CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD

Peer Review Comments and Responses

Initial Statement of Reasons and Supporting Appendices for the Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles

September 2004

Summary of Document

This document presents comments provided as part of the University of California peer review of the June 14, 2004 draft version of Initial Statement of Reasons (ISOR) and supporting appendices for the Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles and staff responses to those comments. In addition to providing peer reviewer comments and staff responses related to the June 14, 2004 ISOR, an addendum is also included as part of this package. The addendum includes additional peer reviewer comments and staff responses based on consideration by the peer reviewers of: 1) staff responses to peer reviewer comments on the June 14, 2004 draft ISOR; and 2) the August 6, 2004 ISOR, associated appendices and addendum.

The six peer reviewers identified below focused their respective reviews on elements of the staff report related to their areas of expertise, with all aspects of the report being reviewed by at least one peer reviewer. With respect to their review, all six peer reviewers concluded the following regarding the staff analysis and conclusions:

<u>No reviewer found that ARB had failed to demonstrate that a scientific portion of the proposed rule was based upon sound scientific knowledge, methods, and practices.</u>

As can be seen from the peer reviewer comments and staff responses presented in this document, the peer reviewers provide several comments to further strengthen the staff analysis. Many of the responses discuss how the draft June 14, 2004 ISOR was revised to reflect the comments. Therefore, in many cases the reader is referred to changes that are reflected in the August 6, 2004 ISOR.

The peer reviewers as well as the area that their review considered are as follows:

Review of Technology Assessment:

- **Robert F. Sawyer**, Ph.D., Professor in the Graduate School, Department of Mechanical Engineering, UC Berkeley

Review of the Emissions Characterization:

- **Joseph Norbeck**, Ph.D., Yeager Families Professor of Engineering, Director, Center for Environmental Research and Technology, Bourns College of Engineering, UC Riverside

Review of Climate Change Science:

- **Michael J. Prather**, Ph.D., Fred Kavli Chair and Professor, Department of Earth System Science, UC Irvine

Review of Economic Analysis:

- **Imran Currim**, Ph.D., Professor of Marketing, Graduate School of Management, UC Irvine

- **Michael Hanemann**, Ph.D., Chancellor's Professor of Agricultural and Resource Economics and Goldman School of Public Policy, UC Berkeley

- **Christopher R. Knittel**, Ph.D., Assistant Professor of Economics, UC Davis

Table of Contents

Peer Reviews
Technology Assessment, Emissions Characterization, and Climate Change Science

The following three peer reviews were submitted by the scientists as indicated below. Based on their expertise, they focused on different aspects of the report as follows:

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- **Robert F. Sawyer**, Ph.D., Professor in the Graduate School, Department of Mechanical Engineering, UC Berkeley

Review of the Emissions Characterization:

- **Joseph Norbeck**, Ph.D., Yeager Families Professor of Engineering, Director, Center for Environmental Research and Technology, Bourns College of Engineering, UC Riverside

Review of Climate Change Science:

- **Michael J. Prather**, Ph.D., Fred Kavli Chair and Professor, Department of Earth System Science, UC Irvine

Comments Submitted by:

STAFF PROPOSAL REGARDING THE MAXIMUM FEASIBLE AND COST-EFFECTIVE REDUCTION OF GREENHOUSE GAS EMISSIONS FROM MOTOR VEHICLES

(Dated: June 14, 2004)

Prepared by

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15 July 2004

MAJOR CONCLUSIONS AND RECOMMENDATIONS

1) The staff proposal lays out a sound rationale that the technology exists, or can be developed, and can be put into production to provide substantial greenhouse gas emissions reduction for California vehicles within the next ten years.

2) The methodology by which the drive train technology for personal motor vehicles is assessed and CO_2 emissions estimated is sound and the results reliable and useful for regulatory decision making.

3) The magnitude of greenhouse gas reductions called for in the proposed regulations is reasonable. The schedule of their implementation is realizable. The analysis of cost effectiveness is sound, within the uncertainties of predicting the future price of motor fuel.

4) The staff proposal is deficient in several areas that do not impact on the broad conclusions above. Attention to the following topics and issues would strengthen the staff proposal:

    a. The Federal Test Procedure and Highway Cycles, as the regulatory test for CO_2 emissions, are seriously deficient.
    b. The treatment and analysis of the role of diesel technology is deficient.
    c. Indirect emissions from air conditioning should not be separated from the regulation of exhaust emissions.
    d. The analysis of alternative fuels and their role in reducing greenhouse gas emissions needs to be made more transparent.
    e. Maintenance costs need to be included in the lifetime cost effectiveness assessment.
    f. The impact of the large uncertainty in the cost of motor fuels upon cost effectiveness needs to be presented by including a range of fuel costs.

5) Conditions on alternative compliance strategies are unnecessarily restrictive, especially that projects are limited 1) to 2009 and later model year vehicles and 2) to alternative fuels.

Response: Staff responses to the above observations are provided in the form of responses to the detailed comments appearing throughout the remainder of this document.

BACKGROUND

This is one of three independent peer reviews provided on the staff of the Air Resources Board proposal regarding the maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles.

These reviews are prepared under Interagency Agreement #98-004-TO-73, between the Regents of the University of California and the California Environmental Protection Agency, the California Air Resources Board (ARB). In addition to the staff proposal, dated June 14, 2004, this review also draws upon other staff documents and other background documents, specifically:

Air Resources Board, *Draft Technology and Cost Assessment for Proposed Regulations to Reduce Vehicle Climate Change Emissions Pursuant to Assembly Bill 1493*. April 1, 2004, including Appendices A-C.

Northeast States Center for a Clean Air Future (NESCCAF), 2004. *Reducing*
Greenhouse Gases from Light-Duty Vehicles. Interim Report.
http://bronze.nescaum.org/committees/mobile/rpt040316ghglightduty.pdf.

Bedsworth, L.W., 2004. *Climate Control--Global Warming Solutions for California Cars*. Union of Concerned Scientists.

California Energy Commission (CEC), 2003. *Integrated Energy Policy Report.*

California Energy Commission (CEC), 2003. *Transportation Fuels, Technologies, and Infrastructure Assessment Report,* Prepared in support of the Integrated Energy
Policy Report Proceeding, (02-IEP-01), July 2003.

Weiss, M.A., Heywood, J.B., Shafer, A., and Natarajan, V.K., 2003. Comparative Assessment of Fuel Cell Cars. MIT LFFE 2003-001-RP.

National Research Council, 2002. *Effectiveness and Impact of Corporate Average Fuel Economy (CAFÉ) Standards.* Board on Energy and Environmental Systems, Transportation Research Board.

The Task Order anticipated that a Technical Support Document (TSD) would accompany the Draft Staff Report. No such document was available at the time of this review. Also not available for review was a report by TIAX, LLL on the analysis of the greenhouse gas benefits of alternative fuel vehicles, cited but not referenced in the Staff Report. Also unavailable were the reports probably prepared by AVL List Gmbh (AVL), Martec, and Meszler Engineering Services in support of the NESCCAF analysis (the NESCCAF report cites the work but does not cite any such reports so they may not be publicly available).

As directed by the ARB staff by emails on 22 June 2004 and 25 June 2004, this review focuses on Chapters 5 (Maximum Feasible and Cost

Effective Technologies), 6 (Climate Change Emission Standards), and 8 (Cost Effectiveness) of the staff proposal.

REVIEW

MODELLING ESTIMATION OF CO_2 REDUCTION FROM VARIOUS TECHNOLOGIES

The staff's CO_2 reduction estimates come, with some slight modifications, from the study published by the Northeast States Center for a Clean Air Future entitled "*Interim Report, Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles*". This report, in turn draws primarily upon the simulation model AVL-CRUISE to predict CO_2 emissions from current and future vehicles that incorporate a variety of engine and drive train technologies. The model has been validated against current technology vehicles and shown to estimate CO_2 emissions, criteria pollutant emissions, and vehicle performance well. Confidence in the model's ability to predict the performance of advanced technology vehicles generally would be enhanced by validation against current advanced technology vehicles, for example, the Toyota Prius. The model does not assess potential CO_2 emissions reductions from weight reduction, aerodynamic drag reduction, tire rolling resistance reduction, or advanced lubricants. Therefore, these approaches for meeting the proposed CO_2 emissions standards are available to manufacturers in addition to the engine and drive train improvements that provide the basis for the staff proposal. Within the limitations described above, the CO_2 emissions prediction model is judged appropriate and state-of-the-art as used in the development of the staff proposal.

TECHNOLOGY ASSESSMENT, ESTIMATE OF EMISSIONS REDUCTIONS, AND PROPOSED STANDARDS

The technology assessment is comprehensive and consistent with other studies of CO_2 reduction (or fuel economy improvement) strategies for motor vehicles. Only the treatment of diesel technology, discussed in more detail below, is considered deficient. The methodology for estimating the magnitude of obtainable reductions is sound and contains a margin of compliance in that applicable technologies other than drive-train improvements are not included. The proposed CO_2 emissions standards and the schedule for their implementation are consistent with the current state of technology development and ability of the industry to put the new technology into production.

ADEQUACY OF EPA FTP AND HWY CYCLES TO REPRESENT ACTUAL CALIFORNIA VEHICLE CO2 EMISSIONS

Since manufacturers will design vehicles to meet the standards, it is important that the test cycle represent actual use. For regulatory

convenience the staff proposes to use EPA Federal Test Procedure and Highway Cycles, currently employed to establish compliance with hydrocarbon, carbon monoxide, oxides of nitrogen, and particulate emission standards. These driving cycles are also used in the AVL-CRUISE modeling. They do not include high accelerations, high speeds, road grade, wind effects, and air conditioning operation. (The staff proposes to treat indirect, load related, air conditioner emissions separately from exhaust emissions. Discussion of this issue appears later.) The highest load operating conditions, which correspond to the highest CO_2 emissions rates, are not represented in the test cycles. There is no assurance that vehicles developed to meet required emissions reductions during the Federal Test Procedure and Highway Cycles will provide the same emissions reductions in actual use. Deactivating or detuning of CO_2 reducing technologies during operating conditions outside of the test cycle is a major potential problem.

Some technologies or combinations of technologies may not provide the same CO_2 reduction at high power operation as during the test cycles. This possibility should be examined using the AVL-CRUISE model to study operation over high power cycles. Experimental testing of current advanced technology vehicles or prototype advanced technology vehicles could also provide valuable information on this issue.

Response: Staff acknowledges that better test cycles for evaluating real-world CO_2 emissions could be developed, but given the constraint of completing a rulemaking by January 2005, it was necessary to limit the scope of staff's development efforts. Further, industry already performs the prescribed tests on large numbers of vehicles each year to demonstrate compliance with criteria pollutant requirements in the current Low Emission Vehicle program, and staff wanted to take advantage of the current testing rather than require large amounts of additional testing for measuring CO_2 emissions. It should be possible, however, to investigate development of an improved test cycle when staff works with industry and other interested parties in developing a proper CO_2 emission test that fully accounts for real-world air conditioning system performance. As part of such an effort existing as well as new cycles would be expected to be considered.

DIESEL

There appears to have been a selection bias against diesels in the technology selection of the NESCCAF analysis. No diesels appear as near term (2009) options. High-speed direct injection (HSDI) diesel technology is widely produced and sold in a range of vehicles. The only question about 2009 is whether the NO_x emission standard can be met. Toyota has demonstrated a light duty HSDI vehicle that comes close to meeting the standards. California should not assume that the automobile

industry will not pursue the diesel option, in any or all of the vehicle classes.

Even in the single appearance of high-speed direct injection diesel technology (mid-term, 2013-2015, for small trucks) the comparison is not equitable. The gasoline technology is *ehCVA, GDI-S, AMT, EPS, ImpAlt* and the diesel technology is *HSDI, AMT, EPS, ImpAlt*. The *ehCVA* (electrohydraulic camless valve actuation) technology also has already been demonstrated on diesel engines and is proposed for use on diesels.

Response: In addition to these peer review comments, staff received similar sentiments from Bosch. Accordingly, staff expanded on the positive developments of diesel combustion and clean-up technology on p. 53 of the August 6, 2004 ISOR. Recent progress in homogeneous change compression ignition engine development could permit much less aftertreatment technology than with current diesel engines. At present, the incremental cost of diesel engines when combined with significant aftertreatment costs make them a more expensive approach for reducing CO_2 equivalent emissions than other technologies, but with further improvements, diesel could be more favorable. It should be cautioned, though, that modeling of these advanced combustion diesel engines predicted higher CO_2 emissions than current high speed diesels. Dr. Sawyer also commented that camless valve actuation has been applied to prototype diesels, so that it should also be an element of another mid-term high speed diesel package to make the comparison of diesels with other mid-term packages more attractive. Staff actually did consider this possibility and contacted International to assess their results from prototype vehicles containing engines with camless valve actuation. International indicated that while the engines performed well with such systems, they did not yield a significant reduction in criteria pollutants or particulate matter (which was their target), nor in CO_2 emissions. The latter was somewhat expected since camless valve actuation mostly reduces pumping losses from conventional gasoline engines whereas diesels already have low pumping losses. Also, please see later response regarding the carbon content of diesel fuel.

AIR CONDITIONING

The estimate of the magnitude of direct emissions from air conditioning systems is reasonable, but necessarily of greater uncertainty that the tailpipe emissions of climate change gases. The proposed design based standard is reasonable, but not ideal. Its implementation needs to be backed and checked with experimental measurements.

The decision to treat CO2 emissions resulting from added engine load due to air conditioning (referred to as indirect emissions) separately from exhaust emissions creates problems. There is no incentive to improve

glazing, or reduce solar load using other approaches, in the current plan. The effect of the interaction of vehicle load and air conditioning load appears to be lost. Again, if this regulatory approach is implemented, it must be checked with on vehicle measurements.

Response: Staff agrees with the comment. Unfortunately, development of suitable test procedures and an environmental chamber that properly simulates outdoor solar and other temperature related effects for testing actual vehicle air conditioning systems remain years away. However, the ISOR indicates that continued work in developing this approach is a longer- term goal. With successful development of this concept, indirect CO_2 emissions due to air conditioning use could be measured along with improvements in vehicle and powertrain technologies from the same test. Therefore, improvements in solar control glass, sealing techniques, glass angles, reflective paints, etc. are not accounted for in the current treatment of air conditioning credits, but future regulatory and test procedure development will be aimed at inclusion of these design elements.

ALTERNATIVE FUEL VEHICLES

The treatment of alternative fuel vehicles as reported in the staff proposal is superficial. It apparently draws from a report prepared by TIAX, LLC, which is not listed in the references and may not be publicly available. The development of the results presented in Table 5.4-1 is difficult to reconstruct. The conclusions are neither obvious nor consistent with other analyses.

Alternative fuels offer substantial CO_2 reductions and are applicable in current technology vehicles. There is no reason to limit their application as alternative strategies to 2009 and later model-year vehicles.

Response: The staff analysis of alternative fueled vehicles is derived in large part from work done by TIAX, LLC. Their report entitled "Climate Friendly Alternative Fuel Vehicle Analysis" is a comprehensive analysis of the costs and benefits of those alternative fueled vehicles with the potential for volume production in the 2009 timeframe. The report is now referenced and available for public review. While not as extensive as the analysis of conventional vehicles, this work provides a general sense of the potential for alternative fueled vehicles to meet the proposed regulations in a cost-effective manner.

All cost estimates presented in Table 5.4-1 include an evaluation of the incremental retail costs associated with equipping vehicles to operate on alternative fuels and the costs of the alternative fuels for 2009. This analysis does not include transitional costs such as vehicle development, certification or fuel transition infrastructure costs. The analysis is consistent with the methodology to determine net present value for

conventional vehicles as described in Section 5.4. Using this approach, only those technologies with a payback period of l6 years or less are shown in black.

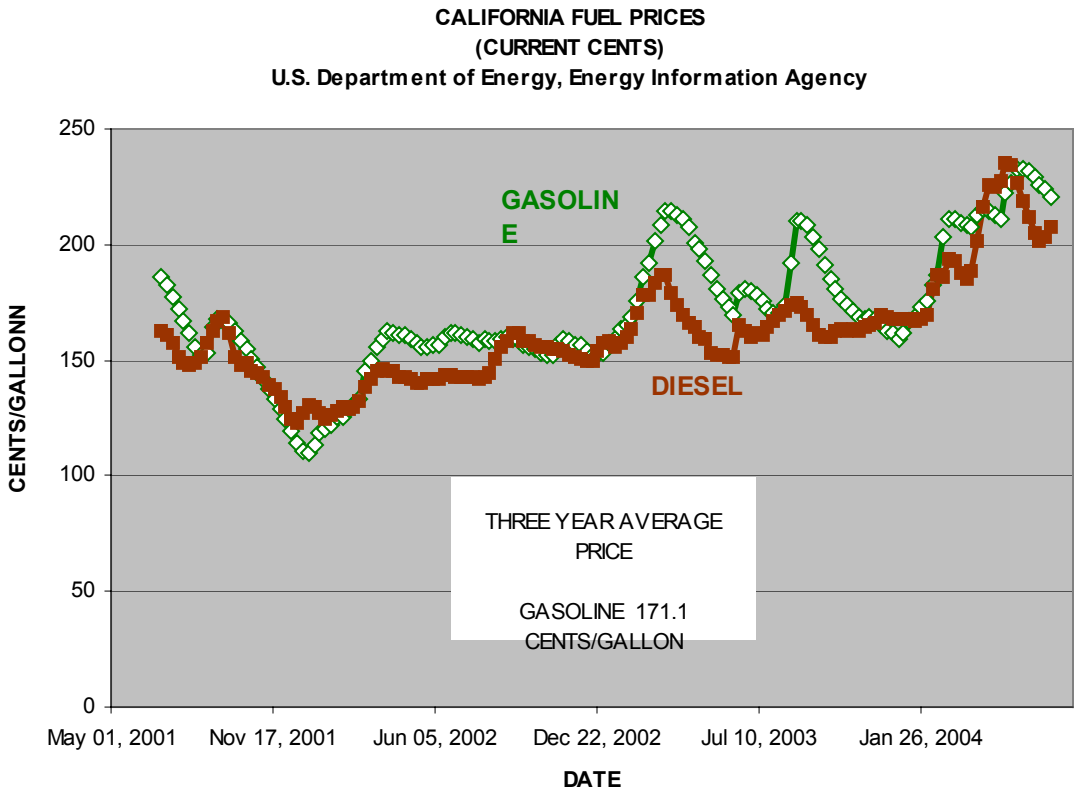
MAINTENANCE COSTS

Differential maintenance costs among the various technologies appear not to have been considered. Over the 16-year lifetime assumed for the staff proposal, these may be substantial for some of the technologies. For example, the hybrid electric vehicles will probably require at least one battery replacement during their lifetime.

Response: Staff responded to this suggestion by including a new section discussing the implications of the newer technology in terms of maintenance costs on p. 86-87 of the August 6, 2004 version of the ISOR. Staff concluded that advanced conventional engine technologies could be implemented with the same level of durability as current engines although there may be some maintenance issues associated with hybrids and advanced diesel aftertreatment. More evaluation is needed regarding the long-term performance of the latter technologies.

UNCERTAINTIES IN THE PRICE OF MOTOR FUELS

The price of motor fuels is a major uncertainty. The effect of this uncertainty should be analyzed and presented through considering a range of fuel prices, not the single prices of $1.74 per gallon for gasoline and $1.73 for diesel. Even these numbers could not be verified. They do not appear in the cited document. Analysis of U.S. Department of Energy, Energy Information Agency data gives the average price for the period July 2001-June 2004 of California reformulated regular gasoline as $1.711 cents per gallon and for California #2 diesel as $1.615 (based on pump price, not inflation adjusted). The three-year average price difference of 9.6 cents per gallon between gasoline and diesel, if correct, may be significant to the staff analyses. (See figure at the end of this review.)



The reduction in the demand for fuels for personal vehicles from that which would occur without the regulations will necessarily impact the price of fuels. This saving should be part of the analysis.

Response: ARB staff used California Energy Commission fuel price data (instead of US DOE EIA data) to be consistent with all other state environment and economic assessments. This is stated in Section 5.4 (p. 100):

> "For gasoline and diesel fuels, the prices are inflation adjusted from the values in the California Energy Commission (CEC) *Integrated Energy Policy Report* (CEC, 2004). For gasoline the price is $1.74 per gallon, and the diesel price is $1.73 per gallon (in 2004 dollars). These values are roughly consistent with the 3-yr historical California fuel prices."

Staff conducted an analysis that investigates higher fuel prices of around $2.30 per gallon. Ultimately this uncertainty analysis will not affect the standard-setting in any way because the technologies used to determine maximum feasible emission reductions were already deemed economical and cost effective with payback periods well below the average lifetime of vehicles.

There would be a high level of uncertainty involved with quantifying the secondary effects of the reduction in demand for petroleum products, thereby reducing the market cost of the fuel, and in turn resulting in further increased cost savings to vehicle owner-operators. In light of these uncertainties, ARB staff did not undertake this task and conservatively assumed that the market price did not fluctuate with respect to the difference in demand caused by the proposed regulation.

COST-EFFECTIVENESS AND BREAK-EVEN LINES

The derivation of the cost-effectiveness lines of Figures 5-6 to 5-10 is difficult to reconstruct. This may be explained in Appendix D of the April 1, 2004 draft technology and cost assessment, which is not available on the ARB website with the parent document and other appendices. Figure 5-9 is of particular concern because it contains non-gasoline technology. Since the fuel values in \$/kg CO_2 reduced are different for gasoline and diesel, there should be two different cost-effectiveness "break even" lines on this figure. (Even though the per gallon price of gasoline and diesel was taken to be very nearly equal, perhaps incorrectly, the value of the CO_2 reduced is significantly different for the two fuels).

Response: It is true that technically the "break even" lines of Figures 5-6 to 5-10 would be altered slightly if derived specifically for the diesel modeling runs than for the lines that are currently presented for gasoline-utilizing vehicles. However, this approach was used for two reasons. (1) For simplicity - to avoid having either overly complex figures with two slightly different "break even" lines or having five separate figures for a few diesel modeling runs that were ultimately inconsequential in the overall analysis. (2) Because the break-even results are consistent either way. That is, diesel runs ("HSDI") in the figures that were above the break even lines have payback periods that were greater than the expected vehicle lifetimes (16 years for passenger cars, 19 years for category 2 light-duty trucks), and those below the lines have payback periods less than the expected vehicle lifetimes. The actual payback periods are shown in summary Table 5.3-8.

ALTERNATIVE METHODS OF COMPLIANCE

AB 1493 requires that alternative methods of compliance.

"(3) Provide flexibility, to the maximum extent feasible consistent with this section, in the means by which a person subject to the regulations adopted pursuant to subdivision (a) may comply with the regulations. That flexibility shall include, but is not limited to, authorization for a person to use alternative methods of compliance with the regulations. In complying with this paragraph, the state board shall ensure that any alternative

methods for compliance achieve the equivalent, or greater, reduction in emissions of greenhouse gases as the emission standards contained in the regulations. In providing compliance flexibility pursuant to this paragraph, the state board may not impose any mandatory trip reduction measure or land use restriction."

Several aspects of the ARB staff proposal seem unnecessarily restrictive. Specifically, the requirement that alternative compliance is limited to vehicles regulated under AB1493, model years 2009 and later. This will exclude an opportunity to reduce GHG emissions from the broader motor vehicle fleet. For example, California has a large fleet of flexible fuel vehicles that could, but do not, burn E-85 fuel. Similarly, restricting projects to reduce personal vehicle GHG reductions to alternative fuels is unnecessarily constraining. For example, improved tires, lubricants, or maintenance could be an effective CO_2 reduction strategy.

Response: The methods of alternative compliance proposed by staff provide manufacturers with additional flexibility for meeting the climate change regulations, yet safeguard against strategies that do not meet the primary goal of the legislation which is to achieve the maximum feasible reduction of climate change emissions from passenger vehicles and light-duty trucks and other vehicles used for noncommercial personal transportation in California.

Under staff's approach, a project that ensures and documents the use of an alternative, lower GHG-emitting fuel in bi-fuel, flex fuel, or grid connected hybrid vehicles would be eligible for alternative compliance credits. Therefore, flexible fuel vehicles that have a documented use of E-85 fuel may earn alternative compliance credit.

Because reductions would need to meet the same criteria used for other emission reduction credit programs (i.e., the reductions must be real, quantifiable, permanent and enforceable), many other types of GHG reduction strategies such as improved tires, lubricants, or maintenance as currently implemented (i.e., beyond the manufacturers' control) would not qualify.

In addition, allowing additional project types to receive alternative compliance credits, such as stationary source projects or projects involving a broader scope of vehicles may undercut the goals of legislation and therefore are not permitted.

TECHNOLOGY FORCING

The staff proposal for implementing the alternative methods of compliance of the bill invokes the concept that the implementation of AB1493 should

be “technology forcing.” This is a concept that has served the state of California well in the institution of motor vehicle pollutant emission standards. While the term “technology forcing” is not mentioned in AB1493, the bill does point to technological solutions for reducing green house gas emissions.

The proposed CO_2 emission standard is fleet averaged within two vehicle size groups with possible transfer of credit from one group to the other possible. The earlier motor vehicle pollutant emission standards applied to every-vehicle. The response of the industry is likely to be different and widespread application of advanced technology not assured. The early response of the manufacturers may be to comply by shifting product line, downsizing, or shifting vehicles from the smaller to the larger category. Manufacturers will probably put new technology in the largest vehicles since reductions in CO_2 emissions from the largest vehicles are more valuable (greater magnitude) than from smaller vehicles. This is the more cost-effective approach for both the manufacturer and customer. Table 6.2-3 presents a different scenario and may need rethinking. Preferential application of CO_2 emissions reduction technology to the larger vehicles could have the perverse effect of making the larger vehicles more attractive to the customer.

Response: In order to maintain market share, large volume manufacturers must remain competitive in all segments of the market, so that shifting market share or emphasis to meet the requirements may not be a real option for them. Further, technology improvements yielded fewer reductions for the heaviest vehicles on a percentage basis, so that focusing on the larger vehicles may not be significantly more attractive from a cost standpoint as a strategy for meeting the proposed requirements. For the largest “domestic” manufacturers with full product lines, at least, the stringency of the standards does not support placing new technology only on a segment of the product mix, as nearly all of the models would need to be significantly upgraded from a technology standpoint to meet the standards.

DETAILED COMMENTS

The following comments treat some of the details of the report, including possible typographical or other relatively minor errors.

Executive Summary, Environmental Impacts, par 2:

The statement “With the regulation 2020 emissions will be lower than today’s, and 2030 will be approximately the same, as shown below.” does not agree with the figure to which it refers. The figure shows 2020 and 2030 emissions that are higher than those in 2004.

Response: The revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons) has been corrected to more precisely describe the future trend in the CO_2 emission inventory.

2 Climate Change Overview, par 1:

The statement "Climate research scientists are also suggesting that climate change in recent decades may have been mainly caused by non-CO_2 green houses gases, particularly tropospheric ozone, methane, hydrofluorcarbons, and black carbon particles." either needs to be referenced or prefaced by a qualifying "Some".

Response: The revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons) reflects the comment.

2.1 Climate Change Overview, par 1:

The statement "The climate change we are seeing today, however, differs from previous climate change in both its rate and magnitude." is not precise as greater extremes of climate change have occurred in the past.

Response: The climate change discussion in the revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons) reflects the comment.

2.5 Indicators of Climate Change in California: Fig. 2-4:

Just how is the April to July Sacramento River runoff defined? If it is the flow of the Sacramento River then the decreasing fraction of the total occurring in April to July could be from changes in upstream storage or use rather than a climate change effect. This should be made clear.

Response: The climate change discussion in the revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons) reflects the comment.

5.1.B Research Method Overview

The Tiax, LLC analysis of greenhouse gas benefits of alternative fuel vehicles is cited but does not appear in the references.

Response: The report, entitled "Climate Friendly Alternative Fuel Vehicle Analysis," is now referenced and available for public review.

5.2 Technology Assessment, Par. 2, sen. 2:

"…small trucks, and light trucks." should probably read "…small trucks, and large trucks."

Response: The revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons) reflects the comment.

5.2.A.1 Carbon Dioxide Reduction Technologies, *Gasoline Direct Injection,* sen. 1:

The condition "where air is already compressed" is not strictly true. The important feature of these engines is that the fuel is injected directly into the cylinder. This can occur during the air intake stroke or early in the compression stroke, certainly well before full compression.

Response: The revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons) reflects the comment.

5.2.A.1 Carbon Dioxide Reduction Technologies, *Diesel Fuel,* sen. 4:

Should be changed from "Diesel vehicles are becoming popular in Europe…" to "Diesel vehicles are popular in Europe…"

Response: The revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons) reflects the comment.

5.2.A.2 Paragraph following Table 5.2-8, sen. 3:

The statement explaining the apparent failure of high speed direct injection diesel engines to significantly lower CO_2 emissions, "This outcome is due largely to diesel fuel's relatively high carbon content that results in relative higher CO_2 emissions." does not capture CO_2 producing potential of diesel versus gasoline completely. The carbon content of diesel is only about 0.4% greater than for gasoline, on a gm C/gm fuel basis. This would lead to about 0.4% more CO_2 emissions for a diesel, on an equal mass of fuel consumed basis. Since gasoline has a higher calorific value (MJ/Kg) than diesel (about 6%), on an equal calorific value basis diesel fuel would produce about 7% more CO_2. It might be better to state: "This outcome is due in part to diesel fuel's greater CO_2 production when compared to gasoline on an equal calorific value basis."

Response: In reviewing the modeling calculations, it appears that the apparent lack of a clear advantage for diesel is due primarily to its higher density as compared to gasoline, so that a gallon of diesel has a greater mass of carbon in it than gasoline. This results in about 14% higher CO_2

production from a gallon of diesel fuel. This was noted on page 67 of the ISOR.

5.2.D Exhaust Catalyst Improvement, par. 1, sen. 2:

"N_2O" for N_20"

Response: The revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons) reflects the comment.

5.3.A Engine, Drivetrain, and Hybrid-Electric Vehicle Technologies, Table 5.3-1:

The cost of intake cam phasing and exhaust cam phasing is stated to be lower for the large truck category than for the small truck category. This seems unlikely, perhaps the numbers are reversed. The relative costs of the "Diesel—HSDI" and "Diesel—Advanced Multi-Mode" do not seem right. Advanced multi-mode diesel engines are generally derivatives of HSDI engines with added sensors and controllers. One would expect the costs of the two technologies to be similar or higher for the diesel—advanced multi-mode. If the high cost anticipates the cost of added exhaust treatment, this should be stated. Also, for these technologies it does not seem correct that the large car costs are lower than the small care costs. Other features of this table require explanation, for example, the constant cost across vehicle class of a number of the technologies whose cost should increase with vehicle size.

Response: Dr Sawyer thought it was incongruous for the large truck to have lower cost for coupled cam phasers than small trucks. However, the cost for coupled cam phasers was lower for the large truck category because the representative large truck that was chosen had a conventional overhead valve configuration whereas the representative small truck had an overhead camshaft arrangement. Thus, for an overhead valve configuration, there is only one camshaft for the engine, and a single phaser is used to vary both the intake and exhaust valve events simultaneously. In the case of the overhead camshaft configuration, there is a separate set of camshafts for each bank of the engine, thus requiring two coupled phasers to accomplish variable valve timing, thereby increasing cost for the small truck category.

It was suggested that the cost of current high speed diesel technology should have been lower than diesel advanced multi-mode since the latter technology uses a more sophisticated control system. As was noted in the question, however, there is greater cost of exhaust cleanup for the conventional diesel than the advanced multi mode configuration, and this is the source for the increase in cost for the current diesel system.

As was also noted, there are often lower costs for improving climate change emissions for large cars relative to small cars. This is, however, correct because it was assumed that current V6 engines could switch to a 5-cylinder inline engine configuration equipped it with a turbocharger and retain the same level of performance. Thus, there would be a cost savings from dropping one cylinder from the engine. For a small 4 cylinder engine, equipping with a turbocharger would not permit going to a 3 cylinder configuration to save costs due to engine roughness and other considerations.

It was also noted that some technologies should have experienced increased costs as vehicle size increased, but for some technologies, this was not the case. This observation was primarily evident in addressing integrated starter generators since a common size was used across the board. Staff agrees that it would have been more correct to model larger units as vehicle size increased, but the NESCCAF study upon which we relied only included evaluation of one size.

Comments Submitted by:

Peer Review
of
ARB Staff Proposal
Regarding the Maximum Feasibility
and
Cost Effective Reduction of Greenhouse Gas
Emissions from Motor Vehicles
AB 1493

By
Joseph M. Norbeck

Background

This report contains a review of the ARB's Staff Proposal of the Technical Document in support of AB1493. Comments will be provided on the entire document provided, but the main focus will be on Chapters 6 & 7 and the associated appendices.

- The document provides a reasonably clear assessment of Staff's proposal and the methodologies suggested for implementation of the proposed regulation. ARB Staff should be complimented on the completeness of the document although Chapter 6 is very difficult to follow. Part of the problem is the long discussion related to A/C. I suggest you move it to the Appendix and the Chapter can flow better. Actually, the impact of the other components is very small but much of the document is spent on developing a very complicated empirical recipe for species that are contributing a small percentage of the total impact.

  Reponses: Staff acknowledges there is considerable information in this section and tried to improve the flow of the discussion on air conditioning. Because of the breadth of interest and participation from numerous parties on the air conditioning issue, and because it breaks new ground in terms of accounting for air conditioning effects on vehicle emissions, staff concluded that a reasonable overview of the methods and accounting for the results was fairly important. Considerable information on air conditioning was included in the Technical Support Document, however.

- I read Chapter 6 several times and still do not understand the actual "certification" procedure for each vehicle/engine family. In particular, a fleet average of the entire PC/LDT1 (and LDT2) fleets is used to calculate the base-year emissions as shown in Figures 6.1-1 and 6.1-2, but it appears that each engine family in the PC/LDT1 category must meet the PC/LDT1 emission standards given in Table 6.1-5 and an overall fleet

average (as is done in CAFÉ) will not be used. Let me give an example from some of the emission data we have in our lab. We recently tested two 2001 model year vehicles: vehicle (1) is 3750 lbs.; 3.8L engine and the FTP CO2 emissions are 425 g/mi; vehicle (2) is 2750 lbs; 2.0L engine and the FTP CO2 emissions are 317g/mi. According to what I understand from Chapter 6, both vehicles must meet the 315 CO2-equivalent standard in 2009 with no averaging over the manufacturer's fleet. What happens if the 3.8L engine vehicle implements the technology package as suggested and does not get to 315g/mi? Please clarify. Is the manufacturer able to average their entire fleet or not? If not, why not? That is how the base line was established?

Response: Tables 6.1-1 and 6.1-2 were utilized only for determining the standard that industry would be required to meet, using Daimler Chrysler because it was judged to have the most difficult time meeting the requirements. Please note that in the final ISOR, staff concluded that General Motors would have the most difficult task in meeting the standards since its average fleet weight is the highest of any manufacturer and switched to them as the basis of the standards). Once the standards' were set as summarized in Table 6.1-5, manufacturers would need to meet them separately for PC/LDT1 and LDT2 by averaging CO_2 - equivalent emissions of their vehicles in each category. In other words, manufacturers would need to meet two separate greenhouse gas fleet average standards. Manufacturers can use credits in one category to offset debits incurred in the other.

- In reference to what was discussed above, I believe that is a potential loop-hole in the overall proposal. What is going to prevent a manufacturer from producing more LDT2 vehicles (SUVs, etc.) at the "expense" of PCs. This has happened in California and has resulted in increase fuel usage/per person in the last 5-8 years. There has to be some lid on the overall fleet average CO2 levels that was not discussed in the document. In other words, what will prevent the manufacturer of increasing the weight of the high-end vehicles to beyond 3750 lbs?

  Response: Staff concurs there is potential for placing more small trucks into the large truck T2 category through upweighting, but there are relatively few such vehicles in the T1 category, and making them heavier would make them less desirable to consumers. There still is the possibility of some cars being redefined as T2s, and staff is investigating methods to minimize such occurrences through definitional changes or other means.

- The mathematical procedures used to calculate the overall impact of the various chemical components for the equivalent CO2 emission rate are straightforward and appear to be appropriate.

  Response: none required.

- There is an error in Table 6.2.4. Toyota's base year sales weighted CO2 should be 301 not 201.

  Response: The correction is reflected in the August 6, 2004 version of the ISOR.

- The measurement procedure (driving cycles) and weighting factors for the two cycles used to determine the carbon dioxide emissions and the ultimate reductions proposed in the regulation need to be justified further. The comparison with CALCARS was not that good (17%) for Model year 2000. And, I would like to see more detail into how Table 4 in the Appendix was developed.

  Response: The emission factors used in EMFAC are derived from emissions tests based on the FTP and UC driving cycles. The UC, or Unified Cycle, was developed to more closely reflect real world driving conditions and includes higher speeds and harder accelerations than the FTP. The emissions factors are adjusted in EMFAC to reflect real world driving conditions by applying correction factors for a wide range of vehicle speeds, varying ambient air temperatures, varying fuel composition, use of air conditioning, varying soak time between starts, relative humidity, and altitude.

  The attached document "Comparison of CEC and ARB Gasoline Consumption Estimates" describes the analysis on which Table 4 is based. We recognize the difference between CALCARS and EMFAC for MY 2000, but some level of inconsistency in a given model year does not mean the models are inconsistent overall. We believe the models give good agreement for the entire light and medium duty fleet in the three calendar years we compared. The fleet-wide difference is 6% in CY 2000, 4% in CY 2002 and only 1% in CY 2010.

- I am not sure that the FTP and the UC cycles represent real-world CO2 emissions or real world fuel-economy. With the introduction of more hybrid-electric vehicles in the fleet in the future this may become much more important and needs to be looked into further. Each hybrid will operate differently based on the energy management system used. There may be very different CO2 emissions that may not be represented by the proposed driving cycles. (My own opinion.)

  Response: We address the FTP and UC in the response to the previous comment on driving cycles. We agree that existing driving cycles may not be adequate for assessing emissions from all types of hybrid vehicles but at this time we have no way of projecting impacts of these hybrids until they are introduced to the fleet and tested.

- The conversion factors shown in Table 2 are only valid to 0.1g/mi. Methane and TOG emissions for the fleet of vehicles being introduced into California are considerably below that value. The difference is not that great but the functions are probably not appropriate.

  Response: Adequate speciation data were not available for THC emission rates below 0.1 gm/mile. In the absence of such data, the EMFAC model uses the 0.1 gm/mile conversion factors and applies them using the ratio of the actual THC rate to the 0.1 gm/mile rate. For THC rates below 0.1 gm/mile, the methane rate will also be lower, however methane expressed as a fraction of THC will remain constant. Given that methane is a small part of total climate change emissions, the impact of this approximation should be slight.

- ARB Staff needs to consider how to handle electric vehicles and hydrogen powered vehicles. First, the up-stream emissions need to be better defined. More importantly we have found that the electric vehicles and hydrogen vehicles vary considerably in energy efficiency. One size does not fit all. There need to be consideration for estimating BTU/mile for these vehicles since you do not have carbon as a marker. This requires modification of the test equipment and a better understanding of the up-stream emissions specific to California.

  Response: The report now references that the fuel cycle emissions for hydrogen and electricity were provided by TIAX LLC using the GREET emissions model. These estimates had been adjusted to reflect California's unique fuel cycle emission issues. ARB staff agrees that these emissions will vary with vehicle size and energy use and has established separate values for hydrogen internal combustion engine vehicles and hydrogen fuel cell vehicles. Staff has also emphasized in the final report that a manufacturer may petition the Executive Officer to adjust the values presented as necessary. The proposed values represent a starting point for determining the relative benefit that these vehicles will receive.

- How will N_2O be measured during the certification process?

  Response: Staff has indicated that credit will automatically be provided for manufacturers accepting staff's default value without measurement. Should manufacturers believe they could achieve further reductions, they could use FTIR or equivalent methods to measure N2O.

- I think the Staff should provide a little more detail on the data they used to classify the normal, moderate, high, very high, and super CO2 emitters referenced on page 6 of the Appendix. Are we suggesting measuring CO2 as part of SMOG CHECK?

Response: No, we are not suggesting that CO_2 be measured as part of Smog Check. Emission regimes are used in the EMFAC model to reflect the increase in emissions that result from the deterioration of emission control systems as a vehicle ages and accumulates mileage. However, the percentage change in CO_2 is not as great as for the criteria pollutants. While all regimes are used for the criteria pollutants, only a "Normal' regime is used for CO_2.

- Although the data is provided in Table 7.1-1 it would be helpful to provide a summary of the percentage impact of all of the species to the CO2-equivalent inventory. A figure in the executive summary would be helpful.

  Response: We have added the percentage impacts to the table. A copy of the revised table is attached. This does help clarify the relative emissions impacts, but we were unable to incorporate this revision in time for the final ISOR.

- The relationship between ozone and ambient temperature is reasonably well understood (Fig. 2.6). The impact of the proposed regulation on ozone will most likely be extremely small and is not quantified to any real extent in the document. There has been a recent publication on this issue. However, the Fig. 2.6 shows a ozone over a large temperature range and really overstates the impact. Please consider adding more technical backup in Chapter 2.

  Response: Staff agree that additional discussion of several topics, including the relationship between ozone and temperature, would be informative. However, the focus of the ISOR is on the proposed regulation and the supporting technologies. As a result, Chapter 2 is intended to provide a condensed overview of climate change science.

- Did Staff investigate basing the emissions on BTU use/mile and then converting to carbon dioxide equivalent based on the fuel used?

  Response: Staff needed to estimate emissions not only for CO_2, but also methane, N_2O, and HFCs in support of developing this regulation. The EMFAC model is a proven emissions estimation tool that provides a consistent basis for estimating all of these emissions. The model not only directly estimates CO_2 and methane emissions based on in-use vehicle testing but also estimates oxides of nitrogen emissions (NOx) which are used in estimating N_2O emissions for the light duty fleet. Vehicle population data from EMFAC are also used to estimate the total HFC emissions.

  Gasoline consumption in EMFAC is estimated by carbon balance based on the emissions of hydrocarbons, CO and CO_2. We have found that this gives reasonable agreement with the gasoline usage reported by the

California Energy Commission's CALCARS model, which is based on fuel sales data from the state Board of Equalization.

- Why is the value for E85 (corn) negative in Table 6.4-1?

  Response: Ethanol produced from corn has a negative GHG ratio because the carbon emitted from the vehicle was recently removed from the atmosphere. The tailpipe CO_2 emissions from ethanol are about the same as those as a gasoline car on a per mile basis. The absorption of this short cycle carbon is treated as a credit towards the fuel cycle emissions.

- Please provide reference for how all of the values in Table 6.4-1 were determined. These values are highly uncertain and are changing continuously.

  Response: As now noted in the final staff report, the emission estimates are from TIAX, LLC using the GREET emissions model (developed by Argonne National Laboratory). The values for hydrogen assume a fuel usage of 32 miles per kilogram for an internal combustion engine vehicle and 45 miles per kilogram for a fuel cell vehicle (DOE Fuel Economy Guide). The production of hydrogen is assumed to be from on-site steam reformation which is consistent with the goals set forth by the California Hydrogen Economy Blueprint Plan for the 2009 timeframe. The hydrogen production emission estimate is also from TIAX, LLC.

Attachment

Comparison of CEC and ARB Gasoline Consumption Estimates

The Air Resources Board (ARB) and California Energy Commission (CEC) have each developed modeling tools to help analyze motor vehicle impacts in California. The ARB model, EMFAC2002, is used primarily to estimate motor vehicle emissions and activity. The CEC model, CALCARS, is used primarily to estimate motor vehicle activity and fuel usage. Since these models are used to support significant programs and policy decisions, it is important that these models provide consistent results. In this analysis, we are comparing each model's estimation of gasoline consumption for light and medium duty on-road vehicles.

Comparison of models

EMFAC2002 version 2.2 is the latest model that ARB uses to estimate emissions from on-road motor vehicles:

- Emissions are calculated using emission rates derived from in-use vehicle testing and estimated vehicle activity
- Vehicle population is derived from DMV data
- Vehicle miles traveled (VMT) are obtained primarily from local and regional transportation planning agencies
- Fuel consumption is calculated for each vehicle class by performing a carbon balance on tailpipe emissions to obtain fuel economy estimates, which are then combined with VMT
- Includes vehicle classes for passenger cars, trucks up through 33,000+ lbs. gross vehicle weight rating (GVWR), buses, motor homes, and motorcycles
- There is one vehicle class for passenger cars and seven classes for trucks based on GVWR ranges

CALCARS is the model used by CEC to estimate vehicle population, VMT, and fuel consumption for light and medium duty on-road motor vehicles:

- CALCARS uses survey data to estimate number and type of vehicles per household, how those vehicles are driven, and what type of replacement vehicles will be selected
- Vehicle population is derived from DMV data
- VMT is calculated based on the number of vehicles and mileage accrual rates that are obtained from survey data
- Fuel consumption is estimated using VMT for each vehicle class and the fuel economy (expressed in miles per gallon) for that vehicle class
- The calculated fuel consumption is adjusted to match fuel sales data from the Board of Equalization by adjusting mileage accrual rates
- Includes vehicle classes for passenger cars and trucks up to 10,000 lbs. GVWR

- There are six vehicle classes for passenger cars based on size (e.g., compact, midsize, large), seven classes for trucks up to 10,000 lbs. GVWR based on size and type (e.g. standard pickup, compact SUV, minivan), and additional classes that represent full hybrid versions

Results

A comparison was made of the statewide fuel consumption estimated by each model for calendar years 2000, 2002, and 2010. For each year the entire light /medium duty fleet (cars and trucks up to 10,000 lbs. GVWR) for all model years was compared. In addition, for calendar year 2002 a comparison was made of just the model year 2000 light/medium duty fleet. The results are summarized in the following table:

CALCARS and EMFAC Models
Comparison of Statewide Gasoline Usage
for Light/Medium Duty Vehicles up to 10,000 lbs. GVWR

	CY 2000 - All Model Years			
	Population	VMT (thousands)	Gasoline Usage (thousands)	Fuel Economy (miles/gallon)
CALCARS	22,221,899	274,123,488	13,195,044	20.77
EMFAC2002	20,722,051	268,103,450	14,001,659	19.15
	CY 2002 - All Model Years			
	Population	VMT (thousands)	Gasoline Usage (thousands)	Fuel Economy (miles/gallon)
CALCARS	22,968,011	284,943,255	13,712,599	20.78
EMFAC2002	21,623,367	277,490,155	14,236,332	19.49
	CY 2002 - Model Year 2000			
	Population	VMT (thousands)	Gasoline Usage (thousands)	Fuel Economy (miles/gallon)
CALCARS	2,063,810	26,987,207	1,307,277	20.64
EMFAC2002	1,422,101	22,460,275	1,119,689	20.06
	CY 2010 - All Model Years			
	Population	VMT (thousands)	Gasoline Usage (thousands)	Fuel Economy (miles/gallon)
CALCARS	26,558,471	336,611,159	16,289,082	20.66
EMFAC2002	25,590,172	323,583,450	16,205,796	19.97

Conclusions

The following table summarizes the percentage difference in gasoline consumption estimates between the models:

CALCARS and EMFAC Models Percent Difference in Gasoline Consumption			
	CY 2000	CY 2002	CY 2010
All Model Years	-6%	-4%	1%
Model Year 2000	--	17%	--

Based on this comparison:

- CALCARS and EMFAC give reasonable agreement when comparing gasoline consumption for the entire light/medium duty fleet
- There was a greater difference between CALCARS and EMFAC when comparing a specific model year gasoline consumption
- For both models VMT determines gasoline usage:
  - CALCARS calculates gasoline usage by combining VMT with fuel economy estimates developed from survey data
  - EMFAC calculates gasoline usage by combining VMT with fuel economy estimates obtained by carbon balance on CO_2, CO, and HC emissions
- VMT estimates used in CALCARS and EMFAC are derived using different methodologies and sources of data:
  - CALCARS VMT based on vehicle population and mileage accrual rates that are based on socioeconomic indicators identifying how different types of households drive their vehicles
  - EMFAC VMT based on estimates developed by local and regional transportation planning agencies using tools such as surveys, traffic counts, and modeling

– Table 7.1-1: Baseline Inventory for Light Duty Motor Vehicles

Calendar Year 2010 Emissions in Tons per Day[1]				
	CH_4	CO_2	N_2O	HFCs
PC/T1 (Passenger Cars and Trucks 0-3750 lb. LVW[2])	26	296,320	12	4
T2 (Trucks 3751 lb. LVW[2]- 8500 lb. GVWR[3])	11	120,760	8	1
Total Light Duty	**37**	**417,080**	**20**	**5**
% of CO_2 equivalent Emissions	**0.2%**	**97.0%**	**1.4%**	**1.5%**

Calendar Year 2020 Emissions in Tons per Day[1]				
	CH_4	CO_2	N_2O	HFCs
PC/T1 (Passenger Cars and Trucks 0-3750 lb. LVW[2])	12	341,640	7	5
T2 (Trucks 3751 lb. LVW[2] - 8500 lb. GVWR[3])	7	143,510	4	2
Total Light Duty	**19**	**485,150**	**11**	**7**
% of CO_2 equivalent Emissions	**0.1%**	**97.5%**	**0.7%**	**1.7%**

Calendar Year 2030 Emissions in Tons per Day[1]				
	CH_4	CO_2	N_2O	HFCs
PC/T1 (Passenger Cars and Trucks 0-3750 lb. LVW[2])	8	390,600	5	6
T2 (Trucks 3751 lb. LVW[2] - 8500 lb. GVWR[3])	5	171,670	4	2
Total Light Duty	**13**	**562,270**	**9**	**8**
% of CO_2 equivalent Emissions	**0.1%**	**97.7%**	**0.5%**	**1.8%**

[1] Annual average
[2] Loaded vehicle weight equals curb weight plus 300 lb.
[3] It is recognized that there are a few vehicle models over 8,500 lbs. gross vehicle weight rating (GVWR) that are used for noncommercial transportation and are thus subject to the climate change regulations. Likewise, there are some vehicles weighing less that 8,500 lbs. that are used in commercial service. It does not appear possible to accurately identify these two sets of vehicles from license registration records. Because both sets of vehicles make up a very small portion of the light duty fleet, we believe that no significant error is introduced by defining the inventory as all vehicles up to 8,500 lbs.

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UC Irvine peer review of

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD

STAFF PROPOSAL REGARDING THE MAXIMUM FEASIBLE AND COST-EFFECTIVE REDUCTION OF GREENHOUSE GAS EMISSIONS FROM MOTOR VEHICLES

June 14, 2004

This is an excellent, fair, and accurately written description of the importance of 21st century climate change to California and also of California's role in causing / mitigating this climate change. There is little doubt that climate change is happening today, that human-caused increases in the atmospheric abundance of greenhouse gases are a large cause of that change, and the 21st century climate change will be greater than that we have experienced in the 20th. Much of that projected climate change is as yet unrealized warming from the greenhouse gases in the atmosphere today. Nevertheless, actions taken to reduce greenhouse gases today can reduce the magnitude and rate of climate change this century.

My overall review is that the current draft is on the whole accurate and can stand as is, but I offer numerous clarifications as "tracked changes" in the following edits of the Exec Summary and Chapter 2. Parenthetical notes and explanations are in brackets [-]. The concluding section of Chapter 2 might be strengthened by use of two figures from the IPCC Synthesis Report (2001) and these are attached as .pdf files.

Michael Prather
13 July 2004

Response: Dr. Prather's comments on the June 14, 2004 draft ISOR were used to develop the August 6, 2004 version of the document. Given the detailed nature of Dr. Prather's comments (they are identified in the track changes function) and staff's concurrence on each point regarding the climate change discussion, the August 6, 2004 ISOR was revised. As a result of staff's concurrence and subsequent revisions to the report, point-by-point responses to Dr. Prather's comments and suggestions with respect to climate change are not provided. However, staff has provided responses to Dr. Prather's comments on the Executive Summary of the staff report.

EXECUTIVE SUMMARY

California has a long history of environmental leadership. This tradition of environmental leadership continues to this day. In 2002, recognizing that global warming would impose compelling and extraordinary impacts on California, the legislature adopted and the Governor signed AB 1493. That bill directs the California Air Resources Board (Board) to adopt regulations to achieve the maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles. This Draft Initial Statement of Reasons presents a preview of the staff proposal that will be considered by the Board at its September 2004 public hearing.

This document describes the conceptual outlines of the staff proposal, including the specific details of the proposed approach, its rationale, and an assessment of its environmental and economic consequences. The reader should bear in mind that this document is a draft. The various elements of the staff proposal as well as the methodology used to evaluate its environmental and economic impacts are all subject to change, due to work in progress as well as comments received from the public.

This draft does not include proposed regulatory language. Staff is in the process of developing specific regulatory language and will release a draft for public comment prior to the September hearing.

Climate Change Overview

The earth's climate has always changed, the paleo-record of the last million years shows large changes with the growth and retreat of the great ice sheets over the continents. Nevertheless, over the past century the northern hemisphere has warmed at a rate faster than any other time over the last millennium, and that change is ~~is changing~~ because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases (GHGs), primarily carbon dioxide (CO_2), methane, nitrous oxide, and hydrofluorocarbons. [Do you want to add that humans are also changing aerosol loading and tropospheric ozone on a global, or at least hemispheric scale here? this is supported by many pubs and the IPCC 2001]

The heat-trapping property of GHGs is undisputed. Although there is uncertainty about exactly how and when the earth's climate will respond to enhanced concentrations of GHGs, combining observations with climate models [!! we need a model to test with the observations] indicates that detectable changes are under way. These observed changes go beyond a global mean rise in temperature, including also ~~There most likely are and will continue to be~~ changes in ~~temperature and~~ precipitation, soil moisture, and sea level, all of which could have significant adverse effects on water resources, many ecological systems, as well as on human health and the economy.

Response: The revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons) reflects the comments in the previous two paragraphs.

California Actions to Address Climate Change

The State of California has traditionally been a pioneer in efforts to reduce air pollution, dating back to 1963 when the California New Motor Vehicle Pollution Control Board adopted the nation's first motor vehicle emission standards. California likewise has a long history of actions undertaken in response to the threat posed by climate change. Beginning with 1988 legislation that directed the California Energy Commission, in consultation with the Air Resources Board and other agencies, to study the implications of global warming on California's environment, economy, and water supply, and continuing on over the years through Governor Schwarzenegger's April 2004 Executive Order outlining his vision for the California Hydrogen Highway Network, California state government has consistently recognized the necessity for state action on climate change to protect California's interests. At the Air Resources Board, attention to the mechanisms and effects of climate change dates back to 1989, when staff first updated the Board on the emerging science.

Maximum Feasible and Cost-Effective Technologies

A key part of the staff's technical work is an assessment of technologies and fuels that can contribute to a reduction of climate change emissions in passenger vehicles from the 2009 model-year and beyond. The staff technology assessment reviews baseline vehicle attributes and their contribution to ~~atmospheric~~ climate change emissions, and evaluates technologies that have the potential to decrease these emissions. The technologies explored are currently available on vehicles in various forms, or have been demonstrated by auto companies and/or vehicle component suppliers in at least prototype form. The report then examines the lifetime cost of these technologies to vehicle owner-operators. This approach is consistent with the AB 1493 directive to require climate change reduction technologies that are economical to an owner or operator of a vehicle, taking into account the full life-cycle costs of a vehicle.

There are near-term, or off-the-shelf, technology packages in each of the vehicle classes evaluated (small and large car, minivan, small and large truck) that results in a reduction of CO_2 emissions of at least 15-20% from baseline 2009 values. [?? can you compare this with the US's Kyoto commitment of 7% reduction 2010 relative to 1990??]

Response: Though inclusion of the comparison may have provided additional perspective, it was considered supplemental and was therefore not included in an effort to maintain a streamlined Executive Summary.

Several technologies stood out as providing significant reductions in emissions at favorable costs. These include discrete variable valve lift, dual cam phasing,

turbocharging with engine downsizing, automated manual transmissions, and camless valve actuation. Potential improvements in the air conditioning system include an improved variable displacement compressor, reduced leakage systems, and the use of an alternative refrigerant (HFC-152a). Packages containing these and other technologies provided substantial emission reductions at prices that ranged from a saving to several hundreds of dollars. Nearly all technology combinations modeled provided reductions in lifetime operating costs that exceeded the retail price of the technology.

Climate Change Emission Standards

Vehicle climate change emissions comprise four main elements: (1) CO_2, CH_4 and N_2O emissions resulting directly from operation of the vehicle, (2) CO_2 emissions resulting from operating the air conditioning system (indirect AC emissions), (3) refrigerant emissions from the air conditioning system due to either leakage, losses during recharging, or release from scrappage of the vehicle at end of life (direct AC emissions, and (4) upstream emissions associated with the production of the fuel used by the vehicle. The climate change emission standard incorporates all of these elements.

Staff elected to incorporate the CO_2 equivalent emission standards into the current LEV program along with the other light and medium-duty automotive emission standards. Accordingly, there would be a CO_2 equivalent fleet average emission requirement for the passenger car/light-duty truck 1 (PC/LDT1) category and another for the light-duty truck 2 (LDT2) category, just as there are fleet average emission requirements for criteria pollutants for both categories of vehicles in the LEV program.

Determination of the specific climate change emission standards for each category involved several steps. First, the maximum feasible emission reductions were modeled for five vehicle types (small and large car, minivan, small and large truck) with various technology packages. These technology packages were then categorized with respect to their technology readiness (i.e. near-, mid-, or long-term). Secondly, manufacturer specific data was collected for the California fleet in order to evaluate individual manufacturer product mix. The emission standards for each category were then determined based on the manufacturer with the highest average weight vehicles (as opposed to the average of all the manufacturers) to ensure that all manufacturers can comply with the standards.

Staff proposes setting near-term standards, phased in from 2009 through 2011, and mid-term standards, phased in from 2012 through 2014. The proposed standards, expressed in terms of CO2 equivalent grams per mile, are as follows:

For the table below, could you explicitly give the current g/mile, or the recent trend in CO2-equiv g/mi ?? It would be interesting. I guess I could take 315 and divide by 0.70, but is that right? Recent trend to larger engines?

Response: Baseline 2002 CO_2 emission rates in California for the six largest vehicle manufacturers are listed in the table below. The data was derived from the Department of Motor Vehicles registration data for 2002 model year vehicles. The percent emission reductions in the staff report are relative to 2002 because of the uncertainty in predicting 2009 baseline emission rates. In general, one could assume that they would be the same for the two categories absent the regulation.

2002 California Baseline Emission Rates

		DC	Ford	GM	Honda	Nissan	Toyota	Weighted Average
Sales-averaged CO2 (g/mi)	PC/LDT1	346	334	318	282	305	301	312
	LDT2	451	445	459	379	447	422	443

Tier	Phase-in Year	CO_2-equivalent emission standard by vehicle category (g/mi)
		PC/LDT1 LDT2
Near-term	30% 2009	315 422
	60% 2010	284 385
	100% 2011	242 335
Mid-term	30% 2012	233 328
	60% 2013	223 321
	100% 2014	211 311

Staff estimates that the average fleetwide incremental cost of control to meet these standards, taking into account the phase-in of the standard and the specific starting point of the individual manufacturers, will be as follows: Thus when fully phased in the near term standards will result in an estimated average cost increase of $241 for PC/LDT1, and $326 for LDT2. The fully phased in mid term standards will result in an estimated average cost increase of $539 for PC/LDT1 and $851 for LDT2. The staff analysis concludes, however, that these increased costs will be more than offset by operating cost savings over the lifetime of the vehicle.

Since you talk about it above, please give the estimated cost savings over 3-yr? Over 10-yr? (Assume $2.25/gal) for each of these rows?

Response: The body of the staff report now includes the costs from a consumer's perspective (i.e., monthly cash flow) for both new and used vehicles with gasoline at both $1.74 and $2.30 per gallon.

Year			All major 6
2009	Near-term phase-in	PC/LDT1	$25
		LDT2	$69
2010		PC/LDT1	$96
		LDT2	$176
2011		PC/LDT1	$241
		LDT2	$326
2012	Mid-term phase-in	PC/LDT1	$294
		LDT2	$421
2013		PC/LDT1	$382
		LDT2	$584
2014		PC/LDT1	$539
		LDT2	$851

Looking at the cost of the technology on a per vehicle basis, staff estimates that applying the maximum feasible near term technology to an individual vehicle would cost an average of $328 for the PC/LDT1 category and $363 for the LDT2 category, compared to the 2009 baseline vehicle. The estimated average cost to apply the maximum feasible mid term technology is $1047 for PC/LDT1 and $1210 for LDT2. These costs are higher than the fleet average shown above because not all vehicles will need to be controlled to the maximum level. Rather, the proposed standard is set at a level that is feasible for the manufacturer in the worst starting position. Therefore the average cost across the fleet will be less than the maximum cost of the technology on a per vehicle basis.

The staff analysis concludes that these standards, when applied to the fleet of the “major six” automakers (GM, Ford, DaimlerChrysler, Toyota, Honda, Nissan), would result in the following emission reductions by year. The reductions needed by individual automakers will vary depending on their initial starting position.

Year			All major 6
2009	Near-term phase-in	PC/LDT1	-2.3%
		LDT2	-5.1%
2010		PC/LDT1	-8.8%
		LDT2	-13.1%
2011		PC/LDT1	-22.2%
		LDT2	-24.3%
2012	Mid-term phase-in	PC/LDT1	-25.3%
		LDT2	-25.9%
2013		PC/LDT1	-28.3%
		LDT2	-27.6%
2014		PC/LDT1	-32.3%
		LDT2	-29.8%

The proposed standards also address upstream emissions (emissions due to the production and transportation of the fuel used by the vehicle). Staff proposes to use the upstream emission levels for conventional fuel vehicles as a yardstick against which to compare the relative emissions of alternative fuel vehicles. This approach simplifies the regulatory treatment of gasoline vehicles, while at the

same time allowing for appropriate consideration of differences in upstream emissions from alternative fuel vehicles.

AB 1493 directs that emission reduction credits be granted for any reductions in greenhouse gas emissions achieved prior to the operative date of the regulations. ARB staff proposes that the baseline against which manufacturer emissions are measured should be the fully phased in near term standards, and that credit for early emission reductions should be available for model years 2000 through 2008. Thus under the staff early credit proposal, manufacturer fleet average emissions for model years 2000 through 2008 would be compared to the near term standards on a cumulative basis. Manufacturers that had cumulative emissions below the near term standards would earn credit.

AB 1493 also requires that the regulations "provide flexibility, to the maximum extent feasible consistent with this section, in the means by which a person subject to the regulations ... may comply with the regulations. That flexibility shall include, but is not limited to, authorization for a person to use alternative methods of compliance with the regulations." Thus the use of alternative compliance strategies must not undercut the primary purpose of the regulation, which is to achieve greenhouse gas reductions from motor vehicles. Accordingly, the ARB's alternative compliance program will be limited to the vehicles that are regulated through AB 1493, and their fuels. This is to ensure that the program does not dilute the technology-forcing nature of the regulation, since the goal is to reduce emissions from the vehicles themselves. The major features of the staff proposal are:

- Projects must be located in California to be eligible as alternative methods of compliance.
- Only companies regulated by AB 1493 (automakers) will be permitted to apply for alternative compliance credits.
- Only those vehicles regulated under AB 1493 are eligible for alternative compliance credits. This includes model year 2009 and later passenger vehicles and light-duty trucks and other vehicles used for noncommercial personal transportation in California.
- Staff proposes that eligible projects be limited to those that achieve greenhouse gas reductions through documented increased use of alternative fuels in eligible vehicles.

Environmental Impacts

Taking into account the penetration of 2009 and later vehicles meeting the new standard into the fleet, staff estimates that the proposed regulation will reduce climate change emissions by an estimated 85,900 CO_2 equivalent tons per day statewide in 2020 and by 143,300 CO_2 equivalent tons per day in 2030. This translates into a 17% overall reduction in climate changes emissions from the light duty fleet in 2020 and a 25% overall reduction in 2030.

Staff estimates that baseline emissions today (2004) are 386,600 CO_2 equivalent tons per day. With the regulation 2020 emissions will be lower than today's, and

2030 will be approximately the same, as shown below. [****Rewrite or fix figure below, I see that the 2020 tons/day are 410,000 vs. 390,000 'today', the 2020 is slightly lower than projected 2010 ??]

Response: The observation is correct. The referenced wording in the Executive Summary has been corrected revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons).

Motor Vehicle Greenhouse Gas Emissions

Cost Effectiveness

Typically, emission control regulations impose a cost. Cost effectiveness is a measure of the cost imposed per ton of reduction achieved (denoted in IPCC parlance as 1990 US$ per t C), and thus is a useful tool to compare various possible approaches. In this instance, however, AB 1493 requires that the regulations be economical to the consumer over the life cycle of the vehicle. Consistent with this direction, the technology packages that provide the basis for the standard result in operating cost savings that exceed the initial capital cost, resulting in a net savings to the consumer over the lifecycle of the vehicle. This translates to a "negative" cost effectiveness value (there is a cost savings per ton reduced). Thus staff estimates that the cost effectiveness of the staff proposal, in terms of dollars per ton of CO_2 equivalent emissions reduced, is -$143 in 2020 and -$136 in 2020. [<=== is this the difference between PC and LDT2 or over different years? is the savings over 1-3-20 yr? ***Also please be consistent with IPCC or other US govt. in $ per ton of C vs. CO2 – a factor of 44/12]

Response: The estimates provided are, for each calendar year, the ratio of the net annualized savings (or negative costs) to the emission reductions in tons per year. These numbers are shown as revised in Table 9.2-1 of the August 6 version of the ISOR. The table is revised further in the staff supplemental analysis, with similar results. We choose to represent emissions in terms of CO_2-equivalents as it places all of the climate change pollutants currently being considered on the same scale including N_2O and HFCs.

Economic Impacts

The climate change regulation may impact several sectors of the economy. The steps that manufacturers will need to take to comply with the regulatory standards are expected to lead to price increases for new vehicles. Many of the technological options that manufacturers choose to comply with the regulation are also expected to reduce operating costs. These two responses to the regulation have combined positive and negative impacts on California businesses and consumers. The vehicle price increase will be borne by purchasers and may negatively affect businesses. However, the operating cost

savings from the use of vehicles that comply with the regulation will positively impact consumers and most businesses. Based on the staff analysis, the net effect of the regulation on the economy is expected to be small but positive. The proposed climate change regulation is not expected to cause any significant adverse impact on the State's economy. It is very likely that savings from reduced vehicle operating costs would end up as expenditures for other goods and services. These expenditures would flow through the economy, causing expansion or creation of new businesses in several sectors. Staff's economic analysis shows that as the expenditures occur, jobs and personal income increase. There will not be any impacts on the ability of California business to compete with businesses in other states. State and local agencies will not be adversely impacted and are likely to realize a net reduction in their cost of fleet operations.

Impacts on Low Income and Minority Communities

The ARB has made the achievement of environmental justice an integral part of its activities. The Board approved Environmental Justice Policies and Actions (Policies) on December 13, 2001. These Policies establish a framework for incorporating environmental justice into the ARB's programs consistent with the directives of State law.

As the ARB developed the climate change regulations, staff worked closely with community leaders involved with environmental justice as well as with environmental and public health organizations to maintain an ongoing dialogue and thus successfully implement the ARB's environmental justice policies.

Staff has undertaken an evaluation to investigate if low-income and minority communities (communities) may be impacted disproportionately by the climate change regulation. The primary direct mechanism identified was the potential effect on used car prices. Because the vehicle price increases caused by the proposed regulation may, over time, increase the price of used vehicles that low-income households tend to purchase, the staff focused on analyzing the potential impacts of the vehicle price increase on low-income purchasers of used vehicles. The analysis showed that the expected impacts of any price increase are minor, and would be more than outweighed by a reduction in operating cost. Thus the proposed regulation should not have a significant impact on low-income purchasers of used vehicles.

Staff has not identified any mechanisms by which the climate change regulation would result in disproportionate impact on low income or minority communities

Other Considerations

Staff also is investigating several approaches that supplement the standard economic analysis. The methods used rely on recent tools and studies that provide additional insight into the potential impacts of the regulation. Using those tools and studies to investigate possible secondary impacts of the regulation, this

report presents additional perspectives on the potential impact of the proposed regulation on fleet mix, emissions, the State's economy, small businesses, and low-income households. The methods discussed are in the early stages of development relative to the standard analysis. As such, it is expected that these methods will be further refined.

The economic impact analysis is based on the staff assessment that the reduced vehicle operating cost resulting from the regulation will be sufficiently attractive to new car buyers to compensate for the vehicle price increase, which results in vehicle sales that are unchanged from the levels that would have been the case without the regulation. Staff also, however, assessed what the consequences would be if one assumes that the changes in vehicle price and other attributes do affect sales. Staff analyzed the potential effect of price and operating cost changes on sales, fleet size, and fleet age using a consumer choice model developed by University of California, Davis. The results show that the net result of increased new vehicle prices and lower operating costs is a tendency to increase sales in the near term, and slightly decrease sales in the longer term as the more stringent second step of the regulation is fully phased in.
Staff also evaluated potential adverse environmental impacts associated with increased VMT [spell out VMT here in exec. summary] due to lower operating costs. Our analysis indicates that the benefits of reduced climate change emission from the regulation will not be affected significantly by any increase in driving attributable to lower operating cost.

Response: The revised document (i.e., the August 6, 2004 version of the Initial Statement of Reasons) reflects the comment.

The staff assessment concludes that communities with low income and minority households are expected to have increased jobs as a result of the regulation. Future employment growth in some sectors may be reduced, but an increase in overall economic activity because of increased purchasing power due to lowered operating costs of vehicles would be expected to create a sufficient number of jobs to more than offset any losses.

Staff will continue to refine these approaches and will consider public comment received before issuing the final staff report.

TABLE OF CONTENTS

1 INTRODUCTION

California has a long history of environmental leadership. Motivated by the stunning natural beauty of our coastline, inland valleys, forests and mountains, as well as by the public health and environmental challenges brought about increasing levels of pollution, California's citizens have repeatedly called for and supported measures to protect California's environmental heritage. Our political leadership and governmental institutions have responded with a variety of initiatives that restore, protect and enhance the environment, to ensure public health, environmental quality and economic vitality. Often these California initiatives have provided a benchmark and template for further action both nationally and internationally.

This tradition of environmental leadership continues to this day. In 2002, recognizing that global warming would impose compelling and extraordinary impacts on California, the legislature adopted and the Governor signed Assembly Bill (AB) 1493. That bill directs the California Air Resources Board (Board) to adopt regulations to achieve the maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles. This Draft Initial Statement of Reasons presents a preview of the staff proposal that will be considered by the Board at its September 2004 public hearing.

1.1 Status of This Document

Staff typically does not provide a draft report of its staff analysis in advance of the release of an Initial Statement of Reasons, 45 days prior to the Board's public hearing. In this case, however, due to the complexity and controversy of the issue and the investigation of several new tools and approaches, staff thought that the rule development process would be best served by giving interested parties an early opportunity to look at the full range of analyses being undertaken by staff and how they will be integrated into a final staff proposal.

This document thus describes the complete staff proposal, including the specific details of the proposed approach, its rationale, and an assessment of its environmental and economic consequences. The reader should bear in mind that this document is a draft. The various elements of the staff proposal as well as the methodology used to evaluate its environmental and economic impacts are all subject to change, due to work in progress as well as comments received from the public.

In addition, please note that different portions of the analysis may use slightly different assumptions. This reflects the fact the staff analysis continues to be refined on an ongoing basis. As a result, the inputs provided to the various elements of the economic and emission modeling may differ slightly depending on when the work was undertaken. These variations will be reconciled and

updated analyses will be prepared in all areas as staff prepares for the release of the final staff proposal on August 6, 2004.

This document does not include proposed regulatory language. Staff is in the process of developing specific regulatory language and will release a draft for public comment prior to the release of the final staff report.

1.2 Organization of the Report

The report begins (Section 2) with an overview of the scientific evidence regarding climate change and its potential effects in California. Section 3 outlines the long history of previous actions that California has taken to understand and address the threat of climate change. Section 0 briefly summarizes the proposed regulation. Section 5 presents the results of staff's detailed technology assessment, which identifies the technologies available to achieve the maximum feasible and cost-effective reduction. Section 6 describes how the vehicle-level reductions outlined in the technology assessment were translated into a standard that can be applied at the manufacturer fleet level. This section also discusses staff's proposed approach towards alternative compliance and credits for early action. Section 7 summarizes the environmental impact of the proposed regulation, and Section 8 provides staff's estimate of its cost-effectiveness. Section 9 presents staff's evaluation of the impact of the regulation on California's businesses and economy. Section 10 looks more specifically at potential impacts on minority and low-income communities. Section 11 discusses the status of staff work to evaluate several other considerations, such as the possible effect of changes in vehicle attributes on vehicle purchase or vehicle miles traveled.

2 CLIMATE CHANGE OVERVIEW

The earth's climate always evolved - the extremes of the 100,000-year ice-age cycles in both climate and greenhouse gases over the last half million years is well documented. The last 10,000 years has been a warm and stable period, and the last millennium, over which current societies have developed, has been one of the most stable climates observed. Yet, over the 20th century, we have observed a rapid changes in the climate and greenhouse gases that are attributable to human activities. These recent changes in greenhouse gases far exceed the extremes of the ice ages, and the global mean temperature is warming at a rate that cannot be explained by natural causes alone. ~~is changing because~~ ~~H~~human activities are directly [***important because H2O, not mentioned is indirectly building up because of the warming***] altering the chemical composition of the atmosphere through the buildup of greenhouse gases (GHGs), primarily carbon dioxide (CO_2), methane, and nitrous oxide~~, and hydrofluorocarbons~~.. Climate research has identified other greenhouse agents that can drive climate change~~scientists are also suggesting that climate change in recent decades may have been mainly caused by non-CO_2 greenhouse gases~~, particularly tropospheric ozone, ~~methane,~~ hydrofluorocarbons, and atmospheric aerosols (particles containing sulfate, black carbon, or other carbonaceous

compounds) particles. Thus it appears that an effective response to the threat of climate change ultimately will need to address both CO2, and other greenhouse gases, and aerosols. [***you must include anthropogenic sulfate aerosols here since their induced cooling is an important component of the observed climate change to date.]

The heat-trapping property of GHGs is undisputed. Although there is uncertainty about exactly how and when the earth's climate will respond to increasing concentrations of GHGs, observations and models indicate that detectable changes are under way. [***detection requires a 'model', it is not just 'observations' - we need to test a theory.] There most likely are and will continue to be changes beyond just a global mean warming, such as in regional temperature extremes, and precipitation, soil moisture, and sea level, all of which could have significant adverse effects on many ecological systems, as well as on human health and the economy.

This chapter first presents an overview of climate change (Section 2.1) as well as a brief discussion of topics that convey the understanding of scientists on related issues. The chapter then discusses climate change pollutants (Section 2.2), concepts and definitions associated with climate change (Section 2.3), pollutants addressed under the proposed regulation (Section 2.4), indicators of climate change in California (Section 2.5), and potential impacts of climate change on California (Section 2.6). The chapter concludes with a brief discussion of abrupt climate change (Section 2.7).

2.1 Climate Change Overview

Climate change is a shift in the "average weather" that a given region experiences. This is measured by changes in the features that we associate with weather, such as temperature, wind patterns, precipitation, and storms. Global climate change means change in the climate of the Earth as a whole. Global climate change can occur naturally; an ice age is an example of naturally occurring climate change. The Earth's natural climate has always been, and still is, constantly changing. The climate change we are seeing today, however, differs from previous climate change in both its rate and its magnitude.

The temperature on Earth is regulated by a system known as the "greenhouse effect". Naturally occurring GHGs, primarily water vapor, carbon dioxide, methane, and nitrous oxide, absorb heat radiated from the Earth's surface. As the atmosphere warms, it in turn radiates heat back to the surface, to create what is commonly called the "greenhouse effect". Without the effect of these naturally occurring gases, the average temperature on the Earth would be –18 °C (-0.4 °F), instead of the current average of 15 °C (59 °F). [***I did not check these numbers, they are approximate and everyone uses slightly different ones, consider using the following quote from the IPCC's common questions: "The Earth's surface temperature would be about 34°C (61°F) colder than it is now if it were not for the natural heat trapping effect of greenhouse gases like carbon

dioxide, methane, nitrous oxide, and water vapor. Indeed, water vapor is the most abundant and important of these naturally occurring greenhouse gases. In addition to its direct effect as a greenhouse gas, clouds formed from atmospheric water vapor also affect the heat balance of the Earth by reflecting sunlight (a cooling effect), and trapping infrared radiation (a heating effect)." This corrects the lack of mention of H2O above and duly notes that the earth does not have a single temperature (i.e., 59F).] Life as we know it would be impossible.

Human activities are exerting a major and growing influence on some of the key factors that govern climate by changing the composition of the atmosphere and by modifying the land surface. The human impact on these factors is clear. The concentration of CO_2 in the atmosphere has risen about 30 percent since the late 1800s (NAST, 2001). This increase has resulted from the burning of coal, oil, and natural gas, and the destruction of forests around the world to provide space for agriculture and other human activities. Rising concentrations of CO_2 and other GHGs are intensifying the Earth's natural greenhouse effect. Global projections of population growth and assumptions about energy use indicate that the CO_2 concentration will continue to rise, likely reaching between two and three times its late-19th-century level by 2100 (Figure 2-1, Source: NAST, 2001). [<<< this figure does not work very well, I would use the IPCC Synthesis (2001) figure for temperature over the last 1000 and next 100 years for more dramatic affect - pdf attached.]

The Third Assessment Report of the International Panel on Climate Change (IPCC, 2001) and the National Research Council of the National Academies (NRC, 2001) conclude that the global climate is changing at a rate unmatched in the past one thousand years. The IPCC Assessment cites new and stronger evidence that most of the global warming observed over the last fifty years is attributable to human activities and that anthropogenic climate change will persist for many centuries. However, while the NRC Report generally agrees with the IPCC Assessment, it does not rule out that some significant part of these changes is also a reflection of natural variability. Also, the IPCC [as opposed to the NRC just mentioned] concludes that t~~T~~he observed changes over the last fifty years and those projected for the future include higher maximum air temperatures, more hot days, fewer cold days, greater extremes of drying and heavy rainfall, and sea level rise (IPCC, 2001 <= this should be to the IPCC Synthesis report, not to WGI).

Many sources of data indicate that the Earth is warming faster than at any time in the previous 1,000 years. The global mean surface temperature has increased by 1.1 $^{\circ}$F since the 19th century (IPCC, 2001). The 10 warmest years of the last century all occurred within the last 15 years. For example, 2002 and 2003 are tied as the second warmest years on record, according to a year-end review of climate data by the National

Both the IPCC (2001 and t~~T~~he NAST (2001) reports project ~~indicates~~ that the warming in the 21st century will be significantly larger than in the 20th century. Scenarios examined in these ~~at a~~Assessments, which assume no major interventions to reduce continued growth of world GHG emissions, indicate that temperatures in the US will rise by about 5-9°F (3-5°C) on average in the next 100 years, which is more than the projected *global average* increase. In general the continental regions of the Northern Hemisphere are expected to warm more than the global average. [The NAST uses IPCC scenarios I believe, in either case it is the IPCC SRES scenarios that everyone thinks of] This rise is very likely to be associated with more extreme precipitation and faster evaporation of water, leading to greater frequency of both very wet and very dry conditions. Climate change, whether a w~~W~~arming or cooling, ~~of the earth~~ will impact public health, air quality, water resources, agriculture, ecological resources, and California's economy. As a result, global climate change issues are receiving increasing national and international attention from governments, business and industry, the research community, environmental interests, and the public (IPCC, 2001). [I think you should discuss the IPCCs Synthesis Report figure 6.3 which shows that damage from climate change grows far worse and impacts more people as the global mean warming becomes larger. - attached pdf, also see Synthesis question 6]

2.2 Climate Change Pollutants

Naturally occurring GHGs include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also GHGs, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromofluorocarbons (i.e., halons). Because CFCs, HCFCs, and halons are substances, which deplete stratospheric ozone, they are regulated ~~covered~~ under the Montreal Protocol on Substances that Deplete the Ozone Layer. The United Nations Framework Convention on Climate Change (UNFCCC) defers to this earlier international treaty; consequently these gases are not included in national GHG inventories. Some other fluorine containing ~~halogenated substanc~~gases—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—do not deplete stratospheric ozone but are potent GHGs. These latter substances are addressed by the UN FCCC and accounted for in State and national GHG inventories. In addition, there are a number of other pollutants such as carbon monoxide, nitrogen oxides, and aerosols that have direct or indirect effects on terrestrial or solar radiation absorption. They are discussed later in this section.

In September 2000, the California Legislature passed Senate Bill 1771 (SB1771, 2000), requiring the California Energy Commission (CEC), in consultation with other state agencies, to update California's inventory of GHG emissions in January 2002 and every five years thereafter. The CEC (2002) report includes emissions of the four ~~six~~ GHGs (~~:~~ CO_2, CH_4, N_2O, ~~HFCs, PFCs, and~~ SF_6~~.~~) and

two classes of GHGs (HFCs, PFCs) that are listed in Annex A of the Kyoto Protocol. Although the first three gases are also emitted from natural sources, the CEC report ~~primarily~~ focuses on emissions due to human activities (anthropogenic emissions). The report concluded that there were major uncertainties associated with the inventory of GHG emissions, and recommended that future GHG inventories could be improved by: (1) incorporating improved data; (2) updating emissions estimates; and, (3) presenting a discussion of the uncertainty in emissions estimates from key sources.
Figure 2-2 shows the distribution of California's emissions by GHG.

Figure 2-2. Distribution of California greenhouse gas emissions by gas in 1999, expressed in terms of CO_2 equivalent (adapted from CEC, 2002).

Individual climate change species are briefly discussed in the following sections. Detailed discussions of GHG emissions are given in the CEC (2002) report.

2.2.A Carbon Dioxide (CO_2)

In the atmosphere, carbon generally exists in its oxidized form, as CO_2. Increased CO_2 concentrations in the atmosphere have been primarily linked to increased combustion of fossil fuels.

Fossil fuel combustion accounted for 98 percent of gross California CO_2 emissions. California's total CO_2 emissions from fossil fuel combustion in 1999 were 356 million metric tons of CO_2 equivalent ($MMTCO_2$ Eq), which accounts for approximately 7 percent of the U.S. emissions from this source. The transportation sector accounted for the largest portion of emissions, averaging 59 percent of the total CO_2 emissions from fossil fuel combustion in California for the period 1990-1999. Within the transportation sector, gasoline consumption accounted for the greatest portion of emissions. Figure 2-3 presents the contribution of each sector to CO_2 emissions from fossil fuel combustion in 1999.

Figure 2-3. CO2 Emissions from the Combustion of Fossil Fuels by Sector for 1999 (adapted from CEC, 2002).

The CEC (2002) report indicates that CO_2 emissions from fossil fuel combustion tracked economic and population growth in the early 1970s. Emissions remained flat through 1986, and then started to grow through the end of the decade. Economic and population growth both outpaced the growth in emissions during

this period.

2.2.B Methane (CH_4)

Methane accounted for approximately 8 percent of gross 1999 GHG emissions in California, in terms of equivalent CO_2 emissions. Methane is produced during anaerobic decomposition of organic matter in biological systems. Decomposition occurring in landfills accounts for the majority of anthropogenic CH_4 emissions in California and in the United States as a whole. Agricultural processes such as enteric fermentation, manure management, and rice cultivation are also significant sources of CH_4 in California.

While it is well established that exhaust from vehicles using hydrocarbon fuels contains CH_4, there are few published data concerning the magnitude of CH_4 emissions from the modern, and likely future, vehicle fleet. Metz (2001) concluded that the anthropogenic contribution of road transport to the global CH_4budget is less than 0.5 percent. Three-way catalyst emission control systems installed on all modern vehicles are effective in removing CH_4 from vehicle exhaust (Nam et al., 2004). It seems highly likely that the future will bring increasingly stringent regulations concerning the effectiveness and durability of vehicle emission control systems. Hence, it is likely that emissions of CH_4 from gasoline- and diesel-powered vehicles will be reduced from their already low values. A possible exception to this trend would be the increased use of compressed natural gas (CNG) powered vehicles. However, based on the emission measurements reported in Nam et al., (2004) even assuming a substantial fraction of CNG-powered vehicles, the tailpipe CH_4emissions from CNG vehicles can be controlled such that they are likely to have negligible environmental impact. While refueling losses would be another source of CH_4 emissions from CNG vehicles, safety considerations would mandate effective control of such emissions. [**I am not sure I agree with this, the safety level for leakage (i.e., explosive mixtures) may still be significant in terms of total leakage - note that with a GWP of 23, a 5% leakage doubles the effective greenhouse effect of fossil CH4.] It seems reasonable to conclude that the environmental impact of CH_4 emissions from vehicles is negligible and is likely to remain so for the foreseeable future.

2.2.C Nitrous Oxide (N_2O)

Nitrous oxide emissions accounted for nearly 6 percent of GHG emissions (CO_2 equivalent) in California in 1999. The primary sources of anthropogenic N_2O emissions in California are agricultural soil management and fossil fuel combustion in mobile sources. Nitrous oxide is a product of the reaction that occurs between nitrogen and oxygen during fuel combustion. Both mobile and stationary combustion emit N_2O, and the quantity emitted varies according to the type of fuel, technology, and pollution control device used, as well as maintenance and operating practices. For example, some types of catalytic converters installed to reduce motor vehicle pollution can promote the formation of N_2O. US EPA (2003) estimates suggest that, in 2001, N_2O emissions from

mobile combustion were 13 percent of U.S. N_2O emissions, while stationary combustion accounted for 3 percent. From 1990 to 2001, combined N_2O emissions from stationary and mobile combustion increased by 9 percent, primarily due to increased rates of N_2O generation from on road vehicles.

Behrentz et al., (2004) conducted a pilot study to measure exhaust emissions of N_2O. Their results indicate that the average N_2O emissions factor for the 37 vehicles tested was 20 ± 4 mg/km, significantly lower than previous reports of average values of ~35 mg/km (Dasch, 1992; Ballantyne et al., 1994; Barton and Simpson, 1994; Michaels et al., 1998). The difference between the previously reported emission factors and those presented in the pilot study could be related to the introduction of new technologies on some of the vehicles tested since they play a significant role in the amount of N_2O emitted by the vehicles. The differences could also be related to difference in the vehicle fleets studied. This issue will be resolved with ARB's future analysis of a much larger database of N_2O emissions. However, It is generally expected that N_2O emissions from light-duty vehicles will continue this pattern of decreasing emissions due to increasingly stringent NOx control technologies.

2.2.D Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)

HFCs are primarily used as substitutes for ozone-depleting substances (ODS) regulated under the Montreal Protocol. PFCs and SF_6 are generally emitted from various industrial processes including aluminum smelting, semiconductor manufacturing, electric power transmission and distribution, and magnesium casting. There is no aluminum or magnesium production in California; however, the rapid growth in the semiconductor industry leads to greater use of PFCs.

For vehicular HFC emissions (specifically HFC-134a, HFC-152b), four emission sources, all related to air conditioning, should be considered: emissions leaking from the hoses, seals and system components of vehicle air conditioning system, and emissions that are released when the air conditioning system is opened for servicing. HFC emissions can also occur when the vehicle is scrapped at the end of its useful life or due to sudden releases (e.g., traffic accident refrigerant releases). HFC-134a, commercially known as R-134a~~, also known as HFC-134a~~, is presently the vehicle refrigerant of choice among vehicle manufacturers. The assessment of mobile air conditioning system technology and associated cost analysis are included in later chapters.

2.2.E Other Radiatively Important Gases

In addition, there are a number of man-made pollutants, emitted primarily as byproducts of combustion (both of fossil fuels and of biomass), that have indirect effects on terrestrial or solar radiation absorption by influencing the formation or destruction of other GHGs. These include carbon monoxide (CO), nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOCs), and sulfur dioxide. These compounds, regulated in the United States and California pursuant to the Clean Air Act, are often referred to as "criteria pollutants." The criteria pollutants are reactive compounds, and they tend to remain in the atmosphere for a much shorter time than the previously discussed gases. As shown in Table 2.3-1 below, CO_2, N_2O, CH_4, and HFC134a have atmospheric lifetimes ranging from a century to ten years. Reactive compounds typically last only hours to months~~or days~~. [CO has lifetime of 1-3 months!!] The sequence of reactions that removes CO, NO_X, and NMVOCs from the atmosphere, however, tends to promote the formation of tropospheric ozone. Ozone in the stratosphere protects life on Earth from ultraviolet radiation, but ozone at ground level causes respiratory distress in people and animals, and throughout the troposphere ozone~~, also,~~ is a potent (though short-lived) GHG. The lifetime of criteria pollutants in the atmosphere is short and varies by location and season. ~~from weeks to months, which imparts an element of uncertainty in estimating tropospheric ozone radiative forcing effects.~~

~~It is generally difficult to make an accurate determination of the contribution of ozone precursors to global warming.~~ The reactions that produce ozone or alter the loss of methane are strongly affected by the relative concentrations of various pollutants, the ambient temperature, and local weather conditions. At present there is large scientific uncertainty in estimating their radiative forcing effects. [<<<no, the IPCC estimated trop ozone RF for the scenarios!!, it is the individual criteria pollutants that have varying impacts.]

[new para] California's unique emissions and fuel standards for cars, trucks, buses, motorcycles, and other motor vehicles have dramatically reduced criteria pollutant emissions, as have controls on non-automotive pollution sources that are administered by the State's 35 local air pollution control districts. California has achieved these improvements despite the State's substantial growth in population, vehicle use, and business activities.

Molecular hydrogen (H_2) is a trace component of the lower atmosphere. Hydrogen is not radiatively-active and therefore does not have a direct impact on climate; however, it has an indirect impact on climate change as (a) it is involved in the production of tropospheric ozone, and (b) it can modify the concentration of methane through its affect on the concentration of the hydroxyl radical (Prather, 2003). [ref the overview piece that appeared with the Schultz paper: Prather, M. J., An environmental experiment with H2?, Science, 302(5645): 581-582, 2003]~~.~~

Since the 1980s, alternative options for fulfilling the global energy demand have been developed. The use of H_2 produced with renewable energy sources

currently appears to be a promising option, in particular for non-stationary energy uses [<==why not just say the transportation sector??]. Although H_2 fuel cells themselves are a "clean" technology, producing water vapor (a GHG) as exhaust, concurrent changes in emissions of GHGs and ozone precursors associated with the production and distribution of H_2 must be considered as well as the changes in vehicle fleet emissions (Schultz et al., 2003). [can you come up with a better "well-to-wheel" description] Furthermore, the release of molecular hydrogen may increase because of leakage attributable to the production, transport, storage, and end use of H_2 (Zittel and Altmann, 1996). At present, the average leak rate to be expected in a full-scale hydrogen-driven economy is very uncertain (Schultz et al., 2003).

2.2.F Aerosols [***sulfates are still the major anthrop aerosol!]

Aerosols are extremely small particles or liquid droplets found in the atmosphere. Various categories of aerosols exist, including naturally produced aerosols (e.g., such as soil dust, sea salt, biogenic aerosols, sulfates, and volcanic aerosols), and anthropogenically [these are not all manufactured]manufactured aerosols (e.g., sulfates, ammonium nitrates, such as industrial dust, and carbonaceous aerosols including (e.g., black carbon and or organic carbon). Anthropogenic aerosols are derived directly or indirectly from transportation, coal combustion, cement manufacturing, waste incineration, and biomass burning. Aerosols affect radiative forcing in both direct and indirect ways: directly by scattering and absorbing solar and thermal infrared radiation;, and indirectly by altering the cloud properties and atmospheric heating rates increasing droplet counts that in turn modify the formation, precipitation efficiency, and radiative properties of clouds. The effect of aerosols on regional and global climate is complex: in general, sulfate aerosols enhance the reflection of sunlight and cool the earth, while black carbon aerosols enhance the absorption of sunlight and warm.

Understanding the role of aerosols in climate change requires inclusion of realistic representations of aerosols and their radiative forcings in climate models. Compared to the long-lived, well mixed GHGs with long atmospheric residence times, however, the optical properties and temporal and spatial patterns of the many different types of aerosols are heterogeneouspoorly understood. Further uUncertainty in aerosol radiative forcing arises because neither emissions factors, atmospheric abundances, which determine atmospheric concentrations, nor optical properties, nor indirect effects are fully known. The IPCC (2001) and the NACIP (2002) have identified the total (direct and indirect) radiative forcing due to aerosols, and in particular light absorbing aerosols, as one of the most uncertain components of climate change models.

2.3 Global Warming Potentials

Radiative forcing is often defined specified as athe net imbalance change in energy flux in the atmosphere, and is expressed in watts per square meter (W/m^2), i.e. heat per area of the Earth's surface. Radiative forcing of the surface-troposphere system, resulting, for example, from a change in GHG

concentrations, is the change in the balance between radiation coming into the atmosphere and radiation going out. A positive radiative forcing tends, on average, to warm the surface of the Earth, and negative forcing tends, on average, to cool the surface. The impact of a GHG emissions upon the atmosphere is related not only to radiative properties of the gas and its initial abundance, but also to the length of time it the GHG remains in the atmosphere. Radiative properties control the absorption of radiation per kilogram of gas present at any instant, but the lifetime of the gas controls how long an emitted kilogram remains in the atmosphere and hence its cumulative impact on the atmosphere's thermal budget. The climate system responds to changes in the thermal budget on time-scales ranging from the order of months to millennia depending upon processes within the atmosphere, ocean, and biosphere.

Gases in the atmosphere can contribute to the greenhouse effect both directly and indirectly. Direct effects occur when the gas itself is a GHG. Indirect radiative forcing occurs when chemical transformations of the original gas produce other GHGs, when a gas influences the atmospheric lifetimes of other gases, and/or when a gas affects atmospheric processes that alter the radiative balance of the Earth (e.g., cloud formation). The concept of a Global Warming Potential (GWP) has been developed in parallel to the concept of ozone depletion potential developed under the Montreal Protocol to compare the cumulative ability of each GHG to trap heat in the atmosphere relative to another gas. CO_2 , as the primary anthropogenic GHG, has been was chosen as the reference gas. to be consistent with IPCC guidelines. GWP is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of CO2a reference gas (IPCC 2001). While any length of integration time period can be selected, the 100-year GWPs are recommended by the IPCC and will be employed by the ARB for policy making and reporting purposes.

GWP values allow a comparison of the impacts of emission changes (and reductions or increases) of different gases. According to the IPCC (2001), GWPs typically have an uncertainty of ±35 percent. In addition to communicating GHG emissions in units of mass, we have also chosen to use GWPs to reflect their inventories in CO_2 equivalent terms because it effectively places all of the GHGs on the same comparative scale. Table 2.3-1 lists GWPs for CO_2, CH_4, N_2O, and HFC-134a for the 20, 100, and 500 years time frames. It should be noted that when the lifetime of the species in question differs substantially from the response time of CO_2 (nominally about 150 years), then the GWP becomes very sensitive to the choice of time horizon. Thus, the GWP concept is only relevant for compounds that have sufficiently long lifetimes to become globally well-mixed. Therefore, short-lived gases and aerosols with varying atmospheric distributions and lifetimes vertical or horizontal variations pose a serious problem in the simple GWP framework.

Table 2.3-1. Numerical Estimates Of Global Warming Potentials Compared With CO2(Kilograms Of Gas Per Kilogram Of CO2 -- Adapted From IPCC 2001).

Climate Pollutants	Lifetime (years)	Global Warming Potential		
		20 years	100 years	500 years
CO_2	~150	1	1	1
CH_4	12	62	23	7
N_2O	114	275	296	156
HFC-134a	~~≈~~14(you can round 13.8 to 14 without putting a ~)	3,300	1,300	400

2.4 Pollutants Included in the Proposed Regulation

Assembly Bill 1493 calls for reductions in GHGs, which are defined in the bill as carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride (? ref to UN FCCC, as listed in Annex A of the 1997 Kyoyo Protocol). The first four of these identified global climate change pollutants are clearly associated with motor vehicle use in California. Perfluorocarbons and sulfur hexafluoride are not known to be associated with motor vehicle emissions in California and therefore are not addressed further in the staff report.

Black carbon and criteria pollutant emissions from motor vehicles are also known to have global climate change impacts. Although these pollutants are not specifically defined as greenhouse gases in AB 1493, the authority for ARB to regulate these pollutants currently exists in the Health and Safety Code (Section 39014). AB 1493 does not limit that authority; rather it supports the need to address the impacts of climate change pollutants.

The 2001 IPCC states that in addition to the gases targeted in the Kyoto Protocol, the contribution of tropospheric O_3 to the greenhouse effect is also important. The report further states that in order to curb global warming it is necessary to reduce the emissions of both GHGs and other gases that influence the concentration of GHGs. Air pollutants such as NO_x, CO, and NMVOC generate O3 and impact tropospheric [they sometimes consume OH!!] ~~produce~~ OH radicals, which in turn alters ~~that affect tropospheric O_3 and~~ CH_4 levels. Hence, ~~, and hence~~ they are called indirect GHGs. Due to the basic uncertainties regarding the actual impact of criteria pollutant emissions on climate, however, it is impossible at this time to have confidence in any numerical prediction of the climate effect of their emissions from light-duty motor vehicles. Because the

uncertainties associated with the impact of criteria pollutants on climate change are large, at this time the ARB has chosen not to consider the potential climate change effects when regulating CO, NO_X, VOC or aerosols. As more definite scientific evidence becomes available, the ARB will, if appropriate, consider the climate change impacts of these criteria pollutants in its regulatory decisions.

2.5 Indicators of Climate Forcing and Climate Change In California

[I do not like using GHG emissions as indicators, but if you must, they cannot be an indicator of climate change!]
The climate is changing under the influence of human activity. Indicators of climate forcing and actual c~~C~~limate change ~~indicators~~ can be used to illustrate trends, measure the suitability of particular actions in certain areas and encourage public awareness of the climate change impacts. Several potential climate change indicators have been suggested, including anthropogenic GHG emissions, air temperature, annual Sierra Nevada snow melt runoff, and sea level rise in California (EPIC, 2002).

Time series of historical emissions of anthropogenic GHGs have been produced for a number of geographic regions. The GHGs emissions trends illustrate that, although California has been able to moderate its GHG emissions, total GHG emissions are still increasing and continue to remain above 1990 levels. With a relatively temperate climate, California uses relatively less energy for heating and cooling energy than other states. California leads the nation in vehicle miles traveled, however, which leads to a concomitant increase in carbon dioxide emissions in the transportation sector. Tracking California's trends in motor vehicle-related GHGs emissions will allow an assessment of the State's contributions to global GHG emissions.

Increases in the concentrations of GHG are predicted to change regional and global climate-related parameters such as temperature, precipitation, soil moisture, and sea level. Temperature data have been collected at many weather stations in the State for almost a century. The air temperature indicator can be used to track trends in statewide surface air temperatures and regional variations, allowing for a comparison of temperature changes in California with those occurring globally.
The warming of global climate could increase evaporation rates, thereby potentially increasing precipitation and storms in the State. Snowmelt and runoff volume data can be used as a climate change indicator to document changes in runoff patterns. These specific regional changes are related, at least in part, ~~due~~ to the climate change associated with the observed global mean warming.~~increased air temperatures and climate changes~~.

[new para] In California, large accumulations of snow occur in the Sierra Nevada and southern Cascade Mountains from October to March. Each winter, at the high elevations, snow accumulates into a deep pack, preserving much of California's water supply in cold storage. If the winter temperatures are warm, more of the precipitation falls as rain instead of snow, and water directly flows

from watersheds before the spring snowmelt. Thus, there is less buildup of snow pack; as a result, the volume of water from the spring runoff is diminished. Lower water volumes of the spring snowmelt runoff may indicate warmer winter temperatures or unusually warm springtime temperatures. Figure 2-4 shows that throughout the 20th century, annual April to July spring runoff in the Sierra Nevada has been decreasing. This decreased runoff was especially evident after mid-century; since then the water runoff has declined by about ten percent.

Figure 2-4. Sacramento River Runoff (1910-2000) - April to July as a Percent of Total Runoff (Roos, 2002).

Sea level rise also provides a physical measure of possible oceanic response to climate change. ~~The rise in sea level may be associated with l~~increasing global mean temperatures will result in result in mean sea level. ~~Based on results from modeling,~~ W~~w~~arming of the ocean water will cause a greater volume of sea water because of thermal expansion [this is not from models, we know that warming water expands it!!] and t~~. T~~his ~~is expected to~~ contributes the largest share of sea level rise, followed by melting of mountain glaciers and ice caps (IPCC, 2001). Along California's coast, sea level already has risen by three to eight inches over the last century, consistent with the global mean value of four to eight inches (IPCC, 2001). Long-term data from 10 of 11 California stations show increases in sea level (Figure 2-5, using San Francisco as an example).
[NB Sea level rise is not expected to be uniform globally and is influenced by shifts in weather patterns as well as the long-term motion of the continents (up and down following glacial rebound or plate tectonics].

Figure 2-5. 1855-2000 San Francisco yearly mean sea level (Roos, 2002).

The climate change indicators described in this report represent key properties of the climate system that are considered sensitive to climate change. Many additional potential indicators remain to be explored. For example, climate change may influence the frequency of extreme weather events, ecosystem structures and processes, and species distribution and survival. It may affect forestry, energy and other industries, insurance and other financial services, and human settlements. In addition, the impacts can vary from one region, ecosystem, species, industry, or community to the next. Research into the regional impacts of climate change is ongoing, and the potential climate change indicators will be updated and expanded as new information becomes available.

2.6 Potential Impacts on California

Climate is a central factor in Californian life. It is at least partially responsible for the State's rapid population growth in the past 50 years, and largely responsible for the success of industries such as agriculture and tourism. The potential effects of climate change on California have been widely discussed from a variety of perspectives (Lettenmaier and Sheer 1991; Gleick and Chalecki 1999; Wilkinson 2002). The signs of a global warming trend continue to become more evident and much of the scientific debate is now focused on expected rates at

which future changes will occur. Rising temperatures and sea levels, and changes in hydrological systems affecting water resources are threats to California's economy, public health, and environment. The following section discusses evidence of a changing climate in California and provides examples of why the State is particularly at risk from an increasingly warmer and more variable climate.

2.6.A Human Health and Air Pollution

Human health in California is likely to be impacted by climate change. Several recent studies have addressed potential implications for human health at the national and

July 7 Workshop Discussion Draft 14 international levels (Patz et al., 2000). Greater climate variability and changes in climate patterns would potentially cause both direct and indirect health effects. Direct health impacts due to climate change include extreme events, such as heat waves, droughts, increased fire frequency, and increased storm intensity resulting in flooding and landslides. Secondary or indirect health effects include damages to infrastructure causing, for example, sanitation and water treatment problems leading to an increase in water-borne infections. Air quality impacts such as increases in ~~tropospheric (i.e.,~~ ground-level~~)~~ ozone due to higher temperatures may also cause secondary health impacts. [do not confuse tropospheric ozone with ground-level - we need to use trop ozone for GHG nomenclature.]

The most obvious direct impacts of projected climate change are~~is~~ higher temperatures and increased frequency of heat waves that may increase the number of heat-related deaths and the incidence of heat-related illnesses. Studies of heat waves in urban areas have shown an association between increases in mortality and increases in heat, measured by maximum or minimum temperature, heat index (a measure of temperature and humidity), or air-mass conditions (Semenza et al., 1996). For example, after a 5-day heat wave in 1995 in which maximum temperatures in Chicago ranged from 93 to 104°F, the number of deaths increased 85 percent over the number recorded during the same period of the preceding year. At least 700 excess deaths (deaths beyond those expected for that period in that population) were recorded, most of which were directly attributed to heat (Semenza et al., 1999).

Until recently, excess deaths occurring during heat waves have been attributed entirely to heat-induced stress. However, analyses in the Netherlands (Fischer et al., 2004) and the United Kingdom (Stedman, 2004) conclude that a substantial portion of the mortality is actually due to elevated O_3 and particulate matter levels. Air quality has a very real and direct effect on the health of many Californians who experience the worst air quality in the nation. Over 90 percent of Californians are living in areas that violate the State ambient air quality standard for ozone and/or particulate matter. In the Los Angeles area, population density and sprawl, cars, climate, and geography conspire to create some of the nation's worst air quality. A study by Kinney and Ozkaynak (1991) of urban air

pollution in Los Angeles County found a significant association between daily mortality and ozone levels. Other California cities including Bakersfield and Fresno are also struggling with severe air quality problems as the San Joaquin Valley suffers from air pollution from various sources.

Climate change can lead to changes in weather patterns that can influence the frequency of meteorological conditions conducive to the development of high pollutant concentrations. High temperatures, strong sunlight, and stable air masses tend to occur simultaneously and increase the formation of ozone and secondary organic carbon particles − weather conditions associated with warmer temperatures increase smog. Figure 2-6 shows the relationship between ozone and temperature in the South Coast Air Basin, and indicates that ozone air quality can be profoundly affected by changes in climate and meteorology.

vectors may also pose concerns. Poor and immigrant populations (residence in urban areas where the heat island effect actually increases warming and the consequent effects of heat) are more vulnerable to climate change as they are often without adequate resources to control their environment with appliances such as air conditioners, or to seek medical attention. Thus, these communities are the first to experience negative climate change impacts like heat death and illness, respiratory illness, infectious disease, and economic and cultural displacement.

2.6.B Water Resources

Much of California is semi-arid and, thus, water resources are a key factor in the State's economic and environmental well being. Water resources are affected by changes in precipitation as well as by temperature, humidity, wind, and sunshine. Water resources in drier climates, such as California, tend to be more sensitive to climate changes. Because evaporation is likely to increase with warmer climate, it could result in lower river flows and lake levels, particularly in the summer. In addition, changes in meteorology could result in more ~~intense~~ precipitation occurring in intense events, which reduces the ability to capture the water and could increase flooding. If stream flow and lake levels drop, groundwater also could be reduced. The seasonal pattern of runoff into California's reservoirs could be susceptible to climatic warming. Winter runoff most likely would increase, while spring and summer runoff would decrease. This shift could be problematic, because the existing reservoirs are not large enough to store the increased winter flows for the demand ~~release~~ in ~~the~~ summer. Increased winter flows to San Francisco Bay could increase the risk of flooding (Gleick and Chalecki 1999; Miller, et al., 2001; Roos 2002).

California is home to about 35 million people. Using the California Department of Finance projections, it is estimated that California's population will grow by an average of 1.4 percent per year over the next 20 years. This projection translates to approximately 10 million more Californians by 2020. The combination of population growth and climate warming could impose serious environmental

challenges. Increased water demands and decreased water availability raise substantially the costs of providing water to urban, agricultural, and hydropower users. It is possible that California's water system could adapt to the population growth and climate change impact. However, even with new technologies for water supply, treatment, and water use efficiency, widespread implementation of water transfers and conjunctive use, coordinated operation of reservoirs, improved flow forecasting, and the close cooperation of local, regional, State, and federal government, this adaptation most likely will be costly.

2.6.C Agriculture

If California's water resource systems face challenges from climate change and variability, so will the State's agricultural sectors. While agricultural production is potentially vulnerable to climate change risks associated with adverse water system impacts, this sector also faces other risks that come with increasingly unpredictable variations in both temperature and precipitation. For example, increases in the frequency of extreme weather at inopportune times can cause significant declines in agricultural productivity (Wilkinson, 2002).

The impacts of global warming on crop yields and productivity will vary considerably by region. But several studies, including one by the US Department of Agriculture, show that maintaining today's levels of agricultural productivity would be difficult. At best, this would require expensive adaptation strategies. Farmers will likely need to change crops and cultivation methods because warming generally hinders crop yields, although the beneficial effects of elevated CO_2 in fertilizing plant growth may cancel out the effects of warming. If climate warming is accompanied by increased drought, however, the detrimental effects would be intensified.

In California, 87 percent of the crop area is irrigated, and increased drought could be countered by human management. Yet there are severe constraints on increased irrigation since 100 percent of the surface water is already allocated. Agricultural water users in the Central Valley are the most vulnerable to climate warming. While wetter hydrologies could increase water availability for these users, [I do not understand the next clause==>]the driest climate warming hydrology could significantly reduce agricultural water deliveries in the Central Valley. If the climate shifts toward a severe drought, not only will more irrigation be needed, but also the snow pack at higher elevations will be lacking. This can be disastrous for producers that grow fruit trees and vines that will require years to reestablish production.

2.6.D Ecological Impacts

California is an ecologically diverse state, with 134 endangered and threatened species, including the sea otter, the California condor, and the American bald eagle. California's unique ecosystems include 25,000 square miles of desert. California's mountain ecosystems in the Sierra Nevada, including Yosemite

National Park, contain alpine wilderness areas with large numbers of sequoia trees. The ranges of many species of plants and animals are restricted and fragmented because of both natural and human causes. Many invading species have colonized large areas and displaced native species in the wake of environmental changes in recent centuries (Wilkinson and Rounds, 1998).

Climate change could have an impact on many of California's species and ecosystems. For example, aquatic habitats are likely to be significantly affected by climatic changes. Most fish have evolved to thrive in a specific, narrow temperature range. As temperatures warm, many fish will have to retreat to cooler waters. Species differ significantly in their abilities to disperse and to become established in new locations with more suitable climates. Poorly dispersed species such as oak trees and related species, and amphibians, may not be able to survive the predicted rapid climatic changes if they have narrow tolerances for specific environmental conditions. Even for easily dispersed species, such as grasses and birds, other biological interactions (i.e., new predators, missing pollinators, lack of specific food sources) or physical environments (i.e., different soils, roads, lack of suitable intervening habitat) may block the success of migration.
With changes in climate, the extent of forested areas in California could also change. The magnitude of change depends on many factors, including whether soils become drier and, if so, how much. Hotter, drier weather could increase the frequency and intensity of wildfires, threatening both property and forests. Along the Sierras, drier conditions could reduce the range and productivity of conifer and oak forests. Farther north and along the northern coast, drier conditions could reduce growth of the Douglas fir and redwood forests. A significant increase in the extent of grasslands and chaparral throughout the State could result. These changes would affect the character of California forests and the activities that depend on them.

2.6.E Impact on Economy

California produces more than one-eighth of total U.S. economic output, which makes it equivalent to the sixth largest economy in the world. Increased climate variability and long-term climate change potentially will affect the state’s sectors in important and different ways. Some activities and enterprises will be impacted directly through changes in natural resource and ecosystem services. Water shortages and increased insect damage to crops due to relatively rapid changes in insect populations, for example, will have direct impacts on the State’s diverse agricultural sector. While field crops may be switched by the season, perennial crops including vineyards and orchards are long-term investments. The reported damages from the El Niño storms in 1997-98 for agricultural losses approached $100 million. From dairy farmers losing cows to exhaustion as they try to escape the mud, or are attacked by diseases, to strawberry growers losing crops to the rain, farmers have experienced significant losses due to strong climate variability (Wilkinson and Rounds, 1998).

Precipitation falling as rain instead of snow will pose major problems for water

managers, as the existing capture will become inadequate, and distribution system designed for the current supply and demand areas will develop bottlenecks. Higher summer temperatures will cause more rapid deterioration of asphalt and concrete, impacting the highway and rail systems. Sea level increases of up to three feet over the next century, with consequent implications for coastal erosion, inundation of wetlands, salt water intrusion of coastal and delta aquifers, and impacts on developed areas would clearly be extremely costly to mitigate, and devastating to some ecosystems and urban communities. Climate change has the potential to affect many aspects of California—the survival of its unique ecosystems, its ability to produce electricity, its supply of water and agricultural products, and the resources that support its economy.

2.7 Abrupt Climate Change

When most people think about climate change, they imagine gradual increases in temperature and only marginal changes in other climatic conditions, continuing indefinitely or even leveling off at some time in the future. It is assumed that human societies can adapt to gradual climate change. However, recent climate change research has uncovered a disturbing feature of the Earth's climate system: it is capable of sudden, violent shifts. This is a critically important realization. Climate change will not necessarily be gradual, as assumed in most climate change projections, but may instead involve relatively sudden jumps between very different states. A mounting body of evidence suggests that continued GHG emissions may push the oceans past a critical threshold and into a drastically different future. Abrupt climate change is the subject of a reports commissioned by the National Academy of Sciences (NRC, 2002 = Abrupt Climate Change, Inevitable Surprises, R.B. Alley, Chair, NRC Press) and the U.S. Department of Defense (Schwartz and Randall, 2003). The latter report stated that abrupt climate change could destabilize the geo-political environment, leading to skirmishes, battles, and even war due to resources constraints such as food shortage, decreased availability and quality of fresh water, and disrupted access to energy supply. [*** the DOD study was NOT peer reviewed and is a marginal reference here, at least point to the recent NAS study.]

Change in any measure of climate or its variability can be abrupt, including a change in the intensity, duration, or frequency of extreme events. For example, single floods, hurricanes, or volcanic eruptions are important for humans and ecosystems, but their effects generally would not be considered abrupt climate changes. A rapid, persistent change in the number or strength of floods or hurricanes might, however, be an abrupt climate change. Although more regionally limited, the apparent change in El Niño behavior (Graham, 1994; Trenberth and Hoar, 1996) could also be considered an abrupt change. El Niño is characterized by a large-scale weakening of the trade winds and warming of the surface layers in the eastern and central equatorial Pacific Ocean. El Niño is notorious worldwide for causing catastrophic disruptions in weather patterns. Floods in California are countered by droughts in Australia.

Societies have faced both gradual and abrupt climate changes for millennia and have learned to adapt through various mechanisms, such as developing irrigation for crops, and migrating away from inhospitable regions. Nevertheless, because climate change will likely continue in the coming decades, denying the likelihood or downplaying the relevance of past abrupt events could be costly. Thus, in addition to the gradual (albeit accelerated) climate changes projected by current climate models, Californians need to be aware of the possibility of much more sudden climate shifts. These shifts have a scientifically well-founded place among the possible futures facing the State and should be among the possibilities accommodated in planning and adaptation measures.

Look at Question 6 of the synthesis report - the figure (attached) is critical to some of the arguments above.

Even with smooth cliamte change the rate of T increase projected for the 21st century must be considered "rapid"! compared to the last millennium.

With slow and gradual global warming the climate change may benefit a large fraction of society, but with large and larger warming, we all become losers.

IPCC Synthesis Question 6:
How does the extent and timing of the introduction of a range of emissions reduction actions determine and affect the rate, magnitude, and impacts of climate change, and affect the global and regional economy, taking into account the historical and current emissions?

What is known from sensitivity studies about regional and global climatic, environmental, and socio-economic consequences of stabilizing the atmospheric concentrations of greenhouse gases (in carbon dioxide equivalents), at a range of levels from today's to double that level or more, taking into account to the extent possible the effects of aerosols? For each stabilization scenario, including different pathways to stabilization, evaluate the range of costs and benefits, relative to the range of scenarios considered in Question 3, in terms of:
Projected changes in atmospheric concentrations, climate, and sea level, including changes beyond 100 years
Impacts and economic costs and benefits of changes in climate and atmospheric composition on human health, diversity and productivity of ecological systems, and socio-economic sectors (particularly agriculture and water)
The range of options for adaptation, including the costs, benefits, and challenges
The range of technologies, policies, and practices that could be used to achieve each of the stabilization levels, with an evaluation of the national and global costs and benefits, and an assessment of how these costs and benefits would compare, either qualitatively or quantitatively, to the avoided environmental harm that would be achieved by the emissions reductions
Development, sustainability, and equity issues associated with impacts, adaptation, and mitigation at a regional and global level.

3 CALIFORNIA ACTIONS TO ADDRESS CLIMATE CHANGE

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UC Irvine peer review of

California Environmental Protection Agency
Air Resources Board
Appendix #
Climate Change Overview

and
Attachment A:
Aerosol Particles and Climate Change

Draft-Nehzat 07/19/04

This is a well written overview of climate change, the factors controlling climate change, and challenges and opportunities for California in the 21st century. I have only a few serious corrections that I feel are needed (listed below) and also urge that this document which is used heavily in the parent ISOR draft be revised in response suggestions made for similar text in my review of the draft ISOR.

Michael Prather
19 July 2004

Response: As with the comments on the June 14, 2004 draft ISOR, the August 6, 2004 version of the TSD addressing climate change science was revised to reflect Dr. Prather's comments as provided below. Given the detailed nature of the comments and staff's concurrence with each point, the TSD document was revised (i.e., the August 6, 2004 version of the package) accordingly. Therefore, point-by-point responses are not provided.

Critical issues:
p.2/para 1 The HFCs are not really changing the climate today, it is the CFCs (particularly -11 and -12) that have a large RF over the past 3 decades. The HFCs and the HCFCs are minor - except that the HFC-134a is projected to take over in the 21st century (but still be of similar magnitude as CFCs today).

/para 1 "The climate change we are seeing today differs ..." I would disagree, some of the glacial-interglacial changes were BIG. If you look at the IPCC SyR (Synthesis Report 2001) the figure on surface T shows that it is large compared to last millennium. It is different in that GHG abundances are greater than at any time over last 500,000 yr! But I do not think the blanket statement above can be made.

p.13 / para 2 "Assembly Bill 1493 .... and SF6 as per the UN FCCC defined greenhouse gases" You need to make it clear the AB1493 did not arbitrarily come up with htis list of greenhosue gases.

p.13/para 4 Much as my own work emphasizes the importance of indirect effects on climate change, I think this is a very good choice at present.

p.25 / para 34 I am not sure I agree with this entire paragraph on what constitutes abrupt climate change. It is not the definition I remember - I would drop the entire paragraph 3 or recheck with the NAS study (Alley et al) to see if this is consistent. Abrupt climate changes must persist over several years or they are not climate changes.

Editorial issues:
p.2/para 3 See the suggested fixes for draft ISOR - e.g., diff temperature difference as about 60 F rather than quoting a mean surface T.

p.3/para 3 The NAST is OK but the IPCC Syr figure is really better (Fig 1 here)

p.5/para 5 The umber 5.5 mmteCO2 for counting out-of-state elect generation seems small compared with the 356 mmteCO2 total - just check the figures.

p.6/last line why not include "or other accidental/fugitive losses" since these may be greater than refueling.

p.7/para 1 As in my ISOR comments - it is not clear that safety requirements alone would keep accidents/fugitive/etc losses to less than 3-4% ! Note that at 5% the CH4 leakage more than doubles the equivalent CO2.

p.8 Please look at suggestions for ISOR similar section on lifetime of CO, and H2 discussion/references

p.8/last para The SO2 discussion needs to begin with a note that SO2 is a gas which becomes a greenhouse agent when it is chemically converted into sulfate

aerosols.

p.9/para 3 The references to Jacobson and later authors is unfair to the originators - please add at least to credit the first work!

Penner JE, Chuang CC, Grant K, Climate forcing by carbonaceous and sulfate aerosols, CLIMATE DYNAMICS 14 (12): 839-851, 1998
Haywood JM, Ramaswamy V, Global sensitivity studies of the direct radiative forcing due to anthropogenic sulfate and black carbon aerosols, JGR 103 (D6): 6043-6058, 1998

p.9/para 4 Be careful and do not confuse the surface dimming (in W/m2) with the top-of-atmosphere (TOA) radiative forcing that you have been talking about to date. The idea that regional RF by aerosols is an order of magnitude larger than the global mean goes well before INDOEX and Ramanathan, the original heterogeneous maps of aerosol optical depth showed that. The INDOEX experiment emphasized that the surface cooling was large by any means (and it must be compared with cloud cover changes etc, not just greenhouse gases).

p.10/para 4 As per ISOR review, the GWP has never really been defined with other than CO2 as the reference gas - so fix the sentence.

p.10/para 5 "impact of enhanced emissions or reduced ..."

p.11/para 1 The GWP concept is valid provided emissions of the gas have the same climate impact wherever and whenever they occur. This will hold for some gases that do NOT mix globally such as CO, but not likely for NOx where location of emissions counts alot. I would just lighten this a bit.

p.11/para 4 "on the lifetime of CH4 (.." no other GHG is important in this context, it is really only CH4.

p.12 / table Is it worth noting that the UN FCCC has not yet adopted the IPCC reporting of a GWP for CO?

p.13/para 4 change "actual impact" to "quantitative impact"

p.14/last para do you want to note that the urban heat island is due to more than just the energy intensity, but in large part to the paving over of land (no sensible/evaporative heat loss) and albedo (darker structures).

p.15/para 2 "increased air temperatures AS WEL AS OTHER climate changes." temperature is part of climate.

p.15/para 3 the logic of the explanation is odd - if we have warmer temperatures in the spring after April 1, then the melt is included, but what is needed is warm EARLY springtime temperatures (i.e., Feb-March).

p.17/para 3 This introduction misses the very important issues of vector-borne

infections like dengue and malaria - just move some of the section on p.20 up here! The infrastructure argument for increased water-borne infections is very weak (could be dropped here) since that is controllable (as opposed to Dengue).

p.19/para 4 "high temperature is concurrent with many other exacer..." note that it is high temperatures, and they are not surrogates, but correlated with .

p.20/para 1 see also the IPCC 2001 SyR figure and discussion of increased insurance costs of extreme weather events.

p.22/para 3 the CO2 fertilization may offset other damaging effects, do not use "cancel" it is too strong. Also the CO2 fertilization studies for real ecosystems (FACE, and a great plains grassland study) are hardly convincing to date.

p.24 ditto - CO2 rise is likely but not certain to enhance forest production....

p.24/para 4 NB - please note that the 1 m rise in sea level is the maximum projected for all scenarios and includes some uncertainties in climate sensitivity of the models.

p.25 / para 2 as per ISOR reference the NAS study on rapid climate change.

p.25/para last The statement on CH4 clathrates is incorrect - ift the temperature rises the clathrates do become unstable, but it does NOT mean they bubble up into the atmosphere - that is one possibility, but the other more likely is that they slowly decompose (as heat diffuses into the clathrate) and the CH4 is eaten in the upper sediments or the open ocean before it gets into the atmosphere. "and may be released" is OK, but not "and bubble up into the atmosphere".

p.26/para 1 This 16C change is very misleading since you have been talking mainly about the global mean and this 16C change occurs (as I remember) on the polar ice sheets which are projected to have much larger warming in the 21st century (3-5C global means >8C over high latitude land masses!)

p.26/last para

(1) Please look at (and try to use) the IPCC Syr figure on the last millennium and next century: Society has NOT faced any climate change comparable to the last 50 yr and certainly the next 100 yr anytime over the last 1000 years. Societies have not in general survived abrupt climate change (last occurred during the Younger Dryas, 12,000 years ago).

(2) the last sentence is OK, but a critical issue with abrupt changes is that with current climate modeling capability, they are not predictable.

====Attachment A comments

p.1/para 1
"so-called" - please drop it is pejorative.
"indirectly by their role in ..." add 'atmospheric heating and the hydrological cycle' drop 'snow and cloud cover' this has never been considered a natural factor in climate forcing (a feedback, yes).
"due to " change to "caused by increasing GH gas[<=singular] concentrations ." to make it more attributable.

page 1/para 3 "their CUMULATIVE radiative impact ..." - it is easier to measure their instantaneous impact, but not their cumulative impact.
page 2/para 2 & Fig 1 this particular Hansen view is very different from the IPCC 2001 picture and to be fair you should show both. I think Hansen has made some improvements, but that other values shown here are far outside the main community.

p.3/para 2 you need to insert: "..measurement of GLOBAL aerosol properties..." since that is the ease of measuring global CO2 from a few sites.

p.3/para 4 This paragraph has the wrong focus. We must have measurements to test and validate the aerosol models - and THEN we use these to predict the RF. It is not done from models alone.

p.4/para 2 "so that at typical relative humidity their effec..."

p.4/para 5&6 This discussion of volcanic influence is very misleading. I am not sure how to fix it but something like: " Explosive volcanic eruptions when large amounts of SO2 gas are injected into the stratosphere can lead to measurable cooling of the surface and lower atmosphere. The SO2 gas is converted into sulfate aerosols in the stratosphere where is has a residence time of about a year. Stratospheric sulfate, like sulfate aerosols in the lower atmosphere, reflect sunlight and lead to planet-wide cooling. ..."
Note that Mt St. Helens was very explosive, but had little climate impact - it did not reach into the stratosphere.
The discussion about high-latitude volcanoes is misleading and needs to be dropped (it is also not right), the last big three were are tropical - Agung, El Chichon, Pinatubo.

p.5/para 3 a major reason why nitrate leaves aerosols is displacement by sulfuric acid, include. Also, this limits the ability to quantify nitrate impacts, it does not "limit the scope"

p.5/para 5 "nonlinear with respect to RH", also, are you sure that "most" of the mass is water?

p.7/para3 "Organic carbon aerosols can be..." as opposed to gases. There is increasing evidence that OC is 'brown' and partly absorbing, at least leave some leeway here and in the rest of this attachment.

p.9/para 2 please make it clear that the "6%" is not 6.63 TgC/yr, the sentence can be read that NAm sources are 0.06*6.63 or just 6.63.

p.10/para 2 "OFTEN, BC is defined as...." it is not just form climate studies that BC is defined by absorption. Also note that OC is 'brown' and sometimes absorbs light.

p.10/para last - This is not really correct. Reductions in GHG emissions ARE realized immediately AND they accumulate over the lifetime of the gas. Aerosol emission reductions are also realized immediately and their cumulative impact is immediate. The current draft is very misleading, without a much more careful redraft, I would drop this paragraph.

Peer Reviews
Economic Assessment

The following three economic peer reviews were submitted by the scientists as indicated below:

- **Imran Currim**, Ph.D., Professor of Marketing, Graduate School of Management, UC Irvine

- **Michael Hanemann**, Ph.D., Chancellor's Professor of Agricultural and Resource Economics and Goldman School of Public Policy, UC Berkeley

- **Christopher R. Knittel**, Ph.D., Assistant Professor of Economics, UC Davis

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Review of Sections 9, 10, and 11 of the CARB Staff Proposal Regarding the Maximum Feasible and Cost-Effective Reduction of Greenhouse Gas Emissions From Motor Vehicles

This working draft describes the specific details of the proposed approach to reduce greenhouse gases, its rationale, an assessment of available or demonstrated technologies and fuels that contribute to a reduction in climate change emissions in passenger vehicles, an the environmental and economic consequences, all 2009 onwards.

Section 9

Section 9 is on the potential economic impact on California business and the economy; on business creation, elimination, and expansion, California business competitiveness and potential costs to local and state agencies. In general I found the material in this section to be very well written and presented. There are two issues that came to mind, which the staff may want to consider to further improve the high quality of this section.

First, the effects on consumers are described at an aggregate level because these estimates are developed from an aggregate model. However, it could be useful to supplement the aggregate effects with some disaggregated effects, at the customer segment level. One can describe customer segments in a variety of ways, based on usage of automobiles (buy vs. lease, new vs. used, etc.), or on demographics (income or taxes paid), etc. Consider the segment that leases new cars every 2 or 3 years, what will be the impact on their purchase decision (minimal), additional lease payments (minimal) and the savings on operating costs (perhaps more than minimal given increases in mpg)? One can outline the results for various such segments.

Response: We agree that the estimates of disaggregated effects are desirable and have therefore evaluated the potential impacts on consumers associated with the purchase of new vehicles subject to the regulations as well as the impact on consumers purchasing such vehicles after several years of use (10 years). The AB 1493 legislation is very specific in terms of the types of economic impacts to be evaluated for the proposed regulations. The legislation, for example, requires an assessment of the impacts of the proposed regulations on low-income and minority population. The legislation also requires that the regulations are to be "economical to an owner or operator of a vehicle, taking into

account the full life-cycle costs of the vehicle." Such analyses were provided in the June 14, 2004 version of the ISOR. However, as indicated above, the August 6, 2004 version of the ISOR provides additional information on the potential impacts that the proposed regulations may have on typical purchasers of new vehicles financing over a five-year period (Section 10.5, page 160-161) as well as low-income purchasers of used vehicles financing over a period of three years (Section 11.4.E, page 170). The result of these analyses is also applicable to consumers who lease their vehicles, as well as to consumers with different income levels. Overall, our analysis indicates that the proposed regulations would benefit all vehicle purchasers significantly because savings from lower operating costs associated with controlled vehicles exceed the annualized cost increase of the vehicles.

Second, I thought it could be useful to provide some insight (about a sentence each) on the main results from the simulation. For example, on page 135 the E-DRAM model is extrapolated out to 2010, 2020, and 2030. The reader is referred to the original report to determine how this was accomplished. It would be useful however if there were a brief description, perhaps one or two sentences, even in a footnote, to explain how this is accomplished (a model based explanation). This could further increase the high credibility of the report. In the following paragraph there are estimates on economic output, personal output, and net employment. Again, it would be useful if there were a brief model based description included, perhaps one or two sentences, even in a footnote, to explain how this is accomplished. In the paragraph above 9.3 there is an explanation provided. However, it is unclear if this is a theoretical explanation or a model based explanation. By model based explanation I mean what independent and dependent variables play a key role in computing the estimate.

To take another example, in the first paragraph of section 9.3, the report indicates, "The California businesses impacted by this regulation tend to be affiliated businesses such as gasoline service stations, automobile dealers, and automobile repair shops. " It is unclear how gasoline service stations are affected, whether these are negatively (because of increased mpg) or positively (by increased mpg inducing people to drive more). It would be useful to include a statement to clarify the direction of the result and the reason we observe it. This too could further increase the high credibility of the report. It would be useful to see some numbers and brief explanation of these in section 9.4.

Response: The ISOR intended to provide a summary of the economic impact results. A more detailed description of the economic impact methodology and results is provided in the staff's Technical Support Documents. Furthermore, additional explanation of the E-DRAM model and its results were added to the Technical Support Document as you suggested.

Incidentally, the results are very well presented as in Tables 9.2-3 to 9.2-5. As I said before the material in this section is well written and presented.

Section 10

Section 10 covers the potential impact on minority and low-income communities. I noticed that in this section the authors do cover the potential impact (costs and benefits) of the regulation on low- income household (who generally acquire used automobiles) at a disaggregated segment level (related to the first point above). This was the nature of the information I was looking for the other segments as well in section 9. This section could benefit from a one or two sentence footnote on a model-based explanation of how the estimates were achieved.

Response: As stated in our response to the previous comment, additional explanation of the E-DRAM model is provided in the staff's Technical Support Document.

Section 11

Section 11 is on several supplemental approaches (to those described in section 9) comprising recent tools (in early stages of development) and studies that provide insight on the potential effects of the regulation fleet mix, emissions, the California economy, state business, and low-income households.

There are a few issues that come to mind. First, when a model was mentioned, I was curious if the model had been tested, e.g., a test of predictions to a holdout sample. Second, I was curious about the accuracy of model predictions of the effects of small changes of the type that are assessed in this report. Both issues can be easily addressed through a few additional sentences in text.

Third, the model described in this section assumes full information or knowledge of the reduced operating costs (and the increased price). There are many ways to increase buyer's awareness of the reduced operating costs, advertising, information on the automobile pricing sheet, etc. It may be useful to include a few sentences on this issue.

Fourth, I was curious if the model-based analysis considers increases in the population of California, and other changes such as new development away from city centers.

Finally, there are some minor points:

In the top paragraph on pg. 147 the last sentence needs some clarification. It would be valuable to provide a one-paragraph description of the model, e.g., what are the independent and dependent variables comprising the model equation(s).

On page 154 it appears that there are two stages of the regulation. These two stages should be briefly described, particularly if they have not been described earlier.

Does Table 11.2-2 only have the automobiles likely to be impacted by the regulation? If not perhaps it should only cover vehicles affected.

Would be useful to describe the model referred to in 11.3. B in a couple sentences (independent and dependent variables, equations, etc). An example of this is in the paragraph at the bottom of p. 161.

The five indents on pg. 164-165 are very good.

All in all, I commend the staff for a fine job on these 3 sections.

Response: This comment provides a number of excellent suggestions. The staff report was modified to incorporate those suggestions. Because of the interest in maintaining a streamlined staff report, the CARBITS description was not expanded significantly. However, additional information about the CARBITS model is provided in the August 6, 2004 Technical Support Document to the Staff report. In addition, Professor Bunch has submitted a memorandum that further explains the CARBITS model and its performance.

** Professor Currim also submitted comments on several reports prepared by contractors to assist with the staff evaluations. The comments, which will be posted on the ARB's web site, were forwarded to the applicable contractor.*

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SCIENTIFIC PEER REVIEW FOR THE CALIFORNIA AIR RESOURCES BOARD (CARB) "Analysis of Consumer Responses to the Proposed Climate Change Regulations"

W. Michael Hanemann

I have reviewed the following documents, which were provided to me by CARB:

CARB *Staff Proposal Regarding the Maximum Feasible and Cost-Effective Reduction of Greenhouse Gas Emissions from Motor Vehicles (Draft Initial Statement of Reasons)*. Draft, June 14, 2004 ("the staff report").

CARB *Staff Proposal Regarding the Maximum Feasible and Cost-Effective Reduction of Greenhouse Gas Emissions from Motor Vehicles Other Considerations. Technical Support Document*. Draft, July 11, 2004 ("the staff report appendix").

Daniel Sperling et al. (2004), *Final Report: Analysis of Auto Industry and Consumer Response to Regulations and Technological Change, and Customization of Consumer Response Models in Support of AB 1493 Rulemaking*. Institute of Transportation Studies, UC Davis, June 1, 2004.

David S. Bunch, (2004) *CARBITS (California Air Resources Board – Institute of Transportation Studies) Vehicle Market Microsimulation Model for California. Documentation* June 8, 2004.

Belinda Chen, Ethan Abeles, Andrew Burke, and Daniel Sperling, (2004) *Analysis of Auto Industry and Consumer Response to Regulations and Technological Change, and Customization of Consumer Response Models in Support of AB 1493 Rulemaking – Effect of Emissions Regulation on Vehicle Attributes, Cost and Price*. Institute of Transportation Studies, UC Davis, June 1, 2004.

Andrew Burke, Ethan Abeles and Belinda Chen (2004), *The Response of the Auto Industry and Consumers to Changes in the Exhaust Emission and Fuel Economy Standards (1975-2003): A Historical Review of Changes in*

Technology, Prices, and Sales of Various Classes of Vehicle. UCD-ITS-RR-04-4, June 2004.

Belinda Chen and Daniel Sperling (2004), *Case Study of Light-Duty Diesel Vehicles in Europe* Draft Final Report, Institute of Transportation Studies, UC Davis, June, 2004.

Kenneth S. Kurani and Thomas Turrentine (2004), *Analysis of Consumer Response to Automobile Regulation and Technological Change in Support of California Climate Change Rulemaking*. Final Report. Institute of Transportation Studies, UC Davis, June 1, 2004.
Kenneth A. Small and Kurt Van Dender, (2004) *Final Report: A Study to Evaluate the Effect of Reduced Greenhouse Gas Emissions on Vehicle Miles Traveled* (Draft, 7/9/04)

In addition, I have consulted various journal articles, working papers and reports which I found in the literature; these are cited in the bibliography appended to this report.

The starting point for my review is (1) the analysis of proposed climate change emission reduction standards set forth in sections 4 and 6 of the CARB staff report, (2) the staff technology assessment in section 5.2 of the staff report, and (3) the staff calculation of incremental costs of climate change emission reduction technologies in section 5.3 of the staff report. These staff analyses are outside my field of expertise, which is economics rather than engineering, and therefore I am not in a position to evaluate them. I take their conclusions as given and focus here on their economic implications as discussed in sections 5.4, 8, 9, 10 and 11 of the staff report, as well as in the other reports listed above.

Rather than commenting on each of these reports separately, because they tend to overlap in their coverage, I will organize this review around a series of themes which cut across various reports.

<u>The Choice of a Discount Rate and Lifetime Cost Calculation</u>

A key economic feature of the climate emission reduction technologies, as analyzed by CARB staff, is that while they are likely to increase the production cost of a new vehicle they are also likely to reduce vehicle operating costs by raising fuel efficiency. Thus, the owner of the vehicle faces an initial increment in purchase cost followed by a stream of savings when operating the vehicle. For an owner-operator, the discount rate becomes a crucial consideration in assessing the tradeoff between the higher capital cost and the lower operating cost, as well as in calculating the annualized cost, or the present value of lifetime cost, of vehicle ownership and operation. A high discount rate means the higher purchase cost could overwhelm the savings in operating cost, while a low discount rate implies the reverse.

The main body of the staff report uses a real discount rate of 5% "based on ten-year averages of automobile interest rates and the general inflation rate." This is used for two sets of calculations in the staff report: a calculation of the cost-effectiveness of the regulations in section 8, and a general equilibrium assessment of their impact on the California economy in section 9. Both calculations employ an estimate of the annualized cost of purchasing motor vehicles based on a 5% interest rate.

It should be noted that real interest rates over the past few years were at an historic low. It seems likely that real interest rates will be higher over the next 5-10 years than they were over the past 5-10 years. I am not sure how this is reflected in the staff analysis.

The discount rate has received considerable attention in the literature on household appliance ownership and utilization, starting with Hausman (1979) who examined the purchase and utilization of room air conditioners by a sample of 65 households. He estimated a model of discrete choice among alternative types of air conditioner where the underlying indirect utility function included both the price of the air conditioner and its operating cost per hour as separate attributes. The ratio of the two coefficients indicates how consumers make a tradeoff between the two types of cost. Hausman found that the ratio of estimated coefficients in this case implied a household discount rate of about 25%,[4] but this varied with household income – the estimated discount rate fell from 39% for households with incomes less than $10,000 (in 1976 dollars) to 8.9% for households with incomes between $25,000 and $35,000. Other researchers studying items such as refrigerators and water heaters have found similar if not higher discount rates; there is also evidence of a similar variation of discount rates with income.[5]

However, owners of automobiles are likely to face a somewhat different situation because, unlike household appliances, there is a dedicated source of finance in the form of automobile loans offered by both vehicle manufacturers and financial institutions. Because of this, would-be purchasers of automobiles are – ceteris paribus -- less likely to be credit constrained than purchasers of other household appliances and they typically enjoy lower interest rates than those associated with the credit cards that are often used to finance household appliance purchases. Consequently, there is no reason to believe that the discount rates measured in the appliance literature should carry over to automobiles.

[4] As explained further in the following section, I do not believe that this ratio is necessarily a reliable measure of the interest rate applied by households to their purchases of durables. However, for the remainder of this section I will follow the convention of treating this ratio of coefficients as though it provided a meaningful estimate of the household's discount rate.

[5] Households with high incomes are likely to face better access to credit than those with low incomes. In addition, Hausman points out that, even with perfect capital markets, the household discount rate should decrease with income because the marginal tax rate rises with income while the services of consumer durables are untaxed.

I am aware of several papers that deal with discount rates as they relate to household purchase of automobiles.[6]

Papers employing the Hausman approach for automobiles include Berkovec (1985), Mannering and Winston (1985), Goldberg (1995), and Goldberg (1998). Berkovec (1985) finds that the tradeoff between purchase price and operating cost varies with both household income and the number of cars owned. The relative weight on vehicle price declines with increasing income, and is about six times lower for families with incomes above $25,000 than for families with incomes below $10,000 (both figures are in 1978 dollars). Mannering and Winston (1985) model the tradeoff as independent of income but they allow it to vary before, during, and after the June 1979 gas price shock – they find that the relative weight on vehicle price (capital cost) fell over time. They estimate the implied individual household discount rate at 26.4% before the price shock (December 1978 – June 1979), 19.8% during it (July 1979 – December 1979), and 15.6% after it (January – June 1980) Like Berkovec, Goldberg (1995) interacts the tradeoff with income as well as automobile type and finds that for vehicles other than luxury and sports car it is lower for families with incomes above $75,000 (in 1982 dollars) than for those below; it is also lower when the family has bought that specific model of car in the past than for first time buyers.[7]

A paper by Dreyfus and Viscusi (1995) estimates the rates of time preference of automobile owners using a different approach from that of Hausman et al. Dreyfus and Viscusi did not have information on the purchase or utilization of automobiles; instead they had data on the prices of alternative models, and they estimated a hedonic price function for automobile prices which included a rate of time preference parameter. They estimated the value of this parameter to be 11%, 13% or 17%, depending on the specific covariates in the hedonic equation. However, I do not believe this is a valid methodology for estimating the time preference of automobile owners; it implicitly assumes that all consumers have exactly the same rate of time preference at the margin, and their indifference curve is tangent to the hedonic frontier at exactly the same point in interest-rate/attribute space, which I find highly implausible. In my view, the hedonic price approach to estimating consumers' rates of time preference is not a valid substitute for the Hausman approach using explicit data on vehicle purchases or utilization.

A very relevant paper is Attanasio, Goldberg and Kyriazidou (2000) which examines the prevalence of borrowing constraints in the market for automobile loans. The study uses household level data from the Consumer Expenditure

[6] Some fraction of the motor vehicle fleet in California is owned and operated by entities that are not households (companies, governments, NGOs, etc). There does not appear to be much analysis of motor vehicle demand by the non-household sector either in the economics literature generally or in the staff report.

[7] The CARBITS Vehicle Microsimulation Model similarly involves a discrete choice model among types of automobile, with separate coefficients for vehicle price and operating cost. From Table A-3 it appears that, while the coefficients do not vary with income or vehicle type, both of the price variable are measured relative to (the log of) household income.

Survey (CES) over the period 1984-1995. The analysis focuses on 11,666 households covered by the CES over this time period who had bought at least one car during the interview period.[8] 46% of these households took auto loans; 33% of them financed more than 90% of the car price, while the average finance share was 78%.[9] Among other results, the authors find that young households are likely to finance at long maturities, and long maturities are used more by households financing through dealers than though other sources (banks, credit unions, other financial institution, or other private sources). A large fraction of the variation in loan maturity and in the real interest rate (i.e. the nominal interest rate adjusted for the rate of inflation in the consumer price index) is accounted for by new versus used cars. Both interest rates and maturities are highly correlated with credit source -- e.g., credit unions are associated with lower interest rates and shorter maturities. The choice of credit source is highly correlated with socioeconomic characteristics, with education, race and gender being major determinants.

The main portion of the econometric analysis in Attanasio, Goldberg and Kyriazidou (2000) focuses on the determinants of the finance share as a function of both sociodemographic characteristics and the interest rate and maturity, correcting for the selection bias (only some purchasers elect to finance) and the endogeneity (the interest rate and maturity depend in part on the choice of a lending source). The authors find that, while the demand for auto loans is sensitive to the interest rate, the interest sensitivity is largest for older consumers and for consumers with relatively large current income; this suggests that other consumers are more likely to be credit constrained. In addition, the authors find strong sensitivity to loan maturity, which is also indicative of binding borrowing restrictions. The maturity effects are more pronounced for younger and less well off consumers, the groups that one would expect to be liquidity constrained; the only groups for which no sensitivity to maturity is observed are the middle age group and the consumer group with the largest current income.

A common message emerging from these papers is that the interest rate used to finance automobile purchases is likely to vary among consumers, especially by income and perhaps by other sociodemographic characteristics. Given this, I think it would be useful, in future work, for CARB staff to further review the information that might be available on how different groups of consumers in California finance their purchases and the interest rates they face. I recognize that the CARB staff has already taken a step in this direction with the special analysis of low-income used car buyers in section 10.4.A, which employs a real discount rate of 10%, including a 5% risk premium for these households. I think it would be useful to extend this analysis to a broader set of consumer groups, and

[8] For each vehicle that a household owns, the CES provides data on the purchase date and source, various vehicle characteristics including whether the vehicle was purchased as new or used, the purchase price, the trade-in allowance, the source of financing, the down payment, the amount of the principal, the size of the monthly payments, the maturity of the loan, and the effective interest rate.

[9] The finance share is that portion of the purchase price not covered by a down payment and/or a trade-in allowance.

to new car purchases, using whatever data is available on the financing of automobile purchases in California.

Response: The first part of the comment suggests that a 5% discount rate used for the analysis of annualized costs may be low. As the comment correctly states, we used a real discount rate of 5% based on ten-year averages of automobile interest rates and the general inflation rate. This rate often signals a historical high for the real interest rates as indicated by a recent study by the Federal Reserve Bank of Dallas[10]. Staff agrees that real interest rates over the past few years were at a historic low. The Federal Reserve Study shows that the real interest rates have been close to zero or negative at times for the past few years. Staff also agrees that real interest rates will be higher over the next 5-10 years than they were over the past 5-10 years. For this reason, staff believes the use of a 5% real discount rate to annualize costs for the purpose of this analysis reflects a very conservative assumption.

The second part of the comment suggests that the interest rate used to finance automobile purchases is likely to vary among consumers, especially by income and perhaps by other sociodemographic characteristics. We agree with this suggestion. That is exactly why we used the assumptions of a 10% real rate of interest and a car loan with 3-year maturities to analyze the impact of the proposed regulations on low-income households. As this analysis shows, the climate change regulations have negligible impacts on these households. Although we agree that the proposed regulations may have slightly different impacts on consumers with different incomes and sociodemographic characteristics, the overall impacts on other consumer segments are expected to be positive.

<u>The Economic Significance of Responses Rooted in Discounting at Financial Interest Rates versus Behavioral Reactions</u>

As noted above, I do not believe that the ratio of the coefficients on the purchase price and the operating cost in an econometric model of the purchase of consumer durables necessarily provides a reliable estimate of the interest rate at which a consumer annualizes current capital outlays and discounts future operating expenditures. I expect that these coefficients reflect not only the actual circumstances of the consumer's financing of the purchase, including the interest rate and the maturity of the loan, but also behavioral factors relating to the consumer's *perception* of these costs and the *decision weights* he places on them.

Moreover, the operating cost used in the econometric analysis is often the cost as measured by the researcher, which may well be different from the cost experienced or perceived by the consumer.[11] If there is a discrepancy between the cost as measured by the researcher and the cost as experienced and/or

[10] Federal Reserve Bank of Dallas, Monetary Policy Prospects, Issue 3, May/June 2004.
[11] This might sometimes apply to the capital cost, also.

perceived by the consumer, this can affect the estimated regression coefficients and it can bias the calculation of the implicit discount rate.

In short, a consumer may appear to place a low relative weight on future operating costs (1) because he is borrowing money at a high rate of interest, (2) because the operating cost used by the researcher is measured with error, or for behavioral reasons such as (3) he is only dimly aware of the operating costs, or (4) his preferences are such that he considers them relatively unimportant. If (2) is the reason, this is problematic because, as noted above, it may bias the estimated regression coefficients. Assuming that (2) does not occur, it still is not clear that one can reliably measure the discount rate from the ratio of regression coefficients because of (3) and/or (4).[12]

To summarize, if one wishes to estimate the actual cost for a consumer to finance the purchase of a durable, it is better to obtain data on consumer borrowing than to rely on inferences from the ratio of coefficients in an econometric model of consumer choice. Conversely, if one wishes to know the weight that a consumer places on operating costs relative to purchase costs for the purpose of predicting his choice behavior, and if there is no error in measuring the cost as perceived by the consumer, it is better to estimate this from a model of consumer choice.

Which one needs to know depends on the purpose of the analysis. One can distinguish three types of analysis: (A) predicting the impact of a regulation on a consumer's purchase or utilization of durable; (B) estimating the general equilibrium impact on the rest of the economy stemming from changes in the purchase and/or utilization of a durable induced by the regulation; (C) conducting a cost-effectiveness assessment of the regulation.

Starting with (A), for making a prediction relating to the purchase and/or utilization of a durable, e.g., predicting the effect of the climate change emission reduction regulations on the size and composition of the vehicle fleet in California, one needs an econometric model of consumer purchasing behavior which includes as explanatory variables the purchase price, the operating cost, and other attributes.[13] While the coefficients on the purchase price, operating cost and other variables obviously determine the model prediction, the discount rate that might be deduced from the ratio of these coefficients is of no independent interest per se.

When it comes to (B), assessing the impact on the rest of the economy of the expenditures associated with (A), one uses data on the actual loan payments and operating costs since these determine consumers' net spending power over the period concerned.

[12] In fact, (3) and (4) are likely to be observationally indistinguishable.

[13] If the purchase price needs to be expressed on an annualized basis, one should employ for this purpose the actual interest rate and loan maturity used by the consumer to finance the purchase.

While the CARB staff report contains an analysis using CARBITS in section 11.1, it does not employ this analysis when predicting the effect of the regulation on the size and composition of the California vehicle fleet in section 9, where these changes are fed into a general equilibrium analysis of the impact of the regulation on the California economy. Instead, the analysis in section 9 assumes no change in vehicle sales or total fleet size. This is inconsistent with the CARBIT analysis, which identifies some small changes in annual automobile sales and fleet size and composition as a result of the regulation (see Table 11.1-7). Since the changes appear to be small, I expect that the inconsistency between the two analyses will be of minor significance, but it is worth noting for the record.

There is also a calculation of cost-effectiveness in section 8, corresponding to (C) above. When it comes to the assessment of cost-effectiveness, the question is: whose perspective should be adopted? Moreover, if one wants the perspective of the consumer, should this be assessed in terms of *utility* or *cost*? If one wants to know whether the consumer is likely to consider himself better or worse off when faced with a vehicle offering a higher purchase price but a lower operating cost, this should be answered by using the fitted utility function underlying the econometric model of consumer choice, since that expresses the consumer's tradeoff between these two items. If one wants to know whether the outflow of money from the consumer's pocket is raised or lowered by regulation, then one should compare the operating cost with the annualized purchase price using the actual interest rate and loan maturity faced by the consumer, whatever these are. Another possibility is that the assessment of cost effectiveness is being made from some perspective other than that of the consumer – e.g., a social or governmental perspective. In that case, I suppose the discount rate used to annualize the purchase price would depend on what this perspective is.

Out of the three approaches listed in the previous paragraph, I assume that the second one best describes the cost-effectiveness analysis in section 8, in which case the appropriate discount rate for annualizing motor vehicle purchase prices is the interest rate likely to be paid by the California consumers who purchase these vehicles.

Response:Your comments on the consumer's actual response to the discount rate and the appropriateness of the discount rate based upon the type of the economic impact analysis are well taken. Staff also agrees with you that the staff report provides supplemental analysis of the compliance costs using CARBITS model, which identifies some small changes in annual automobile sales and fleet size and composition as a result of the regulation. Exactly for the reason you identified, the changes associated with the purchase and/or utilization of vehicles were very small. Thus, considering its early stage of development and the minimal impact on the results, the staff decided not to use the CARBITS results for assessing the overall economic impacts of the proposed climate change regulations. Instead, the staff used the standard analysis for carrying out the economic impact analysis. Although the standard analysis is less complex than the CARBITS model and it relies on simplified assumptions, the overall results

are substantially consistent with those associated with the application of CARBITS.

The Rebound Effect

I have focused so far on the consumer's choice of whether and when to buy an automobile, and which model to select. Another important issue is the utilization decision of how much to drive. This has potential environmental as well as economic implications – it affects the consumption of gasoline and, to the extent that there are environmental impacts from the production and consumption of gasoline and/or the driving of automobiles, it affects these as well. The latter have received considerable attention in the economic literature on the effects of the CAFÉ standards. It has been argued that promoting greater use of cars with a higher mileage per gallon reduces the cost of driving and encourages more driving and more fuel consumption. This is known in the energy literature as the *rebound effect*. The crucial question is the quantitative magnitude of this effect.

There is a substantial literature on the rebound effect for motor vehicle utilization in the context of the federal CAFÉ standards. This literature is reviewed in some detail by Small and Van Dender (2004). In addition to reading Small and Van Dender's report, I have also consulted many of the articles and reports that they cite. After reviewing the literature, Small and Van Dender TO BE COMPLETED

Response: Comments on the rebound work were not submitted as part of the review.

Impact on Used Car Market

The staff analysis understandably focuses almost all of its attention on the new car market in California. The used car market is discussed in section 10.4 in the context of an assessment of potential economic impacts on low-income communities who purchase used vehicles and experience the effects of the regulation when compliant vehicles eventually come for sale in the used car market.

It is possible, at least in principle, that the regulations could have an immediate impact on the prices of used cars in California. First, the increase in the price of new cars could induce some people who would otherwise have bought new cars to purchase used cars instead, thereby *raising* the demand for used cars in California. Second, and conversely, to the extent that used cars lack attributes of new cars induced by the regulation that consumers find attractive (e.g., lower vehicle operating costs), this could lead some people who would otherwise have bought used cars to buy new cars instead, thereby *lowering* the demand for used cars in California. Third, if it were the case that dealers who sell used cars had sufficient market power, they might be able to unilaterally raise the price of late model used cars to match at least a portion of the increase in the price of new

cars triggered by the regulation.[14] The first and third mechanisms imply an increase in the price of used cars, while the second implies a reduction; the net effect is clearly an empirical question.[15] If used car prices were to rise, it would imply a welfare loss for consumers who buy used cars; it used car prices were to fall, it would imply a welfare gain. While I have no reason to believe that the effect is large, I do believe that it would be useful for CARB staff, in future work, to investigate the potential effect of the regulation on the used car market in California.

Response: As the comment correctly identified, the focus of the staff analysis is on the new car market in California. This is because the direct effect of the regulations is on the new car market. The used car market, however, may be impacted indirectly. The staff recognizes such an impact when analyzing the effects on the regulations on low-income households. The staff, however, believes that the potential effect of the proposed regulations on the used car market is very small for two reasons. First, for the reasons cited in the comment the regulations would stimulate market forces that would put both upward and downward pressures on the price of used cars. Therefore, we believe that the net effect of these forces is likely to be small. Second, the proposed regulations would give the auto industry eight years, starting in 2009 model year, to meet a 30 percent reduction in CO_2-equivalent emissions. This long lead-time allows both manufacturers and consumers to adjust to the requirements of the proposed regulations. Thus, we believe that the proposed regulations are likely to have small impacts on the used car market.

Automobile Manufacturers' Response to Regulation and Impact on Prices, Attributes, and Variety.

The point of departure for the CARB staff's economic analysis is its estimates of the increase in manufacturing cost and the reduction in vehicle operating cost for various types of motor vehicle. As noted earlier, these are engineering estimates which lie outside my own field of expertise. Here, I wish to make a different point. The staff analysis makes two assumptions. First, it assumes that the automobile manufacturers respond to the regulations by adopting the technologies which the CARB staff has identified. There are other possibilities – for example, (some) manufacturers might respond by focusing narrowly on lowering motor vehicle weight or, they might leave vehicle characteristics unchanged but use marketing techniques to change the mix of vehicles sold to include more small cars and fewer large cars. Second, even if the automobile manufacturers do adopt the technologies identified by CARB staff, and even if the manufacturing costs are as

[14] The CARB staff report appendix may perhaps have this mechanism in mind when it refers (on page 11) to "the potential increases in the price of used vehicles in response to price increases to new vehicles associated with the regulation. Such an effect would be expected to translate into a further increase in the sales of new vehicles."

[15] The first and second effects were considered by Dunham (1994?) in the context of an assessment of the economic impact of federal safety regulations introduced over the period 1972-1991. Dunham found that consumers appear to have valued the safety regulations by more than their cost, so that the net effect was a reduction in the demand for used cars..

the staff has estimated, it is assumed that the manufacturers raise the price of each model by exactly the increment in its manufacturing cost. There are other possibilities – for example, (some) manufacturers might cross-subsidize, raising the prices of models for which demand is inelastic by more than the increment in manufacturing cost, while raising the prices of other models by less than the increment in manufacturing cost. One can characterize the first as an assumption about the *technologica*l response of the automobile manufacturers, and the second as an assumption about their *marketing* response. Both types of response are hard to predict, but I think the latter is especially difficult – I do not believe it can reliably be characterized either in theory or econometrically, although there are several papers in the literature which have attempted to do something like this.

The impossibility of predicting the marketing response by automobile manufacturers is well recognized by Sperling et al. (2004), who devote several sections of their report to this point, including Section 5 “Compliance costs are not immediately converted into higher price and are recovered with a variety of ad hoc tactics,” Section 6 ”Manufacturers spread the cost of new technologies across a broad range of models and markets,” Section 7, “Regulations sometimes induce manufacturers to alter their volume and mix of vehicles,” Section 8 “Manufacturers have used non-pricing strategies to overcome consumer resistance to price increases resulting from regulations,” and Section 9 “Industry behavior towards new technologies is not related to whether or not they were the result of government regulation.”.

While I know of no way to obtain a reliable prediction of the technological or marketing responses of the automobile manufacturers, this does not mean that one should do nothing about this. I think it would be useful in the future for CARB staff to supplement their existing analysis by considering one or more possible responses by the automobile manufacturers -- besides simply raising each model’s price by the increment in its manufacturing cost -- and then tracing the economic consequence of the regulation if the manufacturers respond in this way.

Response: This comment raises a very interesting point that the auto industry’s response to the regulations may be different from those identified by the staff. It’s certainly true that manufacturers often respond to regulations in ways that were not identified by staff. This is exactly the reason why ARB regulations are mostly performance-based; that is, the standards are set based on the feasibility of the current technologies but allow regulated businesses flexibility to meet the standards in any way they can. The performance-based regulations encourage businesses to be innovative and often businesses have found new innovative ways, not identified by regulators, to meet the requirements of the regulations at significantly lower costs. There is some anecdotal evidence indicating that regulator’s estimates of the expected cost of regulations have historically been higher than the actual costs of the regulations. The ARB currently has a study underway to study the ex ante cost estimates with ex post costs for a number of its past regulations. For this reason, staff believes that its cost estimates based

on available technologies are very conservative and the actual costs of the regulations are likely to be lower.

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Comments Submitted by:

Comments on "Staff Proposal Regarding the Maximum Feasible and Cost-Effective Reduction of Greenhouse Gas Emissions from Motor Vehicles" dated June 14, 2004*

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Overview

I have read the sections of the Draft Staff Report, dated June 14, 2004, most relevant to my expertise. The Air Resources Board is to be commended for their thorough and competent work. Their task is a difficult one and it would be impossible for the ARB to capture all of the features of the automobile industry. Furthermore, the ARB is projecting well into the future and must, therefore, make certain assumptions regarding the outcomes of random variables. The ARB has correctly identified that there will be both costs and benefits to consumers associated with compliance. In addition, the benefits will accrue over the lifetime of the vehicle and the ARB must, therefore, calculate the present value of the benefits.

As with any analysis of this type, certain simplifying assumptions must be made; I realize this. In this report, I have pinpointed a few assumptions that the ARB has either implicitly made, or not discussed in detail. I would recommend that the ARB look into how large of an impact these assumptions may have on this analysis. In the end, the ARB may find that these assumptions do not have a large impact on their results. The ARB may ultimately find that these issues do not have a large impact on the results. Alternatively, the ARB could make explicit assumptions about their magnitudes and calculate the net benefits for a range of values.

I focus my comments on the estimation of the change in vehicle prices that result from compliance and the estimation of the change in operating expenses as a result of compliance. Once these estimates are established one can estimate net effect on consumers from compliance. Of course, this net effect ignores the environmental benefits from the new legislation and is thus a lower bound on the benefits to consumers. Admittedly, the estimation of these relevant numbers is a difficult task and the ARB has taken into account many of the relevant factors. Estimation of the costs and benefits requires assumptions regarding the nature of competition in the automobile industry, an industry often considered to be an oligopoly. Below I discuss results from economic modes of the behavior of firms with market power that are relevant to the report.

Potential Issues to Consider

Firm Capture of Operating Cost Changes

As I read the report, the ARB has (a) predicted the amount of pass through of any increases in costs associated with the new legislation and (b) estimated the decrease in operating expenses associated with the compliance with the new legislation. The ARB assumes that firms increase the price by the full amount of the change in marginal costs plus a forty-percent mark up. The ARB then separately estimates (b) and compares the dollar amount of (a) with the present discounted value of (b).

It is important to note that the legislation will contemporaneously change the marginal cost and the operating costs of the vehicle. Why is this important? There will likely be two effects on price: The main effect from the new legislation is that the new legislation will increase marginal cost, thereby increasing price. The second effect is that it is also optimal for the firm to increase price as a result of the reduction in the operational costs of the vehicle. Ignoring this second effect will bias the predicted increase in price downward, overstating the gains from the legislation to consumers (or, equivalently, understating the losses). In some respects, this is a second type of "rebound effect" dealing with prices rather than quantities. In my opinion, this is the most important issue that the ARB should look into.

A simple example will also motivate the point. Suppose an automobile manufacturer has two models that are equal in every way except for fuel efficiency. Suppose that the two cars even have the same marginal cost. The firm would almost certainly charge more for the more efficient vehicle, thereby capturing some of the decrease in operating costs. The extent of this effect on price will be dependent on the degree of competition, but the ARB may want to consider this secondary effect on prices. Perhaps the ARB can look at current pricing strategies for automobiles that have different emissions models (e.g., the Civic Hybrid vs. "conventional" Civic). Alternatively, the ARB can make an explicit assumption regarding the magnitude of this effect and calculate the net benefits. This is similar to the assumption regarding the pass through of increases in marginal costs (i.e., a forty percent mark up).

Response: This comment suggests that manufacturers may try to capture at least part of the cost savings to consumers that would result from the proposed regulations. It's certainly true that such cases may occur for certain vehicles, especially when there are similar vehicles in the market with one vehicle model distinguishing itself by offering attractive features that others lack. This situation is not stable and would not be expected to last long because other manufacturers would soon offer the same features for their vehicles in order to stay competitive. Furthermore, the proposed regulations would be expected to reduce the operational costs for the majority of vehicles sold in California. Because of the

competitive nature of the vehicle market, it would be difficult for automobile manufacturers to charge a premium over their marginal cost for long.

Issues Related to Alternative Fuels

The ARB calculates the net benefits to consumers for vehicles that use alternative fuels using current fuel prices. This implicitly assumes that the long run supply curve for these alternative vehicles is flat, at the current price. It would be nice to see more evidence on this. The switch to these alternative fuels will, by definition, increase the demand causing a movement along the supply curve. If the supply curve is upward sloping, then the price will increase as a result. How large of an impact this has on price is an empirical question.

Related to the supply curve of alternative fuels are the fixed costs associated with building new alternative fueling stations. This, if large, can potentially be a drag on the California economy. Does the ARB have a sense of how large these will be? This will obviously depend on the method of compliance.

It appears as though most of the gains will come from using new technologies with gasoline engines, so these two issues may not have a large effect on the analysis.

Response: Your comment is well taken. We agree that there may be upward pressure on the price of alternative fuels if demand for those fuels pick up significantly. Certainly, if the suppliers of alternative fuels perceive the increase in demand to be permanent, they would make the necessary investment for new refueling stations. However, given great uncertainty associated with forecasting alternative fuel prices, the staff believes that the use of current fuel prices represents a conservative assumption for estimating the net benefits to consumers for vehicles that use alternative fuels. The staff also agrees that the above issues would not be expected to have significant impacts on the staff's cost and benefit analysis because much of the gains from the proposed regulations would result from the use of new technologies with gasoline engines.

Firm Pass Through of Changes in Marginal Costs

Presently, the report assumes that the increase in marginal costs associated with compliance is passed through to consumers with a forty-percent mark up. While this seems like a reasonable assumption, many models of firm behavior would predict that the pass through of an increase in marginal cost will be less than 100 percent. The magnitude of this derivative depends on the relative slopes of the marginal costs and demand. If demand is linear, then increases in marginal costs will not be entirely passed through to consumers. In contrast, if demand has a constant elasticity form, they will be passed through with a "mark up."

My point here is that just because a firm prices above marginal cost does not necessarily imply they will mark up changes in marginal cost. By ignoring this effect, the study maybe underestimating the gains to consumers. It would be

nice to see some evidence regarding previous changes in marginal cost and the resulting changes in prices. Alternatively, the ARB can mention that because of this, they are providing conservative estimates of the gains to consumers.

Response: Given the competitive nature of the auto industry, we agree automobile manufacturers may not be able to pass on the entire costs of compliance to consumers in terms of higher prices. Because of the uncertainty associated with estimating the extent of the cost pass through, the staff assumes 100% cost pass through. This provides, as you correctly recognize, conservative estimates of gains to consumers.

E-DRAM Model: The more macro effects of the legislation rely heavy on the economic model developed by the Department of Finance (E-DRAM). As such, I also plan to analyze the validity of this model and will include any potential issues in my next report.

Response: We certainly appreciate your comments on the E-DRAM model and its results.

Impact on Low Income Households: Could the ARB use the information on the compliance methods more likely to be used for certain classes of vehicles to gauge the impact on low-income households? Given that low income households tend to buy lower priced vehicles, the ARB could provide a more specific estimate of the effect on low income households, compared to other income group.

Response: This comment offers an excellent suggestion. However, lack of data prevented us from determining differing technological packages that manufacturers may choose to use as a function of vehicle classes beyond those discussed in the staff report. We believe that the staff report presents a conservative estimate of the potential impacts of the regulations on low-income households.

CARBITS MODEL: This is an important component of the analysis. As I understand it, the CARBITS model was developed a few years ago. It would be nice to know how well it has performed. Specifically, the ARB could use the predictions of the model for the period after the model was developed and compares those predictions with actual outcomes. This sort of out-of-sample testing is common in the economics literature and adds credibility to the results. This might be beyond the scope of the Staff Report, but would be helpful information.

Response: Additional information about the CARBITS model and its performance were provided in the supplemental documents to the staff's report.

Summary

In this review I have discussed certain simplifying assumptions that the ARB has made that may, or may not, have a large effect on the results. The first three would tend to overstate the gains to consumers from the new legislation, while the last one would tend to understate the gains. As such, if the ARB is interested in providing a conservative estimate of the gains to consumers that last issue can be ignored, but the ARB may want to consider the first three.

Response: We believe the above effects would not have a significant impact on the results for reasons mentioned above.

- *Professor's Knittel's comments were provided in pdf format as they included mathematical formulas. Therefore, the text of his comments are provided here with responses. The responses include a consideration of the formulas discussed in his comments. Further, a copy of Professor's Knittel's original comments are available.*

ADDENDUM

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD

Additional Peer Review Comments and Responses on:

1) **Staff Responses to Peer Review Comments on the June 14, 2004 Draft Initial Statement of Reasons and Supporting Appendices for the Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles;**
2) **The August 6, 2004 Initial Statement of Reasons and Supporting Appendices for the Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles, August 6, 2004**

September 21, 2004

Table of Contents

Summary of Document

This document presents a second round of comments provided as part of the University of California peer review of:

- The August 6, 2004 Initial Statement of Reasons and Supporting Appendices for the Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles;
- The September 10, 2004 Addendum Presenting and Describing Revisions to the Initial Statement of Reasons; and,
- Peer Review Comments and Responses, September 2004, which contains staff responses to peer reviewer comments on the June 14, 2004 Initial Statement of Reasons and Supporting Appendices for the Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles.

As indicated previously, the peer reviewers focused their respective reviews on elements of the report related to their areas of expertise with all aspects of the report being reviewed by at least one peer reviewer. With respect to their review, all six peer reviewers concluded the following regarding the staff analysis and conclusions:

<u>No reviewer found that ARB had failed to demonstrate that a scientific portion of the proposed rule was based upon sound scientific knowledge, methods, and practices.</u>

Three of the peer reviewers provided additional comments based on their consideration of staff responses to their comments on the June 14, 2004 draft ISOR as well as the August 6, 2004 ISOR, associated appendices, and addendum, as follows:

- **Robert F. Sawyer**, Ph.D., Professor in the Graduate School, Department of Mechanical Engineering, UC Berkeley

- **Michael Hanemann**, Ph.D., Chancellor's Professor of Agricultural and Resource Economics and Goldman School of Public Policy, UC Berkeley

- **Christopher R. Knittel**, Ph.D., Assistant Professor of Economics, UC Davis

This document provides the above peer reviewers' additional comments, as well as staff responses in italics.

Review of:

California Environmental Protection Agency
California Air Resources Board

STAFF REPORT:
INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING, PUBLIC HEARING TO CONSIDER ADOPTION OF REGULATIONS TO CONTROL GREENHOUSE GAS EMISSIONS FROM MOTOR VEHICLES

(Dated: August 6, 2004)

Prepared by:

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17 September 2004

BACKGROUND

This review is further to the earlier review: Sawyer, R.F., *"Review of California Environmental Protection Agency, California Air Resources Board, Staff Proposal Regarding the Maximum Feasible and Cost-Effective Reduction of Greenhouse Gas Emissions from Motor Vehicles (Dated: June 14, 2004),"* 15 July 2004. This review is prepared under Interagency Agreement #98-004-TO-73, between the Regents of the University of California and the California Environmental Protection Agency, the California Air Resources Board (ARB). The review focuses on:

> *California Environmental Protection Agency, California Air Resources Board, Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles (Dated: August 6, 2004).*

Additionally, the following documents were examined:

> *California Environmental Protection Agency, California Air Resources Board, Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles (Dated: August 6, 2004). Appendix A, Proposed Regulation Order, Amendments to Sections 1900 and 1961, and Adoption of new Section 1961.1, Title 13, California Code of Regulations.*
>
> *California Environmental Protection Agency, California Air Resources Board, Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles (Dated: August 6, 2004).*
>
> ***California Environmental Protection Agency, Air Resources Board, California Emissions Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles, as adopted and amended, as proposed for amendment dated May 28, 2004.***
>
> ***California Environmental Protection Agency, Air Resources Board, Addendum presenting and describing revisions to Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations Control Greenhouse Gas Emissions from Motor Vehicles, Addendum to Initial Statement of Reasons, September 10, 2004.***

MAJOR REVIEW CONCLUSIONS

1) The Staff Report provides a sound basis for regulatory rule making. The scientific and engineering portions of the proposed rule are based upon sound knowledge, methods, and practices. Uncertainties are identified.

2) Most of the issues identified in the earlier reviews of the *"Staff Proposal Regarding the Maximum Feasible and Cost-Effective Reduction of Greenhouse Gas Emissions from Motor Vehicles," (Dated: June 14, 2004),* have been addressed.

3) The proposed rule is considered modest in that:

a) It only accomplishes the maintenance of light duty vehicle greenhouse gas emissions in California at their 2010 levels.
b) It is based on the implementation of technology that largely has been already demonstrated in production.
c) The full implementation of the rule occurs twelve years following the proposed adoption of the rule.
d) It does not include weight reduction through the introduction of high-strength, light-weight materials, which the industry does and will increasingly employ.

4) Opportunities exist for further reductions in greenhouse gas emissions from the light-duty motor vehicle fleet and, importantly, from the heavy-duty sector as well.

5) As the importance of particulates as climate change agents is quantified, the assessing and, if appropriate, further controlling their emissions from mobile sources will be required.

6) Issues that deserve additional attention, particularly in the implementation of the proposed rule, if adopted, are identified and discussed briefly.

ISSUES FOR CONTINUING ATTENTION

Some of the following were identified in the earlier review. Primarily they should be treated as issues to be monitored and explored during the period before and during the phase-in of the proposed greenhouse gas reduction rule.

Test Method: The current combined Federal Test Procedure and Highway test cycles used for regulated motor vehicle emissions testing is adopted as a regulatory convenience. They do not appropriately reflect in-use driving in that they do not include high-power, high-speed vehicle operation (at which greenhouse gas emissions are their greatest). Even the U.S.E.P.A must correct

its measurements when it uses exhaust carbon emission rates to predict fuel economy. The same problem will exist for the estimation of greenhouse gas emission rates. It is important that the difference between in-use and regulated emissions be assessed. The risk is that vehicles designed to meet the test method requirements will not provide equivalent in-use emissions reductions. An early assessment using the Supplemental Federal Test Procedure (SFTP) and other higher speed and load testing is essential.

Response: As indicated in our earlier response, staff agree that better test cycles for evaluating real- world CO_2 emissions could be developed, but given the constraint of completing a rulemaking by January 2005, it was necessary to limit the scope of staff's development efforts. Further, industry already performs the prescribed tests on large numbers of vehicles each year to demonstrate compliance with criteria pollutant requirements in the current Low Emission Vehicle program, and staff wanted to take advantage of the current testing rather than require large amounts of additional testing for measuring CO_2 emissions. It should be possible, however, to investigate development of an improved test cycle when staff works with industry and other interested parties in developing a proper CO_2 emission test that fully accounts for real-world air conditioning system performance. As part of such an effort, existing as well as new cycles would be expected to be considered.

Air Conditioning: The treatment of secondary air conditioning greenhouse emissions (those related to increased load) separately from exhaust emissions risks missing the non-linear effect on greenhouse gas emissions of adding air condition load to other vehicle loads. This is related to the test method issues raised above.

Response: It is staff's intent to develop an improved test cycle that better characterizes real world driving and one that accurately measures the emission effects of air conditioning use. This will be a significant effort since it will involve emission inventory groups that can best evaluate available driving cycles such as the unified cycle. Perhaps other driving cycles might be more appropriate as we look to the future in California and take into account the effects of increasing population and vehicle miles traveled. At the same time, staff would want to develop an appropriate environmental chamber that properly simulates real world effects relative to vehicle air conditioning systems. Efforts to date are not yet accurate or repeatable for such testing. Staff would work with the Society of Automotive Engineers and industry to develop the appropriate facilities and test procedures. This will take some time to get right, but having a regulation for controlling global warming emissions in place will provide momentum for accomplishing these tasks. The staff would like this to be a combined test to minimize resources. We share Dr. Sawyer's view that better tests are important for properly characterizing and crediting new technologies and vehicle designs.

Diesels: The ARB technology assessment of diesels, and the Northeast States Center for a Clean Air Future report upon which it heavily draws, largely neglects what could be a major role of diesels as an industry preferred future light duty vehicle propulsion technology for achieving greenhouse gas reductions. Diesel technology has progressed rapidly in the European market, where greenhouse gas reduction is already a priority. It is possible, even likely, over the period of implementation of the proposed rule that the control technology to meet California's stringent NO_x and particulate emission standards will be demonstrated for diesels.

Response: Staff agrees emission control development for diesels is progressing rapidly and that compliance with the Low Emission Vehicle program standards is within sight. Staff was able to justify significant reductions in global warming emissions in this proposal using technologies that are more certain in terms of emission controls and for which the costs are better defined. Staff is hopeful that further efforts in diesel advanced multi-mode will yield emission compliant engines with lower cost emission controls than currently required for conventional diesels. Staff is also currently meeting with manufacturers of diesel engines to ascertain their capabilities in on-board diagnostics for monitoring the performance of diesel aftertreatment controls such as traps and adsorbers. It is just as important that on board diagnostic systems are capable of signaling deteriorated emission control devices when emissions go above applicable standards as it is to have effective emission controls. This is especially of concern in the case of diesels where aftertreatment will likely be more complex than for gasoline engines and the implications of poorly controlled emissions are more serious. Staff is pursuing the on-board diagnostics evaluation strongly at the present time and has been inviting suppliers and manufacturers to consult with us. With greater definition of diesel progress, staff would be able to review the proposed regulation and make adjustments as developments in diesel evolve. We believe industry will continue to exceed our expectations when developing new technologies and fuels for lower greenhouse gas emissions and the attendant low emission control technology.

Alternative compliance: AB 1493 (Pavley) calls for allowance for alternative compliance. The ARB interpretation that alternative compliance is restricted to 2009 model year and later light duty vehicles is not obvious and precludes what might be cost effective reductions of mobile source greenhouse gas emissions. The promotion of renewable fuels, improved lubricants, and low rolling resistance tires for the in-use fleet are examples of approaches that might be attractive to the industry. These technologies could bring early and substantial cost-effective greenhouse gas emission reductions to in-use fleet.

Response: The methods of alternative compliance proposed by staff provide manufacturers with additional flexibility for meeting the climate change regulations, yet safeguard against strategies that do not meet the primary goal of the legislation which is to achieve the maximum feasible

reduction of greenhouse gas emissions from passenger vehicles and light-duty trucks and other vehicles used for noncommercial personal transportation in California.

Under staff's approach, a project that ensures and documents the use of an alternative, lower greenhouse gas emitting fuel in bi-fuel, flex fuel, or grid-connected hybrid vehicles would be eligible for alternative compliance credits. This is to ensure that the program does not dilute the technology-forcing nature of the regulation, since the goal is to improve the vehicles themselves.

Regarding the promotion of renewable fuels, in implementing this program, staff is using the upstream greenhouse gas emissions associated with the different alternative fuels. Although staff is using default values to calculate these emissions, the manufacturers have the opportunity to provide their own values if they have supporting documentation. This should encourage the use of renewable fuels that have lower upstream greenhouse gas emissions.

Finally, because strategies such as low rolling resistance tires or improved lubricants are beyond the manufacturers' control, they would not meet the criteria used for other emission reduction credit programs, that is the reductions must be real, quantifiable, permanent and enforceable. Therefore, these types of strategies were not considered further.

Fuel cost: The issue of fuel cost uncertainty has been added, by brief mention, to the staff report, but is not treated quantitatively. Adding a range of fuel costs, both greater than and less than the assumed $1.74 per gallon, for example to Table 10.2-2, would allow quantification of this uncertainty. This would demonstrate that the proposed regulations are cost-effective over the range of likely fuel costs.

Response: Staff conducted an analysis that investigates higher fuel prices of $2.30 per gallon. The quantitative results of the analysis with respect to the impact on individual consumers as well as the overall economy are presented in Table 12.7-1 of the August 6, 2004 ISOR. However, this uncertainty analysis does not affect the standard-setting in because the technologies used to determine maximum feasible emission reductions were already deemed economical and cost-effective (based on $1.74 per gallon gasoline) with payback periods well below the average lifetime of vehicles.

9/17/04

SCIENTIFIC PEER REVIEW FOR THE
CALIFORNIA AIR RESOURCES BOARD (CARB)
"Analysis of Consumer Responses to the Proposed Climate Change Regulations"

Some Additional Comments

W. Michael Hanemann

I have now reviewed the revised CARB staff report dated August 6, 2004 and the *Addendum* dated 9/10/04 as well as the CARB Staff document *Peer Review Comments and Responses*, September 2004.

Comment:

With regard to the economic portion of the analysis, which is my area of competence, I believe that the staff analysis is scientifically sound, as is the staff's conclusion that the aggregate economic benefit of the proposed regulation to the owners and operators of motor vehicles in California exceeds the aggregate economic cost to these owners and operators.

The staff analysis does not include the economic benefits from the proposed regulations in terms of the reduced adverse impacts on California from a lower concentration of greenhouse gasses in the atmosphere. My own research suggests that the climate change impacts resulting from higher greenhouse gas concentrations could impose a substantial economic cost on California. Thus, the staff analysis likely understates the full economic benefit to California resulting from the proposed regulations.

Response: We agree with your assessment that the staff report does not account for the full economic benefits (avoided costs) that would result from a significant reduction in greenhouse gas emissions. Therefore, the staff analysis can be characterized as conservative as there are certain benefits that are not represented in the estimated presented in the staff report.

Comment:

While I agree that the aggregate economic benefits of the proposed regulations outweigh the aggregate economic costs, it is possible that there may be some pockets where significant costs are imposed on some groups. For example, in my earlier comments I suggested that, in future work, the staff collect more information on the pricing of late-model vehicles in the used vehicle market. It is possible that there could be some transient adverse economic impacts here which, while they are unlikely to change the assessment of the overall economic net benefit of the regulations, could merit some policy action not necessarily by CARB but by some other organ of California state government. For example (and

this is purely illustrative), if it were found that the regulations induced a spike in the price of late-model used vehicles when the regulations take effect, it might be appropriate for the California Legislature to provide some relief to purchasers of those vehicles by temporarily reducing the motor vehicle registration fee for those vehicles for one year. The point I want to make is a general one: while I believe the proposed regulations are cost-beneficial in the aggregate, I also think it would be prudent for the appropriate entities in California state government to monitor their economic impact on sub-sectors of the motor vehicle market in California, and to consider the adoption of temporary mitigation measures for particular subsets of the market if there turns out to be strong evidence that this is warranted.

Response: It is certainly true that while the overall impact of the proposed regulations is positive for California, some groups could be affected adversely. Because of such concerns about the potential adverse impacts of the proposed regulations on low-income and minority households and affiliated businesses, the legislation specifically required an assessment of the economic impacts of the proposed regulations on these groups which are presented in the staff report. We agree that additional disaggregated analyses are desirable if adequate data are available on the affected groups. However, limited or lacking data on other groups has precluded us from conducting a more disaggregated analysis of the impacts on those groups. However, based on the substantial benefits to costs associated with the proposed regulations and the fact that the ratio is even greater with respect to aged vehicles, it is anticipated that other subgroups would also experience net savings.

SCIENTIFIC PEER REVIEW FOR THE
CALIFORNIA AIR RESOURCES BOARD (CARB)
"Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles"

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I have read the sections of the August 6, 2004 Staff Report that are relevant to my expertise. Once again, I am impressed with the thorough analysis of the staff. The staff has addressed many of my comments from my initial review and has improved the Staff Report in a number of other ways. It is important to note that any report of this significance will require a number of simplifying assumptions. These simplifying assumptions are necessary, and what is important is the degree to which these assumptions affect the conclusions of the Staff Report. I focused my previous comments on assumptions that seemed implicit; I do so again in this review.

Comment:
The Effect on the California Economy: The report states that the E-DRAM model predicts that economic output will fall as a result of the legislation. I assume this is the result of higher vehicle prices and the inability of the model to incorporate operating cost changes. However, given the estimates of price and operating expense changes, it would seem that economic activity should *increase* because of the legislation. The *true* price of a vehicle is the retail price plus the operating expenses (correctly discounted). If capital markets are perfect (or close to perfect), then businesses will realize that the legislation has reduced the net cost of vehicles. This reduction will therefore lead to an increase in economic activity. Therefore, without a richer model that incorporates the true price, one can view the estimates as a lower bound on the change in economic activity.

> *Response: Your intuition is accurate. The reported fall in the California output is the result of the assumption in the model that the overall price level would change. As you stated correctly, the proposed regulations would reduce the true price of a vehicle (i.e., the retail price plus the operating expenses); thus leading to an increase in the economic activity in California. Therefore, as you note, the estimated impacts on the economy can be viewed as a lower bound.*

Comment:
The Effect on Automobile Manufacturer Profits: The Staff Report focuses on the economic impacts of the new legislation on changes in marginal costs and operating costs. One could argue that the Report incorrectly ignores changes in automobile manufacturer profits. It is true that the majority of the production of motor vehicles occurs outside of California, and the reduction in profits from the legislation will be borne by firms incorporated outside of California. However, these firms are publicly traded; therefore their owners live in numerous states, California being one of them. Thus, legislation that reduces the profits of the automobile manufacturers directly affects share owners. I am not sure if the model can incorporate this, but it should at least be discussed. It would be nice to see some discussion of the magnitude of the fixed/sunk costs associated with the legislation.

Response: It is true that automobile manufacturer profits would be affected adversely if manufacturers absorbed the compliance costs. In the short-run, manufacturers may not be able to pass on the entire cost of compliance to consumers due to competitive market forces. To the extent that a manufacturer's profit is affected adversely, its stockholders would experience a decline in the value of their stockholdings. However, we believe this adverse effect, if it occurs, is transitory. In the long-run, the manufacturers would have to maintain a normal profit level. Thus, automobile manufacturers, if they were unable to reduce their cost structure, would be expected to pass on the compliance cost to consumers in the form of higher prices as we assumed in our analysis.

Comment:
Firm Capture of Operating Cost Changes: I will reiterate my concern regarding the ability of firm to capture some of the operating costs reductions in the form of price increases and offer a suggestion. I am sympathetic to the difficulty in quantifying this effect. One method for partially dealing with this would be to report the amount of the operating cost changes that would need to be captured by firms such that consumers "break even" on the legislation. If this is a large number, which it appears to be, then it would be clear that, while ignoring this effect would tend to overstate the gains, the *presence* of gains is still likely. For example, if firms would have to capture 50% of the reduction in operating costs in order for consumers to "break even" from the proposed legislation, this would, in my opinion, offer strong support for the legislation from a consumer point of view.

I do not believe the Staff Report can simply say that competition will drive this effect away, since it is widely accepted that automobile manufacturers possess market power.[16]

Response: Your suggestion is well taken. As we stated in our earlier response, it is true that some manufacturers may try to capture some of

[16] See, for example, Berry, Levinsohn and Pakes (1995) and Goldberg (1995).

the operating cost reductions in the form of higher vehicle prices. This situation may occur when manufacturers have market power and we agree that such a situation may exist in the short-run because of the oligopolistic nature of the auto industry. However, we believe the automobile market is more competitive in the long-run and manufacturers cannot sustain above-normal profits for long. It is also true that we may have overstated the gains to consumers if manufacturers are able to capture some of the operating cost reductions in the short-run. On the other hand, as you also stated, we have been conservative in our assumption that manufacturers are able to pass the entire compliance costs to consumers in the short-run. To the extent that manufacturers have to absorb part of the compliance costs, we have understated the gains to consumers. We believe that these two forces tend to cancel out one another.

Comment:
Robustness of the Conclusions: In general, I would like to know how robust the Staff Report's conclusions are to changes in the parameters. As I read the Staff Report, the main conclusion to draw from the analysis is that the proposed legislation will actually *improve* consumer welfare. This is certainly possible and the result of one set of assumptions regarding the parameters associated with changes in automobile prices and the cost savings associated with the proposed legislation. How robust is this general conclusion to parameter changes?

There are a number of reasons the parameter values cannot be known with certainty. I list a few here:

1. Technological advances may reduce the cost of compliance.
2. Firms may choose not to comply by using the least cost method for marketing reasons.
3. As I mentioned in my previous review, the change in price from a change in marginal cost depends the industry's model of competition and the nature of industry demand. If the industry is perfectly competitive, then changes in marginal cost will be passed on to consumers at 100 percent. If the industry is oligopolistic, then changes in marginal cost may be passed on at *less* than 100 percent, or more than 100 percent.[17]
4. The ability of firms to capture changes in operating costs.

If possible, I would like to see how robust the general conclusion that consumers benefit from the proposed legislation to changes in parameter values. This could simply be an appendix where the staff varies one parameter at a time (*e.g.*, changing only the amount of marginal cost that is passed through to consumers,

[17] The degree of pass through depends on the relative slopes of demand and marginal revenue. It is important to note that when changes in marginal costs are passed through at less than 100 percent, this is not a result of competition driving prices down. Even a *monopolist* will choose to pass through changes in marginal cost at less than 100 percent if demand is linear.

changing the discount rate, etc.). I believe this would strengthen the conclusions of the study as my prior is that the general result is robust.

Response: Your suggestions are well taken. Certainly, the staff report does not fully represent the gamut of analyses that could be performed for the proposed regulations. You're correct in your assessment that the analysis would yield different results under different sets of assumptions. However, staff believes the results presented in the ISOR are based on the most robust sets of the assumptions. The staff report is intended to provide a summary of the analysis. A more detailed analysis of the results including some sensitivity analyses is provided in the staff's Technical Support Documents.

References:
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