Estimating Emission Benefits from Vehicle Electrification in Turkey

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ABSTRACT

- This study investigates the comparison of different vehicle types like electric vehicle, gasoline vehicle and hybrid vehicle in order to estimate their energy consumption, efficiency and CO_2 emissions with using Turkey's energy generation with different percentage of energy sources in different years.
- We found that today electric vehicles can cause 57.5% reduction in CO_2 emissions and Hybrid vehicles can cause 51.8%.
- In addition, this study worked on different scenarios to guess Turkey's energy plan and their consequences of CO_2 emission in our comparison in near future.

INTRODUCTION

- Electric vehicles do not have tailpipe emissions, however depending on the electricity generation source, they can still cause CO_2 emissions.
- Primary energy sources used to generate electricity in Turkey are lignite, hard coal, hydro power, and natural gas. The other energy source used in Turkey are non-hydro renewable and oil derivatives (naphtha, LPG, and diesel) (Ari & Koksal, 2011).
- Hard coal and lignite have the maximum fuel-specific CO_2 emission factor. Municipal waste gas and natural gas have the minimum fuel-specific CO_2 emission factor.
- Several governments are trying to set objectives for the development of electric vehicles. However, Turkey doesn't have any short- or long-term targets and objectives for EV deployment according to IEA (2018).
- In this work we try to answer these questions:
  - What is the difference between electric vehicle and conventional fuel vehicle emissions in Turkey?
  - Under different scenarios, if we built/import electric vehicles, will transportation related CO_2 emissions increase? If yes, by what degree?

DATA & METHODS

a. Electricity Generation Mix in Turkey

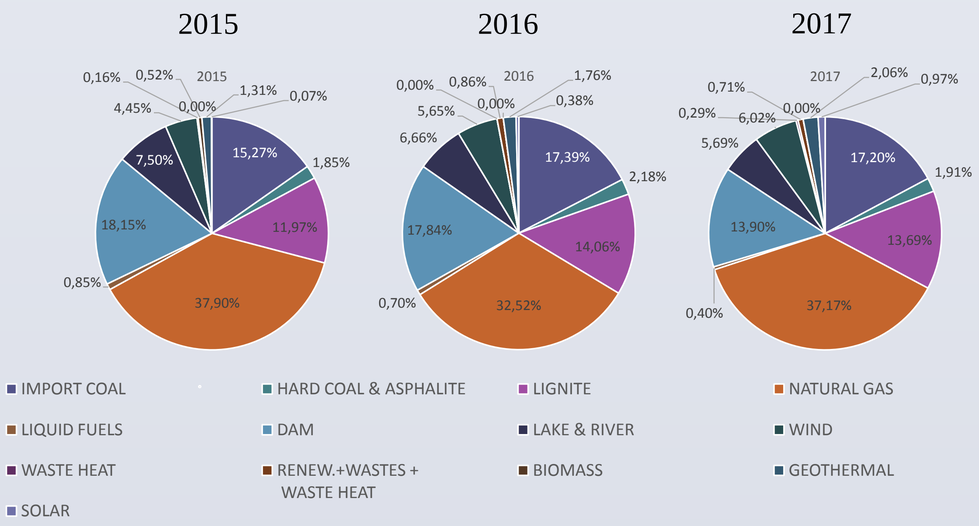

Figure 1. Distribution of energy sources of Turkey with percentages in years

Table 2. Carbon dioxide emission from the Turkish electricity sector and its mitigation in 2001 - 2008 (gCO_2/kWh)

	MWG	NG	Fuel Oil	Lignite	LPG	Diesel	Naphtha	Hard coal
Number of Data	7	131	28	107	7	6	7	26
Mean	373	374	755	1080	413	805	461	1018
Median	357	367	753	1057	413	789	480	1014
Std. Deviation	27	20	9	129	0	31	33	28
Minimum	357	356	741	712	413	780	413	919
Maximum	413	456	789	1384	413	860	480	1078

b. CO_2 Emissions from Different Vehicle Types (Gasoline, Electric Vehicles, Hybrids)

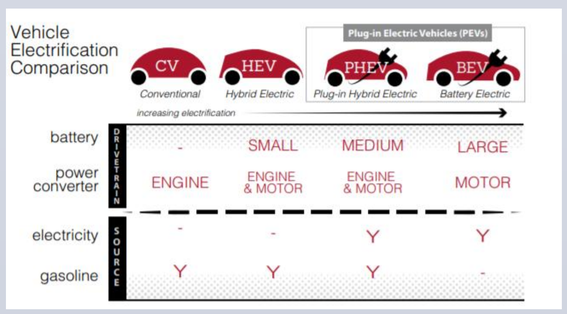

Figure 2. Vehicle Electrification comparison (Michalek, 2015)

- In this study, there were 3 vehicle types with 14 different models in total.
- We found their efficiency and then we found their CO_2 emissions separately. In order to find EV's CO_2 emission in Turkey, the efficiency of vehicles, Turkey's electricity generation with their types and the CO_2 production of energy sources are found with Equation 1.
- In order to find Gasoline and Hybrid vehicles' CO_2 emission, the fuel consumption of vehicles and gasoline CO_2 emission constant are found with Equation 2.
- Moreover, average emissions factor has been calculated with Equation 3.

c. Application of Formulas

$$EV\ CO_2\ emission\ \left(\frac{gCO_2}{100km}\right) = Grid\ Average\ \left(\frac{gCO_2}{kWh}\right) \times Efficiency\left(\frac{kWh}{100km}\right)$$

Equation 1. Electric Vehicle's grams of CO_2 emission (gCO_2/100km)

$$Gasoline\ Car\ CO_2\ emission\ \left(\frac{gCO_2}{100km}\right) = Emission\ Constant\ \left(\frac{gCO_2}{Liter}\right) \times Consumption\left(\frac{Liter}{100km}\right)$$

Equation 2. Hybrid's and Gasoline Vehicle's grams of CO_2 emission (gCO_2/100km)

$$Average\ Emission\ Factor\ \left(\frac{gCO_2}{kWh}\right) = \sum_{nonrenewable\ sources} \left(Grid\ Average\ \left(\frac{gCO_2}{kWh}\right) \times Energy\ Source\ Percentage\right)$$

Equation 3. Average Emission Factor (gCO_2/kWh)

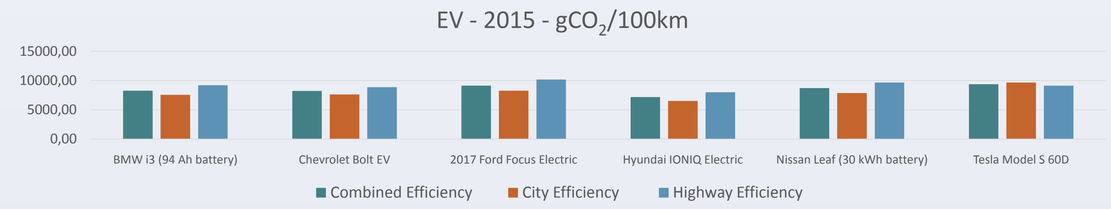

Figure 3. CO_2 emissions of several EV with the distribution of Turkey's energy sources in 2015 (gCO_2/100km)

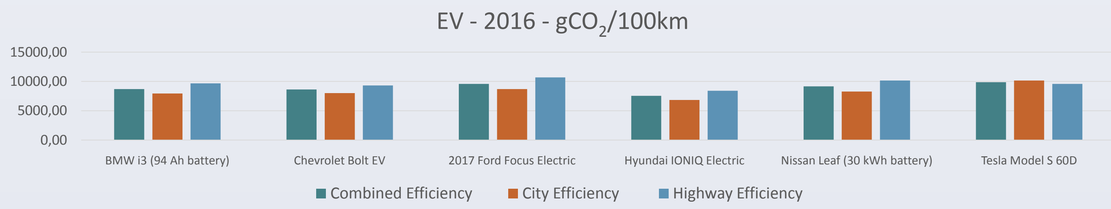

Figure 4. CO_2 emissions of several EV with the distribution of Turkey's energy sources in 2016 (gCO_2/100km)

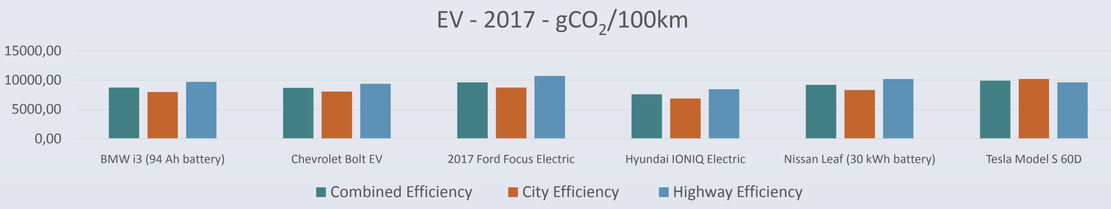

Figure 5. CO_2 emissions of several EV with the distribution of Turkey's energy sources in 2017 (gCO_2/100km)

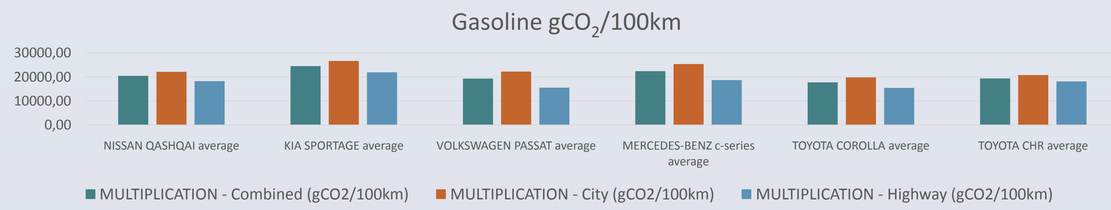

Figure 6. CO_2 emissions of several Gasoline Vehicles (gCO_2/100km)

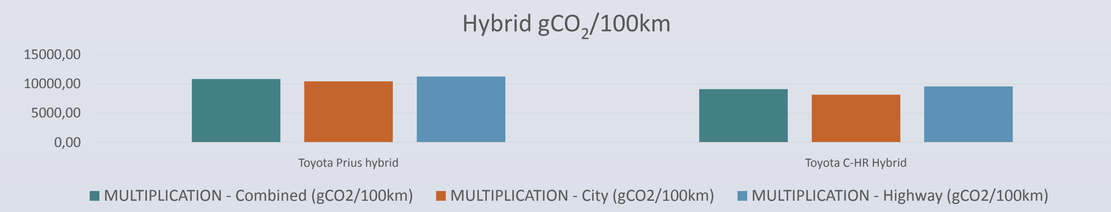

Figure 7. CO_2 emissions of several Hybrid Vehicles (gCO_2/100km)

CONCLUSION

- According to our work, EV's average CO_2 emissions are less than (less than half) gasoline cars and also hybrid's average. However, Toyota C-HR has significantly low emissions. This situation is a result of Turkey's energy source distribution.
- In recent years Turkey's major electricity production sources were natural gas and coal. Nonrenewable sources (coals, natural gas, liquid fuels) have very big percentage. That's why some EV's emissions are higher than hybrids.
- If we look at the recent years percentage increment in energy generation source and guess the next years emissions with them, Turkey's nonrenewable energy production increased, but renewable energy decreased. Therefore, in the near future the CO_2 emissions might stay the same in electric, gasoline and hybrid vehicles.
- Ministry of Energy and Natural Resources (2014) state that Turkey aims to increase their electric generation to 424000GWh, and they aim that 91800GWh comes from dam and 67633GWh comes from other renewable sources. If this aim is achieved, this will cause increase the renewable source percentage to 38% . In that case EVs will have less CO_2 emissions compared to all other vehicles.
- In future work, hour by hour electricity generation of Turkey can be used rather than annually. That will be useful for different scenarios analyses with using electric vehicle charging time distribution and that will cause different CO_2 emissions for EVs.

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