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Economic Analysis of the Proposed 1994 State Implementation Plan Conducted Prior to its Consideration by the California Air Resources Board

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

AIR RESOURCES BOARD
Research Division

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By

M.Cubed

With Assistance From
Acurex Environmental
Radian Corporation
Regional Economic Models, Inc.

February 1996

San Francisco, California

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Final Report
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Abstract

This report examines the economic implications of a package of proposed measures to reduce ambient atmospheric ozone contained in the California Air Resources Board's (CARB) draft 1994 State Implementation Plan (SIP). The proposed measures addressed emissions from mobile sources and consumer products regulated by CARB, and stationary measures regulated by local air quality management districts. The analysis focused on the most signficant measures in reducing emissions or in creating potential costs. The report relies on existing analytic data--principally derived from CARB and individual air districts--several spreadsheet models, and the Regional Economic Models, Inc. impact model to estimate the economic consequences from implementing the draft SIP measures. Through this examination it was determined that the draft SIP would have modest economic impacts on the California economy, but could significantly affect particular economic segments, such as the transportation sector. Particular policies that were determined to have substantial impacts--such as regulations related to mobile source emissions--were ultimately modified by CARB to reduce their adverse impacts.

Disclaimer

The analysis presented in this report is of the State Implementation Plan as proposed by the California Air Resources Board staff on November 8, and of several alternative measures proposed by other parties to the California Air Resources Board. It does not assess the economic costs and impacts of the final SIP as adopted by the Board and submitted to the U.S. Environmental Protection Agency. Nor does it evaluate several measures adopted by the Board to replace certain proposals made by the staff after consideration at the Board meeting subsequent to submittal of the Proposed SIP. The statements and conclusions in this report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgements

M.Cubed wishes to acknowledge and thank those individuals who helped in developing and reviewing the analysis contained herein. In particular, M.Cubed appreciates the efforts put forth by its subcontractors, Acurex Environmental, Radian Corporation, and Regional Economic Models, Inc. Likewise, M.Cubed thanks the staff of the California Air Resources Board--particularly Terry McGuire and Reza Mahdavi--Department of Pesticide Regulation, the South Coast Air Quality Management District, the California Energy Commission--specifically Leigh Stamets--and the Governor's Office of Policy and Research for providing key data and analytical insight. We would also like to acknowledge the cooperation provided to M.Cubed by various industry and environmental groups. This analysis could not have been completed within the mandated resource and time constraints without this assistance.

Table of Contents

List of Tables

List of Figures

Executive Summary

M.Cubed, an economic consulting firm specializing in public policy analysis and resource economics, was retained by the California Air Resources Board (CARB), Trade and Commerce Agency, and the Governor's Office of Planning and Research to conduct an economic analysis of the staff's proposed California State Implementation Plan (SIP). The SIP consists of the mobile source, inspection and maintenance, and consumer product proposals as put forth by CARB; the Department of Pesticide Regulation's (DPR) draft pesticide measures; and the local emission control and ozone attainment plans developed by the state's air quality districts, in particular the Sacramento Area Districts, South Coast Air Quality Management District, and Ventura County Air Pollution Control Board.

The analysis presented in this report is of the State Implementation Plan as proposed by the California Air Resources Board staff on November 8, and of several alternative measures proposed by other parties to the California Air Resources Board. It does not assess the economic costs and impacts of the final SIP as adopted by the Board and submitted to the U.S. Environmental Protection Agency. Nor does it evaluate several measures adopted by the Board to replace certain proposals made by the staff after consideration at the Board meeting subsequent to submittal of the Proposed SIP.

The scope and content of this analysis was constrained by several factors. First, the project team had less than one month to complete the main body of the work. Second, in many cases SIP proposals were either vague or still evolving as the draft analysis was being completed, making it difficult to assign costs to them. And third, the SIP frequently relies on emerging or yet-to-be-developed technology, creating large uncertainties related to the probability and cost of certain measures. However, the project team consisted of experienced air quality engineers and resource analysts, and was provided excellent access to public and private sector data and models. As a result, while far from comprehensive, the findings contained herein are based on best available information and significant analytical expertise.

Estimated Proposed SIP Impacts

The costs associated with SIP proposals consist of two primary elements: the direct, technological and demand-side costs affiliated with the measures, and the economic impacts resulting from these costs. Direct costs relate to the actual "out-of-pocket" expenses which individuals and institutions have to pay to comply with regulations.* Economic impacts

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*See Moss, Steven J., Richard J. McCann, and Marvin Feldman. *A Guide for Reviewing Environmental Policy Studies*. Monograph, Sacramento, California: California Environmental Protection Agency, 1995, p. 68 for a more complete discussion of the difference between direct, indirect and induced economic impacts.

result from these direct costs, as regulations act to change consumer behavior, reallocate resources, and affect economic growth.

Table E-One lists each statewide measure in the Proposed SIP and the projected emission reductions, cost per ton of pollutant reduced and total direct costs in 2010 as assessed by the analytic team. Figure E-One shows how the costs of these measures rise with the level of total reductions, and the upper and lower bounds on the expected cost range. Estimated impacts for individual measures are as follows:

- ***Excluding district proposals, statewide SIP direct costs are estimated at $750 million to $1.6 billion annually in the year 2010*** (1987$). Total direct SIP costs--including district plans-- are estimated at approximately $5.5 billion a year. This compares to total direct FIP costs of $8 billion or more annually. However, it is important to note that SIP and FIP cost estimates are not directly comparable, as analyses related to the two plans include different sets of emission reductions.

- ***The SIP's statewide elements alone--again excluding district measures--could reduce expected employment by between 22,000 and 58,000 jobs annually by 2010.*** In 2010 Gross State Product (GSP) would be from $800 million to $4.3 billion lower than GSP without SIP implementation (1987$). Tables E-One and E-Two display estimates of SIP-induced direct and economic costs. Table E-One also shows proposal-specific cost-effectiveness estimates. Figure E-One illustrates how marginal direct costs rise for each ton of emissions reduced as total reduction targets increase.

- ***A fleet average 0.026 grams per mile standard for light-duty vehicles could engender uncertain, but potentially large, direct and indirect costs.*** Ultimate costs for this standard would depend on the extent to which zero-emission vehicles with similar cost and quality characteristics as gasoline-powered cars can be developed by shortly after the turn-of-the-century. Although proposed as part of the draft Plan, this standard was not included in the final SIP.

- ***Assuming a 2 grams per brake-horsepower hour national emission standard for diesel engines beginning in 2004--and no other HDV-related requirements--SIP-induced heavy duty truck costs are likely to range from $180 million to $670 million annually by 2010, depending on future fuel prices and technology costs.*** A California-only 2 gram standard proposed to be in place in 2002 does not appear to be institutionally feasible, and this analysis ignores the costs and emission reductions associated with that measure.

- ***Based on a review of CARB's analysis, the SIP's locomotive proposal would cost between $80 and $165 million annually by 2010.***

TABLE E-ONE
Independent Analysis SIP Estimates

Proposed SIP #	Adopted SIP #	Control Measure	Implemented	Reductions in 2010 (d) NOx	ROG	Cost-Effectiveness/Ton Low	Mid	High	Annual Cost $MM Low	Mid	High
		Mobile Source Measures									
M2	M3	MDT 100% ULEV	1998-2002	97	6	$1,122		$4,493	$42		$169
M3	M8	HDGV CA Standards*	1998-2002	7	0		$2,500			$6	
M4	M4	HDDT Incentives*	1995-2003	7	0		NA				
M6	M6	HDDT 2g/bhp-hr: US	2004	145	8	$3,258		$11,922	$182		$667
M8	M9	Off Road 2.5g/bhp-hr > 175hp: CA	2005	54	7	$7,393		$8,170	$343		$379
M9	M10	Off Road 2.5g/bhp-hr < 175hp: US (c)	2005	56	10	$7,393		$8,170	(c)		(c)
M10A	M11A	Ind. equip 3-way cat. Gasoline: CA*	2000-2004	10	17		$393			$4	
M10B	M11B	Ind. equip 3-way cat. LPG/CNG: CA*	2000-2004	12	17		$416			$4	
M11	M12	Ind. equip 3-way catalyst: US*	2000-2004	14	23		$405			$5	
M12	M16	Pleasure Craft: US*	1998	0	75		$120			$3	
M13	M13	Marine Vessels: IMO*	1998-2001	11	0	$264	$3,350	$4,187	$1	$13	$17
M14	M14	Locomotives: US	2000-2010	95	0	$2,337		$4,796	$81		$166
M15	M15	Aircraft: US**	2003	12	10		$2,638			$21	
Alternative/Modified Measures:											
M1#		LDV LEV/ZEV 0.026 gpm (a)	2004-2005	--	--	NA	NA	NA	(a)	(a)	(a)
M5&	M5	HDDT 2g/bhp-hr: CA (b)	2002	0	0		NA				
M7#		HDDT 1g/bhp-hr: CA	2004-2007	22	0	($19,265)		$7,858	($155)		$63
		TOTAL: Adopted Mobile Sources		520	173				$694		$1,442
		Consumer Product Measures									
CP1	CP2	Consumer Prod.: Mid-Term	1999		60	$8	$2,100	$16,800	$0.2	$46	$368
CP2	CP3	Aerosol Paint: Near-Term	1995		15		$8,400			$46	
CP3	CP4	Long-Term: Consumer & Paint Prod.	2005		70		NA			NA	
		TOTAL: Adopted Consumer Products			145				$46	$92	$414
		SIP TOTAL		520	318				$740		$1,856

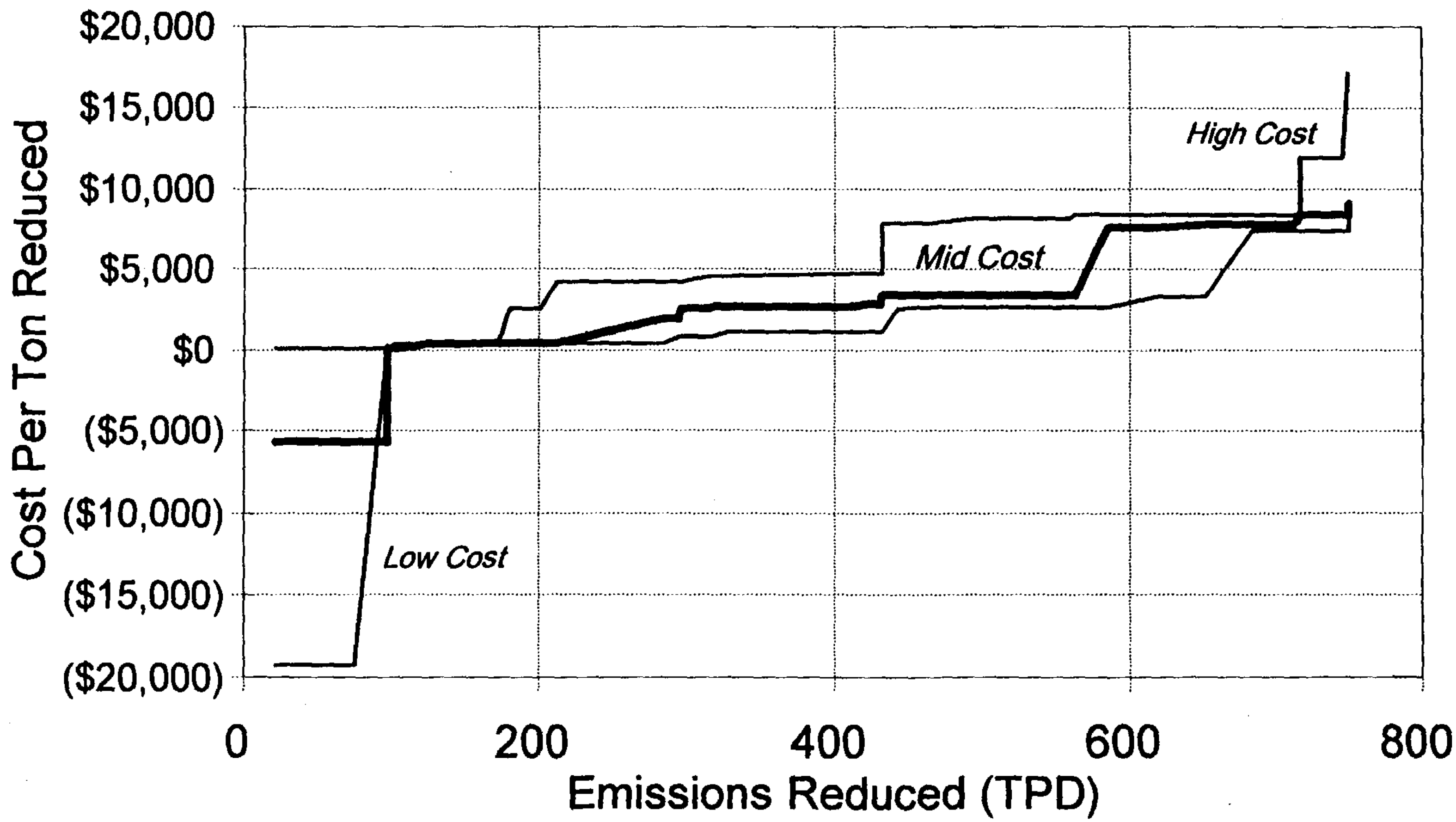
- Adopted as Alternative SIP Measure.
& - Modified and adopted in Final SIP 11/10/94
* - Cost-effectiveness estimates from Bob Cross, CARB, Memo 10/20/94; not reviewed independently.
** - Derived from CARB Staff Proposed SIP, 10/8/94, V.II, Ch.III, Tables 3-4.
(a) - Costs not estimated due uncertainty about production costs and consumer acceptance; emission estimates also uncertain.
(b) - Assumed CA-only 2g/bhp-hr in 2002 not feasible due to logistic, economic and political barriers.
(c) - Costs combined for Measures M8 & M9.
(d) - Emission reductions updated per ARB memo, 3/95.

FIGURE E-ONE

SIP Least Cost Curve

Statewide Reductions - 2010

Low, Mid & High Cost Range



- ***SIP-induced off-road vehicle costs are likely to range from $343 to $379 million annually in 2010.*** This estimate includes over- and under-175 horsepower (HP) equipment. Costs will fall on the manufacturing, agricultural, and construction sectors, as well as consumers.

- ***SIP-induced medium duty truck costs are likely to range from $40 to $170 million annually in 2010.*** The burden of these costs would be placed on the trucking, retail, and wholesale, construction, food, and manufacturing sectors.

- ***Insufficient information is available to independently assess the impacts of the consumer product and aerosol paint proposals.*** However, while consumer prices for these goods may rise, and particular firms may be adversely affected, the statewide economic impact of the aerosol paint proposal is likely to be insignificant.

- ***The built-in flexibility of the pesticide proposal makes it impossible to determine its economic implications.*** The determining cost factor will be the development and appropriate use of VOC data for pesticides.

- ***With the exception of South Coast and potentially Sacramento, none of the air quality district proposals are likely to have a significant impact on the California economy.*** District proposals may, however, engender adverse regional and firm-specific consequences. In addition, sensitivity tests on South Coast's cost-effectiveness analysis indicates that the District may have underestimated the potential costs of its plan by $1 billion or more.

Industry Alternatives

- ***A light duty vehicle accelerated turnover program may be a cost-effective method of obtaining emission reductions.*** However, the costs associated with achieving incremental units of emission reductions are unknown, and may be substantially higher than existing industry-sponsored estimates. This alternative was adopted as part of the final SIP.

- ***A heavy duty vehicle turnover program may likewise be cost-effective in certain parts of the state.*** However, the socio-economic impacts of this measure could be significant and have not been examined. This alternative was adopted as part of the final SIP.

Estimated Statewide Economic Impacts

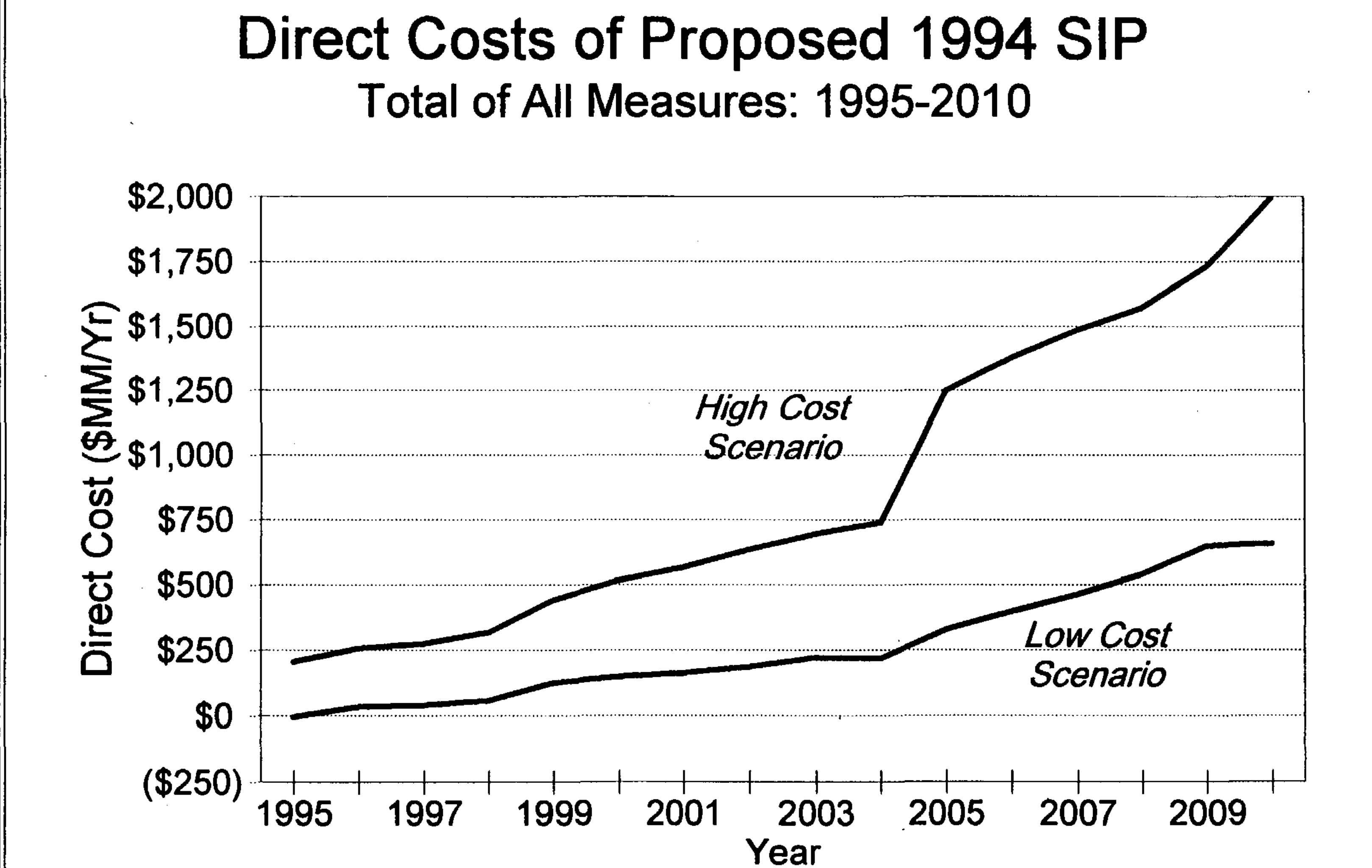
The estimates contained herein focus on average statewide SIP impacts. Figure E-Two shows how these direct costs are aggregated across measures in the low and high cost scenarios. Figure E-Three shows how gross state product (GSP) and employment will change in the corresponding cases. The aggregated nature of this analysis may mask significant impacts on particular economic segments. For example, truck engine suppliers--who are almost exclusively located out-of-state--would have to cope with a myriad of technology-based measures simultaneously, necessitating significant investment in research and new product development in a short period of time. That is, the SIP would require engine manufacturers to finance the development and marketing of a large number of new products. Whether or not the necessary financing is available, and how such requirements would affect particular manufacturers, was not examined in this report.

Regardless of statewide impacts, the SIP's cumulative impact on particular economic segments could be sizeable. For example, the agricultural sector would have to simultaneously adjust to higher transportation costs, increased production expenses associated with off-road equipment, and changes in pesticide product availability. The transportation sector would also face both higher production costs and some demand reduction as the California economy--and specific state regions--adjust to the SIP's higher costs. These sector-specific impacts were not fully examined as part of this analysis.

In addition to its economic impacts, the SIP would alter existing patterns of technological innovation and penetration. As indicated in the Plan, itself, "...significant [technological] advances also mean a big disparity between the cleanest equipment in-use and the dirtiest." Many economic segments are dependent on the availability of highly-depreciated--and frequently higher polluting--technologies. These industries either rely on "hand-me-down" technologies from more profitable firms, or maintain equipment for the greatest possible length of time. For example, growers tend to rely on old trucks for farm operations, both because trip lengths may be short, and also because agriculture's profit structure does not allow for constant modernization in all production areas. Potential changes in these patterns have not been explicitly examined in this report.

Finally, it is important to note that analyzing some SIP portions was difficult because of the paucity of research in a given area. For example, additional inquiry into potential behavioral responses to zero emission vehicles would be worthwhile. To this end, SIP areas which merit additional attention are identified in this report, and suggested research agendas are described.

FIGURE E-TWO


Direct Costs of Proposed 1994 SIP
Total of All Measures: 1995-2010
$2,000
$1,750
$1,500
$1,250
$1,000
$750
$500
$250
$0
($250)
Direct Cost ($MM/Yr)
High Cost Scenario
Low Cost Scenario
1995
1997
1999
2001
2003
2005
2007
2009
Year

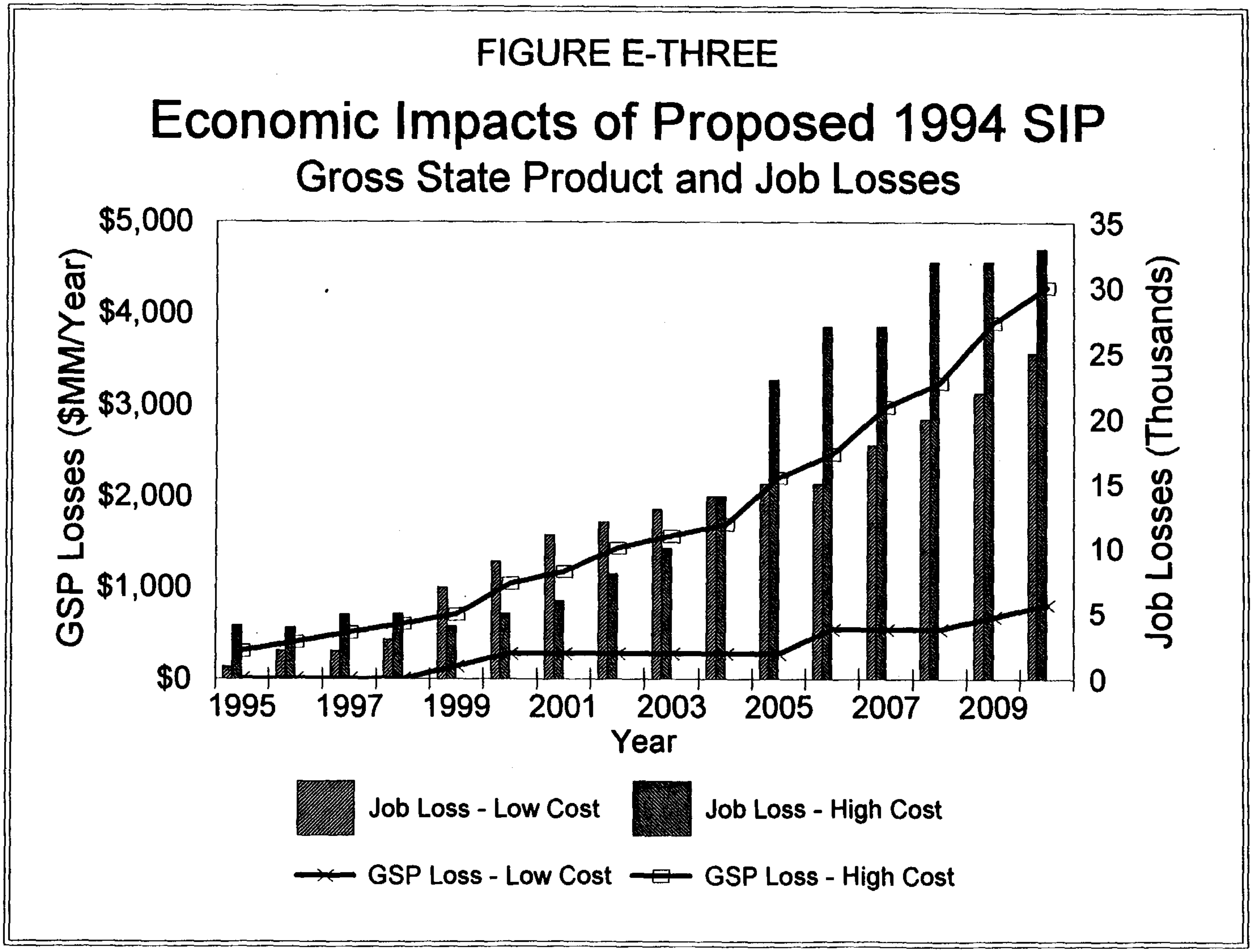


FIGURE E-THREE
Economic Impacts of Proposed 1994 SIP
Gross State Product and Job Losses
GSP Losses ($MM/Year)
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Job Losses (Thousands)
35
30
25
20
15
10
5
0
1995
1997
1999
2001
2003
2005
2007
2009
Year
Job Loss - Low Cost
Job Loss - High Cost
GSP Loss - Low Cost
GSP Loss - High Cost

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1.0 Introduction

Under order from the Federal Ninth Circuit Court of Appeals, the U.S. Environmental Protection Agency (EPA) published draft Federal Implementation Plans (FIPs) for the Sacramento, South Coast, and Ventura Air basins in the May 5, 1994 *Federal Register*. The FIPs contain several regulatory proposals directed at improving air quality in the three areas, principally through reductions in oxides of nitrogen (NOx) and volatile organic compound (VOC) emissions.

If implemented as drafted, EPA's policies would have had a profound impact on the way in which business is conducted in the state, adversely affecting the entire California economy. Analyses of EPA's proposed mobile source regulations alone indicate potential FIP-induced employment reductions could reach one-half million jobs, with direct costs of $8 billion or more annually over the FIP implementation period.[1] As stated by EPA:

> ...the plans proposed here will directly affect more than 15 million people--almost half of California's population--and virtually all businesses in the South Coast, Sacramento, and Ventura areas...Mobile source emission reduction requirements for autos, trucks, planes, trains, boats, ships, and off-road equipment may result in higher costs to some and significant changes in the mode of transportation for others.[2]

Simultaneous with the development of EPA's FIPs, the California Air Resources Board (CARB) was developing a State Implementation Plan (SIP) focusing on achieving federal Clean Air Act-mandated air quality goals. CARB staff's proposed SIP was published on October 7, 1994.* The SIP will replace the Sacramento, South Coast, and Ventura FIPs.

Because of the significant economic costs associated with the FIPs, Governor Pete Wilson requested that the proposed SIP be subjected to "an independent, outside economic analysis."[3] M.Cubed, an economic consulting firm specializing in public policy and resource issues, was retained by the California Air Resources Board (CARB), Trade and Commerce Agency (DTC), and the Office of Planning and Research (OPR) to develop this analysis.

1.1 The Role of Economics in Environmental Decision-making

Historically, economics and associated formal analytical techniques have played only a limited role in environmental policy decision-making.[4] Environmental economics, as employed by regulators, frequently focuses on the benefits and costs of tangible investments, such as alternative energy sources. Benefit-cost analysis is occasionally used as part of analytical efforts to determine whether or not a proposed regulation is worthwhile. Economic techniques are also used to identify the least-cost means of achieving an adopted environmental goal or emission reduction target. For example, least-cost analysis, which is more commonly used in energy-related regulatory forms, seeks to determine how a particular level of emission reductions can be achieved most cost-effectively.**

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*The SIP includes the mobile source, consumer product, and inspection and maintenance (I/M) provisions contained in CARB Volume II; the Department of Pesticide Regulation's Draft Pesticide Element in CARB Volume III; and the Local Emission Control Plans and Attainment Demonstrations outlined in CARB Volume IV. For the purposes of this analysis it was assumed that costs associated with the I/M program are already part of the "baseline." The final SIP was adopted by the Board on November 15, 1994.

**Both of these questions are most appropriately addressed during the regulatory planning process (i.e., before final regulations have been promulgated).

Another analytical inquiry relates to the economic costs associated with an individual or set of environmental policies. Economic impact analysis is used to evaluate the level and distribution of economic changes associated with individual or groups of proposed policies. Impact analysis is perhaps the most frequently used and highest profile economic technique employed in environmental debates. In many cases economic impact analyses result in relatively blunt findings, and do not provide policymakers with the richness of information they need to address complex problems. For example, various analyses of the FIP imply that if implemented the measure would induce total direct costs of $8 billion or more annually. In the face of such a large potential economic burden decision-makers generally prefer to identify alternative means of achieving the established goals.

This report attempts to address a number of issues related both to least-cost and economic impact concerns. The analysis does not address benefit-cost issues--the study does not question whether or not the benefits of achieving the Clean Air Act (CAA) goals reflected in the SIP are greater than the costs. The analysis contained herein focuses on the following questions:

- *What is the overall direct cost of the SIP?* Direct costs include expenditures associated with developing and manufacturing the mandated new technology (supply side) and putting into place the necessary incentives or penalties for the technology to be adopted at a pace sufficient to achieve the required emission reductions (demand side).

- *How do the SIP's direct costs compare with the FIP?*

- *What is the aggregate economic cost of the SIP, including changes in employment and gross state product?*

- *What key assumptions drive the direct and economic cost estimates* (e.g., how do fuel price forecasts and expected research and development investments affect the cost of meeting the heavy-duty truck emission standard)?

1.2 Report Structure

In addition to this introduction, this report is composed of the following sections:

- A general discussion of the economic implications of achieving air quality goals.
- A discussion of the report methodology and broad assumptions used in the analysis.
- Estimates of the direct emission reduction costs associated with the mobile source proposals contained in the SIP.
- Estimates of the direct emission reduction costs associated with the stationary source proposals contained in the SIP and AQMPs.
- Estimates of the economic implications of the SIP and AQMPs.

Limited resources acted to severely restrict the depth and scope of this study. Although the project team has worked to provide policymakers, the regulated community, and interested parties with comprehensive and detailed information to evaluate the SIP proposals, there are portions of the SIP which received little or no analytical attention. However, the project team attempted to provide analyses for all those provisions which were likely to have significant impacts on the California economy.

It is also important to note that this report represents an analysis of the November 8 version of the CARB staff's *proposed* SIP. As a result the analysis does not reflect subsequent changes made to the SIP prior to its submission to U.S. EPA on November 15, 1994.* Likewise, many of the measure numbers and expected emission reductions in the final SIP do not correspond to this report. In addition, at the time this report was prepared the U.S. EPA had proposed FIPs for the South Coast, Ventura, and Sacramento areas, and this study attempts to compare CARB's proposed SIP with these FIPs. However, the FIPs were subsequently eliminated. On April 10, 1995, President Clinton signed California-sponsored legislation rescinding the FIPs, and the U.S. EPA formally withdrew the FIPs in an August 21, 1995 *Federal Register* notice.

*The final SIP is embodied in *The California State Implementation Plan for Ozone, Volumes I-IV, Adopted November 15, 1994.*

2.0 The Economic Implications of Achieving Air Quality Goals

Before presenting M.Cubed's findings, it is important to understand the SIP's underlying assumptions. Although significant air quality improvements have been made since the early-1970s, California's air remains among the dirtiest in the nation. Six of the top ten metropolitan areas that exceeded federal ozone standards in 1989 were located in California. The South Coast region has the distinction of being the only area in the country to have its air pollution defined as "extreme" by an act of Congress. And recent air quality gains are being threatened by a steady increase in automobile use. While one forecast predicts population to grow by 30 percent in the South Coast region alone between 1987 and 2010, vehicle miles traveled (VMT) is estimated to increase by 60 percent, twice the population growth rate, with concomitant implications to polluting air emissions.[5]

Californians' exposure to polluting air emissions has likely resulted in higher statewide morbidity and mortality rates.[6] Ozone can act to permanently scar lung tissue, cause respiratory irritation and discomfort, and make breathing more difficult. Children, the elderly, and persons who exercise heavily are particularly adversely affected by polluting air emissions.[7] Likewise, certain pollutants can act to degrade natural environments; reduce agricultural productivity;[8,*] and adversely affect buildings and infrastructure.[9,**] Air pollution can constrain our ability to engage in strenuous outside activity without harmful consequences and obscure beautiful landscapes behind an ugly haze.

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[*]Ozone may reduce national crop yields by 5 to 10 percent, at a cost of \$3 to \$5 billion annually. Ozone-induced crop damage in California is estimated to reduce agricultural yields by up to 20 percent. See Ventura County Air Pollution Control Board, "Ventura County 1994 Air Quality Management Plan," November 1994.

[**]Ozone may create national material damages of between \$1.5 and \$3.9 billion a year. See Ventura County, op. cit.

Overall, air pollution in California may induce costs of several billion--and perhaps tens of billions--of dollars annually.[10,*] By reducing polluting air emissions society avoids paying the public health, environmental, and other costs associated with air pollution. Air quality regulation can provide both "hard" economic savings--in the form of reduced health care expenditures; longer building depreciation rates; and higher crop yields--and "soft" benefits--such as improved quality of life.

While society pays a price as a result of polluting air emissions--and receives concomitant benefits from emission reductions--a reliable accounting of these benefits is difficult. This is because the public health and environmental effects of pollution increments are not well understood, and the methods for placing an economic value on these benefits are still evolving.[11]

Likewise, although there are benefits associated with reducing polluting air emissions there are also costs. In the short-term--ten to twenty years--environmental policies can disrupt status quo economic relationships, increase production costs, shift demand for goods and services, and force some firms out-of-business entirely.[**] Short-term costs tend to be particularly high in cases where regulation is limited to a single discrete region (e.g., the State of California), enabling firms to flee to lower cost areas.[12]

Environmental regulation can also induce substantial economic changes in the long-term. Economists have found that environmental regulation was an important contributor

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*The national economic loss from air pollution could be as much as $75 billion annually. For example, approximately 10 percent of the nation's health care costs may be the result of illnesses associated with polluting air emissions. According to Ventura County Air Pollution Control District, "1994 Air Pollution Management Plan" Draft.

**The U.S. Department of Commerce estimates the nation spends almost $90 billion a year on pollution abatement. See Gary L. Rutledge and Christine R. Vogan, "Pollution Abatement and Control Expenditures, 1972-92," *Survey of Current Business*, May 1994.

to the slowing of national economic growth during the 1970s and 1980s.[13] On the other hand, by providing for better amenities and inducing the development of improved technology, environmental regulation can in some cases contribute to long-run economic growth.[14]

Whether or not the benefits of any *particular* regulation exceed its costs can only be determined through a rigorous evaluation of the policy in question. However, given California's decades-long experience with air quality policies, three overall features are likely to greatly impact the relative benefits and costs of ongoing environmental efforts. These are:

(1) **High marginal costs for pollution control measures.** Many of the lowest-cost pollution control methods have already been adopted. As a result, it will be increasingly costly--both in political and economic terms--to reduce polluting air emissions by additional units. This factor implies that regulatory-induced environmental costs are likely to escalate in the future. For example, as indicated in the SIP "...nowhere in the world has such an aggressive approach to air pollution been taken."[15] "Dramatic" emission reductions, particularly beyond those already obtained, are likely to result in equally dramatic economic consequences.

(2) **Fundamental technology shifts.** In some cases environmental regulation could result in entirely new production paradigms for many economic sectors. For example, when combined with existing rules the SIP proposals could push California's transportation sector into a significantly alternative fuel (e.g., natural gas; electricity) environment. Such a paradigm shift would result in substantial transition costs in the short-term, but could induce economic benefits--in the form of new export industries and lower production costs--in the more distant future.

(3) **Technology-driving regulations.** Air quality regulations are increasingly relying on technology that does not yet exist. To the extent that environmental policies are structured to create demand for low-cost, low-emission technology these policies may succeed in inducing a new generation of beneficial products (i.e., market-based policies could encourage the development of new cost-effective pollution control methods). However, to the extent that regulators rely on specific technologies to be developed under constrained time frames, the targeted products may either be too costly or may not emerge in a usable form at all. Decision makers' heavy reliance on specific new technologies to achieve air quality goals can create huge uncertainties related to the feasibility and cost of meeting air quality goals.*

2.1 Uncertain Costs, Uncertain Benefits

It is important to note that while both the federal government and the State of California have enacted policies directed at improving air quality, there are considerable uncertainties related to the costs of these policies as well as their potential benefits. Uncertainty related to benefits stems from a number of factors, including:

- Although our knowledge is more advanced than twenty years ago, there is significant uncertainty about the mechanics of how health- and environment-threatening pollution is created. For example, scientists and policy makers continue to debate the trade-offs between controlling NOx or VOCs to reduce ozone.[16] As a result, there is uncertainty about which pollutants should be controlled at what level.

*While costs for particular air pollution technologies have generally declined over time, this is a typical pattern for emerging industries. As an industry matures costs tend to stabilize and then begin to rise (e.g., electric industry).

- The trade-offs inherent in isolating and controlling individual pollutants as opposed to bundles of pollutants, and the adverse unintended impacts associated with reducing emissions in one medium as opposed to another, have not been fully investigated (e.g., increased solid toxic wastes may be created by pollution control catalysts; massive electric vehicle (EV) use may lead to the need to dispose of large amounts of toxic battery material). As a result, the total environmental and public health benefits associated with pollutant-specific regulations are uncertain.

- There is a great deal of uncertainty associated with accounting for aggregate emission levels. For example, emission estimates are based on assumptions about regional growth patterns, which in most cases do not account for the feedback effects on regional economies of implementing the stringent air quality improvement efforts.[17,*]

- The precise emission levels associated with various sources--mobile or stationary--and various control measures are generally unknown. For example, there is some uncertainty related to mobile sources' share of emissions, as well as the emissions generated by particular truck engine technologies.[18]

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[*]Uncertainty resulting from the use of regional economic forecasts to predict polluting emissions is illustrated by the fact that the South Coast Air Quality Management District's (South Coast or The District) 1994 year 2000 South Coast population forecast is almost one million people higher than their 1991 estimate (i.e., six percent higher); the District's 1994 year 2000 VMT forecast is 24.4 million miles higher than their 1991 estimate (i.e., eight percent higher); and the District's 1994 year 2000 in-use vehicle forecast is almost two million vehicles higher than their 1991 estimate (i.e., twenty percent higher). These estimates to a large extent drive emission reduction targets.

- The cost estimates associated with technology-based control measures are based on reasonably expected cost and performance parameters. However, relying solely on a technological "breakthrough"--related to battery technology, low-NOx diesel engines, or low VOC aerosals--to make a measure cost-effective raises the risk of large economic costs if such a breakthrough fails to occur.*

Because the FIP and the SIP are based on different baselines and seek different emission reduction levels they cannot be directly compared. That is, while the FIP may impose greater absolute costs on California, it may also obtain greater environmental benefits. As a result, the FIP/SIP comparisons contained in this analysis should be viewed with caution.

2.2 "Scoring" the Economic Impacts--Who Is Responsible for What?

It is important to note that the SIP represents the next of a number of steps towards cleaner air. This fact raises three key issues, as follows:

- The SIP consists of all proposed attainment strategies needed to achieve CAA-mandated air quality standards. These strategies are contained in federal, state, and regional planning documents. Although SIP cost estimates must include all of these elements to be comprehensive, there was insufficient time in this project to evaluate all SIP components.

- Analysts must be careful to assign incremental costs to incremental regulations. For example, if current regulations impose a 4 gram per brake-horse power (bhp) heavy duty diesel standard, and a proposed policy would lower this standard to 2 grams per

*The electric utility industry took a similar risk in committing to nuclear power in the mid-1960s. This gamble ultimately resulted in substantial rate increases to consumers.

bhp, the cost of the additional regulation stems from the need to reduce by 2 grams, not 4 grams.

- To the extent that the proposals represent an extension of current regulations, the costs of the additional technology or market penetration may be more or less than the original regulatory costs. For example, natural gas truck engine production costs may be lower after certain economies of scale have been developed. On the other hand, it may be more costly to sell into a larger number of niche markets once initial low-cost markets have been saturated.

2.3 Understanding Economic Impact Analyses

California's economy is intensively diverse, supporting industries from agriculture to zippers. Many different firm types operate within the state's various sectors, ranging from small to large, using low- to high-technology, serving different markets and with access to a range of production and distribution resources. There is nothing average about the state's economy. However, in order to be manageable economic analysis generally focuses on *average* impacts, thereby necessarily missing potentially notable impacts on particular sectors. No analysis can completely capture all of the impacts on the state's many productive operations stemming from environmental regulation.

Likewise, California's economy is huge, producing $665.3 billion (constant 1987 dollars) worth of goods and services in 1990.[19] From a statewide perspective the economic costs of environmental regulation would have to be quite significant to substantially influence the overall economy. However, while a regulation costing $50 million may be small relative to the gross state product (GSP), such an expenditure could be quite substantial if forced on a small region or limited number of firms. Although over 14 million people are employed in the state, another 1.4 million are without jobs.[20] Regulatory-induced job losses of 50,000 may seem insignificant in comparison with these numbers--but not if it is your job that is forced out-of-state or out-of-existence.

Partially as a result of the enormity of the California economy, various groups have begun to suffer from "impact-inflation" in an attempt to garner policymakers' attention. Despite the fact that very few Californians will ever actually see even $1 *million*, affected parties must claim impacts of $1 *billion* or more to attract media and regulator interest. The implications of these numbers has begun to lose meaning.

Finally, the state's economy is only beginning to recover from its worst economic downturn in 60 years. Between 1990 and 1994 the state's unemployment rate has been between two to three percent higher than the national average, and personal income growth has been one-half to two percent lower. Although local, regional, and state agencies influence the health of the economy, regulatory efforts represent one of the few areas of state activity which imposes significant new changes to the economy. For example, because of its heavy technology-dependence, environmental regulation may have as large an influence on the state's "industrial policy" as any other government activity. As a result, "at the margin" environmental regulation can have a profound effect on economic activity, particularly during periods of recovery.

3.0 Report Methodology and Assumptions

Although this report focuses on the SIP's impacts on the California economy, a number of policy decisions had to be made before economic estimates could be derived. Each of the following decisions resulted in a better definition of the SIP's potential impacts:

(1) **Setting emission reduction goals.** The emission reduction goals contained in the SIP were defined by the CAA, as amended in 1990. Although little information about the regional and statewide costs associated with the Act were available at the time Congress voted on it, the fact that these goals are embodied in law implies that through the political process it was determined that CAA's potential benefits exceeds its potential costs.[*] In other words, based on the information available during the time of the debate, the federal government has determined that the emission goals contained in the SIP are worth their associated costs.

(2) **Establishing the emission baseline.** Although the CAA established air quality goals, there is uncertainty over the appropriate emission baseline; which sources are responsible for which emissions levels; and what level of emission reductions are associated with particular control strategies.[21] Although there are references to various emission baseline issues in this analysis, in general this area was left unexamined. Table One shows how this uncertainty creates different emission reduction goals depending on the assumptions used by a particular regulatory agency. The CARB and the U.S. EPA use different analytic approaches which leads to differing results.

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[*]Some economic analyses were presented as part of the CAA debate. These studies suggest that the 1990 CAA amendments alone could add $20 billion or more to the existing $30 billion annually spent on air quality nationwide. (Committee for Economic Development, *What Price Cleaner Air?* Washington, D.C., 1993.)

Table One

Polluting Air Emission Reduction Goals[22]

District	Pollutant	% Reduced from 1990 Baseline		Attainment Year Allowable Emissions (TPD)	
		FIP	SIP	FIP	SIP
Sacramento	ROG/VOC	40%	39%	140	136
	NOx	30%	40%	130	98
Ventura	ROG/VOC	40%	48%	58	49
	NOx	40%	47%	50	40
South Coast	ROG/VOC	90%	85%	168	323
	NOx	70%	59%	375	553

(3) **Adopting a regulatory framework.** Over the past few decades two general approaches to achieving environmental goals have been developed: command and control (CAC) and market-based or "incentive-compatible" policies. CAC-based policies chiefly rely on specific government mandates--such as technological standards--to achieve air quality goals. Market-based policies, on the other hand, rely on harnessing the "invisible hand" as a means to obtain environmental goals. In other words, market-based policies focus on creating ongoing incentives for pollution reduction and allowing these inducements to drive emissions down. Market-based policies, *if implemented carefully*, are generally thought to be more cost-effective than CAC policies.[*,23]

*Poorly designed market-based program may be no better -- or even worse -- than CAC-based measures. See for example M.Cubed, *Evaluation of the South Coast Air Quality Management District's Socio-Economic and Environmental Assessments*, Prepared for The Southern California Gas Company, Los Angeles, California, August, 1993.

Although the SIP discusses the desirability of employing market-based policies in place of CAC to obtain needed emission reductions, neither the FIP nor the SIP is based on a market-based framework. As a result, from a theoretical point of view both the FIP and the SIP are likely to impose higher costs on the State of California than a carefully crafted market-based implementation plan.*

(4) **Defining the SIP**. The cost of the SIP is partially dependent on the regulatory authority and flexibility of the document itself. The SIP must meet somewhat contradictory expectations. On the one hand, its intended purpose is to ensure that California achieves CAA air quality goals. To that extent it is a regulatory document, whose proposals are likely to be implemented in their drafted form. On the other hand, CARB staff have repeatedly asserted that the SIP is a flexible document, and will be subjected to substantial amendments throughout its implementation period.[24] For example, according to the Sacramento Area Air Quality Management Districts, "SIPs are amended on an ongoing basis as new rules are adopted, new plans developed, or changes to overall control strategies are made."[25] This dichotomy influences the success of the proposals themselves--if new technology is to be developed, or substantial investment made in market-based approaches to emission reductions, then the private sector must be assured of the government's long-term commitments to its technology-based strategies.

The SIP's costs would be minimized by "structural flexibility." For example, the SIP could be viewed as a rigorous planning document, such as a general plan for land use, subject to formal amendments as needed. In this vein the SIP could serve as a general emission reduction purchasing plan, with an open request-for-proposal (RFP)

*In addition to providing potentially more certain outcomes, CAC has one resource advantage over market-based approaches. That is, while CAC policies rely on the existing regulatory structure market-based approaches necessitate the development of new institutions -- such as air pollution permit markets -- to be effective.

for lower cost emission reduction strategies. The more certain both the ultimate strategies and the process by which these techniques can be altered or replaced, the lower the SIP's costs.

(5) **Distribution of emission reduction responsibility.** Separate from emissions baseline issues is the need to allocate emission reduction responsibility among potential parties. Emission reduction responsibility could be distributed based on existing mobile and stationary source emission levels (e.g., responsibility is divided between the entire universe of emitters based on their contribution to pollution); on a per capita basis (e.g., every individual in the state is given equal responsibility for emission reductions); or based on the least emitting source per unit in each pollution group (e.g., emission reduction responsibility is adjusted to reflect historical air quality efforts put forth by emitters). Allocation of emission reduction responsibility has important equity implications, which have not been examined as part of this analysis.

(6) **Distribution of actual emission reductions.** Under most CAC regimes emission reductions are more or less equal to emission reduction responsibility. That is, polluters reduce their emissions to meet their abatement requirements. Under a market-based regime the actual incidence of emission declines might be quite a bit different than the distribution of reduction responsibility. That is, emitters may seek the least-cost means of reducing emissions, and purchase these reductions from another source. The ability to satisfy reduction responsibilities flexibly is one of the most important factors behind the greater efficiencies and lower costs derived from market-based approaches to environmental regulations. If, for example, responsibility must equal actual reductions, then emission reduction is a zero-sum game. That is, emission reduction responsibility requires that reductions be made regardless of cost. If, however, responsibility can differ from reductions based on voluntary behavior of

the regulated community, emission reduction can become a "win-win" situation. That is, responsible emitters may be able to induce others to reduce pollution at a lower cost, benefiting all.

Both the FIP and the SIP provide for some limited emissions permit trading among sources. However, in neither case are these trading programs comprehensively presented or carefully designed. As a result, this area was evaluated in this report only to the extent that trading was an explicit element of a particular proposal.

(7) **Proposed emission reduction technologies and methods**. Because both the FIP and the SIP are CAC-based plans the specific reduction technologies and methods contained within them are at the heart of their associated costs. In other words, the SIP represents a bundle of notions, ideas, and policies, which, if implemented, would result in direct costs and economic changes. Although these costs are frequently termed "engineering" in nature, the engineering costs of technology represent only one side--the supply side--of the equation. The second important cost feature of the SIP's technology policies is the demand side--the costs associated with forcing adoption of the selected methods over the required period.

To analyze the direct costs associated with the bundle of proposals contained in the SIP the following general steps were taken (more specific methodological detail is included in Section 4):

- Through individual meetings, CARB workshops, and telephone consultations the M.Cubed project team met with CARB and DPR staff, as well as various interest groups, to discuss possible interpretations of the SIP proposals.

- In cases where SIP proposals could be interpreted to lead to more than one potential path, an evaluation of the factors influencing possible outcomes was undertaken. For example, the proposed Improved Control Technology Measure M1 Light Duty Vehicles--which ultimately was removed from the SIP--could act to require that thirty-five percent of total new automobile sales in the state consist of ZEVs. Alternatively, the proposal could result in lower ZEV sales and increased purchases of "super" ULEVs or other low-emission vehicles.

- Available engineering cost estimates were obtained from public and private sector sources. These cost data were then examined to determine the key assumptions upon which the estimates were based, and to evaluate possible plausible cost scenarios.

- In cases were the proposal's success depended on rapid adoption of one or more technologies, economic techniques--as described later in this report -- were used to model the incentives or disincentives necessary to achieve the needed penetration rates. For example, incentives or disincentives would need to be provided to encourage the sale of EVs, which in the near-term will be considerably more costly and less convenient than gasoline-powered vehicles. Simply extrapolating engineering cost estimates based on static baseline conditions acts to ignore potential behavioral responses, and in many cases will lead to misleading results. The technique used to model the cost of demand-side changes is discussed in the individual proposal analyses.

(8) **Implementation timing.** The time schedule for SIP proposal implementation can significantly affect associated costs, particularly in the case of technology-forcing measures. For example, extremely short time requirements increase the development

and adoption costs of new products. Timing also affects the ability of economic sectors to adjust to the costs of environmental regulations. The costs associated with the SIP's time mandates are generally accounted for as part of the engineering cost estimates--see (7) above--as well as the economic impact model runs.

(9) **Timing and technological flexibility**. Whether or not mandated emission reduction target dates can slip, or emitters can trade an identified technology for an alternative compliance method, also affects SIP costs. In some cases, such as the pesticide regulation, the SIP builds in some flexibility to account for the development of additional data related to the targeted emissions. As previously discussed, the SIP also discusses the importance of market-based approaches to regulation. However, while the SIP presents somewhat more flexible proposals than the FIP--and for that reason alone is likely to induce lower costs than the federal plan--neither of the proposals provides for much compliance flexibility. *In particular, neither proposal offers sufficient compliance flexibility to match the significant uncertainty associated with the air quality goals themselves (see (2) above).*

(10) **Enforcement and compliance or incentives and markets.** Under CAC policies regulatory compliance is generally enforced through fines, fees, and legal liability. Under a market-based approach fees may also be used to ensure compliance, but more generally markets and a variety of incentive mechanisms are used. While the FIP imposes stringent enforcement penalties, the SIP contains only limited enforcement mechanisms.[*] This is a critical distinction, which in itself vastly reduces the SIP's cost relative to the FIP, but also puts into question the SIP's ability to achieve its air quality goals.

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[*]CARB staff indicate that enforcement mechanisms will only be developed if and when the SIP proposals are converted into actual regulations.

The FIP's enforcement mechanisms generally focus on a $10,000 per ton of NOx emission fee, with additional penalties--such as a $1,000 to $20,000 new vehicle emission fines--associated with particular measures. Although EPA claims its proposed fee schedule reflects the "incremental cost" of controls, the Agency has provided no evidence to support such an assertion.[26] Based on a previous M.Cubed analysis EPA's proposed NOx fee may be twice as high as can be defended by existing data.[27] Fees which are arbitrarily set too high become a penalty, and are in no way reflective of market-based approaches to achieving emission reductions. The FIP's aggressive enforcement mechanisms to a large extent drive the plan's substantial costs.

The SIP, on the other hand, generally relies on loose discussions of unspecified market-based approaches for enforcement. As a result, while the SIP may succeed in mandating the supply of particular technologies, it has no ability to ensure that these technologies are adopted by the market in any significant quantities under the schedule needed to meet air quality goals. For example, the draft proposed SIP proposes that only those heavy-duty vehicle (HDV) engines meeting a 2.0 grams per brake horsepower (g/bhp-hr) standard be offered for sale in the State of California as of the year 2002. Given the higher costs likely to be associated with engines meeting this standard, trucking firms are likely to respond to these engines by either delaying new truck purchases (i.e., maintaining their existing equipment longer); increasing their purchases of higher emitting, lower cost engines prior to the year 2002 deadline (e.g., stockpiling trucks); baseplatting their fleets outside the state; or purchasing new truck engines across the border. Although the extent of these actions is constrained by firm resources, truck markets, and current laws restricting the importation of new truck engines, these barriers may be insufficient to ensure 2.0

g/bhp-hr engine purchases at the pace assumed by the SIP without additional enforcement mechanisms.*

(11) **Backstop measures.** The backstop measure for the SIP is the FIP, the cost of which is perhaps best measured by its enforcement mechanisms.

(12) **Economic impact analysis.** Economic impact estimates are based on an analysis of the previous eleven issues. In this sense most of the analytical work is conducted by the "sous chef," and this analysis is then sifted through a regional economic framework to develop impact numbers.

Based on the direct cost estimates discussed in Sections 4 and 5, the Regional Economic Models, Inc. (REMI) model was used to estimate the SIP's impacts on the state's economy. The REMI model uses general economic theory, combined with up-to-date national and state-specific data, to estimate the economic implications of public policies. The REMI model relies on long-run historical relationships between key variables to predict future economic patterns. The REMI model is used throughout the United States to plan economic and transportation development and evaluate the impacts of fiscal and environmental policies. For example, the REMI model has been used by the California Department of Transportation, the Minnesota Department of Revenue, and the South Coast Air Quality Management District.**

Different portions of the SIP were modeled separately, as follows:

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*The proposed California-only truck standard for 2002 was dropped from the adopted SIP in favor of the 2004 national standard.

**For more information on the REMI model, see Appendix F.

- Most of the proposals contained in Volume II were separately analyzed using a statewide REMI model. In cases where direct costs were unavailable or unimpressive, these proposals were omitted from the REMI runs. The SIP model runs are discussed in greater detail in Section 6.

- The economic costs associated with the SIP proposals adopted by the South Coast Air Quality Management District were taken from the District's REMI model run (i.e., M.Cubed did not separately run REMI for the District SIP rules). However, an examination was conducted of the District's direct cost estimates and REMI model data inputs, as discussed in Section 6.

- The economic costs associated with the SIP proposals contained in other District AQMPs were generally not analyzed. Where these costs were separately evaluated, they are discussed in Section 5.

It should be noted that although REMI can estimate sector-specific employment changes, it cannot capture the full implications of complex policies to discrete regions or economic segments. Such an analysis requires a more in-depth evaluation of the characteristics and variables affecting the area of interest.

4.0 Mobile Sources

This section reviews the mobile source emission reductions proposed in Volume II of the Proposed SIP released October 7.[28] The measures, which have been evaluated in varying degrees of detail, are listed in Table Two. Measure numbers in the table come from the November 15 SIP.[29] However, the report is organized to follow the numbering from the Proposed SIP.

The measures analyzed herein were chosen because they represent the largest potential emission reductions and cost impacts. In cases where independent analyses were not conducted, CARB's cost estimates were adopted so that total SIP costs could be determined. However, the measures for which CARB estimates were used are expected to have relatively low total costs of control.

The draft proposed SIP was modified by the Board at its November 9-10 hearing.[30] Due to the time frame required to undertake the analysis presented in this report, cost estimates are included for only one measure proposed as an "alternative" in the final SIP--heavy-duty vehicle 1.0 gram of NOx per brake horsepower-hour. Three other measures--new light-duty vehicle fleet average emission standards, and light and heavy-duty vehicle scrappage programs, are discussed only qualitatively. Further work is necessary to fully assess the effectiveness and costs of the latter programs.

Table Two

Proposed SIP Mobile Source Measures

Proposed SIP #	Adopted SIP #	Measure
		Measures Independently Evaluated
M1	Alternate	Enhanced LEV/ZEV program for LDVs--0.026 gpm fleet average emissions
M2	M3	Accelerated ULEV requirement for MDVs
M5	M4[1]	Heavy Duty Diesel Vehicles; 2.0g/bhp-hr NOx standard - California
M6	M6	Heavy Duty Diesel Vehicles; 2.0g/bhp-hr NOx standard - national
M7	Alternate	Heavy Duty Diesel Vehicles; 1.0g/bhp-hr NOx engines through incentives
M8	M9	Off-road diesel equipments; 2.5g/bhp-hr NOx standard in California
M9	M10	Off-road diesel equipments; 2.5g/bhp-hr NOx standard - national
M14	M14	Locomotives - national
		Measures Evaluated by ARB Staff Only
M3	M8	Heavy Duty Gasoline Vehicle standards in California
M4	M5	Heavy Duty Diesel Truck Emission Reduction Incentives
M10	M11	Industrial equipment 3-way catalyst in California
M11	M12	Industrial equipment 3-way catalyst - national
M12	M16	Pleasure craft - national
M13	M13	Marine vessels - IMO
M15	M15	Aircraft - national
		Measures Not Evaluated and Included in Adopted SIP
WSPA	M1	Light Duty Vehicle Accelerated Retirement
	M2	Light Duty Vehicle Improved Control Technology
WSPA	M7	Heavy Duty Vehicle Accelerated Retirement

1 - M5 measure modified in the Adopted SIP to M4 - Early introduction through incentives.

4.1 Cost-Effectiveness Analytic Methodology

Cost estimates for the SIP's technologically-based mobile-source control measures are based on modelling reasonably expected cost and performance parameters, rather than using stated performance and cost goals for these new technologies. To accomplish this analysis, scenarios were developed building on assessments of the outcomes likely to be induced by a given policy. This approach in part avoids estimates which reflect the need for rapid, but uncertain, technology "breakthroughs," and better represents probable cost ranges.*

The modelling approach presented here also recognizes that the increased costs associated with control measures will alter the demand and use of affected products. That is, consumer and business acceptance and use of regulated products will significantly affect cost-effectiveness. For example, if new car prices rise because of a regulation, fewer new cars will be purchased and more older cars will remain on the road. In this sense, the emission savings and cost-effectiveness estimates are dependent on how many new cars are sold as well as the improvement in pollution control on a single car. Simply extrapolating engineering cost estimates to static baseline conditions will give misleading results because such an approach ignores potential behavioral responses by consumers.

M.Cubed estimated the costs of the measures independently from associated emission reductions.** The costs per individual unit were aggregated to the population of regulated

*Reliance on a technological "breakthrough" to make a measure cost-effective can risk large economic costs if such a breakthrough fails to occur. The electric utility industry took a similar risk in committing to nuclear power in the mid-1960s that resulted in substantial rate impacts to consumers.

**Based on this premise, M.Cubed employed a somewhat different approach to evaluating cost-effectiveness than CARB staff. CARB staff calculates the engineering costs of a measure at the individual unit level (e.g., per automobile or truck), estimates the emission reductions at the individual unit level (e.g., tons per automobile per year) and (continued...)

products to estimate total statewide direct costs. In this aggregation process, consideration was given to how consumers and businesses might alter their purchasing or production patterns in the face of new costs. Cost-effectiveness was then calculated by dividing the total statewide cost by CARB's estimate of statewide emission reductions attributable to the measure.*

There are two primary differences between the M.Cubed and CARB staff approach to calculating cost-effectiveness. First, M.Cubed assumed that firms and individuals *respond* to changes in prices and costs. In contrast, the staff assumed that firms and individuals do <u>not</u> respond to these factors. Second, M.Cubed assumed that one ton of emission reduction is worth more today than a ton reduced next year. The staff assumes that present and future reductions are valued equally. The implication of the staff approach is that Californians do not care when pollution is reduced. However, economic theory suggests that obtaining environment benefits is better sooner rather than later. If this is the case, the future value of environmental improvement must be discounted in the same manner as is done with other types of investments in material well-being.**

**(...continued)
divides unit cost by reductions per unit of regulated product to obtain the cost-effectiveness at the individual product level per unit of emission reduction. Total costs are then calculated by multiplying the cost per unit of emission reduction by the total amount of emission reductions.

*The preferred method would have been to adjust the forecasted regulated product population for changes in economic behavior, and to forecast emission reductions with this new population. In other words, a base case of total emissions would have been developed with one set of population estimates based on existing regulations, and then alternative emissions estimates would be developed based on the proposed SIP measures.

**For example, under CARB's method assume emission reductions of "10" every year for a total of ten years, at a cost of $100,000. These emission reductions would total to "100," and CARB would estimate a cost-effectiveness of $1,000 per ton. Under these same assumptions M.Cubed would discount the stream of emission reductions by 10 percent,
(continued...)

4.2 M1–Light Duty Vehicles Enhanced LEV/ZEV Program

Current CARB regulations call for the fleet-average emission standard for non-methane organic gases (NMOG) in new cars to be reduced to 0.062 grams per mile (gpm) and 10 percent of sales to be zero-emission vehicles (ZEVs) by 2003.[31] The measure proposed in the October 1994 draft SIP would have further reduced the new car standard to 0.026 gpm and raised the upper limit on affected vehicle size from 3,700 pounds to 6,000 pounds gross vehicle weight.[32] While the proposed SIP did not call for a prescribed mix of vehicle types, the CARB draft suggested that this standard could be met with a fleet of two-thirds ultra-low emission vehicles (ULEVs) and one-third ZEVs. The Staff's cost-effectiveness analysis reflected this fleet mix, and our discussion about analytic methodology reflects this general assumption.[33,*]

The cost of 0.026 gpm fleet standard is driven substantially by prospective ZEV costs. At the moment, only electric vehicles are expected to meet the ZEV criteria at a cost low enough to be commercially viable. For ULEVs--whether fueled by gasoline or other energy sources, the initial cost increment over conventional cars in 2010--$75 to $600 per car--is expected to be relatively small due to improvements in production through learning and economies of scale.[**] Because this added cost is relatively small and non-controversial, this section focuses on issues of estimating emission reductions and costs for ZEVs.

[**](...continued)
estimating a cost effectiveness of $1,480 per ton.

[*]The Staff suggested in its briefings that a "super-ULEV" could meet this standard, most likely with a hybrid electric-gasoline motive system. However, the technical and commercial feasibility for such a vehicle has not been adequately explored to include it in the economic analysis at this time.

[**]See Appendix A for technical assumptions provided by Acurex.

Assessing the economic feasibility of a ZEV-based standard requires three analytic steps:

(1) Determining the *technological feasibility* of constructing a ZEV that meets the general requirements of automobile use among the broader population;

(2) Projecting *production costs* based on initial setup costs, and how the manufacturing learning process causes the per unit costs to fall over time; and

(3) Forecasting *consumer acceptance* and *willingness to pay* for alternative-fueled vehicles compared to conventional automobiles based on performance factors and operating costs.

The first step, technological feasibility, has been the focus of most of the work on electric vehicles to date.* However, *technological* feasibility does not necessarily imply *economic* feasibility--we have the ability to send people to the moon, but we cannot afford to do it on a regular basis. Whether an expanded ZEV program is economically viable cannot be adequately assessed without understanding how production costs might fall or if consumers will buy ZEVs at likely prices. **Without this information, M.Cubed could not evaluate the cost-effectiveness of an enhanced fleet emission standard, nor even the likelihood of success for increasing ZEV sales. On this basis, it is unclear whether CARB has sufficient information to adopt any rules that further lower fleet-average emissions for LDVs.**

The following discussion summarizes the analytic framework for assessing the economic feasibility of a ZEV program. In addition, several important policy issues are

*See for example California Air Resources Board 1994d; California Air Resources Board 1994e.

discussed, such as the relationship of California's regulations to other states' and the U.S. EPA's, and potential ZEV pricing strategies.

4.2.1 Assessing ZEV Production Costs

ZEVs are initially expected to cost more to produce than gasoline-powered automobiles. Based on studies of other industrial goods, however, this cost increment should decline at a predictable rate that reflects a production "learning curve".[34,*] Two other key issues to be addressed are:

(1) What are the "incremental" cost differences between ZEVs and conventional vehicles? and

(2) How will research and development (R&D) investments be recovered in future automobile sales?

These two questions are linked because many of the developments in materials use and drive train engineering will be applicable to a wide range of vehicle types. This has two implications. First, ZEV production cost improvements may lead to decreased costs for gasoline or other alternative-fueled vehicles as well, so that the cost difference between ZEVs and conventional cars may not fall as fast as expected. Second, R&D costs aimed at developing ZEVs can be recuperated through research application to other types of vehicles. That is, simply assigning all ZEV R&D costs to ZEVs will not reflect likely cost allocations.

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*Studies of industrial learning curves or "learning by doing" typically find that the cost of producing an additional unit falls by 10 to 30 percent with each doubling of cumulative output. The learning curve rate is usually expressed as the percent of cost after doubling cumulative production. An 80 percent learning curve implies that costs fall by 20 percent each time that cumulative production doubles. For example, if the initial production run is 10,000 cars and these cars cost $30,000 each, at the end of the next 10,000 car production run, the costs should fall by $6,000 or 20 percent to $24,000 each.

In addition, much of the ZEV market demand is likely to be met through joint production efforts similar to the General Motors/Toyota NUMMI facility in Fremont, California. In this situation, R&D and other fixed production costs will be allocated over a larger production run. Manufacturers may also "forward price" their products, (i.e., set prices to recover R&D costs with later sales) to increase early sales and thus accelerate the learning process to make costs fall faster. This type of pricing is common in industries with rapid product innovation, such as computers and aerospace.

Another important issue is the treatment of battery costs. In some analyses, batteries are included in the vehicle's purchase cost; in others, batteries are expensed as operational costs. Because batteries are likely to be replaced several times during the lifetime of a car, the latter approach is probably more accurate. If battery costs are treated in this fashion, the annual operating costs for both conventional and electric vehicles are roughly comparable, with the differences depending on assumptions about energy prices and battery costs and life cycles. Battery cost estimates are quite sensitive to assumptions about annual vehicle use. For example, if ZEVs are driven less miles per year than a gasoline car, but receive the same number of recharges as currently forecasted, then battery costs will be higher per mile than currently estimated.* How battery technology will evolve, and what the cost of the new types of batteries will be, are critical factors in projecting overall ZEV costs.

CARB analysis of ZEV technical and economic topics to date have not adequately addressed these issues.[35] CARB staff's assumption that incremental costs attributable to producing ZEVs will dissipate within three years is not consistent with the existing learning-by-doing literature, although further research could resolve this issue.** Similarly, the CARB

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*Battery life is driven by the number of charge cycles rather than the amount of energy drawn.

**The staff's assumption implies a learning curve of 25 percent or lower (i.e., costs fall (continued...)

analysis also does not specify what share of costs are attributable to components that might be shared with other vehicle types.

Various industry cost estimates have been developed for the LEV and ZEV programs for the Western States Petroleum Association and the American Automobile Manufacturers Association.[36] While these analyses provide detailed breakouts of costs and assess the impacts on vehicle markets from the sales mandate, they do not answer the two key production costs questions of how rapidly production costs will fall as more vehicles are sold and how upfront investments will be recovered in the vehicle market. These analyses also include batteries in the initial purchase cost rather than as operating costs. For example, if one adjusts the cost increments compiled by Virag, the initial cost difference can fall by half.

4.2.2 Consumer Acceptance

Qualitative differences will exist for the foreseeable future between ZEVs (e.g., electric vehicles or hybrids) and gasoline-fueled cars in the same class in range, performance, storage room and other factors. Consumers are unlikely to view ZEVs as being direct replacements for all of the cars they drive today, just as compacts are not substitutes for sport utility vehicles. Due to these qualitative differences, automobile dealers would likely have to lower their prices on ZEVs to expand their market share, for example from a 10 percent to 35 percent, without significant improvements in vehicle quality.* This postulate

**(...continued)
75 percent or more with each doubling of cumulative production).

*An important consideration in any analysis: at the outset of the ZEV market, the characteristics of ZEVs in a world with a 10 percent sales level is unlikely to be any different from the characteristics in a world with a 35 percent sales level. More models may be available, but the technological constraints are likely to remain in any case until and if (continued...)

is based on the fundamental economic principle that as any product's sales increase, consumers' willingness to pay for an additional sale will be lower. For example, although pickups and compacts are roughly priced at equivalent levels today, dealers would have to lower the price of a pickup to increase its relative sales share to attract consumers who put a lower value on owning a pickup.

Demand will be affected by whether ZEVs fit into a market niche similar to that of other commuter cars as a second car for a household or have a broader market appeal.* ZEVs are likely to have a limited ability to penetrate into specific markets such as sports cars, sports utility vehicles or luxury cars. If ZEVs are constrained to the small-car niche, consumers' willingness to pay might be only 75 percent of that for an average car (i.e., roughly equivalent to the price difference between a subcompact and an average car). A ZEV's resale value will be further constrained as well, since general-purpose cars have the ability to move "downward" into less-valuable and more limited niche markets (e.g., commuter, utility, etc.) as they age.**

How consumers will use ZEVs also is an important consideration. Assuming the same pattern as for present-day use may not be consistent with electric vehicle design as

*(...continued)
increased sales lead to higher profits that can be plowed back into R&D.

*This approach is based on work done at the Institute for Transportation Studies at the University of California. (See "New Study Says Range Alone Won't Limit EV Market Acceptance," *California Report*, April 1, 1994, p. 9.)

**For example, a subcompact is unlikely to be used as a family vacation car, which limits its demand in a resale market to the commuter-only segment. On the other hand, a station wagon might be resold not only in the commuter market, but also in utility, family travel or second-car markets.

commuter cars that travel substantially less per year than conventional autos.* If ZEVs are used less per year than conventional autos and consumer vehicle miles travelled (VMT) continue to grow at present rates, the emission reductions from the current emission baseline may be overestimated.**

An additional consideration is how rapid improvements in ZEV technology will affect both their desirability and their resale value. Battery technology is expected to evolve quickly from lead-acid to metal hydride to lithium-ion, with the third-generation technology being introduced as early as 2005. As the technology increases vehicle range, battery durability and operational flexibility, consumers acceptance is likely to rise, and the range of uses for ZEVs should increase. These factors should lead to a rising willingness to pay in the marketplace.

However, a rapidly evolving technology can make an older ZEV obsolete more rapidly. In addition, vehicle design may not be compatible among battery types.[10] As consumers recognize that they may not be able to recoup much of their initial purchase price when they resell a ZEV, they will discount the value they put on a new ZEV. This may further depress the market acceptance of ZEVs.*** On the other hand, ZEVs may

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*Discussion with the CARB Staff indicated that the annual mileage for electric vehicles and gasoline-fueled vehicles were assumed to be the same.

**However the large uncertainty over actual auto emissions may dwarf the impact of ZEVs on the baseline itself. We ignore that problem here, but it only highlights our earlier point that large uncertainty exists about emission levels in general and their relationship to ambient air quality. This scientific uncertainty often is not reflected adequately in policy formulation.

***The personal computer industry has witnessed the effects of accelerated obsolescence. The dominant Intel microprocessor chip is now moving into its sixth generation in about 15 years. Computers built with the second generation 286 chip just five years ago are now virtually worthless. The prices for new 386 and 486 machines have been (continued...)

experience slower physical depreciation rates because electric motors and drive trains are usually more durable compared to internal combustion engines, as is seen in the water pumping market. However remaining technical life may not be relevant to economic value if obsolescence is accelerated for technological reasons.

To date few studies have been conducted on consumers' willingness to buy electric vehicles. Most have been pilot studies that target a small, already-enthusiastic, population that provide only anecdotal information. The only extensive public study available is the Personal Vehicle Model (PVM) created for the California Energy Commission's *1993-1994 California Transportation Energy Analysis Report*.[38,*] The PVM compares the characteristics of a hypothetical electric vehicle against the expected characteristics of a wide range of new and used automobile models fueled by gasoline or alternative fuels. The model also includes the ability to assess consumers' willingness to pay for the full environmental benefits bestowed by the purchase of a ZEV, even though society in general benefits from the improved air quality. While the PVM has several shortcomings, it represents the preferred framework for forecasting consumer acceptance of new technologies. The CEC plans to update the PVM with new survey information in 1995 with work currently being conducted by the University of California's Institute of Transportation Studies (ITS).

In the preliminary analysis conducted by M.Cubed, the CEC was asked to run some cases with the PVM based on assumptions provided about ZEV costs and sales levels. Because of uncertainty about these and other PVM assumptions, M.Cubed did not rely on the quantitative results in preparing this report, although the qualitative findings provide

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[***](...continued)
falling rapidly as their expected value declines with the introduction of yet another new chip technology. While software is generally "backward" compatible, battery technology may not be, and this will further depress resale values.

[*]The California Energy Commission's Personal Vehicle Model (PVM) relies on this premise in developing consumer willingness to pay estimates for electric cars.

useful insights. First, ZEV prices may compete with those of used cars in the commuter-car market. This finding is consistent with the research work at the University of California ITS that ZEVs would be the second car in most households. But with this expansion into the used car market, ZEV sales could actually increase, possibly accelerating turnover of older vehicles. Second, the valuation of ZEVs is highly sensitive to assumptions about ZEV performance. Both of these findings are borne out in the CEC's report as well.

As an interim analytic tool, reasonable price elasticity values for other car model can be used to estimate the likely effect of actions to increase ZEV market share.* Based on data provided by the CARB staff** and adjusted to reflect market share,*** the elasticity for ZEVs might range from -5.0 (consumers are somewhat less responsive to price changes in this case)**** to -7.5 (relatively small price changes create large consumer responses).***** Moving from a 10 percent to 35 percent market share implies an increase in sales of 250

*Elasticity is the responsiveness of one variable (in this case sales quantities) to changes in another (in this case vehicle prices), measured as the percentage change in one variable caused by a one percent change in another explanatory variable. For example, a price elasticity of -2 implies that an increase of 1 percent in the price of an item will result in a 2 percent decrease in the sales of that item.

**The demand elasticity for conventional car models of the type likely to compete with ZEVs is -1.7, i.e., a price decrease of 1 percent would increase sales by 1.7 percent.

***See Carlton, Dennis W. and Jeffery M. Perloff, *Modern Industrial Organization*, United States, Harper Collins, 1990, pp. 79 and 210 for a further explanation of how elasticities for the car market can be adjusted to reflect elasticities for market segments or individual models. The usual economic assumption of a demand elasticity equaling infinity really reflects an implicit assumption that an infinite number of firms could enter the market if the price for the product rises.

****This equals -1.7 divided by the 35 percent target market share for ZEVs.

*****This elasticity is derived from dividing the median small car elasticity of -1.7 by the average of the 10 and 35 percent market shares (22.5 percent).

percent; based on these elasticities, ZEV prices would have to fall by 33 to 50 percent to increase sales to the target level.

4.2.3 Policy Considerations

The cost differences among policy scenarios can be influenced substantially by how costs are recovered, whether through a nationwide subsidy embedded in new car prices or a California-specific subsidy provided by the state government. The dictates of economics almost assuredly rule out the ability of auto manufacturers to completely contain these costs within the California market. To do so would leave a manufacturer open to being undercut by another company that spreads the subsidy nationwide or even worldwide. Maintenance of California-only pricing would leave manufacturers open to charges of collusion and anti-trust action.

Whether the Northeastern U.S. states will adopt a ZEV sales mandate similar to current California policy could have a profound effect on the program's costs.* Inclusion of these states would hasten the production learning process and expand the scale of production, thus leading to lower ZEV costs.

An additional consideration is whether automobile manufacturers could claim ZEV production as credit towards meeting the federal corporate average fuel economy standard (CAFE). The current CAFE standard is 27.5 miles per gallon (mpg).[39] Incorporation of ZEVs at zero gallons per mile would allow a manufacturer to reduce the average for the remainder of its fleet to 26.6 mpg; the 0.026 gpm standard could reduce that further to 25.7 mpg.** This would allow manufacturers to build larger, more profitable vehicles while still

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*Many Northeastern states have included ZEV mandates in their proposed SIPs.

**Assuming that both California and the Northeast U.S. adopt a ZEV mandate.

meeting the CAFE standard. Possibly the ZEV mandate could pay for itself through this mechanism; this issue requires further exploration.

4.3 M2--Medium Duty Vehicle 100 Percent ULEV Penetration

Current CARB regulations call for a 15 percent penetration rate for the sale of ultra-low emission vehicles in the medium duty truck (MDT) category (between 6,000 and 14,000 pounds gross vehicle weight) by 2003. The SIP proposes that this penetration rate be increased and accelerated to achieve 100 percent penetration by 2002.[40] Given the dominance of gasoline-fueled vehicles in this smaller size range[41] and the large number of centrally-fueled fleets, this standard may be achievable technologically, logistically and economically.

M.Cubed's economic analysis assumes that the additional production cost for MDVs will fall in the same range as for LEV and ULEV light duty vehicles, as provided by Acurex.* Additional assumptions are as follows:

- ULEVs are expected to have an incremental cost of $400 to $1200 above conventionally-fueled trucks in 1998, based on Acurex estimates.

- A "learning curve"--where costs decline by 20 percent for each doubling of cumulative production--was used to model falling production costs as familiarity with the technology increased.

*See Appendix A for Acurex discussion of technical assumptions.

- The number of new MDTs was estimated based on California Department of Transportation highway usage forecasts.[42,*]

The annual incremental costs of measure M2 are estimated to range from $40 million to $170 million in 2010. This translates to a cost-effectiveness of $1,120 to $4,495 per ton of reduced NOx and ROG. This cost range is driven by the uncertainty over the incremental cost of the ULEV technology over conventional engines.

4.4 M5, M6 and M7--Heavy Duty Vehicle Standards

The SIP contains a number of measures aimed at controlling emissions from heavy duty vehicles larger than 14,000 pounds gross vehicle weight. The analysis presented here focuses on the three measures aimed at establishing technological emission standards for diesel trucks--M5, M6 and M7.[43] The proposed M5 measure would have required sale of 2.0 gram NOx emissions per brake-horsepower-hour (g/bhp-hr) heavy duty diesel trucks (HDDTs) in California beginning in 2002. The M6 measure requires sale of 2.0 g/bhp-hr HDDTs in the U.S. market beginning in 2004. The proposed M7 measure would have required a phase-in of 1.0 g/bhp-hr truck engines into local centrally-fueled fleets, comprising 25 percent of new sales by 2007.

4.4.1 M5/M6--HDDT 2.0 g/bhp-hr NOx Standard

The Board expressed a desire to "harmonize" the state's proposed 2.0 g/bhp-hr standard with a nationwide standard that cannot be implemented before 2004 under the

[*]The number of new MDTs equals the turnover of the CalTrans-defined TRK2 category plus 30 percent of the TRK3 category plus the addition of new trucks based on the increase in vehicle miles travelled (VMT) in the CalTrans MVSTAFF forecast. The turnover rate was assumed to be 1/12 of the truck population per year based on a life expectancy of 12 years for MDTs.

1990 Clean Air Act Amendments. The Board adopted a replacement measure to accelerate introduction of 2.0 g/bhp-hr engines in California through incentives.

The heavy duty diesel truck (HDDT) analysis proceeded by estimating the cost for a base case, including the 1998 U.S. EPA emission standards, and then estimating low and high cost scenarios for both the 1.0 and 2.0 g/bhp-hr standards to bracket the likely outcomes.* A single point expected-value forecast was not estimated directly. The analysis assumed that all 2.0 gram trucks would be diesel-fueled; all 1.0 gram trucks would be natural-gas-fueled. The cost for M5 - Heavy Duty Vehicles; 2.0g/bhp-hr NOx California-only Standard is not included in this analysis because we found that the measure is unlikely to be feasible due to several constraints.** The analysis presented by M.Cubed reduces the projected emission reductions in 2010 for the 2.0 g/bhp-hr standard for this two-year deferral.*** **As a result, this analysis assumes that the M5 measure is delayed to 2004 and subsumed into the national standards adopted under M6.**

Two additional premises are used in the M.Cubed analysis:

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*See Appendix B for a further discussion of data, assumptions and methodology in assessing HDT costs.

**The constraints on implementing the proposed M5 measure are as follows: First, uncertainty exists about the technological and economic feasibility of meeting the standard by 2002 according to testimony by engine manufacturers and the assessment of Acurex. Second, implementing a separate California-only fleet-wide standard in 2002 is unlikely to be logistically, economically or politically feasible. With the added technological uncertainty of producing a diesel engine to meet the earlier date and the nationwide deregulation of trucking, enforcing such a standard in California would be difficult. Facing a state-specific standard, truck owner/operators would either defer the purchase of new rolling stock until national standards arrived (only two years later) or would buy new trucks and register them out-of-state under the International Registration Program (IRP).

***This equals about 14 percent of the reduction under M5.

- *A diesel-fueled engine meeting the 2.0 g/bhp-hr standard must be commercially available by 2004.* CARB, U.S. EPA and Engine Manufacturers Association reached an agreement subsequent to adoption of the SIP to produce a diesel engine meeting a 2.5 g/bhp-hr standard by 2004. However if such an engine is unavailable at that time and alternative fuel use (e.g., natural gas) is necessary to meet this measure, this analysis may significantly underestimate the costs of the standard. For example, the use of alternative-fueled trucks in the long-haul market would require the creation of a parallel fueling and service infrastructure that would have to coexist with the diesel-fuel infrastructure for at least three decades as the fleet composition transitions over to be completely fueled by natural gas.

- *The analysis assumes that the trucking industry will begin recovering the costs of these measures beginning in 1995--long before the measure is implemented.* That is, truck owner/operators will begin to pass on the added costs for the low-emission engines as soon as the rule is adopted to spread the costs over a longer period of time. This assumption of "perfect foresight" by truck owner/operators tends to underestimate the actual costs of the measure.

Due to time limitations, this analysis does not address two important economic factors that will significantly affect the adoption and use of lower-emission engines:

- First, increased trucking prices will depress demand for trucking services. An increase of 10 percent in trucking costs per mile likely will decrease truck travel by 1.5 percent.* Higher transportation costs also will slow economic growth. Reduced

*See Appendix B for derivation of the income and price elasticities of demand for trucking services in California. This demand response implies a combination of less goods being sold due to higher consumer prices, businesses relying on closer but more expensive suppliers, and substitution with other modes of transportation (e.g., rail or air).

demand will retard the introduction of new low-emission trucks, but also may reduce overall emissions from the entire fleet due to less travel. On the other hand, the aging existing fleet may emit more even with lower vehicle miles travelled (VMT) due to being "dirtier."

- Second, trucking firms will not be able to pass on their entire cost increases to customers. Absorbing some of these costs will make holding older trucks longer more attractive. This in turn will decrease turnover rates, delay penetration of lower-emitting engines and shrink expected emission reductions.

The 2.0 gram national standard is expected to cost between \$182 and \$667 million per year by 2010. This equals a cost-effectiveness of \$3,258 to \$11,922 per ton of reduced NOx and ROG emissions.* This cost range reflects the uncertainty about required research and development costs by manufacturers to meet the standard, ultimate engine performance and fuel consumption parameters, and future fuel prices.

4.4.2 M7–Centrally-Fueled HDDT 1.0 g/bhp-hr Standard

The M7 measure foresees a phase-in of 1.0 g/bhp-hr trucks in to local centrally-fueled fleets comprising 25 percent of new sales by 2007. The Board later modified the proposed M7 measure to defer consideration of the 1.0 g/bhp-hr and to replace it with an accelerated HDDT retirement program.[44] This analysis still incorporates this measure as proposed in the original draft SIP document for consistency and future considerations in rulemaking.

Based on the analysis by Acurex, we assume that the 1.0 gram standard can only be met by natural-gas engines by 2004. While the 2.0 gram standard appears achievable for diesel-

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*The table summarizing the projected costs to trucking of the two feasible proposed measures, M6 and M7, is in the Appendix B.

fueled engines, insufficient evidence exists supporting the potential for a 1.0 gram diesel-fueled engine. Even if diesel-fueled engines are available by 2007, fleets that had to invest in natural-gas fueling systems early during the four-year phase-in will likely commit to purchasing only natural-gas trucks. This is in addition to the other assumptions made about diesel engines for the 2.0 g/bhp-hr measure.

The 1.0 g/bhp-hr standard is projected to incur substantially higher investment costs and significant performance penalties, but also could create large fuel savings if low natural gas prices continue into the future. The initial cost increment for natural gas trucks is expected to be five to ten times higher than for meeting the 2.0 gram diesel standard, and central-fueling stations are expected to cost $360,000 to $600,000 each. The natural gas price trajectory was assumed to take one of two paths explored by the CEC to delineate the most likely outcomes.[45,*] The high case calls for a near-tripling of natural gas prices in constant dollar terms by 2010. The low case foresees a less than 10 percent rise over the same period.

The analysis presented here excludes consideration of two key issues that are likely to increase measure costs. The first is the required expansion of the service infrastructure to meet the needs of parallel fueling systems--diesel and natural gas. For example, parts will have to be stocked for two different types of engines and mechanics will have to be trained on new technologies. These costs will be significant, especially in the technology's early years. Second, many relatively new underground diesel fuel storage tanks (UST) will become economically underutilized and prematurely obsolete. The accelerated replacement of most USTs to mitigate groundwater contamination since beginning in the mid-1980s is now virtually complete. In the case of centrally-fueled fleets, these tanks are likely to have

*The first followed continued lower prices as demand remained consistent with current patterns; the second projected higher prices as demand increased with movement from petroleum in transportation and other uses. The CEC's natural gas price forecast was updated to conform with the more recent Delphi VII oil price forecast.

an economically useful remaining life of 10 to 20 years. If the typical cost of a UST is $100,000 and it is replaced after 15 years of an expected 30-year life, the net economic cost of converting to natural gas is an additional $50,000 per UST. To better estimate this cost would require a more accurate census of affected fleets and activity under the State Water Resources Control Board's Underground Storage Tank program.

Lower forecasted natural gas prices may create net savings of $155 million a year in 2010 in the low-cost scenario for the 1.0 gram standard, or a cost-effective savings of $19,265 per ton reduced. This lower bound reflects the current economic attractiveness of natural gas to some centrally-fueled fleet operations--substantiated by recent fuel-switching by various delivery fleets such as Federal Express and United Parcel Service. **The high cost scenario lead to increased costs of $63 million in 2010, or about $7,858 per ton.** Along with the uncertainty specified in the M6 measure estimates, the cost of the fueling infrastructure also is variable and site dependent.

4.5 M8 and M9--Off-Road Equipment

The SIP calls for a national 2.5 g/bhp-hr standard for off-road equipment. Key cost assumptions include the following:

- Between 3,400 and 3,900 new 175 horsepower (HP) or greater pieces of equipment will be sold in California annually between 2005 and 2010. Another 46,000 to 51,000 units of less than 175 HP will be sold annually in the state during the period.[46]

- New engine costs for 175 HP-plus equipment will range from $10,540 to $14,700 as a result of the SIP. New sub-175 HP units will be from $9,430 to $13,590 more expensive than current engines. These equipment would also be 5 percent less fuel efficient than pre-2005 units.*

- New equipment purchases will be predominately made by four sectors: agriculture (16 percent of new sales); construction (16 percent); industrial (34 percent); and consumers (33 percent).[47]

Table Three displays low and high cost estimates based on the assumptions indicated above and multiplying the cost increments by the number of units sold.** The high cost estimate reflects lagging unit sales in the early years in response to higher prices, and thus total costs are less than in the low-cost scenario.

Table Three

Statewide Direct Costs Associated with SIP Off-Road Proposed Measures

Year	Low Case Estimate	High Case Estimate
2005	$80 million	$61 million
2006	$120 million	$104 million
2007	$160 million	$124 million
2008	$200 million	$144 million
2009	$280 million	$235 million
2010	$343 million	$379 million

*See technical assumptions detailed by Acurex in Appendix A.

**These cost estimates are based on the assumption that demand does not respond to SIP-induced price increases; and that there is no production "learning curve" during the forecast period.

4.6 M12–Pleasure Craft

The SIP calls for national standards that would reduce ROG emissions from new outboard and personal watercraft equipment by 75 percent, and new inboard and sterndrive pleasure craft by 35 percent, with a fleet average phase-in beginning in 1998. Additional reductions may be achieved by accelerating engine turnover rates, reducing use, and through engine retrofit. *Based on CARB's SIP analysis this proposal would cost $3 million annually by 2010.*

4.7 M13–Marine Vessels

The SIP calls for the establishment of international standards to reduce NOx emissions from new diesel engines used in ocean-going vessels by 30 percent. Additional reductions may also be derived from local measures. *Based on CARB's SIP analysis this proposal would cost between $2 and $30 million annually by 2010.*

4.8 M14–Locomotives

The SIP calls for the establishment of national NOx emission standards for new locomotive engines of 5.0 grams per brake horsepower-hour (g/bhp-hr) in 2000 and 4.0 g/bhp-hr in 2005. In addition, the SIP proposes a requirement that each locomotive fleet in the South Coast Air Basin emits on average no more than 5.5 g/bhp-hr by 2007 and 4.0 by 2010, with an overall NOx emission reduction of 67 percent from current baseline.

In 1993 CARB commissioned an analysis of the engineering costs associated with various options to control locomotive emissions for a California-only fleet.[48] In the absence of other detailed documentation, the estimates contained in this report are based on the 1993 report, which was conducted by Engine, Fuels, and Emissions Engineering, Inc. (EFEE). M.Cubed used the EFEE data to compile costs for individual technological measures, and ranked the costs of adding each measure until the proposed SIP's emission reduction target was reached. Based on the EFEE report, meeting the SIP's 2010 reduction objectives would require retrofitting the entire in-state fleet with liquified natural-gas (LNG)/diesel dual-fuel capability and adding selective catalytic reduction (SCR) controls.

M.Cubed's analysis uses a simple engineering-cost approach, rather than the more sophisticated economic-cost analysis employed in the HDDT analysis. No adjustments were made for the likely decrease in rail traffic resulting from the higher rates caused by increased equipment costs. Likewise, EFEE's cost estimates ignored lost salvage value when existing locomotives are retrofitted for dual-fuel capability at accelerated maintenance schedules, a gap which was not corrected in this analysis. However, M.Cubed's analysis does correct the EFEE study for projected fuel prices in 2010 rather than assuming such prices will remain unchanged for that time horizon. As with the HDDT analysis, CEC fuel price forecasts were used to derive lower and upper bounds on likely cost ranges.[49] To limit the number of price scenarios used in the analysis a single diesel fuel price was adopted as the baseline comparison to a range of natural gas prices.[50] In addition, a high and low cost of capital assumption was used to estimate the present value of emission-reduction investments.*

Based on the EFEE analysis, the proposed locomotive-control measure is estimated to cost between $2,340 and $4,800 per ton of NOx reduced. The statewide costs in 2010 would range between $80 and $165 million annually. This range reflects different assumptions about future fuel prices and the railroads' cost of capital.

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*The table detailing the cost assumptions used in the locomotive-cost analysis is in Appendix B.

4.9 M15–Aircraft

The SIP call for national standards to reduce ROG and NOx emissions by 30 percent beginning in 2000. *Based on CARB's SIP analysis this proposal would cost $25 million annually by 2010.*

4.10 Industry Alternative Proposals

Two alternative proposals were submitted by industry groups shortly after the draft SIP was issued. These consisted of light- and heavy-duty vehicle accelerated turnover programs. Although insufficient time was available to conduct an in-depth analysis of these proposals, based on previous project team work a brief evaluation of the measures is provided below.[51]

The proposed *light-duty vehicle accelerated turnover program* may be a cost-effective method of obtaining emission reductions. However, several issues should be addressed as part of program design for this measure, as follows:

- The emission reduction level that can be purchased for a program cost of $75 million a year may be substantially less than indicated by existing analyses.[52] For example, Resources for the Future estimates that direct costs could range from $5,370 to $7,500 per ton of ROG reduced to purchase 30 percent of the pre-1980 fleet in the State of Delaware. Scrappage costs tend to rise as more recent models are purchased.*

*This converts to approximately $3,000 to $4,200 per ton of NOx and ROG reduced.

- Unless effective barriers are created, the program could induce "negative recruitment" of high-emitting vehicles from attainment areas within and outside of the state, as well as rarely-used automobiles within non-attainment regions.

- The scrappage fee is likely to be capitalized into the new and used car markets, acting to increase automobile prices, and thereby reducing affordability to low-income drivers. This effect would be similar to the capitalization of federal agricultural subsidies into land prices, or the capitalization of home mortgage rates into housing prices, and has less to do with total program costs than the increased market price induced by the program for used cars (e.g., a guaranteed $1,000 per vehicle).*

- In "scoring" the emission reductions associated with this program, regulators must be careful to net out the influences of existing area-specific scrappage initiatives. For example both the Bay Area Air Quality Management District and South Coast currently sponsor accelerated vehicle turnover programs.

The proposed *accelerated turnover program for heavy-duty vehicles* would likewise be a cost-effective method of reducing emissions in non-attainment areas. However, in addition to the issues raised above, a truck scrappage program may create barriers to entry into the transportation sector, and as a result have noticeable socio-economic impacts. Trucking provides substantial opportunities for small and family-owned businesses. Over two-thirds of businesses in the trucking and warehousing sector employ fewer than ten people. Likewise, 95 percent of all truck companies generate revenues of less than $5 million annually.[53] Because of the small firm characteristics of the majority of trucking enterprises, trucking companies tend to operate at the edge of profitability. For example, trucking firms go out-of-business far more frequently--almost twice as often--than other firms.[54] As a

*In a large enough program the scrappage fee could put an effective regional "floor" on used car prices, and influence relative values among various models and vintages.

result, unless truck scrappage fees provide operators with sufficient funds to purchase necessary capital equipment, accelerated turnover programs may raise the cost of entry into the transportation sector, foreclosing economic opportunities for some Californians, though potentially increasing profitability for remaining firms.

5.0 Direct SIP Costs Related Consumer Products, Aerosol Paint, Pesticides

This section examines potential impacts engendered by the SIP's statewide consumer product, aerosol paint, and pesticide measures. In general, the analyses contained in Section Five serve largely as an evaluation of CARB's cost estimates, rather than a presentation of independently derived forecasts. Although insufficient time was available to create new estimates, it is hoped that this critique will provide readers with greater insight with which to evaluate key issues associated with these measures.

5.1 Consumer Products

CARB's consumer product proposal's goal is to reduce statewide 1990 baseline VOC emissions from consumer products by 55 percent and 85 percent by 2005 and 2010, respectively. In addition to existing control programs,* SIP measures to meet these reduction targets are divided into two categories: Mid-Term Measures; and Long-Term Measures.

- *Mid-Term* measures consist of extending VOC content regulations to include several categories of consumer products not currently regulated. According to the SIP, candidate products include "lubricants, aerosol tire inflators, specialty cleaners, nail polish, and numerous other categories."

- *Long-Term* measures are described in the SIP as "strategies that depend on significant advancement of technologies and market incentive methods that can be fostered and developed between 1994 and 2010." Specific measures are not defined, but possible approaches include initiation of research programs to develop low- or zero-VOC products; RD&D tax incentives, tax rebates, and other financial incentive programs

*See Appendix C for a discussion of current consumer product regulations, and their relationship to the proposed SIP measures.

to foster investment in low-VOC product development; incentives to lower the price of low-VOC products relative to high-VOC products; and consumer education programs designed to increase consumer preference for low-VOC products. CARB expects Long-Term measures to reduce VOC emissions from consumer products by an additional 30 percent between 2005 and 2010, relative to the 1990 emissions baseline.

CARB's estimates of the annual direct costs to industry to comply with current consumer product regulations range between $175,000 and $46 million. The estimated per ton emission reduction cost ranges between $8 and $2,100. CARB ascribes this broad range to the variety of technologies which could potentially be used to reformulate a large number of consumer products.

An independent analysis of potential consumer product-related economic impacts was not conducted in this analysis. This is because the direct costs associated with Mid- and Long-Term Measures have not been estimated, and specific measures for these programs have not as yet been defined. It is important to note, however, that the total emission reductions required under the medium and long-term measures is substantial, implying that associated costs could likewise be significant. The following critique points to the key CARB assumptions which drive the Board's cost estimates, as follows:[55]

- *Assumption 1: Products reformulated to comply with Existing Control Measures will be sold nationally.*[*] This assumption results in lower per unit reformulation costs than would be the case if reformulated products were sold only in California, since it acts to spread research, development, and demonstration (RD&D) and capital costs over substantially more production units. In this regard, CARB's unit cost estimates

[*]CARB adopted this assumption based on consumer product representatives assertions.

should be regarded as lower-bound forecasts of potential regulatory-induced unit cost increases.

- *Assumption 2: Emission reductions due to Existing Control Measures will be realized on a national level.* CARB uses this assumption in its cost-effectiveness estimates by dividing total direct costs by total emission reduction realized on a national level, rather than limiting benefits to California-only emission reductions. An alternative assumption would be that costs should only be measured against California VOC reductions, since this is a California rather than a national policy. The CARB methodology produces the absolute lowest-bound cost-effectiveness measure. If reformulation costs were measured against reductions of VOC emissions in California only, the cost effectiveness ratios would increase by a factor of eight (e.g., instead of an annual cost of $2,200 per ton, cost per ton would approach $17,000, or annual total of $367 million).

- *Assumption 3: Cost data collected through industry surveys are representative of the industry as a whole.* CARB's cost estimates are based on information collected from six completed survey instruments, workshops with industry, and data provided by trade organizations, such as the Chemical Specialty Manufacturers Association.

The proposed VOC content standards would result in higher consumer product prices. CARB staff estimate that the Existing Control Measures would increase unit production by between $0.01 and $0.60. This estimate assumes that cost increases are fully passed through to consumer product prices.

5.2 Aerosol Paint

CARB's aerosol coating product proposal's goal is to reduce 1999 sales weighted average VOC emissions from aerosol coating products by 60% from a 1989 emissions baseline. The proposal covers 35 aerosol coating categories. The proposal has several key institutional characteristics that will influence rule development and implementation:

- The proposal includes new labeling and reporting requirements for aerosol coating products sold in California. The reporting requirements are extensive and, as currently drafted, would require disclosure of product research, development and demonstration (RD&D) information that may be considered proprietary by manufacturers.

- CARB is required by state law to hold hearings prior to 1999 to determine the technical and economic feasibility of the 1999 VOC content requirements. If found infeasible, the compliance date may be extended by up to five years.

- CARB is considering amending the Alternative Control Plan (ACP) for consumer products to include aerosol coating products.* The ACP would allow aerosol coating manufacturers more flexibility in reformulating their products, and would also enable them to trade emission credits.

*The purpose of the ACP is to provide a compliance alternative to industries that will be subject to consumer product VOC emission reduction regulations. It will establish a tradeable quota-based system that caps total VOC emissions for a set of product categories but leaves industry free to determine the most cost-effective approach to meeting the emissions reduction target.

Table Four shows CARB's direct cost estimates for the proposed 1996 interim VOC content standards.[56] Estimates of potential emission reductions and total costs range between $9.0 million and $14.8 million annually, as shown in Table Four. These cost increases would likely be passed through to product prices, raising unit production costs by between $0.34 - $0.38. **Neither CARB nor the private sector has developed cost estimates associated with the 1999 proposed standards--the technology necessary to achieve these standards does not yet exist.**[57]

Table Four

Preliminary Draft Estimated Direct Costs of Proposed 1996 VOC Content Standard for Aerosol Products

	Low Cost	High Cost
Estimated Baseline VOC Emission (TPY)	6,700	11,000
Emissions Reduction Factor	16%	16%
Emissions Reduction (TPY)	1,072	1,760
Cost per Ton	$8,400	$8,400
Total Annual Cost ($Millions)	$9	$14.8

CARB staff have not completed an assessment of potential industry-level employment and income changes resulting from the proposed VOC content standards. However, an earlier analysis that addressed potential industry costs associated with the most likely VOC emission reduction strategies for aerosol paints did not anticipate significant employment or income impacts for the following reasons:[58]

- Because aerosol paints are a small fraction of the total paint market, the small demand reductions anticipated for aerosol coating products are not expected to result in significant employment effects for industries supplying pigments, solvents, and other inputs to aerosol coating product manufacturers (see below).

- Similarly, because aerosol paints are a very small fraction of retail sales of household and hardware products, small demand reductions for aerosol paints are not expected to result in significant employment effects for the transportation, wholesale, distribution, and retail sectors.

CARB's cost estimates rely on several key assumptions, as follows:

- *Assumption 1: Products reformulated to comply with 1996 interim standards will only be sold in California.* This assumption is based on industry responses to CARB inquiries. Based on this information it appears that the most likely marketing outcome from the proposal is where "California-only" products are manufactured, inventoried, and distributed for sale in state. This scenario results in higher per unit costs than would be the case with national distribution, since it necessitates special product inventory and tracking, and spreads RD&D and capital costs over fewer units of production. For example, because of the California-only assumption the estimated cost of the 1996 interim standards for aerosol coating products on a dollar per ton basis may be as much as four times greater than that estimated for Phase I and Phase II consumer product regulations. If distribution of reformulated products were to extend to the national level, CARB estimates that per ton VOC reduction costs for aerosol coating products would be equivalent to or less than those for Phase I and Phase II consumer product regulations.

- *Assumption 2: Cost data collected through industry surveys are representative of the industry as a whole.* It is important to note that the CARB industry survey did not employ random sampling methods, and as a result cost estimates may be significantly biased. For example, the sample proportion of firms may not correspond to their population proportion, in which case the sample may under- or over-state costs for the industry as a whole, depending on whether this group of producers was under- or oversampled relative to their population proportion.

- *Assumption 3: Product sales will remain constant, neither decreasing due to high price nor increasing due to growth.* CARB's zero demand elasticity assumption is extreme, and would not likely be verified empirically.* If higher product prices and lower demand were to result from the VOC content requirements, the CARB methodology would produce inaccurate emission reduction and cost-effectiveness estimates. For example, if demand were to decline by 1 percent because of higher prices, CARB estimates would understate emission reductions by 5 percent and overstate the cost per ton by slightly more than 5 percent. Demand reductions may require less stringent VOC content standards, since some of the emission reduction goal would be achieved through reduced sales. This potential source of emission reduction was not evaluated in the CARB cost analysis.

5.3 Pesticides

The Department of Pesticide Regulation (DPR) is responsible for SIP proposals related to agricultural and commercial pesticide use and related VOC emissions. The proposal's goal is to reduce VOC emissions from agricultural and commercial pesticide use by 20 percent. Pesticide product registrants are required to submit VOC emission factor data for their products. These data will be combined with DPR use data to estimate product-specific and aggregate VOC emissions. Initial reduction efforts will focus on voluntary and ongoing programs to reduce pesticide use; switch to more environmentally benign pest control methods; and reduce the VOC emission content of existing products.

*For example, industry and retail surveys by CARB suggest that higher costs associated with BAAQMD VOC content standards for aerosol coating products were partially absorbed by manufacturers and retailers to keep shelf prices down.

If voluntary measures do not succeed in reducing pesticide-related VOC emissions by at least 8 percent by 1996, increasingly stringent regulations will be implemented in each of the local air districts. Reduction measures are likely to consist of a more aggressive application of voluntary efforts coupled with pesticide use prohibitions. Pesticides targeted for prohibition could be retained if they are considered to be irreplaceable.

The built-in flexibility of the pesticide proposal makes it impossible to determine its economic implications at this time. However, the proposal is likely to have several broad impacts, as follows:

- Given the existing paucity of information on pesticide-related VOCs, unless adequate time and resources are invested in developing a comprehensive understanding of the level and characteristics of these emissions, costly environmental and economic mistakes could be made. For example, integrated pest management (IPM) strategies frequently rely on a number of different chemical interventions. If a pesticide which is an integral component of a particular management approach is eliminated from the market, greater amounts of alternative pesticides may be needed to protect against decreases in crop yields.

- VOC emission restrictions will most likely have the largest impacts on petroleum-based pesticide products. These consist predominately of insecticides. For example, oils are a key component of scale control programs for oranges, especially as part of IPM programs and organic operations.[59] Given current use patterns, the most significantly affected pesticides may be those used for tree crops in Northern California.

- Any dislocation associated with the pesticide proposals will occur in one or more of the following counties: Imperial, Fresno, Kern, Tulare, Riverside, San Joaquin, Stanislaus, Ventura, Kings, and Merced. Agriculture accounts for at least one out of every five jobs in these counties, with over half of the jobs in Merced and Stanislaus counties related to food production and distribution.[60]

- It is important to note that VOC-induced reductions in useful pesticides could result in more intensive farm management requirements, including the use of more sophisticated information, trained labor, management skills, and farm equipment. More intensive use of the latter would have concomitant emission implications (e.g., diesel exhaust and particulate matter--PM10).[61]

Pesticide-related SIP impacts would almost certainly be significantly less than potential FIP impacts. This is because the FIP focuses on VOC *content*, while the SIP focuses on VOC *emissions*, and provides for greater flexibility related to methods of achieving the required reductions.

6.0 Selected Local District Air Quality Management Plans

While most districts submitted plans for CARB approval as part of the SIP, the most significant economic impacts are most likely to be in a selected set of regions, particularly those targetted by the U.S. EPA in the FIP: Sacramento Area, South Coast Air Quality Management District, and Ventura County Air Quality Management District, plus the San Joaquin Unified Air Pollution Control District. In general, the analyses contained in Section Six rely largely on cost estimates supplied by the districts, rather than a presentation of independently derived forecasts.

6.1 Sacramento Area Proposed Regional Ozone Attainment Plan

The Sacramento Area consists of the El Dorado County Air Pollution Control District, Feather River Air Quality Management District, Placer County Air Pollution Control District, Sacramento Metropolitan Air Quality Management District, and Yolo-Solano Air Quality Management District. In October the Area Plan included proposals to achieve reductions in NOx and reactive organic gases (ROG) emissions from the general sources that follow.[62] However, it is important to note that the Sacramento Area proposals were not finalized--and appeared to be changing rapidly--at the time of this analysis. Key potential measures proposed at the time of this analysis include the following:

- Mobile NOx sources, including interaction with CARB proposals--5 tons per day (TPD).

- Stationary and area measures--7 TPDs of NOx, 19 TPDs of ROG.

- Transportation control measures and land use policies--1 TPD of NOx and ROG.

- Community bank--1 TPD of NOx and ROG.

Sacramento Area Plan proposals are displayed in Table Five, with key elements including the following:[63]

- For on-road heavy-duty engines, a program to remove or retrofit to 5 g/bhp-hr NOx levels any pre-1991 model year engines operating in the nonattainment area; as well as a program to encourage accelerated turnover of the HDV fleet through subsidies and incentives. This latter program would be funded by a motor vehicle fee.*

- For non-road heavy-duty engines, the programs proposed for on-road engines would be adopted, financed through local fees. In addition, non-road leasing and engine companies would be required to concentrate their new, cleaner engines in the Sacramento area.

- Stationary and area source measures principally target coatings and solvents, stationary combustion sources, petroleum operations, refueling and fugitive emissions, and miscellaneous sources, including restaurants, bakeries, waste-related emissions, soil remediation, and waste burning. Many of these measures have previously been adopted in one or more of the Sacramento Area districts.

Insufficient information is available to develop a comprehensive economic impact assessment for the Sacramento Area proposals. However, relative to the SIP measures, the Sacramento proposals are unlikely to have a significant impact on the California economy. Based on existing information the proposals could have the following impacts:[64]

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*Although not part of the existing plan, the Sacramento Area is also considering a proposal to require 2.0 gram HDV engines for all new vehicles operating in certain fleets starting in 1996.

Table Five

Proposed Sacramento Area Control Measures

	Reductions in 2005 (TPD)	
Measure	**ROG**	**NOx**
Adhesives	1.5	--
Architecutural Coatings	2.7	--
Auto Refinishing	3.4	--
Boilers & Steam Generators	--	1.0
Fugitive Emissions	1.5	--
Gas Turbines	--	0.3
Graphics Arts	0.5	--
IC Engines-Stationary	--	0.5
Landfill Gas	1.3	--
Mobile Measures	--	5.0
Pleasure Craft Coatings	0.2	--
Pleasure Craft Refueling	0.2	--
Polyester Resin Operations	0.2	--
Semiconductor Manufacturing	0.2	--
SOCMI Distillation & Reactors	1.7	--
Surface Prep & Cleanup	4.9	--
Underground Storage Tanks	0.2	--
Wood Products Coatings	0.5	--
Total Reductions-2005	19.0	6.8

- Although cost data are unavailable, the incentives or subsidies necessary to encourage rapid turnover of heavy duty engines may require significant fees. The impact of the fees would depend on their size--how much--and incidence--who pays. Given the ability of truck owner/operators to relocate out-of-the-region (e.g., to Reno, Nevada), any significant cost increases could act to dampen economic activity within the area.

- The "low-emission enrichment program"--which would provide incentives for manufacturers to sell their most advanced low-emission technology in the Sacramento area--may provide Sacramento with a low-cost means of harnessing available low-emission technologies as early as possible. However, the efficacy of this program would depend on the quantity of equipment demanded in each sub-market--some off-road is used only rarely. To the extent that a particular equipment group is used infrequently, Sacramento may be competing with other non-attainment areas within and outside of California for low-emission vehicles.

- Over 90 percent of firms engaged in architectural coatings maintain less than 100 employees. As a result, the architectural coating proposal could adversely affect small firms, particularly painting contractors.

- Two firms could face substantial economic costs as a result of the adhesives and sealants and automotive refinishing proposals.

- Two firms could be significantly affected by the boiler and steam generator proposal.

6.2 San Joaquin Valley Unified Air Pollution Control District (SJVAPCD)

Although SJVAPCD proposals are not expected to induce statewide economic impacts, measures which have the potential to engender the most significant local costs are related to the Valley's petroleum sector. Table Six lists the key air emission control measures affecting the SJV petroleum industry--the sector most likely to be impacted by SIP requirements--including estimated VOC and NOx reductions and cost-effectiveness.

Table Six

SJVUAPCD Measures Related to the Petroleum Sector

#	Measure	Date	1999 VOC Reductions (TPD)	1999 NOx Reductions (TPD)	Estimated Compliance Costs ($/TPD)*
4306	Sm. Boil./Steam/Proc. Htr.	1999		7.60	N/A
4411	Oil Well Cellars	1998	0.56		$10,000
4412	Drill/Workover Rigs	1998		0.87	$14,000
4621	Gas Transfer Stationary Tanks	1998	0.41		$400-$16,000
4622	Gas Transfer Vehicle Tanks	1998	0.41		$400- $16,000
4623	Store Organic Liq.	1996	3.00		$900-$2,100
4662	Org. Solv. Degrease	1998	2.44		NA
4663	Org. Solv. Waste	1998	0.19		NA
4702	Stationary IC Engines	1999		12.44	NA

*To determine the constant annual payment on capital costs associated with these measures a 10 percent cost of capital or interest rate, zero inflation, and a 15 year useful life were assumed. This results in a capital recovery factor of 13 percent per year on investment costs.

Key proposals are as follows:

- *4306 Smaller Boilers, Steam Generators, Steam Process Heaters*: sources affected by this proposal include gaseous or liquid fuel boilers, steam generators and, or process heaters with rated capacities of less than 5 MMBTU/hour. The proposal would result in total costs of between $14 to $24 million.* However, these costs include investments related to a previously adopted large boiler rule (4305).

- *4411 Oil Well Cellars*: would require all wells with cellars to be lined with an impervious layer, and that cellars be evacuated of oil residues. Assuming a capital cost of $1,000 for lining the cellar and that the cellars are evacuated twice per year at a cost of $50, the total annualized cost associated with this proposal is estimate to be $180 per well, or $2 million annually.** It should be noted that the wells which have cellars tend to be older, and may be near their economic limits (i.e., lining expenditures might not be considered worthwhile for these marginal wells).

- *4412 Drill/Workover Rigs*: drilling and workover (servicing) rigs currently employ diesel engines in the 850 horsepower range. This rule would reduce NOx emissions by requiring rigs to be replaced with either cleaner burning diesel engines or electric

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*According to CARB, 1991 (page 7-27) the capital costs associated with converting a radiant boiler in the 5 to 10 MMBTU/hour range is $25,000 to $30,000 per unit. Jernigan estimates a cost of $20,000 per unit. This annualizes at $2,600 per year. The total number of units affected by both 4305 and 4306 are 700 to 800.

**CARB 1991 estimates indicate that there are about 11,000 well cellars in the SJV.

motors.* Electrification costs would fall most heavily on remote well sites--West Valley sites which are predominately smaller wells.

- *4621 Gasoline Transfer to Stationary Tanks/4622 Gasoline Transfer to Vehicle Fuel Tanks*: This proposal--which covers smaller tanks in the 250 to 2,000 gallon range--seeks to reduce VOC emissions by recovering vapors from transfer operations.** The rule would be implemented in two phases. The first phase requires a simple device (i.e., a well cellar) costing about $2,300.*** Assuming that the smaller tanks thus controlled have a throughput of 20,000 gallon per year, Phase I controls would have a cost effectiveness of $423 per ton of ROG reduced. At a lower throughput of 5,000 gallons per year cost effectiveness would be $1,700 per ton. The Phase II rule would require vacuum assisted devices at a cost of $3,200 to $6,400 per tank on existing stations, with a cost effectiveness of $4,200 per ton for 20,000 gallon throughputs and $16,000 per ton for 5,000 gallon per year throughputs. As larger facilities have already complied with similar rules, the burden of this proposal would chiefly fall on smaller independent operators.

- *4623 Storage of Organic Liquids*: this proposal would apply mainly to tanks storing the heavy petroleum produced in the area. The proposal would lower VOC emissions by requiring floating roofs on tanks and vapor recovery systems to reduce

*According to CARB, 1991, there are 518 servicing rigs working 5 days per week in the Valley. These rigs would have to be repowered. Electrical distribution systems would have to be upgraded at many well sites in order to supply high power electric motors. CARB 1991 estimates a cost effectiveness of $14,000 per ton of NOx reduced for the measure.

**Tanks above 2000 gallons are already covered by a previous rule.

***CARB, 1991 converted to 1993$.

and remove volatile gasses. The measure would induce a levelized cost of between $1 and $2.3 million annually.*

6.2.1 Economic Impacts of SJVAPCD's Attainment Plan

In 1991 Kern County oil and gas production generated more than 13,000 full-time jobs and a payroll of approximately $500 million. After consideration of indirect and induced effects of this employment on the regional economy, it is estimated that more than 30,000 jobs and a payroll of $1 billion is associated with Kern County petroleum production.[65] This region is dominated by thermally-enhanced oil recovery (TEOR) production where steam is injected to heat and force petroleum to the wells. This method is high cost, and the Kern County fields are generally marginally profitable in the world oil market (i.e., lower prices or higher costs may lead to the closing of many wells). For example, the number of operational wells shrunk dramatically in 1986 when world oil prices collapsed.

Rough estimates of the very small independent producers on the west side of the Valley--primarily the Midway-Sunset Field--indicate that there are approximately 1,300 wells which are marginally economic at current prices. These wells, and their associated production and employment, are at risk of abandonment if additional environmental compliance costs cause them to reach their economic limits. However, while inducing some localized effects, these impacts are unlikely to have significant statewide implications.

*According to Western States Petroleum Association (WSPA) there are between 800 and 900 tanks to which this rule would apply. At a capital cost of $10,000 to $20,000, the proposal would have a capital cost of between $8 and $18 million.

6.3 South Coast Air Quality Management Plan

Table Seven displays the South Coast Air Quality Management District's SIP-related proposals, and Figure One shows the range of their relative cost-effectiveness. As with other SIP components, the costs associated with South Coast's proposals consist of two primary elements: the direct, technological and demand-side costs associated with the measures, and the economic impacts resulting from these costs.

Radian Corporation* analyzed thirty District measures accounting for over 90 percent of the total average annual stationary costs estimated by the District.** Table Eight lists the assumptions used in analyzing each measure. Table Nine shows a ranking of District stationary control measures by total annual cost, as well as ranges of uncertainty for those estimates. Although South Coast has based its estimates on standard engineering-cost methodology, substantial uncertainties are associated with any proposal where costs are based on innovative and unproven technology. *Based on a review of the District's proposals, cost uncertainty could act to increase or decrease existing stationary source cost estimates by 50 percent or more*. Figure One shows how the costs for these measures rise with increasing emission reductions, and the range of uncertainty around these estimates--a range that increases with cost.

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*This analysis was conducted by Radian Corporation as a subcontractor to M.Cubed.

**The first three stationary source control measures -- architectural coatings (CTS-07), restaurant operations (PRC-03), and metal surface coating (CTS-H) -- alone account for approximately 80 percent of total stationary source costs.

Table Seven

SCAQMD Proposed Control Measures

Measures	**Reductions in 2010 (TPD)** ROG	NOx
Advanced Technologies (Unspecified)	66.97	--
Ozone Depleting Compound Adjustment	-16.47	--
Stationary ICEs	7.1	3.6
Clean Stationary Fuels	4.09	1.56
VOC RECLAIM	49.9	--
Solvents & Coatings--Non-RECLAIM Area Sources	65.55	--
Solvents & Coatings--Non-RECLAIM Point Sources	27.28	--
Advance Technology-CTS (Long Term)	54.69	--
Advance Technology-CTS (Mid Term)	23.88	--
Further Reductions--Architectual Coatings	62.26	--
Further Reductions--Perc. Dry Cleaning	2.99	--
Organic Liquid Transfer	4.98	--
Active Draining of Liquid Products	4.76	--
Further Reduction--Fugitive Emissions	0.75	--
Advance Technology--Fugitive Emissions	23.11	--
Refueling--Mobile, utility, pleasure boats	6.52	--
SIP Amendments--Miscellaneous Sources	0.05	--
Livestock Waste	10.07	--
Waste Burning	0.06	--
VOC Disposal (FIP: 40 CFR 52.2954)	2.37	--
Indirect Sources	5.32	9.16
TCMs 1-4-Regulated Mobile Adjustments	22.26	27.67
Total Reductions in 2010	**453.34**	**41.99**

Table Eight
SCAQMD Cost Effectiveness Estimates and Assumptions for Stationary Source Control Measures

RULE NUMBER	RULE DESCRIPTION	POLLUTANT	CAP COSTS ($1,000)	OP & MAINT ($1,000)	LIFETIME (YEARS)	OPS./YR (DAYS)	REDUCTIONS (TONS/DAY)	AQMP CE ($/TON)
CTS-05	Perchloroethylene Dry Cleaning Operations						2.3	$4,800
	ATCM	VOC	$37,200	$900	15	250		
	Other 94 AQMP requirements beyond ATCM	VOC	$300	$0	16 (a)	250		
CTS-07	Architechtural Coatings	VOC		$311,500 (b)	16	250	53.2	$16,500
FUG-01	Organic Liquid Transfer	VOC	$6,600	$700	16	365	4.3	$600
FUG-02	Active Draining	VOC	$27,000	$0	10	250	3.8	$2,800
RFL-01	Utility Engine Refueling Operations	VOC	$6,600	$0	10	365	0.1	$30,000
RFL-02	Gasoline Dispensing Facilities							$200
	A-B-5	VOC	$4,800	$0	10	365	5.3	$300
	A-B-2	VOC		$0		365	0.3	$100
RFL-03	Pleasure Boat Fueling Operations	VOC	$500	$0	10	365	0.8	$300
CMB-05	Clean Stationary Fuels	VOC, NOx	$42,000	$27,000	10	250	28.6	$3,500
PRC-02	Bakeries	VOC	$8,300	$500	10	250	0.5	$9,200
PRC-03	Restaurant Operations							$2,800
	Electrostatic precipitator	VOC	$12 (c)	$2 (c)	10	NA (d)	6.2 (c)	$4,400
	Catalyst	VOC	$5 (c)	$1 (c)	5	NA	7.2 (c)	$1,300
	Carbon Adsorption	VOC	$2 (c)	$1 (c)	10	NA		$31,300
WST-01	Livestock Waste	VOC	$77,500	$10,100	16	365	23.2	$1,400
CTS-A	Electronic Components Manufacturing	VOC	$1,500	$43	10	250	1.1	$700
CTS-B	Petroleum Cold Cleaning	VOC	$0	$5,700 (b)	16	250	1.7	$9,400
CTS-C	Solvent Cleaning Operations	VOC	$0	$7,000 (b)	16	250	1.5	$13,000
CTS-D	Marine and Pleasure Craft Coating Operation	VOC	$0	$900 (b)	16	250	0.1	$51,000
CTS-E	Adhesives	VOC	$0	$200 (e)	16	250	0.1	$7,200
CTS-F	Motor Vehicle and Mobile Equipment Refinishing	VOC	$0	$8,300 (f)	16	260	0.7	$31,100
CTS-G	Paper, Fabric, and Film Coating Operations	VOC	$0	$300 (e)	16	250	6.1	$100
CTS-H	Coating of Metal Parts and Products	VOC	$0	$66,400 (b)	16	250	17.1	$10,700
CTS-I	Graphic Arts	VOC	$0	$2,700 (b)	16	250	0.7	$10,700
CTS-J	Wood Products	VOC	$0	$6,100 (f)	16	250	2.0	$8,400
CTS-K	Aerospace Coating	VOC	$0	$5,000 (g)	16	250	2.3	$6,100
CMB-A	Miscellaneous Combustion Sources	NOx	$81,600	($8,600)	10	250	0.7	$6,100
CMB-B	Small Boilers and Process Heaters	VOC	$149,400	($15,200)	10	260	0.3	$36,500
CMB-C	Curing and Drying Ovens	NOx	$35,300	$0	10	260	0.9	$16,000
CMB-D	Afterburners	VOC	$61,200	($5,600)	10	365	0.9	$5,700
CMB-F	Internal Combustion Engines	NOx	$6,200	$3,100	4	250	9.7	$1,700

a 16 years is the number of years to the attainment year 2010
b Assumed $4/gallon increased cost of coating
c Per unit cost and emission reduction estimate
d NA - Not used in estimating control effectiveness
e Assumed $2/gallon increased cost of coating
f Assumed $8/gallon increased cost of coating
g Assumed $20/gallon increased cost of coating

Table Nine Ranking of SCAQMD Stationary Source Control Measures by Total Cost								
MEASURE	DESCRIPTION	REDUCTIONS (TONS/DAY) VOC	NOx	CE ($/TON)	ANNUAL COST ($1,000)	(%)	ASSUMED ERROR (%)	APPROXIMATE RANGE ($1,000)
CTS-07	Architectural Coatings	53.2		$16,500	$320,000	62.3%	60%	130,000 - 790,000 (a)
PRC-03	Restaurant Operations	11.8		$12,300	$53,000	10.3%	25%	40,000 - 66,000
CTS-H	Coating of Metal Surfaces and Products	10.1		$9,400	$35,000	6.8%	60%	14,000 - 56,000
CTS-I	Graphic Arts	6.2		$9,500	$21,000	4.1%	60%	8,000 - 34,000
CTS-C	Solvent Cleaning	2.9		$11,400	$12,100	2.4%	60%	5,000 - 19,000
CMB-05	Phase Out of Fuel Oil	4.3	3.1	$3,500	$9,500	1.8%		
CTS-J	Wood Products Coating	1.6		$15,200	$8,900	1.7%	60%	4,000 - 14,000
CTS-F	Motor Vehicle Coatings	1.0		$20,400	$7,400	1.4%	60%	3,000 - 12,000
CTS-B	Cold Solvent Cleaning	26.1		$600	$5,700	1.1%	60%	2,000 - 9,000
CMB-C	Curing & Drying Ovens		2.9	$4,800	$5,100	1.0%	60%	2,000 - 8,000
WST-01	Livestock Waste	10.1		$1,400	$5,100	1.0%		
CTS-05	Perchloroethylene Dry Cleaners	2.3		$4,800	$4,000	0.8%		
FUG-02	Aerospace Coatings	3.8		$2,800	$3,900	0.8%		
CTS-K	Drain Systems	2.1		$5,100	$3,900	0.8%	60%	2,000 - 6,000
CMB-D	Afterburners	0.9		$11,300	$3,700	0.7%		
CMB-B	Small Boilers and Process Heaters	6.1		$1,600	$3,600	0.7%		
CMB-A	Miscellaneous Combustion Sources		6.2	$1,400	$3,200	0.6%		
CMB-F	Internal Combustion Engines	4.8	1.4	$1,100	$2,500	0.5%		
RFL-02	Gasoline Dispensing Facilities	5.6		$900	$1,800	0.4%		
PRC-02	Bakeries	0.5		$9,200	$1,700	0.3%		
RFL-01	Utility Equipment Refueling	0.1		$30,000	$1,100	0.2%		
FUG-01	Organic Liquid Transfer	4.3		$600	$940	0.2%		
CTS-D	Marine & Pleasure Craft Coating	1.3		$1,500	$710	0.1%	60%	300 - 1,000
CTS-A	Electronic Components Manufacturing	0.9		$600	$200	0.04%	60%	100 - 300
CTS-E	Adhesives	20.1		$20	$150	0.03%	60%	100 - 200
RFL-03	Pleasure Boat Refueling	0.8		$300	$88	0.02%		
CTS-G	Paper, Fabric, and Film	2.1		$100	$77	0.01%	60%	0 - 100
TOTAL		183.0	13.6		$514,000	100%		

TPD - tons per day

a Upper limit includes a 1.55 growth factor for architectural coatings from 1988 to 2010 at a 2% growth rate.

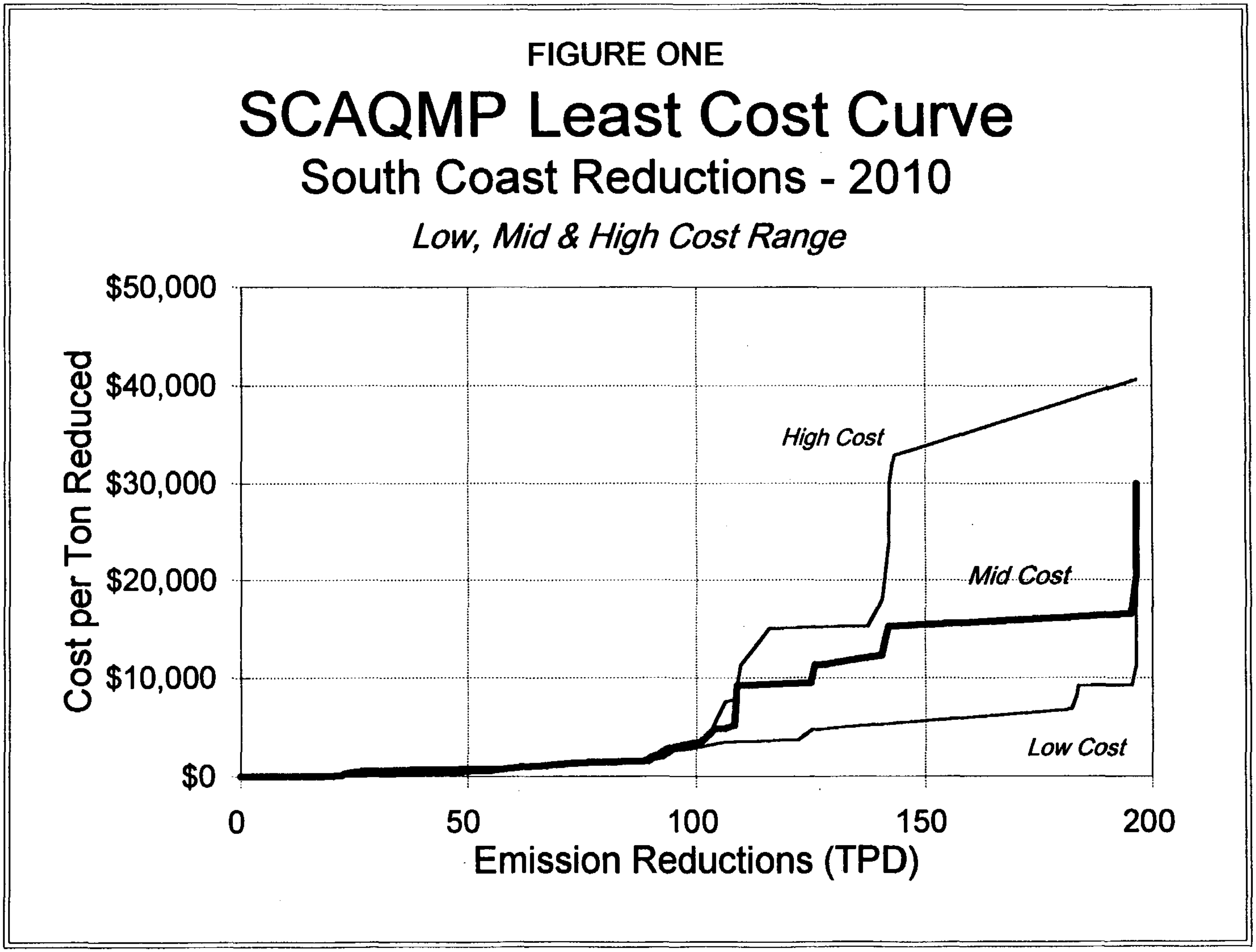


FIGURE ONE
SCAQMP Least Cost Curve
South Coast Reductions - 2010
Low, Mid & High Cost Range
Cost per Ton Reduced
$50,000
$40,000
$30,000
$20,000
$10,000
$0
High Cost
Mid Cost
Low Cost
0
50
100
150
200
Emission Reductions (TPD)

The uncertainty indicated in the table does not incorporate the possible impacts related to the paint market itself. The District based its architectural coatings cost estimates on the number of gallons of coating sold in 1988. However, costs are more accurately based on the number of gallons of coating to be sold in 2010. Assuming a nominal sales growth rate of 2 percent, the estimated cost of the coating proposal could be 55 percent higher than the AQMP's forecast. If compliance coatings are less durable than existing products, the frequency of repainting--and resulting proposal costs--would increase even faster.

6.3.1 Economic Impacts in SCAB

Insufficient resources were available to develop a separate analysis of the potential economic impacts of South Coast's Plan. However, the District estimates that approximately \$5.6 billion in quantifiable average annual benefits will be generated from its 1994 air quality measures between 1994 and the year 2000.* Between \$0.6 and \$1.3 billion in additional benefits may be engendered by "unquantified" measures.[66]

The District's benefit estimates raise several issues, as follows:

- The benefits estimates have been subjected to significant critiques by other analysts. In this respect these estimates should generally be used with some understanding of their overall weaknesses.

- Only a portion of South Coast's benefit estimate--less than half--can be attributed to achieving federal ozone (SIP) standards. For example, the great majority of the estimated health care benefits are derived from reductions in PM10 emissions. In addition, the benefits associated with reduced traffic congestion appear to be highly uncertain, particularly to the extent that the Plan relies on new vehicle technology

*Unless otherwise stated the District's numbers are in 1990 dollars.

to meets its air quality goals.* This is an important area of uncertainty, since more than a third of the new jobs the District estimates will be created by quantified measures are related to congestion relief.

- The REMI model as reconfigured for the District's use treats air quality benefits--such as improved visibility or reductions in congestion--as an "amenity" improvement which can attract additional population and economic activity to the District. This is a somewhat controversial aspect of the model. Although, for example, reductions in automobile operating and maintenance costs would result in real cost savings to South Coast residents, it seems unlikely that at the margin such a change would induce more migration into the area, particularly in the short-term. If the District's proposals succeed in returning Southern California's air quality to the 1940s, then a resurgence of the 1960s inward migration may be plausible. This is a long-term prospect at best, however, and is probably not an apt assumption during the forecast period.**

*To the extent that new technology vehicles have lower operating costs congestion could potentially increase. For example, little congestion benefit will accrue if gasoline-powered vehicles are simply replaced by alternative-fueled cars.

**Likewise, the District estimates that real disposable income in the region would be reduced by approximately $0.3 billion in 1994, and would be approximately $5.6 billion lower in 2010 than it would have otherwise been without Plan implementation. It is important to note that the District appears to indicate that increases in regional population stemming from air quality improvements will significantly outpace the net dollar benefits associated with the Plan.

The District's treatment of population flows -- which are generally based on Southern California Association of Governments (SCAG) estimates -- seems incomplete. In the near future population in-flow into the area would most likely be related to low-wage employment, while population outflow will be related to higher-paying jobs. Given this pattern in the short-term air quality improvements would seem to have a greater impact on retaining high-wage jobs than in attracting new ones.

The District estimates that the Plan will induce approximately $5.4 billion in direct costs. This translates into per capita control costs of approximately $365.[67] The District considers approximately $2 billion of these costs to be based on "quantifiable" analysis, with an additional $3.4 billion based on unquantified measures--in other words, a significant portion of potential costs are based on inadequate information. As a result, actual expenditures could be higher or lower.* Some of these costs are related to non-SIP or statewide proposals, and as a result should not be "scored" to the SIP. In the case of both benefits and costs the District's year 2000 estimates are in the $4 billion a year range, growing to $10 billion annually or more by the year 2010.

South Coast's cost estimates similarly raise a number of issues, as follows:

- Should the uncertainty issues and potential calculation errors related to the District's engineering cost estimates ultimately result in higher costs than estimated (see above), quantified costs alone could have been underestimated by $500 million. This in turn would impact the estimated average cost of the quantified measures, and act to increase economic impacts.

- South Coast appears to claim emission credit for transportation improvements (TCM-01), telecommunications (ATT-01), advanced shuttle transit (ATT-02), and alternative fuel vehicles/infrastructure (ATT-04), while only including the costs associated with transportation improvements ($1.5 billion).** Although the telecommunications proposal is estimated to generate savings of $6,990 per ton, the

*South Coast bases its unquantified measure costs on the average per ton cost associated with quantified proposals. Although obviously lacking in certainty, this seems like a reasonable assumption in the face of inadequate data.

**It is difficult to sort through District emission reduction and cost estimate documents. This finding is based on discussions with District staff members Francis Goh and Sue Lieu in the Planning Office.

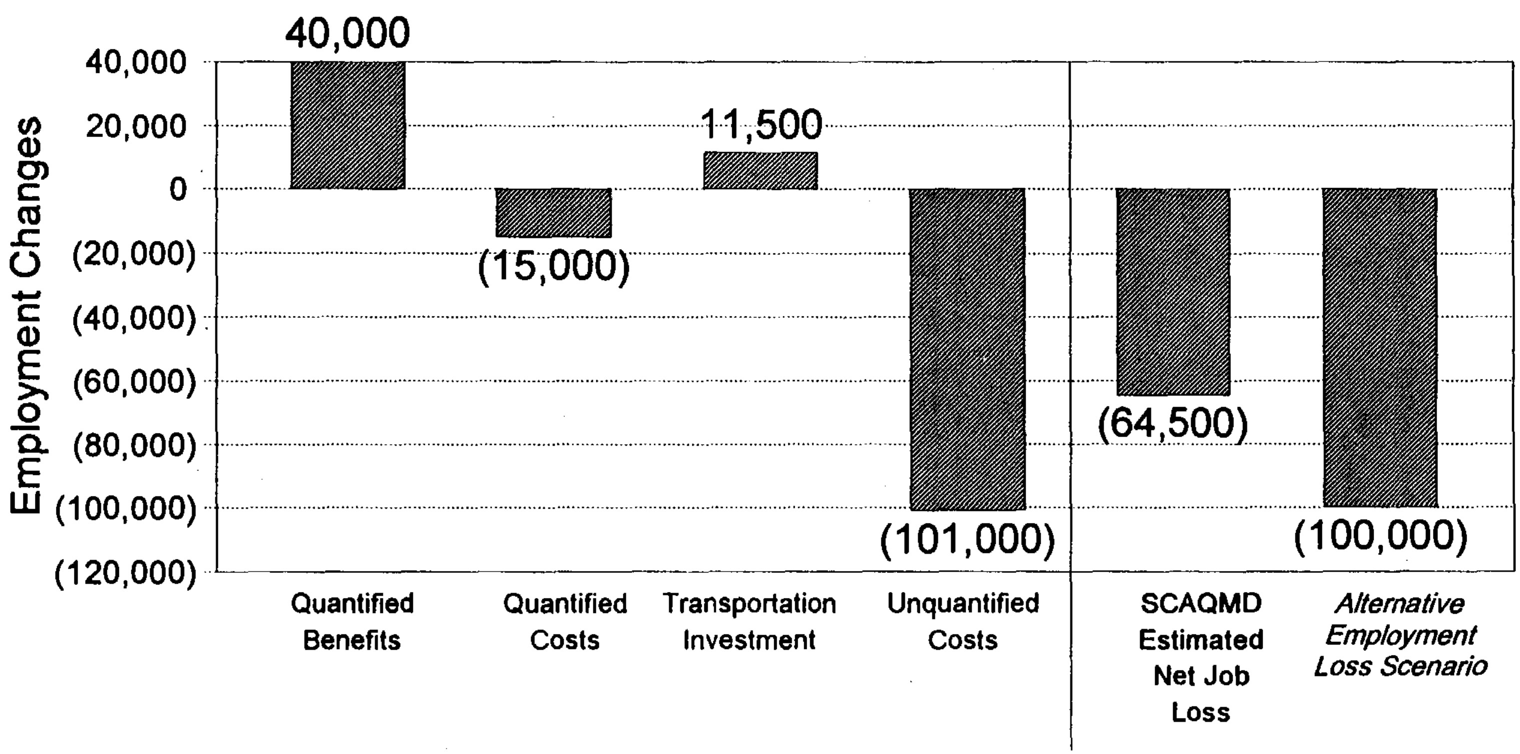
advanced shuttle transit proposal is expected to cost $147,500 per ton, and alternative fuel vehicles $32,000 per ton.[68] In other words substantial costs associated with assumed emission reductions--$280 million annually or more--may have been omitted from the District analysis.[69]

As previously indicated, $1.5 billion of the District's cost estimates is related to transportation improvements to be funded partially by federal grants, with the remainder financed through local gasoline taxes and transit fares. It is questionable whether the economic benefits and costs associated with this investment should be attributable to the AQMP, for two reasons. First, these expenditures have already been approved (i.e., are part of the baseline). Second, at an estimated cost of $956,500 per ton of NOx reduced these investments would not appear to be a cost-effective measure from an air quality perspective alone (i.e., demand for this expenditure is more likely driven by infrastructure and congestion reduction needs).[70]

- As a result of its direct benefit and cost estimates the District forecasts that there will be approximately 63,000 fewer jobs in the South Coast on average every year between 1994 and 2010 as a result of the AQMP. Significant potential job losses are offset by State of California investment related to transportation improvements. As indicated in Figure Two, a reasonable alternative scenario--based on excluding the transportation improvement measure and reducing the estimated job benefits somewhat--might show average annual employment losses closer to 100,000 between 1994 and 2010.

FIGURE TWO

SCAQMD Estimated Employment Changes in 2010



Source: SCAQMD,, M.Cubed (See text).

6.4 Ventura County Air Quality Management Plan

Table Ten displays the Ventura County Air Pollution Control Board's proposed SIP control measures. As indicated in the table, additional Board measures would in general result in modest emission reductions--principally of ROG--and as a result minimal economic disruption to the state. Although insufficient information is available to estimate potential economic impacts, Ventura County proposals which may have short-term adverse impacts on the local economy include the following:

- Additional penetration of LEV's into public and private sector vehicle fleets--beyond SIP proposals--may be required by the Plan. However, the Plan does not provide details on the structure or content of a county-specific LEV program, making it impossible to determine its potential impacts.

- Implementation of Best Available Retrofit Technology (BART) for gas turbines could impose $20 million or more in costs on specific public and private sector organizations, including hospitals, military bases, and petroleum facilities.[71] Although these costs are not large relative to the Ventura County economy, they could impose hardship on the affected entities.

It is important to note that the County's Plan substantially counts on emission reductions from either the SIP or the FIP. For example, the Plan depends on VOC emissions reductions related to the FIP's pesticide measure; as well as NOx emission reductions associated with diesel-powered commercial marine vessels. Should the SIP fail to achieve the necessary emission reductions, the County would have to find other means of lowering emissions, thereby imposing additional costs.

Table Ten

Proposed VCAPCD Area Control Measures

	Measure	**Reductions in 2005 (TPD)** ROG	NOx
R-105	Glycol Dehydrators	0.54	--
R-317	Clean-up Solvents	1.76	--
R-322	Painter Certification	0.53	--
R-324	Screen Painting	0.31	--
R-327	Electronic Components	0.08	--
R-403	Gasoline Dispensing	0.23	--
R-410	Marine Tanker Loading	--	--
R-419	Tank Degassing	0.02	--
R-420	Pleasure Craft Fuel Transfer	0.08	--
R-421	Utility Engine Refueling	--	--
R-424	Gasoline Transfer	0.04	--
R-425	Fugitive Emissions	2.43	--
R-608	Soil Decontamination	0.11	--
N-101	Gas Turbines	--	0.49
N-102	Small Commercial Turbines	--	0.06
	Total Reductions-2005	**6.13**	**0.55**

7.0 Estimated Economic Costs of the SIP and AQMPs

Estimates of SIP-induced direct and economic costs for the low-cost and high-cost scenarios are shown in Table Eleven. In addition, Figure Three displays the range of cost-effectiveness for the proposed SIP measures ranked from lowest to highest cost measures. As indicated in the executive summary tables, the SIP's direct costs--excluding district proposals--would range from $0.7 to $1.7 billion annually by 2010. These direct costs, in turn, would result in from 22,000 to 77,000 fewer jobs in California by the year 2010, and a reduction in expected gross state product (GSP) of between $0.8 to $4.3 billion, based on REMI model runs.

Figure Four compares the estimated costs of the SIP to the FIP and other existing public sector expenditures. As indicated in the figure, including District proposals the SIP may cost $6 billion in the year 2010, compared to potential FIP costs of $8 billion. It is important to note that the FIP cost estimates include only those federal proposals which would be implemented in the Sacramento, South Coast, and Ventura Air Basins. That is, FIP cost estimates include only a portion of the costs likely to be incurred as a result of ozone compliance measures. As a result, the FIP cost estimates almost certainly understate the total costs associated with the federal plan.

Table Eleven-A
COST OF CALIFORNIA PROPOSED SIP

Low Case

Direct Costs (Millions)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
HDV--2 Gram 2004	$55	$57	$59	$63	$67	$72	$78	$84	$92	$101	$123	$133	$144	$156	$169	$182
Medium Duty Trucks				$6	$24	$33	$31	$40	$38	$36	$35	$40	$40	$41	$42	$42
Off-Road Vehicles											$80	$120	$160	$200	$280	$343
Locomotives						$5	$10	$15	$20	$25	$30	$40	$50	$70	$80	$81
Industrial Equipment						$1	$2	$3	$4	$5	$6	$7	$8	$9	$10	$13
Pleasure Craft				$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
Aircraft									$21	$21	$21	$21	$21	$21	$21	$21
Marine Vessels				$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Consumer Products											$0	$0	$0	$0	$0	$0
Aerosol Paints		$3	$6	$9	$12	$15	$18	$21	$24	$27	$30	$33	$36	$39	$42	$46
Total Direct Costs	*$55*	*$60*	*$65*	*$82*	*$107*	*$130*	*$143*	*$167*	*$203*	*$219*	*$329*	*$398*	*$463*	*$540*	*$648*	*$732*
Employment Changes (,000)																
HDV--2 Gram 2004	-1	-1	-1	-2	-3	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4
Medium Duty Trucks					-1	-1	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2
Off-Road Vehicles											-1	-1	-3	-4	-6	-8
Locomotives							-1	-1	-2	-2	-2	-2	-3	-3	-3	-3
Industrial Equipment																
Pleasure Craft																
Aircraft						-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Marine Vessels																
Consumer Products																-1
Aerosol Paints							-1	-1	-1	-2	-2	-2	-2	-3	-3	-3
Total Employment Changes	*-1*	*-1*	*-1*	*-2*	*-4*	*-6*	*-8*	*-9*	*-10*	*-11*	*-12*	*-12*	*-15*	*-17*	*-19*	*-22*
Gross State Product (1987$)					*($135)*	*($270)*	*($270)*	*($270)*	*($270)*	*($270)*	*($270)*	*($540)*	*($540)*	*($540)*	*($675)*	*($810)*
Alternatives																
HDV--2 Gram 2004/1 Gram 2007	($60)	($60)	($60)	($60)	($60)	($60)	($60)	($60)	($60)	($80)	($80)	($80)	($80)	($80)	($80)	($155)
HDV Accelerated Turnover Program		$1	$1	$3	$4	$4	$4	$4	$4	$4	$4	$4	$4	$4	$4	$4
Employment Changes																
LDV Accelerated Turnover Program		$35	$35	$35	$75	$75	$75	$75	$75	$75	$75	$75	$75	$75	$75	$75
Employment Changes		-1	-1	-1	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3

Table Eleven-B
COST OF CALIFORNIA PROPOSED SIP

High Case

Direct Costs (Millions)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
HDV–2 Gram 2004	$185	$197	$208	$221	$238	$257	$279	$303	$329	$359	$424	$471	$517	$564	$614	$667
Medium Duty Trucks				$17	$72	$112	$126	$159	$152	$145	$142	$158	$161	$163	$166	$169
Off-Road Vehicles											$61	$104	$124	$144	$235	$379
Locomotives						$2	$8	$15	$30	$40	$50	$60	$90	$100	$110	$166
Industrial Equipment						$1	$2	$3	$4	$5	$6	$7	$8	$9	$10	$13
Pleasure Craft				$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
Aircraft									$21	$21	$21	$21	$21	$21	$21	$21
Marine Vessels				$5	$10	$17	$17	$17	$17	$17	$17	$17	$17	$17	$17	$17
Consumer Products											$368	$368	$368	$368	$368	$368
Aerosol Paints		$3	$6	$9	$12	$15	$18	$21	$24	$27	$30	$33	$36	$39	$42	$46
Total Direct Costs	*$185*	*$200*	*$214*	*$255*	*$335*	*$407*	*$453*	*$521*	*$580*	*$817*	*$1,122*	*$1,242*	*$1,345*	*$1,428*	*$1,586*	*$1,849*
Employment Changes (,000)																
HDV--2 Gram 2004	-5	-6	-7	-8	-10	-11	-12	-13	-14	-16	-18	-20	-22	-25	-26	-26
Medium Duty Trucks					-1	-2	-3	-4	-4	-5	-5	-5	-5	-6	-6	-6
Off-Road Vehicles											-2	-3	-4	-5	-6	-9
Locomotives								-1	-2	-3	-3	-3	-3	-4	-4	-4
Industrial Equipment																
Pleasure Craft																
Aircraft									-1	-1	-1	-1	-1	-1	-1	-1
Marine Vessels						-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Consumer Products											-6	-7	-7	-7	-7	-8
Aerosol Paints							-1	-1	-1	-2	-2	-2	-2	-3	-3	-3
Total Employment Changes	*-5*	*-6*	*-7*	*-8*	*-11*	*-14*	*-17*	*-20*	*-23*	*-28*	*-38*	*-42*	*-45*	*-52*	*-54*	*-58*
Gross State Product (1987$)	*($300)*	*($400)*	*($500)*	*($600)*	*($700)*	*($1,040)*	*($1,170)*	*($1,430)*	*($1,560)*	*($1,690)*	*($2,210)*	*($2,470)*	*($2,990)*	*($3,250)*	*($3,900)*	*($4,290)*
Alternatives (Millions)																
HDV--2 Gram 2004/1 Gram 2007	$21	$22	$24	$25	$27	$29	$32	$35	$37	$41	$48	$53	$58	$63	$63	$63
HDV Accelerated Turnover Program		$1	$1	$3	$4	$4	$4	$4	$4	$4	$4	$4	$4	$4	$4	$4
Employment Changes																
LDV Accelerated Turnover Program		$35	$35	$35	$75	$75	$75	$75	$75	$75	$75	$75	$75	$75	$75	$75
Employment Changes		-1	-1	-1	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3

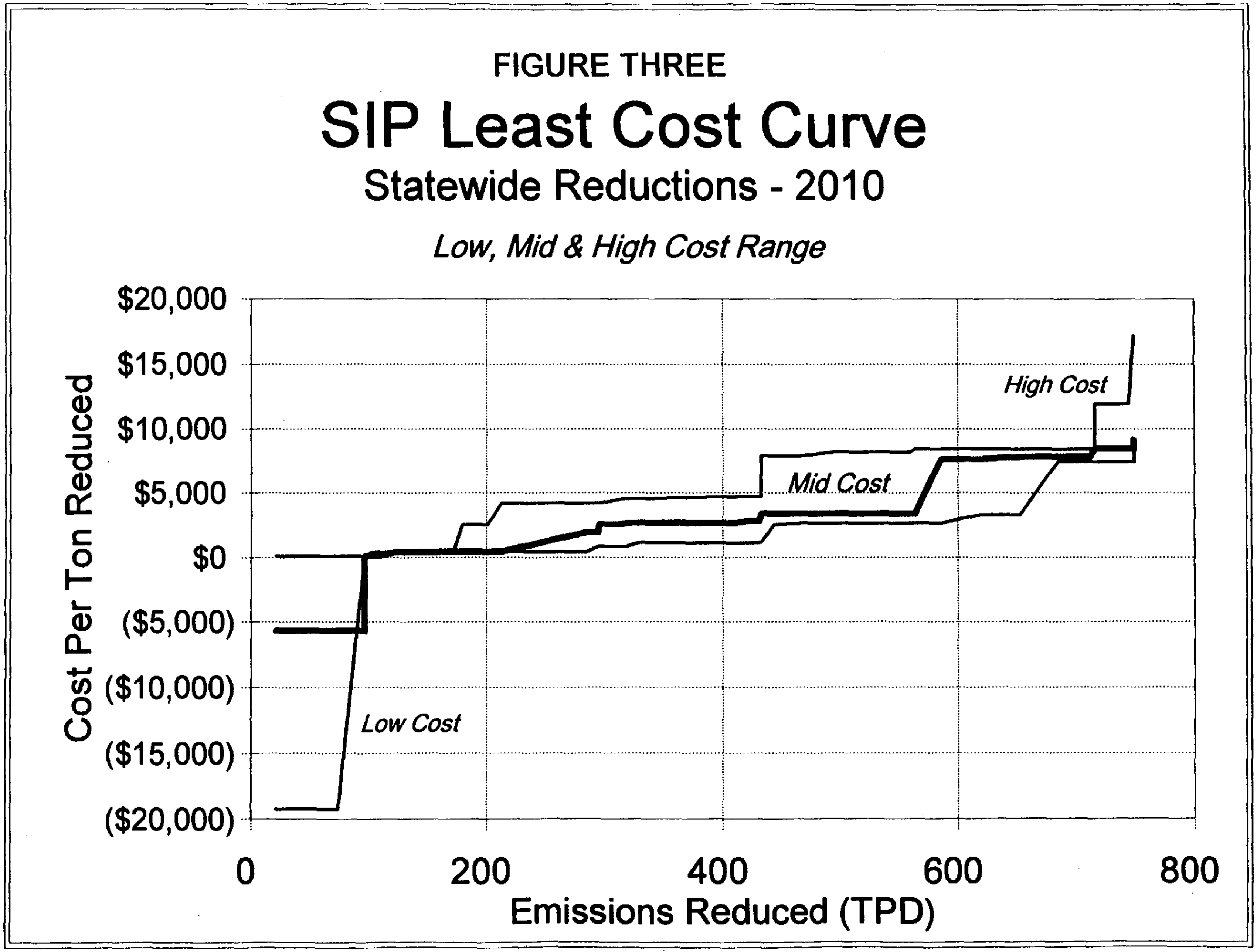
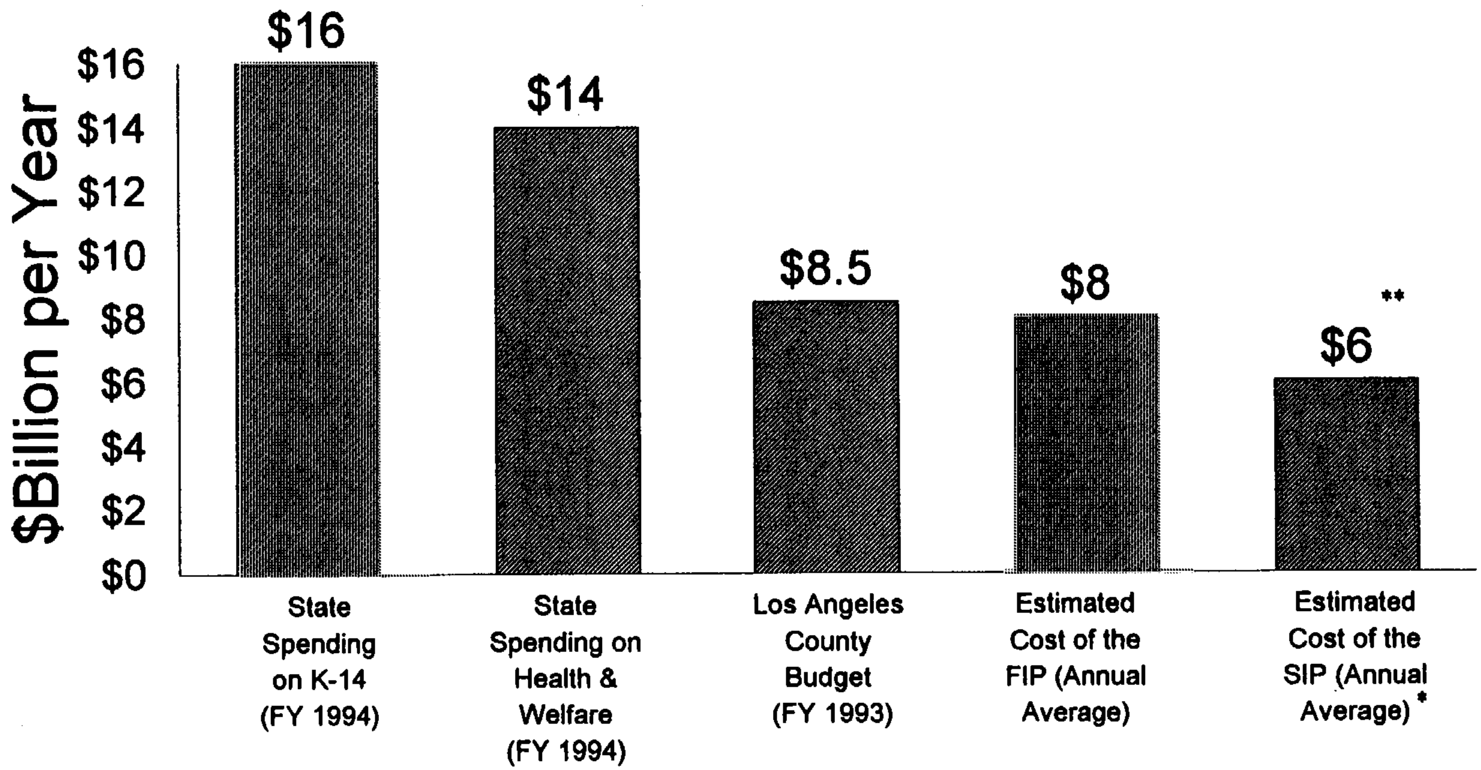


FIGURE THREE
SIP Least Cost Curve
Statewide Reductions - 2010
Low, Mid & High Cost Range
$20,000
$15,000
$10,000
$5,000
$0
($5,000)
($10,000)
($15,000)
($20,000)
Cost Per Ton Reduced
0
200
400
600
800
Emissions Reduced (TPD)
High Cost
Mid Cost
Low Cost

FIGURE FOUR

Comparisons of Annual Expenditures in California



Source: State Controller's Office, Dept. of Finance, Governor's Office of Planning and Research, SCAQMD, Air & Waste Magazine, M.Cubed (See text).

* Excludes .026 gram LDV fleet emission standard, Enhanced I&M, pesticides meausres.

** High Cost Scenario, includes selected district plans

The estimates contained herein focus on average statewide SIP impacts. The aggregated nature of this analysis may mask significant impacts on particular economic segments. For example, engine suppliers--who are almost exclusively located out-of-state--would have to cope with a myriad of technology-based measures simultaneously, necessitating significant investment in research and new product development in a short period of time. That is, the SIP would require engine manufacturers to finance the development and marketing of a large number of new products. Whether or not the necessary financing is available, and how such requirements would affect particular manufacturers, was not examined in this report.

Likewise, the SIP's cumulative impact on particular economic segments could be sizeable. For example, the agricultural sector would have to simultaneously adjust to higher transportation costs, increased production expenses associated with off-road equipment, and changes in pesticide product availability. These adjustments would take place at the same time growers are coping with reductions in surface water supplies and higher electricity prices. The transportation sector would also face both higher production costs and some demand reduction as the California economy--and specific state regions--adjust to the SIP's higher costs. These sector-specific impacts were not fully examined as part of this analysis.

7.1 Technology Gap

It is important to note that, in addition to its economic impacts, the SIP would alter existing patterns of technological innovation and penetration. As indicated in the Plan itself, "...significant [technological] advances also mean a big disparity between the cleanest equipment in-use and the dirtiest."[72] Many economic segments are dependent on the availability of highly-depreciated--and frequently higher polluting--technologies. These industries either rely on "hand-me-down" technologies from more profitable firms, or maintain equipment for the greatest possible length of time.* For example, growers tend to rely on old trucks for farm operations, both because trip lengths may be short, and also because agriculture's profit structure does not allow for constant modernization in all production areas.

7.2 Impact of Federal Adoption of National Standards

Table Twelve displays CARB's proposed national standards related to the SIP. The SIP to some extent depends on U.S. EPA adoption of these standards to ensure that required emission reductions are achieved, and to minimize California-specific economic impacts.

Table Twelve

National Advanced Technology Measures

Control Measures	Adoption Date	Implementation Date
On-Road		
Heavy-Duty Diesel Vehicles; National 2.0 g/bhp-hr NOx Standard	1997	2004
Off-Road		
Off-Road Diesel Equipment 2.5 g/bhp-hr NOx Standard	2001	2005
Industrial Equipment, Gas and LPG; Three-Way Catalyst Technology	1997	2000-2004
Pleasure Craft, National Fleet Average Standard	1995	1998
Locomotives--New and In-Use	1995	2000

*The same is true for non-technology-based inputs. For example, restaurants depend on the availability of low-wage workers; students rely on used textbooks; and rural hospitals rely on older medical equipment.

Imposition of national standards as an extension of California SIP proposals would have three key implications, as follows:

- National standards would act to "level the playing" field between the costs of doing business in California versus the rest of the nation. For example, to the extent that all new HDVs operating nationwide must feature 2.0 gram truck engines, any cost-disadvantage created by a California-only standard would be eliminated.

- National standards could potentially increase transportation and other costs throughout the nation, thereby inducing price inflation. The extent of this effect was not explored in this analysis.

- To the extent that most of the rest of the United States does not need cleaner-burning truck, off-road, and locomotive engines to maintain air quality standards, national standards may not represent the least-cost means of achieving California's air quality goals from a U.S. perspective. The use of higher cost, cleaner burning engines in areas in which reductions in polluting air emissions are not necessary would act to impose extra expenses with little net benefit to those regions. A lower cost alternative may be to transfer federal funding from the rest of the nation to California and other nonattainment areas to finance expensive, cleaner burning engines where they are needed. Alternatively, a more flexible national planning approach, in which additional emissions reductions were obtained from moderate technological improvements in engine standards (e.g., a 3.0 gram engine), combined with more aggressive local emission reduction strategies where appropriate, may provide non-attainment areas with the reductions they need at the least cost to the nation.

Endnotes

1. Philip J. Romero, et. al., *The Economic Costs of the FIP*, Governor's Office, State of California, Sacramento, California, September 1994; M.Cubed, *Estimated Impacts of the Trucking Provisions of EPA's FIPs on the California Economy*, Prepared for the California Trucking Association, San Francisco, California, July, 1994.

2. U.S. Enivornmental Protection Agency, "Federal Implementation Plans for Sacramento, Ventura, and South Coast, California," *Federal Register*, February 14, 1994.

3. Governor Pete Wilson, "Letter to the Honorable Jacqueline E. Schafer, Chair, California Air Resources Board," October 8, 1994.

4. See Moss, Steven J., et al., A Guide for Reviewing Environmental Policy Studies, California Environmental Protection Agency, Sacramento, California, 1995, for a discussion of the role of economic analysis in environmental policymaking.

5. J.V. Hall, "The Atmosphere We Breath," in California's Threatened Environment: Restoring the Dream, T. Palmer, Editor, Island Press: Washington, D.C., 1993

6. Hilary F. French, *Clearing the Air: A Global Agenda*, Worldwatch Paper 94, January 1990.

7. South Coast Air Quality Management District, *1994 Air Quality Management Plan: Meeting the Clean Air Challenge*, Final, Diamond Bar, California, September, 1994.

8. Robert D. Rowe and Lauraine G. Chestnut, "Economic Assessment of Air Pollution on Agricultural Crops in the San Joaquin Valley," Journal of the Air Pollution Control Association, 35(7), July 1985.

9. TRC Environmental Consultants, Inc., *Assessment of Material Damage and Soiling from Air Pollution in the South Coast Air Basin*, Prepared for the California Air Resources Board, December 10, 1985.

10. Jane V. Hall, et.. al., *Economic Assessment of the Health Benefits from Improvement in Air Quality in the South Coast Air Basin*, prepared for the South Coast Air Quality Management District, Fullerton, California, June 1, 1989; and David Harrison, Jr. and Albert L. Nichols, *Benefits of the 1989 Air Quality Management Plan for the South Coast Air Basin: A Reassessment*, prepared for the California Council for Environmental and Economic Balance, Cambridge, Massachusetts, March 1, 1990.

11. Hall, et.al., "Economic Assessment..." op. cit.; David Harrison, Jr. and Albert L. Nichols, op. cit.; Dimitrios A. Giannias, "Consumer Benefit from Air Quality Improvements," Applied Economics, 21:1099-1108, 1989.

12. Steven Moss, Robert Mott, and David Mitchell, *Economic Models, Manufacturing Data and the Health of the California Economy*, prepared for the California Manufacturers Association by Foster Associates, San Francisco, California, 1991.

13. Dale W. Jorgenson and Peter J. Wilcoxen, *Environmental Regulation and U.S. Economic Growth*, Rand Journal of Economics, 21(2): 314-340, Summer 1990.

14. Bank of America, "Economic Growth and the Environment," Economic and Business Outlook, June/July 1993; and Steven Moss, Richard McCann, and Robert Vergun, "*The Economic and Environmental Benefits of Increased Natural Gas RD&D Investment in Southern California*, prepared for The Gas Company by Foster Associates, San Francisco, California, October 1992.

15. CARB, *Proposed SIP*, Volume II, ES-7.

16. Committee on Geoscience, Environment and Resources, Rethinking the Ozone Problem in Urban and Regional Air Pollution, National Academy of Sciences, December 1991.

17. SCAQMD, "1994 Air Quality Management Plan," op. cit., page 3-10.

18. California Manufacturers Association/Southern California Air Quality Alliance, *Comments of the California Manufacturers Association/Southern California Air Quality Alliance on the Federal Implementation Plan*, filed in U.S. EPA Docket A-94-09, August 1994.

19. Department of Finance, *California Statistical Abstract 1995*, Sacramento, California, November 1995, Table D-1.

20. California Department of Employment and Development, California Labor Market Bulletin, Sacramento, California, August 1994.

21. See Moss, Steven, et al., *Market-Based Approaches to Achieving Air Quality Goals in California*, M.Cubed Working Paper, Prepared for Southern California Gas Company, San Francisco, California, July, 1994, for a discussion of potentially efficient methods of establishing the emission reductions associated with various air quality compliance strategies.

22. U.S. EPA, *Federal Implementation Plan*, pages 23398-9; 1990 stationary emissions from CARB, *Proposed SIP*, Volume II, pages 1-5, 1-6; Volume IV; 1990 mobile sources from *FIP* page 23397.

23. W.E. Oates, Paul R. Portney, and A. McGartland, "The Net Benefits of Incentive-Based Regulation: A Case Study of Environmental Standard Setting," American Economic Review, 79:1233-1242, 1989; Scott E. Atkinson and T.H. Tietenberg, "The

Empirical Properties of Two Classes of Designs for Transferable Permit Markets," Journal of Environmental Economics and Management 9:101-121, 1982; California Air Resources Board, *Mobile Source Emission Reduction Credits: A Concept Paper on the Generation of Emission Reduction Credits from Mobil Sources*, Sacramento, California, prepared by Stationary Source and Mobile Source Divisions, July 1992; Robert Hahn and Roger Noll, "Designing a Market for Tradeable Emissions Permits," in Reform of Environmental Regulation, ed. Wesley A. Magat, Cambridge, Massachusetts: Ballinger, 1982.

24. CARB SIP workshop, October 28, 1994.

25. El Dorado County Air Pollution Control District (APCD), Feather River Air Quality Management District (AQMD), Placer County APCD, Sacramento Metropolitan AQMD, Yolo-Solano AQMD, *Sacramento Area Proposed Regional Ozone Attainment Plan*, Revision, Sacramento, California, October 19, 1994.

26. Joan Jackson Stephens, U.S. EPA, "Memorandum," Public Docket: A-94-09, May 4, 1994.

27. M.Cubed, "Market-Based Approaches," op. cit.

28. California Air Resources Board (1994a). *The Proposed 1994 California State Implementation Plan for Ozone: The Air Resources Board's Mobile Source and Consumer Product Elements*, California Air Resources Board, Public Hearing to Consider Approval of a Revision to the California State Implementation Plan, 94-11-2, October 7. Sacramento, California.

29. California Air Resources Board (1994b). *The California State Implementation Plan for Ozone: The Air Resources Board's Mobile Source and Consumer Product Elements*, Volume II, California Air Resources Board, Adopted November 15, 1994. Sacramento, California.

30. California Air Resources Board (1994c). *Summary of Staff Alternative to the Proposed SIP: Mobile Source Element*, California Air Resources Board, Public Hearing to Consider Approval of a Revision to the California State Implementation Plan, 94-11-2, November 9-10. Sacramento, California.

31. California Air Resources Board (1994a), op. cit.

32. Ibid

33. Cross, Bob (1994). *Cost-Effectiveness of Mobile Source SIP Element*. Memorandum to Bob Barham, Assistant Division Chief, Research Division, Sacramento, California, Mobile Source Division, Air Resources Board.

34. Adler, Paul S. and Kim B. Clark (1991). "Behind the Learning Curve: A Sketch of the Learning Process." Management Science **37**(3): 267-281; Dick, Andrew R. (1991). "Learning by Doing and Dumping in the Semiconductor Industry." Journal of Law and Economics **34**: 133-159; Gruber, Harald (1992). "The learning curve in the production of semiconductor memory chips." Applied Economics **24**: 885-894; Lieberman, Marvin B. (1984). "The learning curve and pricing in the chemical processing industries." RAND Journal of Economics **15**(2): 213-228.

35. California Air Resources Board (1994d). *1994 Low-Emission Vehicle and Zero-Emission Vehicle Program Review*. Staff Report, Sacramento, California, Prepared by Mobile Source Division; California Air Resources Board (1994e). *Technical Support Document: Zero-Emission Vehicle Update*. Staff Report, Sacramento, California, Prepared by Mobile Source Division.

36. Sierra Research Inc. (1994). *Supplement to: The Cost-Effectiveness of Further Regulating Mobile Source Emissions. The Effects of Using EMFAC7F Instead of MOBILE5a*. Report No. SR94-08-01. Sacramento, California, Prepared for American Automobile Manufacturers Association; Sierra Research Inc., et al. (1994). *The Cost-Effectiveness of Further Regulating Mobile Source Emissions*. Report No. SR94-02-04. Sacramento, California, Prepared for American Automobile Manufacturers Association; Virag, Dennis (1994). *Prepared Testimony of Dennis Virag on Behalf of the Western States Petroleum Association*, California Public Utilities Commission, Low Emission Vehicle Program Applications of San Diego Gas and Electric Co., Southern California Gas Co., Southern California Edison Co, and Pacific Gas and Electric Co., I.91-10-029/R91-10-028, A.93-11-002, A.93-11-004, A.93-11-006, A.93-11-011, May 2. San Francisco, California.

37. Carl Moyer, Acurex, Personal Communication, November 1994.

38. California Energy Commission (1994). *1993-1994 California Transportation Energy Analysis Report*. Draft, P300-94-002. Sacramento, California, Staff.

39. Davis, Stacy C. (1994). *Transportation Energy Book, 14th Edition*. ORNL-6798. Oak Ridge, Tennessee, For U.S. Department of Energy, Office of Transportation Technologies by Center for Transportation Analysis, Energy Division, Oak Ridge National Laboratory.

40. California Air Resources Board (1994a), op. cit.

41. Lynch, R. A. and L. F. Lee (1993). *California Motor Vehicle Stock, Travel and Fuel Forecast*. California Department of Transportation, Office of Traffic Improvement.

42. Ibid

43. California Air Resources Board (1994a), op. cit.

44. California Air Resources Board (1994c), op. cit.

45. California Energy Commission Staff (1993). *1993 Natural Gas Market Outlook*, California Energy Commission, 1994 Electricity Report, Docket No. 93-ER-94, Sacramento, California.

46. U.S. EPA, "Regulatory Impact Analysis and Regulatory Support Document," Docket A-94-09, 1994.

47. Booz-Allen, Hamilton, "On-Road Mobile Equipment Emission Inventory Estimate," prepared for California Air Resources Board, January 1992.

48. Weaver, Christopher S. and Douglas B. McGregor (1993). *Controlling Locomotive Emissions in California: Technology, Cost-Effectiveness, and Regulatory Strategy*. Final Report, Contract No. A032-169. Sacramento, California, For California Air Resources Board by Engine, Fuel, and Emissions Engineering, Inc.

49. California Energy Commission Staff (1993) op. cit.

50. California Energy Commission, *Fuels Report*, P300-93-019, Sacramento, California, February 1994, pp. 13, 37.

51. See for example M.Cubed, "Market-Based Approaches," op. cit.

52. Sierra Research Inc., et al., *The Cost-Effectiveness of Further Regulating Mobile Source Emissions*, Report No. SR94-02-04, Prepared for American Automobile Manufacturers Association, Sacramento, California, February 28, 1994.

53. U.S. Department of Commerce, *County Business Patterns*, Washington, D.C., 1991.

54. American Trucking Association, *American Trucking Trends*, 1993-1994 Edition.

55. California Air Resources Board, *Proposed Regulation to Reduce Volatile Organic Compound Emissions from Consumer Products*, Sacramento, California, August 1990; California Air Resources Board, *Proposed Amendments to the Statewide Regulation to Reduce Volatile Organic Compound Emissions from Consumer Products, Phase II: Technical Support Document*, Sacramento, California, October 1991; California Air Resources Board, *Technical Support Document for a Proposed Regulation to Reduce Volatile Organic Compound Emissions from Antiperspirants and Deodorants*, Sacramento, California, September 1989; ICF Consulting Associates, *Study of Economic Incentives to Control Photochemically Reactive Organic Compound Emissions from Consumer Products*, prepared for California Air Resources Board (Contract No. A732-150), Sacramento, California, August, 1990.

56. This analysis is presented in California Air Resources Board, *Draft Technical Support Document for Proposed Aerosol Paint Regulations*, Sacramento, California,

forthcoming, 1994, Chapter VII.

57. Battelle Laboratories, *Survey of Emissions from Solvent Use: Volume I, Aerosol Paints*, prepared for California Air Resources Board (Contract No. A132-086), Sacramento, California, September, 1994; California Air Resources Board, *Draft Technical Support Document for Proposed Aerosol Paint Regulations*, op. cit.; ICF Consulting Associates, 1990, op. cit.

58. ICF Consulting Associates, op. cit.

59. Steven Moss, Julie Hewitt, et. al., *Impacts on California Agriculture of the Food Safety and Pesticides Section, Proposition 128*, prepared for the California Coordinating Council by Spectrum Economics, Inc, San Francisco, California, July 1990.

60. Ibid.

61. Ibid.

62. El Dorado County Air Pollution Control District, et. al., *Sacramento Area Proposed Regional Ozone Attainment Plan*, October 19, 1994 Version.

63. Ibid.

64. U.S. EPA, *Regulatory Impact Analyses for the Sacramento Nonattainment Area, South Coast Nonattainment Area, and Ventura County*, Docket A-94-09, Washington, D.C., April 15, 1994.

65. William W. Wade, *et al*, *Cost of Regulatory Compliance to the Petroleum Production Industry in California*, Draft Report, Prepared for the Division of Oil and Gas, California Resources Agency by Foster Economics, San Francisco, California, March 1993, Table 2.11.

66. South Coast Air Quality Management District, *Socioeconomic Assessment Report for the 1994 Air Quality Management Plan*, Final, Diamond Bar, California, September 1994.

67. SCAG, "Letter to EPA FIP Docket A-94-09," August 25, 1994.

68. Ibid.

69. SCAQMD, *1994 Air Quality Management Plan*, Appendix IV-C: Transportation Control Measures, Diamond Bar, California, September 1994.

70. SCAG, op. cit.

71. Ventura County Economic Development Association, *Ventura County Federal Implementation Plan Review/Analysis Project*, April 1994.

72. CARB, *Proposed SIP*, Volume II, page I-11.

Appendix A

Mobile-Source Technology Cost Analyses to Support the Economic Analysis of the Proposed 1994 State Implementation Plan Conducted Prior to Its Consideration by the California Air Resources Board

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Foreword to Appendix A

Acurex Environmental, acting as a subcontractor to M.Cubed for this study, provided estimates of the direct costs of low-emissions technology for mobile sources. We supplied the results of our analyses to M.Cubed in the form of first year cost per vehicle and an associated "learning curve". The learning curve concept is described in detail in Section A.1.1. The analyses presented here are based on available, for the most part published, information. This work was not a large, original study but rather an amalgamation of many sources of information specifically to assess the costs of the proposed California State Implementation Plan (SIP).

In some instances a low or "base case" cost is provided together with a higher cost estimate. In these instances, "low" and "high" do not represent the lowest and the highest costs that have been reported but are intended to show a reasonable range. In the cost analyses for light- and medium-duty vehicles "low" and "high" should be interpreted, respectively, in the sense of "expected" and "plausible high cost case", where the implied judgements are those of Acurex Environmental. The cost estimates here encompass neither the most optimistic outcome that could occur in favorable circumstances, nor the worst case, highest-cost scenario.

There are two important items to note about the analyses presented in this Appendix. First, our analyses necessarily address incremental costs, not possible prices, associated with low emission technologies. Some discussion of electric vehicle pricing is included in the following text but all of the numbers provided to M-Cubed were costs. Second, this study was not intended to be a technical feasibility study. We costed proposed SIP measures based on our understanding of the types of technologies that would be used to implement the measures in the timeframe described in the proposed SIP. That costs are estimated here under certain assumptions does not indicate that this study has made any findings regarding the technical feasibility of any SIP measures or candidate technologies. Technical feasibility is addressed elsewhere in the SIP process by CARB staff and through public comments on proposed measures.

A.1. Light-Duty Vehicle LEV/ZEV Extension

A.1.1 Introduction

The draft SIP proposal for light-duty vehicles (measure M1) includes a continuing reduction of the "LEV program" tailpipe emission standards (which includes a sales-weighted average declining tailpipe nonmethane organic gas emission standard from 1994 through 2003) from the value of 0.062 g/mile at 2003 in the current regulation to 0.026 g/mile by 2005. The SIP proposal contemplates that manufacturers might meet the reduced standard in a variety of ways, including increased fractions of ULEV and ZEV sales, or sales in a new sub-ULEV category yet to be developed. This new category might include provisions for crediting reductions of evaporative emissions against the tailpipe standard. This would be an attractive option for manufacturers of natural gas vehicles.

For the purposes of assessing economic impacts, we will not conjecture on the standards and technologies for a yet-to-be-proposed sub-ULEV category, but instead recommend that any quantitative modeling consider a mix of 65% ULEVs and 35% ZEVs, as suggested in the SIP text itself. For this purpose, we provide estimates of incremental costs of LEV-category vehicles appropriate to their first year of introduction. To estimate costs for the purpose of assessing impacts of the proposed SIP, we recommend that incremental costs be reduced each year through "learning curve" or "experience curve" effects as increasing number of reduced-emissions vehicles are deployed. We suggest an "80 per cent learning curve," with incremental costs reduced by 20% (an 0.80 multiplier) for each doubling of the total number of vehicles in each category supplied. Thus the per-vehicle incremental costs after N vehicles have been deployed, CN, can be computed from the incremental costs in the first year of deployment, C1, from a formula of the form CN/C1 = (N/N1)**(-0.3219), where N1 is the number of vehicles deployed in the first year of commercial sales. This "80 per cent learning curve" has been observed in a wide range of industrial and consumer product manufacturing (Reference 1).

For the purpose of using the learning curve in estimating costs of low-emissions vehicles in various years, it should be sufficiently accurate to use the deployment schedule suggested in the original CARB staff report in 1990 as describing the expected deployment schedules of TLEVs, LEVs, and ULEVs, and the mandatory deployment schedule of ZEVs.

Available published cost estimates for reduced emission vehicles are presented in several different formats, none of which follows the learning curve format we recommend here. Most estimates represent "program averages" for some assumed (though usually not defined explicitly) large volume of production or size of manufacturing program, and are for use in determining average cost effectiveness over the life of the regulatory measure being considered in the assessment being reported. We have recast these estimates of average incremental costs into a format of first year incremental costs and learning curve decreases. For this purpose it has been necessary to make assumptions if the original cost assessment did not provide enough information.

Generally, the base cost estimates were derived from the CARB staff report for the LEV review that occurs each two years, most recently in April of 1994 (References 2 and 3). For LEVs, ULEVs, and ZEVs, we provide some alternative higher estimates of incremental costs obtained from other sources. These higher cost estimates might be used in an analysis of economic impacts if a range of possible outcomes is being assessed. It should be noted, however, that the Air Resources Board did accept in April of 1994 the staff estimates of incremental costs of reduced emission vehicles as accurate and reliable. Therefore, staff estimates should form the baseline for analysis.

Note that in all cases we are reporting incremental costs above the costs of a "base" or "Tier I" light-duty vehicle meeting a tailpipe standard of 0.25 g/mile of nonmethane hydrocarbons. Here, "costs" refer to manufacturers' costs for materials, components, and manufacture, plus allowances for costs of distribution, marketing, and sales, as well as profit (return on investment). Actual prices to buyers may depend on many factors, but for TLEVs, LEVs, and ULEVs we believe that it is adequate to assume that increments in cost are equal to increments in purchase price. This assumption that incremental consumer price is equal to incremental manufacturer cost may not, however, be true for ZEVs, as discussed in the section on ZEV incremental costs.

A.1.2 Incremental Costs for TLEVs

Costs for the TLEV vehicle should not be needed in the assessment of SIP cost estimates, since these vehicles will not be playing a role beyond 2003. However, in case such costs are needed for the purpose of assessing program cost up to the proposed LEV program extension beyond 2003, we provide some estimates.

The CARB staff report gives an incremental TLEV cost of $60 for the entire program. Considering the expected total number of TLEVs to be manufactured, and assuming an 0.80 learning curve cost reduction effect, a first year TLEV cost would be $80 above the costs of a "base" or "Tier I" 0.25 g/mile light-duty vehicle in 1994. No fuel economy penalty is expected. Maintenance costs, if scaled on vehicle cost; will be higher by the appropriate annual maintenance cost fraction times the incremental cost.

All TLEVs are assumed to be gasoline vehicles.

A.1.3 Incremental Costs for LEVs

Costs for LEVs should also not be germane to an economic impact of the SIP, but in case these are needed a first year incremental cost derived from the CARB staff estimate of program-average incremental cost of $113 can be taken as $200, with an experience cost reduction curve of 0.80.

Some other published estimates are higher than CARB staff estimates. Sierra Research has provided one such set of cost estimates (References 4 and 5). Lareau has summarized a number of estimates (Reference 6). If a higher estimate for LEV estimated costs is desired, we would suggest a first year incremental cost of $400 as representative of higher cost estimates, when translated into a first year incremental cost. It is our opinion, however, that a cost increment as high as $400 is very unlikely.

All LEVs can be assumed to be gasoline vehicles with no fuel economy penalty. Incremental maintenance costs can be calculated in the same manner as suggest above for TLEVs.

A.1.4 Incremental Costs for ULEVs

Estimates of incremental costs reported by the CARB staff in References 2 and 3 for ULEVs, translated into a first year incremental cost appropriate to a 0.80 experience curve for cost reductions, would equal about $400. Representative higher incremental costs reported in the literature, as summarized by Lareau in Reference 6, could be translated into a higher first year incremental cost of $1200. We believe, however, that an incremental cost this high is very unlikely. Note again that the Board has already accepted the lower staff estimates.

It can be assumed that all light-duty ULEVs will be gasoline vehicles, although it is possible that some natural gas ULEVs will be sold where natural gas vehicles can attain cost competitiveness with gasoline vehicles. It is unlikely that natural gas vehicles can attain such a decisive cost advantage over gasoline vehicles that the SIP economic impact assessment needs to consider an extensive penetration of natural gas in the ULEV category of light-duty vehicles.

Gasoline ULEVs should show no fuel economy penalty over the fuel economy of base cars, and incremental maintenance costs can be estimated as suggested above for TLEVs.

A.1.5 Incremental Cost Estimates for ZEVs

A.1.5.1 Introduction

Estimates of incremental costs for zero emission vehicles, assumed for the most part to be battery-electric vehicles in the years from 1998 to 2005, present more difficult problems than estimates for TLEVs, LEVs, and ZEVs. Incremental costs for ZEVs are much higher than for the improved gasoline vehicles, which causes the potential economic impact to be greater and sharpens the need for accurate cost assessments. Since however the technology for the ZEVs is still emerging and the actual deployment of a large number of ZEVs is still a number of years away, there tends to be a wide range of cost estimates, representing uncertainty about the technologies to be used (battery choice, most importantly, and whether the vehicles will be "purpose-built" to accommodate the limited performance of batteries or will be conversions of vehicles designed originally as gasoline vehicles - this second choice will reduce costs but may reduce the appeal of the vehicle to potential buyers and thus restrict the potential markets). Other uncertainties which affect cost estimates include the scale of production imagined (will electric vehicles gain some market in other States than California?), the expected degree of cost reduction as production expands (will normal "learning curve" cost reductions prevail over the possible need to adjust design approaches to accommodate several generations of improving battery technologies?) and varied estimates of the infrastructure required to support electric vehicles.

Finally, the various cost studies are frequently imagining different expectations for the electric vehicle, ranging from small neighborhood vehicles suitable only for limited uses and most appropriate for communities or multi-use "villages" well suited for a limited performance vehicle, to full-size vehicles that come close to the performance of an average gasoline car. Thus there are many "apples and oranges" problems in comparing estimates of incremental costs for electric vehicles.

A.1.5.2 Suggested Baseline Assumptions

The CARB staff presented detailed ZEV cost assessments in the recent LEV program review documents (References 2 and 3). As the Board approved these estimates, we recommend that they be used as the base case. To use the staff estimates for the purpose of estimating the economic impacts of an extended program, it is best to translate the CARB staff estimates, which constituted a program average incremental cost for the years 1998-2003, into expected first-year of deployment incremental costs plus an "experience curve" statement. This format will allow cost estimates to be extended into the post-2003 period, as needed for the assessment of economic impacts of the proposed extension in the SIP.

Assuming an "80 per cent experience curve," as was done for the TLEV, LEV, and ULEV technologies, and reworking the CARB average 1998-2003 cost into an expected first-year incremental cost, yields a starting incremental cost of approximately $5000 per vehicle. This approximately matches the cost increment estimates of several independent studies that appear to be appropriate to the early years of electric vehicles roughly comparable in performance to typical gasoline vehicles. It also matches some of the actual advertised prices available for aftermarket converted electric vehicles today.

Note that there are potential flaws to this recasting of the staff cost information for use beyond 2003. If extending the program beyond 2003 contemplates a larger share of new vehicle sales for electric vehicles, the vehicles may need to become larger and more capable, implying more costs or some falling off from the normally expected cost reduction experience curve. This would especially be true if continued deployment of electric vehicles implied one or more transitions in battery technology, in which case it is possible that a new "experience curve" must be started each time. (On the other hand, a progression of battery or fuel cell technologies, or other energy storage approaches such as flywheels, might as well imply substantial "breakthrough" technology improvements with associated cost reductions.) Furthermore, continued deployment of vehicles might involve cost reductions in the "platform" itself, so that experience-curve cost declines might apply to more than the incremental costs. That is, the total costs of some ZEVs might become lower than the costs of competing gasoline and diesel vehicles.

Nevertheless, all factors considered, the staff estimates provide the most thoroughly examined and consistent set of cost estimates for use, and correspond well to several other independent cost estimates.

Manufacturers are still considering a number of choices for battery types in the 1998-2003 period. Candidates included lead-acid, nickel-cadmium, and nickel metal hydride, as well as some others. For a working assumptions, we suggest a simple lead-acid model for the years 1998-2006. This corresponds fairly well with a recent study of potential battery recycling issues in California associated with electric vehicles (Reference 7). For this technology, assume a battery replacement every 2 years at a cost of $1000 (no experience curve effect). For years beyond 2006, it is highly likely that electric vehicles will employ advanced batteries such as lithium polymer. To simulate this, we recommend for the model years 2007 and after an assumed 5-year replacement period at one-half of the then year incremental cost for the total vehicle. As a computational model, we suggest assuming that no pre-2007 models shift to new battery choices (such a possibility definitely exists, especially given the interest of manufacturers in preserving as much resale value as possible for the vehicles, but the design issues need to be sorted out).

The Staff Reports (References 2 and 3) provide some guidance on expected energy use. We suggest using a figure of 0.3 kWh/mile, which is within the range of staff estimates.

Various projections are available for the time-of-day distribution of recharging. Estimates for the daytime portion range from 6% to 10%. Note, however, that daytime charging generally is not expected to occur during true peak hours.

Acurex Environmental is not responsible for the assumptions to be used for energy costs. However, we suggest that M.Cubed use projections of the California Energy Commission and use estimates that have consistent electricity and oil price scenarios.

A.1.5.3 Suggested High Cost Case

Some published estimates for incremental costs of electric vehicles are very much higher than the CARB staff estimates shown in (References 2 and 3). To investigate possible impacts of the proposed LEV/ZEV extension M.Cubed may wish to examine a high-estimate case. Estimates by Austin and co-workers (References 4 and 5) were funded by the vehicle manufacturers and have gained some currency in discussions of the ZEV mandate. The publications are too incomplete to allow an unambiguous translation of Sierra cost estimates into the first-year plus experience-curve form recommended here. However, making reasonable assumptions about the unreported aspects of the Sierra analysis would lead to a first year estimated cost increment of $15,000 with a composite 80 per cent experience curve. (It should be noted that this is not the approach recommended by Sierra, which is more complex and has several different independent cost elements following different experience curve declines. Unfortunately, the reports do not provide enough detail to allow this approach to be extended into additional years. The cost increment suggested here, combined with the 80% experience curve assumption, does generally replicate the Sierra results for the 1998-2003 time period.)

A.1.5.4 Infrastructure Costs

Most estimates for the required infrastructure needed to support an electric vehicle cluster in the range of $800 to $1000. This covers 220V conductive charging at a residence, provided that an expensive retrofit is not needed. Some estimates of recharging infrastructure assume such a limited performance capability for electric vehicles that an extensive public recharging infrastructure would be needed to support the vehicles, with recharging available at parking facilities, especially at work and shopping sites. In these scenarios, infrastructure requirements might amount to $4000 per vehicle, especially if the more expensive inductive coupling systems prevail in the marketplace. It appears justifiable to assume, however, that all infrastructure estimates are for the early years of deployment, and that costs would decline according to normal 80 per cent experience curve assumptions.

In some locations the proliferation of electric vehicles might imply that local distribution of electric power is inadequate and would need upgrading, especially to support parking facilities. In some urban areas the cost implications might be significant, and added infrastructure costs might be large enough to deserve a separate accounting. For the moment, however, we suggest that this possibility be ignored, especially since some move toward local generation (including more self-generation at some large buildings and manufacturing facilities, as well as the possible broadening commercialization of local photovoltaic charging systems) might greatly reduce the costs otherwise implied by enhanced distribution needs.

A.1.5.5 Some Suggestions Concerning Pricing of Electric Vehicles

The topics above have dealt with costs, not prices. Much of the impact to the California economy that might be associated with ZEVs concerns prices, not costs, most of which would be borne by manufacturers in other States. (The expected amount of electric vehicle manufacture that might take place in California is disputed. Most major vehicle manufacturers have no plans to manufacture vehicles or components in California. However, some independent converters of electric vehicles, such as U.S. Electricar, do plan to assemble in California. For a baseline case, we suggest assuming that no manufacturing takes place in California.)

Clearly ZEVs in the early years will cost more than competing conventional vehicles, and perform less capably, especially in range. Therefore to obtain early year sales the manufacturers will need to discount the vehicles to obtain sales, even the low level of sales implied by the early year mandates. Manufacturers may handle the early year losses implied either by cross-subsidization from gasoline vehicle sales, or by absorbing losses against the expectation of future profits from electric vehicle sales once costs have been forced down through experience effects.

Manufacturer pricing strategy is not known at this time, presumably even to the manufacturers. For the purpose of assessing economic impacts we make the suggestion that manufacturers will not be confident of any future year profits, and will subsidize ZEV sales to the maximum extent possible from the national (or even international) sales of conventional vehicles. Manufacturers sometimes suggest that cross-subsidy will be limited to the pool of conventional vehicles sold in California, leading to a drastic increase in the prices of conventional vehicles sold in California and thus to a substantial suppression of new vehicle sales and a delay in the introduction of newer lower-emitting vehicles generally. While slowed sales due to the effects of more expensive emission controls is always a possibility in California, the specific drastic effect of a ZEV cross-subsidy from a California-only universe seems unrealistic on several grounds. First, such a pricing strategy by one manufacturer would expose the manufacturer to a potentially harmful loss of market share to other manufacturers who elect to cross subsidize from a larger pool so that the impact of the ZEVs on the prices (and hence sales) of their conventional vehicles in California is much less. Furthermore some significant manufacturers do not need to meet a ZEV mandate until later years. These manufacturers could readily capture market share from a mandated manufacturer who elects a California-only cross-subsidy strategy. Finally, once ZEV sales reach 5% of the California sales, the aggregate sales are high enough to affect a manufacturers Corporate Average Fuel Economy (CAFE). This would be of significant value to a manufacturer with opportunities to sell larger vehicles or otherwise adjust sales mix to a more profitable form but for CAFE constraints that limited choices. Thus the California ZEVs may have significant national value that might amount to several thousand dollars per ZEV (see the analysis of Reference 8, for example). For all these reasons, a high-price California-only cross-subsidy appears not likely to be selected by any manufacturer. In California, the mandated ZEVs could be offered at prices representing no significant increase over the prices of California vehicles. (Indeed, the prices may need to be considerably less even than the prices of "equivalent" gasoline vehicles, since the electric vehicle, at least in the early years, will suffer from real or perceived performance deficits and from real or perceived reduced resale value. The economic impact analysis of M.Cubed will be considering the implications of such discounted prices and performance decrements.)

A.2 Medium-Duty Vehicles

The draft SIP proposes to change the roll-in schedule for medium-duty vehicles between 8500 pounds and 14,000 pounds gross vehicle weight to a 100% at ULEV requirement by 2002 (measure M2). This corresponds to a 2 g/mile standard for the heaviest weight category in this class, if certified as a complete vehicle, or 2.5 g/bhp-hr hydrocarbon plus NOx if the engine is certified separately.

For gasoline engines, the implied technology is the same as for light-duty vehicles, and the CARB staff reports have recommended cost estimates equal to the LEV and ULEV cost estimates for light-duty vehicles (Reference 9). We recommend this as a baseline cost assumption. The cost estimates were provided in Sections A.1.3 and A.1.4 above.

However, the extension of the standard from the earlier 15% ULEV requirement to a 100% ULEV requirement creates certain complexities in assessing costs. The modification was made to provide a logical "splice" between the medium-duty standards and the 2 g/bhp-hr California heavy-duty standard (for vehicles above 14,000 gross vehicle weight) in 2002 and the requested federal heavy-duty standard of 2 g/bhp-hr in 2004. If heavy-duty engines are achieving 2 g/bhp-hr levels, then the heavier end of the medium-duty category should be achieving about the same levels. This expectation is captured by a 100% medium-duty ULEV requirement in the SIP.

At 100% ULEV requirement, it would not be reasonable to project costs based solely on gasoline-technology costs. Diesel enjoys a certain share of the medium-duty market, especially in the upper range above 10,000 pounds and 14,000 gross vehicle weight. Should the cost estimates include some provision for diesel-engine costs at the 2 g/bhp-hr level? These low-NOx diesel costs are discussed in Section A.3 below and are considerably higher than the gasoline ULEV cost increment suggested above.

Indeed, the whole question of the 100% ULEV requirement in medium-duty was sharply questioned by the engine Manufacturers Association and by some manufacturers at the SIP hearings because the manufacturers disputed that a 2 g/bhp-hr diesel technology would be available in a timely way at reasonable costs. The CARB staff indicated some agreement with the suggestions that some relaxation of the proposed SIP plan might be needed in the heavier end of the medium-duty SIP proposal. This was left for future work.

In summary, because the exact nature of the medium-duty proposal is still somewhat flexible, and because the standards can be met with gasoline vehicles at relatively low costs, we recommend that the cost impact assessment ignore any possible high costs for diesel engines in the medium-duty sector. We will assume that either the diesel technology will appear in time at reasonable costs, or that gasoline technologies will substitute at reasonable costs, or that the proposed standard will be modified to allow a smooth evolution of lower-cost diesel technologies in this sector.

A.3 On-Road Heavy-Duty Vehicles

A.3.1 Measure Description

The draft SIP includes a medley of measures (measures M3 through M7) for on-road heavy-duty vehicles (HDVs). Low-emission HDVs at two levels of NOx emissions are included in these measures: 2 g/bhp-hr NOx HDVs and 1 g/bhp-hr HDVs. Particulate standards are not described in the draft SIP; we assume for the purpose of this analysis that the PM standard would remain at 1994 levels. This analysis did not separately consider gasoline HDVs as gasoline fuels only a small percentage of vehicles over 14,000 pounds GVWR.

The draft SIP calls for HDVs certified to 2 g/bhp-hr to be introduced into nonattainment areas beginning in 1996 at 5% of annual sales. Beginning in 2000 the measure would introduce 1 g/bhp-hr NOx trucks at 10% of annual sales. The SIP describes these "early introduction" measures as locally-implemented, market-based programs; because they were not proposed to be a State requirement they were not costed as part of this analysis. Another component of the HDV program is implementation of a 2 g/bhp-hr NOx standard in 2002 (California) and 2004 (nationwide). A final component is a State 1 g/bhp-hr standard to be phased in from 2004 to 2007, at maximum implementation covering 25% of new sales.

We provided cost estimates for 2 g/bhp-hr diesel vehicles and for 1 g/bhp-hr vehicles, which were assumed to be natural gas fueled.

A.3.2. Low-NOx Diesel On-Road Heavy-Duty Vehicles

A.3.2.1 Introduction to Cost Assumptions

The cost assumptions described below are derived from Reference 10 for two primary technology options: exhaust gas recirculation (EGR) plus an oxidation catalyst or, alternatively, a diesel engine NOx catalyst (DE-NOx catalyst). See Reference 10 for a comprehensive discussion of low-emission HDV technology.

Costs were taken from Reference 10 in a straightforward manner except for EGR costs which were adjusted to reflect the draft SIP proposal for a national low-NOx HDV standard. Because Reference 1 examined a California-only standard, research and development costs were distributed over California sales only. Under the SIP proposal, these costs would be distributed over the larger national market, reducing costs per low-NOx HDV. For the purpose of this analysis research and development costs were estimated to account for half of the EGR costs reported in Reference 10. California HDV sales were estimated at 10% of national sales.

These costs essentially include incremental hardware costs, recovery of R&D costs, increased warranty costs, and any increased cost of manufacture/ assembly. Costs are for commercial production volumes, not prototypes.

A.3.2.2 Cost Assumptions for Heavy-heavy-duty Vehicles (33,000+ lbs GVWR)

Technology: Direct Injection Diesel with EGR and Oxidation Catalyst

Initial Incremental Capital Cost (compared with baseline 1998 4 g/bhp-hr NOx engine):

EGR, fixed hardware costs:	$5,000-$6000
EGR, recovery of sunk R&D costs:	$500 - $600
Oxidation catalyst:	$500 - $1000

Learning curve: 80% as described in Section A.1.1 (apply to fixed hardware costs)

Additionally: Recovery of R&D costs complete after 5 years

Increased maintenance costs: $80 - $190/yr

Increased fuel consumption: Additional fuel consumption of 0.2 to 0.5 mpg diesel

Technology: Direct Injection Diesel with DE-NOx Catalyst

Initial Incremental Capital Cost (compared with baseline 1998 4 g/bhp-hr NOx engine):

De-NOx engine modifications, fixed hardware costs:	$3,750 -$5,000
De-NOx engine modifications, recovery of sunk R&D costs:	$375 - $500
Fuel system modifications:	$500 - $1000
De-NOx catalyst:	$1000 - $1500

Learning curve: 80% as described in Section A.1.1 (apply to fixed hardware costs)

Additionally: Recovery of R&D costs complete after 5 years

Increased maintenance costs: $80 - $190/yr

Increased fuel consumption: Additional fuel consumption of 0.5 to 0.9 mpg diesel

A.3.2.3 Cost Assumptions for Medium-heavy-duty trucks (14,000 - 33,000 lbs GVWR)

Technology: Direct Injection Diesel with EGR and Oxidation Catalyst

Initial Incremental Capital Cost (compared with baseline 1998 4 g engine):

EGR, fixed hardware costs:	\$1000-\$1500
EGR, recovery of sunk R&D costs:	\$100 - \$150
Oxidation catalyst:	\$500 - \$1000

Learning curve: 80% as described in Section A.1.1 (apply to fixed hardware costs)

Additionally: Recovery of R&D costs complete after 5 years

Increased maintenance costs: \$90 - \$170/yr

Increased fuel consumption: Additional fuel consumption of 0.4 mpg gasoline

Incremental rebuild costs for all of the above:

No incremental rebuild cost associated with the EGR system, and catalysts must be replaced 1 to 2 times over the life of the truck.

A.3.3 Natural Gas Technologies

A.3.3.1 Vehicle Issues

The proposed 1 g/bhp-hr standard is low enough that only natural gas or other alternative fuel technologies might be available to meet the standard in a timely manner. The base case expectation should be that diesel technologies will be forced to compete at the 1 g/bhp-hr level at costs consistent with those presented in Section A.3.2 above. However, we suggest that the economic impact assessment also examines a case in which the 1 g/bhp-hr standard can only be met by natural gas technologies.

Natural gas trucks and buses will show substantial incremental first costs compared with base diesel technologies.certified at 4 g/bhp-hr. However, natural gas will generally be available to vehicles at less cost than diesel fuel. Therefore, the total cost impact must consider both first costs and fuel costs.

For modelling purposes, we suggest initial incremental first costs for natural gas heavy-duty vehicles of $40,000. Half the incremental costs can be attributed to compressed gas storage cylinders and half to engine and fuel management modifications. Acurex Environmental has performed an extensive strategy assessment for natural gas vehicles for the Gas Research Institute, the American Gas Association, and the Natural Gas Vehicle Coalition (Reference 11). This work included a detailed model of the growth of natural gas technologies in different vehicle classes. The model used an 80 per cent experience curve for cost reductions for that half of the incremental costs attributable to engine and fuel management systems (exponent of -0.321), and a 12 per cent experience curve for storage cylinders (exponent of -0.202). Learning curves can be assumed to apply only to aggregate sales of heavy-duty natural gas vehicles. That is, despite some technology commonality or carryover, such as for storage cylinders, we assume that the different classes of vehicles have enough differences in equipment and manufacture that the learning curves are independent, and cost reductions in natural gas heavy-duty vehicles are affected only by sales of heavy-duty vehicles, and not by sales of natural gas vehicles in other weight classes.

The economic impacts of natural gas will depend on experience curve cost reductions, which in turn will depend on the market share captured by natural gas technologies not only in California but in other States and even in other nations. We do not believe it is reasonable to assume that natural gas technologies would only be deployed in California. The draft natural gas vehicle strategy document describes an expected national deployment strategy which would see the sales of 40,000 natural gas heavy-duty trucks between now and 2003. We suggest that this figure represents the early deployment at the full incremental cost. Additional national sales are projected to be 40,000 in 2004, 56,000 in 2005, 73,000 in 2006, and 84,000 for 2007 and following years.

A.3.2.2 Fuel Consumption and Cost Issues

The average heavy-duty truck can be assumed to consume 6,333 gal/year of diesel fuel (128,000 Btu(LHV)). As a natural gas vehicle, the same truck would consume 1,090,000 scf of natural gas at a heating value of 930 Btu(LHV)/scf, taking into account a 20% loss in efficiency associated with the throttle-controlled natural gas engine compared with a diesel engine.

Gas costs appropriate to California will be defined by M.Cubed. We recommend projections developed by the California Energy Commission. It will be important in assessing economic impacts to use gas prices that are consistent with an oil price scenario and the resulting scenarios for diesel fuel prices.

Costs for compressing the gas to the pressures needed for storage on the vehicle can be assumed to be $0.10 per therm, considering electricity prices prevalent in California. We suggest an additional margin of $0.05 per therm to cover normal retail margin.

There should also be an element of capital recovery in the computation of total gas costs. This element will be quite dependent on the skill in executing the natural gas business generally. In particular, the gas industry must deploy stations in such numbers that they are highly loaded, and must avoid situations in which stations are deployed but have little load for a prolonged period of time. It is our belief that a well-executed truck strategy can deploy stations in such a way that the total capital investment required for refueling infrastructure will maintain a more or less constant ratio to the growing fuel demand of the trucks. Detailed modeling described in Reference 11 indicates a capital charge of about \$0.02/therm is a good assumption for quite a few years for sales to heavy-duty trucks. In any case, the number is small compared with requirements for compression and normal retail margin.

A.4 Off-Road Diesel Equipment

A.4.1 Measure Description

Measures M8 and M9 in the October 7 draft of the SIP address off-road diesel equipment. These categories include farm and construction equipment but does not include locomotives, marine vessels, or aircraft. Both the CARB and the EPA have adopted new emission standards for diesel equipment which will phase in beginning with the 1996 model year*; prior to these standards going into effect, emissions from off-road diesel equipment are not regulated. The 1996 NOx standard (CARB and EPA) is 6.9 g/bhp-hr which provides large reductions, roughly 40% on average, compared with unregulated NOx levels. CARB further increases the stringency of the NOx standard in 2001 to 5.8 g/bhp-hr for engines of 175 to 750 horsepower, inclusive.

* CARB has authority to regulate new farm and construction equipment of 175 horsepower and higher sold in California while EPA has the sole authority to regulate new farm and construction equipment of less than 175 horsepower. EPA rulemaking for the 6.9 g/bhp-hr standard extends down to 50 horsepower.

The SIP proposal for this source category is that EPA will adopt a new emission standard to go into effect in 2005 nationwide. The SIP calls for a NOx standard of 2.5 g/bhp-hr for off-road, diesel equipment. The SIP does not describe a horsepower range for engines to which this standard would apply; we have assumed that the 2.5 g/bhp-hr NOx standard would apply to off-road diesel equipment of 50 horsepower and higher.

The particulate standard that would be associated with the 2.5 g/bhp-hr NOx standard is not discussed in the draft SIP. CARB's 1996 standards require 0.4 g/bhp-hr PM with the 6.9 g/bhp-hr NOx standards and 0.16 g/bhp-hr PM starting in 2001 when the NOx standard drops to 5.8 g/bhp-hr. The EPA 1996 standards only regulate NOx and smoke. We are assuming that the PM standard associated with the proposed 2.5 g/bhp-hr NOx standard would be no lower than 0.16 g/bhp-hr.

A.4.2 Expected Technologies

We expect that if manufacturers of off-road engines were to achieve levels of 2.5 g/bhp-hr NOx it require the following*:

- broader application of the technologies projected to be used with certain models to meet the 6.9 and 5.8 g/bhp-hr NOx standards

* We realize that there are characteristics of off-road engines and vehicles that render achievement of low emissions standards more challenging compared with on-road vehicles. These include lack of ram air for air-to-air aftercooling because off-road equipment does not experience high speed travel as on-road trucks do, highly cyclic duty cycles, unique power and torque requirements, dusty operating environments, and highly specialized applications with small markets. As stated earlier, this study does not attempt to evaluate the technical and commercial feasibility of the proposed NOx standard but merely estimates the costs of the combination of technologies which, based on studies of off-road and on-road engine technology, we expect would be employed to achieve low NOx levels.

- addition of exhaust gas recirculation (EGR) plus an oxidation catalyst or, alternatively, a reduction (DE-NOx) catalyst

The technologies projected to be used to meet 6.9 and 5.8 g/bhp-hr NOx standards include:

- Timing retard
- Improved fuel injectors and injection mechanism (e.g., low-sac volume, high pressure injectors, possible electronic control)
- High pressure inline fuel pumps or unit injectors
- Turbocharging
- Aftercooling (jacket water and, to a lesser extent, air-to-air)
- Oil control
- Combustion chamber modifications
- Smoke limiters

References 12 and 13 estimate the percentage of heavy-duty off-road engines that would require each of these technologies to meet the 6.9 and 5.8 g/bhp-hr NOx standard. This analysis considers that any engines not already using these technologies to meet the 1996 standards would need to add these technologies to meet the standards proposed in the draft SIP.

In order to achieve 2.5 g/bhp-hr NOx, we assume that either exhaust gas recirculation (EGR) combined with an oxidation catalyst or, alternatively, a DE-NOx catalyst would be required as well. This is based on a study of the feasibility of achieving low NOx and PM levels with heavy-duty engines for use in on-road vehicles (Reference 10). Note that Reference 10 examined the feasibility of 2.0 g/bhp-hr NOx and 0.05 g/bhp-hr PM standards for on-road heavy-duty vehicles; this set of standards is more stringent than what is being costed in this analysis for off-road diesel engines. However, given the difficulties of meeting low emission standards that are unique to the off-road equipment sector, we assumed similar technologies would be required to achieve the less stringent off-road standards.

Finally, we assume that modifications to the chassis would be needed to accommodate changes to the engine and the fuel management and cooling systems.

A.4.3 Methodology

The methodology used here to analyze the per-vehicle incremental cost attributable to the emissions standards proposed in the draft SIP mimics that used by CARB and EPA in estimating the per-vehicle cost of complying with the 1996 standards. That is, the cost associated with each new component or modification needed to reduce emissions is multiplied by the percentage of engines expected to use that technology to comply with the standard. For example, both EPA and CARB project use of jacket-water aftercooling (JWAC) in 10% more engines than would otherwise use JWAC (25% of all engines rather than 15%) in order to meet the 1996 standards (References 12 and 13). Therefore, in calculating the cost of complying with the 1996 standards, CARB and EPA included 10% of the cost of adding JWAC in the total incremental cost of the average off-road vehicle meeting the 1996 standards. All cost and market share information used in this assessment was taken or derived from References 10 and 12 through 18.

To meet 2.5 g/bhp-hr NOx, we assume that any engines not already incorporating the technologies listed above would need to add those technologies. Tables A.4-1 and A.4-2 show the expected use of technologies for the 1996 standards and the draft SIP standards. Note that engines of 175 horsepower and higher are considered separately as information from CARB analyses was specific to this higher horsepower range.

Table A.4-1

Estimated technologies for off-road engines of less than 175 horsepower meeting draft SIP standards (from References 10 and 12 through 17)

Technology	% of market using technology prior to meeting draft SIP standards	% of market expected to add technology in order to meet draft SIP standards
Timing retard	98%	2%
Improved fuel injectors	5%	95%
Improved injection mechanism	20%	15%
High pressure pump or unit injectors	35%	65%
Turbocharger	65%	35%
JWAC	25%	0%
ATAAC	5%	85%
Smoke limiter	70%	30%
EGR[a]	0%	100%
Oxidation Catalyst[b]	0%	100%

[a] Alternatively, a DE-NOx catalyst might replace the EGR and oxidation catalyst (100% attributable for draft SIP standard)

[b] Note that no new oil control was assumed to be needed to meet draft SIP standards compared with the 1996 standards and that the costs of any combustion chamber modifications are assumed to be included in the costs of other items. Recovery of research and development costs for combustion chamber modifications may not be adequately represented in this analysis, but no information was available to allow these costs to be included explicitly.

Table A.4-2

Estimated technologies for off-road engines of 175 horsepower and higher meeting draft SIP standards (References 10 and 12 through 17)

Technology	% of market using technology prior to meeting draft SIP standards	% of market expected to add technology in order to meet draft SIP standards
Timing retard	100%	0%
Improved fuel injectors	100%	0%
Improved injection mechanism	40%	60%
Inline fuel pump	10%	90%
High pressure pump	50%	0%
Turbocharger	100%	0%
JWAC	13%	0%
ATAAC	56%	44%
Smoke limiter	70%	30%
EGR[a]	0%	100%
Oxidation Catalyst[b]	0%	100%

[a] Altematively, a DE-NOx catalyst might replace the EGR and oxidation catalyst (100% attributable for draft SIP standard)

[b] Note that no new oil control was assumed to be needed to meet draft SIP standards compared with the 1996 standards and that the costs of any combustion chamber modifications are assumed to be included in the costs of other items. Recovery of research and development costs for combustion chamber modifications may not be adequately represented in this analysis, but no information was available to allow these costs to be included explicitly.

Data from Tables A.4-1 and A.4-2 were combined with incremental cost estimates to arrive at overall incremental first-year costs* per off-road vehicle meeting draft SIP standards. Note that high and low cost estimates were provided. The difference between the high and low cost cases was the cost of EGR, taken to be $2,000 per vehicle (Reference 18) in the low case and $5,200 per vehicle in the high case (derived from Reference 10).

In summary, the following cost estimates for draft SIP measures related to off-road diesel equipment were given to M-Cubed for use in the economic modeling:

<175 horsepower:	$10,500 to $15,000 incremental first year cost per vehicle
175 + horsepower:	$9,000 to $14,000 incremental first year cost per vehicle
All equipment:	80% learning curve (see section A.1.1) 5% fuel economy reduction

*Cost information in CARB and EPA regulatory support documents do not appear to include learning curve considerations and do appear to generally include early-year research and development cost recovery costs and retooling or increased assembly costs (Reference 19).

References for Appendix A

1. Boston Consulting Group, Boston, Massachusetts, "Perspectives on Experience," 1972.

2. California Air Resources Board, Sacramento, California, Staff Report, *1994 Low-Emission Vehicle and Zero-Emission Vehicle Program Review*, April, 1994.

3. California Air Resources Board, Sacramento, California, *Technical Support Document, 1994 Low-Emission Vehicle and Zero-Emission Vehicle Program Review*, April, 1994.

4. Austin, T.C., Lyons, J.M., Heirigs, P.L., Caretto, L.S., Joy, R.W., and Fauth, G., *The Cost-Effectiveness of Further Regulating Mobile Source Emissions*, Sierra Research, Inc., Sacramento, California, Report No. SR94-02-04, February, 1994.

5. Austin, T.C,. and Lyons, J.M., *Cost Effectiveness of the California Low Emission Vehicle Standards*, SAE 940471, Society of Automotive Engineers, Warrendale, Pennsylvania, 1994 (SAE International Congress and Exposition, Detroit, Michigan, February 28-March 3, 1994).

6. Lareau, T.J., *Improving Cost-Effectiveness Estimation: A Reassessment of Control Options to Reduce Ozone Precursor Emissions*, American Petroleum Institute, Washington, D.C., Research Study #075, August, 1994.

7. Unnasch, S., Montano, M., Franklin, P., Nowell, G., Martin, C., and Craig, E., *Reclamation of Automotive Batteries: Assessment of Health Impacts and Recycling Technology*, Interim Draft, Task 1, Acurex Environmental Corporation, Mountain View, California, October 21, 1994 (for California Air Resources Board, Sacramento, California).

8. California Advisory Board on Air Quality and Fuels, *Economics Report*, Vol. IVb, Appendix D, Value of CAFE Incentives in Sharp/Rockefeller Alternative Motor Fuels Act of 1988 and Probable Effect on Sales of Alternative Fuel Vehicles (California Air Resources Board, Sacramento, California, June 13, 1990).

9. California Air Resources Board, Sacramento, California, *Proposed Regulation for Low-Emission Vehicles and Clean Fuels*, Staff Report, August 13, 1990, p. 63.

10. L. H. Browning, et al., Acurex Environmental Corporation, Mountain View, California, *Technical Feasibility of Reducing NOx and Particulate Emissions from Heavy-Duty Engines*, final report prepared for the California Air Resources Board, April, 1993

11. Acurex Environmental Corporation, Mountain View, California, *Natural Gas Vehicle Industry Strategic Plan*, Supporting Analyses and Documentation, in preparation (for Gas Research Institute, Chicago, Illinois).

12. California Air Resources Board, Sacramento, California, "Staff Report: Public Hearing To Consider the Adoption of Regulations Regarding the California Exhaust Emissions Standards and Test Procedures for New 1996 and Later Heavy-Duty Off-Road Diesel Cycle Engines and Equipment Engines", Mail-out 91-51, November 22, 1991

13. U.S. Environmental Protection Agency, Ann Arbor, Michigan, "Draft Regulatory Support Document: Control of NOx and Smoke Emissions from Nonroad Compression-Ignition Engines Greater Than or Equal to 50 Horsepower (37.5 Kilowatts)", April, 1993

14. U.S. Environmental Protection Agency, Ann Arbor, Michigan, "Nonroad Engine and Vehicle Emission Study -Report", November, 1991

15. U.S. Environmental Protection Agency, Ann Arbor, Michigan, "Notice of Proposed Rulemaking: Control of Air Pollution from New Nonroad Mobile Source Engines; Determination of Significance for Nonroad Sources and Emissions Standards for Emissions of Oxides of Nitrogen and Smoke from New Nonroad Compression-Ignition Engines At or Above 50 Horsepower"

16. K. G. Duleep, et al., Energy and Environmental Analysis, Inc., Arlington, Virginia, *Feasibility of Controlling Emissions from Off-Road, Heavy-Duty Construction Equipment*, final report prepared for the California Air Resources Board, Sacramento, California, December, 1988

17. Booz-Allen & Hamilton, Inc., Los Angeles, California, *Off-Road Mobile Equipment Emission Inventory Estimate*, final draft report prepared for the California Air Resources Board, Sacramento, California, January, 1992

18. California Air Resources Board, Sacramento, California, "Cost Effectiveness of Mobile Source SIP Element", memorandum from B. H. Cross to R. D. Barham, October 20, 1994

19. Personal communication with Bob Cross and Scott Rowland of the California Air Resources Board, El Monte, California, October, 1994

Appendix B

Documentation for Economic Cost Analyses of Truck and Locomotive Measures

B.1 Summary of Analytic Assumptions

Table B-1 summarizes the key analytic assumptions used in evaluating several of the proposed measures.* These measures underwent relatively complete independent analyses compared to other measures for which the M.Cubed team accepted CARB staff evaluations without review.

Table B-1

Key Analytical Assumptions

Measure	Technology /Production	Fuel & O&M Costs	Users' Response	Cost Burden & Sharing
HDDT 1g/2g	Higher inital costs w/ learning curve	CEC diesel & natural gas price forecasts	Truckers anticipate long-term costs, pass through to businesses	National 2 g standards borne by U.S.; 1 g by California
MDT ULEV	Constant incremental cost; no learning curve	Same as current costs	Costs passed through to business with no demand reduction	Costs borne by California
LDV .026 gpm	Higher inital costs w/ learning curve accelerated by N.E. U.S. sales	Conventional NPV roughly equivalent to ZEV	Higher market penetration requires lower consumer prices	Low: Costs spread across U.S. new car sales; High: Cost borne by California
Off-Road 2.5g	Constant incremental cost; no learning curve	Fuel efficiency loss, CEC diesel price forecast	No demand response; sales increase from US EPA; CARB sector-specific inventory	Costs borne by California for in-state standards
Consumer Products	Uses high/low reformulation costs prepared by CARB	NA	No demand response to higher prices; no sales growth	Low: Costs borne by U.S. High: Costs borne by California.

*See the corresponding sections in the main report for elaboration on each of these assumptions.

B.2 Heavy Duty Diesel Truck Analysis

The direct-cost calculation for the heavy-duty diesel truck emission standards proposed in Measures 5, 6 and 7 follows these steps:

(1) Estimate current fleet age distribution, annual and cumulative mileage, scrappage and turnover rates;

(2) Estimate new baseline truck costs for appropriate size classes;

(3) Calculate expected range of initial engineering costs for emission controls including performance changes;

(4) Project fleet turnover and new truck acquistions through 2010 to establish baseline. Estimate net present value costs through three truck lifecycles.

(5) Estimate costs for emission controls incorporating learning curve and fuel price projections; and

(6) Assume costs are passed through to business, and businesses reduce demand for trucking in response to higher prices. Iterate to step (4) to adjust new truck sales.

The Heavy Duty Diesel Truck (HDDT) Cost Model uses this approach to project the long-term fleet-wide costs associated with the purchase and operation of a "typical" truck that reflects likely technological measures needed to meet emission control standards. The costs are projected over a minimum 36-year time horizon and calculated on a net present value basis. The time horizon equals three times the expected life of a truck; in other words, the analysis assesses the costs of purchasing three trucks in succession. In this way, the analysis compares the costs for one possible future course against another. Often, a regulation may not impose large costs because the affected equipment is of sufficient age that it is cost-effective to make new investments with more advanced technology in any case.

This analytical approach--"dynamic programming"--better reflects the trade-offs in costs and savings over time than a "static" analysis that simply compares the costs of two new trucks without considering the value of holding an existing truck. Calculating net present value per revenue-mile assumes that prospective purchase and operating costs are allocated over the expected lifetime miles travelled by the truck, but that future revenue miles are less valuable ("discounted") relative to current revenue-miles. Revenue-miles are a surrogate for revenues accrued by hauling on the assumption that a trucking firm charges just enough to cover its expenses plus make a normal profit.

B.2.1 The Model

The HDDT Cost Model is composed of two components. The first projects the number of new trucks added to the California trucking fleet. The second projects the costs for existing and new trucks of particular class sizes. The two models are linked through a cost-sensitive economic forecasting equation for trucking demand. The costs of the emission standards under various assumptions are derived by comparing scenarios with and without the control technologies necessary to meet the standards.

The first component forecasts the number of new trucks based on:

(1) the base year (1993) registration by vintage;
(2) a "survival curve" that estimates what proportion of trucks is retired in each vintage year;
(3) the average vehicle miles travelled (VMT) by vintage; and
(4) a forecast of total trucking VMT.

The number of new trucks equals the number of trucks retired times the VMT for those trucks retired, the reduction in VMT for existing trucks due to aging, and the added increment of VMT created by increased demand for trucking, all divided the VMT for an average new truck:

$$NewTrucks = \frac{(\sum Trucks_v * \%Retired * VMT_v) + (\sum Truck_v * (1 - \%Retired) * (VMT_{v-1} - VMT_v)) + (\sum VMT_{yr} - \sum VMT_{yr-1})}{VMT_{new}}$$

The second component forecasts the net present value (NPV) cost for providing trucking services over three truck life cycles. The model forecasts the costs for:

- *existing* trucks based on per mile operating and maintenance (O&M) costs that escalate for both external economic conditions (e.g., inflation, fuel prices) and with deteriorating physical conditions multiplied by the expected remaining lifetime VMT, and on foregone salvage value for <u>not</u> scrapping the vehicle; and

- *new* trucks based on the same O&M costs, including projections for how such costs change with technological innovations and improvements, plus the upfront purchase cost of the truck based on the assumed control technology.

The projected costs are discounted and summed to derive the NPV cost to a trucking company of investing in the requisite control technology--whether existing or proposed. The dynamic programming problem is:

$$NPV_{ct} = \sum_{t=v}^{T} \frac{O\&M_{vt} * VMT_v + Salvage_{vt}}{(1+r)^t} + \sum_{i=1}^{3} \frac{1}{(1+r)^{iT}} \left[Purchase_{cTi} + \sum_{t=1}^{T} \frac{O\&M_{v(t+Ti)} * VMT_v + Salvage_{v(t+Ti)}}{(1+r)^t} \right]$$

where:

r = *discount rate*

t = *year*

T = *expected remaining life of existing or new truck*

v = *vintage in years*

c = *technology type and vehicle class*

i = *new truck purchase iteration*

The total cost equals the NPV cost for each truck in the fleet times the number of trucks.

B.2.2 Data and Assumptions

Assumptions and data on truck use and costs were drawn from a number of sources. The distribution of the truck population by vintage was provided by the California Trucking Association, and the total conforms with CalTrans forecast assumptions.[1] Truck turnover rates were based on a national study.[2] Purchase and operating costs for existing and new baseline trucks were either provided by the CTA or drawn from the Acurex report completed for CARB.[3] Diesel and natural gas fuel price forecasts were drawn from California Energy Commission-adopted forecasts.[4]

The incremental costs for the new emission control technologies were provided by Acurex.[*] The incremental cost for a new truck meeting these standards equals the weighted average of these costs based on the proportion of the fleet meeting these standards. The incremental costs for the 2.0 g/bhp-hr engines include added component costs, performance penalties, increased maintenance costs and recovery of research and development (R&D) investment. Implied R&D investment in the Acurex analysis amounts to about $250 to $500

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[*]See documentation by Acurex in Appendix A of technical assumptions.

million to meet a national standard. The incremental costs for the 1.0 g/bhp-hr engine include refueling infrastructure of $3,600 to $6,000 per truck, and added engine and fuel tank costs of $20,000 to $40,000 per truck. These costs are projected to decline along an 80 percent learning curve path in the low-cost scenario, and along a 90 percent learning curve in the high-cost scenario.

The demand for truck hauling services was forecast based on economic growth in California and changes in diesel fuel prices, using a 1992 base year in the CalTrans MVSTAFF forecast.[5] The forecast reflects how demand for trucking services increases with state income growth, and decreases as fuel prices rise and are passed on to consumers. The trucking demand forecast equation is:

Truck VMT Growth = 1.5(% CA Personal Income Growth) - 0.015*(% Diesel Price Changes)*

This is based on a regression analysis done on California truck vehicle miles travelled from 1974 to 1992. The equation states that truck vehicle miles travelled (VMT) grows at 1.5 times the rate of growth for California's personal income, holding diesel prices constant, and that a 10 percent rise in the diesel fuel price, either at the pump or indirectly through increased regulatory compliance costs, decreases VMT by 1.5 percent.[*] As demand for trucking services rises, new trucks are added to the fleet by dividing the increment in VMT by the average annual VMT for a new truck.

Table B-2 shows the projected cost patterns for complying with the M6 and proposed M7 measures. The low and high cost ranges reflect the assumptions discussed in the Appendix A and in Section 4.3. The projections also reflect the assumption that truck fleet

[*]While this model is rudimentary, it reflects the realistic economic assumption that increased costs will lead to decreased use of trucking. The assumption that demand will remain the same in the face of increased costs is neither theoretically sound nor empirically substantiated.

owners begin accumulating the required additional capital to meet the standard before the measures are actually adopted.*

*This assumption is based on the economic theory of "rational expectations" which is the basis for the work done by 1995 Nobel Prize Laureate Dr. Robert Lucas at the University of Chicago.

Table B-2

Proposed SIP: Heavy Duty Diesel Truck Costs for Emission Reductions

	M6:2004-2g/bhp-hr		Alternative M7: 2004-2007: Fleets 1g/bhp-hr					
	Low Cost	High Cost	Low Cost			High Cost		
Year	Total	Total	Trucks	Infrastructure	Total	Trucks	Infrastructure	Total
1994	$43.4	$150.6	($33.5)	$2.8	($30.7)	$16.2	$6.9	$23.1
1995	$55.3	$185.4	($36.2)	$2.9	($33.3)	$16.6	$7.4	$24.0
1996	$57.0	$196.6	($40.4)	$3.3	($37.2)	$18.3	$8.2	$26.5
1997	$59.3	$207.7	($46.0)	$3.7	($42.3)	$20.0	$9.2	$29.3
1998	$62.5	$221.1	($51.3)	$4.0	($47.2)	$21.1	$10.1	$31.2
1999	$66.7	$237.7	($55.3)	$4.3	($51.0)	$22.0	$10.8	$32.9
2000	$71.7	$256.7	($62.6)	$4.7	($57.8)	$21.7	$11.9	$33.6
2001	$77.8	$278.8	($65.8)	$5.6	($60.2)	$29.6	$14.0	$43.6
2002	$84.4	$302.7	($74.2)	$6.0	($68.2)	$29.2	$15.0	$44.2
2003	$91.5	$328.5	($82.4)	$6.5	($75.9)	$29.5	$16.3	$45.7
2004	$101.4	$359.0	($90.8)	$7.0	($83.7)	$30.3	$17.6	$47.9
2005	$123.0	$424.4	($99.3)	$7.6	($91.7)	$31.5	$19.1	$50.6
2006	$133.2	$471.0	($108.7)	$8.4	($100.4)	$34.3	$21.0	$55.3
2007	$144.1	$517.2	($120.4)	$9.3	($111.1)	$37.3	$23.3	$60.6
2008	$155.6	$563.5	($135.7)	$10.2	($125.5)	$36.9	$25.6	$62.5
2009	$168.5	$613.8	($151.1)	$11.0	($140.1)	$34.6	$27.7	$62.3
2010	$182.3	$667.0	($166.6)	$11.9	($154.7)	$33.3	$29.9	$63.1

Notes:

Proposed M5 not included because independent analysis concluded M5 was infeasible as designed.

All emission reductions included in M6, lagged for implementation 2 years later.

Differences in Low Cost and High Cost Scenarios: CEC low and high fuel price forecasts, RD&D expenditures on new trucks, engine fuel economy.

Infrastructure Scenarios: $350,000 to $600,000 per refueling location for natural gas-fueled trucks in urban fleets.

B.3 Locomotives

The cost estimates for controlling emissions from locomotives are detailed in Table B-3, *Locomotives: LNG/SCR Cost*. The table shows the cost estimates for producing LNG fuel instate, and the costs of converting line-haul and short-haul locomotives to LNG with SCR controls based on the EFEE study for the CARB.[6] The table compares diesel and LNG fuel costs, determines annual capital recovery requirements, and adds the costs for maintaining a California-only fleet calculated by EFEE. The total NOx reductions identified by EFEE in this study is virtually identical to those estimated in the SIP, indicating the correspondence between the two studies.

Table B-3 Locomotives: LNG/SCR Costs				
			Scenarios	
	Diesel Base Case	EFEE Inc Forecast	Low Cost 2010	High Cost 2010
LNG Production (1)				
Gas Feedstock $MM/Yr		$3.376	$3.342	$8.491
$/MMBtu		$2.000	$1.980	$5.030
Capital $MM/Yr		$0.953	$0.953	$0.953
Plant O&M $MM/Yr		$0.775	$0.775	$0.775
Total $MM/Yr		$5.104	$5.070	$10.219
Prod. LNG gal/yr		19.8	19.8	19.8
$/LNG gal		$0.258	*$0.256*	*$0.516*
Locomotives				
Line Haul				
Efficiency Loss (2)		3.0%	3.0%	3.0%
Diesel $/Gal	$0.70	$0.70	$0.73	$0.73
Diesel gal/yr	259,440	47,395	47,395	47,395
LNG gal/yr		386,720	386,720	386,720
Fuel Costs $/yr	$181,608	$132,866	$133,625	$234,180
LNG Conversion $ (3)		$566,054	$566,054	$566,054
Interest Rate		8%	8%	12%
Capital & O&M $/Yr		$121,358	$121,358	$137,183
Net Cost $/Yr		$72,617	$65,614	$181,993
NOx Rdtns T/Yr (4)		57	57	57
Cost/NOx Ton		$1,283	$1,159	$3,215
Calif Locomotives		633	633	633
Total Cost-Line Haul		$46	$42	$115
Short Haul (5)				
Diesel gal/yr	104,135	35,009	35,009	35,009
LNG gal/yr		121,396	121,396	121,396
Capital & O&M $/Yr		$82,654	$82,654	$100,783
Net Cost $/Yr		$65,560	$63,285	$112,979
NOx Rdtns T/Yr (5)		23	23	23
Cost/NOx Ton		$2,850	$2,752	$4,912
Calif Locomotives		254	254	254
Total $MM/Yr-Yard/SH		$17	$16	$29
Calif Only Fleet $MM/Yr (6)		$24.4	$24.4	$24.4
Total Cost $MM/Yr		$87	*$82*	*$168*
NOx Rdtns T/Yr (7)		35,103	35,103	35,103
NOx Rdtns TPD			96	96
Cost/NOx Ton		$2,480	*$2,337*	*$4,796*

Fuel Price Forecasts: CEC, "Fuels Report" Feb 94, High & Low Gas Prices.
References: EFEE Inc. "Controlling Locomotive Emissions in Calif." 10/93.
(1) - Table 33
(2) - Table 28
(3) - Table 42
(4) - Table 35
(5) - Table 43
(6) - Chap. 4
(7) - Table 52

Appendix B Endnotes

1. Rados, Dan (1994). *California Trucking Costs*. Personal Communication, October 27, West Sacramento, California, California Trucking Association.

2. Miaou, Shaw-Pin (1994). *U.S. Truck Scrappage Rates*. Memorandum, November 3, Oak Ridge, Tennessee, Center for Transportation Analysis, Energy Division, Oak Ridge National Laboratory.

3. Acurex Environmental Corporation (1993). *Technical Feasibility of Reducing NO_x and Particulate Emissions from Heavy-Duty Engines*. Final Report, Acurex Environmental Project 8450, Contract No. A132-085. Mountain View, California, Prepared for California Air Resources Board; Rados, op. cit. (1994).

4. California Energy Commission (1993). *Fuels Report*. Committee Final Draft, P300-93-019. Sacramento, California; Fore, Jim, Wendy Reid, et al. (1993); *Results of the Delphi VII Survey of Oil Price Forecasts*. P300-93-019B. Sacramento, California, California Energy Commission, Fuels Planning Office, California Energy Commission Staff (1993).

5. Lynch and Lee (1993)

6. Weaver, Christopher S. and Douglas B. McGregor (1993). *Controlling Locomotive Emissions in California: Technology, Cost-Effectiveness, and Regulatory Strategy*. Final Report, Contract No. A032-169. Sacramento, California, For California Air Resources Board by Engine, Fuel, and Emissions Engineering, Inc.

Appendix C

Current Consumer Product Regulations

C.1 Current Consumer Product Regulations

Existing CARB regulations cover 27 consumer product categories, as follows: antiperspirants and deodorants, air fresheners (includes 5 subcategories), automotive windshield washer fluids (includes 2 subcategories), bathroom and tile cleaners, engine degreasers, floor polishes/waxes (includes 3 subcategories), furniture maintenance products (includes 2 subcategories), general purpose cleaners, glass cleaners, hairsprays, hair styling gels, insect repellents, laundry prewash (includes 2 subcategories), nail polish removers, oven cleaners (includes 2 subcategories), and shaving creams. Current controls are expected to reduce VOC emissions from consumer products by approximately 30 percent relative to the 1990 emissions baseline. Under existing controls an upper limit VOC content by weight is stipulated for each product category. VOC content limits effective starting either in 1/1/93 (11 product categories) or 1/1/94 (15 product categories) have been identified. In addition, more restrictive future effective VOC content limits are specified for four product categories: (1) single-phase aerosol air fresheners (effective 1996); (2) engine degreasers (effective 1996); (3) hairsprays (effective 1998); and (4) nail polish removers (effective 1996). Future effective VOC content limits are "technology forcing" in that reformulation technology necessary to meet the standards may not yet be developed. It should be noted that current CARB regulations already include a VOC content standard for nail polish remover.

Current regulations also include two flexibility provisions intended to lower overall compliance costs. The first is the Innovative Products Provision, which allows the sale of a product which exceeds its VOC limit but, because of special formulation or packaging, can be shown to emit less VOCs than a representative product that meets the limit. The second is the Alternative Control Plan regulation, which establishes an emissions cap and emissions credit trading system for VOC regulated consumer products. Under the ACP, consumer product manufacturers would be able to place their product line, or a subset of it, under an emissions cap, such that *total* emissions do not exceed the emissions that would have resulted had the products been formulated to meet the VOC standards. Manufacturers could then reformulate ACP some products to exceed their VOC standards, so long as aggregate emissions remain at or below the emissions cap. Emission credits could be banked and applied to future emission deficits, or sold to other ACP manufacturers.

Appendix D

Additional Tables Detailing Measures Proposed by the U.S. EPA in the FIP and CARB Staff in the SIP

FIP/SIP COMPARISONS

Provision	FIP Requirements	SIP Requirements	Additional SIP Provisions
Heavy Duty Vehicles	$10,000 per ton NOx fees; potential one stop/ two stop limit for interstate trucks; 2.5/ 1.5 gram engines by 1999; engine rebuild/certification program.	2.0 b/bhp-hr engines by 2002, with proposed national adoption in 2004. Phase in 1.0 gram engine by 2007.	Replace 1.0 gram with accelerated turnover program.
Light Duty Vehicles	No out of state registration; parking cash-out; no drive days in Sacramento.	Fleet average of .026 grams per mile by 2005.	Supplement/replace .026 gram standard with accelerated turnover program.
Medium Duty Trucks	Strict LEV standards. In-use compliance program.	100 percent ULEVs by 2002.	
Buses	Emission standards.		
Off-Road Industrial Equipment Greater than 175 HP (SIP) Greater than 50 HP (FIP)	1.5 g/bhp NOx engine for SCAB and Ventura; 2.5 g/bhp for Sacto. by 1999; fleet averaging with emission fees; labeling requirements.	National 2.5 g/bhp-hr NOx engine standards by 2005.	Potential vehicle turnover acceleration.
Gas and LPG Equipment 25-175 HP		Closed-loop three-way catalyst systems	Nationwide standards accelerated vehicle turnover.
Motorcycles	Stringent exhaust standards by 1996.		
Pleasure Craft	Fleet averaging with NOx fees by 2004; 35 percent ROG emission reductions by 1998 through national standards.	Direct injection technology; adoption of FIP standards.	Potential vehicle turnover acceleration.

Marine Vessels	30 percent NOx emission reductions for ocean vessels; 65 percent reductions for non-ocean vessels. $10,000 per ton NOx fees.	District-level operational controls (e.g., shipping lane changes).	Potential for locally-imposed enforcement measures.
Locomotives	Locomotive fleet average in the SCAB of no more than 5.5 g/bhp-hr by 2007 and 4 g/bhp-hr in 2010. National standards by 2000.	Locomotive fleet average in the SCAB of no more than 5.5 g/bhp-hr by 2007 and 4 g/bhp-hr in 2010. Proposed national 4 gram standard by 2005.	
Aircraft	Declining bubble with NOx fees; intra-airline trading; take-off fees for private planes with reductions for clean engines. $10,000 per ton NOx fees.	Adoption of national standards.	More stringent national standards; Review of military's exempt status.
Consumer Products	Severely limit VOC content of individual products.	Additional 25 percent reduction in VOC emissions by 2005, chiefly by expanding scope of regulated products; 85 percent reduction in VOC emissions by 2010.	Unclear what mechanisms will be adopted to achieve emission reductions.
Aerosol Paints	Severely limits VOC content of individual products.	State law requires 25 percent VOC emission reduction by 1996, and a 60 percent reduction by 1999. Achieved through VOC content limits. Compliance schedule may be extended up to five years if technically necessary.	Some flexibility allowed related to compliance timing.
Pesticides	Achieve 20 to 40 percent VOC reduction by limits on VOC contents of individual chemicals.	Achieve 20 to 40 percent VOC reductions through current law efforts and reductions in VOC emissions.	Data needed for proposal implementation.

Architectural Coatings	National VOC restrictions.	District rules.
Military Bases	Emission bubble with declining cap; inter-base trading.	No requirements.
Stationary Sources	Declining emission cap, with area-specific NOx reductions.	

SIP #	Control Measure	Implemented	Reductions in 2010 NOx	ROG	Cost-Effectiveness/Ton Low	Mid	High	Annual $MM
	CARB Staff SIP Estimates							
	Mobile Source Measures							
M1	LDV LEV/ZEV 0.026 gpm	2004-2005	41	28		$2,500		$63
M2	MDT 100% ULEV	1998-2002	97	6		$2,500		$94
M3	HDGV CA Standards	1998-2002	12	0		$2,500		$11
M4	HDDT Incentives	1995-2003	7	0		NA		NA
M5	HDDT 2g/bhp-hr: CA	2002	129	7	$2,684		$3,659	$157
M6	HDDT 2g/bhp-hr: US	2004	37	2	$2,684		$3,659	$45
M7	HDDT 1g/bhp-hr: CA	2004-2007	22	0		NA		NA
M8	Off Road 2.5g/bhp-hr > 175hp: CA	2005	54	7		$1,310		$29
M9	Off Road 2.5g/bhp-hr < 175hp: US	2005	56	10		$2,440		$59
M10A	Ind. equip 3-way cat. Gasoline: CA	2000-2004	10	17		$393		$4
M10B	Ind. equip 3-way cat. LPG/CNG: CA	2000-2004	12	17		$416		$4
M11	Ind. equip 3-way catalyst: US	2000-2004	14	23		$405		$5
M12	Pleasure Craft: US	1998	0	75		$120		$3
M13	Marine Vessels: IMO	1998-2001	11	0	$264	$3,350	$4,187	$9
M14	Locomotives: US	2000-2010	95	0	$2,000		$4,000	$104
M15	Aircraft: US**	2003	12	10		$2,638		$21
	TOTAL: MOBILE SOURCES		609	202				$610
	Consumer Product Measures							
CP1	Consumer Prod.: Near/Mid-Term**	1999-2005		60		$2,100		$46
CP2	Aerosol Paint: Near/Mid-Term	1999-2005		20	$6,000		$10,000	$58
CP3	Long-Term: Group I**	>2000		15		$2,192		$12
CP4	Long-Term: Group II**	>2000		50		$2,082		$38
CP5	Long-Term: Group III**	>2000		100		$2,110		$77
	TOTAL: CONSUMER PRODUCTS			245				$231
	SIP TOTAL		609	447				$841

* - Bob Cross, CARB, Memo 10/20/94

** - Derived from CARB SIP V.II, Ch.III, Tables 3-4

Appendix E

A Case Study
on a Vehicle Scrappage Program
in Southern California

Case Study: Old Car Accelerated Retirement Programs

Description: Pre-1980 cars and light trucks emit, on a vehicle-miles-traveled (VMT) basis, significantly greater amounts of pollution than newer vehicles equipped with modern emission controls. These older cars and trucks can be significant contributors to mobile source pollution. Market-based programs designed to accelerate the retirement of these vehicles can reduce emissions from this source and may forestall or eliminate the need to implement more costly emission control alternatives in other sectors.

The model for the evaluation of such programs is presented in EPA's *Guidance for the Implementation of Accelerated Retirement of Vehicles Programs* (Feb. 1993). Older cars that meet program requirements are purchased and either destroyed or partially recycled. The quantity and longevity of emission reductions achieved by vehicle purchases are estimated based on (1) the pollution profiles of the scrapped vehicles, (2) the pollution profiles of likely replacement vehicles, (3) the estimated annual VMTs for the scrapped and replacement vehicles, and (4) the estimated remaining life of the scrapped vehicle had it not been purchased by the program. EPA provides a methodology to calculate values for these variables as well as default values for vehicle life expectancy (3 years) and the probability that the vehicle would have been scrapped during each year of the program had it not been purchased (20%).

Unocal's South Coast Recycled Auto Program (SCRAP) program, initiated in the Los Angeles area during 1990, was one of the first of its kind in the nation, purchasing more than 8,000 pre-1971 cars for $700 each. This program has received substantial publicity and wide-spread public support, and has proven to be a public relations boon for Unocal.[1] Unocal has plans to expand its scrapping efforts, and under South Coast Air Quality Management District (SCAQMD) Rule 1610, generate credits to offset stationary source emissions from some of its facilities in the region. According to Rule 1610, the accelerated retirement program must reduce emissions an additional 20% above what Unocal would have been required to do at the source. Even with this additional 20% requirement, Unocal believes scrapping old cars will be more cost effective than installing control equipment.

Advantages: Programs to accelerate the retirement of high emission cars and trucks have several advantages.

- First, as stated in Section 108(f) of the 1990 Clean Air Act (CAA), they are a legitimate market-based approach to facilitate attainment of required federal emission reduction milestones and goals.

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[1] "'The goodwill Unocal has engendered by its public lesson in environmental civics have burnished the impression that it is a very good corporate citizen,' said Bernard J. Picchi, managing director of Salomon Bros. in New York. 'That can only help the company in the long run, because firms that conduct their operations without being mindful of the environment are asking their shareholders to take a blind gamble.'" *Scrap fever: Unocal's effort to get jalopies off Southern California roads catches fire; widespread support show for smog-reducing program*. Los Angeles Business Journal, August 13, 1990 v13 n33 p4(1).

- Second, they can serve as part of either a mobile or stationary source emissions reduction program. A state or regional authority may implement an accelerated retirement program as part of its strategy to achieve mobile source emission reduction targets. Alternatively, an accelerated retirement program can be used to offset emissions from a stationary source or sources. Unocal's SCRAP program is an example of an accelerated retirement program to mitigate pollution from a stationary source.

- Third, participation by vehicle owners is voluntary and involves financial compensation. People with highly polluting vehicles are provided a targeted incentive to voluntarily remove them from operation.

- Fourth, the programs are pro-active. They allow firms to initiate measures to control pollution rather than simply respond to mandates.

- Fifth, by adding to the mix of control alternatives for stationary sources, accelerated retirement programs provide additional flexibility in obtaining least-cost emission control measures. They offer one more step away from the costly "one-size-fits-all" approach to pollution control.

Limitations: For either mobile or stationary source emission reduction, the bottom line test for an accelerated retirement program is its cost-effectiveness in achieving a stated reduction in emissions for some specified period of time as compared to other alternatives.[2] There are several important considerations that may limit the cost-effectiveness of an accelerated retirement program. Unless the cost-effectiveness analysis takes these into account, program costs may be grossly understated and the program will appear better than it really is.

- First, an accelerated retirement program does not create a permanent reduction in emissions in the same way as would a more traditional control technology such as a stack scrubber. Had the vehicles not been purchased, they would have "died" of natural causes eventually, and emissions would be reduced of their own accord. Related to this is the observation that as things get old, they tend to slow down. Annual VMTs for older cars generally do not remain constant but decline as the vehicles approach the end of their useful lives. Both of these factors must be taken into account by a cost-effectiveness analysis. This is particularly important if the achieved reductions are offsetting stationary source emissions. The offsets should be in effect only as long as the vehicles would have remained in operation and the offsets should decline in relation to the decline in VMTs that would have occurred. The shorter this period and/or the greater the decline in VMTs, the less likely an accelerated retirement program will be cost-effective compared

[2] Emission reductions from market-based strategies – such as accelerated retirement – that are to be included as part of a CAA State Implementation Plan must be "quantifiable, enforceable, surplus to other Federal and State requirements, permanent within the time frame specified by the program, and consistent with all other statutory and Federal regulatory requirements." (EPA 1993) Therefore, a program meeting these requirements would be desirable if it can be shown to be more cost-effective than its alternatives. In the context of CAA mandates, a full cost-benefit analysis would be unnecessary.

to other alternatives. Based on national fleet data, EPA estimates that vehicles most likely to participate in such programs have, on average, three years of useful life remaining. The decline in VMTs during these years can be estimated with EPA's MOBILE model.

- Second, emission reduction estimates should be adjusted to account for the probability that a participating vehicle would have been retired anyway sometime during the duration of the program had it not participated. While the average life expectancy of a participating vehicle may be three years, there is a significant probability that the life of any given participant would have been less than average. Based on national fleet data, EPA estimates a 20% annual scrapage rate. Thus, if 100 vehicles were purchased and the program lasted three years, emission reductions would be calculated for 100 vehicles in the first year, 80 in the second, and 64 in the third.[3]

- Third, emission reductions from the removal of old cars and trucks will be partially offset by emissions from the vehicles that replace them. How much less pollution these vehicles will create, however, is uncertain for two reasons. First, it is uncertain how participants will replace these vehicles. Some participants may purchase new or newer vehicles; some may rely more on mass transit or ride-sharing; and some may purchase an equally or even worse polluting vehicle. This is an empirical question for which data does not yet exist to answer. According to EPA guidelines, a reasonable approximation for the net reduction in emissions per VMT is the emissions per VMT for the scrapped vehicles less the fleet average emissions per VMT. Second, it is uncertain whether participant VMTs will increase, decrease, or stay the same after they sell their old car. EPA guidelines suggest the assumption that VMTs remain constant be made. A survey conducted by Resources for the Future (RFF) of participants of a Delaware scrapping program suggests this to be reasonable.

- Fourth, it is reasonable to expect that a program offering to purchase old vehicles might result in "negative" recruitment. Owners of vehicles with the least desirable characteristics from the viewpoint of emission reduction -- such as vehicles that would be junked within one or two years, or vehicles that are seldom used -- would realize the most benefit and be the most likely to participate. On the other hand, due to data limitations, emission reduction estimates will most likely be based on the average characteristics of the eligible population of vehicles. It also is possible that a regularly repeated accelerated retirement program may induce people to continue to use their older cars longer than otherwise, knowing that they will be able to sell them to the program. The RFF study of the Delaware program found the potential magnitude of these biases significant, and noted the need for continued monitoring and data collection to ensure the program is achieving its expected results.

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[3] By the same logic, there is also the probability that a participating vehicle would have lived longer than average. EPA does not factor the probability of this event into its program guidelines.

- Fifth, there may be significant diseconomies of scale associated with accelerated retirement programs. To date, only small scale pilot programs have been tried. Moving from a small to large scale may increase the cost per unit of pollutant beyond that suggested by the pilot studies. For example, in its study of the Delaware program, RFF estimated that to scale-up the program from approximately 2% of the pre-1980 fleet to 30% would increase the average cost per ton of hydrocarbon reductions by 40%, from $5,370/ton to $7,509/ton.

Appendix F

Description of How the REMI Model Works

F.1 Introduction

REMI provides standard and customized dynamic economic models to government and industry for forecasting and policy analysis. The antecedents of the company are the Treyz-Friedlaender-Stevens regional model developed for the National Academy of Sciences, and the Massachusetts Economic Policy Analysis model developed by Dr. George Treyz in the early 1980s. Dr. Treyz is founder and president of REMI, as well as Professor of Economics at the University of Massachusetts.

F.2 Type and Use of Model

REMI's standard model is called the REMI EDFS-53 model, which stands for Economic and Demographic Forecasting and Simulation Model. It has 53 industrial sectors (approximately equivalent to the two-digit SIC level of industry groupings) and 202 age/sex demographic cohorts. The model produces year-by-year projections and is supported by a historical data base for every county in the country going back to 1969. Three variants of the model are also available: the REMI FS-53 model, which excludes the demographic component, and the FS-14 models, one with and one without demographics. The 14-sector model is roughly equivalent to the one-digit SIC level of industrial aggregation. A 466-sector input-output model can be conjoined to the REMI models for carrying out detailed inter-industry impact analyses, and the firm also offers an ancillary program that generates occupational forecasts for 585 occupational categories. The models can be applied to any single or multiple-county grouping in the United States, and may be constructed for a single area or several interlinked areas to show trade movements among them.

REMI models are in use throughout the United States for such purposes as planning economic and transportation development by state agencies, evaluating the effects of tax and environmental policies on industries and areas, and analyzing rates and charges for use of natural resources and energy. REMI provides the basis for much of the economic impact modeling conducted by the South Coast Air Quality Management District. Models may be purchased for indefinite use, with the company providing unlimited consulting and upgrading support, or they may be rented for a specific time or specific project. The models run on IBM-compatible PCs, for which all programs and data are supplied on floppy disks, backed by an extensive user manual and model documentation. REMI will also produce one-time, quick turnaround simulations or forecasts for any subnational area.

F.3 Data Requirements

The REMI models require the user to specify the direct effects of a policy that would alter industry costs. For example, if the policy to be tested is the implications of a proposal to reduce statewide carbon dioxide (CO2) emissions by 20 percent in ten years, the model user must specific the cost implications of this policy in a form the model can accomodate. These costs could be expressed in terms of changes in wage levels, energy costs, taxes, or other production inputs. The independent assumptions used to calculate the costs to be fed into the model are of great importance in determining ultimate model outcomes.

All other data is supplied by the model's data base (although provision is made for the user to adjust the values of the control forecast's variables that are used to distinguish the local study area's characteristics vis-a-vis the national economy). As an example of how a policy impact analysis would be run, consider the case of a legislative proposal to require industrial dischargers to upgrade the technology for treating waste water before discharge to the waters of the state or to a publicly-owned treatment system as a condition for renewal of a National Pollution Discharge Elimination System (NPDES) permit. The REMI model requires the user to estimate the annualized capital and operating costs to achieve the incremental improvement, including breaking them down between in-state and out-of-state labor and non-labor costs and, preferably, also disaggregating the in-state costs by industry group supplying inputs to the technical upgrade. The REMI model has a wide spectrum of labor and non-labor cost variables in its structure that can be modified to reflect the direct cost effects of the policy.

F.4 Data Outputs and Format

Once the changes to the direct effect policy variables ("POLVARS" as they are called in the model) have been input, the model initiates a sequence of iterative calculations in which changes in factor costs set off compensatory adjustments in supply and demand for labor, goods and services throughout the study area economy (all superimposed on an underlying "without disturbance" control forecast based on the area's long-term demographic and economic trends). A report is then generated that compares the "with" versus the "without policy" forecasts of all the demographic and economic variables in the model on a year by year basis for as long as two decades into the future, depending on the user's analysis horizon. Particular interest would be focused on trends in values of real output and employment in industries directly affected by the proposed policy, to see whether they advanced or declined relative to their paths in the control (without policy) forecast. In all, the REMI FS-53 model produces up to 47 tables of economic variables at various levels of summarization and detail.

As was noted earlier, the REMI models are available in a 53-sector format or a 14- sector format, with or without a demographic module. The demographic module is of particular interest to local and regional governments concerned about in- and out- migration trends that development programs or tax policies might stimulate. The 14-sector model is useful for general regional impact analysis where broad industry groupings are appropriate indicators of policy effects. The 53-sector model provides much greater discrimination of impacts, particularly when it is conjoined with the 466-sector input-output model to show inter-industry impacts. The I-O model's inter-industry transactions coefficients are updated periodically on the basis of analysis of regional industrial trade trends.

F.5 Strengths, Weaknesses and Usefulness

REMI is essentially a modified "shift-share" model, in which economic activity is allowed to shift between regions depending on relative production costs and other factors. That said, the

REMI model is probably the most comprehensive and robust of *available* economic modeling techniques for conducting regional economic policy impact analysis. It has the best developed methodology for considering variations in factor costs and projecting out the shifts in economic and demographic trends that occur as a local economy attempts to reestablish an equilibrium following some policy change. The breadth of the REMI model's industrial sectoring and associated policy variables for labor and non-labor costs allow considerable specificity in assessing impacts on manufacturing and other industrial activities.

The principal weakness of the REMI model is that it uses national forecasts of future growth or decline to drive its local forecasts. It therefore cannot project turning points in the business cycle independently of the national forecast. This is not a *major* drawback of the model, however, since the objective of the modeling is to discern how a regional industry might fare versus without some policy action, assuming that no major national disturbances would otherwise occur. The REMI model attempts to mitigate this problem by using national forecasts prepared by the U.S. Bureau of Labor Statistics, which break the control projections down among major industry groups, each with its own growth trajectory and technology evolution. The model also estimates shifts in competitive positions of each industry in a given region compared to that industry elsewhere in the country. These adjustments avoid the problem of conventional input-output models that have to assume that production and cost relationships among industries remain relatively fixed over time.

References

1. Glen Weisbrod, Cambridge Systematics, (1990). "REMI and I-O Models Compared," *Information Update* (brochure), Amhurst, Massachusetts, Summer.

2. Regional Economic Models, Inc., (1990). REMI (brochure). Amhurst, Massachusetts, 1990.

3. Treyz, George I, *et al.*, (1990). "Regional Modeling: A Systematic Approach to Economic Forecasting and Policy Analysis." Draft text, Amhurst, Massachusetts.

4. ________________, (1990). "The REMI Economic-Demographic Forecasting and Simulation Model." Working Paper. Amhurst, Massachusetts.