Title

Feasibility Study Of Advanced Technology Hov Systems: Volume 2b: Emissions Impact Of Roadway-powered Electric Buses, Light-duty Vehicles, And Automobiles

Authors

Miller, Mark A.
Dato, Victor
Chira-chavala, Ted

Publication Date

1992

CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Feasibility Study of Advanced Technology HOV Systems

Volume 2B: Emissions Impact of Roadway-Powered Electric Buses, Light-Duty Vehicles, and Automobiles

Mark A. Miller
Victor Dato
Ted Chira-Chavala

PATH Research Report

UCB-ITS-PRR-92-~~3~~ 4

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California, Business and Transportation Agency, Department of Transportation, and the United States Department of Transportation, Federal Highway Administration.

December 1992

ISSN 1055-1425

FEASIBILITY STUDY OF ADVANCED TECHNOLOGY HOV SYSTEMS

Volume 2B:

EMISSIONS IMPACT OF ROADWAY'POWERED ELECTRIC BUSES, LIGHT-DUTY VEHICLES, AND AUTOMOBILES

by

Mark A. Miller
Victor Dato
Ted Chira-Chavala

December 1992

ABSTRACT

Changes in pollutant emissions as a result of adopting roadway-powered electric buses, Light Duty Vehicles (LDV's), and automobiles in California are analyzed. The analysis involves comparing emissions of hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), oxides of sulfur (SOx), and particulate matter (PM), in grams per vehicle-mile of travel, between roadway-powered' electric vehicles (RPEV's) and existing internal-combustion-engine vehicles (ICEV's). The comparison is based on the assumption that RPEV's and ICEV's are operated under identical conditions. Findings indicate that significant reductions in emissions of HC and CO can be expected from the adoption of RPEV's, while fluctuations between emission increases and reductions are likely for NOx, SOx, and PM depending on energy consumption by vehicle type, the split between roadway/battery power usage, power flow efficiencies from the power plant to the roadway, and the mix of fuel sources and processing technologies assumed for electricity generation.

CONTENTS

INTRODUCTION

Air pollution is a serious issue facing many urban metropolitan areas. A major component of air pollution are vehicle emissions of five pollutants---hydrocarbon (HC), carbon-monoxide (CO), oxides of nitrogen (NOx), oxides of sulfur (SOx) and particulate matter (PM). For California, with its large population and very substantial highway network, air pollution has been a very major concern for the general public, the government, and the private sector. For example, in 1987 in the South Coast Air Basin (SCAB) of Southern California, annual average daily tonnage of mobile-source pollutant emissions contributed about 66.4% of emissions from all polluting sources. On-road vehicle mobile-source HC, CO, NOx, SOx, and PM emissions contributed about 43.9, 87.8, 60.5, 25.8, and 4.9 percent from all pollution sources in SCAB (South Coast Air Quality Management District 1990), respectively.

Alternative clean propulsion systems could help to alleviate mobile-source pollution problems, and a large number of these systems are emerging. One alternative clean propulsion system is the roadway-powered electric vehicle, or RPEV (Systems Control Technology, Inc. 1986; Lechner et al. 1986; Shladover 1989). The RPEV was conceived as a means of addressing the range problem of the pure-electric vehicle (EV). The former could be designed to have considerably further range between battery rechargings for urban travel, depending on the extent of the electrified network.

RPEV's themselves do not emit emissions but the power plants which supply the electric energy to these vehicles do pollute the air. Nesbitt et al. (1990) reported that on a per-mile of travel basis, under a particular set of input assumptions, emissions of HC, CO, and NOx were less than those for conventional Internal Combustion Engine Vehicles (ICEV's), while emissions of SOx and PM increased as a result of using RPEV's.

This report investigates potential near-term (1995) air quality benefits due to RPEV's relative to conventional ICEV's, when the two are assumed to operate under identical conditions. Prior studies (e.g., Wang et al. 1990; and Nesbitt et al. 1990) have investigated air quality benefits of EV's, roadway-powered electric automobiles, and light duty vehicles (LDV's). Buses were not included in these prior studies. Principal contributions of this report lie in three major areas:

- This report extends the air quality investigation to include roadway-powered electric buses, in addition to LDV's and automobiles.
- Although this report uses the emission estimation procedure reported by Wang et al. (1990) and later Nesbitt et al. (1990), it incorporates a number of significant modifications. They are: more detailed driving cycles which affect vehicle energy consumption; modified RPEV's energy distribution losses; and modified power flows in an RPEV system, including components such as static roadway inductor charging and battery overcharging. These modifications are results of recent

knowledge gained from the progress that has been made in RPEV research, as well as the availablity of updated data on RPEV's performance.

- This report incorporates a sensitivity analysis, in which a range of the percentage split between the electric energy drawn from the electrified roadway and from the onboard battery is assumed for RPEV's. The sensitivity analysis is performed because there is currently no electrification route in existence for use in this investigation.

OBJECTIVE

The objective of this report is to estimate changes in emissions of the five pollutants due to roadway-powered electric buses, LDV's, and automobiles relative to conventional ICEV buses, LDV's, and automobiles, when the two are assumed to operate under identical conditions.

ORGANIZATION OF THIS REPORT

This report is organized into six sections. Section 1 provides an overview of the RPEV technology. In Section 2, a procedure for estimating pollutant emissions for RPEV's is presented. In Section 3, parameter input for the estimation is described. In Section 4, variation in implementation strategies for the sensitivity analysis is presented. In Section 5, estimation results are presented for roadway-powered electric buses, light duty vehicles (LDV's), and automobiles. The sixth and last section is the conclusion and summary, in which comparison of the results from this report, with findings from prior studies is made.

I. RPEV TECHNOLOGY DESCRIPTION

The roadway-powered electric vehicle (RPEV) is an electric-electric hybrid vehicle. Its two power sources are the on-board battery and inductive coupling system (ICS). The ICS consists of the roadway inductor, buried just beneath the road surface, and the pickup inductor, mounted on the underside of the vehicle. The coupling consists of the inductive power transfer from the roadway inductor to the pickup inductor. No physical contact exists between these two inductors. The on-board battery can store power emanating from (a) a conventional wall-outlet, for example, while the battery is being recharged overnight, (b) the ICS, as excess power during dynamic roadway charging, or (c) the ICS, as static roadway recharging, while the vehicle is parked over a roadway inductor segment. In addition to the roadway and pickup inductors, other RPEV system components include the distribution links to the electric utility grid, power conditioner located near the roadway, distribution network that carries power from the power conditioner to the roadway, onboard controller, onboard battery, motor controller, and electric drivetrain.

Energy from electrified roadway charging during driving may go directly to the onboard motor controller, and then to the motor.

When the vehicle motive requirement is less than the power drawn from the roadway, the excess power would be directed to the onboard battery for later use. The amount of battery recharging from the roadway changes from day to day, as well as by time of day, vehicle type, and driving cycle.

One desirable feature of RPEV's is that the electrified roadway can be shared by electric and non-electric vehicles. This flexibility is advantageous for the introduction of new technologies because existing traffic will not be adversely affected.

The technology behind roadway electrification has been under development since 1976. It has been tested in both static and dynamic modes at the University of California, Berkeley, Richmond Field Station since 1987. A 400-foot electrified roadway was developed to test the inductive coupling technology. An electric bus has been equipped with an inductive pickup device and an on-board controller (OBC). The bus has undergone dynamic testing in the past three years.

The initial round of testing resulted in redesign of the inductor technology to substantially minimize acoustic noise and electromagnetic field strength problems. The more recent testing was on a G-Van which was modified to accomodate new design parameters. The redesigned roadway and pickup technology has undergone testing during the first half of 1991. The test results have been favorable and the technology is being extended to an ongoing evaluation effort as part of another project in Los

Angeles, including plans which are underway to build a facility in 1992 to test further technical feasibility of roadway electrification. All studies to date on the RPEV technology have demonstrated its technical viability, and if currently planned studies are carried to fruition, the technology could be available for applications on the road in the late 1990's or early 2000's.

II. EMISSION ESTIMATION PROCEDURE

This section presents a methodology for estimating pollutant emissions for RPEV's relative to ICEV's, in terms of grams of pollutant per vehicle-mile-of-travel. Estimation procedures for RPEV's and ICEV's are presented separately below. Estimations of emissions for buses, light duty vehicles, and automobiles follow the same procedure.

Procedure for RPEV Pollutant Emissions

The procedure used to estimate emissions of HC, CO, NO_x, SO_x, and PM for RPEVs is based on that reported by Wang et al. (1990) and Nesbitt et al. (1990). This report incorporates a number of modifications to the assumptions concerning the driving cycle, energy flow, and power loss of RPEV's.

Case I: Exclusion of Conventional Coal-fired Power Plants

The procedure consists of the following steps:

1. For each power plant type, tabulate emission rates per million Btu fuel input (pounds per million Btu) for power plants with no emission control technologies, as provided by the

California Air Resources Board (CARB 1988).

2. Identify emission control technologies, both currently in existence and for the future, applicable to particular pollutants (Wang et al. 1990; and CARB 1988); then determine the percentages of power'plant types that will implement individual future emission control technologies.

3. Convert uncontrolled emission rate for fuel input (lbs. per million Btu) into future controlled emission rate per unit of electricity output from the power plant (grams per kilowatt-hour), using the formula reported by Wang et al. (1989):

$$EF_{ele} = EF_{,,} \times 454/(1000000/3412)/CE \times \{\sum_i (1-ER_i) x K_i + (1-\sum_i K_i)\}$$

Where:

EF_{ele} = emission rate of controlled power plants (grams per kilowatt-hour electricity output)

EF_{fuel}= emission rate of uncontrolled power plants (lbs. per million Btu fuel input)

454 = a constant designating the number of grams in a pound.

1000000/3412 = a constant designating kwh's in million Btu

CE = conversion efficiency of the power plant

ER_i = emission reduction rate due to emission control technology i

K_i = the percent of power plants with emission control technology i

4. Obtain the fuel feedstock mix of coal, gas, and oil for electricity generation from California Energy Commission (CEC) reports (1989, 1991), for use in estimating average emission rates

of power plants using coal, gas, and oil.

5. Convert emissions at the power plant (in grams per kwh of electricity output) into vehicle emissions (in grams per mile traveled), taking into consideration the flow of energy and energy distribution losses from the power plant to the RPEV. This conversion can be expressed as:

Vehicle emissions = (power plant emissions) x (vehicle energy consumption)/efficiency

where

Power plant emissions are in grams per kwh;

Vehicle energy consumption is in kwh per mile; and

Efficiency is the reciprocal of distribution loss, expressed in percentages.

6. Calculate changes in emissions due to adopting RPEV's relative to conventional ICEV's, when both are operated under identical conditions.

Case II: Conventional Coal-fired Power Plants

The procedure consists of the following steps:

1. Identify emission rate per million Btu fuel input (pounds per million Btu) for this type of power plant with no emission control technologies (Wang et al. 1990).

2. Convert uncontrolled emission rate for fuel input into the current actual emission rate (Wang et al. 1990).

3. Identify future emission control technologies (Wang et al. 1990); then determine the percent of conventional coal-fired

power plants that will implement these technologies.

4. Convert current actual emission rate for fuel input (pounds per million Btu) into future controlled emission rate per unit of electricity output from the power plant (grams per kilowatt-hour), using the formula in Step 3 of Case I above, except now EF, = current actual emission rate of conventional coal-fired power plants.

5. Same as Step 4 in Case I, except restricted to coal.

6. Same as Step 5 in Case I.

7. Same as Step 6 in Case I.

Approximately 8 percent of electricity produced for California consumption in 1995 is expected to come from conventional coal-fired power plants (CEC 1989; CEC 1990), although none are licensed in the state. This amount of the electricity is produced in other Western U.S. states such as Nevada, Arizona, New Mexico, and Colorado. Whether or not this power plant type should be included in the analysis is an issue of overall emissions reduction or emissions displacement, respectively. That is, including conventional coal-fired power plants in the analysis could underestimate RPEV emissions benefits <u>within</u> California, yet more accurately reports the overall emissions impact of RPEV's resulting from electricity production for California consumption. While excluding conventional coal-fired power plants from the analysis, though correctly reflects the beneficial impact on California, ignores the increase in emissions of certain pollutants in other states. Both cases are evaluated in this report.

Procedure for Estimating Emission of ICEV's

To estimate emission changes due to the adoption of RPEV's, it is necessary to know emissions from the portion of the baseline ICEV fleet in 1995 that would be replaced by RPEV's. In this report, it is assumed that RPEV's first enter the vehicle fleet in 1995. Thus, the replaced ICEV fleet consists of new vehicles with a zero-mileage emission rate. Estimates of ICEV emissions for both exhaust and evaporative emissions for the five pollutants for 1995 were provided by CARB (1990). These estimates are derived from the most recent version of CARB's emission rate model, EMFAC7E for automobiles, LDV's, and buses, and are based on a vehicle speed of approximately 20 miles per hour. Emissions from refinery plants are also included, with their estimates derived from the data from Wang et al. (1990), CARB (1990), and American Petroleum Institute (1991).

III. PARAMETER INPUT

This section describes the input necessary for estimating emissions for RPEV's for the year 1995. The input required includes projections for:

- Types of power plants in California
- Uncontrolled emission rates for the five pollutants by power plant type
- Emission reduction percentages for control technologies by pollutant and power plant type.
- Percent of different emission control technologies

assumed to be implemented by individual power plant types and pollutants.

- Percent of electricity generated for individual power plant types
- Power plant conversion efficiency (defined as the ratio of electric energy output per unit of energy used)
- Vehicle energy consumption by the driving cycle
- Energy flow for both battery-powered and roadway-powered vehicle operation
- Distribution losses from the utility substation to the RPEV

Power Plant Types

The following types of power plants are assumed in the analysis:

- ***Gas:*** These include gas-fired turbines and gas-fired boilers.
- ***Oil:*** These include oil-fired boilers and oil-fired turbines.
- ***Coal:*** These include coal-fired circulating fluid bed (CFB) combustors and coal-fired integrated gasification combined-cycle (IGCC). As previously stated, the analysis is performed for cases with and without conventional coal-fired power plants.

Other types of power plants such as solar power, hydropower, or nuclear power are excluded from the analysis because each of these fuel feedstocks produce negligible air pollutants (Wang et al. 1990).

Uncontrolled Emission Rates

Uncontrolled emissions are those associated with power plants which have no emission control technology installed. Uncontrolled emission rates for the abovementioned power plants are reported by CARB (Table 2; CARB 1988).

The uncontrolled emission rates in Table 2 are the Statewide average emission factors. The use of these factors in estimating RPEV emissions could result in underestimates for some pollutants. The incremental emissions attributed to the RPEV, strictly speaking, should be only those associated with the production of the marginal power that is turned on during the day to meet the extra load demanded by the RPEV. Prior studies have attempted to address this issue. At least one prior study (Dowlatabadi et al. 1990) has derived a functional relationship between the amount of electricity produced and the level of emissions-that for NOx emission from gas-fired boiler power plants in Southern California. The authors found that NOx emissions are a highly non-linear function of power plant operating levels (Figure 1). However, such a function could vary both by time-of-day and the location of the power plant. Accurate relationships are not sufficiently known at this time for incorporation in our analysis.

Percentage of Emission Control Technologies for Power Plant Types

Emission control technologies for power plants, as well as their percentage emission reductions are shown in Table 3 (CARB 1988). Emission control technologies are applied mainly to NOx because of its relatively high uncontrolled emission rates. Emission control technologies are usually not implemented for HC and CO for reasons related to the tradeoff between implementation costs and level of uncontrolled emissions for these two pollutants (Wang et al. 1989). Table 4 shows the percent of power plant types that are assumed to have the respective control technologies in 1995 (Wang et al. 1989). These percentages are based on the two emission control strategies defined by Wang et al. (1989) as "less" and "more" stringent control strategies.

Percentage of Electricity Generated by Power Plant Types

Projected percent of electricity generated by individual power plant types for 1995 is obtained from the California Energy Commission (CEC) (1989, 1991), and is shown in Table 5. The table indicates that the power plant types included in this analysis account for about 40 percent of total electricity generated in California. The remaining 60 percent is derived from power plant types that have negligible emissions (Wang et al. 1990).

Power Plant Conversion Efficiency

Power plant conversion efficiency is defined as the ratio between electric energy output for each unit of energy used in generating the electricity. Power plant efficiency values of 30-35 percent are assumed in the analysis, as reported by Wang et al.

(1989).

Vehicle Energy Consumption

Evidence in the literature indicates that vehicle energy consumption is significantly affected by both the driving cycle, and to some extent, regenerative braking (Systems Control Technology, Inc. 1992). The driving cycle represents the driving pattern due to different acceleration and deceleration rates, average cruise speed, and the number of stops per mile. For analysis purposes, four different driving cycles for RPEV's are assumed to represent a range of driving environments from constant speed without any stops, to stop-and-go congestion conditions. The four driving cycles are summarized below (SAE Handbook 1987; Gris 1991).

Constant-Speed Driving Cycle: This driving cycle is characterized by a cruise speed of 45 mph over a distance of at least 15 miles.

SAE-D: This driving cycle is approximated by 1 stop per mile and maximum cruise speed of 45 mph.

SAE-C: This driving cycle is approximated by 3 stops per mile and maximum cruise speed of 30 mph.

SAE-B: This driving cycle is approximated by 5 stops per mile and maximum cruise speed of 20 mph.

Regenerative braking affects energy consumption because the energy due to braking is not dissipated as heat. Instead, it is converted back into electricity and returned to the vehicle's battery. Thus, it is a means of reducing the vehicle's energy consumption (Systems Control Technology, Inc. 1992).

Vehicle energy consumption versus the driving cycle for roadway-powered electric buses, light-duty vehicles, and automobiles are shown in Table 6. These values are derived from an engineering simulation model (Systems Control Technology, Inc. 1992).

Distribution Losses

Figure 2 shows a diagram of the power flow for RPEV's from the utility substation to the vehicle's motor. This power flow can be described by two types of system charging---dynamic roadway charging and static charging. The latter is further divided into static roadway and static conventional charging. Dynamic roadway charging occurs when the RPEV is being driven on the electrified road. Energy from the electric utility grid goes into the power conditioner located near the roadway, which in turn is distributed and finally reaches the roadway inductor. From there, electric energy is transferred from the roadway inductor to the vehicle's pickup inductor. The onboard control circuitry directs electrical power to the motor controller. When the vehicle's motive requirements are less than the power drawn from the roadway, the excess power would then go to the vehicle's on-board battery for later use. The amount of battery recharging from the roadway could change from day to day, as well as by time of day, vehicle type, and driving cycle.

Static charging may occur conventionally through a standard household electric wall outlet, or inductively when the RPEV is parked over a roadway inductor segment. During static roadway charging, the flow of electric energy from the utility substation to the motor is identical to the flow during dynamic roadway charging. However, the distribution losses in the static roadway charging are about 15 percent lower than those in the dynamic roadway charging. Static conventional charging occurs off the electrified roadway, and the charging is typically accomplished from the wall outlet, either at home or during mid-day recharging in parking facilities. Off the electrified roadway, the motor controller draws power from the battery.

Conventional battery recharging is slightly more efficient than static inductive recharging (Figure 2), and thus would be expected to have an impact on cost. However, total system distribution loss is not the only factor determining which recharging alternative to use. For example, buses could take advantage of the dwell time at bus stops used for passenger drop-off and pick-up to recharge. However, the amount of time required to "plug-in" and "unplug" the bus compared to the relatively short total dwell time would preclude the use of conventional battery recharging by buses. When time is not such a dominant factor, such as during overnight recharging, convenience also plays a role in deciding which recharging options to use.

Systems Control Technology, Inc. (1992) reports the following distribution losses for roadway and static charging:

(i) For dynamic roadway charging, the distribution efficiency from the utility substation to the onboard control circuitry (OBCC) ranges from about 73 to 79 percent. That is, the cumulative distribution loss at the OBCC is about 21 to 27 percent.

(ii) For the static roadway charging, the cumulative distribution loss at the OBCC is about 6 to 12 percent. The difference in distribution losses between dynamic roadway and static roadway charging occur within the (a) roadway inductor, (b) pickup inductor, and (c) onboard control circuitry. The majority of this difference occurs within the roadway inductor because distribution losses are proportional to roadway inductor length, which is considerably shorter during static roadway charging than during dynamic roadway charging.

(iii) For the static conventional charging, the cumulative losses at the battery charger is about 2 to 8 percent.

(iv) The loss in the onboard battery itself can range from 20 to 25 percent. In addition, there is usually another 5 to 10 percent loss due to battery overcharging (i.e., resulting from charging an already fully charged battery; and is the electric vehicle equivalent of topping off a fuel tank in an ICEV).

Ranges are given specifically to encompass vehicle type and driving cycle differences. These were derived from tests on actual vehicles, simulations, and best engineering judgment (Systems Control Technology, Inc. 1992).

Energy Flow in Inductive Coupling System

As previously mentioned, when vehicle motive requirements are less than the actual power drawn from the roadway, the excess power would go to the vehicle's on-board battery for later use. Systems Control Technology, Inc. (1992) suggests that because dynamic roadway recharging of the battery depends on several factors, an allowance be made for this variability. The percentage of energy drawn from the roadway going directly to the motor controller could vary between 50% and 95%. The percentage of energy split between the motor controller and the battery assumed in this analysis are 95/5, 75/25, and 50/50, respectively.

IV. VARIATION IN IMPLEMENTATION STRATEGIES FOR SENSITIVITY ANALYSIS

In estimating emissions for roadway-powered electric buses, LDV's and automobiles for the year 1995, the effects of variations in the following implementation parameters are investigated.

Emission Control Technology Scenarios

Because of uncertainties in predicting future percent of power plants with emission control technologies, this report defines two scenarios for the sensitivity analysis, as follows:

"Optimistic" Scenario: This scenario incorporates the "more stringent" power plant implementation strategy (shown in Table 4), the lower-bound distribution loss values (shown in Figure 2), and a higher power plant conversion efficiency of 35 percent.

"Pessimistic" Scenario: This scenario incorporates the "less

stringent" power plant implementation strategy (shown in Table 4), the upper-bound distribution loss values (shown in Figure 2), and a lower power plant conversion efficiency of 30 percent.

Split Between Roadway and Battery Power

While on the electrified roadway, RPEV's can draw power from the roadway; off the electrified roadway, they will have to rely solely on the power from the onboard battery. In this analysis, a range in the percentage split between these two power sources (roadway/battery) are assumed for the sensitivity analysis-80/20; 60/40; 40/60; and 20/80. Because conventional static charging is about 4% more efficient than roadway static charging, the former is used in all of the emission estimations. The sensitivity analysis based on this variability in the percentage split between roadway and battery power is performed across all vehicle types. This variability in percentage split of power reflects a full range of differences in the power source an RPEV could experience, whether an automobile, an LDV, or a bus. If the roadway/battery percentage split for a particular RPEV was constant from day to day, which is not assumed in this analysis, then the appropriate battery size for that power split could be determined. In this analysis, it is implicitly assumed that the battery size varies by the vehicle type; and for each vehicle type, the battery is sufficient for travel which has up to 80 percent of the mileage off the electrified roadway.

V. ESTIMATION RESULTS

Results of the analysis are presented separately for the three types of RPEV's: roadway-powered electric buses; LDV's; and automobiles. Results for both scenarios ("pessimistic" and "optimistic") and both cases (with and without the use of conventional coal-fired power plants) are discussed. The relationships between emissions and roadway/battery power split depicted in Figures 3 through 8 are based on the 75/25 percentage split of energy flow from the dynamic roadway into the motor controller and the battery, respectively; whereas the range of estimated changes in emissions described in Tables 7 through 102 cover the full range of this power flow split (95/5 to 50/50). Note that the relationship between percentage of roadway power and percentage of emission change for HC emissions and for CO emissions are graphically depicted in Figures 3 through 8 as equivalent. This single representation is made because the percentage changes for these two pollutants relative to the ICEV baseline are similar.

For Roadway-Powered Electric Buses

- ***Range of Estimated Changes in Emissions:***

Estimated emission levels due to the adoption of roadway-powered electric buses for the five pollutants are shown in Tables 7 through 10 for the roadway/battery power percentage splits of 20/80 through 80/20, respectively. Moreover, these tables report data for the "pessimistic" scenario, with the conventional coal-fired power plant type included in the analysis. Corresponding percentage emission changes follow in Tables 11 through 14. Tables 15 through 22 depict the corresponding data for the "optimistic" scenario. Tables 23 through 30 and Tables 31 through 38 show the corresponding information for the "pessimistic" and "optimistic" scenarios, respectively, exluding conventional coal-fired power plant production of electricity. Please note that the range of both emission levels and emission percentage changes of the five pollutants shown in all tables correspond to the minimum and maximum percentage splits of energy flow from dynamic roadway charging to the motor controller and to the battery of 50/50 and 95/5, respectively. Examining these results indicates that:

For "pessimistic" scenario, with conventional coal-fired power plant production of electricity:

* Implementation of roadway-powered electric buses in California could result in potential emissions reduction for all pollutants except SOx. The reductions could be nearly 100 percent for HC and CO; 75-90 percent for NOx; and 45-75 percent for PM. Emission changes of SOx could decrease just slightly or increase up to 100 percent, depending on the roadway/battery split and the driving cycle.
* The percentage split of energy flow from dynamic roadway charging to the motor controller and to the battery affects the magnitude of the emissions for SOx and PM, though not for HC, CO, NOx.

* Of the four driving cycles considered, the constant-speed cycle always shows the smallest value of emissions for all five pollutants. The differences for each pollutant among the other three cycles are within 10 percent.

For "optimistic" scenario, with conventional coal-fired power plant production of electricity:

* Implementation of roadway-powered electric buses in California could result in potential emissions reduction for all pollutants, except SOx. The reductions could be nearly 100 percent for HC and CO; 85-90 percent for NOx; and 60-80 percent for PM. Emissions of SOx could both decrease and increase, from a 40 percent reduction to a 10 percent increase, depending on the roadway/battery split and driving cycle.
* The percentage split of energy flow from dynamic roadway charging to the motor controller and to the battery affects the magnitude of the emissions for SOx and PM, though not for HC, CO, NOx.
* Of the four driving cycles considered, the constant-speed cycle always shows the smallest value of emissions for all five pollutants. The differences for each pollutant among the other three cycles are within 10 percent.

o ***Relationships Between Emissions And Roadway/Battery Power Split:***

Estimated emission changes of HC, CO, NOx, SOx, and PM versus the percentage split in roadway/battery power are shown in Figures

3 and 4, respectively, for the constant-speed and SAE-B driving cycles. In addition, these figures depict relationships for the "pessimistic" scenario, with the conventional coal-fired power plant type included in the analysis. The emission changes are expressed as percentage changes for roadway-powered electric buses, relative to existing diesel buses. The figures indicate that:

- * The percentage reductions for HC, CO, PM, and NOx are slightly greater with increasing percentage of roadway power utility.
- * The emission increases for SOx level off at a relatively sharp rate as the percentage of roadway power utility increases.

For Roadway-Powered Electric LDV's

o ***Range of Estimated Changes in Emissions:***

Estimated emission levels for the five pollutants due to the use of roadway-powered electric LDV's are shown in Tables 39 through 42 for the roadway/battery power percentage splits of 20/80 through 80/20, respectively, for the "pessimistic" scenario, including conventional coal-fired power plant production of electricity. Corresponding percentage emission changes follow in Tables 43 through 46. Tables 47 through 54 depict the corresponding information for the "optimistic" scenario. Tables 55 through 62 and Tables 63 through 70 show the corresponding information for the "pessimistic" and "optimistic" scenarios, respectively, exluding conventional coal-fired power plant production of electricity. The values shown are the range corresponding to the minimum and maximum percentage splits of energy flow from dynamic roadway charging to the motor controller and to the battery of 50/50 and 95/5, respectively. Examining these results indicates that:

<u>For "pessimistic" scenario, with conventional coal-fired power plant production of electricity:</u>

* Implementation of roadway-powered electric LDV's in California could result in significant reductions in emissions for HC and CO and substantial increases for NOx, SOx, and PM. The reductions for HC and CO would be in the 90-95 percent range. The increase could range from about O-80 percent for NOx; approximately 25-130 percent for SOx; and 95-255 percent for PM.
* The percentage split of energy flow from dynamic roadway charging to the motor controller and the battery could affect the magnitude of emission changes for NOx, SOx, and PM, but not for HC or CO.

<u>For "optimistic" scenario, with conventional coal-fired power plant production of electricity:</u>

* Implementation of roadway-powered electric LDV's in California could result in significant reductions in emissions for HC and CO, changes ranging from small reductions to small increases for NOx and SOx, and sizable increases for PM. The reductions for HC and CO would be about 95 percent. The change for NOx could

range from about a 20 percent reduction to approximately a 15 percent increase. The change for SOx could range from a reduction of about 15 percent to an increase of approximately 30 percent; the increase could range from 75-160 percent for PM.

- The percentage split of energy flow from dynamic roadway charging to the motor controller and the battery could affect the magnitude of emission changes for NOx, SOx, and PM, but not for HC or CO.

o ***Relationships Between Emissions And Roadway/Battery Power Split:***

Figures 5 and 6 show the estimated percentage changes in emissions of the five pollutants for roadway-powered electric LDV's (relative to gasoline LDV's) versus the split in roadway/battery power, for the constant-speed and the SAE-B driving cycles, respectively, for the "pessimistic" scenario including conventional coal-fired power plant production of electricity. Similar to the roadway-powered electric buses, higher percent of roadway power would result in a decrease of RPEV emissions for all five pollutants. This is particularly true for for NOx, SOx, and PM.

For Roadway-Powered Electric Automobiles

o ***Range of Estimated Changes in Emissions:***

Estimated emission levels for the five pollutants as a result of adopting roadway-powered electric automobiles are depicted in Tables 71 through 74 for the roadway/battery power percentage splits of 20/80 through 80/20, respectively, for the "pessimistic" scenario, including conventional coal-fired power plant production of electricity. Corresponding percentage emission changes follow in Tables 75 through 78. Tables 79 through 86 show the corresponding information for the "optimistic" scenario. Tables 87 through 94 and Table 95 through 102 depict the corresponding information for the "pessimistic" and "optimistic" scenarios, respectively, excluding conventional coal-fired power plant production of electricity. The range of emission reductions shown corresponds to the minimum and maximum splits of energy flow from dynamic roadway charging to the motor controller and to the battery of 50/50 and 95/5, respectively. Examimation of these tables reveals that:

<u>For "pessimistic" scenario, with conventional coal-fired power plant production of electricity:</u>

* Implementation of roadway-powered electric automobiles could result in significant reductions in emissions for all five pollutants. The reductions could be nearly 100 percent for HC and CO; about 30-75 percent for NOx; about 25-70 for SOx; and approximately 5-60 percent for PM.
* The percentage split of energy flow from dynamic roadway charging to the motor controller and battery could affect the magnitude of emission reductions for NOx, SOx, and PM, but not for HC or CO.
* Of the four driving cycles examined, the constant-speed cycle always shows the smallest emissions for all five

pollutants. The differences among the other three driving cycles are slight.

For "optimistic" scenario, with conventional coal-fired power plant production of electricity:

* Implementation of roadway-powered electric automobiles could result in significant reductions in emissions for all five pollutants. The reductions could be nearly 100 percent for HC and CO; about 55-80 percent for NO-x, about **60-80** for SOx; and approximately 30-65 percent for PM.
* The percentage split of energy flow from dynamic roadway charging to the motor controller and the battery could affect the magnitude of emission reductions for NOx, SOx, and PM, but not for HC or CO.
* Of the four driving cycles examined, the constant-speed cycle always shows the smallest emissions for all five pollutants. The differences among the other three driving cycles are slight.

o Relationships Between Emissions And Roadway/Battery Power Split:

Figures 7 and 8 show the estimated percentage changes in emissions of the five pollutants as a result of adopting roadway-powered electric automobiles versus the split in roadway/battery power, for the constant-speed and the SAE-B driving cycles, respectively. Moreover, these figures depict relationships for the "pessimistic" scenario, with the conventional coal-fired power plant type included in the analyis. The figures indicate that as the percentage of the roadway power utility (as opposed to the battery power) increases, RPEV emission levels decrease for all five pollutants. Emission reductions for HC and CO could increase slightly'with increasing percent of the roadway power utility. Emission reduction for NOx, SOx, and PM varies more significantly with the percent of roadway power utility.

Effects of Excluding Conventional Coal-fired Power Plants:

The magnitude of changes in emissions with the inclusion and the exclusion of conventional coal-fired power plants is examined. A few patterns emerged. Emission reductions in HC and CO due to RPEV's which were on the order of 95-100 percent are not sensitive to whether or not conventional coal-fired power plants are included in the analysis. Emission changes for NOx, SOx, and PM due to RPEV's are greater when conventional coal-fired power plants are excluded from the analysis, across all three vehicle types, driving cycles, and both scenarios. An illustration characteristic of this behavior is provided in Table 103 for the "pessimistic" scenario, as well as the SAE-B driving cycle.

VI. CONCLUSIONS AND SUMMARY

Conclusions

Roadway-powered electric buses, LDV's, and automobiles all show significant reductions in emissions for both HC and CO (up to

99, 96, and 99 percent, respectively). For NOx and PM, reductions are also likely for roadway-powered buses and automobiles, though the magnitude of reductions appears smaller than for HC and CO. NOx and PM emission increases could be expected for roadway-powered LDV's, up to 79 and 253 percent respectively, in the "worst" case event of the "pessimistic" scenario coupled with the inclusion of conventional coal-fired power plants for production of electricity. However, emissions decreases for NOx and PM could be expected, up to 55 and 25 percent respectively, in the "best" case event of the "optimistic" scenario excluding conventional coal-fired power plants. For SOx, reductions of up to 70 percent are likely for roadway-powered automobiles in the "worst" case event, and up to 95 percent in the "best" case event. However, SOx emissions for both roadway-powered LDV's and buses could be expected to increase by up , to 128 and 99 percent, respectively in the "worst" case, yet decrease up to 85 and 90 percent respectively, in the "best" case.

Estimates of changes in emissions for all five pollutants for RPEV's relative to conventional ICEV's obtained in this report are supportive of trends reported by Nesbitt et al. (1990). However, some assumptions and parameter values used in this study, Nesbitt et al. (1990) and Wang et al. (1990) are different, as follows:

(i) The values of emissions due to existing ICEV's used in this report are based on updated data from the CARB's EMFAC7E model; Nesbitt et al. (1990) used the data available from the CARB's EMFAC7D model (i.e., an older version).

(ii) The baseline exhaust and evaporative emissions for

ICEV's used in this report are based on zero-mile emission rates for new 1995 ICEV's. The baseline ICEV estimates used by Wang et al. (1990) for the target year 1995 were based on emissions from a fleet of ICEV's assumed to enter the market in 1991.

(iii) The fuel efficiency for internal-combustion engine automobiles and LDV's assumed in this analysis is lower than that used by Wang et al. (1990). This makes the baseline refinery emissions greater in this report.

(iv) This report assumes slightly greater energy flow efficiencies for RPEV's than did Nesbitt et al. (1990).

(v) Energy consumption values for RPEV's used in this report are lower than those used in Nesbitt et al. (1990).

(vi) Projected percentages of electricity generated from each of the three major fuel sources (gas, oil, and coal) assumed in Nesbitt et al. (1990) are greater than assumed in this report. The effect is to increase RPEV emission estimates, and to reduce the emissions benefit from RPEV's relative to ICEV's.

Summary

The purpose of this analysis is to provide potential air quality impacts in the near term, i.e., 1995, due to the implementation of roadway-powered electric vehicles relative to conventional internal combustion engine vehicles. There is another concurrent advanced technology impact evaluation study under contract to PATH. The prime contractor is the Southern California Association of Governments (SCAG) and the focus of that study is the long-term (Year 2025). In addition to air quality impacts, the SCAG study considers the impact on petroleum usage and the utility industry. Moreover, topics such as costs (capital and operating), technological availability, fundability, organizational feasibility, construction phasing, social and political acceptance, monitoring, and near-term demonstration opportunities are also addressed. Even though the two studies focus on different time periods, valuable information gleaned from the SCAG study may be applied to the HOV study.

References

American Petroleum Institute, ***Basic Petroleum Data Book-Petroleum Industry Statistics,*** Volume XI, Number 3, Washington, D.C., September 1991.

California Air Resources Board, Industrial Projects Section, ***Uncontrolled and Controlled Power Plant Emissions,*** Sacramento, California, July 1988.

California Air Resources Board, Emission Inventory Branch, ***Predicted California Vehicle Emissions,*** Sacramento, California, 1990.

California Energy Commission, ***Fuels Report and Appendices,*** Sacramento, California, December 1989.

California Energy Commission, Energy Forecasting and Planning Division, ***Projection of Utility Generation,*** Sacramento, California, 1991.

Chira-Chavala T. et al. (1992; forthcoming), ***Feasibility of Advanced-Technology HOV Systems,*** Institute of Transportation Studies, University of California, Berkeley for CALTRANS, 1992.

Dowlatabadi, H., Krupnick, A.J., and Russell, A., ***Electric Vehicles and the Environment: Consequences for Emissions and Air Quality in Los Angeles and U.S. Regions,*** Electric Power Research Institute, Report Number RP2664-13, October 1990.

Gris, A.E., (1991). ***Evaluation of Potential Hybrid Electric Vehicle Applications,*** PATH Research Report, UCB-ITS-PRR-91-4, Institute of Transportation Studies, Program on Advanced Technology for the Highway, University of California at Berkeley, Berkeley, California.

Lechner, E.H. and Shladover, S.E. (1986), ***The Roadway Powered Electric Vehicle---An All-Electric Hybrid System,*** Presented at the 8th International Electric Vehicle Symposium, Washington, D.C., October 1986.

Lechner, E.H., Empey, D.H., Shladover, S.E. (1990), ***Testing of a Roadway Powered Electric Vehicle Prototype,*** Presented at the 10th International Electric Vehicle Symposium, Hong Kong, December 1990.

Nesbitt, K., Sperling, D., DeLuchi, M.A., (1990). "Initial Assessment of Roadway-Powered Electric Vehicles." ***Transportation Research Record, Number 1267 Energy and Environment - Global Warming: Transportation and Energy Considerations 1990,*** Transportation Research Board, National Research Council, Washington D.C., 1990.

SAE Handbook 1987. Volume 4, pp. 28.01-28.06

Santa Barbara Electric Bus Project, ***Prototype Development and Testing Program, Phase 3C, Final Report,*** 1986.

Shladover, S.E. (1989), "Roadway Electrification and Automation Technologies," Preseneted at ASCE 1st International Conference on Apllications of Advanced Technologies in Transportation Engineering, San Diego, CA, February 1989.

South Coast Air Quality Management District and Southern California Association of Governments (1990). ***Draft Air Quality Management Plan - South*** Coast ***Air Basin,*** Los Angeles, CA.

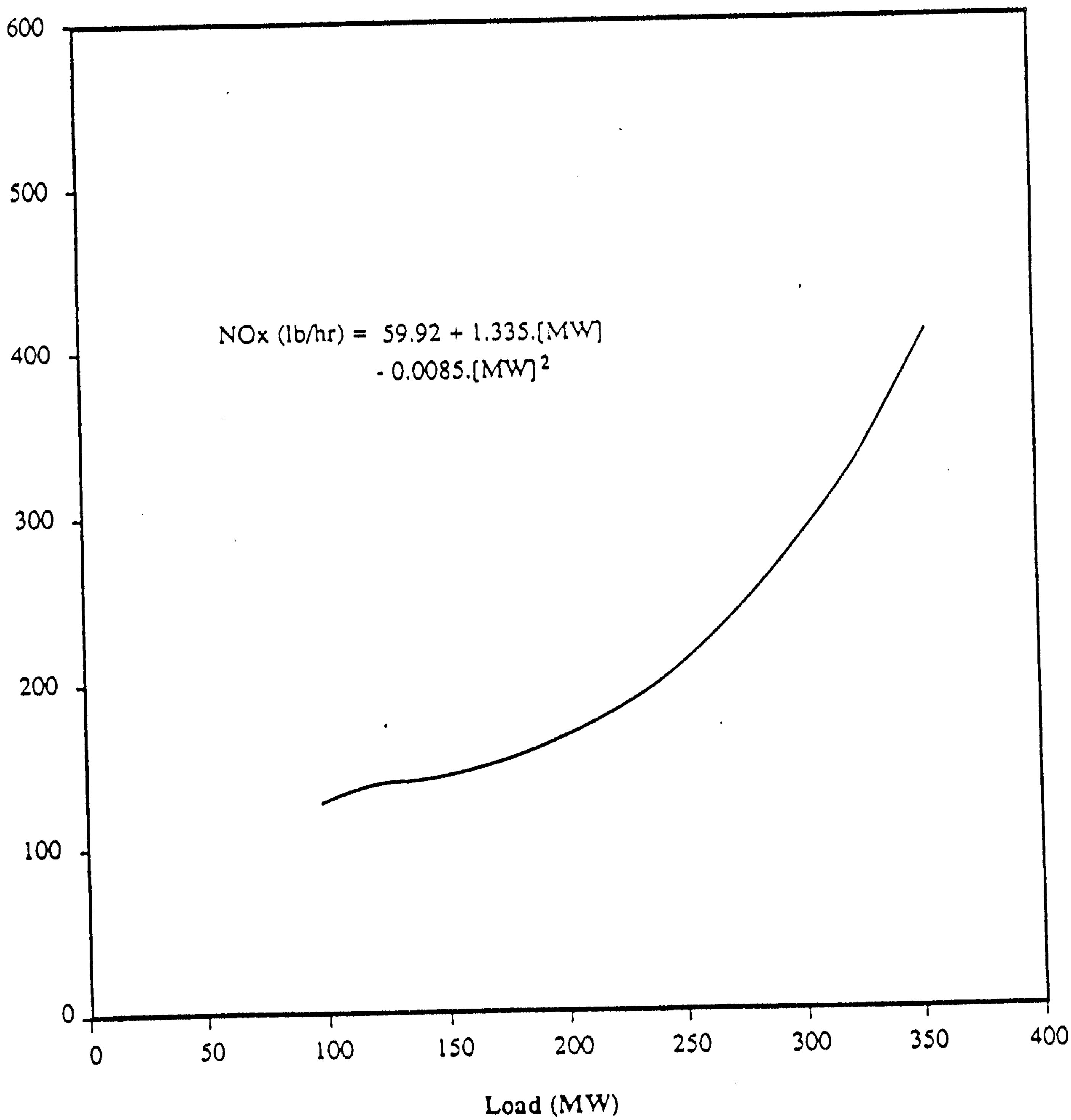
Systems Control Technology, Inc. (1992; forthcoming). ***Electric BUS Project-Parametric Studies Final Report,*** for the Program on Advanced Technology for the Highway (PATH), University of California, Berkeley.

Wang, Q., DeLuchi, M.A., Sperling, D. (1989). ***Air Pollutant Emissions and Electric Vehicles,*** Research Report, UCD-TRG-RR-89-1, Transportation Research Group, University of California at Davis, Davis, California.

Wang, Q., DeLuchi, M.A., Sperling, D. (1990). "Emission Impacts of Electric Vehicles." ***Journal of Air Waste Management Association,*** Volume 40, Number 9, September 1990.

FIGURES

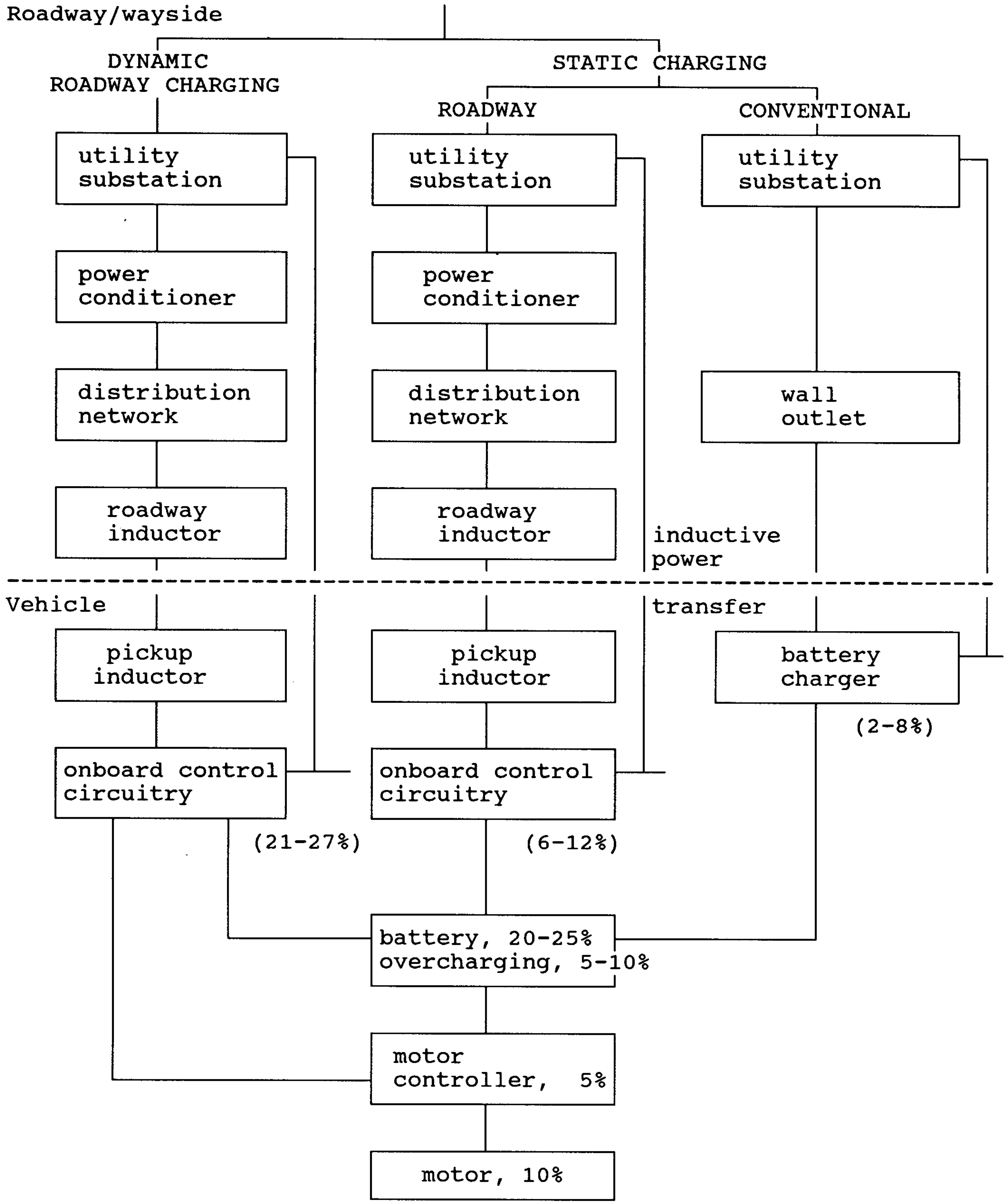
FIGURE 1: NOx Emissions Vs. Load



The emissions vs. load profile in this diagram is based on the Haynes 6 plant of the LA Department of Water and Power, burning natural gas.

Source: Dowlatabadi, H. et al (1990)

FIGURE 2: POWER FLOWS IN AN RPEV SYSTEM



(a-b%) is range of distribution loss

Source: Systems Control Technology, Inc. (1992)

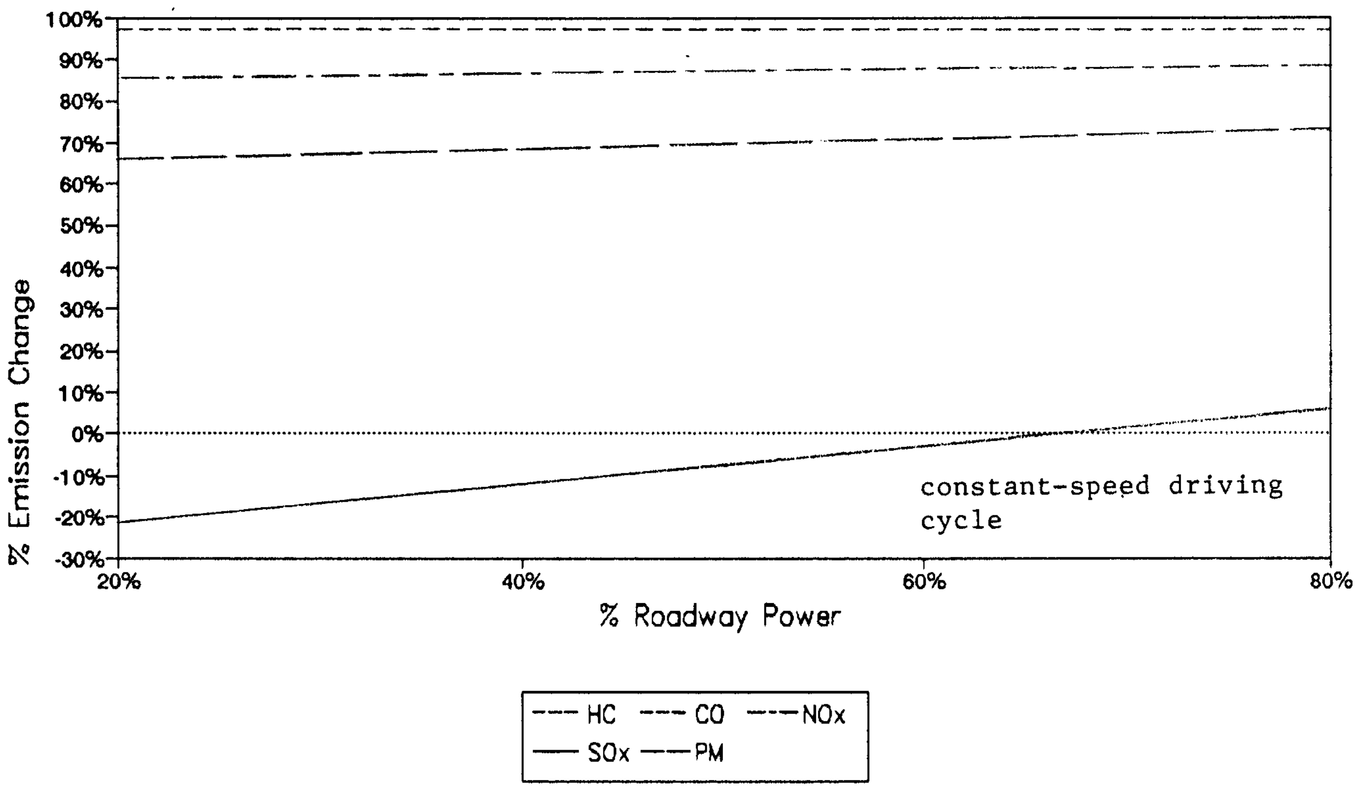


FIGURE 3: Emission Changes for Roadway-Powered Electric Buses

(Expressed as % of Emissions of Diesel Buses)

(- %: reduction; + %: increase)

Pessimistic Scenario

With Conventional Coal-fired Power Plants for Production of Electricity

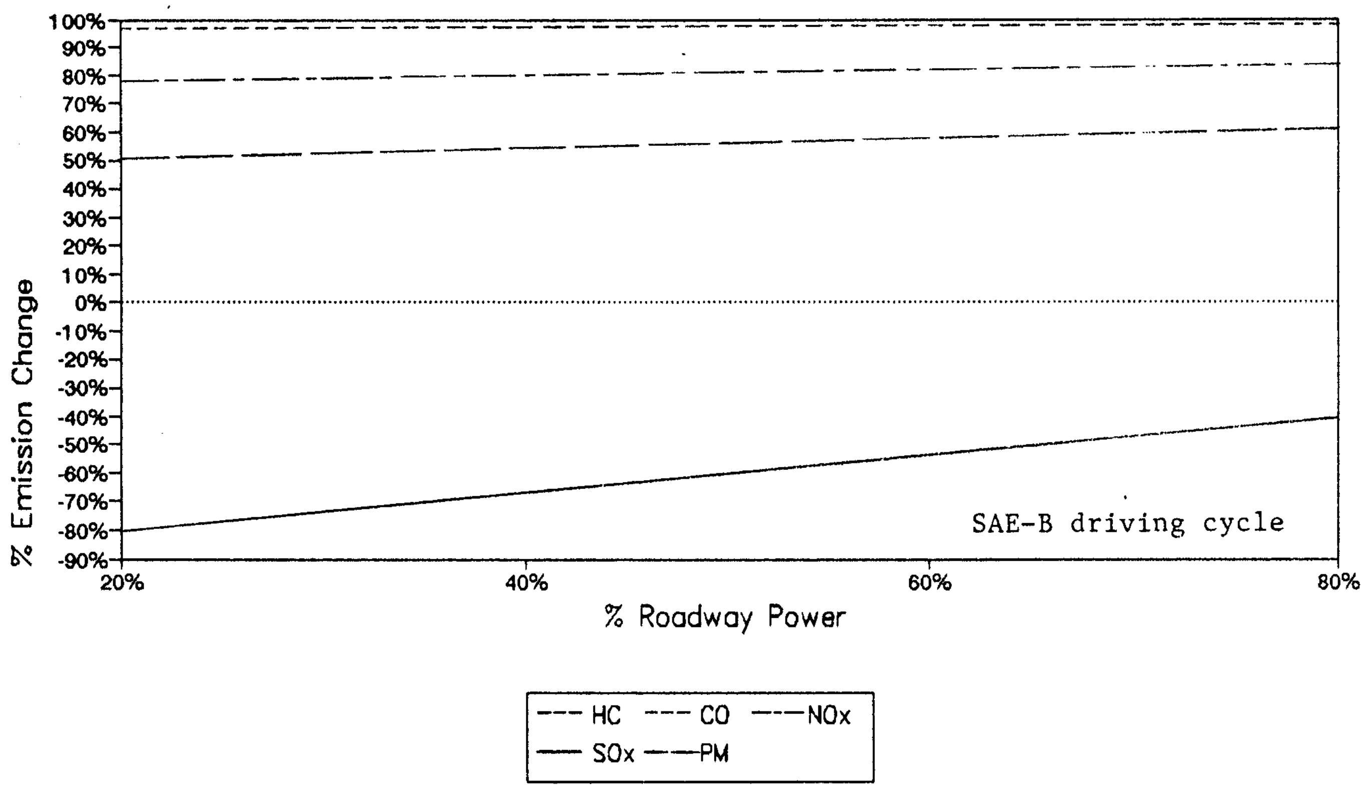


FIGURE 4: Emission Changes for Roadway-Powered Electric Buses

(Expressed as % of Emissions of Diesel Buses)

(- %: reduction; + %: increase)

Pessimistic Scenario

With Conventional Coal-fired Power Plants for Production of Electricity

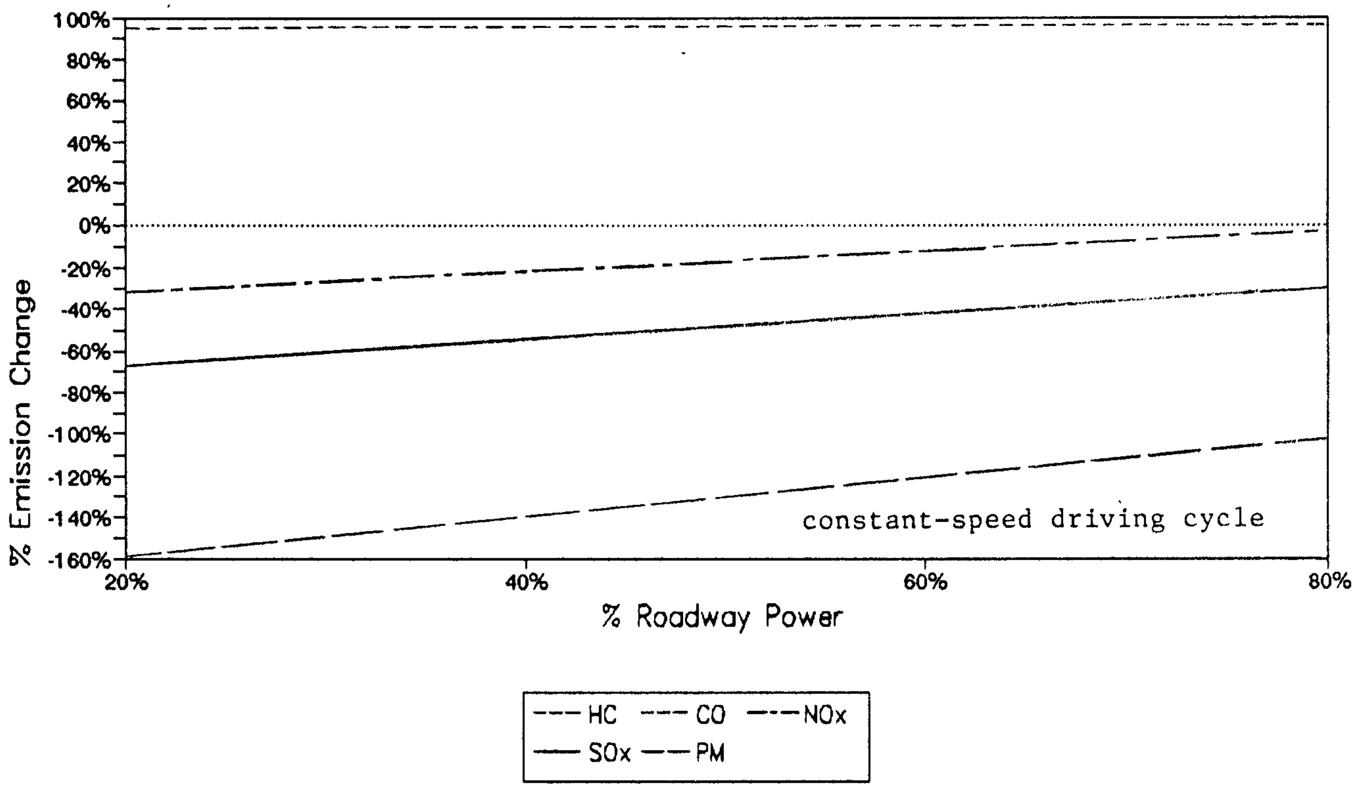


FIGURE 5: Emission Changes for Roadway-Powered Electric LDVs

(Expressed as % of Emissions of ICEV LDVs

(- %: reduction; + %: increase)

Pessimistic Scenario

With Conventional Coal-fired Power Plants for Production of Electricity

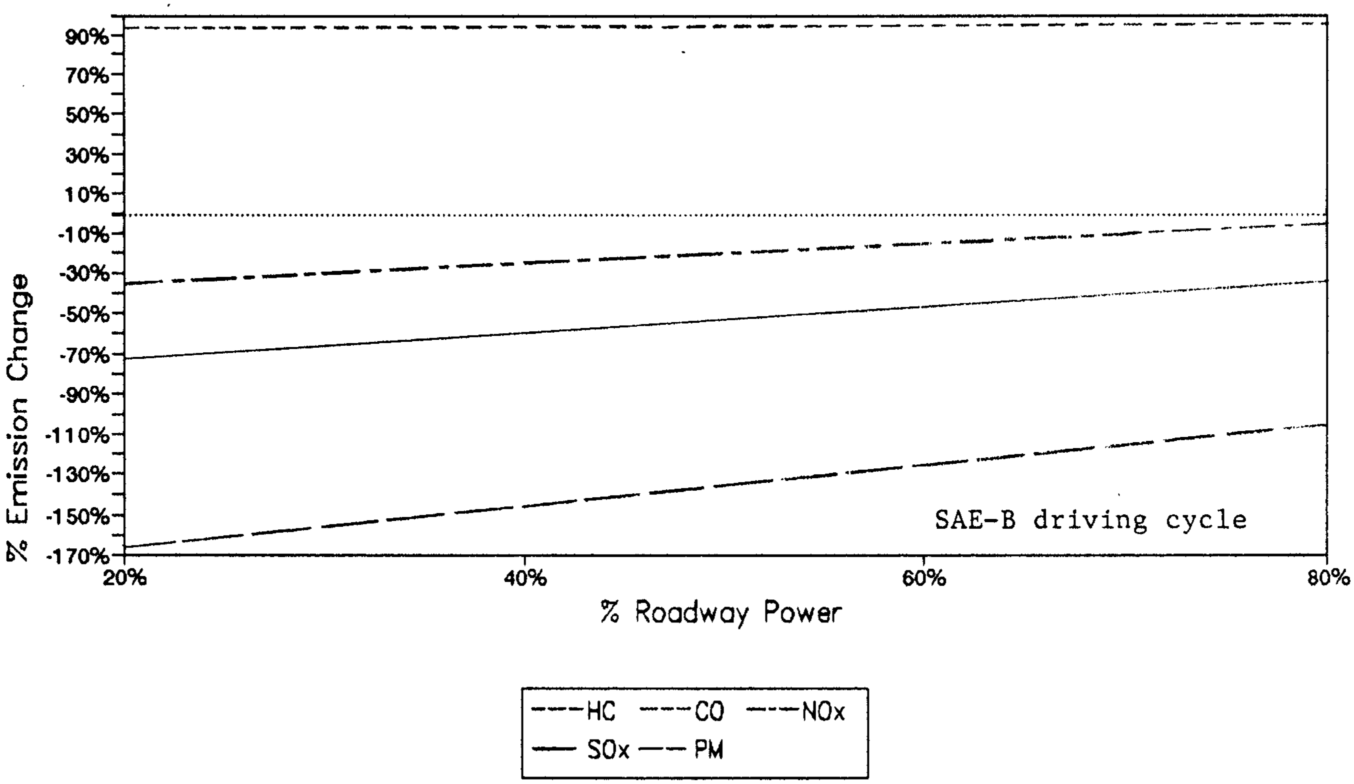


FIGURE 6: Emission Changes for Roadway-Powered Electric LDVs

(Expressed as % of Emissions of ICEV LDVs

(- %: reduction; + %: increase)

Pessimistic Scenario

With Conventional Coal-fired Power Plants for Production of Electricity

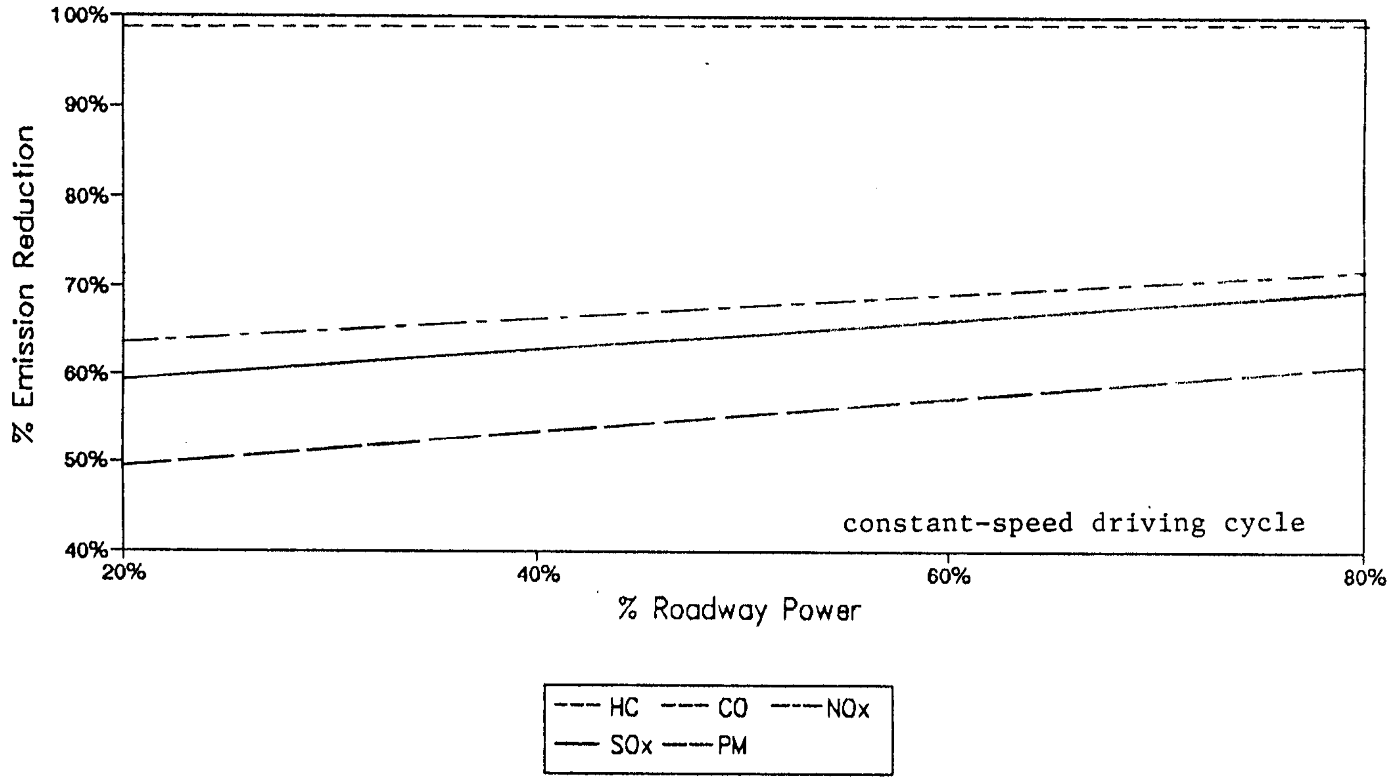


FIGURE 7: Emission Reductions for Roadway-Powered Electric Automobiles

(Expressed as % of Emissions of ICEV Automobiles)

Pessimistic Scenario

With Conventional Coal-fired Power Plants for Production of Electricity

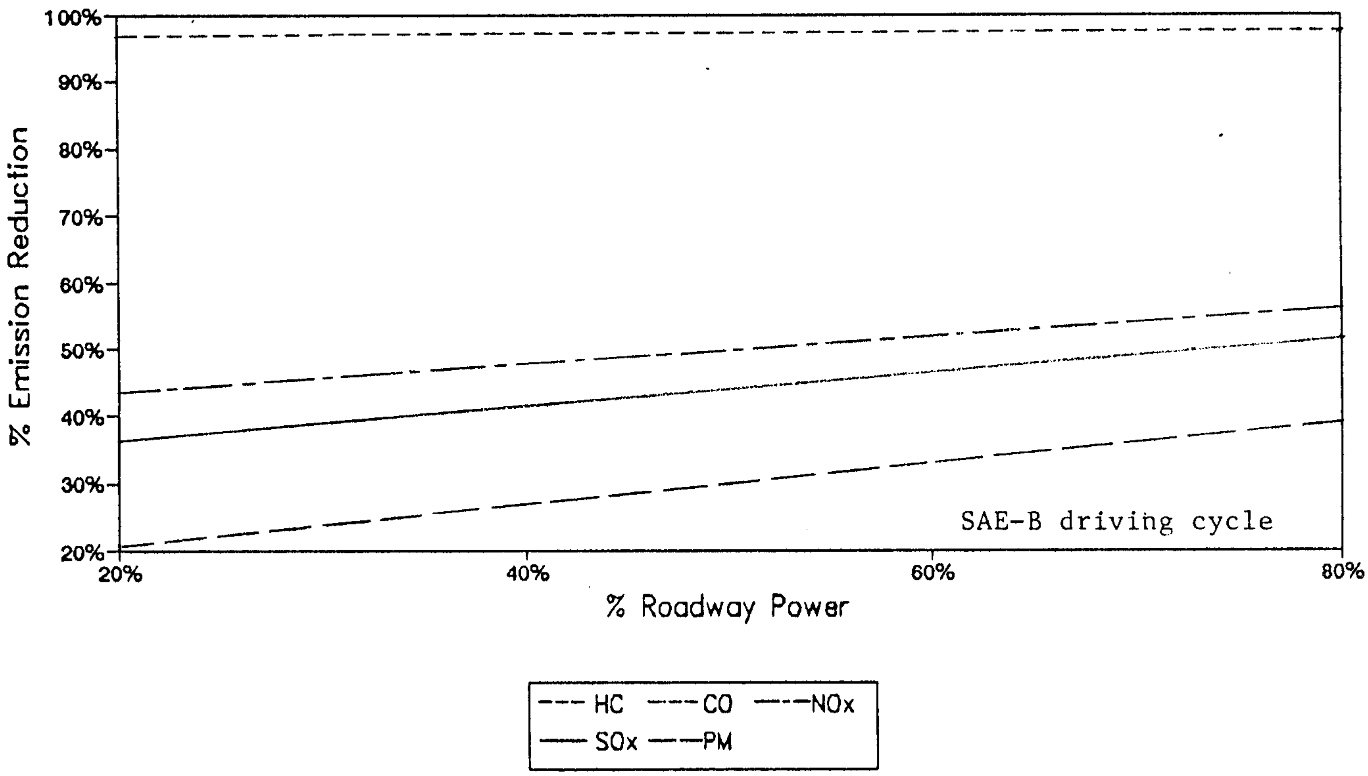


FIGURE 8: Emission Reductions for Roadway-Powered Electric Automobiles

(Expressed as % of Emissions of ICEV Automobiles)

Pessimistic Scenario

With Conventional Coal-fired Power Plants for Production of Electricity

TABLES

Table 1

1995 Replaced Fleet Emission Rates for **ICEVs**
(grams/mile)

	Automobile	LDV	Bus
HC	0.380	0.463	4.189
CO	1.351	1.797	17.119
NOx	0.356	0.541	14.280
SOx	0.256	0.340	1.377
PM	0.014	0.015	0.341

Source: California Air Resources Board, Predicted California Vehicle Emission, 1990.
American Petroleum Institute, Basic Petroleum Data Book, 1991.

Table 2

Uncontrolled Emission Rates
(pounds/mmBtu)

	HC	CO	NOx	SOX	PM
Gas-fired:					
Simple Turbine	0.04	0.11	0.39	0.0006	0.013
Combined Turbine	0.04	0.11	0.39	0.0006	0.013
Cogen-Turbine	0.04	0.11	0.39	0.0006	0.013
Boiler	0.002	0.04	0.52	0.0006	0.002
Coal-fired:					
Conventional	0.005	0.029	1.627	2.468	3.313
CFB	0.07	0.06	0.20	0.93	0.02
IGCC	N/A	0.004	0.07	0.018	0.004
Oil-fired:					
Residual Boiler	0.007	0.03	0.44	0.54	0.05
Cogen-Turbine	0.04	0.11	0.49	0.26	0.04

Source: California Air Resources Board, Industrial Projects Section, Uncontrolled and Controlled Power Plant Emissions, 1988.

Table 3

Power Plant Emission Control Technologies

Technology	Emission Reduction Percentage
Simple Gas Turbine	
NO_x - water injection	70
Combined Gas Turbine	
NO_x - water injection	70
NO_x - SCR[1]	80
Cogeneration Gas Turbine	
NO_x - water injection	70
NO_x - SCR	80
Gas Boiler	
NO_x - burners	50
NO_x - FGR[2]	70
Coal (CFB and Conventional)	
NO_x - thermal	80
SO_x - limestone injection	95
Residual Oil Boiler	
NO_x - burners	70
NO_x - FGR	40
SO_x - scrubber	98
PM - scrubber	40
Cogeneration Oil Turbine	
NO_x - water injection	70
NO_x - SCR	80
SO_x - low sulfur oil	80

[1]SCR = Selective Catalytic Reduction
[2]FGR = Flue Gas Recirculation

Source: California Air Resources Board, Industrial Projects Section, Uncontrolled and Controlled Power Plant Emissions, 1988.
Wang, et al. 1990.

Table 4

Power Plant Implementation Strategy Percentages

Technology	Less Stringent	More Stringent
Simple Gas Turbine		
NO_x - water injection	30	30
Combined Gas Turbine		
NO_x - water injection	30	30
NO_x - SCR	30	70
Cogeneration Gas Turbine		
NO_x - water injection	30	30
NO_x - SCR	30	70
Gas Boiler		
NO_x - burners	20	20
NO_x - FGR	30	30
Coal (CFB and Conventional)		
NO_x - thermal	30	30
SOx - limestone injection	30	50
Residual Oil Boiler		
NO_x - burners	20	20
NO_x - FGR	30	30
SOx - scrubber	30	30
PM - scrubber	30	30
Cogeneration Oil Turbine		
NO_x - water injection	30	30
NO_x - SCR	30	70
SOx - low sulfur oil	30	30

Source: Wang, et al. (1989).

Table 5

Projected Power Plant Mix for Electricity Generation

	Percentages
Gas-fired	
Simple Turbine	**0.1**
Combined Turbine	**1.0**
Cogen-Turbine	12.0
Boiler	15.6
Coal-fired	
CFB	0.4
IGCC	0.0
Conventional	7.6
Oil-fired	
Residual Boiler	2.7
Cogen-Turbine	0.3
Subtotal	39.6
All Others	60.4

Source: California Energy Commission, Fuels Report and Appendices, December 1989 and Projection of Utility Generation, 1991.

Table 6

Energy Consumption
(kwh/mile)

	Constant Velocity	SAE-B	SAE-C	SAE-D
Automobile[1]	0.093	0.145	0.171	0.137
LDV	0.512	0.525	0.516	0.688
Bus	1.503	2.230	2.430	2.350

[1] = Sub-compact size automobile

Source: Systems Control Technology, Inc., 1992.

TABLE'7

BUSES. Potential Emission Levels Due to RPEV's
(grains per mile) for 1995
[20/80 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.09	0.14	0.15	0.14-0.15
co	0.34-0.35	0.51-0.52	0.55-0.56	0.53-0.54
NOx	2.08-2.12	3.08-3.14	3.36-3.42	3.25-3.3 1
sox	1.66-l.69	2.46-2.5 1	2.68-2.73	2.60-2.65
PM	0.11-0.12	0.17	0.18-0.19	0.18

TABLE 8

BUSES. Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[40/60 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.08-0.09	0.13	0.14	0.13-0.14
co	0.31-0.33	0.46-0.48	0.51-0.53	0.49-0.5 1
NOx	1.91-1.98	2.83-2.94	3.08-3.21	2.99-3.11
sox	1.52-1.59	2.26-2.35	2.46-2.56	2.39-2.48
PM	0.10-0.11	0.15-0.16	0.17	0.16-0.17

TABLE 9

BUSES. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [60/40 Split of Roadway/Battery Power] Pessimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.08	0.11-0.12	0.13	0.12-0.13
CO	0.28-0.3	0.42-0.45	0.46-0.49	0.45-0.48
NOx	1.74-1.85	2.58-2.75	2.81-3	2.72-2.9
SOx	1.39-1.48	2.06-2.2	2.24-2.39	2.17-2.32
PM	0.09-0.1	0.14-0.15	0.15-0.16	0.15-0.16

TABLE 10

BUSES. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [80/20 Split of Roadway/Battery Power] Pessimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.07-0.08	0.10-0.11	0.11-0.12	0.11-0.12
CO	0.26-0.28	0.38-0.42	0.42-0.46	0.40-0.44
NOx	1.57-1.72	2.32-2.56	2.53-2.78	2.45-2.7
sox	1.25-1.38	1.86-2.04	2.02-2.23	1.96-2.16
PM	0.09	0.13-0.14	0.14-0.15	0.13-0.15

TABLE 11

BUSES. Potential Percentage Emission **Changes** Due to RPEV's
(- reduction, **t increase)**
[20/80 **Split** of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-97	-96	-97
CO	-98	-97	-97	-97
NOx	-85	-78	-76	-77
SOx	21 to 23	79 to 82	95 to 99	89 to 92
PM	-67	-50	-46	-47

TABLE 12

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, **t increase)**
[40/60 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional **Coal**

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-97	-97	-97
CO	-98	-97	-97	-97
NOx	-86	-80	-78	-79 to -78
SOx	**11 to 15**	64 to 71	79 to 86	73 to 80
PM	-70 to -68	-53 to -55	-51 to -49	-52 to -50

TABLE 13

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[60/40 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-97	-97	-97
co	-98	-98	-97	-97
NOx	-88	-81	-80	-80
sox	1 to8	50 to 60	63 to 74	58 to 69
PM	-72 to -70	-59 to -56	-55 to -52	-57 to -54

TABLE 14

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[80/20 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-9%	-97	-97	-97
co	-98	-98	-98	-98
NOx	-88	-84 to -82	-82 to -81	-83 to -81
sox	-9 to 0	35 to 48	47 to 62	42 to 57
PM	-75 to -72	-63 to -59	-59 to -55	-61 to -57

TABLE 15

BUSES. Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[20/80 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.06-0.07	0.1	0.10-0.11	0.1
CO	0.24	0.35-0.36	0.38-0.39	0.37-0.38
NOx	1.28-1.31	1.90-1.95	2.07-2.12	2-2.06
SOx	0.88-0.9	1.30-1.34	1.42-1.45	1.37-1.41
PM	0.08	0.12	0.13	0.12-0.13

TABLE 16

BUSES. Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[40/60 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.06-0.07	0.09-0.1	0.10-0.11	0.1
CO	0.23-0.25	0.35-0.37	0.38-0.40	0.37-0.39
NOx	1.27-1.34	1.88-1.99	2.05-2.16	1.99-2.09
SOx	0.87-0.92	1.29-1.36	1.40-1.48	1.36-1.43
PM	0.08	0.12	0.13	0.12-0.13

TABLE 17

BUSES. Potential Emission Levels Due to RPEV's
(grams per mile) for 19 9 5
[60/40 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.06-0.07	0.09-0.1	0.10-0.11	0.10-0.11
CO	0.23-0.25	0.35-0.37	0.38-0.41	0.36-0.39
NOx	1.26-1.36	1.87-2.02	2.03-2.2	1.97-2, 13
SOx	0.86-0.93	1.28-1.38	1.39-1.51	1.35-1.46
PM	0.08	0.12	0.13	0.12-0.13

TABLE 18

BUSES. Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[80/20 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.06-0.07	0.09-0.1	0.10-0.11	0.10-0.11
CO	0.23-0.26	0.34-0.38	0.37-0.41	0.36-0.4
NOx	1.25-1.39	1.85-2.06	2.02-2.24	1.95-2.17
SOx	0.85-0.95	1.28-1.41	1.38-1.53	1.34-1.49
PM	0.08	0.11-0.13	0.12-0.14	0.12-0.13

TABLE 19

BUSES. Potdntial Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[20/80 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-98	-98	-98
CO	-99	-98	-98	-98
NOx	-91	-87	-85	-86
SOx	-35	-6 to -3	3 to 6	0 t0 2
PM	-77	-66 to -65	-63 to -62	-64 to -63

TABLE 20

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[40/60 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-98	-98	-98
CO	-99	-98	-98	-98
NOx	-91	-87	-85	-86
SOx	-37 to -34	-6 to -1	2 to 8	-1 to 4
PM	-77 to -76	-66 to -64	-63 to -61	-64 to -62

TABLE 21

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[60/40 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-98	-98	-98
CO	-99	-98	-98	-98
NOx	-91	-86	-86 to -85	-86 to -85
SOx	-37 to -32	-7 to 0	1 to 10	-2 to 6
PM	-77 to -75	-66 to -64	-63 to -60	-64 to -61

TABLE 22

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[80/20 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-98	-98	-98
CO	-99	-98	-98	-98
NOx	-91	-87 to -86	-86 to -84	-85
SOx	-38 to -31	-8 to 2	0 to 11	-3 to 8
PM	-77 to -75	-67 to -63	-64 to -60	-65 to -61

TABLE 23

BUSES. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [20/80 Split of Roadway/Battery Power] Pessimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.09	0.13	0.14	0.14
CO	0.31	0.46	0.50-0.5 1	0.48-0.49
NOx	1.35-I.37	Z-Z.03	2.18-2.22	2.1 1-2.15
sox	0.19-0.2	0.29	0.3 I-O.32	0.30-0.3 1
PM	0.05	0.07	0.08	0.08

TABLE 24

BUSES. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [40/60 Split of Roadway/Battery Power] Pessimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.08	0.12	0.13	0.13
CO	0.29-0.3	0.42-0.44	0.46-0.48	0.44-0.46
NOx	1.24-1.29	1.83-1.91	2-2.08	1.94-2.01
SOx	0.18	0.26-0.27	0.29-0.3	0.28-0.29
PM	0.05	0.07	0.07	0.07

TABLE 25

BUSES. Potential Emission Levels Due to RPEV's
(grains **per mile) for 1995**
[60/40 **Split of Roadway/Battery Power]-**
Pessimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.07	0.11-0.12	0.12	0.11-0.12
CO	0.26-0.28	0.38-0.41	0.42-0.45	0.41-0.43
NOx	1.13-1.2	1.67-1.78	1.82-1.94	1.76-1.88
SOx	0.16-0.17	0.24-0.26	0.26-0.28	0.25-0.27
PM	0.04	0.06-0.07	0.07	0.06-0.07

TABLE 26

BUSES. Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[80/20 **Split of Roadway/Battery Power]**
Pessimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.07	0.10-0.11	0.11-0.12	0.10-0.11
CO	0.23-0.26	0.35-0.38	0.38-0.41	0.37-0.4
NOx	1.02-1.12	1.51-1.66	1.64-1.8	1.59-1.75
SOx	0.15-0.16	0.22-0.24	0.24-0.26	0.23-0.25
PM	0.04	0.05-0.06	0.06-0.07	0.06

TABLE 27

BUSES. Pofential Percentage Emission Changes Due to RPEV's
(– reduction, t increase)
[20/80 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-97	-97	-97
CO	-98	-97	-97	-97
NOx	-90	-86	-85	-85
SOx	-86	-79	-77	-78
PM	-86	-79	-77	-77

TABLE 28

BUSES. Potential Percentage Emission Changes Due to RPEV's
(– reduction, t increase)
[40/60 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-97	-97	-97
CO	-98	-97	-97	-97
NOx	-91	-87	-86	-86
SOx	-87	-81	-79	-80
PM	-87	-80	-78	-79

TABLE 29

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[60/40 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-97	-97	-97
co	-98	-98	-98	-98
NOx	-92	-88	-87 to -86	-87
sox	-88	-82	-80	-82 to -80
PM	-88	-82 to -81	-81 to -79	-80

TABLE 30

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[80/20 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-98	-98	-97	-97
CO	-99	-98	-98	-98
NOx	-93	-90 to -88	-89 to -87	-88
SOx	-89	-84	-83 to -81	-83
PM	-89	-84 to -82	-81	-83 to -81

TABLE 31

BUSES. Potential Emission Levels Due to RPEV's (grains per mile) for 1995 [20/80 Split of Roadway/Battery Power) Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.06	0.09	0.1	0.09-0.1
CO	0.21-0.23	0.32-0.33	0.35-0.36	0.33-0.35
NOx	0.76-0.81	1.13-1.20	1.24-1.30	1.20-1.26
SOx	0.13	0.19-0.2	0.20-0.22	0.20-0.21
PM	0.03	0.05	0.05-0.06	0.05

TABLE 32

BUSES. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [40/60 Split of Roadway/Battery Power] Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.06	0.09-0.1	0.1	0.09-0.1
co	0.06	0.09-0.1	0.1 o-o.1 1	0.09-0.1
NOx	0.75-0.84	1.12-1.24	1.22-l.35	1.18-1.31
SOx	0.12-0.14	0.18-0.20	0.20-0.22	0.19-0.22
PM	0.03-0.04	0.05	0.05-0.06	0.05-0.06

TABLE 33

BUSES. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [60/40 Split of Roadway/Battery Power] Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
CO	0.06	0.09-0.10	0.1	0.09-0.10
NOx	0.2 0.76-0.82 l-0.23	0.3 1.13-1l-0.34 .22	0.34-0.37 1.23-l .33	0.33-0.36
				1.19-1.29
sox	0.13-0.14	0.19-0.20	0.20-0.22	0.20-0.21
PM	0.03-0.04	0.05	0.05-0.06	0.05-0.06

TABLE 34

BUSES. Potential Emission Levels Due to RPEV's (grams per mile) for 199 5 [80/20 Split of Roadway/Battery Power] Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.06	0.09-0.10	0.10-0.11	0.09-0.10
CO	0.21-0.23	0.31-0.35	0.33-0.38	0.33-0.37
NOx	0.75-0.84	1.12-1.24	1.22-1.35	1.18-1.31
SOx	0.12-0.14	0.18-0.20	0.20-0.22	0.19-0.22
PM	0.03-0.04	0.05	0.05-0.06	0.05-0.06

TABLE 35

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[20/80 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-98
CO	-99	-98	-98	-98
NOx	-95	-92	-91	-91
SOx	-91	-86	-85	-85
PM	-90	-85	-84	-84

TABLE 36

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[40 /6 0 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-98
CO	-99	-98	-98	-98
NOx	-95	-92	-91	-91
SOx	-91	-86	-85	-85
PM	-90	-85	-84	-84

TABLE 37

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[60/40 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-98
CO	-99	-98	-98	-98
NOx	-95	-92	-91	-91
SOx	-91	-86	-85	-86 to -85
PM	-90	-85	-84	-85 to -83

TABLE 38

BUSES. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[80/20 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-98
CO	-99	-98	-98	-98
NOx	-95	-92	-91	-91
SOx	-91	-86	-85	-86 to -84
PM	-90	-86 to -84	-84	-85 to -83

TABLE 39

LDVs Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[20/80 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.03	0.03	0.03	0.04
CO	0.12	0.12	0.12	0.16
NOx	0.71-0.72	0.73-0.74	0.71-0.73	0.95-0.97
SOx	0.57-0.58	0.58-0.59	0.57-0.58	0.76-0.77
PM	0.04	0.04	0.04	0.05

TABLE 40

LDVs Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[40/60 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.03	0.03	0.03	0.04
CO	0.11	0.11	0.11	0.14-0.15
NOx	0.65-0.68	0.67-0.69	0.65-0.68	0.87-0.91
SOx	0.52-0.54	0.53-0.55	0.52-0.54	0.70-0.73
PM	0.04	0.04	0.04	0.05

TABLE 41

LDVs **Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [60/40 Split of Roadway/Battery Power] Pessimistic Scenario, With Conventional Coal**

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.03	0.03	0.03	0.04
CO	0.1	0.1	0.1	0.13-0.14
NOx	0.59-0.63	0.61-0.65	0.60-0.64	0.79-0.85
SOx	0.47-0.5	0.48-0.52	0.48-0.51	0.64-0.68
PM	0.03	0.03-0.04	0.03	0.04-0.05

TABLE 42

LDVs **Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [80/20 Split of Roadway/Battery Power] Pessimistic Scenario, With Conventional Coal**

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02-0.03	0.02-0.03	0.02-0.03	0.03-0.04
CO	0.09-0.1	0.09-0.1	0.09-0.1	0.12-0.13
NOx	0.53-0.59	0.55-0.6	0.54-0.59	0.72-0.79
SOx	0.43-0.47	0.44-0.48	0.43-0.47	0.57-0.63
PM	0.03	0.03	0.03	0.04

TABLE 43

LDVs Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[20/80 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-93	-93	-93	-91
CO	-94	-93	-93	-91
NOx	31 to 33	34 to 37	32 to 34	76 to 79
SOx	66 to 69	71 to 74	68 to 71	123 to 128
PM	158 to 162	164 to 169	160 to 164	246 to 253

TABLE 44

LDVs Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[40/60 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-94	-94	-94	-91
CO	-94	-94	-94	-92
NOx	20 to 25	23 to 28	21 to 26	61 to 68
SOx	53 to 59	57 to 63	54 to 60	105 to 114
PM	136 to 146	142 to 152	138 to 148	218 to 231

TABLE 45

LDVs Potential Percentage Emission Changes Due to RPEV's
(– reduction, + increase)
[60/40 Split of Roadway/Battery Power]-
Pessimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-94	-94	-94	-92
CO	-94	-94	-94	-93
NOx	9 to 17	12 to 20	10 to 18	47 to 57
SOx	39 to 48	43 to 52	40 to 50	87 to 99
PM	115 to 130	121 to 136	117 to 132	189 to 209

TABLE 46

LDVs Potential Percentage Emission Changes Due to RPEV's
(– reduction, + increase)
[80/20 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-95	-94	-95	-93
CO	-95	-95	-95	-93
NOx	-1 to 9	1 to 11	-1 to 9	33 to 46
SOx	25 to 38	29 to 41	26 to 39	69 to 85
PM	94 to 114	99 to 119	96 to 115	161 to 187

TABLE 47

LDVs Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[20/80 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02	0.02	0.02	0.03
CO	0.08	0.08	0.08	0.11
NOx	0.44-0.45	0.45-0.46	0.44-0.45	0.56-0.60
SOx	0.30-0.31	0.31	0.30-0.31	0.40-0.41
PM	0.03	0.03	0.03	0.04

TABLE. 48

LDVs Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[40/60 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02	0.02	0.02	0.03
CO	0.08	0.08-0.09	0.08-0.09	0.11
NOx	0.43-0.46	0.44-0.47	0.44-0.46	0.58-0.61
SOx	0.30-0.31	0.30-0.32	0.30-0.31	0.40-0.42
PM	0.03	0.03	0.03	0.04

TABLE 49

LDVs Potential Emission Levels Due to RPEV's
(giams per mile) for 1995
[60/40 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02	0.02	0.02	0.03
CO	0.08	0.08-0.09	0.08-0.09	0.11-0.12
NOx	0.43-0.46	0.44-0.48	0.43-0.48	0.58-0.62
SOx	0.29-0.32	0.30-0.33	0.30-0.32	0.39-0.43
PM	0.03	0.03	0.03	0.04

TABLE 50

LDVs Potential Emission Levels Due to RPEV's
(grams per mile) for 19 95
[80/20 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02	0.02	0.02	0.03
CO	0.08-0.09	0.08-0.09	0.08-0.09	0.11-0.12
NOx	0.43-0.47	0.44-0.48	0.43-0.48	0.57-0.63
SOx	0.29-0.32	0.30-0.33	0.29-0.33	0.39-0.43
PM	0.03	0.03	0.03	0.04

TABLE 51

LDVs Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[20/80 Split of Roadway/Battery Power]·
Optimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-95	-95	-95	-94
CO	-95	-95	-95	-94
NOx	-19 to -17	-17 to -15	-19 to -17	8 to 11
SOx	-12 to -10	-10 to -8	-12 to -9	18 to 21
PM	79 to 84	84 to 89	81 to 85	141 to 147

TABLE 52

LDVs Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[40/60 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-95	-95	-95	-94
CO	-95	-95	-95	-94
NOx	-20 to -16	-18 to -14	-20 to -15	7 to 13
SOx	-13 to -8	-11 to -6	-12 to -8	17 to 23
PM	78 to 87	82 to 92	79 to 89	139 to 152

TABLE 53

LDVs Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[60/40 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-95	-95	-95	-94
co	-95	-95	-95	-94
NOx	-21 to -14	-19 to -12	-20 to -14	6 to 15
sox	-14 to -7	-12 to -4	-13 to -6	16 to 26
PM	76 to 91	81 to 96	78 to 92	137 to 156

TABLE 54

LDVs Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[80/20 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	−95	−95	−95	−94
CO	−95	−95	−95	−94
NOx	−21 to −13	−19 to −11	−21 to −12	6 to 17
SOx	−14 to −5	−12 to −3	−14 to −4	15 to 28
PM	75 to 94	79 to 99	76 to 96	135 to 161

TABLE 55

LDVs **Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [20/80 Split of Roadway/Battery Power]**
Pessimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.03	0.03	0.03	0.04
CO	0.11	0.11	0.11	0.14
NOx	0.46-0.47	0.47-0.48	0.46-0.47	0.62-0.63
SOx	0.07	0.07	0.07	0.09
PM	0.02	0.02	0.02	0.02

TABLE 56

LDVs **Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [40/60 Split of Roadway/Battery Power] Pessimistic Scenario, Without Conventional Coal**

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.03	0.03	0.03	0.04
CO	0.1	0.1	0.1	0.13-0.14
NOx	0.42-0.44	0.43-0.45	0.42-0.44	0.57-0.59
sox	0.06	0.06	0.06	0.08
PM	0.02	0.02	0.02	0.02

TABLE 57

LDVs Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[60/40 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02-0.03	0.03	0.03	0.03
CO	0.09	0.09-0.1	0.09	0.12-0.13
NOx	0.38-0.41	0.39-0.42	0.39-0.41	0.52-0.55
SOx	0.06	0.06	0.06	0.07-0.08
PM	0.01	0.01	0.01	0.02

TABLE 58

LDVs Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[80/20 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02	0.02	0.02	0.03
CO	0.08	0.08-0.09	0.08	0.11-0.12
NOx	0.35-0.38	0.35-0.39	0.35-0.38	0.46-0.51
SOx	0.05	0.05-0.06	0.05-0.06	0.07
PM	0.01	0.01	0.01	0.02

TABLE 59

LDVs Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[20/80 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollu– tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	–94	–93	–94	–91
CO	–94	–94	–94	–92
NOx	–14	–13 to –11	–15 to –13	14 to 16
	–81	–80	–80	–74
PM	11 to 14	14 to 17	12 to 15	50 to 53

TABLE 60

LDVs Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[40/60 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollu– tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-94	-94	-94	-92
co	-94	-94	-95	-93
NOx	-22 to -19	-20 to -17	-22 to -18	5 to 9
sox	-82	-81	-82	-76
PM	2 to 7	5 to 9	3 to 7	38 to 43

TABLE 61

LDVs Potential Percentage Emission Changes Due to RPEV's
(– reduction, t increase)
[60/40 Split of Roadway/Battery Power}
Pessimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	–95	–94	–94	–93
CO	–95	–95	–95	–93
NOx	–29 to –24	–27 to –22	–29 to –24	–5 to 2
	–83	–83	–83	–77
PM	–7 to –1	–4 to 2	–6 to 0	25 to 34

TABLE 62

LDVs Potential Percentage Emission Changes Due to RPEV's
(– reduction, t increase)
[80/20 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	–95	–95	–95	–93
CO	–95	–95	–95	–94
NOx	–36 to –30	–35 to –28	–36 to –29	–14 to –6
SOx	–85	–84	–85	–80 to –78
PM	–16 to –8	–14 to –5	–15 to –7	13 to 24

TABLE 63

LDVs Potential Emission Levels Due to RPEV's (grams per mile) for 1995
[20/80 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02	0.02	0.02	0.03
co	0.07-0.08	0.08	0.07-0.08	0.1
NOx	0.26-0.27	0.27-0.28	0.26-0.27	0.35-0.36
sox	0.04	0.04-0.05	0.04	0.06
PM	0.01	0.01	0.01	0.02

TABLE 64

LDVs Potential Emission Levels Due to RPEV's (grams per mile) for 1995
[40/60 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02	0.02	0.02	0.03
co	0.07-0.08	0.07-0.08	0.07-0.08	0.1
NOx	0.26-0.27	0.27-0.28	O-26-0.28	0.35-0.37
sox	0.04	0.04-0.05	0.04	0.06
PM	0.01	0.01	0.01	0.01

TABLE 65

LDVs Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[60/40 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02	0.02	0.02	0.03
co	0.07-0.08	0.07-0.08	0.07-0.08	0.1
NOx	0.26-0.28	0.26-0.29	0.26-0.28	0.35-0.38
sox	0.04-0.05	0.04-0.05	0.04-0.05	0.06
PM	0.0 1	0.01	0.01	0.02

TABLE 66

LDVs Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[60/40 Split of Battery/Roadway Power]
Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.02	0.02	0.02	0.03
CO	0.07-0.08	0.07-0.08	0.07-0.08	0.10-0.11
NOx	0.26-0.28	0.26-0.29	0.26-0.29	0.34-0.38
SOx	0.04-0.05	0.04-0.05	0.04-0.05	0.06
PM	0.01	0.01	0.01	0.02

TABLE 67

LDVs Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[20/80 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-96	-95	-96	-94
CO	-96	-96	-96	-95
NOx	-51 to -50	-50	-50	-35 to -33
SOx	-87	-87	-87	-82
PM	-23 to -20	-21 to -18	-22 to -20	4 to 7

TABLE 68

LDVs Potential Percentage Emission **Changes Due to** RPEV's
(- reduction, t increase)
[40/60 Split of Roadway/Battery **Power]**
Optimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-96	-95	-96	-94
co	-96	-96	-96	-94
NOx	-52 to -49	-51 **to -48**	-52 to -49	-35 **to -32**
sox	-87	-87	-87	-83
PM	-23 **to** -19	-21 to -17	-23 to -18	3 to 9

TABLE 69

LDVs Potential Percentage **Emission** Changes Due to RPEV's
(- reduction, t increase)
[60/40 Split of Roadway/Battery **Power]**
Optimistic Scenario, Without Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	S&E C	SAE D
HC	-96	-95	-96	-94
co	-96	-96	-96	-95
NOx	-52 to -48	-51 to -47	-52 to -48	-35 to -31
sox	-87	-87	-87	-82
PM	-24 to -18	-22 to -15	-23 to -17	3 to 11

TABLE 70

LDVs Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[80/20 Split of Roadway/Battery Power]
Optimistic Scenario, **Without Conventional Coal**

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-96	-95	-96	-94
co	-96	-96	-96	-95
NOx	-53 to -47	-51 to -46	-52 to -47	-36 to -29
sox	-87	-87	-87	-83
PM	-23 to -16	-23 to -14	-24 to -15	2 to 13

TABLE 71

CARS. Poténtial **Emission Levels Due to** RPEV's
(grams per mile) for 1995
[20/80 **Split of Roadway/Battery Power]**
Pessimistic Scenario, With Conventional Coal

Pollu tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.006	0.009	0.01	0.009
CO	0.02	0.03	0.04	0.03
NOx	0.13	0.2	0.24	0.19
SOx	0.1	0.16	0.19	0.15
PM	0.007	0.01	0.01	0.01

TABLE 72

CARS. Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[40/60 **Split of Roadway/Battery Power]**
Pessimistic Scenario, With Conventional Coal

Pollu– tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.005	0.008	0.01	0.008
co	0.02	0.03	0.04	0.03
NOx	0.12	0.38-0.19	0.22-0.23	0.17-0.18
sox	0.09–.1	0.15	0.17-0.18	0.14
PM	0.006-0.007	0.01	0.01	0.009–.01

TABLE 73

CARS. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [60/40 Split of Roadway/Battery Power] Pessimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.005	0.008	0.009	0.007
CO	0.02	0.03	0.03	0.03
NOx	0.11	0.17-0.19	0.20-0.21	0.16-0.17
SOx	0.09	0.13-0.14	0.16-0.17	0.13-0.14
PM	0.006	0.009-0.01	0.01	0.009

TABLE 74

CARS. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [80/20 Split of Roadway/Battery Power] Pessimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.004-0.005	0.007	0.008-0.009	0.006-0.007
CO	0.02	0.02-0.03	0.03	0.02
NOx	0.10-0.11	0.15-0.17	0.18-0.20	0.14-0.16
SOx	0.08	0.12-0.13	0.14-0.16	0.11-0.13
PM	0.005-0.006	0.008-0.009	0.01	0.008

TABLE 75

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[20/80 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-97	-98
co	-98	-98	-97	-98
NOx	-64	-43	-34 to -32	-46
sox	-60	-38 to -36	-26 to -25	-40
PM	-50	-22 to -20	-8 to -6	-26

TABLE 76

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[40/60 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-97	-98
co	-99	-98	-97	-98
NOx	-66	-48 to -46	-39 to -37	-51 to -49
sox	-63 to -62	-43 to -40	-32 to -30	-46 to -44
PM	-54 to -52	-28 to -25	-15 to -12	-32 to -29

TABLE 77

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[60/40 Split of Roadway/Battery Power]-
Pessimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-98
CO	-99	-98	-97	-98
NOx	-70 to 68	-53 to -50	-45 to -41	-56 to -53
SOx	-67 to -64	-48 to -44	-38 to -34	-51 to -47
PM	-58 to -55	-30 to -35	-18 to -23	-34 to -38

TABLE 78

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[80/20 Split of Roadway/Battery Power]
Pessimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-98
CO	-99	-98	-98	-98
NOx	-73 to -70	-58 to -53	-50 to -45	-60 to -56
SOx	-70 to -67	-53 to -48	-44 to -39	-55 to -51
PM	-58 to -62	-41 to -35	-31 to -24	-44 to -39

TABLE 79

CARS. Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[20/80 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.004	0.006	0.007	0.006
CO	0.01	0.02	0.03	0.02
NOx	0.08	0.12-0.13	0.15	0.12
SOx	0.05-0.06	0.08-0.09	0.1	0.08
PM	0.005	0.008	0.009	0.007

TABLE 80

CARS. Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[40/60 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.004	0.006	0.007-0.008	0.006
CO	0.01	0.02	0.03	0.02
NOx	0.08	0.12-0.13	0.14-0.15	0.12
SOx	0.05-0.06	0.08-0.09	0.1	0.08
PM	0.005	0.008	0.009	0.007

TABLE 81

CARS. Potential Emission Levels Due to RPEV's (grains per mile) for 1995 [60/40 Split of Roadway/Battery Power} Optimistic Scenario, With Conventional Coal

Pollu tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.004	0.006-0.007	0.007-0.008	0.006
co	0.0l-0.02	0.02	0.03	0.02
NOx	0.08	0.12-0.13	0.15	0.1 l-0.12
sox	0.05-0.06	0.08-0.09	0.1	0.08-0.09
PM	0.005	0.008	0.009-0.0 1	0.007-0.008

TABLE 82

CARS. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [80/20 Split of Roadway/Battery Power] Optimistic Scenario, With Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.004	0.006-0.007	0.007-0.008	0.006
co	0.0 l-0.02	0.02	0.03	0.02
NOx	0.8-0.09	0.12-0.13	0.14-0.16	0.1 l-0.13
sox	0.05-0.06	0.08-0.09	0.1-0.1 1	0.08-0.09
PM	0.005	0.007-0.008	0.009-0.0 1	0.007-0.008

TABLE 83

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[20/80 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-98
co	-99	-98	-98	-98
NOx	-77	-65 to -64	-59 to -58	-67 to -66
sox	-79 to -78	-67 to -66	-61 to -60	-69 to -68
PM	-65 to -64	-46 to -44	-36 to -34	-49 to -47

TABLE 84

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[40/60 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-98
co	-99	-98	-98	-98
NOx	-77	-64 to -66	-59 to -57	-68 to -66
sox	-78	-67 to -66	-69 to -59	-69 to -67
PM	-65 to -64	-46 to -43	-36 to -33	-49 to -46

TABLE 85

CARS. Potential Percentage Emission Changes Due to RPEV's
(– reduct ion, t increase)
[60/40 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	–99	–98	–98	–98
CO	–99	–98	–98	–98
NOx	–78 to –76	–66 to –63	–60 to –57	–68 to –65
SOx	–79 to –78	–68 to –65	–62 to –59	–69 to –67
PM	–66 to –63	–47 to –42	–37 to –32	–50 to –45

TABLE 86

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t irk-ease)
[80/20 Split of Roadway/Battery Power]
Optimistic Scenario, With Conventional Coal

Pollu– tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-98
co	-99	-98	-98	-98
NOx	-78 to -76	-66 to -62	-60 to -56	-68 to -65
SOx	-79 to -77	-68 to -64	-62 to -58	-70 to -66
PM	-66 to -62	-47 to -41	-38 to -31	-50 to -44

TABLE- 87

CARS. Potential Emission Levels Due to RPEV's
(grains per mile) for 1995
[20/80 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollu tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.005	0.008	0.01	0.008
CO	0.02	0.03	0.04	0.03
NOx	0.08	0.13	0.15	0.12
SOx	0.01	0.02	0.02	0.02
PM	0.003	0.005	0.006	0.005

TABLE 88

CARS. Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[40/60 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollu–tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.005	0.008	0.009	0.007
CO	0.02	0.03	0.03	0.03
NOx	0.08	0.12	0.14	0.11–0.12
SOx	0.01	0.02	0.02	0.02
PM	0.003	0.004	0.005	0.004

TABLE 89

CARS. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [60/40 Split of Roadway/Battery Power] Pessimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.005	0.007	0.008-0.009	0.007
CO	0.02	0.03	0.03	0.02-0.03
NOx	0.07	0.11	0.13-0.14	0.10-0.11
SOx	0.01	0.02	0.02	0.01-0.02
PM	0.003	0.004	0.005	0.004

TABLE 90

CARS. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [80/20 Split of Roadway/Battery Power] Pessimistic Scenario, Without Conventional Coal

Pollu-tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.004	0.006-0.007	0.007-0.008	0.006
CO	0.01-0.02	0.02	0.03	0.02
NOx	0.06-0.07	0.1	0.12-0.13	0.09-0.1
SOx	0.009-0.01	0.01	0.02	0.01
PM	0.002-0.003	0.004	0.004	0.003

TABLE 91

CARS. Potential Percentage Emission Changes Due to RPEV's
(– reduction, t increase)
[20/80 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	–99	–98	–97	–98
CO	–99	–98	–97	–98
NOx	–76	–63	–56	–65
SOx	–95	–93	–91	–93
PM	–78	–66	–60	–68

TABLE 92

CARS. Potential Percentage Emission Changes Due to RPEV's
(– reduction, t increase)
[40/60 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollu–tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-97	-98
co	-99	-98	-98	-98
NOx	-78	-65	-61 to -59	-68 to -67
sox	-96	-93	-92	-94
PM	-80	-68	-63 to -62	-71 to -70

TABLE 93

CARS. Potential Percentage Emission Changes Due to RPEV's
(– reduction, t increase)
[60/40 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-93	-98
co	-99	-98	-98	-98
NOx	-80	-70 to -67	-64 to -62	-71 to -69
sox	-96	-94	-93	-94
PM	-81	-72 to -70	-67 to -64	-73 to -71

TABLE 94

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[80/20 Split of Roadway/Battery Power]
Pessimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	–99	–98	–98	–98
CO	–99	–98	–98	–98
NOx	–81	–73 to –70	–68 to –64	–74 to –71
SOx	–96	–94	–93	–95
PM	–84 to –82	–75 to –72	–70 to –67	–76 to –74

TABLE 95

CARS. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [20/80 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.004	0.006	0.007	0.006
CO	0.01	0.02	0.02	0.02
NOx	0.05	0.08	0.09	0.07
SOx	0.008	0.01	0.01	0.01
PM	0.002	0.003	0.004	0.003

TABLE 96

CARS. Potential Emission Levels Due to RPEV's (grams per mile) for 1995 [40/60 Split of Roadway/Battery Power] Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.004	0.006	0.007	0.006
CO	0.01	0.02	0.02	0.02
NOx	0.05	0.07-0.08	0.09	0.07
SOx	0.008	0.01	0.01	0.01
PM	0.002	0.003	0.004	0.003

TABLE 97

CARS. Potential Emission Levels Due to RPEV's
(grains per mile) for 1995
[60/40 Split of Roadway/Battery Power}
Optimistic Scenario, Without Conventional Coal

Pollu tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.004	0.006	0.007	0.005-0.006
CO	0.01	0.02	0.02-0.03	0.02
NOx	0.05	0.07-0.08	0.09	0.07
sox	0.008	0.01	0.0 l-0.02	0.01
PM	0.002	0.003	0.004	0.003

TABLE 98

CARS. Potential Emission Levels Due to RPEV's
(grams per mile) for 1995
[80/20 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	0.004	0.006	0.007	0.005-0.006
c o	0.01	0.02	0.02-0.03	0.02
NOx	0.05	0.07-0.08	0.09	0.07
sox	0.008	0.01	0.0 l-0.02	0.01
PM	0.002	0.003-0.004	0.004	0.003

TABLE 99

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[20/80 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollutant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-99
co	-99	-98	-98	-99
NOx	-86	-79	-75	-80
sox	-97	-95	-94	-95
PM	-85	-76	-72	-78

TABLE 100

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[40/60 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollu- tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-99
co	-99	-98	-98	-99
NOx	-86	-79	-76 to -74	-80
sox	-97	-95	-94	-95
PM	-85	-76	-73-7 1	-78

TABLE 101

CARS. Potential Percentage Emission Changes Due to RPEV's
(– reduction, t increase)
[60/40 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollu tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	-99	-98	-98	-99
co	-99	-98	-98	-99
NOx	-86	-79	-76 to -74	-81 to -79
sox	-97	-95	-94	-95
PM	-85	-76	-73 to -71	-78 to -76

TABLE 102

CARS. Potential Percentage Emission Changes Due to RPEV's
(- reduction, t increase)
[80/20 Split of Roadway/Battery Power]
Optimistic Scenario, Without Conventional Coal

Pollu– tant type	DRIVING CYCLES constant speed	SAE B	SAE C	SAE D
HC	–99	–98	–98	–99
CO	–99	–98	–98	–99
NOx	–86	–80 to –77	–76 to –73	–81 to –79
SOx	–97	–95	–94	–95
PM	–85 to –84	–77 to –75	–73 to –70	–78 to –76

Table 103

Comparison of Percent Emission Changes for Inclusion (I) and Exclusion (E) of Conventional Coal-fired Power Plants (Pessimistic Scenario with SAE-B Driving Cycle)

	CAR		LDV		BUS	
	I	E	I	E	I	E
NOx	-43	-63	34 to 37	-13 to -11	-78	-80
sox	-38 to -36	-93	71 to 74	-80	79 to 82	-79
PM	-22 to -20	-66	164 to 169	14to 17	-50	-79