Journal of Traffic and Transportation Engineering 14 (2026) 30-46
doi: 10.17265/2328-2142/2026.01.005

Climate-Stabilizing, California Light-Duty Vehicle Requirements, Versus Air Resource Board Goals

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Abstract: An Introduction is provided, including the importance of light-duty vehicles (LDVs: cars and light duty trucks) and a definition of the top-level LDV requirements to limit their carbon dioxide ("CO2") emissions. Anthropogenic climate change fundamentals are presented, including its cause, its potential for harm, California mandates, and a greenhouse gas (GHG) reduction road map to avoid disaster. A 2030 climate-stabilizing GHG reduction target value is calculated, using statements by climate experts. The formula for GHG emissions, as a function of per-capita driving, population, fleet CO2 emissions per mile, and the applicable low-carbon fuel standard (LCFS) is given. The ratio of the 2015 value of car-emission-per-mileto the 2005valueof car-emission-per-mileis obtained. Internal Combustion Engine (ICE) mileage values from 2000 to 2030 are identified, as either mandates or new requirements. A table is presented that estimates 2015 LDV fleet mileage. Zero Emission Vehicle (ZEV) parameters are given. A table is shown that uses 2030 ZEV and ICE (ICE LDVs) requirements, named the "Heroic Measures" case,to compute the LDV fleet-equivalent mileage. That equivalent fleet mileage is used, with population and the requiredemission reduction, to compute a required per-capita driving reduction, with respect to 2005. Measures to achieve this per-capita driving reduction are described, with reductions allocated to each measure. The energy used per year for the Heroic Measures case is estimated The "Heroic Measures" set of fractions of ZEV's purchased, as a function of year, is compared to the California Air Resources Board (CARB) goals.

Key words: Driving, climate, mandates, s-3-05, sb 375, rtp, ceqa, unbundled, ghg, café, zevs.

Abreviations and Acronyms

AB 1493	California's Assembly Bill 1493
AB 32	California's Assembly Bill 32
APS	Alternative Planning Strategy
CAFE	Corporate Average Fuel Efficiency
CARB	California Air Resources Board
CBD	Center for Biological Diversity
CCAP	Center for Clean Air Policy
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CNFF	Cleveland National Forest Foundation
CO_2	Carbon Dioxide
CO_2_e	Carbon Dioxide Equivalent GHG
CPUC	California Public Utilities Commission
EHM	"Extra Heroic Measures" LDV Case
GEO	Governor's Executive Order
GHG	Greenhouse gas
GW-h	Giga Watt-Hours
HM	"Heroic Measures" LDV Case
ICE	Internal Combustion Engine LDV
kW-h	Kilo Watt-hour
LCFS	Low Carbon Fuel Standard
LDV	Light-Duty Vehicle
MPO	Metropolitan Planning Organization
Pavley	Senator Pavley's AB 1493
PPM	Parts per Million
RPS	Renewable Portfolio Standard
RTP	Regional Transportation Plan
S-3-05	Governor's Executive Order S-3-05
SANDAG	San Diego Association of Governments
SB 375	California's Senate Bill 375
SCS	Sustainable Community Strategy
TransNet	San Diego County sales tax
URL	Universal Resource Locator
VMT	Vehicle Miles Travelled
ZEV	Zero Emission Vehicle LDV

1. Introduction

Within the context of working the anthropogenic-climate-change problem and from a systems engineering

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perspective, the 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 the subsystem of LDVs, especially due to the magnitude of their emissions. (As an example, LDVs emit 41% of the GHG in San Diego County[1].)

More specifically,LDV requirements will be identified that, taken together, will result in GHG emission reductions sufficient to “support climate stabilization”. “Support climate stabilization”means that the LDV emission level will be equal to a climate-stabilizing target. Such a target is expressed as an emission level in some target year. The target is based on climate science.

From a systems engineering perspective, at the top level, the needed LDV requirements are

- LDV fleet efficiency, meaning the greenhouse gas (GHG) emissions per mile driven, applicable to the entire fleet, on the road in the year of interest and
- an upper bound on per-capita driving, given the derived fleet efficiency and the predicted population growth.

The fleet efficiency requirement will be developed as a function of lower-level requirements, such as Corporate Average Fuel Efficiency (CAFÉ) requirements, requirements on how fast Battery Electric Vehicles (BEVs) must be added into the fleet each year, and requirements to get low-efficiency vehicles off the roads. The second top-level requirement, the upper bound on per-capita driving, will spawn transportation-system requirements designed to result in less driving, such as better mass transit. This paper will derive a formulae to compute therequired per-capita driving levels, based on fleet efficiency, predicted population growth, and the latest, science-based, climate-stabilizing GHG emission target.

In this work, three categories of LDV emission-reduction strategies will be considered:cleaner cars, cleaner fuels, and less driving.

2. Background: Our Anthropogenic Climate Changeproblem

2.1 Purpose of This Section

Before going to work to solve a systems-engineering problem, it is important to understand the nature of the problem. How complex is the problem? How much is at stake if the problem is not solved? Is it reasonable to take a chance and only solve the problem with a reasonably high probability or is there too much at stake to gamble? This section is an attempt to answer these questions.

2.2 Basic Cause

Anthropogenic climate changeis driven by these two processes[2]: First, our combustion of fossil fuels is adding “great quantities” of CO_2 into our atmosphere. Second, that additional atmospheric $CO_2$is trapping additional heat.

2.3 California’s First Three Climate Mandates

California’s Governor’s Executive Order S-3-05[3]is similar to the Kyoto Agreement andis based on thegreenhouse gas (GHG) reductions that were recommended by climate scientists for industrialized nationsback in 2005. In 2005, many 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 degreeCelsius, above the preindustrial temperature. It attempts to do this by limiting our earth’s level of 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 are2000 emission levels by 2010,1990 levels by 2020, and80% 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 degreesCelsius, thus leaving a 50% chance that it would be larger than 2 degreesCelsius.A 2 degree increase would put over a billionpeople on the planet into a condition described as "water stress" and it would mean a loss of 97% of the earth's coral reefs.

There would also be a 30% chance thatthe temperature increase would be greater than 3 degreesCelsius. 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*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. AB 32 requires CARB to always implement measures that achieve the maximum *technologically feasible and cost-effective*(words taken from AB 32) greenhouse-gas-emission reductions.

In 2015 Governor Brown signed Executive Order B-30-15. This Executive Order established a mandate to achieve an emission level of 40% below 2020 emissions by 2030, as can be seen by a Google search. If Executive Order S-3-05 is interpreted as a straight line between its 2020 target and its 2050 target, then the B-30-15 target of 2030 is the same as S-3-05's implied target of 2035, because 2035 is halfway between 2020 and 2050 and 40% down is halfway to 80% down.

California is on track to achieve its S-3-05 second (2020) target. However, the world emission levels have, for most years, been increasing, contrary to the S-3-05 trajectory. In part because the world has been consistently failing to follow S-3-05's 2010-to-2020 trajectory, if California is still interested in leading the way to stabilizing the climate at a livable level, it must do far better than S-3-05, going forward, as will be shown.

2.4 Failing to Achieve these Climate Mandates

What could happen if we fail to achieve S-3-05, AB 32, and B-30-15 orif 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[4]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[5] 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."

2.5 PicturesThat Are Worth a ThousandWords

Figure 1shows (1) atmospheric CO_2 (in blue) and (2) averaged-over-a-year-then-averaged-over-the surface-of-the-earthworld atmospheric temperature (in red). This temperature is with respect to a recentpreindustrialvalue. 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 tothe 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.

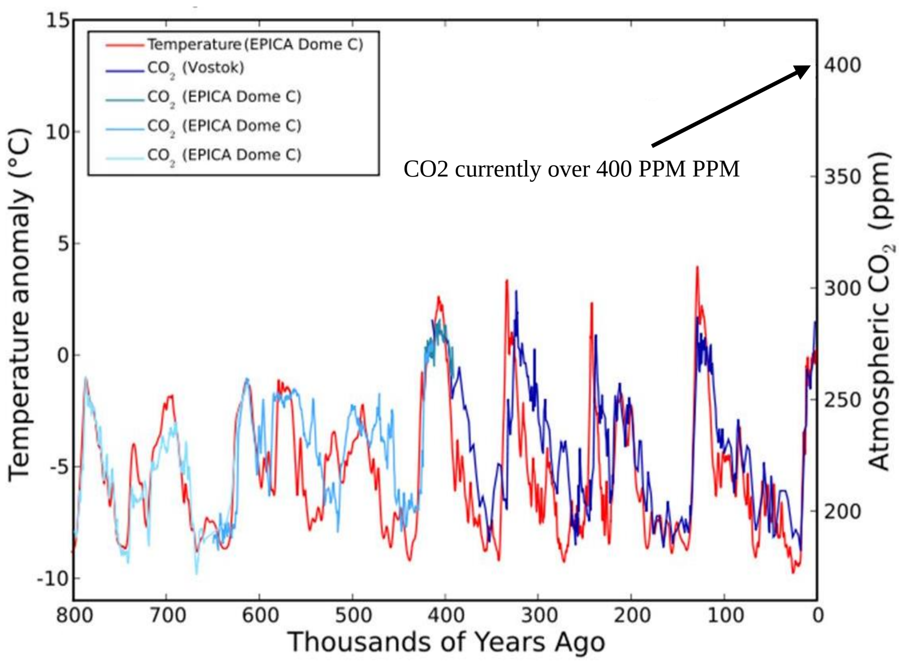

Fig. 1 Atmospheric CO_2 and Mean Temperaturefrom800,000 Years Ago.

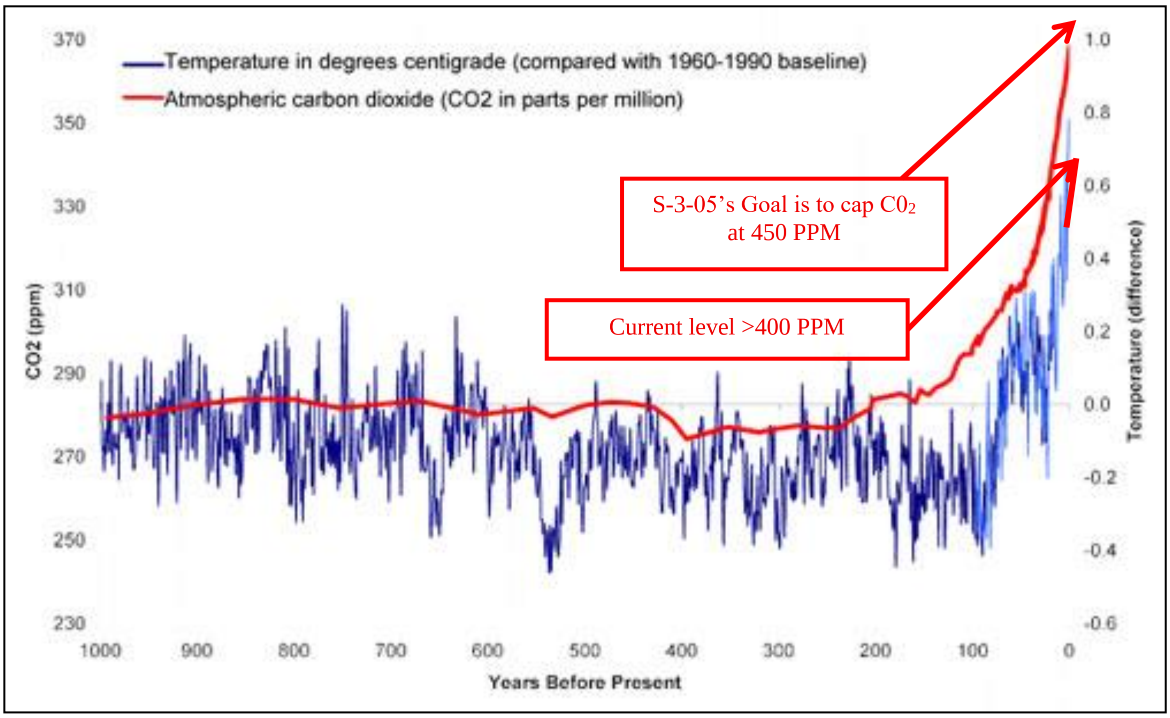

Fig. 2 Atmospheric CO_2 and Mean Temperature,Over the Last 1,000 Years.

3. Further Background: CALIFORNIA'S SB 375 ANDan important data set

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),worked on this problem.

3.1 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 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. It is important to note that although this link and many other sources show the targets to be "GHG" and not "VMT", SB 375 clearly states that the reductions are to be the result of the MPO's Regional Transportation Plan (RTP), or, more specifically, the Sustainable Communities Strategy (SCS) portion of the RTP. Nothing in the SCS will improve average mileage. That will be done by the state and federal government by their Corporate Average Fleet Efficiency (CAFÉ) standards. The SCS can only reduce GHG by reducing VMT. The only way an SCS can reduce GHG by 12%, for example, is to reduce VMT by 12%.

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). 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.

3.2 Critical Data: Useful Factors from Steve Winkelman's Data

Figure 3[6].shows 6 variables as a percent of its 2005 value. The year 2005 is the baseline year of SB 375. The red line is the Caltrans prediction of VMT. The purple line is California's current mandate for a Low Carbon Fuel Standard (LCFS). As shown, by 2020,

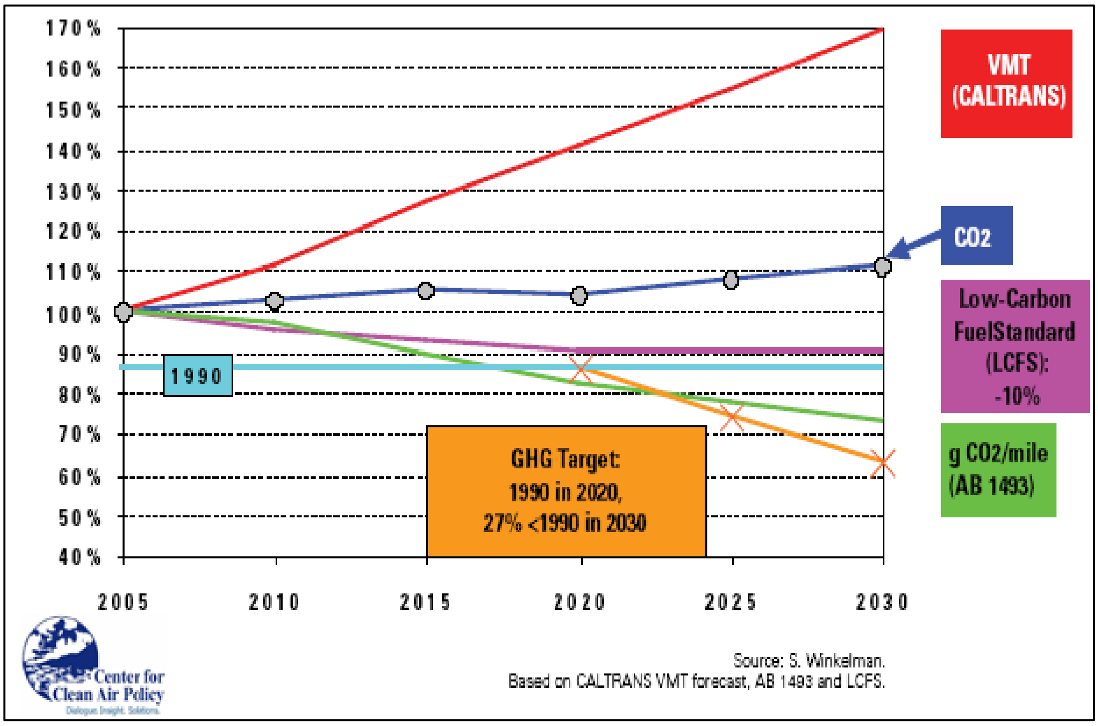

Fig. 3 The S-3-05 Trajectory (the Gold Line) AND the CO_2 Emitted from Personal Driving (the Blue Line), where that CO_2 is a Function (the Product) of the California-Fleet-Average CO_2 per Mile (the Green Line), The Predicted Driving (VMT, the Red Line), and the Low-Carbon Fuel Standard (the Purple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

fuel in California must emit 10% less per gallon than in 2005. The turquoise line is the 1990 GHG emission in California. As shown, it is 12% below the 2005 level. This is important because S-3-05 specifies that in 2020, state GHG emission levels must be at the 1990 level. The green line is the C02 emitted per mile, as specified by AB 1493, also known as “Pavley 1 and 2” named after Senator Fran Pavley. The values shown do not account for the LCFS. The yellow (or gold) line is the S-3-05 mandate, referenced to 2005 emission levels. The blue line is the product of the red, the purple, and the green line and is the percentage of GHG emissions compared to 2005. Since VMT is not being adequately controlled, the blue line is not achieving the S-3-05 line. Figure 3 shows that driving must be reduced. For this reason, Steve Winkelman can be thought of as the true father of SB 375.

This table provides inspiration for a road map to climate success for LDVs. Climate stabilization targets must be identified and achieved by a set of requirements to define fleet efficiency and per-capita driving.

4. The Development of California’s Top-level LDV Requirements to Support Climate Stabilization

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. A significant fleet-fraction of Zero-Emission Vehicles (ZEVs, either Battery-Electric LDVs or Hydrogen Fuel Cell LDVs) will be needed. Since mileage and equivalent mileage is more heuristic than emissions per mile, they 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.

4.1 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.

4.2 Notes on Methods

The base year is 2005. An intermediate year of 2015 is used. The car efficiency factor of 2015 with respect to 2005 is taken directly from Figure 3. The car efficiency factor of 2030 with respect to 2015 is derived herein, resulting in a set of car-efficiency requirements. It is assumed that cars last 15 years.

4.3 Primary Variable Used

Table1 defines the primary variables that are used.

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 the 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

4.4 Fundamental Equations

The emissions are equal to the CO2 per mile multiplied by the per-capita driving multiplied by the population, since per-capita driving multiplied by the population is total driving. This is true for any year.

Future Year k: $$e_k = c_k * d_k * p_k \quad \text{(Eq. 1)}$$

Base Year i: $$e_i = c_i * d_i * p_i \quad \text{(Eq. 2)}$$

Dividing both sides of Equation 1 by equal values results in an equality. The terms on the right side of the equation can be associated as shown here:

$$\frac{e_k}{e_i} = \frac{c_k}{c_i} * \frac{d_k}{d_i} * \frac{p_k}{p_i} \quad \text{(Eq. 3)}$$

Since carbon dioxide emitted per gallon is just a constant (about 20 pounds per gallon), the constant cancels out of the ratio of emissions per mile, leaving the following relationship.

To work with mileage: $$\frac{m_i}{m_k} = \frac{c_k}{c_i} \quad \text{(Eq. 4)}$$

Putting Equation 4 into Equation 3 results in the following equation:

$$\frac{e_k}{e_i} = \frac{m_i}{m_k} * \frac{d_k}{d_i} * \frac{p_k}{p_i} \quad \text{(Eq. 5)}$$

Showing the base year of 2005, the future year of 2030, introducing the intermediate year of 2015 and the year of 1990 (since emissions in 2030 are with respect to the 1990 value) results in Equation 6.

$$\frac{e_{2030}}{e_{1990}} * \frac{e_{1990}}{e_{2005}} = \frac{c_{2030}}{c_{2015}} * \frac{c_{2015}}{c_{2005}} * \frac{d_{2030}}{d_{2005}} * \frac{p_{2030}}{p_{2005}} \quad \text{(Eq. 6)}$$

The ratio on the far left is the climate-stabilizing target, which is the factor of the 2030 emission to the 1990 emission. It is shown to be 0.20 or 80% less. The next ratio is the emission of 1990 compared to 2005. It is the turquoise line of Figure 3, which is 0.87. The first ratio on the right side of the equation is the fleet emission per mile in 2030 compared to the value in 2015. This ratio will be derived in this report and it will result in a set of car efficiency requirements. Moving to the right, the next ratio is the car efficiency in 2015 compared to 2005. It can obtained by multiplying the purple line 2015 value times the green line 2015 value, which is 0.90 * 0.93.The next term is the independent variable. It is the driving reduction required, compared to the 2005 level of driving. The final term on the far rightis the ratio of the population in 2030 to the population in 2005. 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,

$$p_{2030}/p_{2005} = 44279354 \div 35985582 = 1.2305 \quad \text{(Eq. 7)}$$

Putting in the known values results in Equation 8:

$$0.20 * \ 0.87 = \frac{c_{2030}}{c_{2015}} * 0.90 * 0.93 * \frac{d_{2030}}{d_{2005}} * 1.2305 \quad \text{(Eq. 8)}$$

Combining the values, solving for the independent variable (the per-capita driving ratio), and changing from emission-per-mile to equivalent-miles-per-gallon results in the following:

$$\frac{d_{2030}}{d_{2005}} = 0.1689 * \frac{m_{2030}}{m_{2015}} \quad \text{(Eq. 9)}$$

With the coefficient being so small, it is doubtful that we can get the equivalent mileage in 2030 to be high enough to keep the driving ratio from falling below one. The mileage of the 2005 fleet will be based on the best data we can get and by assuming cars last 15 years. The equivalent mileage in 2030 will need to be as high as possible to keep the driving-reduction factor from going too far below 1, because it is difficult to reduce driving too much. The equivalent mileage will be dependent on the fleet-efficiency requirements in the near future and going out to 2030. Those requirements are among the primary results of this report.

4.5 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 4. The "Both" values are used.

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.

4.6 Mileage of California's LDV Fleet in 2015

Table 2 uses these values of the Internal Combustion Engine (ICE) LDV mileage to compute the mileage of the LDVfleet 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 Equation10, using the definition for $L_k$that is shown in Table 1.

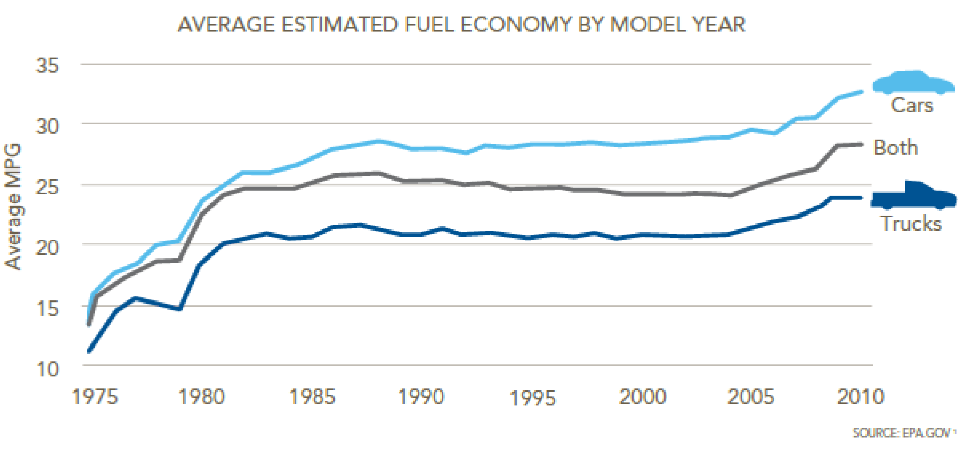

Fig. 4 Mileage Values From the PEW Environment Group.

$$Gallons\ Used\ per\ f * 100\ miles = \frac{fx100}{(\ CAFE\ MPG)/L_k} \quad \text{(Eq. 10)}$$

4.7 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.

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 renewable sources of energy. 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. More specifically, he value of 80% is assumed. This therefore becomes a fleet-efficiency requirement.

Table 2 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

4.8 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 3 are used.

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 3, the following equation can be written.

$$\boldsymbol{G} = \frac{\boldsymbol{r} \times \boldsymbol{D}}{\boldsymbol{m_{zr}}} + \frac{(\boldsymbol{1} - \boldsymbol{r}) \times \boldsymbol{D}}{\boldsymbol{m_{zf}}} \quad \text{(Eq. 11)}$$

$$\boldsymbol{m_z} = \boldsymbol{D}/\boldsymbol{G} = \boldsymbol{D}/(\frac{\boldsymbol{r} \times \boldsymbol{D}}{\boldsymbol{m_{zr}}} + \frac{(\boldsymbol{1} - \boldsymbol{r}) \times \boldsymbol{D}}{\boldsymbol{m_{zf}}}) \quad \text{(Eq. 12)}$$

Dividing the numerator and the denominator by D and multiplying them both by the product of the two equivalent mileage values results in Equations 13.

$$\boldsymbol{m_z} = \boldsymbol{m_{zr}} \times \boldsymbol{m_{zf}} / (\boldsymbol{r} \times \boldsymbol{m_{zf}} + (\boldsymbol{1} - \boldsymbol{r}) \times \boldsymbol{m_{zr}}) \quad \text{(Eq. 13)}$$

Again, using the definitions in Table 3 results in the following.

$$\boldsymbol{m_z} = \boldsymbol{Num}/(\boldsymbol{Den}\ ) \quad \text{(Eq. 14)}$$

Table 4 shows an assignment of assumed values and the result of a calculation, using Equations 13, 14, and the definitions in Table 3, to produce a ZEV equivalent mileage.

4.9 Computing an LDV Fleet Mileage Assuming Heroic Measures (HM)

Table 5 shows the additional definitions that will be used in this calculation. Table 6 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 Figure 3 minimum of 0.90.

Table 3 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
G	Gallons of equivalent fuel used
D	Arbitrary distance travelled
Num	$\boldsymbol{m_{zr}} \times \boldsymbol{m_{zf}}$
Den	$\boldsymbol{r} \times \boldsymbol{m_{zf}} + (\boldsymbol{1} - \boldsymbol{r}) \times \boldsymbol{m_{zr}}$

Table 4 Variable Assignment and the Resulting ZEV Mileage

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

Table 5 Additional Variables Used in the Calculation of 2030 LDV Mileage

Variable	Definition
$\boldsymbol{D_i}$	Distance travelled by ICE vehicles
$\boldsymbol{D_z}$	Distance travelled by ZEVs
$\boldsymbol{G_i}$	Gallons of Equivalent fuel used by ICE vehicles
$\boldsymbol{G_z}$	Gallons of Equivalent fuel used by ZEVs

Table 6 Calculation of 2030 LDV Mileage Assuming 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	.04	4	.012	32.8	.7901	41.51
2017	35.1	.9200	38.15	.4	40.0	1.0484	.07	7	.021	44.2	.9962	44.37
2018	36.1	.9133	39.53	.5	47.5	1.2018	.12	12	.036	56.0	1.1494	48.72
2019	37.1	.9000	40.92	.6	54.0	1.3197	.18	18	.054	67.2	1.2567	53.47
2020	38.3	.8500	42.56	.7	52.5	1.2337	.24	24	.072	77.2	1.3225	58.37
2021	40.3	.8000	47.41	.8	48.0	1.0124	.34	34	.103	86.8	1.2162	71.37
2022	42.3	.8000	52.88	.9	40.5	.7660	.48	48	.145	94.8	1.0299	92.05
2023	44.3	.8000	55.38	1.0	30.0	.5418	.62	62	.187	100.0	.8733	114.51
2024	46.5	.8000	58.13	1.0	15.0	.2581	.76	76	.229	100.0	.6422	155.71
2025	48.7	.8000	60.88	1.0	5.0	.0821	.90	90	.272	100.0	.4358	229.46
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	.98	98	.296	100.0	.3255	307.24
2028	56.2	.8000	70.25	1.0	5.0	.0712	.99	99	.299	100.0	.3129	319.56
2029	58.7	.8000	73.38	1.0	5.0	.0681	.99	99	.299	100.0	.3123	320.18
2030	61.2	.8000	76.50	1.0	5.0	.0654	.99	99	.299	100.0	.3118	320.75
Sum of Miles and then Gallons of Equivalent Fuel: :										1259.00	11.34	
Equivalent MPG of LDV Fleet in 2030: l:										*111.03*		
Sum of ZEV Miles = 865. Fraction of Miles Driven by ZEVs = 68.7%												

As shown by the values for “f”, government policies must be adopted, in 2030, to reduce the miles driven by the ICE’s, from model years 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 12%, just 2 years from now (shown in the green field.)It then proceeds upward, to 18% in 2019; 24% in 2020;34% in 2021; and so on, until it reaches 99% by 2028.

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 111.03 miles per gallon, will be considered as a potential 2030 LDV requirement.

4.10 Computing the Heroic-Measures (HM) Case Per-Capita and Net Driving Factor Requirements, Based on the Result Shown in Table 6

Plugging the

- equivalent MPG of the LDV fleet in Year 2030, taken from the bottom of Table 6, which is 111.03 MPG (m_{2030}), and
- the MPG of the LDV fleet in Year 2015, taken from the bottom of Table 2, which is 27.63 MPG (m_{2015}),

into Equation 9, gives the following result:

$$\frac{d_{2030}}{d_{2005}} = 0.1687 * \frac{m_{2030}}{m_{2015}}$$

$$= 0.1687 * \frac{111.03}{27.63} \quad \text{(Eq. 14)}$$

$$= 0.68$$

This means that the per-capita driving in 2030 will need to be about 32% less than in year 2005. The net driving can be computed by multiplying the per-capita driving, 0.68, by the population factor of 1.2305, computed in Equation 7, resulting in 0.84 (since 0.68 x 1.2305 = 0.84.) This means that, even with the 23% increase in California's population, the net driving will have to drop by 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. The good news is that there can be little or no congestion because highway capacity now is larger than it was in 2005. Policies will be needed to achieve the required reduction in driving.

4.11 Case 2: Computing LDV Requirements that Support Climate Stabilization but Still Allow 2005 Per-Capita Driving

The first step is to use Equation 9 and the value of the mileage in 2015 to compute the needed LDV equivalent fleet mileage for 2030 if the left side of the equation is equal to 1.0.

$$m_{2030} = 1.0 \text{ x } m_{2015} / 0.1689 = 27.63 / 0.1689 = 163.59 \text{ MPG} \quad \text{(Eq. 15)}$$

Table 7 is constructed, with the fraction of ZEVs selected to achieve the needed equivalent fleet mileage of about 163.59 MPG. Since its ZEV fractions are larger and sooner than in the "Heroic Measures" table, Table 7 is showing what has been called 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 7, the net driving would also increase by 23%. If this LDV requirement

Table 7 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	.04	0	.012	32.8	.7901	41.51
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	.25	25	.075	62.5	1.024	61.02
2019	37.1	.9000	40.92	.6	30.0	.7332	.40	40	.121	76.0	1.000	75.96
2020	38.3	.8500	42.56	.7	21.0	.4935	.65	65	.196	89.5	.7718	115.96
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	99.5	.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	.98	98	.296	100.0	.3301	302.95
2025	48.7	.8000	60.88	1.0	5.0	.0821	.98	98	.296	100.0	.3285	304.38
2026	51.2	.8000	64.00	1.0	5.0	.0781	.999	99	.299	100.0	.3143	318.14
2027	53.7	.8000	67.13	1.0	5.0	.0745	.99	99	.299	100.0	.3136	318.88
2028	56.2	.8000	70.25	1.0	5.0	.0712	.99	99	.299	100.0	.3129	319.56
2029	58.7	.8000	73.38	1.0	5.0	.0681	.99	99	.299	100.0	.3123	320.18
2030	61.2	.8000	76.50	1.0	5.0	.0654	.99	99	.299	100.0	.3118	320.75
Sum of Miles and then Gallons of Equivalent Fuel: :										1304.30	7.97	
Equivalent MPG of LDV Fleet in 2030: l:										*163.59*		

Table 8 HM Case and the EHM Case Which Supports 2005 Per-Capita Driving.

Cases	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	20292	2030
HM	.04	.07	.12	.18	.24	.34	.48	.62	.76	.90	.95	.98	.99	.99	.99
EHM	.04	.10	.25	.40	.65	.90	.95	.95	.98	.98	.99	.99	.99	.99	.99

set were to be implemented, a lot of California's transportation money would be needed to expand the highway system, leaving less to improve transit, improve active transportation (mainly walking and biking), and maintain roads.

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

Table 8 shows the direct comparison of the ZEV fractions that are ZEV requirements for the HM Case and the EHM Case. The largest differences are highlighted. The EHM case does not appear to be achievable.

5. Achieving the Required Driving Reduction of the Heroic-measures (hm) Case

As shown in Equation 14, 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.

5.1 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 ofexisting transit systems. The redesign could include electrification and automation or even upgrading to a different technology.

5.2 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.

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 6 and 7. This system could probably be implemented in less than 5 years.

5.3 Unbundling the Cost of Car Parking (7.5%)

Unbundling the cost of car parking[11] throughout California is conservatively estimated to decrease driving by 7.5%, based on Table 1 of Reference11. That table shows driving reductions resulting from introducing a price for parking, for 10 cases. Its average reduction in driving is 25% and its smallest reduction is 15%.

5.4 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.

5.4.1 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.

5.4.2 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.

5.3 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[11]) that can be assumed.

5.4 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%.)

6. 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 0.84 factor reduction of driving, computed right after the calculation shown in Equation 14, and the fraction of miles driven by ZEVs, shown at the bottom of Table 6, of 0.687 (from 68.7%), to give the 2030 miles driven by ZEVs = 325 Billion x 0.84 x 0.687 = 188 Billion miles per year.

Using the Tesla information herehttp://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 188 Billion miles x 0.217 kW-h = 40,699 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. Table 4 shows that 80% (r = 0.80, with "r" defined in Table 3) of electricity must generated without producing CO2. This estimated 15.34% increase in demand should help the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) with their planning.

7. Comparison with California Air Resources Board (carb) Planning

The following quote[13] allows us to compare the CARB plan for LDVs with what would be required to stabilize the climate at a livable level, in the form of the Heroic Measures case:

Regulations on the books in California, set in 2012, require that 2.7 percent of new cars sold in the state this year be, in the regulatory jargon, ZEVs. These are defined as battery-only or fuel-cell cars, and plug-in hybrids. The quota rises every year starting in 2018 and reaches 22 percent in 2025. Nichols wants 100 percent of the new vehicles sold to be zero- or almost-zero-emissions by 2030

Table 9 shows the values implied by this statement and compares them to the HM values. Table 10, which is similar to Tables 6 and 7, computes the overall mileage of the 2030 fleet, using the CARB values.

9.1 Computing the Heroic-Measures (HM) Case Per-Capita and Net Driving Factor Requirements, Based on the Result Shown in Table 10

Plugging the equivalent MPG of the LDV fleet in Year 2030, taken from the bottom of Table 10, which is 74.25 MPG, and the MPG of the LDV fleet in Year 2015, taken from the bottom of Table 2, which is 27.63 MPG, into Equation 8, gives the following result:

$$\frac{d_{2030}}{d_{2005}} = 0.1687 * \frac{m_{2030}}{m_{2015}} = 0.1687 * \frac{74.25}{27.63} = 0.45 \quad \text{(Eq. 16)}$$

This means that the per-capita driving will need to be about 55% less in 2030 than in year 2005. The net driving can be computed by multiplying the per-capita driving, 0.45, by the population factor of 1.2305, computed in Equation 7, resulting in 0.55. This means that, even with the 23% increase in California's population, the net driving will have to drop by 45%. If CARB wants the LDV sector to achieve a reasonable climate-stabilizing target, it will need to require ZEV

Table 9 Zero Emission Vehicle (ZEV) % of Fleet, for Two Cases.

Year	CARB	Heroic Measures	Year	CARB	Heroic Measures
2016	2.7%	4.0%	2024	19.6%	76.0%
2017	2.7%	7.0%	2025	22.0%	90.0%
2018	5.1%	12.0%	2026	37.6%	95.0%
2019	7.5%	18.0%	2027	53.2%	98.0%
2020	9.9%	24.0%	2028	68.8%	99.0%
2021	12.4%	34.0%	2029	84.4%	99.0%
2022	14.8%	48.0%	2030	100.0%	99.0%
2023	17.2%	62.0%			

Table 10 Calculation of 2030 LDV Mileage Assuming the CARB Values.

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	.03	3	.008	31.9	.79681	40.02
2017	35.1	.9200	38.15	.4	40.0	1.0484	.03	3	.008	41.6	1.0283	40.48
2018	36.1	.9133	39.53	.5	47.5	1.2018	.05	5	.015	52.6	1.2158	43.23
2019	37.1	.9000	40.92	.6	54.0	1.3197	.08	8	.023	63.0	1.3787	45.70
2020	38.3	.8500	42.56	.7	52.5	1.2337	.10	10	.030	73.0	1.5114	48.29
2021	40.3	.8000	47.41	.8	48.0	1.0124	.12	12	.037	82.5	1.5162	54.39
2022	42.3	.8000	52.88	.9	40.5	.7660	.15	15	.045	91.5	1.4954	61.17
2023	44.3	.8000	55.38	1.0	30.0	.5418	.17	17	.052	100.0	1.5475	64.62
2024	46.5	.8000	58.13	1.0	15.0	.2581	.20	20	.059	100.0	1.4425	69.32
2025	48.7	.8000	60.88	1.0	5.0	.0821	.22	22	.066	100.0	1.3477	74.20
2026	51.2	.8000	64.00	1.0	5.0	.0781	.38	38	.113	100.0	1.0884	91.87
2027	53.7	.8000	67.13	1.0	5.0	.0745	.53	53	.161	100.0	.8577	116.59
2028	56.2	.8000	70.25	1.0	5.0	.0712	.69	69	.208	100.0	.6517	153.44
2029	58.7	.8000	73.38	1.0	5.0	.0681	.84	84	.255	100.0	.4673	214.02
2030	61.2	.8000	76.50	1.0	5.0	.0654	1.0	100	.302	100.0	.3017	331.44
Sum of Miles and then Gallons of Equivalent Fuel: :										1236.00	16.65	
Equivalent MPG of LDV Fleet in 2030: l:										*74.25*		

adoption profile closer to the Heroic Measures Case. The adoption profile they have now will required a reduction in driving that will probably be very difficult to achieve.

10. Conclusion

A requirement set named "Heroic Measures" (HM) is quantified. Table 8 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, which has been quantified as the "Extra Heroic Measures Case". 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. The current CARB plan for ZEV adoption is shown to require a very large reduction in driving if LDVs are to achieve a climate-stabilizing target.

Acknowlegements

Darrell Clarke, Lead Volunteer for the Sierra Club's "Beyond Oil Campaign"; Dr. Dennis Martinek, Oceanside Planning Commissioner; Sandra Goldberg, formerly California Deputy Attorney General; Dr. Nilmini Silva-Send, Senior Policy Analyst of the Energy Policy Initiative Center; Diane Nygaard, Director of Preserve Calavera and founder of *Nelson Nygaard Consulting Associates*; Jack Shu, CNFF President;Joan Bullock; San Diego Sierra Club Executive Committee Chairs:Caroline Chase, John Stump, and (former Assembly Member) Lori Saldaña; Malinda Dickenson, *Law Offices of Malinda R. Dickenson*;Conservation Committee ChairMollie Biggers;Ed Mainland and Jim Stewart, Co-Chairs, Energy-Climate Committee, Sierra Club California; Bern Grush, Chief Scientist, *Skymeter Corporation*; andSANDAG Staff: Susan Baldwin, Senior Regional Planner; Charles Stoll, Director of Land Use and Transportation Planning; and Stephan Vance, Senior Regional Planner.

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