My Green Car

Car emissions and costs

CE 186E Design of Cyber Physical Spaces

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Environmental Footprint of the user's car

To obtain the carbon footprint of the user's fuel consumption emissions, the analysis was divided into three sections: i) table 1 has the calculation of the well-to-tank CO2 emissions, ii) table 2 calculation of the CO2 emissions from combustion of gasoline and iii) table three has the total CO2 emissions at Oakland, CA. To perform the calculations of this beta release of the software, a control vehicle had to be selected, so we choose to perform the calculations for a Toyota Camry. The specifications of the vehicle where obtained from the 2017 Toyota Camry (Toyota, 2017).

To perform the sample calculations for the the well to tank emissions in one year, the distance traveled by the car will be assumed to be 10000 miles; the grams of CO2 e will be calculated by using the estimated footprint of well to tank emissions for a user living in Oakland, CA (Cooney, 2017); the energy content of gas was obtained from Tester, 2005).

Well to tank Emission 1 year						
City	**g CO2 e/MJ gasoline** (Cooney, 2017)	**Energy in gas (GJ/gallon)** (Tester, 2005)	**mpg (avg)** (Toyota, 2017)	**Distance (miles)**	**g CO2 e**	**g CO2 e/km**
Oakland, CA	26.3	0.125	28.5	10000	1153509	**72.1**

Table 1: Well to tank Emissions

To calculate the emissions from combustion of gasoline the distance was assumed to be 1000 miles. The CO2 content per gallon of gasoline (Penma, 2006) was used to convert between the total number of gallons consumed by the car and the total number of CO2 produced.

Emission from combustion of gasoline 1 year					
City	**mpg (avg)** (Toyota, 2017)	**Distance (miles)**	**Total gasoline (gallons)**	**lb CO2/gallon** (Penma, 2006)	**g CO2/km**
Oakland, CA	28.5	10000	351	19.6	195

Table 2: Emissions from combustion of gasoline.

To obtain total Carbon footprint from driving the Toyota Camry, we add the well to wheel emissions per km and the emissions from combustion per km.

	Well to Tank (g CO2 e/km)	Combustion (g CO2 e/km)	Total (g CO2 e/km)
Oakland, CA	72.1	195	**267**

Table 3: CO2 emissions (g CO2 e/km) at each of the office locations.

<u>Calculations of the environmental footprint of the Control Car #1</u>

To calculate the footprint from driving the Nissan Leaf the following steps where taken: i) obtain the electricity generation sources and percentage of electricity from each source. Since we are assuming the user lives in Oakland, the data was obtained from information publicized by PG&E (PG&E Power Mix, 2015) ii) calculate the efficiency of the Nissan Leaf using the total capacity of the batteries and the miles per full charge (Nissan, 2017). iii) use the range of electric power technology emissions and resource-use factor (per unit generation) (Masanet, 2013) to calculate the minimum and maximum emissions by energy source. iv) add the emission from the different energy sources to calculate the total CO2 emissions per km.

Energy Source	Oakland (PG&E Power Mix, 2015)	Oakland adjusted*
Non Hydro Renewables	**29.00%**	**34.94%**
Biomass and waste	4.00%	4.82%
Geothermal	5.00%	6.02%
Small Hydro	1.00%	1.20%
Solar	11.00%	13.25%
Wind	8.00%	9.64%
Hydro	**6.00%**	**7.23%**
Nuclear	**23.00%**	**27.71%**
Oil	**0.00%**	**0.00%**
Gas	**25.00%**	**30.12%**
Coal	**0.00%**	**0.00%**
Unspecified	**17.00%**	**0.00%**
Total	**100.00%**	**100.00%**

Table 4. Electric Power Profiles for the three cities in question.

* The Unspecified electric power from PG&E was distributed to the other sources of power reported.

The calculation the total power required by the Nissan Leaf we multiply the kWh/mile times the total number of miles.

Formula1.
*EnergyRequirement (kWh/year) = EnergyConsumption(kWh/mile) * MilesTraveled(miles/year)*

Where Energy Consumption (kWh/mile) is 0.2804kWh/mile (Nissan, 2017) and the miles traveled are assumed to be 10000 miles. By using this inputs, we obtain an Energy Requirement of 2800 kWh/year.

With the **Electric Power Profiles** and the total **Energy Requirement** by the Nissan Leaf, we can calculate the total emissions produce by energy source. To obtain the grams of CO2 e per km traveled kilometer we use *Formula 2*. Table 5 provides the results obtained for the city of Oakland. The same analysis procedure could be performed for other cities.

Emissions from Energy source			**Oakland**		
	min gCO2e/kWh (Tester, 2005)	**max gCO2e/kWh** (Tester, 2005)	**Energy by Source (kWh/year)**	**g CO2 e min***	**g CO2 max***
Non Hydro Renewables	-	-	980	-82018	125898
Biomass and waste	-633	75	135	-85531	10134
Geothermal	6	76	169	1013	12836
Small Hydro	3	12	34	101	405
Solar	5	217	372	1858	80633
Wind	2	81	270	540	21889
Hydro	0	165	203	0	33442
Nuclear	1	220	777	777	170927
Oil	530	900	0	0	0
Gas	245	930	844	206902	785385
Coal	1022	0	0	0	0
		Total (g CO2 e/year)		**125662**	**1115651**
		Total (g CO2 e/km)		**8**	**70**

Table 5. Total number of g CO2 e /km for the city of Oakland.
*Used *Formula 2* to perform this calculation

Formula 2.
*CarbonFoortprint (gCo2 /km) = EnergyPercentage (%) * EnergyRequirement(kWh/year) * EmissionBySource (gCo2e/kWh)*

Where EnergyPercentage (%) corresponds to the values in Table 4 (i.e. Geothermal 6.02%). The EnergyRequirement (kwh/year) corresponds to the value named Energy by Source in table 5 (i.e. Geothermal 169 kWh/year). EmissionBySource (gCo2e/kWh) corresponds to the max and min values in Table 5 (i.e. 6 gCo2e/kWh & 76 gCO2e/kWh respectively). Minimum and maximum values are used to give a complete range of CO2 emissions as different energy productions plants may have different efficiencies and it is unlikely that CO2 emissions are the same for two different plants even when they employ similar technology. The number reported to the user will be the average between the maximum and the minimum value.

	Oakland	
e by source (kWh/year)	**gCO2e min**	**gCO2e max**
Total/km	**8**	**70**
Total/life	**1256615**	**11156514**

Table 6. Presents the total emissions in gCO2e per kilometer traveled by the Nissan Leaf. It also presents the total gCO2e per lifetime, assuming a total travel of 160000km.

Projection emissions for 10 yr

To perform the 10 yr projection for CO2 emission the problem was analyses by analyzing the user vehicle (Camry) and the control vehicle (Leaf) separately and then the obtaining the savings from switching to the control vehicle. To calculate the emissions from the Nissan Leaf, the vehicle life cycle CO2 emissions where decomposed into three sections: i) CO2 emissions from manufacture, maintenance and end of life of the vehicle, not including the battery, ii) CO2 emissions from the manufacturing, maintenance and end of life of the battery and iii) CO2 emissions from the operation of the vehicle.

The value used for the CO2 emissions from manufacture, maintenance and end of life of the vehicle was estimated to be 35gCO2e/km for a total life of 200,000km (Hawkins, 2012). To obtain this estimate 51 different studies where taken into account. In some cases, for example Mercedes S, have a higher estimated CO2 emissions, but this case is treated as an outlier and not comparable to the Nissan Leaf. When multiplied, we obtain a total emission of 7,000,000 gCO2e for the manufacturing, maintenance and end of life of the Nissan Leaf. Since reporting all the emissions from manufacturing, maintenance and end of life in one lump upfront number, we have assumed that the vehicle will have a useful life of 200,000km and we will distribute the emissions evenly in a per km basis. Thus, the analysis adds 35gCO2e per km of distance traveled by the user.

To calculate the emissions from that correspond to the life cycle of the battery we used a similar procedure and the emission factor in a per km basis is 12gCO2e (Hawkins, 2012).

The emissions from the operation of the vehicle are obtained from Table 6. The combined results for the life cycle CO2 emissions are presented in table 7.

To calculate the emissions from the Toyota Camry, the vehicle life cycle CO2 emissions where decomposed into two sections: i) CO2 emissions from the manufacturing, maintenance and end of life and ii) CO2 emissions from combustion of gasoline from the operation of the vehicle.

The value used for the CO2 emissions from manufacture, maintenance and end of life of the vehicle was estimated to be 35gCO2e/km for a total life of 200,000km (Hawkins, 2012). To obtain this number, we used similar assumptions as those made to obtain the emissions of the manufacture, maintenance and end of life of the Nissan Leaf. When multiplied, we obtain a total emission of 7,000,000 gCO2e. Since reporting all the emissions from manufacturing, maintenance and end of life in one lump upfront number, we have assumed that the vehicle will have a useful life of 200,000km and we will distribute the emissions evenly in a per km basis. Thus, the analysis adds 35gCO2e per km of distance traveled by the user.

The emissions of the operation of the vehicle are obtained from Table 3.

Oakland, CA						
	Sample Distance (km)	Manufacture (gCO2e/km)	Battery (gCO2e/km)	Operation (gCO2e/km)	Total/km (gCO2e)	**Total (gCO2e)**
Toyota Camry	10000	35	0	267	302	**3020000**
Nissan Leaf	10000	35	12	39	86	**860000**

Table7. Comparison of CO2 emission by car for a sample distance traveled of 10000km.

<u>Projections of cost for 10 yr</u>

To perform the economical analysis of the two cars we use the Net Present Value of the investment. The initial cost of the Toyota Camry and the Nissan Leaf is USD 23,495 (Toyota, 2017) and USD 30,680. The cost of fuel (electricity or gasoline) depends on the city, for example the cost of gasoline and electricity in Topeka is USD 2.312 per gallon (GasBuddy, 2017) and USD 0.107 per kWh (Electricity Local, 2017). The analysis is perform using a discount rate of 6% and the Net Present Value formula.

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