Kenneth C. Johnson
2502 Robertson Rd
Santa Clara, CA 95051
408-244-4721
kjinnovation@earthlink.net

May 18, 2005

Clerk of the Board
Air Resources Board
1001 I Street, 23rd Floor
Sacramento, California 95814

Re: Commentary in response to "Second Notice of Public Availability of Supporting Documents and Information," posted on May 11, 2005.

The "Additional Supporting Documents and Information" posted on May 11 indicates that staff is in the process of preparing responses to the comments received during the 45 day and initial 15 day comment periods, and that staff has not identified any issues that would warrant further changes to the regulatory language. On Aug. 11, 2004 I submitted written commentary and analysis concerning several deficiencies of the proposed regulations, and I have recently revised the analysis based on new information that staff provided me in March, 2005. (The new data[1] identifies the LEV classifications of the Model Year 2002 vehicle models on which the proposed AB 1493 emission standard is based. This was missing in the data that staff provided me in 2004.) Based on this information, I have replicated staff's calculation of the standard and have clearly identified a methodological error that would warrant revision of the standard, and which would also impact the additional analysis and calculations documented in the May 11 posting.

The proposed mid-term (2016) emission standard is as follows,

PC/LDT1: 205 g/mi
LDT2: 332 g/mi

This is actually what the optimal LEV-compatible emission limits would be if the regulations allowed emissions trading within, but not between, the two LEV vehicle classes. Allowing for trading between the two classes, the standard should be as follows,

PC/LDT1: 189 g/mi
LDT2: 343 g/mi

These limits satisfy the Board's feasibility and cost-effectiveness criteria for all six manufacturers; and based on the data from which the standard was calculated, average per-vehicle emissions would be 3.2 g/mi lower with these limits. (To put this in the

[1] This data was provided to me by Paul Hughes in the following two Excel files,
for_costeffect,_inventory,etc_082404.xls
Corporate Fleet Average Weights (2002).xls
These spreadsheets, along with explanatory comments from Mr. Hughes and my own calculations (AB1493.xls) are posted at http://kjinnovation.com/Climate_Policy.html .

context of environmental performance, if AB 1493-type regulations are adopted worldwide the difference would correspond to an estimated 50 million metric tons of annual global CO2 emissions in 2030.)

Note that under the proposed standard the emissions allowance for an LDT2 SUV is 62% higher than that of a car, even if the SUV and car have the same weight and seating capacity. It is not clear what policy objective is served by this disparity. Moreover, if trading between the LEV classes is taken into account in defining the standard, the disparity increases to 81%. This result is dictated by a self-consistent application of the Board's policy rationale and methodology, which rely on trading and sales averaging to enforce LEV compatibility on the standard. The present analysis does not address the question of whether the LEV-based standard is reasonable from the perspective of the AB 1493 legislative mandate or broader policy concerns; it is rather focused on explaining how the proposed standard is inconsistent with the Board's stated policy rationale and how the standard could be revised to at least at least avoid the inconsistency.

The Board's specification criterion for defining the mid-term emission standard is described in section 6 of the ISOR. I will paraphrase this criterion in somewhat more formal terms here to clearly elucidate its underlying rationale and explain the inconsistency. A particular vehicle model that is subject to the mid-term standard will be denoted as $model\ (i, j, k)$, wherein the index i indicates the manufacturer, j identifies the LEV vehicle class, and k enumerates all of the models from manufacturer i in class j. The major six manufacturers for MY 2002 are enumerated as follows,

Table 1: MY 2002 manufacturers

DC	$i = 1$
Ford	$i = 2$
GM	$i = 3$
Honda	$i = 4$
Nissan	$i = 5$
Toyota	$i = 6$

There are two LEV vehicle classes,

Table 2 LEV classification

PC/LDT1	$j = 1$
LDT2	$j = 2$

The following notational definitions will be used below:

$sales_{i,j,k}$: Annual sales volume for $model\ (i, j, k)$

$weight_{i,j,k}$: Test weight (lbs) for $model\ (i, j, k)$

$CO2_{i,j,k}$: Per-vehicle emissions (g/mi) of $model\ (i, j, k)$

$feasCO2_{i,j,k}$: Feasible emissions level for *model* (i, j, k) (corresponding to the maximum feasible and cost-effective emissions reduction).

The ISOR defines "regression lines" (the sloped lines in Figures 6-1 and 6-2 of the Sept. 10, 2004 ISOR Addendum), which represent an estimate of the maximum feasible emissions reduction level as a function of vehicle weight. Separate regression functions are defined for the two LEV classes. These functions define an emission standard for class j and weight wt, which will be denoted as $regStd_j(wt)$. The feasible emissions level for *model* (i, j, k) is defined as

$$feasCO2_{i,j,k} = regStd_j(weight_{i,j,k}) \qquad (1)$$

This emission limit is defined to satisfy the AB 1493 mandate. However the Board does not adopt this standard, but rather enforces LEV compatibility on the standard by constraining the emission limit to be weight-independent within each LEV class. The LEV-compatible standard's emission limit for class j will be denoted as $levStd_j$. (The horizontal lines in Figures 6-1 and 6-2 of the ISOR Addendum correspond to $levStd_1$ and $levStd_2$, respectively.)

The fleet-average test weight for manufacturer i and class j, denoted as $avg\_weight_{i,j}$, is defined as

$$avg\_weight_{i,j} = \frac{\sum_k sales_{i,j,k}\ weight_{i,j,k}}{\sum_k sales_{i,j,k}} \qquad (2)$$

The LEV standard is defined so that it matches the maximum feasible standard at the fleet-average weight for General Motors ($i = 3$),

$$levStd_j = regStd_j(avg\_weight_{3,j}) \qquad (3)$$

GM is used to set the standard because it is not possible to require maximum feasible and cost-effective emissions reduction for all six manufacturers with an LEV-type standard, but by basing the standard on the manufacturer with the heaviest average vehicle weight, it can at least be assured of satisfying the feasibility and cost-effectiveness requirements for all six (assuming their California, MY 2002 fleets).

$regStd_j(wt)$ is a linear function of wt, so equation (3) can be equivalently restated as follows,

$$levStd_j = regStd_j \left(\frac{\sum_k sales_{3,j,k}\ weight_{3,j,k}}{\sum_k sales_{3,j,k}} \right) = \frac{\sum_k sales_{3,j,k}\ regStd_j(weight_{3,j,k})}{\sum_k sales_{3,j,k}}$$
$$= \frac{\sum_k sales_{3,j,k}\ feasCO2_{3,j,k}}{\sum_k sales_{3,j,k}} \qquad (4)$$

In other words, within each LEV vehicle class the standard is set equal to the sales-average feasible emissions level for GM's fleet. Another way to express the above relationship is

$$\sum_k sales_{3,j,k}\ levStd_j = \sum_k sales_{3,j,k}\ feasCO2_{3,j,k} \qquad (5)$$

This relationship states that the total CO_2 emissions allowed by the LEV standard is identical to the total emissions defined by the feasible emissions level (for GM's California, MY 2002 vehicles in LEV class j).

The policy rationale underlying the standard is based on the principle of *aggregation*, that a manufacturer's environmental performance depends only on the total emissions of its fleet, and not on individual vehicle emissions. If individual vehicles were controlled to the maximum feasible reduction level, the regulations would require that

$$CO2_{i,j,k} \le feasCO2_{i,j,k} \qquad (6)$$

But this requirement would be overly constraining because the regulation's environmental performance depends only on total emissions aggregated over all vehicles, and not on how emission allowances are distributed between vehicles. Therefore, the policy objective is only to limit aggregate emissions,

$$\sum_{i,j,k} sales_{i,j,k}\ CO2_{i,j,k} \le \sum_{i,j,k} sales_{i,j,k}\ feasCO2_{i,j,k} \qquad (7)$$

Aggregation is synonymous with *sales averaging* because the aggregate emissions level is equal to the sales-average emissions multiplied by sales volume.

Aggregation is also related to *trading*. Manufacturers are free to reallocate emission allowances between their fleets in any way that does not impact aggregate emissions. The policy objective can be achieved by imposing the following regulatory requirement on each manufacturer i,

$$\sum_{j,k} sales_{i,j,k}\ CO2_{i,j,k} \le \sum_{j,k} sales_{i,j,k}\ \ feasCO2_{i,j,k} + credits_i - debits_i \tag{8}$$

wherein $credits_i$ and $debits_i$ are emission credits and debits (denominated in g/mi units) accrued by manufacturer i through trading. (Summing both sides of relation (8) over i, the credits and debits cancel out, resulting in the policy objective (7).) The reallocation of emission allowances within a particular manufacturer's own fleet is also referred to as *trading*.

The regulatory requirement (8) would be unaffected by replacing the feasible emission limit $feasCO2_{i,j,k}$ with an LEV standard $levStd_j$ that matches the aggregate emissions level,

$$\sum_{j,k} sales_{i,j,k}\ levStd_j = \sum_{j,k} sales_{i,j,k}\ \ feasCO2_{i,j,k} \tag{9}$$

For GM's fleet ($i = 3$), this condition is similar to condition (5), except that equation (5) applies separately to each vehicle class ($j = 1$ or 2) whereas equation (9) aggregates emissions across both vehicle classes (as indicated by the "j" summation index). Condition (5) is overly constraining, because the regulations' environmental performance only depends on aggregate emission over both vehicle classes, and is unaffected by emissions allowance reallocation ("trading") between classes.

The Board's policy rationale is clearly intended to accommodate trading between the PC/LDT1 and LDT2 categories. As stated in the ISOR (p. 113), "Trading offers flexibility for each manufacturer to overcomply with one category's standard and trade those credits to compensate for a debit, or under-compliance, within the other category." Due to the cancellation of credits and debits between the two categories, compliance only depends on the manufacturer's aggregate emissions across both categories, so the emission standard's definition criterion should be based on emissions aggregation across both categories, not just within each category.

Taking into account trading between PC/LDT1 and LDT2, condition (5) should be replaced by the following less constraining condition,

$$\begin{aligned}\sum_{k} sales_{3,1,k}\ levStd_1 + \sum_{k} sales_{3,2,k}\ levStd_2 = \\ \sum_{k} sales_{3,1,k}\ \ feasCO2_{3,1,k} + \sum_{k} sales_{3,2,k}\ \ feasCO2_{3,2,k}\end{aligned} \tag{10}$$

Condition (5) represents two equations (corresponding to $j = 1$ and $j = 2$), which determine the two LEV emission limits, $levStd_1$ and $levStd_2$. Condition (10), by contrast, represents a single defining equation involving two unknowns, $levStd_1$ and $levStd_2$.

Hence the condition can also be imposed on a second manufacturer. Choosing Honda ($i = 4$) as the second manufacturer, the second defining condition is

$$\sum_k sales_{4,1,k}\ levStd_1 + \sum_k sales_{4,2,k}\ levStd_2 = \sum_k sales_{4,1,k}\ \ feasCO2_{4,1,k} + \sum_k sales_{4,2,k}\ \ feasCO2_{4,2,k} \qquad (11)$$

(Equations (10) and (11) can be simultaneously solved for $levStd_1$ and $levStd_2$.) By choosing GM and Honda as the standard-setting manufacturers, the standard not only satisfies the legislative mandate for at least those two manufacturers, it also satisfies the feasibility and cost-effectiveness requirements for the other four (based on their California, MY 2002 fleets).

The accompanying spreadsheet, AB1493.xls, replicates the Board's computation of the mid-term emission standard, and also recomputes the standard according to the Board's policy rationale, allowing for trading between PC/LDT1 and LDT2. Following is an explanation of how the spreadsheet relates to the above analysis. (Some portions of the spreadsheet are not relevant to the present analysis and will not be discussed.)

Columns A-N in the spreadsheet summarize the California, MY 2002 market data provided by staff. (See the cell comments for explanatory notes.) The proposed emission standard is based on this data. In column L, "PCT1" means PC/LDT1 and "T23" means LDT2. Several cells in column L are highlighted, indicating classification errors. For compatibility with staff's calculations, these errors are not corrected but they are comparatively minor.

Column O ("Std1") represents the regression lines in the ISOR Addendum, Figures 6-1 and 6-2. The values in this column are denoted above as $feasCO2_{i,j,k}$. These values are calculated from the NESCCAF simulation results (cells W5:X9) by the method outlined in the ISOR, section 6.1.C.

The proposed LEV-compatible emission standard is computed in cells W16:W17. These values correspond to $levStd_1$ and $levStd_2$, and the calculation formulas are equivalent to equation (3). (GM's fleet-average weights, equation (2), are calculated in cells X12:X13.) Cells W20:W21 use an alternative, but equivalent, method of computing the standard based on sales averaging (equation (4)). Column P ("Std2") tabulates the proposed emission standard for each vehicle model.

Cells X27:X28 recompute the standard, taking into account trading between PC/LDT1 and LDT2 (equations (10) and (11)). The numbers in cells V23:W24 represent the coefficients multiplying $levStd_1$ and $levStd_2$ on the left sides of equations (10) and (11), and the values in cells Y23:Y24 represent the right sides of these equations. Column Q ("Std3") tabulates the corrected emission standard for each vehicle model.

The table in cells AB3:AI14 replicates Table 6.1-4 in the ISOR. There are some discrepancies, but the computed emission standard only depends on the sales-averaged test weights (specifically the GM weights), which have the correct values in the ISOR.

The table in cells AK3:AQ15 represents the estimated emissions reduction that would be achieved if any one of several alternative emission standards was applied to the California, MY 2002 vehicle fleet. The "Std1" column represents the maximum feasible and cost-effective emissions reduction for the assumed fleet (as defined by the regression lines). "Std2" represents the reduction achieved with the proposed LEV-compatible standard, and "Std3" is the reduction level with the corrected LEV-compatible standard. The reductions are tabulated as fleet-average values, in g/mi units, for each of the six major manufacturers and for the aggregation of all six. Also, the aggregate potential emissions reduction, in ton-CO2e/day units, is estimated for the California MY 2002 new-vehicle fleet and for the total California 2030 vehicle fleet. The results are extrapolated to estimate global emissions reduction in 2030, assuming that AB 1493-type standards are adopted worldwide and that California represents 3% of global light-duty vehicle emissions in 2030.

The table in cells AK17:AQ29 tabulates each standard's excess emissions relative to the maximum feasible reduction levels. For the proposed standard (Std2), the excess is zero for GM and positive for the other five manufacturers, indicating that standard achieves maximum feasible and cost-effective emissions reduction for GM, and is feasible and cost-effective for the other five. (If a manufacturer other than GM was chosen to set the standard, the computed excess emissions for one or more manufacturers would be negative, indicating a violation of the feasibility and cost-effectiveness constraints.) With the corrected standard (Std3) the excess is zero for both GM and Honda, and is positive for the other four manufacturers.

Cells AN29:AO29 compare the excess emissions of the proposed and corrected LEV standards in terms of projected global emissions in 2030. The correction reduces the calculated excess from 123 to 71 million metric tons CO2e per year.