The Development of California Light-Duty Vehicle (LDV) Requirements to Support Climate Stabilization: Fleet-Emission Rates & Per-Capita Driving

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ABSTRACT

An Introduction to the topic is provided, including the importance of cars and light duty trucks (Light Duty Vehicles, LDVs), and an identification of the top-level LDV requirements.

The fundamentals of our climate crisis are presented, including its cause, its potential for harm, and existing mandates: *California's Executive Order S-3-05, California's Global Warming Solutions Act of 2006* (AB 32), and *California's Sustainable Communities and Climate Protection Act* (SB 375). An earlier calculation of a driving reduction target is described.

Reference year 2005 is identified. The latest climate-stabilizing greenhouse-gas (GHG) reduction target value, for 2030, is calculated, using unambiguous statements by recognized climate experts and California's expected 2020 emissions. The formula for GHG emissions, as a function of per-capita driving, population, fleet CO2 emissions per mile, and low-carbon fuel standards is given. From that expression, a mathematical relationship between defined factors associated with these variables is derived. These factors are the ratio of the value at the specified later year to the reference year. The factor of car-emission-per-mile driven, for year 2015, with respect to year 2005, is obtained.

Internal Combustion Engine (ICE) mileage values from 2000 to 2030 are identified, as either mandates or assumptions. A table is presented that estimates LDV fleet mileage, for year 2015.

Zero Emission Vehicle (ZEV) values to support a calculation of equivalent-fleet mileage with a significant fraction of ZEVs (ZEV LDVs) are given. A table is shown that uses assumptions about ZEVs, ICEs (ICE LDVs), and the fraction of electricity that comes from renewables, to compute the LDV fleet equivalent mileage, for year 2030. This set of assumptions is dubbed the "Heroic-Measures" (HM) case. It includes having the fraction of ZEVs quickly climb up to significant values, while the ICEs, for the years before significant fractions of ZEVs appear, are, to a significant degree, taken off the road or otherwise caused to be driven less, due to assumed strong governmental policies. The equivalent fleet mileage computed by this table is used, with population and the needed factor of emission reductions, to compute a needed per-capita driving reduction, for 2030, with respect to 2005. Policies to achieve this per-capita reduction are described, with reductions allocated to each policy.

The fleet-equivalent mileage for 2030 that would support a 2005 per-capita driving level is computed. A table is constructed to achieve that equivalent mileage. The assumptions in that table are said to define an "extra-heroic-measures" (EHM) case. They would probably be very difficult to achieve. The electricity required to power the HM case is estimated and compared to current usage.

INTRODUCTION

Humanity's top-level requirement is to reduce greenhouse gas (GHG) emissions enough to support stabilizing our climate at a livable level. This top-level requirement must flow down to LDVs, due to the significance of their emissions. As an example, LDVs emit 41% of the GHG in San Diego County[1].

From a systems engineering perspective, the needed requirements are an upper bound on greenhouse gas (GHG) emissions per mile driven (applicable to the entire fleet of LDVs on the road in the year of interest) and an upper bound on per-capita driving, given population growth. This paper will do a calculation of required driving levels, based on calculations of how clean our cars and fuels could be, predicted population growth, and the latest, science-based, climate-stabilizing target. All three categories of LDV emission-reduction strategies will be considered: cleaner cars, cleaner fuels, and less driving.

BACKGROUND: OUR CLIMATE PREDICAMENT

Basic Cause

Our climate crisis exists primarily because of these two facts[2]: First, our combustion of fossil fuels adds "great quantities" of CO_2 into our atmosphere. Second, atmospheric CO_2 traps heat.

California's First Two Climate Mandates

California's Governor's Executive Order S-3-05[3] is similar to the Kyoto Agreement and is based on the greenhouse gas (GHG) reductions recommended by climate scientists for industrialized nations, back in 2005. In 2005, climate scientists believed that the reduction-targets of S-3-05 would be sufficient to support stabilizing Earth's climate at a livable level, with a reasonably high level of certainty. More specifically, this executive order aims for an average, over-the-year, atmospheric temperature rise of "only" 2 degree Celsius, above the preindustrial temperature. It attempts to do this by limiting atmospheric CO_2_e to 450 PPM by 2050 and then reducing emissions further, so that atmospheric levels would come down to more tolerable levels in subsequent years. The S-3-05 emission targets are as follows: 2000 emission levels by 2010, 1990 levels by 2020, and 80% below 1990 levels by 2050.

It was thought that if the world achieved S-3-05, there might be a 50% chance that the maximum temperature rise will be less than 2 degrees Celsius, thus leaving a 50% chance that it would be larger than 2 degrees Celsius. A 2 degree increase would put over a billion people on the planet into a position described as "water stress" and it would mean a loss of 97% of our coral reefs.

There would also be a 30% chance that the temperature increase would be greater than 3 degrees Celsius. A temperature change of 3 degree Celsius is described in Reference 3 as being "exponentially worse" than a 2 degree Celsius increase.

The second California climate mandate is AB 32, the so-called *Global Warming Solutions Act of 2006*. It includes provisions for a cap and trade program, to ensure meeting S-3-05's 2020 target of the 1990 level of emissions. It continues after 2020. Over all years, AB 32 requires CARB to implement measures that achieve the maximum *technologically feasible and cost-effective* (words taken from AB 32) greenhouse-gas-emission reductions.

California is on track to achieve its second (2020) target. However, the world emission levels have, for most years, been increasing, contrary to the S-3-05 trajectory. Because the world has effectively failed to achieve S-3-05, California, if it still is interested in leading the way to human survival, must do far better than S-3-05, going forward, as will be shown.

Failing to Achieve these Climate Mandates

What if we fail to achieve S-3-05 and AB 32 or we achieve them but they turn out to be too little too late and other states and countries follow our example?

It has been written[R4] that, "A recent string of reports from impeccable mainstream institutions-the International Energy Agency, the World Bank, the accounting firm of PricewaterhouseCoopers-have warned that the Earth is on a trajectory to warm by at least 4 Degrees Celsius and that this would be incompatible with continued human survival."

It has also been written[R5] that, "Lags in the replacement of fossil-fuel use by clean energy use have put the world on a pace for 6 degree Celsius by the end of this century. Such a large temperature rise occurred 250 million years ago and extinguished 90 percent of the life on Earth. The current rise is of the same magnitude but is occurring faster."

Pictures That Are Worth a Thousand Words

Figure 1 shows (1) atmospheric CO_2 (in blue) and (2) averaged-over-a-year-then-averaged-over-the surface-of-the-earth world atmospheric temperature (in red). This temperature is with respect to a recent preindustrial value. The data starts 800,000 years ago. It shows that the current value of atmospheric CO_2, which is now over 400 PPM, far exceeds the values of the last 800,000 years. It also shows that we should expect the corresponding temperature to eventually be about 12 or 13 degrees above preindustrial temperatures. This would bring about a human disaster[3,4,5].

Figure 2 shows the average yearly temperature with respect to the 1960-to-1990 baseline temperature (in blue). It also shows atmospheric levels of CO_2 (in red). The S-3-05 goal of 450 PPM is literally "off the chart", in Figure 2. Figure 2 shows that, as expected, temperatures are starting to rise along with the increasing levels of CO_2. The large variations in temperature are primarily due to the random nature of the amount of solar energy being received by the earth.

FURTHER BACKGROUND: CALIFORNIA'S SB 375 AND A PREVIOUS CALCULATION OF HOW MUCH WE CAN DRIVE

As shown in the Introduction, LDVs emit significant amounts of CO_2. The question arises: will driving need to be reduced or can cleaner cars and cleaner fuels arrive in time to avoid such behavioral change? Steve Winkelman, of the Center for Clean Air Policy (CCAP), has worked on this problem. Using CCAP data, an S-3-05-supporting driving reduction, for San Diego County, will be estimated.

SB 375, the *Sustainable Communities and Climate Protection Act of 2008*

Under SB 375, the California Air Resources Board (CARB) has given each Metropolitan Planning Organization (MPO) in California driving-reduction targets, for the years 2020 and

Figure 1. Atmospheric CO_2 and Mean Temperature from 800,000 Years Ago

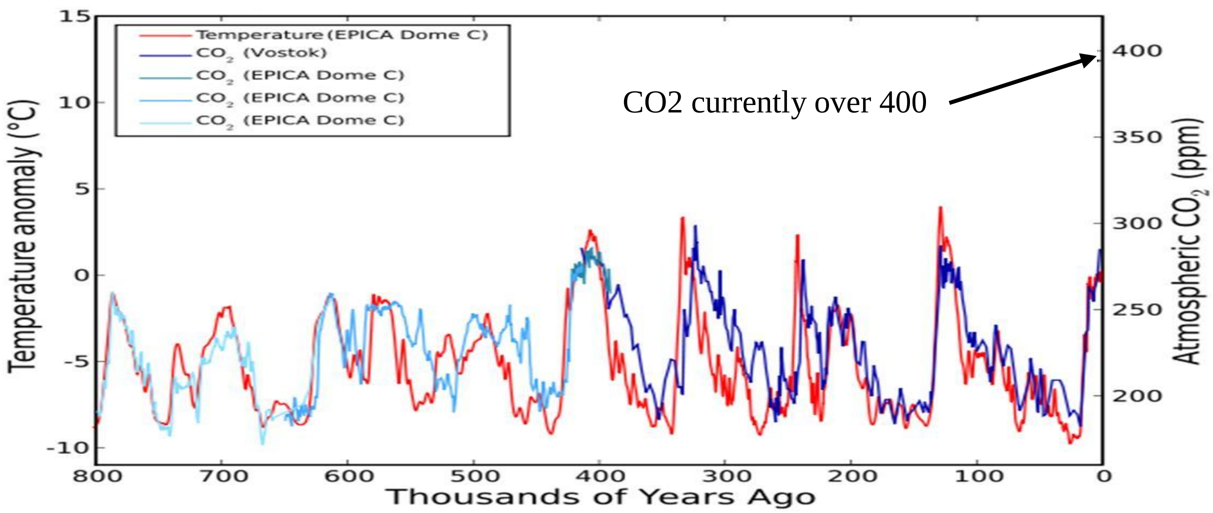
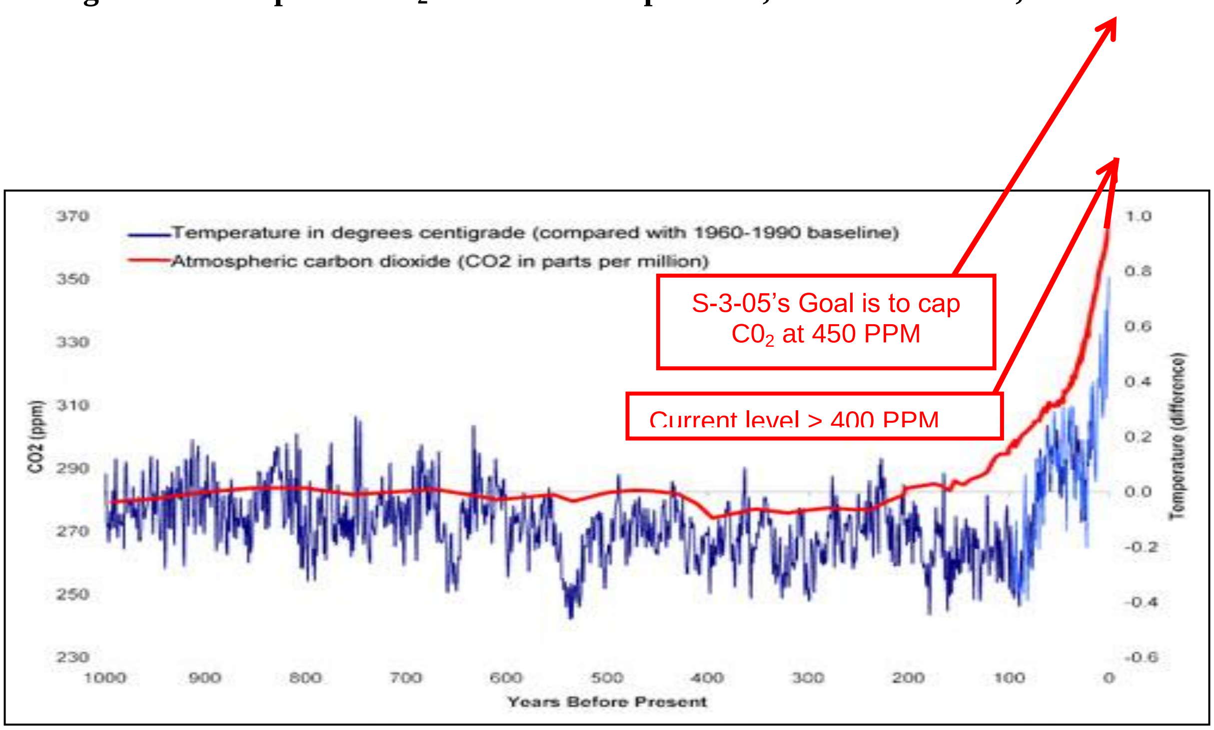


Figure 2. Atmospheric CO_2 and Mean Temperature, Over the Last 1,000 Years



2035. "Driving" means yearly, per capita, vehicle miles travelled (VMT), by LDVs, with respect to 2005. The CARB-provided values are shown at this Wikipedia link, http://en.wikipedia.org/wiki/SB_375.

Under SB 375, every Regional Transportation Plan (RTP) must include a section called a Sustainable Communities Strategy (SCS). The SCS must include driving reduction predictions corresponding to the CARB targets. Each SCS must include only *feasible* transportation, land use, and transportation-related policy data. If the SCS driving-reduction predictions fail to meet the CARB-provided targets, the MPO must prepare an Alternative Planning Strategy (APS), which must also appear in the MPO's RTP. An APS uses *infeasible* transportation, land use, and transportation-related policy assumptions. The total reductions, resulting from both the SCS and the APS, must at least meet the CARB-provided targets.

Factors Used to Compute the Required Driving Reduction

The definitions in Tables 1 and the two conventions in Table 2 will be used to compute the needed driving reductions, with respect to year 2005, from known and estimated variables and the S-3-05 GHG reductions that were thought to support climate stabilization, back in 2005. By SB 375 convention, Year "*i*", the reference year, is 2005.

The fractional reduction in per-capita personal driving, with respect to 2005 driving, needed to achieve any desired level of GHG emission, can be computed using predicted population growth and two of the variables shown in Figure 3[6]. The two needed values are the factor with respect to year 2005 of CO_2 emitted per mile driven (the green line, sometimes referred to as "Pavley", since AB 1493 was authored by Senator Fran Pavley) and the factor with respect to year 2005 of the advantage from achieving the low carbon fuel standards (LCFS, the purple line).

The variables plotted in Figure 3 are the factors which can be used to multiply the 2005 values to get the values for the years shown. For example, in 2030, the CO_2 emitted from the cars and light-duty trucks in California (the dark blue line), can be computed to be 1.12 times as large as it was in 2005. It can also be said that the value will be 12% larger than it was in 2005. Likewise, the green line, which is the average CO_2 emitted per mile driven, for California's fleet of LDVs, is predicted, in 2030, to be .73 times the 2005 value. This means the value is predicted to be reduced 27%, below its 2005 value. Figure 3 also shows that the 1990 value of emissions (on the light blue line) was about 13% less than it was in 2005.

The S-3-05 trajectory is shown as the gold (or dark yellow) line. It is the factors that can be used to convert 2005 values of emissions to values for the years shown. For example in 2030, emissions will need to be 37% lower than they were in 2005, to meet the S-3-05 mandate.

The SB 375 convention is for CARB to require and for the Metropolitan Planning Organizations (MPOs) to estimate and report their predicted per-capita driving reductions. To compute the per-capita driving reduction, the equation for computing the emissions is used. That equation is the product of the following four factors:

- the Low Carbon Fuel Standard, "*L*" (which reduces the CO2 emitted from each gallon of fuel burned),
- the fleet-average CO2 per mile driven (using the CO2 per gallon burned without accounting for "L"),

Table 1. Variable Definitions

Variable Definitions	
e_k	**LDV Emitted C02, in Year "*k*"**
L_k	**Low Carbon Fuel Standard (LCFS) Factor that reduces the Per-Gallon CO2 emissions, in Year "*k*"**
C_k	**LDV CO2 emitted per mile driven, average, in Year "*k*", not accounting for the Low Carbon Fuel Standard (LCFS) Factor**
c_k	**LDV CO2 emitted per mile driven, average, in Year "*k*", accounting for the Low Carbon Fuel Standard (LCFS) Factor**
p_k	**Population, in Year "*k*"**
d_k	**Per-capita LDV driving, in Year "*k*"**
D_k	**LDV Driving, in Year "*k*"**
M_k	**LDV Mileage, miles per gallon, in Year "*k*"**
m_k	**LDV Equivalent Mileage, miles per gallon, in Year "*k*" accounting for Low Carbon Fuel Standard (LCFS) Factor, so this is M_k/L_k**
N	**Number of pounds of CO2 per gallon of fuel but not accounting for the Low Carbon Fuel Standard (LCFS) Factor**

Table 2. Two Conventions

Two Conventions: Variable in a Given Year and Factors to Compute a Variable's Value in Year "*k*" from it's Value in Year "*i*"	
X_i	**Variable "*X*" in year "*i*"**
$f_{x_{k/i}}$	**Ratio of the value of "*X*" in year "*k*" to the value of "*X*" in Year "*i*", which could also be expressed as x_k/x_i. Note that this is the factor that could be used to multiply the value in Year "*i*" to get the value in Year "*k*".**

- the per-capita driving, and
- the population. (The per-capita driving multiplied by population gives the miles driven.)

$$e = \boldsymbol{L} * \boldsymbol{C} * \boldsymbol{d} * \boldsymbol{p} \qquad \textbf{(Eq. 1)}$$

For Year "*k*", this is the following:

$$e_k = L_k * C_k * d_k * p_k \qquad \textbf{(Eq. 2)}$$

For Year "*i*", this is the following:

$$e_i = L_i * C_i * d_i * p_i \qquad \textbf{(Eq. 3)}$$

Since the two sides of Equation 3 are equal, an equation can be formed by dividing the left side of Equation 2 by the left side of equation 3 and the right side of Equation 2 by the right side of Equation 3. Associating the terms on the right side of this new equation gives Equation 4

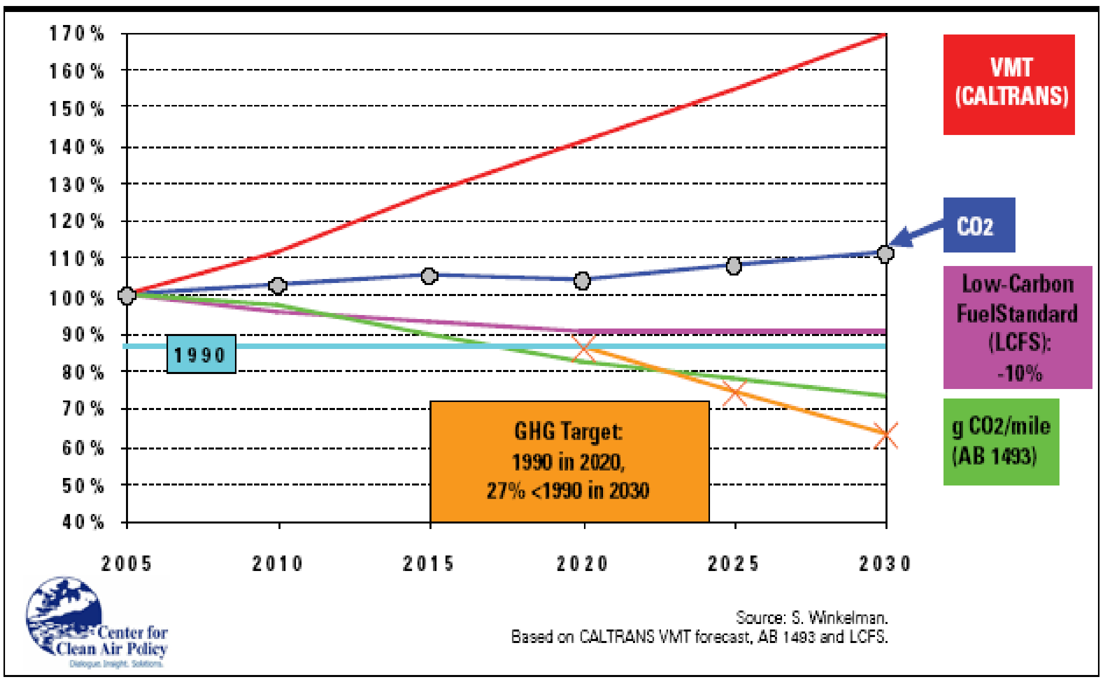
$$\frac{e_k}{e_i} = \frac{L_k}{L_i} * \frac{C_k}{C_i} * \frac{d_k}{d_i} * \frac{p_k}{p_i} \quad \text{(Eq. 4)}$$

The convention of the 2nd row of Table 2 can be used to create Equation 5 from Equation 4.

$$f_{e_{k/i}} = f_{L_{k/i}} \times f_{C_{k/i}} \times f_{d_{k/i}} \times f_{p_{k/i}} \quad \text{(Eq. 5)}$$

The first factor (from left to right) of the right side of Equation 5 is the purple line of Figure 3; the second factor of Equation 5 is the green line of Figure 3; and the product of the last two factors of

Figure 3 **The S-3-05 Trajectory (the Gold Line) AND the CO_2 Emitted from Personal Driving (the Blue Line), where that CO_2 is a Function (the Product) of the California-Fleet-Average CO_2 per Mile (the Green Line), The Predicted Driving (VMT, the Red Line), and the Low-Carbon Fuel Standard (the Purple Line)**



the right side of Equation 5 is the red line of Figure 3. Figure 3's, dark-blue-line values are the product of the purple-line values, the green-line values, and the red -line values. For example, in 2030, the dark-blue value of 1.12 can be computed by multiplying the purple-line value of 0.9 times the green-line value of 0.73, times the red-line value of 1.7, times the red-line value of 1.7. As a check, (0.9)*(0.73)*(1.7) = 1.1169, which is reasonably close to the (eye-ball-estimate) value of the dark-blue line, for year 2030, 1.12.

The Required Driving Reduction for San Diego County, for 2035, Using Winkelman's LDV and Fuel Efficiency Values and S-3-05

As described in Footnote 3 of this report, the CARB-supplied targets are per-capita driving reduction targets. Page 8, of http://arb.ca.gov/cc/sb375/staffreport_sb375080910.pdf, says, "The RTAC recommended that targets be expressed as a percent reduction in per-capita greenhouse gas emissions from a 2005 base year". However, Footnote 3 applies.

The Key Relationship and Derivation of the Needed Formula

They key relationship is Equation 5. Solving for the fractional reduction in per-capita driving, with respect to 2005, results in Equation 6.

$$f_{d_{k/i}} = \frac{f_{e_{k/i}}}{f_{L_{k/i}} \times f_{C_{k/i}} \times f_{p_{k/i}}} \qquad \textbf{(Eq. 6)}$$

This driving reduction is a per-capita value, matching the convention of the CARB-supplied target.

Getting the Values to Use in the Equation

Figure 3 will supply all of the needed values, except for the factor of population. Neither Figure 3's red-line values nor its blue-line values are used.

Getting the Net Factor of the Emissions of GHG, for Year 2035, With Respect to 2005

To get the factor of the emissions of GHG, for year 2035, with respect to year 2005, it is necessary to extrapolate the Governor's Executive Order target values (the gold line of Figure 3), out to year 2035. Figure 3's gold line shows that this factor is 0.87 in 2020 and is 0.64 in 2030. Therefore, in year 2035, the factor will be

$$0.64 + [(.64 - .87) / (2030\text{-}2020)] * (2035\text{-}2030) = 0.525$$

Getting the (Pavley) Factor of the Average CO2 per Mile Driven, in 2035, with Respect to 2005

To get the Pavley reduction factor, for Year 2035, it is necessary to extrapolate the average CO2 per mile driven, which is Figure 3's green line, out to Year 2035. It is 0.82 in 2020 and it is 0.73 in 2030. Therefore, in Year 2035 the statewide mileage factor data will be

$$0.73 + [(.73 - .82) / (2030\text{-}2020)] * (2035\text{-}2030) = 0.685$$

Getting the Factor of the Reduction of GHG Due to Fuels that Burn less Carbon

To get the factor of the reduction of GHG due to fuels that burn less carbon, it is only necessary to observe the purple line of Figure 3. It indicates that the factor will be 0.9 in 2035.

Getting the Factor of the Increase in Population

The factor for population in San Diego County is computed using the populations estimated in CARB's http://arb.ca.gov/cc/sb375/mpo.co2.reduction.calc.pdf, namely 3,034,388 people in 2005 and 3,984,753 people in 2035. So the factor, from 2005 to 2035 is 3,984,753/3,034,388 = 1.313.

Computing the Required Per-Capita Driving Reduction, for 2035

These 4 values are used in Eq. 6, to compute the required factor of per-capita driving (VMT), for 2035, with respect to 2006.

$$f_{d_{k/i}} = .525 \div (.685 \times 0.9 \times 1.313)$$

Therefore, $f_{d_{k/i}} = f_{Per\ Capita\ VMT} = .649.$

This corresponds to a 35.1% reduction in per-capita driving, in year 2035, compared to 2005.

Computing the <u>Net</u> Amount of Driving, in 2035, Compared to 2005 and its Significance

The net factor of driving in 2035, compared to 2005, is the product of the per-capita factor of driving (.649, as just computed) and the factor of population change (1.313, as computed above).

Factor of net driving in 2035 compared to 2005:

$$\boldsymbol{f}_{\boldsymbol{VMT}} = .649 \times 1.313 = 0.8515.$$

Based on this set of assumptions, even though San Diego County's population would grow by 31.3%, from 2005 to 2035, the people would have to drive 15% less than they did in 2005.

THE DEVELOPMENT OF CALIFORNIA'S TOP-LEVEL LDV REQUIREMENTS TO SUPPORT CLIMATE STABILIZATION

The above work is obsolete due to our latest understanding of how fast emissions will need to be reduced. It is also clear that cleaner cars will be needed and can probably be achieved. As will be seen, much cleaner cars will be needed if driving reductions are going to remain within what many people would consider achievable. Mileage and equivalent mileage will need to be specified. Some of the above equations will need to be modified, since a significant fleet-fraction of Zero-Emission Vehicles (ZEVs, either Battery-Electric LDVs or Hydrogen Fuel Cell LDVs) will be needed and mileage and equivalent mileage will be used instead of CO2 per mile driven.

Since the SB-375 work used 2005 as the reference year, it will remain the reference year here.

GHG Target to Support Climate Stabilization

The primary problem with S-3-05 is that California's resolve and actions have been largely ignored by other states, our federal government, and many countries. Therefore, rather than achieving 2000 levels by 2010 and being on a track to achieve 1990 levels by 2020, world emission have been increasing. Reference 7 states on Page 14 that the required rate of reduction, if commenced in 2020, would be 15%. That rate means that the factor of 0.85 must be achieved, year after year. If this were done for 10 years, the factor would be $(0.85)^{10} = 0.2$. We don't know where world emissions will be in 2020. However, it is fairly safe to assume that California will be emitting at its 1990 level in 2020, in accordance with S-3-05. This situation shows that the correct target for California is to achieve emissions that are reduced to 80% below California's 1990 value by 2030. Note that if the reductions start sooner, the rate of reduction of emissions can be less than 15% and the 2030 target could be relaxed somewhat. However, it is doubtful that the world will get the reduction rate anywhere near the needed 15% by 2020. Therefore, the target, of 80% below 1990 levels by 2030 is considered to be correct for California. Reference 7 also calls into question the advisability of aiming for a 2 degree Celsius increase, given the possibilities of positive feedbacks that would increase warming. This concern for positive feedbacks is another reason that this paper will work towards identifying LDV requirement sets that will support achieving 80% below 1990 values by 2030.

Using the top-row definition in Table 1, and this requirement, results in the following equation.

$$\frac{\boldsymbol{e_{2030}}}{\boldsymbol{e_{1990}}} = \boldsymbol{0.2} \qquad \textbf{(Eq. 7)}$$

From Figure 3,

$$\frac{\boldsymbol{e_{1990}}}{\boldsymbol{e_{2005}}} = \boldsymbol{0.87} \qquad \textbf{(Eq. 8)}$$

Multiplying the equations together give the following:

$$\frac{e_{2030}}{e_{2005}} = \mathbf{0.87\ x\ 0.2 = .174} \qquad \textbf{(Eq. 9)}$$

Using the convention shown in Table 2 gives this equation:

$$\boldsymbol{f}_{e_{2030/2005}} = \mathbf{.174} \qquad \textbf{(Eq. 10)}$$

How Miles-Per-Gallon (MPG) Updates the LDV Efficiency Estimates

The number of pounds of CO2 per mile driven, defined as "C" in Table 1, is equal to the number of pounds of CO2, per gallon of fuel, divided by the number of miles travelled on that gallon of fuel. However, in different years, this amount can change from the standard value of "N" as defined in the last line of Table 1, because of the Low Carbon Fuel Standard. Therefore, using the definitions in Table 1, the following equation can be written:

$$c_k = \frac{\boldsymbol{NxL_k}}{\boldsymbol{M_k}} \qquad \textbf{(Eq. 11)}$$

For the baseline year "*i*", this is the following:

$$c_i = \frac{\boldsymbol{NxL_i}}{\boldsymbol{M_i}} \qquad \textbf{(Eq. 12)}$$

Using Table 1's definition of mileage that accounts for the Low Carbon Fuel Standard gives these equations, since m = M/L:

$$c_k = \frac{\boldsymbol{N}}{\boldsymbol{m_k}} \qquad \textbf{(Eq. 13)}$$

$$c_i = \frac{\boldsymbol{N}}{\boldsymbol{m_i}} \qquad \textbf{(Eq. 14)}$$

Using Table 2's second convention and dividing Equation 13 by Equation 14 gives:

$$\boldsymbol{f}_{c_{k/i}} = \frac{\boldsymbol{c_k}}{\boldsymbol{c_i}} = \frac{\boldsymbol{m_i}}{\boldsymbol{m_k}} \qquad \textbf{(Eq. 15)}$$

This shows that to get the factor to convert CO2-emission-per-mile from the baseline value to a future-time value, the new value is divided by the baseline value. However, if the mileage values are used, the baseline value must be divided by the newer value.

It is also useful to use an intermediate year to get the factor from the baseline year to the year of interest. This can be done by using Equation 13 for different years to result in Equation 14 and Equation 15, where "j" denotes the intermediate year.

$$\boldsymbol{f}_{c_{j/i}} = \frac{\boldsymbol{m_i}}{\boldsymbol{m_j}} \qquad \textbf{(Eq. 14)}$$

$$\boldsymbol{f}_{c_{k/j}} = \frac{\boldsymbol{m_j}}{\boldsymbol{m_k}} \qquad \textbf{(Eq. 15)}$$

Multiplying these equations together results in Equation 16.

$$\boldsymbol{f}_{c_{j/i}} \times \boldsymbol{f}_{c_{k/j}} = \frac{\boldsymbol{m_i}}{\boldsymbol{m_j}} \times \frac{\boldsymbol{m_j}}{\boldsymbol{m_k}} = \frac{\boldsymbol{m_i}}{\boldsymbol{m_k}} \qquad \textbf{(Eq. 16)}$$

Recognizing the right side of Equation 16 shows that these factors can be strung together, as shown by Equation 17, which is a direct result of Equation 16.

$$\boldsymbol{f_{c_{k/i}} = f_{c_{j/i}} \times f_{c_{k/j}}} \qquad \textbf{(Eq. 17)}$$

Since the low carbon fuel standard has been incorporated into the carbon emission per mile parameter, “c”, the following equations result, using the definitions of Table 1.

For Year “*k*”, this is the following:

$$\boldsymbol{e_k} = c_k * d_k * p_k \qquad \textbf{(Eq. 18)}$$

For Year “*i*”, this is the following:

$$e_i = c_i * d_i * p_i \qquad \textbf{(Eq. 19)}$$

Since the two sides of Equation 19 are equal, an equation can be formed by dividing the left side of Equation 18 by the left side of equation 19 and the right side of Equation 18 by the right side of Equation 19. Associating the terms on the right side of this new equation gives Equation 4

$$\boldsymbol{\frac{e_k}{e_i} = \frac{c_k}{c_i} * \frac{d_k}{d_i} * \frac{p_k}{p_i}} \qquad \textbf{(Eq. 20)}$$

The convention of the 2nd row of Table 2 can be used to create Equation 5 from Equation 4.

$$\boldsymbol{f_{e_{k/i}} = f_{c_{k/i}} \times f_{d_{k/i}} \times f_{p_{k/i}}} \qquad \textbf{(Eq. 21)}$$

This can be expanded by using Equation 17 to give the following.

$$\boldsymbol{f_{e_{k/i}} = f_{c_{j/i}} \times f_{c_{k/j}} \times f_{d_{k/i}} \times f_{p_{k/i}}} \qquad \textbf{(Eq. 22)}$$

For the purposes here, the intermediate year “j” is 2015 and, recalling that “c” takes into account the Low Carbon Fuel Standard, Figure 3 shows that the following is true, where 0.9 is taken (eyeballed) from the green line at 2015 and the .93 is taken (eyeballed) from the purple line.

$$\boldsymbol{f_{c_{j/i}} = 0.9\, x\, 0.93 = 0.837} \qquad \textbf{(Eq. 23)}$$

Using Equation 22, to solve for the per-capita driving-reduction factor, results in Equation 24.

$$\boldsymbol{f_{d_{k/i}} = \frac{f_{e_{k/i}}}{f_{c_{j/i}} \times f_{c_{k/j}} \times f_{P_{k/i}}}} \qquad \textbf{(Eq. 24)}$$

Reference 8 shows that California’s population in 2005 was 35,985,582. Reference 9 shows that California’s population in 2030 is predicted to be 44,279,354. Therefore,

$$\boldsymbol{f_{P_{k/i}} = 44279354 \div 35985582 = 1.2305} \qquad \textbf{(Eq. 25)}$$

Using the values in Equation 10, 23, and 25 gives Equation 26, where “j” is the intermediate year of 2015 and Equation 15 is also used.

$$\boldsymbol{f_{d_{k/i}} = \frac{0.174}{0.837 \times \frac{m_j}{m_k} \times 1.2305}} \qquad \textbf{(Eq. 26)}$$

Evaluating the values shown and with j = 2015 and k = 2030 gives Equation 27.

$$\boldsymbol{f_{d_{k/i}} = 0.1689\, x\, \frac{m_{2030}}{m_{2015}}} \qquad \textbf{(Eq. 27)}$$

If the per-capita driving factor was 1 (no per-capita driving reduction needed from 2005 to 2030), the 2030 fleet (all LDVs on the road) mileage would need to exceed the 2015 fleet mileage by a factor of 1 divided by 0.1689, which is 5.92. For example, if the mileage for the 2015 fleet is 25 MPG, then the 2030 value would need to be 148 MPG. Clearly, most LDVs in 2030 will need to be ZEVs.

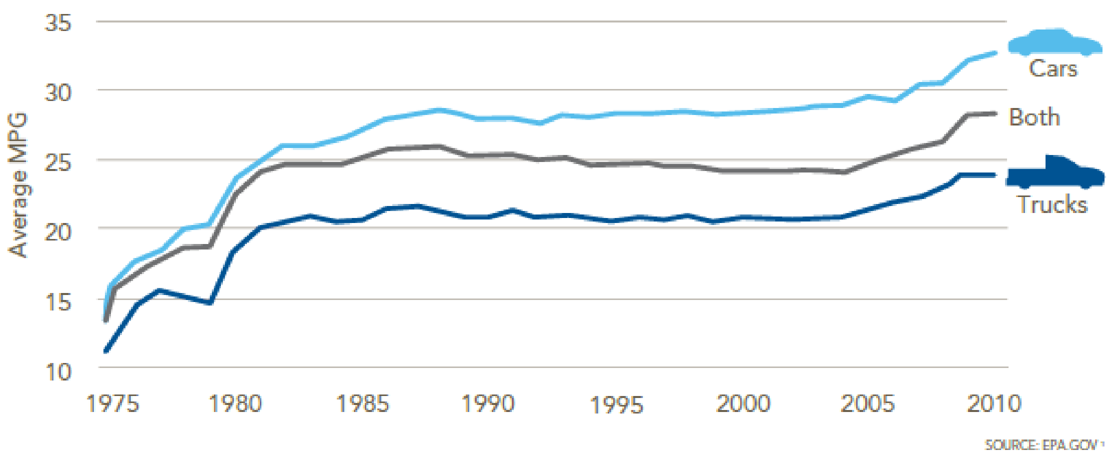
Internal Combustion Engine (ICE) Mileage, from Year 2000 to Year 2030

The years from 2000 to 2011 are taken from a plot produced by the PEW Environment Group,

http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Fact_Sheet/History%20of%20Fuel%20Economy%20Clean%20Energy%20Factsheet.pdf

The plot is shown here as Figure 6. The "Both" values are used.

Figure 6 **Mileage Values From the PEW Environment Group**



The values from 2012 to 2025 are taken from the US Energy Information Agency (EIA) as shown on their website, http://www.c2es.org/federal/executive/vehicle-standards#ldv_2012_to_2025. They are the LDV Corporate Average Fleet Efficiency (CAFÉ) values enacted into law in the first term of President Obama. From 2025 to 2030, it is assumed that the yearly ICE improvement in CAFÉ will be 2.5 MPG.

Mileage of California's LDV Fleet in 2015

Table 3 uses these values of ICE mileage to compute the mileage of the LDV fleet in 2015. It assumes that the fraction of ZEVs being used over these years is small enough to be ignored. The 100 miles driven, nominally, by each set of cars, is an arbitrary value and inconsequential in the final calculation, because it will divide out. It is never-the-less used, so that it is possible to compare the gallons of fuel used for the different years. The "f" factor could be used to account for a set of cars being driven less. It was decided to not use this option by setting all of the values to 1. The Low Carbon Fuel Standard (LCFS) values are taken from Figure 3. The gallons of fuel are computed as shown in Equation 28, using the definition for L_k that is shown in Table 1.

$$\textbf{Gallons Used per } f * 100 \textbf{ miles} = \frac{f x 100}{(CAFE\ MPG)/L_k} \qquad \textbf{(Eq. 28)}$$

How ICE Mileage Values Will Be Used with ZEV Equivalent Mileage Values

As will be seen, after 2015, the net (computed using both ICEs and ZEVs) mileage values for each year are assumed to greatly improve by having a significant fraction of ZEVs. The ICE CAFÉ standards are used in this report as just the ICE contribution to fleet MPG. The ICE MPG values are inadequate by themselves and will therefore need to become less important because ZEVs will need to quickly take over the highways.

Federal requirements will need to change dramatically. Currently, federally-mandated corporate average fuel efficiency (CAFÉ) standards have been implemented, from 2000 to 2025. These standards require that each corporation produce and sell their fleet of cars and light-duty trucks in the needed proportions, so that the combined mileage of the cars they sell, at least meet the specified mileage.

Table 3.Calculation of the Fleet MPG for 2015

LDV Set	Years Old	Model Year	CAFE MPG	LCFS Factor L_{Year}	Factor Driven f	Gallons Used Per f*100 Miles
1	14-15	2001	24.0	1.0	1.0	4.17
2	13-14	2002	24.0	1.0	1.0	4.17
3	12-13	2003	24.0	1.0	1.0	4.17
4	11-12	2004	24.0	1.0	1.0	4.17
5	10-11	2005	25.0	1.0	1.0	4.00
6	9-10	2006	25.7	.9933	1.0	3.87
7	8-9	2007	26.3	.9867	1.0	3.75
8	7-8	2008	27.0	.9800	1.0	3.63
9	6-7	2009	28.0	.9733	1.0	3.48
10	5-6	2010	28.0	.9667	1.0	3.45
11	4-5	2011	29.1	.9600	1.0	3.30
12	3-4	2012	29.8	.9533	1.0	3.20
13	2-3	2013	30.6	.9467	1.0	3.09
14	1-2	2014	31.4	.9400	1.0	2.99
15	0-1	2015	32.6	.9333	1.0	2.86
Sum of Gallons:						54.29
Miles = 100*Sum(f's):						1500
MPG = Miles/(Sum of Gallons):						27.63

The car companies want to maximize their profits while achieving the required CAFÉ standard. In California, the car companies will already be required to sell a specified number of electric vehicles, which have a particularly-high, equivalent-value of miles-per-gallon. If the laws are not changed, this will allow these companies to sell more low-mileage, high profit cars and light-duty trucks, and still achieve the federal CAFÉ standard.

It will be better to apply the CAFÉ standards to only the ICEs and then require that the fleet of LDVs sold achieve some mandated fraction of ZEVs. The ZEVs will get better and better equivalent mileage, as our electrical grid is powered by more renewables. Therefore, their equivalent mileage is not fixed, but will improve over the years. Requirements developed here are for 2030. Therefore a high percentage of all the electricity generated in the state, including both the "in front of the meter" (known as the "Renewable Portfolio Standard" or "RPS") portion and the "behind the meter" portion is assumed to come from sources that do not emit CO2. The value of 80% is assumed.

ZEV Equivalent Mileage Values

To calculate the mileage of the 2030 fleet of LDVs, it is necessary to derive a formula to compute the equivalent mileage of ZEVs, as a function of the percent of electricity generated without emitting CO2, the equivalent ZEV mileage if the electricity is from 100% fossil fuel, and the equivalent ZEV mileage if the electricity is from 100% non-C02 sources. The variables defined in Table 4 are used.

Table 4. Variables Used in the Calculation of ZEV Equivalent Mileage

Variable	Definition
$\boldsymbol{m_z}$	**ZEV Equivalent mileage**
$\boldsymbol{m_{zr}}$	**ZEV Equivalent mileage if the electricity is from renewables**
$\boldsymbol{m_{zf}}$	**ZEV Equivalent mileage if the electricity is from fossil fuels**
$\boldsymbol{r}$	**fraction of electricity generated from sources not emitting CO2**
$\boldsymbol{G}$	**Gallons of equivalent fuel used**
$\boldsymbol{D}$	**Arbitrary distance travelled**
$\boldsymbol{Num}$	$\boldsymbol{m_{zr} \times m_{zf}}$
$\boldsymbol{Den}$	$\boldsymbol{r \times m_{zf} + (1 - r) \times m_{zr}}$

The derivation of the equation for equivalent ZEV mileage is based on the notion that the ZEV can be imagined to travel "r" fraction of the time on electricity generated from renewables and "(1-r)" fraction of the time on fossil fuel. If the vehicle travels "D" miles, then, using the definitions shown in Table 4, the following equation can be written.

$$\boldsymbol{G = \frac{r \times D}{m_{zr}} + \frac{(1-r) \times D}{m_{zf}}} \qquad \textbf{(Eq. 29)}$$

$$\boldsymbol{m_z = D/G = D/(\frac{r \times D}{m_{zr}} + \frac{(1-r) \times D}{m_{zf}})} \qquad \textbf{(Eq. 30)}$$

Dividing the numerator and the denominator by D and multiplying them both by the product of the two equivalent mileage values results in Equations 31.

$$\boldsymbol{m_z = m_{zr} \times m_{zf} / \left(r \times m_{zf} + (1 - r) \times m_{zr}\right)} \qquad \textbf{(Eq. 31)}$$

Again, using the definitions in Table 4 results in the following.

$$m_z = Num/(Den\ ) \qquad \textbf{(Eq. 32)}$$

Table 5 shows an assignment of assumed values and the result of a calculation, using Equations 31 and 32, to produce a ZEV equivalent mileage.

Table 5. Variable Assignment and the Resulting ZEV Mileage

m_{zr}	m_{zf}	r	1-r	Num	Den	m_z
5000	70	0.8	0.2	350000.00	1056.00	331.44

Computing an LDV Fleet Mileage Assuming Heroic Measures (HM)

Table 6 shows the additional definitions that will be used in this calculation. Table 7 computes the 2030 LDV mileage, assuming "Heroic Measures" to reduce the miles driven in poor-mileage ICE's, in building and selling a significant fraction of ZEVs, and in getting the Low Carbon Fuel Standards to continue to improve beyond the Table 3 minimum of 0.90.

Table 6. Additional Variables Used in the Calculation of 2030 LDV Mileage

Variable	Definition
D_i	Distance travelled by ICE vehicles
D_z	Distance travelled by ZEVs
G_i	Gallons of Equivalent fuel used by ICE vehicles
G_z	Gallons of Equivalent fuel used by ZEVs

As shown by the values for "f", government policies must be adopted to reduce the miles driven by the ICE's, from 2016 to 2023. The 2016 model ICE's are driven only 30% as much as the nominal amount. The 2017 year ICE's can be driving 10% more. This rate of change continues up to 2023, when the ICE's are doing less damage, due to the large fraction of ZEVs on the road.

As shown, the ZEV fraction of the fleet assumes the value of 5%, just 4 years from now. It then proceeds upward, to 10% in 2019, 25% in 2020, 40% in 2021, and so on, until it reaches 95%.

Achieving these fractions of ZEVs might be compared to what was done during World War II, when automobile productions lines were rapidly converted to produce tanks. This reduced the new cars that could be purchased. Besides this, rationing gasoline made it difficult to drive at times and, due to shortages of leather, which was being used to produce boots for soldiers, some citizens found it hard to even buy shoes. These rapid and inconvenient changes were tolerated, because most people agreed that the war needed to be won. The heroic measures assumed here may not be possible unless citizens and the political leaders they elect understand the dire consequences of climate destabilization and therefore accept, and even demand, the measures that are needed to support climate stabilization.

The equivalent miles per gallon of the LDV fleet in 2030, specifically 111.12 miles per gallon, will be considered as a potential 2030 LDV requirement.

Computing the Heroic-Measures (HM) Case Per-Capita and Net Driving Factor Requirements, Based on the Result Shown in Table 7

Plugging the

- equivalent MPG of the LDV fleet in Year 2030, taken from the bottom of Table 7, which is 111.12 MPG, and
- the MPG of the LDV fleet in Year 2015, taken from the bottom of Table 3, which is 27.63 MPG,

into Equation 27, gives the following result:

$$f_{d_{k/i}} = 0.1689\ x\ \frac{m_{2030}}{m_{2015}} = .1689 \times \frac{111.12}{27.63} = .6795 \qquad \text{(Eq. 31)}$$

This means that the per-capita driving will need to be about 32% less than in year 2005. The net driving can be computed by multiplying the per-capita driving, 0.6795, by the population factor of 1.2305, computed in Equation 25, resulting in 0.8361. This means that, even with the 23% increase in California's population, the net driving will have to drop by about 16%. If this LDV requirement set is selected, all of California's transportation money can be used to improve transit, improve active transportation (mainly walking and biking), and maintain, but not expand, roads.

Computing LDV Requirements that Support 2005 Per-Capita Driving

The first step is to use Equation 27 and the value of the mileage in 2015 to compute the needed LDV equivalent fleet mileage for 2030 so that $f_{d_{k/i}}$ is equal to 1.0.

Table 7. Calculation of 2030 LDV Mileage Assuming Heroic Measures

	ICE Parameters and Calculations						ZEVs			Yearly Totals		
Year	CAFÉ MPG	LCFS	Eq. MPG	f	D_i	G_i	z	D_z	G_z	Total Miles	Total Gallons	2030 MPG
2016	34.3	.9267	37.01	.3	30.0	.8105	0	0	.000	30.0	.8105	37.01
2017	35.1	.9200	38.15	.4	40.0	1.0484	0	0	.000	40.0	1.0484	38.15
2018	36.1	.9133	39.53	.5	47.5	1.2018	.05	5	.015	52.5	1.2168	43.14
2019	37.1	.9000	40.92	.6	54.0	1.3197	.10	10	.030	64.0	1.3498	47.41
2020	38.3	.8500	42.56	.7	52.5	1.2337	.25	25	.075	77.5	1.3091	59.20
2021	40.3	.8000	47.41	.8	48.0	1.0124	.40	40	.121	88.0	1.1331	77.66
2022	42.3	.8000	52.88	.9	40.5	.7660	.55	55	.166	95.5	.9319	102.48
2023	44.3	.8000	55.38	1.0	30.0	.5418	.70	70	.211	100.0	.7530	132.81
2024	46.5	.8000	58.13	1.0	15.0	.2581	.85	85	.257	100.0	.5145	194.36
2025	48.7	.8000	60.88	1.0	5.0	.0821	.95	95	.287	100.0	.3688	271.18
2026	51.2	.8000	64.00	1.0	5.0	.0781	.95	95	.287	100.0	.3648	274.16
2027	53.7	.8000	67.13	1.0	5.0	.0745	.95	95	.287	100.0	.3611	276.92
2028	56.2	.8000	70.25	1.0	5.0	.0712	.95	95	.287	100.0	.3578	279.48
2029	58.7	.8000	73.38	1.0	5.0	.0681	.95	95	.287	100.0	.3548	281.87
2030	61.2	.8000	76.50	1.0	5.0	.0654	.95	95	.287	100.0	.3520	284.10
Sum of Miles and then Gallons of Equivalent Fuel:										1247.5	11.23	
Equivalent MPG of LDV Fleet in 2030:										***111.12***		

Sum of ZEV Miles = **860**. Fraction of Miles Driven by ZEVs = **68.9%**

$$\boldsymbol{m_{2030} = f_{d_{k/j}} \times \frac{m_{2015}}{0.1689} = 1.0 \times \frac{27.63}{0.1689} = 163.54\ \text{MPG}} \qquad \textbf{(Eq. 32)}$$

Table 8 is constructed, with the fraction of ZEVs selected to achieve the needed equivalent fleet mileage of about 163.54 MPG. Since its ZEV fractions are larger and sooner than in the "Heroic Measures table, Table 8 is the "Extra-Heroic Measures" (EHM) case. The ICE "f" values are unchanged; as are the LCFS values. The EHM ZEV differences from the HM case are the highlighted "z" values.

This means that with the 23% increase in California's population, computed in Equation 25, the net driving would also increase by 23%. If this LDV requirement set were to be implemented, a lot of California's transportation money will be needed to expand the highway system, leaving less to improve transit, improve active transportation (mainly walking and biking), and maintain roads.

Comparing the ZEV Fraction Values of the "Heroic-Measures" (HM) Case to the "Extra-Heroic Measures" (EHM) Case

Table 9 shows the direct comparison of the ZEV fractions that are ZEV requirements for the HM Case and the EHM Case. The differences are highlighted.

ACHIEVING THE REQUIRED DRIVING REDUCTION OF THE HEROIC-MEASURES (HM) CASE

As shown in Equation 31, in 2030, the per-capita driving will need to at least 32% below the 2005 value. As shown in this link, http://en.wikipedia.org/wiki/SB_375, California's Metropolitan Planning Organizations (MPOs) are adopting Region Transportation Plans (RTPs) that will achieve reductions in year 2020 and 2035. As also shown there, the targets, for year 2035, range from 0% for Shasta to 16% for Sacramento Area Council of Governments Since this is for 2030 instead of 2035, and to be reasonably conservative, it is assumed here that the state will achieve a 10% reduction in per-capita driving, in 2030, compared to 2005. This leaves 22% to be achieved by new programs.

The title of each of the following subsections contains the estimated per-capita driving reduction each strategy will achieve, by 2030.

Reallocate Funds Earmarked for Highway Expansion to Transit and Consider Transit-Design Upgrades (3%)

San Diego County has a sales tax measure called "TransNet", which allocates one-third for highway expansion, one-third for transit, and one-third for road maintenance. It has a provision that allows for a reallocation of funds, if supported by at least two-thirds of SANDAG Board members, including a so-called weighted vote, where governments are given a portion of 100 votes, proportional to their population. It is hereby proposed to reallocate the TransNet amount, earmarked for highway expansion, to transit and to do similar reallocations throughout California.

This money could be used to fund additional transit systems; improve transit operations; and/or the redesign and implementation of the redesign of existing transit systems. The redesign could include electrification and automation or even upgrading to a different technology.

A Comprehensive Road-Use Fee Pricing and Payout System to Unbundle the Cost of Operating Roads (7.5%)

Comprehensive means that pricing would be set to cover all costs (including road maintenance and externalities such as harm to the environment and health); that privacy and the interests of low-income drivers doing necessary driving would be protected; that the incentive to drive fuel-efficient cars would be at least as large as it is under the current fuels excise tax; and, as good technology becomes available, that congestion pricing is used to protect critical driving from congestion.

The words *payout* and *unbundle* mean that some of the money collected would go to people that are losing money under the current system.

User fees (gas taxes and tolls) are not enough to cover road costs[10] and California is not properly maintaining its roads. Reference 10 shows that in California user fees amount to only 24.1% of what is spent on roads. Besides this, the improved mileage of the ICEs and the large number of ZEVs needed mean that gas tax revenues will drop precipitously.

Table 8. Calculation of 2030 LDV Mileage Assuming Extra-Heroic Measures

Year	ICE Parameters and Calculations						ZEVs			Yearly Totals		
	CAFÉ MPG	LCFS	Eq. MPG	f	D_i	G_i	z	D_z	G_z	Total Miles	Total Gallons	2030 MPG
2016	34.3	.9267	37.01	.3	30.0	.8105	.00	0	.000	30.0	.8105	37.01
2017	35.1	.9200	38.15	.4	36.0	.9436	.10	10	.030	46.0	.9738	47.24
2018	36.1	.9133	39.53	.5	35.0	.8855	.30	30	.091	65.0	.9760	66.60
2019	37.1	.9000	40.92	.6	30.0	.7332	.50	50	.151	80.0	.8840	90.50
2020	38.3	.8500	42.56	.7	21.0	.4935	.70	70	.211	91.0	.7047	129.14
2021	40.3	.8000	47.41	.8	8.0	.1687	.90	90	.272	98.0	.4403	222.59
2022	42.3	.8000	52.88	.9	4.5	.0851	.95	95	.287	95.5	.3717	267.66
2023	44.3	.8000	55.38	1.0	5.0	.0903	.95	95	.287	100.0	.3769	265.31
2024	46.5	.8000	58.13	1.0	5.0	.0860	.95	95	.287	100.0	.3727	268.35
2025	48.7	.8000	60.88	1.0	5.0	.0821	.95	95	.287	100.0	.3688	271.18
2026	51.2	.8000	64.00	1.0	5.0	.0781	.95	95	.287	100.0	.3648	274.16
2027	53.7	.8000	67.13	1.0	5.0	.0745	.95	95	.287	100.0	.3611	276.92
2028	56.2	.8000	70.25	1.0	5.0	.0712	.95	95	.287	100.0	.3578	279.48
2029	58.7	.8000	73.38	1.0	5.0	.0681	.95	95	.287	100.0	.3548	281.87
2030	61.2	.8000	76.50	1.0	5.0	.0654	.95	95	.287	100.0	.3520	284.10
Sum of Miles and then Gallons of Equivalent Fuel:										1309.5	8.07	
Equivalent MPG of LDV Fleet in 2030:										*162.27*		

Table 9. HM Case and the EHM Case Which Supports 2005 Per-Capita Driving

Cases	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
HM	.00	**.00**	**.00**	**.05**	**.10**	**.25**	**.40**	**.55**	**.70**	**.85**	.95	.95	.95	.95	.95	.95
EHM	.00	**.10**	**.30**	**.50**	**.70**	**.90**	**.95**	**.95**	**.95**	**.95**	.95	.95	.95	.95	.95	.95

This system could be used to help reduce the ICE LDV miles driven in 2016 to 2022, as shown in the "f" column of Tables 7 and 8. This system could probably be implemented in less than 5 years.

Unbundling the Cost of Car Parking (7.5%)

Unbundling the cost of car parking[R11] throughout California is conservatively estimated to decrease driving by 7.5%, based on Table 1 of Reference 11. That table shows driving reductions due to introducing a price, for 10 cases. Its average reduction in driving is 25% and its smallest reduction is 15%.

Good Bicycle Projects and Bicycle Traffic Skills Education (3%)

The best criterion for spending money for bicycle transportation is the estimated reduction in driving per the amount spent. The following strategies may come close to maximizing this parameter.

Projects to Improve Bicycle Access

All of the smart-growth neighborhoods, central business districts, and other high trip destinations or origins, both existing and planned, should be checked to see if bicycle access could be substantially improved with either a traffic calming project, a "complete streets" project, more shoulder width, or a project to overcome some natural or made-made obstacle.

League of American Bicyclist Certified Instruction of "Traffic Skills 101"

Most serious injuries to bike riders occur in accidents that do not involve a motor vehicle[12]. Most car-bike accidents are caused by wrong-way riding and errors in intersections; the clear-cut-hit-from-behind accident is rare[12].

After attending *Traffic Skills 101*, students that pass a rigorous written test and demonstrate proficiency in riding in traffic and other challenging conditions could be paid for their time and effort.

As an example of what could be done in San Diego County, if the average class size was 3 riders per instructor and each rider passes both tests and earns $100 and if the instructor, with overhead, costs $500 dollars, for a total of $800 for each 3 students, that would mean that $160M could teach $160M/$800 = 200,000 classes of 3 students, for a total of 600,000 students. The population of San Diego County is around 3 million.

Eliminate or Greatly Increase the Maximum Height and Density Limits Close to Transit Stops that Meet Appropriate Service Standards (2%)

As sprawl is reduced, more compact, transit-oriented development (TOD) will need to be built. This strategy will incentivize a consideration of what level of transit service will be needed, how it can be achieved, and what levels of maximum height and density are appropriate. Having no limits at all is reasonable if models show that the development can function without harming the existing adjacent neighborhoods, given the level of transit service and other supporting transportation policies (such as car parking that unbundles the cost and supports the full sharing of parking[12]) that can be assumed.

Net Driving Reduction from All Identified Strategies

By 2030, the sum of these strategies should be realized. They total 23%, resulting in a 1% margin over the needed 22% (which is added to the existing 10% to get the needed 32%).

ADDITIONAL ELECTRICITY REQUIRED

The URL http://www.energy.ca.gov/2013_energypolicy/documents/2013-06-26_workshop/presentations/09_VMT-Bob_RAS_21Jun2013.pdf shows that Californians drove about 325 Billion miles per year, from 2002 to 2011. This value can be multiplied by the 0.8361 factor reduction of driving, computed right after the calculation shown in Equation 31, and the fraction of miles driven by ZEVs, shown at the bottom of Table 7, of 0.689 (from 68.9%), to give the 2030 miles driven by ZEVs = 325 Billion x 0.831 x 0.689 = 187 Billion miles per year.

Using the Tesla information here http://en.wikipedia.org/wiki/Tesla_Roadster, it is assumed that 21.7 kW-h is used per 100 miles, or 0.217 kW-h per mile. The total energy used per year is therefore 187 Billion miles x 0.217 kW-h = 40,648 GW-h.

http://www.cpuc.ca.gov/cfaqs/howhighiscaliforniaselectricitydemandandwheredoesthepowercomefrom.htm, shows that California is using about 265,000 GW-h per year. Therefore the electricity needed to power California's HM ZEV LDF fleet in 2030 is 100% x 40,648/265,000 = 15.34% of the amount of electricity California is currently using.

CONCLUSION

A requirement set named "Heroic Measures" (HM) is quantified. Table 9 shows that the HM LDV efficiency requirements are much easier to achieve than those needed to allow per-capita driving to remain close to its 2005 level. Strategies to achieve the required HM driving reductions are also allocated and described. They are perhaps about as difficult as achieving the HM LDV fleet efficiency. It is computed that the 2030 fleet of LDV HM ZEVs would require an amount of electricity which is equal to about 15% of what California is using today.

ABREVIATIONS AND ACRONYMS

AB 1493	California's Assembly Bill 1493	**ICE**	Internal Combustion Engine LDV
AB 32	California's Assembly Bill 32	**kW-h**	Kilo Watt-hour
APS	Alternative Planning Strategy	**LCFS**	Low Carbon Fuel Standard

CAFE	Corporate Average Fleet Efficiency	**LDV**	Light-Duty Vehicle
CARB	California Air Resources Board	**MPO**	Metropolitan Planning Organization
CBD	Center for Biological Diversity	**Pavley**	Senator Pavley's AB 1493
CEQA	California Environmental Quality Act	**PPM**	Parts per Million
CCAP	Center for Clean Air Policy	**RPS**	Renewable Portfolio Standard
CNFF	Cleveland National Forest Foundation	**RTP**	Regional Transportation Plan
SB 375	California's Senate Bill 375	**S-3-05**	Governor's Executive Order S-3-05
CO_2	Carbon Dioxide	**SANDAG**	San Diego Association of Governments
CO_2_e	Carbon Dioxide Equivalent GHG		
EHM	"Extra Heroic Measures" LDV Case	**SCS**	Sustainable Community Strategy
GEO	Governor's Executive Order	**TransNet**	San Diego County sales tax
GHG	Greenhouse gas	**URL**	Universal Resource Locator
GW-h	Giga Watt-Hours	**VMT**	Vehicle Miles Travelled
HM	"Heroic Measures" LDV Case	**ZEV**	Zero Emission Vehicle LDV

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KEYWORDS

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