	282	0	0	0	282
New Mexico	0	0	636	0	0	636
New York	0	282	0	0	0	282
North Carolina	0	0	636	0	0	636
North Dakota	0	282	0	0	0	282
Ohio	0	282	0	0	0	282
Oklahoma	0	0	636	0	0	636
Oregon	400	0	0	0	0	400
Pennsylvania	0	282	0	0	0	282
Rhode Island	0	282	0	0	0	282
South Carolina	0	0	636	0	0	636
South Dakota	0	282	0	0	0	282
Tennessee	0	0	636	0	0	636
Texas	0	0	636	0	0	636
Utah	0	282	0	0	0	282
Vermont	0	282	0	0	0	282
Virginia	0	282	0	0	0	282
Washington	400	0	0	0	0	400
West Virginia	0	282	0	0	0	282
Wisconsin	0	282	0	0	0	282
Wyoming	0	282	0	0	0	282

APPENDIX C
Average Mileage From BEA Area to State Border for Interstate Rail Movements

SACRAMENTO

Origin/Destination	Klamath	Reno	Williams	Yuma	Las Vegas	Total
	Entry/Exit Route					
Alabama	0	0	610	0	0	610
Alaska	333	0	0	0	0	333
Arizona	0	0	610	0	0	610
Arkansas	0	0	610	0	0	610
Colorado	0	205	0	0	0	205
Connecticut	0	205	0	0	0	205
Delaware	0	205	0	0	0	205
District of Columbia	0	205	0	0	0	205
Florida	0	0	610	0	0	610
Georgia	0	0	610	0	0	610
Hawaii	0	0	0	0	0	0
Idaho	0	205	0	0	0	205
Illinois	0	205	0	0	0	205
Indiana	0	205	0	0	0	205
Iowa	0	205	0	0	0	205
Kansas	0	205	0	0	0	205
Kentucky	0	205	0	0	0	205
Louisiana	0	0	610	0	0	610
Maine	0	205	0	0	0	205
Maryland	0	205	0	0	0	205
Massachusetts	0	205	0	0	0	205
Michigan	0	205	0	0	0	205
Minnesota	0	205	0	0	0	205
Mississippi	0	0	610	0	0	610
Missouri	0	205	0	0	0	205
Montana	0	205	0	0	0	205
Nebraska	0	205	0	0	0	205
Nevada	0	205	0	0	0	205
New Hampshire	0	205	0	0	0	205
New Jersey	0	205	0	0	0	205
New Mexico	0	0	610	0	0	610
New York	0	205	0	0	0	205
North Carolina	0	0	610	0	0	610
North Dakota	0	205	0	0	0	205
Ohio	0	205	0	0	0	205
Oklahoma	0	0	610	0	0	610
Oregon	333	0	0	0	0	333
Pennsylvania	0	205	0	0	0	205
Rhode Island	0	205	0	0	0	205
South Carolina	0	0	610	0	0	610
South Dakota	0	205	0	0	0	205
Tennessee	0	0	610	0	0	610
Texas	0	0	610	0	0	610
Utah	0	205	0	0	0	205
Vermont	0	205	0	0	0	205
Virginia	0	205	0	0	0	205
Washington	333	0	0	0	0	333
West Virginia	0	205	0	0	0	205
Wisconsin	0	205	0	0	0	205
Wyoming	0	205	0	0	0	205

APPENDIX C
Average Mileage From BEA Area to State Border for Interstate Rail Movements

STOCKTON

Origin/Destination	Klamath	Reno	Williams	Yuma	Las Vegas	Total
	Entry/Exit Route					
Alabama	0	0	436	0	0	436
Alaska	570	0	0	0	0	570
Arizona	0	0	436	0	0	436
Arkansas	0	0	436	0	0	436
Colorado	0	350	0	0	0	350
Connecticut	0	350	0	0	0	350
Delaware	0	350	0	0	0	350
District of Columbia	0	350	0	0	0	350
Florida	0	0	436	0	0	436
Georgia	0	0	436	0	0	436
Hawaii	0	0	0	0	0	0
Idaho	0	350	0	0	0	350
Illinois	0	350	0	0	0	350
Indiana	0	350	0	0	0	350
Iowa	0	350	0	0	0	350
Kansas	0	350	0	0	0	350
Kentucky	0	350	0	0	0	350
Louisiana	0	0	436	0	0	436
Maine	0	350	0	0	0	350
Maryland	0	350	0	0	0	350
Massachusetts	0	350	0	0	0	350
Michigan	0	350	0	0	0	350
Minnesota	0	350	0	0	0	350
Mississippi	0	0	436	0	0	436
Missouri	0	350	0	0	0	350
Montana	0	350	0	0	0	350
Nebraska	0	350	0	0	0	350
Nevada	0	350	0	0	0	350
New Hampshire	0	350	0	0	0	350
New Jersey	0	350	0	0	0	350
New Mexico	0	0	436	0	0	436
New York	0	350	0	0	0	350
North Carolina	0	0	436	0	0	436
North Dakota	0	350	0	0	0	350
Ohio	0	350	0	0	0	350
Oklahoma	0	0	436	0	0	436
Oregon	570	0	0	0	0	570
Pennsylvania	0	350	0	0	0	350
Rhode Island	0	350	0	0	0	350
South Carolina	0	0	436	0	0	436
South Dakota	0	350	0	0	0	350
Tennessee	0	0	436	0	0	436
Texas	0	0	436	0	0	436
Utah	0	350	0	0	0	350
Vermont	0	350	0	0	0	350
Virginia	0	350	0	0	0	350
Washington	570	0	0	0	0	570
West Virginia	0	350	0	0	0	350
Wisconsin	0	350	0	0	0	350
Wyoming	0	350	0	0	0	350

APPENDIX C
Average Mileage From BEA Area to State Border for Interstate Rail Movements

FRESNO

	Entry/Exit Route					
Origin/Destination	Klamath	Reno	Williams	Yuma	Las Vegas	Total
Alabama	0	0	436	0	0	436
Alaska	570	0	0	0	0	570
Arizona	0	0	436	0	0	436
Arkansas	0	0	436	0	0	436
Colorado	0	350	0	0	0	350
Connecticut	0	350	0	0	0	350
Delaware	0	350	0	0	0	350
District of Columbia	0	350	0	0	0	350
Florida	0	0	436	0	0	436
Georgia	0	0	436	0	0	436
Hawaii	0	0	0	0	0	0
Idaho	0	350	0	0	0	350
Illinois	0	350	0	0	0	350
Indiana	0	350	0	0	0	350
Iowa	0	350	0	0	0	350
Kansas	0	350	0	0	0	350
Kentucky	0	350	0	0	0	350
Louisiana	0	0	436	0	0	436
Maine	0	350	0	0	0	350
Maryland	0	350	0	0	0	350
Massachusetts	0	350	0	0	0	350
Michigan	0	350	0	0	0	350
Minnesota	0	350	0	0	0	350
Mississippi	0	0	436	0	0	436
Missouri	0	350	0	0	0	350
Montana	0	350	0	0	0	350
Nebraska	0	350	0	0	0	350
Nevada	0	350	0	0	0	350
New Hampshire	0	350	0	0	0	350
New Jersey	0	350	0	0	0	350
New Mexico	0	0	436	0	0	436
New York	0	350	0	0	0	350
North Carolina	0	0	436	0	0	436
North Dakota	0	350	0	0	0	350
Ohio	0	350	0	0	0	350
Oklahoma	0	0	436	0	0	436
Oregon	570	0	0	0	0	570
Pennsylvania	0	350	0	0	0	350
Rhode Island	0	350	0	0	0	350
South Carolina	0	0	436	0	0	436
South Dakota	0	350	0	0	0	350
Tennessee	0	0	436	0	0	436
Texas	0	0	436	0	0	436
Utah	0	350	0	0	0	350
Vermont	0	350	0	0	0	350
Virginia	0	350	0	0	0	350
Washington	570	0	0	0	0	570
West Virginia	0	350	0	0	0	350
Wisconsin	0	350	0	0	0	350
Wyoming	0	350	0	0	0	350

APPENDIX C
Average Mileage From BEA Area to State Border for Interstate Rail Movements

LOS ANGELES

Origin/Destination	Klamath	Reno	Williams	Yuma	Las Vegas	Total
	Entry/Exit Route					
Alabama	0	0	329	0	0	329
Alaska	834	0	0	0	0	834
Arizona	0	0	329	0	0	329
Arkansas	0	0	329	0	0	329
Colorado	0	0	0	0	303	303
Connecticut	0	0	329	0	0	329
Delaware	0	0	329	0	0	329
District of Columbia	0	0	329	0	0	329
Florida	0	0	0	0	271	271
Georgia	0	0	329	0	0	329
Hawaii	0	0	0	0	0	0
Idaho	0	0	0	0	303	303
Illinois	0	0	329	0	0	329
Indiana	0	0	329	0	0	329
Iowa	0	0	329	0	0	329
Kansas	0	0	329	0	0	329
Kentucky	0	0	329	0	0	329
Louisiana	0	0	329	0	0	329
Maine	0	0	329	0	0	329
Maryland	0	0	329	0	0	329
Massachusetts	0	0	329	0	0	329
Michigan	0	0	329	0	0	329
Minnesota	0	0	329	0	0	329
Mississippi	0	0	329	0	0	329
Missouri	0	0	329	0	0	329
Montana	0	0	0	0	303	303
Nebraska	0	0	0	0	303	303
Nevada	0	0	0	0	303	303
New Hampshire	0	0	329	0	0	329
New Jersey	0	0	329	0	0	329
New Mexico	0	0	329	0	0	329
New York	0	0	329	0	0	329
North Carolina	0	0	329	0	0	329
North Dakota	0	0	0	0	303	303
Ohio	0	0	329	0	0	329
Oklahoma	0	0	329	0	0	329
Oregon	834	0	0	0	0	834
Pennsylvania	0	0	329	0	0	329
Rhode Island	0	0	329	0	0	329
South Carolina	0	0	329	0	0	329
South Dakota	0	0	0	0	303	303
Tennessee	0	0	329	0	0	329
Texas	0	0	329	0	0	329
Utah	0	0	0	0	303	303
Vermont	0	0	329	0	0	329
Virginia	0	0	329	0	0	329
Washington	834	0	0	0	0	834
West Virginia	0	0	329	0	0	329
Wisconsin	0	0	329	0	0	329
Wyoming	0	0	0	0	303	303

APPENDIX C

Average Mileage From BEA Area to State Border for Interstate Rail Movements

SAN DIEGO

Origin/Destination	Klamath	Reno	Williams	Yuma	Las Vegas	Total
	Entry/Exit Route					
Alabama	0	0	0	311	0	311
Alaska	850	0	0	0	0	850
Arizona	0	0	0	311	0	311
Arkansas	0	0	0	311	0	311
Colorado	0	0	0	311	0	311
Connecticut	0	0	0	311	0	311
Delaware	0	0	0	311	0	311
District of Columbia	0	0	0	311	0	311
Florida	0	0	0	311	0	311
Georgia	0	0	0	311	0	311
Hawaii	0	0	0	0	0	0
Idaho	0	0	0	0	443	443
Illinois	0	0	0	311	0	311
Indiana	0	0	0	311	0	311
Iowa	0	0	0	311	0	311
Kansas	0	0	0	311	0	311
Kentucky	0	0	0	311	0	311
Louisiana	0	0	0	311	0	311
Maine	0	0	0	311	0	311
Maryland	0	0	0	311	0	311
Massachusetts	0	0	0	311	0	311
Michigan	0	0	0	311	0	311
Minnesota	0	0	0	311	0	311
Mississippi	0	0	0	311	0	311
Missouri	0	0	0	311	0	311
Montana	0	0	0	0	443	443
Nebraska	0	0	0	311	0	311
Nevada	0	0	0	0	443	443
New Hampshire	0	0	0	311	0	311
New Jersey	0	0	0	311	0	311
New Mexico	0	0	0	311	0	311
New York	0	0	0	311	0	311
North Carolina	0	0	0	311	0	311
North Dakota	0	0	0	311	0	311
Ohio	0	0	0	311	0	311
Oklahoma	0	0	0	311	0	311
Oregon	850	0	0	0	0	850
Pennsylvania	0	0	0	311	0	311
Rhode Island	0	0	0	311	0	311
South Carolina	0	0	0	311	0	311
South Dakota	0	0	0	311	0	311
Tennessee	0	0	0	311	0	311
Texas	0	0	0	311	0	311
Utah	0	0	0	0	443	443
Vermont	0	0	0	311	0	311
Virginia	0	0	0	311	0	311
Washington	850	0	0	0	0	850
West Virginia	0	0	0	311	0	311
Wisconsin	0	0	0	311	0	311
Wyoming	0	0	0	0	443	443

Appendix D

Annual NO_x Emissions Estimation Process by Locomotive Model

Emissions Summary for: GP60 Linehaul

Throttle Notch	Percent Time in Notch	NOx Emissions in Notch (lb/hr)					Weighted NOx Emissions in Notch (lb/hr)				
		Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR	Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR
off	22.9%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
brake	6.1%	6.8	1.0	1.0	6.8	1.0	0.4	0.1	0.1	0.4	0.1
idle	39.7%	3.4	3.4	0.5	3.4	3.4	1.3	1.3	0.2	1.3	1.3
1	3.0%	10.2	10.2	1.5	10.2	10.2	0.3	0.3	0.0	0.3	0.3
2	3.2%	18.1	18.1	2.7	18.1	18.1	0.6	0.6	0.1	0.6	0.6
3	3.1%	32.8	4.9	4.9	32.8	4.9	1.0	0.2	0.2	1.0	0.2
4	3.9%	37.4	5.6	5.6	7.5	1.1	1.5	0.2	0.2	0.3	0.0
5	3.1%	43.6	6.5	6.5	4.4	0.7	1.4	0.2	0.2	0.1	0.0
6	2.9%	51.6	7.7	7.7	5.2	0.8	1.5	0.2	0.2	0.1	0.0
7	2.2%	74.7	11.2	11.2	7.5	1.1	1.6	0.2	0.2	0.2	0.0
8	9.9%	112.3	16.8	16.8	11.2	1.7	11.1	1.7	1.7	1.1	0.2
Weighted Average NOx Emissions (lb/hr)							20.7	5.0	3.1	5.5	2.7
Annual NOx Emissions (tons)				88% Availability			**79.9**	**19.3**	**12.0**	**21.3**	**10.5**

Emissions Summary for: B40-8 Linehaul

Throttle Notch	Percent Time in Notch	NOx Emissions in Notch (lb/hr)					Weighted NOx Emissions in Notch (lb/hr)				
		Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR	Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR
off	22.9%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
brake	6.1%	3.2	0.5	0.5	3.2	0.5	0.2	0.0	0.0	0.2	0.0
idle	39.7%	0.7	0.7	0.1	0.7	0.7	0.3	0.3	0.0	0.3	0.3
1	3.0%	6.7	6.7	1.0	6.7	6.7	0.2	0.2	0.0	0.2	0.2
2	3.2%	13.2	13.2	2.0	13.2	13.2	0.4	0.4	0.1	0.4	0.4
3	3.1%	27.6	4.1	4.1	27.6	4.1	0.9	0.1	0.1	0.9	0.1
4	3.9%	46.1	6.9	6.9	9.2	1.4	1.8	0.3	0.3	0.4	0.1
5	3.1%	82.8	12.4	12.4	8.3	1.2	2.6	0.4	0.4	0.3	0.0
6	2.9%	76.7	11.5	11.5	7.7	1.2	2.2	0.3	0.3	0.2	0.0
7	2.2%	93.7	14.1	14.1	9.4	1.4	2.1	0.3	0.3	0.2	0.0
8	9.9%	105.6	15.8	15.8	10.6	1.6	10.5	1.6	1.6	1.0	0.2
Weighted Average NOx Emissions (lb/hr)							21.1	3.9	3.2	4.0	1.4
Annual NOx Emissions (tons)				88% Availability			**81.2**	**15.1**	**12.2**	**15.6**	**5.3**

Emissions Summary for: F40-PH Passenger

Throttle Notch	Percent Time in Notch	NOx Emissions in Notch (lb/hr)					Weighted NOx Emissions in Notch (lb/hr)				
		Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR	Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR
off	41.4%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
brake	0.4%	10.0	1.5	1.5	10.0	1.5	0.0	0.0	0.0	0.0	0.0
idle	29.7%	19.2	19.2	2.9	19.2	19.2	5.7	5.7	0.9	5.7	5.7
1	0.0%	7.0	7.0	1.1	7.0	7.0	0.0	0.0	0.0	0.0	0.0
2	0.0%	14.0	14.0	2.1	14.0	14.0	0.0	0.0	0.0	0.0	0.0
3	6.2%	22.7	3.4	3.4	22.7	3.4	1.4	0.2	0.2	1.4	0.2
4	6.0%	31.0	4.7	4.7	6.2	0.9	1.9	0.3	0.3	0.4	0.1
5	4.0%	42.5	6.4	6.4	4.3	0.6	1.7	0.3	0.3	0.2	0.0
6	2.9%	54.8	8.2	8.2	5.5	0.8	1.6	0.2	0.2	0.2	0.0
7	1.1%	91.0	13.7	13.7	9.1	1.4	1.0	0.2	0.2	0.1	0.0
8	8.3%	108.1	16.2	16.2	10.8	1.6	9.0	1.3	1.3	0.9	0.1
Weighted Average NOx Emissions (lb/hr)							22.3	8.2	3.3	8.8	6.2
Annual NOx Emissions (tons)				88% Availability			**85.8**	**31.5**	**12.9**	**34.1**	**23.8**

Emissions Summary for: SD40-2 Linehaul

Throttle Notch	Percent Time in Notch	NOx Emissions in Notch (lb/hr)					Weighted NOx Emissions in Notch (lb/hr)				
		Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR	Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR
off	22.9%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
brake	6.1%	8.4	1.3	1.3	8.4	1.3	0.5	0.1	0.1	0.5	0.1
idle	39.7%	3.1	3.1	0.5	3.1	3.1	1.2	1.2	0.2	1.2	1.2
1	3.0%	7.4	7.4	1.1	7.4	7.4	0.2	0.2	0.0	0.2	0.2
2	3.2%	10.7	10.7	1.6	10.7	10.7	0.3	0.3	0.1	0.3	0.3
3	3.1%	18.3	2.7	2.7	18.3	2.7	0.6	0.1	0.1	0.6	0.1
4	3.9%	23.7	3.6	3.6	4.7	0.7	0.9	0.1	0.1	0.2	0.0
5	3.1%	34.5	5.2	5.2	3.5	0.5	1.1	0.2	0.2	0.1	0.0
6	2.9%	43.0	6.5	6.5	4.3	0.6	1.2	0.2	0.2	0.1	0.0
7	2.2%	63.7	9.6	9.6	6.4	1.0	1.4	0.2	0.2	0.1	0.0
8	9.9%	76.2	11.4	11.4	7.6	1.1	7.5	1.1	1.1	0.8	0.1
Weighted Average NOx Emissions (lb/hr)							15.1	3.8	2.3	4.2	2.2
Annual NOx Emissions (tons)				88% Availability			**58.1**	**14.6**	**8.7**	**16.1**	**8.3**

Emissions Summary for: SD40-2 Local

Throttle Notch	Percent Time in Notch	NOx Emissions in Notch (lb/hr)					Weighted NOx Emissions in Notch (lb/hr)				
		Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR	Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR
off	35.7%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
brake	1.2%	8.4	1.3	1.3	8.4	1.3	0.1	0.0	0.0	0.1	0.0
idle	47.1%	3.1	3.1	0.5	3.1	3.1	1.5	1.5	0.2	1.5	1.5
1	2.9%	7.4	7.4	1.1	7.4	7.4	0.2	0.2	0.0	0.2	0.2
2	2.7%	10.7	10.7	1.6	10.7	10.7	0.3	0.3	0.0	0.3	0.3
3	2.6%	18.3	2.7	2.7	18.3	2.7	0.5	0.1	0.1	0.5	0.1
4	2.2%	23.7	3.6	3.6	4.7	0.7	0.5	0.1	0.1	0.1	0.0
5	1.4%	34.5	5.2	5.2	3.5	0.5	0.5	0.1	0.1	0.0	0.0
6	1.1%	43.0	6.5	6.5	4.3	0.6	0.5	0.1	0.1	0.0	0.0
7	1.0%	63.7	9.6	9.6	6.4	1.0	0.6	0.1	0.1	0.1	0.0
8	2.1%	76.2	11.4	11.4	7.6	1.1	1.6	0.2	0.2	0.2	0.0
Weighted Average NOx Emissions (lb/hr)							6.3	2.6	0.9	3.0	2.1
Annual NOx Emissions (tons)			88% Availability				**24.1**	**10.0**	**3.6**	**11.4**	**8.1**

Emissions Summary for: GP38-2 Yard/Switch

Throttle Notch	Percent Time in Notch	NOx Emissions in Notch (lb/hr)					Weighted NOx Emissions in Notch (lb/hr)				
		Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR	Baseline	Dual-Fuel	LNG-SI	SCR	DF+SCR
off	31.7%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
brake	0.0%	6.2	0.9	0.9	6.2	0.9	0.0	0.0	0.0	0.0	0.0
idle	55.4%	2.8	2.8	0.4	2.8	2.8	1.5	1.5	0.2	1.5	1.5
1	3.2%	4.0	4.0	0.6	4.0	4.0	0.1	0.1	0.0	0.1	0.1
2	3.2%	9.6	9.6	1.4	9.6	9.6	0.3	0.3	0.0	0.3	0.3
3	2.2%	17.9	2.7	2.7	17.9	2.7	0.4	0.1	0.1	0.4	0.1
4	2.2%	27.4	4.1	4.1	5.5	0.8	0.6	0.1	0.1	0.1	0.0
5	0.8%	37.4	5.6	5.6	3.7	0.6	0.3	0.0	0.0	0.0	0.0
6	0.4%	51.2	7.7	7.7	5.1	0.8	0.2	0.0	0.0	0.0	0.0
7	0.0%	65.3	9.8	9.8	6.5	1.0	0.0	0.0	0.0	0.0	0.0
8	0.9%	76.6	11.5	11.5	7.7	1.1	0.7	0.1	0.1	0.1	0.0
Weighted Average NOx Emissions (lb/hr)							4.1	2.3	0.6	2.6	2.1
Annual NOx Emissions (tons)				88% Availability			**16.0**	**8.8**	**2.4**	**10.0**	**7.9**