

HW 2: Energy Demand and CO₂ Emissions

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1

Creating a new category combining all buses, single-unit trucks, and combination trucks gives the following:

1.1

The average fuel economy is

Table 1: Average Fuel Economy of HDVs

Year	Fuel economy (mpg)
2020	21.2
2019	20.8

1.2

The CO₂ emissions per mile is given by $\frac{1}{\text{miles/gal}} \times \frac{\text{CO}_2}{\text{gal}} = \frac{\text{CO}_2}{\text{mile}}$. This gives

Table 2: HDV Fuel Consumption

Year	Fuel economy (mpg)	Fuel consumption (gpm)	Emissions (g CO ₂ /gal)	Emissions (g CO ₂ /mile)
2020	21.2	0.0471698	10180	480.1887
2019	20.8	0.0480769	10180	489.4231

1.3

The total CO₂ emissions for all LDVs and HDVs is

Table 3: Emissions of LDVs and HDVs

Vehicle category	Year	Fuel consumed (thousand gallons)	Emissions (g CO ₂ /gal)	Emissions (g CO ₂)	Emissions (M tons CO ₂)
ALL LDV	2020	111930145	8887	994723198615000	994723199
	2019	131455731	8887	1168247081397000	1168247081
ALL HDV	2020	46853407	10180	476967683260000	476967683
	2019	48094540	10180	489602417200000	489602417

Calculating the percentage of emissions from HDVs per year:

Table 4: HDV Emissions Proportion

Year	LDV Emissions	HDV Emissions	HDV Proportion
2020	994723199	476967683	0.324
2019	1168247081	489602417	0.295

From this we can see that HDVs made up a greater percentage of CO₂ emissions in 2020 than in 2019.

1.4

Comparing the values I got to the values from the EPS's Greenhouse Gas Emissions Inventory:

Table 5: Comparison to EPA Reported Emissions Values

Year	LDV Emissions	HDV Emissions	Total Emissions (MMT CO ₂)	EPA Values (MMT CO ₂)
2020	994723199	476967683	1471.691	1627.619
2019	1168247081	489602417	1657.849	1874.291

Though the values from my calculations differ from the EPA reported values, they are not wildly different from each other. They are close enough in my judgement that the difference could largely be explained by things like different measuring procedures.

2

The drive cycle I'm analyzing is the "Fleet DNA drayage Representative" cycle from NREL. The cycle is shown in Figure 1.

I am also using the assumed values in Table 6 for my calculations.

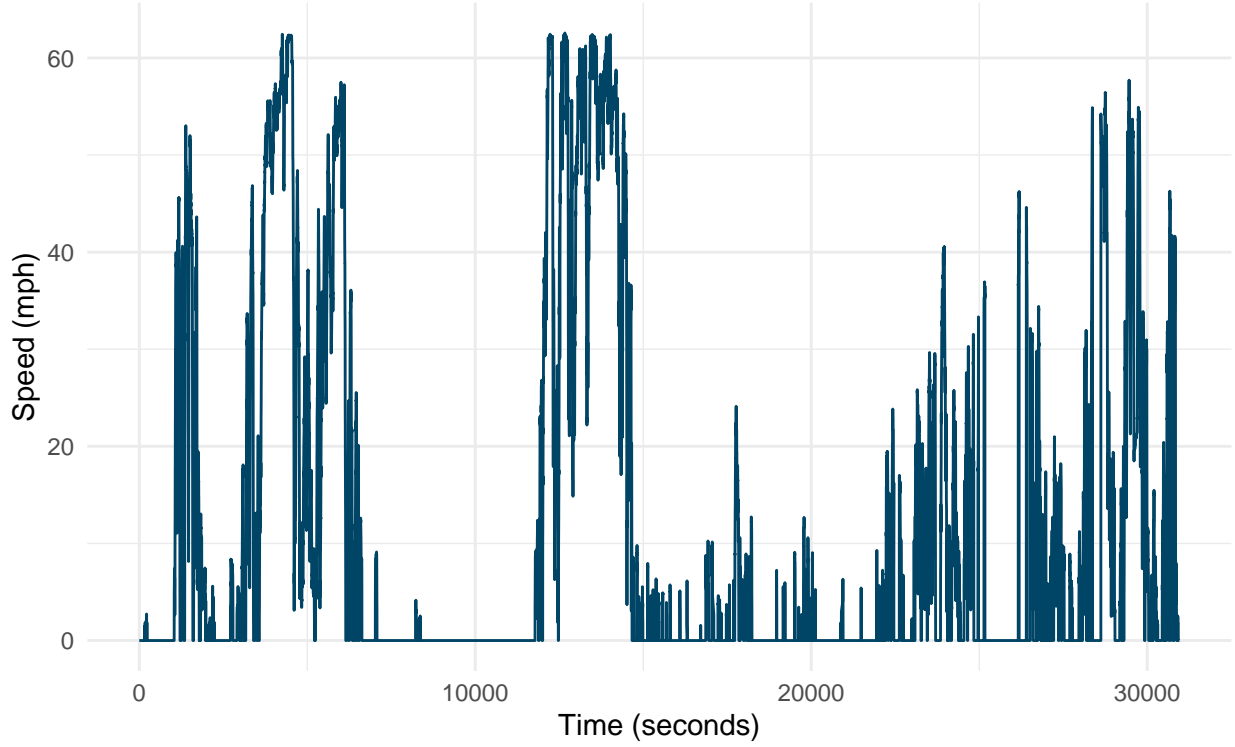


Figure 1: Fleet DNA drayage Representative drive cycle.

Table 6: Assumed Values for Calculations

Coefficient	Symbol	Value
Drag coefficient	C_D	0.6
Frontal area	A_v	8.5 m ²
Empty vehicle weight	m_E	11,000 kg
Cargo weight	m_C	9,000 kg
Rolling resistance coefficient	C_R	0.006
Density of air	ρ_a	1.17 kg/m ³
Acceleration of gravity	g	9.81 m/s ²

2.1

The road-load equation for power is given by

$$P_V = \frac{1}{2} \rho_a C_D A_v v^3 + v (C_R m_v g + m_v g \sin \alpha + m_v a_v),$$

where $m_v = m_E + m_C$, and $\sin \alpha \approx \text{grade (rise/run)}$.

Using this equation, we can calculate the tractive power for each second in the drive cycle. Note that since this is not a hybrid electric vehicle, there is no regenerative braking, and so all negative values of power are set to 0. We also set a limit on acceleration due to speed gaps causing unrealistic values. The limits are $-3.5 < a < 2.5$.

The plot of the tractive power is given in Figure 2.

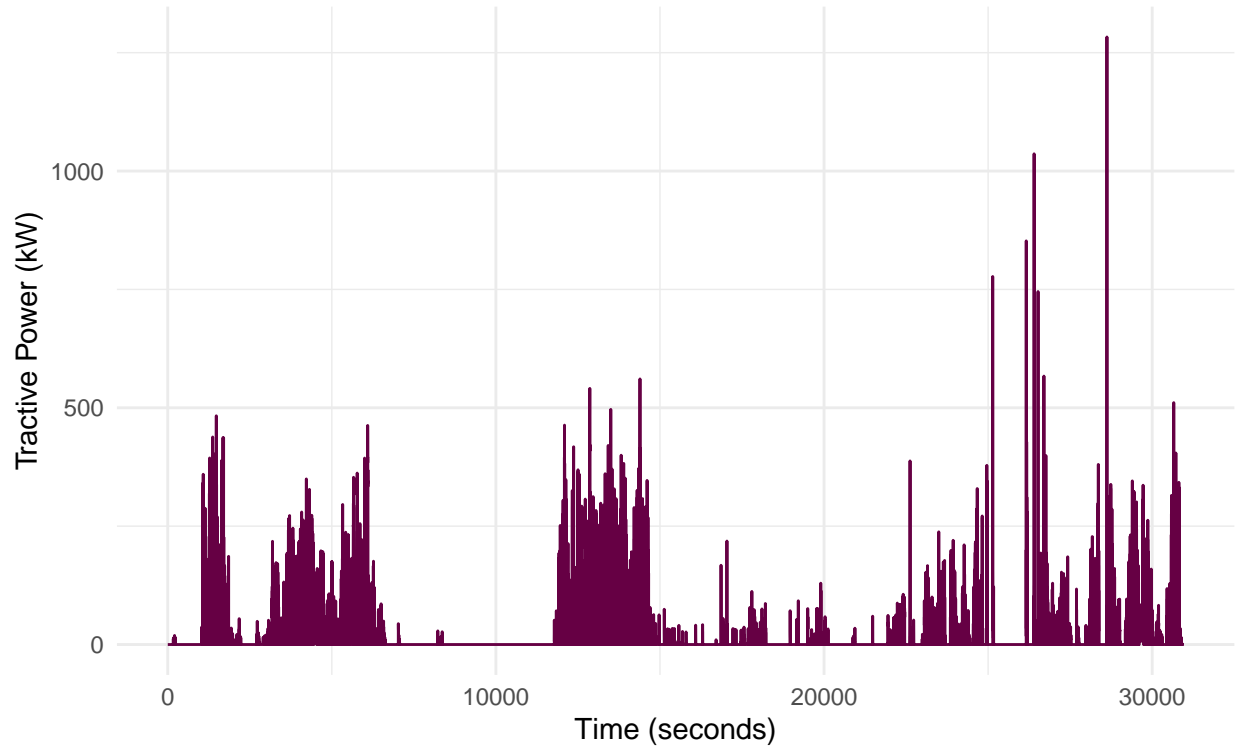


Figure 2: Plot of tractive power for drayage drive cycle.

2.2

A graph of engine power along with tractive power is given in Figure 3. I am using only from 10000 to 15000 seconds for clarity of the graph.

The data generally seem to make sense, as the engine power is often more than the tractive power, which is expected due to losses. Though I am not sure why tractive power sometimes exceeds engine power; it appears to have something to do with the spikes in tractive power, which are perhaps due to some time gaps.

2.3

The total power required to move the vehicle for this drive cycle is 690756 kW.

2.4

Table 7: Components of Total Tractive Power

	Drag	Rolling	Acceleration	Gravity	Total
Power (kW)	189373.4	183655.0	424208.3	104830.1	902066.8
%	21.0	20.4	47.0	11.6	100.0

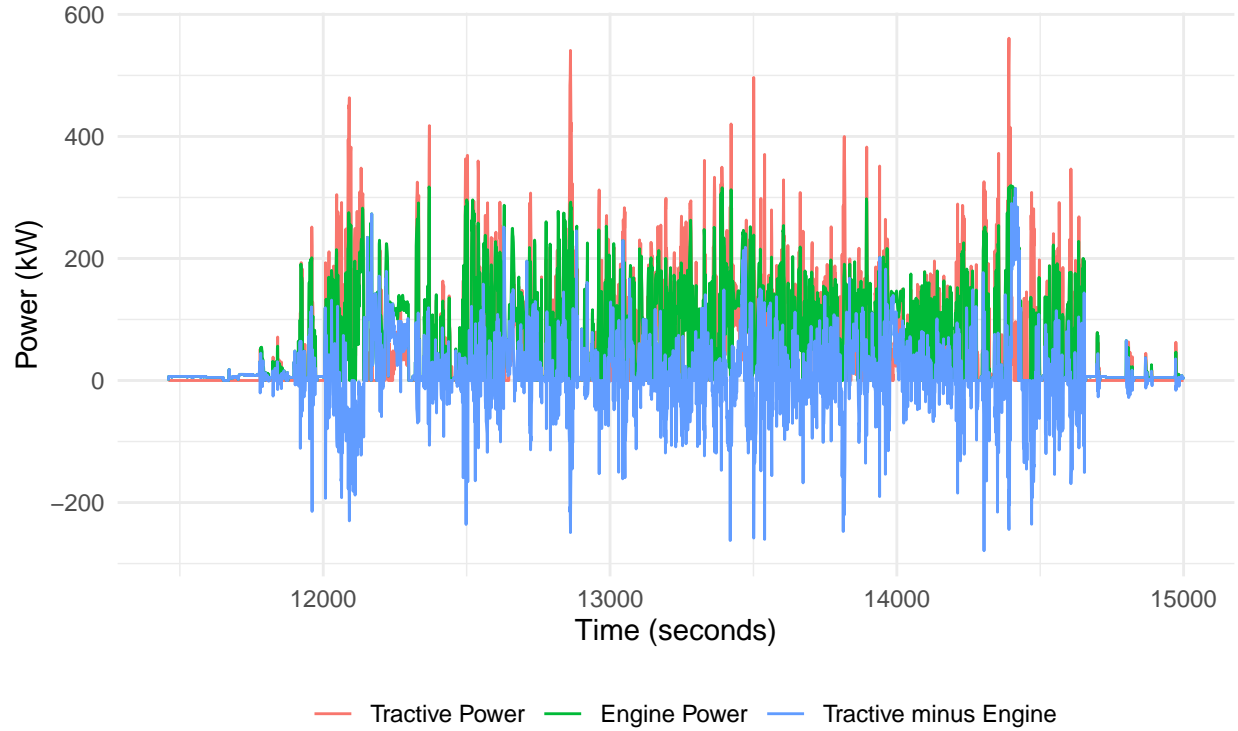


Figure 3: Comparison of engine and tractive power.

2.5

Assuming the “negative” tractive power would be used for regenerative braking, an additional 2423294 kWh would be available (281806 Kw over 8.6 hours). If 50% of that power was recaptured, then the additional tractive power needed would be reduced to 408950 kW, a reduction of 40.8%.

2.6

Assuming an auxiliary power load of 7 kW, the engine power used to move the vehicle is $P_{Engine} - 7$ kW, but not less than 0 kW. Finding the total energy expended by the engine attempting to move the vehicle gives 6668782 kWh. The total energy actually required to move the vehicle is 5939927 kWh, so the efficiency of the drivetrain is 89.1%.

2.7

Low-sulfur diesel has an energy content of 138,488 Btu/gal according to the AFDC. This is equivalent to 40.587 kWh/gal. Assuming an engine efficiency of 0.3, the total fuel needed for this drive cycle is $F[\text{gal}] = \frac{5939927[\text{kWh}]}{40.587[\text{kWh/gal}]} / 0.3 = 487835$ gal. The total distance in this drive cycle is 157965 meters or 98 miles, giving