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Will EVs save us from global warming? Are we on the right track?

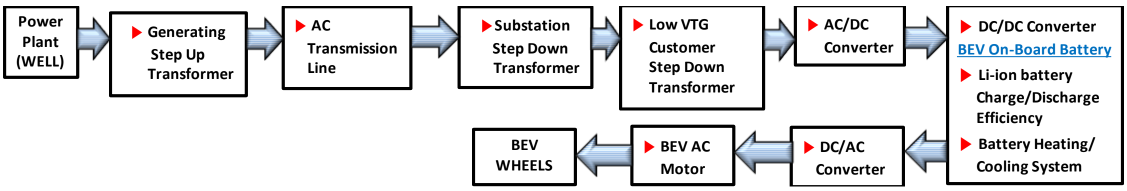
Michael Song

Introduction

The power generation sector is no longer **the biggest source of CO_2 emissions in US**, the transportation sector is. Tesla surpassed 200,000 US EV (electric vehicle) deliveries in July 2018 and GM is supposed to achieve the same within the year. Many people had shifted over to diesel powered vehicles based on the hype of low emissions, but Volkswagen has proven that what glitters isn't always gold. What about other behemoth **auto makers**? Can we trust EV makers and the PR surrounding them? Does the purchase of an EV contribute in preventing climate change?

Energy Efficiency is All That Counts!

Regarding EVs charged by grid-tied chargers, the electricity comes from a combination of fossil fuel, hydroelectric, nuclear, and renewable energy including solar PV and wind. To transmit electricity from the well (power plants) to the wheels of EVs (WTW), we use various power and power-electronic components between the well and EV wheels, and each component causes a loss in energy efficiency. The components included are shown in the Figure 1. below. Assuming the efficiency of each component is 90%, the well-to-wheel (WTW) efficiency of EVs would be $(0.9)^{10}$, or 35%.



[Figure 1] Power/power electronic components involved in well-to-wheel transmission of electricity.

According to US EIA, each US state has a different well makeup. The makeup includes 7 categories of CO_2 generating fuels: coal, natural gas, petroleum, other biomass, wood & wood derived fuels, other gases, and **other biomass.** In this context, we need to define power mix weighted specific CO_2 emission for each state.

The power mix weighted specific CO_2 emission is determined by the sum (∑) percentage of power generated by a specific CO_2 generating fuel x specific CO_2 emission of the fuel (g CO_2/kWh). The resulting number may be interpreted as g CO_2/kWh for the given power mix.

WTW efficiency is as important as fuel economy or energy efficiency in ICE vehicles. If we charge our EV batteries with a WTW efficiency of 35%, 65% of the energy is lost in the course of well-to-wheel transmission of electric energy. In this context, the CO_2 multiplication factor is defined as "f

= 1/WTW efficiency." In this calculation, f = 1/0.35 = 2.87 was used. For an EV to drive km/kWh, power plants must supply 2.87 kWh, and should burn 2.87 times more CO_2 emitting fuels. This is why "f" is interpreted as the CO_2 multiplication factor.

Burden of EV Charging Network to Grid

A recent analysis showed that an EV charging network could **sink the Texas grid** (ERCOT). According to the analysis, the simultaneous charging of 60,000 next-generation EVs (100-kilowatt EV battery with a 5-minute charge time) could one day threaten the ERCOT. According to the report, 60,000 vehicles make up 0.25% of registered vehicles in Texas.

According to the **US EIA**, the net generation capacity of California is less than 50% of Texas. However, the number of registered vehicles in California is nearly twice that of Texas. With less than 50% of the net generation capacity and almost twice as many registered vehicles, CAISO has a lot to be prepared for the future.

Grid-Tied EV Charger can make EVs to emit more CO_2 than modern gasoline ICE vehicles

Let's start with the **US EIA's spreadsheet**. The IEA publication of 2017 provides **specific CO_2 emission** for coal, natural gas and petroleum for OECD member countries. Wood and wood derived fuels, other biomass, and other gases take up 1.85% of the US total. Without a coherent specific CO_2 emission data for electricity generation for the fuels, emission contribution or wood & wood derived fuel, other gases, and other biomass were added to coal, natural gas, and petroleum, respectively.

The power mix weighted specific CO_2 emission was calculated by "(percentage of coal power/100) x specific CO_2 emission of coal (940 g CO_2/kWh) + (percentage of natural gas power/100) x specific CO_2 emission of natural gas (400 g CO_2/kWh) + (percentage of petroleum/100) x specific CO_2 emission of fuel oil (675 g CO_2/kWh)."

The energy efficiency of a Tesla Model 3 (6.3 km/kWh) was used in this calculation because it is **the most popular EV in America**. Dividing the power mix weighted specific CO^2 emission (g CO_2/kWh) by the energy efficiency of Tesla Model 3 (6.3 km/kWh), we obtained the Model 3's power mix weighted emission/km.

The WTW efficiency of EVs charged by grid-tied charging stations and the CO_2 multiplication factor were calculated earlier and found to be 35% and 2.87, respectively. To compare the Tesla Model 3 to a California standard ICE passenger vehicle (CSICEPV) in CO_2 emission, the California standard of 128 g CO_2/km (2016) was used in this calculation.

The result of calculation for 51 states and the US total (average) is shown in the table below. The last column proves that EV emits more CO_2 into atmosphere than CSICEPV in the 41 states.

No.	US State	Coal (%)	Natural Gas (%)	Petroleum (%)	Power mix weighted specific CO_2 emission (g CO_2 / kWh)	Power mix weighted Emission of Tesla Model 3 (g CO2/ km)	Multiplied by GHG multiplication factor f=2.87	Divided by SICEPV emission (128 g CO_2 / km) (times)
1	Alsaka	9.38	47.99	13.80	373	59	170	1.33
2	Alabama	26.38	40.61	0.06	411	65	187	1.46
3	Arkansas	41.45	30.06	0.26	512	81	233	1.82
4	Arizona	28.12	31.43	0.08	391	62	178	1.39
5	California	1.70	50.01	1.57	227	36	103	0.81
6	Colorado	55.19	23.30	0.15	613	97	279	2.18
7	Connecticut	1.14	49.19	1.95	221	35	100	0.78
8	Washington D.C.	0.00	29.69	70.31	593	94	270	2.11
9	Delaware	5.49	92.37	1.50	431	68	196	1.53
10	Florida	17.38	66.52	2.30	445	71	203	1.58
11	Georgia	31.63	39.63	0.36	458	73	209	1.63
12	Hawaii	15.05	0.51	70.36	618	98	282	2.20
13	Iowa	46.33	5.44	0.97	464	74	211	1.65
14	Idaho	2.82	21.21	0.76	116	18	53	0.41
15	Illinois	31.68	9.44	0.29	338	54	154	1.20
16	Indiana	71.28	21.88	1.03	764	121	348	2.72
17	Kansas	48.52	4.26	0.18	474	75	216	1.69
18	Kentucky	83.69	10.25	1.65	839	133	382	2.98
19	Louisiana	13.80	63.93	4.57	416	66	190	1.48
20	Massachusetts	6.27	66.17	4.69	355	56	162	1.26
21	Maryland	37.53	14.59	1.57	422	67	192	1.50
22	Maine	23.21	30.38	2.56	357	57	163	1.27
23	Michigan	37.50	27.57	1.60	474	75	216	1.68
24	Minnesota	41.06	15.01	1.19	454	72	207	1.61
25	Missouri	76.79	7.67	0.22	754	120	343	2.68
26	Mississippi	10.90	79.67	0.05	421	67	192	1.50
27	Montana	51.43	1.74	1.66	502	80	228	1.78
28	North Carolina	30.12	30.01	0.65	408	65	186	1.45
29	North Dakota	70.21	2.94	0.09	672	107	306	2.39
30	Nebraska	59.95	1.47	0.00	569	90	259	2.03
31	New Hampshire	10.30	24.60	0.85	201	32	92	0.71
32	New Jersey	1.69	56.71	1.45	253	40	115	0.90
33	New Mexico	55.80	30.26	0.21	647	103	295	2.30
34	Nevada	5.45	72.69	0.17	343	54	156	1.22
35	New York	1.79	42.25	1.67	197	31	90	0.70
36	Ohio	58.06	24.94	1.37	655	104	298	2.33
37	Oklahoma	24.67	46.44	0.17	419	66	191	1.49
38	Oregon	4.22	25.43	0.60	145	23	66	0.52
39	Pennsylvania	25.66	31.87	1.04	376	60	171	1.34
40	Rhode Island	0.00	95.82	3.52	407	65	185	1.45
41	South Carolina	23.92	16.88	0.30	294	47	134	1.05
42	South Dakota	18.07	7.97	0.02	202	32	92	0.72
43	Tennessee	40.35	14.29	0.27	438	70	199	1.56
44	Texas	26.91	50.32	0.21	456	72	207	1.62
45	Utah	68.02	22.93	0.30	733	116	334	2.61
46	Virginia	21.05	44.20	1.77	387	61	176	1.38
47	Vermont	24.17	0.10	1.03	235	37	107	0.83
48	Washington	5.53	9.98	0.28	94	15	43	0.33
49	Wisconsin	52.71	23.82	1.13	598	95	272	2.13
50	West Virginia	94.17	1.64	0.16	893	142	406	3.18
51	Wyoming	85.79	2.46	0.12	817	130	372	2.91
	US-TOTAL	31.40	34.12	1.13	439	70	200	1.56

***[Table 1]** CO_2 emission of Tesla Model 3 compared to California standard ICE passenger vehicle (CSICEPV) for various electric power mix in US.*

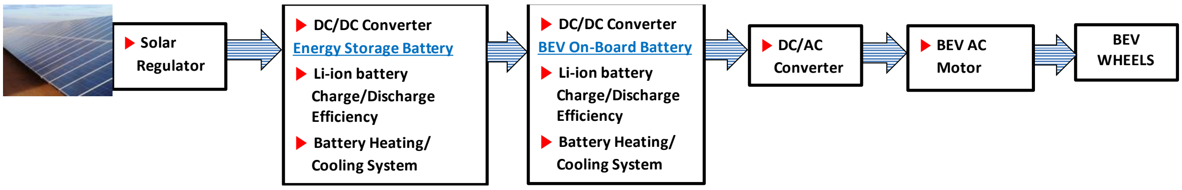
Results and Discussion

The Tesla Model 3 wheeling emits less CO_2 than CSICEPV in 10 states. In 16 states, the Model 3 generates 1～1.5 times more CO_2 than CSICEPV. In 11 states, the Model 3 generates 1.5～2 times more CO_2 than CSICEPV. In 8 states, the Model 3 spews 2～2.5 times more CO_2 than CSICEPV. In 6 states, driving the Tesla Model 3 emits more than 2.5 times of CO_2 than CSICEPV. In West Virginia, the Model 3 charged by grid-tied charging station spews 3.18 times more CO_2 than CSICEPV. The Model 3 generate 1.56 times more CO_2 than CSICEPV in the US on average.

Based on these calculations, grid-tied EV charging does not reduce but rather amplifies CO_2 emissions. For EVs to be true ZEVs, grid-tied EV charging should be prohibited.

Then, what's the solution?

The direct use of solar/wind energy for EV charging is the only available path toward ZEVs with no carbon footprint. Solar/wind direct EV charging will provide higher WTW efficiency and zero emission at the same time. As shown in the Figure 2, solar PV direct EV charging process may include 9 power electronic components to have WTW efficiency of $(0.9)^9$, or 39%. That is 4% higher than the WTW of EVs charged by grid-tied charging system and also carries no carbon footprint.



[Figure 2] Power electronic components involved in well-to-wheel transmission of electricity.

Also, the grid will be free from the burden of **proliferating demands** from EV charging stations, and ERCOT and CAISO would be free from the stress caused by power demand from EV charging networks.

Conclusion

Except in 10 states, EVs charged by grid-tied charging stations act as CO_2 emission amplifiers. Even in California, a Model 3 will spew 103 g CO_2/km into atmosphere. This is 22% less emission than CSICEPV. An EV charging network should be completely disconnected from grid. Solar/wind energy should be applied to EV charging network directly to be free of carbon footprint.

For a healthy energy transition in both the power generation sector and transportation sector, policy makers should ban **rapid expansion of grid-tied EV charging network**.

By disconnecting EV charging networks from grid, the stress to grid caused by EV charging will be removed. Even ERCOT and CAISO would be free from the disruptive stress from the EV charging network.