Transportation Systems Planning
Air Quality Planning and Science Division
California Air Resources Board
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To: California Department of Transportation
CTP 2040 Staff

Subject: Preliminary ARB Vision CTP results for Alternatives 1, 2, and 3

Summary

Preliminary results for CTP 2040 Alternatives 1, 2, and 3 have been completed. The baseline, Alternative 1, achieved a 7% reduction in GHG emissions by 2040, but shows a slight increase of 3% in 2050 over the 2020 base year. Alternative 2 reduced GHG emissions, with 27% and 21% reductions in 2040 and 2050 respectively below the Alternative 1 2020 base year, but still did not achieve an 80% reduction by 2050 (the target is 32 MMT CO_{2e} for this analysis). Finally, Alternative 3 achieved an 80% reduction in 2050 achieving the GHG goal. Detailed analysis, input assumptions, and results are given below.

Background

For reference, Figure 1 below is a pie graph of the 2012 official Air Resources Board (ARB) greenhouse gas (GHG) emission inventory for all sectors. Total GHG emissions in 2012 were estimated to be 459 MMT CO_{2e} of which transportation accounted for 37% (167 MMT CO_{2e}) and industrial emissions, which include refineries and oil and gas extraction, accounted for 19% (89 MMT CO_{2e}) of the inventory. Figure 2 further breaks down the transportation section emissions, while Figure 3 expands the industrial section emissions. Figure 2 illustrates that on-road emissions from light-duty vehicles (LDV) and heavy-duty vehicles (HDV) account for 92% (154 MMT CO_{2e}) of the transportation sector emissions with LDV contributing the greatest portion (71% or 118 MMT CO_{2e}). From Figure 3, refineries and oil and gas extraction contribute ~50% of the industrial sector emissions (46 MMT CO_{2e}). Adding the three sectors together, transportation, refineries, and oil and gas extraction, gives a wheel-to-wheel (WTW) perspective of the transportation sector total emissions occurring in California, which account for nearly half of all the GHG emission (214 MMT CO_{2e}) in the 2012 emission inventory.

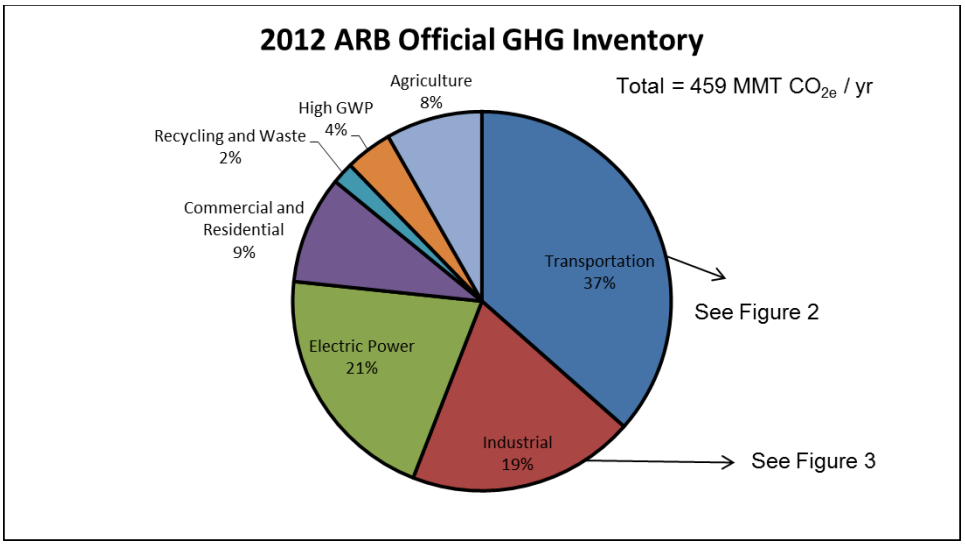

Figure 1: 2012 ARB Official GHG Inventory

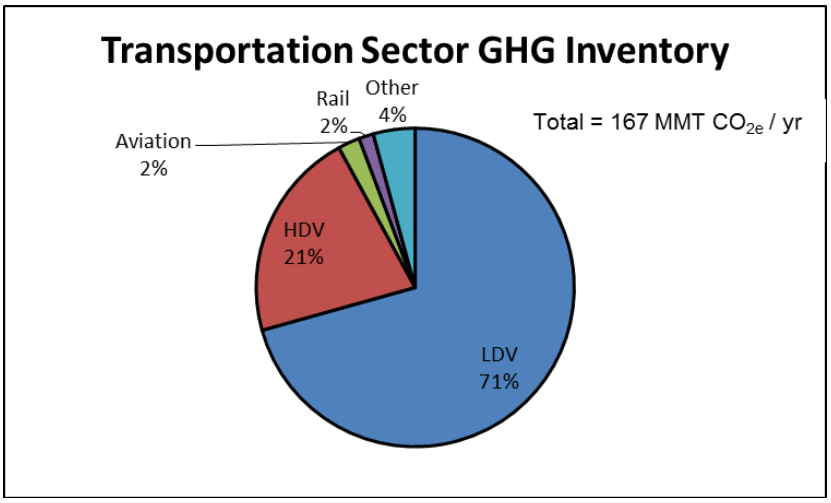

Figure 2: Transportation Sector GHG Inventory

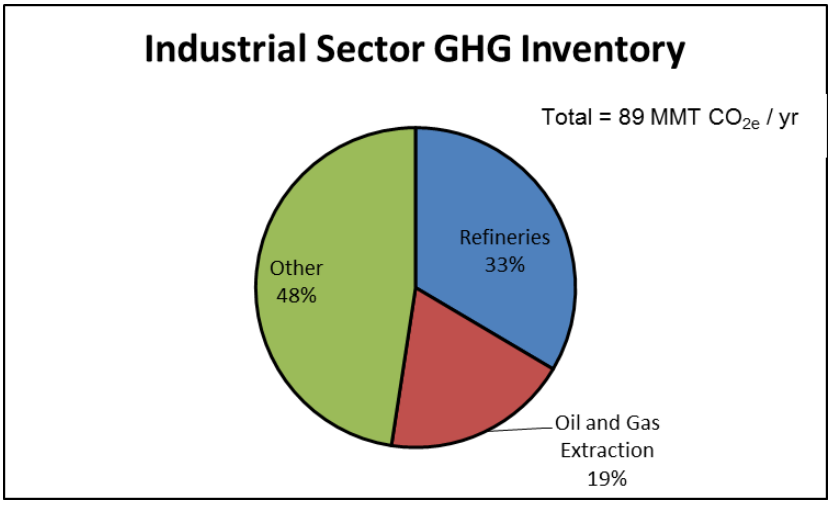

Figure 3: Industrial Sector GHG Inventory

Methodology

Scenarios were run for Caltrans Alternatives 1, 2, and 3 to determine total GHG emissions and fuel demand from 2010 to 2050. The sectors highlighted in this analysis, which were most relevant for CTP, were LDV, HDV, high speed rail (HSR), aviation (intrastate), and rail (passenger and freight). The ARB Vision 2.0 model was used for the analysis and other transportation sectors (ocean going vessels, harbor craft, cargo handling equipment, and off-road vehicles) lumped together under "other transportation" emissions. Vision 2.0 incorporates the latest data from ARB's EMFAC 2014 as well as the newest baseline policy assumptions for other sectors.

LDV and HDV activity data was supplied to ARB from the Caltrans CSTDM model, which gave VMT by speed bin for three select years (2010, 2020, and 2040). Table 1 below displays total VMT in billions of miles for Alternative 1 in 2010, 2020 and 2040 and the 2040 VMT for the other two Alternatives. Also shown in the table is the percent reduction in VMT between Alternatives 1 and 2 (3 is the same VMT as 2). Note that VMT was reduced by 30% in 2040 for Alternative 2 and Alternative 3. ARB extrapolated VMT annually for years between 2010 and 2040. Beyond 2040, VMT growth rates from EMFAC 2014 were applied to the 2040 data point.

Table 1: Total VMT from CSTDM for
Alternatives 1, 2 and 3 in billions of miles per year

	2010	2020	2040
Alternative 1			
LDV	189.7	208	251
HDV	74	73.5	83
Total	264	282	334
Alternatives 2 and 3			
LDV	-	-	161.9
HDV	-	-	71.3
Total	-	-	**233**
% Reduction			**30%**

Inputs for HSR came from the HSR Authority High Speed Rail plan, which gives LDV VMT offsets and intrastate aviation trip reductions. HSR authority assumes that HSR will be entirely powered by renewable electricity so there are no GHG emissions associated with HSR and HSR only affects VMT and aircraft trips. For conventional passenger rail, inputs were matched to Vision 2.0 and the Caltrans rail plan for Alternative 1. Ridership was assumed to double for Alternative 2. It was assumed that there were no aircraft fuel efficiency improvements for Alternatives 1 and 2, but HSR aircraft trip reductions were included for both alternatives. Finally, all other assumptions, including the off-road sectors, came from the ARB Vision 2.0 baseline scenario (projections of existing policies and sector growth estimates).

In order to achieve the 2050 GHG target, additional assumptions were made for Alternative 3 in ARB Vision 2.0 for the following sectors. For LDVs, the assumptions are that fuel efficiency increases such that new vehicle fuel efficiency is four times higher by 2050 from today's levels and an assumption of ~20 million LDV ZEVs on the road in 2050. For HDVs, the assumptions are that fuel efficiency is more than 50% higher by 2030 for new vehicles and ZEVs (BEV, FCV) will represent 12% of total sales by 2030. For freight rail and aviation, the assumptions are that fuel efficiency increases by 2.0% per year starting in 2015. Assumptions for HSR and conventional passenger rail remained the same as in Alternative 2.

For transportation fuels, this analysis assumes 7 billion gallons gasoline equivalent ("BGGE") bio-fuels are available, including drop-in renewable fuel, by 2050 (~1 BGGE in Alternative 1). Also assumed is a 75% renewable electricity and hydrogen supply mix by 2050 as compared to 33% for both in Alternative 1 (for years 2020 – 2050).

Alternatives 1 and 2 Results

Preliminary results are shown in Tables 2 and 3 below for Alternatives 1 and 2, respectively. The table displays total fuel demand (quadrillion BTUs or "quads" and billion gallons gasoline equivalent or "BGGE"), GHG emissions (MMT $CO2_e$ / yr), and relative percent reduction below Alternative 1 2020 for 2040 and 2050.

Table 2: Alternative 1 Results

Alternative 1					
	2010	2012	2020	2040	2050
Fuel Demand (Quads)					
Gasoline (CaRFG)[1]	1.31	1.25	1.10	0.76	0.83
Diesel (ULSD)[2]	0.61	0.61	0.69	0.87	0.98
Jet Fuel	0.47	0.46	0.51	0.68	0.77
Electric Power	0.000	0.001	0.008	0.026	0.033
Hydrogen	0.000	0.000	0.001	0.007	0.009
Fuel Demand (BGGE)					
Gas (CaRFG)[1]	11.7	11.1	9.8	6.8	7.4
Diesel (ULSD)[2]	5.5	5.5	6.2	7.8	8.8
Jet Fuel	4.2	4.1	4.6	6.1	6.9
Electric Power	0.00	0.01	0.07	0.23	0.30
Hydrogen	0.00	0.00	0.01	0.07	0.08
GHG Emissions (MMT CO_{2e} / yr)					
LDV + Bus	114	108	94	66	73
HDV	50	49	50	60	64
Rail	2	3	3	5	6
Aviation	4	4	5	6	7
Other Transportation	4	4	6	10	14
Total	**175**	**168**	**158**	**147**	**163**
Target	**-**	**-**	**-**	**-**	**32**
GHG Relative Reduction Below Alternative 1 2020[3] (%)					
LDV + Bus	-	-	-	30%	23%
HDV	-	-	-	-19%	-27%
Rail	-	-	-	-53%	-91%
Aviation	-	-	-	-26%	-40%
Other Transportation	-	-	-	-70%	-129%
Total	-	-	-	**7%**	**-3%**
Target	-	-	-	**-**	**80%**

[1]California Reformulated Gasoline (CaRFG) includes 10% ethanol blended by volume
[2]Diesel includes 5% biodiesel by volume
[3]AB32 requires that the 2020 total GHG inventory is the same as the 1990 GHG inventory, while the law does not require that each individual sector achieve its absolute 1990 value. Because the CTP project does not include all sectors, it is assumed that the transportation sector 2020 GHG value calculated for Alternative 1 will be the reference point for the 2050 GHG reductions.

Table 3: Alternative 2 Results

Alternative 2					
	2010	2012	2020	2040	2050
Fuel Demand (Quads)					
Gasoline (CaRFG)[1]	1.31	1.25	1.10	0.49	0.54
Diesel (ULSD)[2]	0.61	0.61	0.69	0.78	0.84
Jet Fuel	0.47	0.46	0.51	0.68	0.77
Electric Power	0.000	0.001	0.008	0.027	0.034
Hydrogen	0.000	0.000	0.001	0.013	0.014
Fuel Demand (BGGE)					
Gasoline (CaRFG)[1]	11.7	11.1	9.8	4.4	4.8
Diesel (ULSD)[2]	5.5	5.5	6.1	7.0	7.5
Jet Fuel	4.2	4.1	4.6	6.1	6.9
Electric Power	0.00	0.01	0.07	0.25	0.31
Hydrogen	0.00	0.00	0.01	0.12	0.13
GHG Emissions (MMT CO_{2e} / yr)					
LDV + Bus	114	108	94	43	48
HDV	50	49	50	52	51
Rail	2	3	3	5	6
Aviation	4	4	5	6	7
Other Transportation	4	4	6	10	14
Total	**174**	**168**	**157**	**116**	**125**
Target	**-**	**-**	**-**	**-**	**32**
GHG Relative Reduction Below Alternative 1 2020[3] (%)					
LDV + Bus	-	-	-	54%	49%
HDV	-	-	-	-3%	-2%
Rail	-	-	-	-43%	-80%
Aviation	-	-	-	-26%	-40%
Other Transportation	-	-	-	-70%	-129%
Total	-	-	-	**27%**	**21%**
Target	-	-	-	**-**	**80%**

[1]California Reformulated Gasoline (CaRFG) includes 10% ethanol blended by volume
[2]Diesel includes 5% biodiesel by volume
[3]AB32 requires that the 2020 total GHG inventory is the same as the 1990 GHG inventory, while the law does not require that each individual sector achieve its absolute 1990 value. Because the CTP project does not include all sectors, it is assumed that the transportation sector 2020 GHG value calculated for Alternative 1 will be the reference point for the 2050 GHG reductions.

Note that a negative percent in the tables above equates to an increase in GHG emissions. For Alternative 1, LDV GHG emissions are reduced by 30% in 2040 and 23% in 2050, while HDV emissions increase by 19% and 27%. For all transportation sectors, there is a 7% reduction in GHG emissions by 2040 and an increase of 3% by 2050. For Alternative 2, overall transportation GHG reductions are 27% in 2040 and

21% in 2050. LDV emissions were reduced by 54% in 2040 and 49% in 2050, while HDV increased by 3% and 2%.

Figure 5 below displays the aggregate fuel demand by sector for Alternative 1 from 2010 to 2050 in BGGE. There is a reduction in total gasoline demand, but an increase in demand for the other fuels, such that the total demand in 2050 is higher than the demand in 2010.

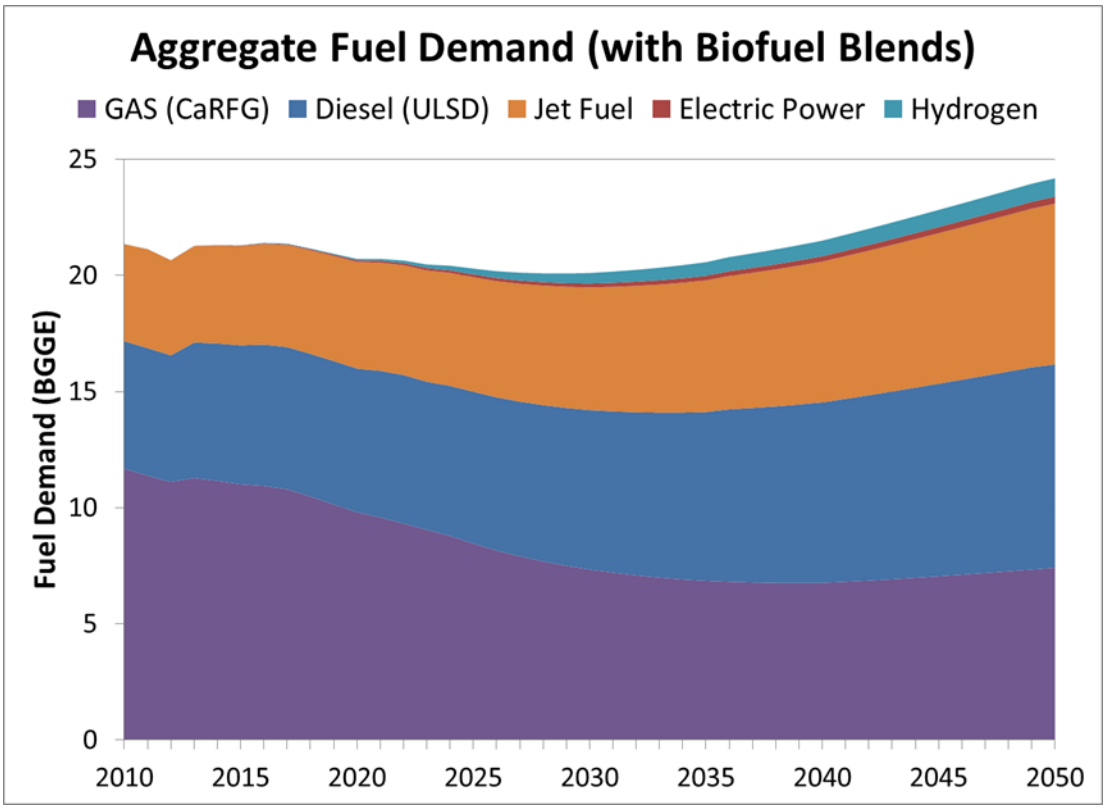

Figure 4: Aggregate Fuel Demand by sector for Alternative 1

Figures 5 and 6 below illustrate total WTW GHG emissions by sector for Alternative 1 (Figure 5) and Alternative 2 (Figure 6). For Alternative 1, there are significant reductions in LDV GHG emissions as a result of existing policies, but these are somewhat offset by the increase in GHG emission for the other sectors. Overall, there is a slight decrease in GHG emissions for this alternative from 2010. For Alternative 2, there are substantial reductions in LDV GHG emissions, which lead to greater total GHG reductions. As a reference, each figure contains red "X's", which represent the 2020 and 2050 targets. The 2020 target is based on Alternative 1 (see footnotes on Table 2 or 3) and the 2050 target is 80% of that value. Neither scenario meets or exceeds the target of 32 MMT CO_{2e} in 2050. Furthermore, the more aggressive Alternative 2 would still need to reduce GHG emissions by more than 50% to reach the expected goal.

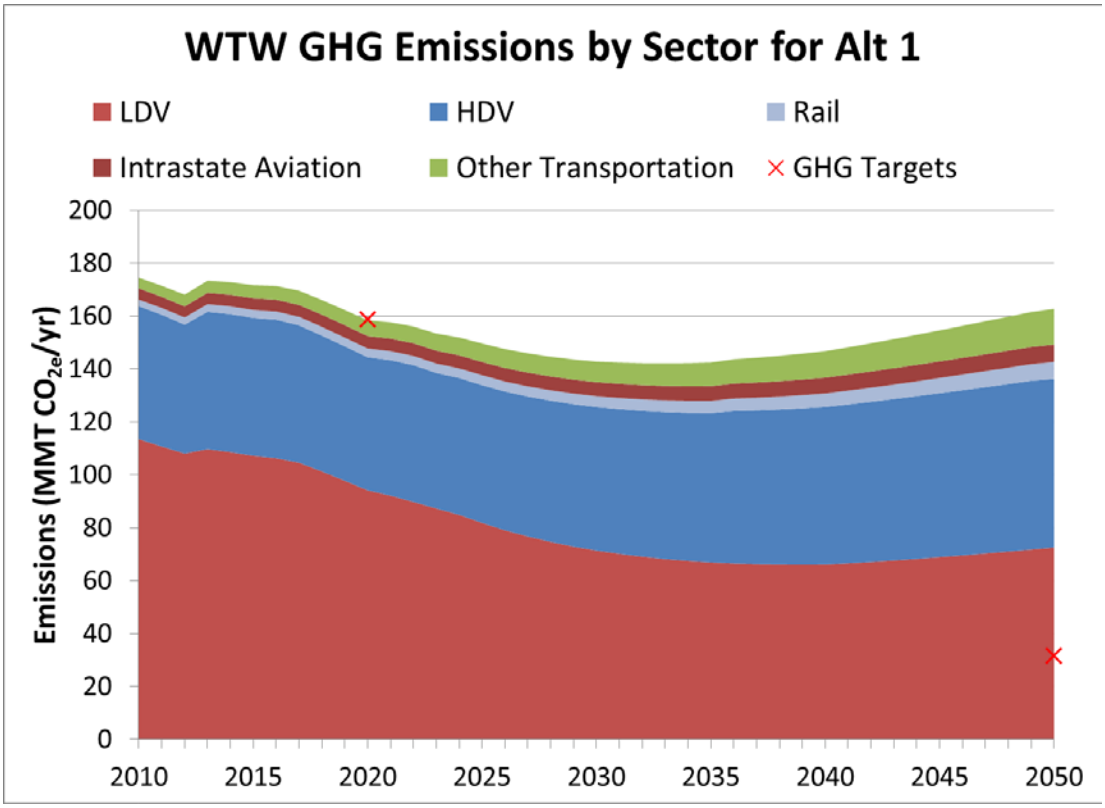

Figure 5: WTW GHG Emissions by Sector for Alternative 1

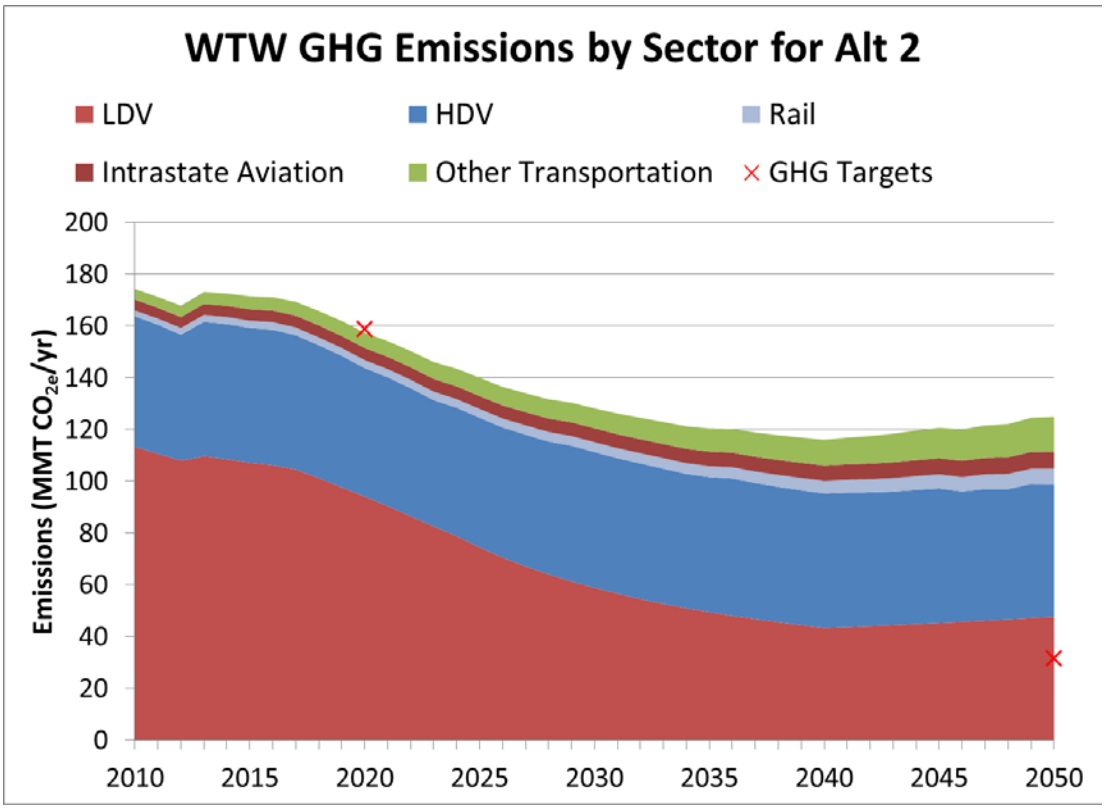

Figure 6: WTW GHG Emissions by Sector for Alternative 2

Alternative 3 Results

Preliminary results are shown in Table 4 below for Alternative 3. The table displays total fuel demand (quadrillion BTUs or "quads" and billions gallons gasoline equivalent or "BGGE"), GHG emissions (MMT CO_{2e} / yr), and relative percent reduction below 2020 for 2040 and 2050.

Table 4: Alternative 3 Results

Alternative 3					
	2010	2012	2020	2040	2050
Fuel Demand (Quads)					
Gasoline (CaRFG)[1]	1.31	1.25	1.10	0.30	0.17
Diesel (ULSD)[2]	0.61	0.61	0.68	0.67	0.67
Jet Fuel	0.47	0.46	0.44	0.38	0.35
Electric Power	0.000	0.001	0.011	0.060	0.097
Hydrogen	0.000	0.000	0.001	0.032	0.052
Fuel Demand (BGGE)					
Gasoline (CaRFG)[1]	11.7	11.1	9.8	2.6	1.5
Diesel (ULSD)[2]	5.5	5.4	6.0	6.0	6.0
Jet Fuel	4.2	4.1	3.9	3.4	3.1
Electric Power	0.00	0.01	0.10	0.54	0.88
Hydrogen	0.00	0.00	0.01	0.28	0.46
GHG Emissions (MMT CO_{2e} / yr)					
LDV + Bus	114	108	94	23	11
HDV	50	49	49	26	12
Rail	2	3	3	3	3
Aviation	4	4	4	2	2
Other Transportation	4	4	6	5	4
Total	**175**	**168**	**156**	**60**	**32**
Target	**-**	**-**	**-**	**-**	**32**
GHG Relative Reduction Below Alternative 1 2020[3] (%)					
LDV + Bus	-	-	-	75%	88%
HDV	-	-	-	47%	76%
Rail	-	-	-	13%	22%
Aviation	-	-	-	52%	62%
Other Transportation	-	-	-	12%	28%
Total	-	-	-	**62%**	**80%**
Target	-	-	-	**-**	**80%**

[1]California Reformulated Gasoline (CaRFG) includes 10% ethanol blended by volume
[2]Diesel includes 5% biodiesel by volume
[3]AB32 requires that the 2020 total GHG inventory is the same as the 1990 GHG inventory, while the law does not require that each individual sector achieve its absolute 1990 value. Because the CTP project does not include all sectors, it is assumed that the transportation sector 2020 GHG value calculated for Alternative 1 will be the reference point for the 2050 GHG reductions.

For Alternative 3, LDV GHG emissions are reduced by 75% in 2040 and 88% in 2050, while HDV emissions decrease by 47% and 76%. For all transportation sectors, there is a 62% reduction in GHG emissions by 2040 and 80% reduction by 2050.

Figure 7 below displays the aggregate fuel demand by sector for Alternative 3 from 2010 to 2050. There is a large reduction in total demand due to the decrease in gasoline demand and the decrease in demand for the other sectors, such that the total demand in 2050 is 24% lower than the base value in 2010.

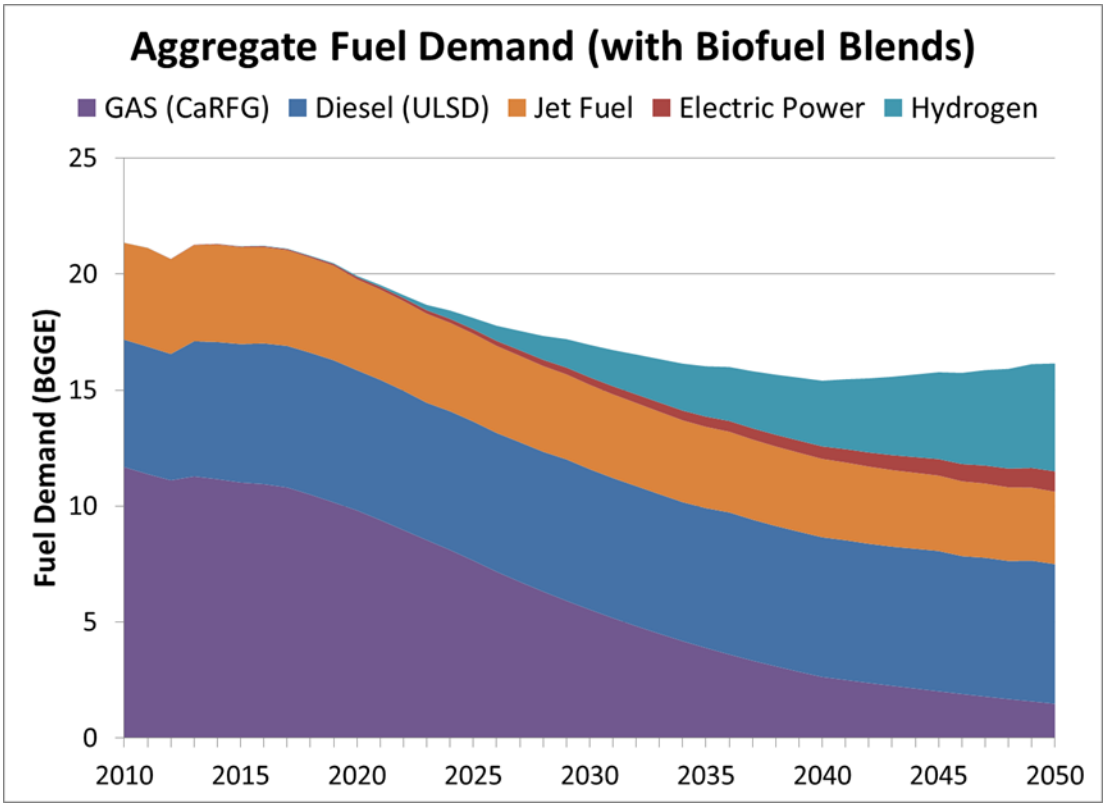

Figure 7: Aggregate Fuel Demand by sector for Alternative 3

Figure 8 below illustrates the total WTW GHG emissions by sector for Alternative 3. There are significant reductions in LDV GHG emissions as well as reductions in the other transportation sectors such that this Alternative meets the target of 32 MMT CO_{2e}. As a reference, the figure contains red “X’s”, which represent the 2020 and 2050 targets (see explanation above).

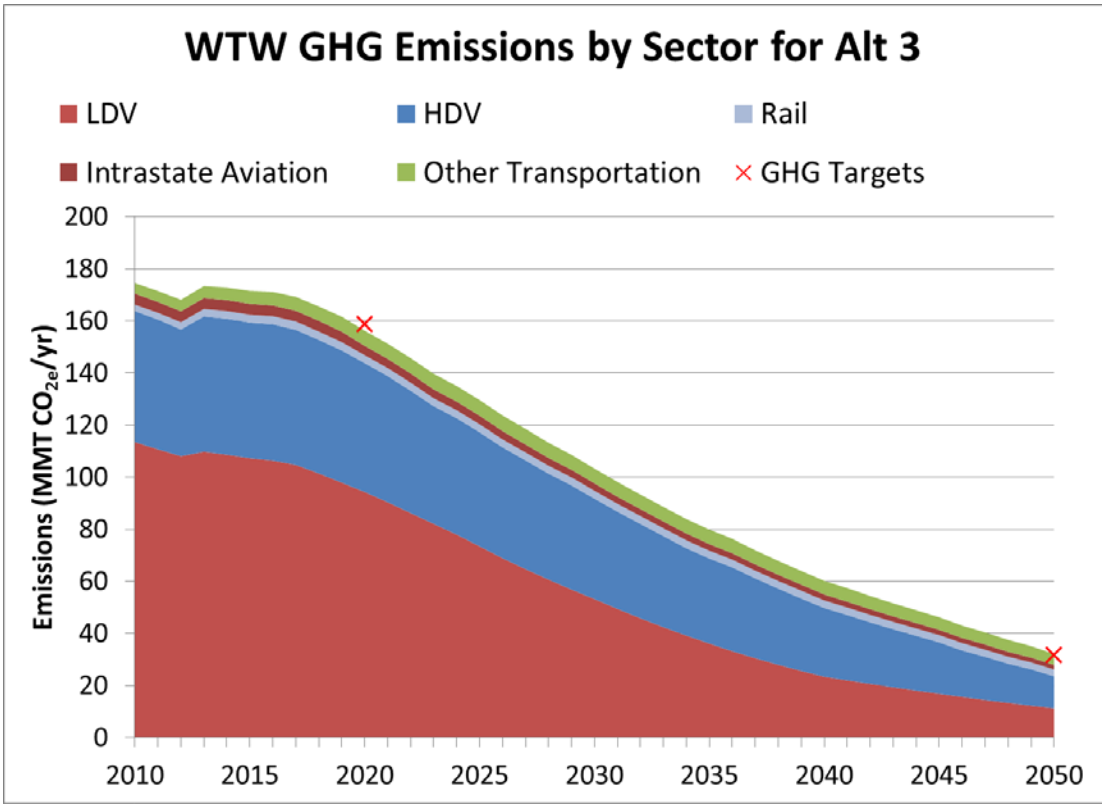

Figure 8: WTW GHG Emissions by Sector for Alternative 3

Conclusions

The 2050 GHG target for CTP2040 is 80% below the 2020 data point for Alternative 1, or a target of approximately 32 MMT CO_{2e} for the entire transportation sector, to meet its "equal share" of the GHG emissions target. Neither Alternative 1 nor 2 attained this target for the entire transportation sector. In Alternative 2, the LDV mode nearly attained its "equal share" target but because the other modes did not reach their "equal share" the alternative did not reach the 2050 target. In Alternative 3, the LDV mode attained more than its equal share and the other sectors reduced emissions significantly such that the 2050 target was obtained. It's important to note that the official full statewide GHG Inventory 2050 target equals 86 MMT CO_{2e} for all sectors, with many of those sectors likely unable to reach their equal share, such that the transportation sector may have to reduce beyond their equal share.

Comment on Methodology

CSTDM has not been fully validated against official state records for gasoline, diesel, and jet fuel consumption in the 2010 base year demand. As a result, CSTDM Alternative 1 VMT for HDVs is approximately double what ARB estimates in EMFAC 2014 statewide. Alternative 1 LDV VMT is approximately 20% lower than EMFAC 2014. For the next draft, as an improvement to CSTDM, the base year should be validated against these records.