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Comparison of two electric vehicles in terms of real range in different types of operations

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Abstract: Electromobility is currently seen as an effective way to reduce the production of harmful emissions from the transport sector and, thus, prevent further environmental pollution and the associated global warming. The article is focused on the comparison of selected types of electric vehicles (EVs) in terms of real range in different types of operations and environments. Firstly, the driving characteristics and operating parameters of the selected EVs were tested in operation, under different conditions and in different geographical environments. The test drives took place on a pre-selected route, which was the same for all the EVs. The pre-selected operating parameters were measured and monitored for the subsequent comparison. Also, the specific conditions under which the test runs took place, such as the outside temperature, geographic terrain or traffic conditions along the route, were also monitored. Then, the obtained data were evaluated and conclusions were made.

Keywords: electric vehicles; emission; test drives; electromobility; power consumption; electric tractor

These days, electromobility is an effective way to reduce the production of harmful emissions from the transport sector, prevent further environmental pollution and the associated global warming. Another reason in favour of electric vehicles is the fact that there is a limited supply of fossil fuels. Furthermore, the current EU Regulation 443/2009 established emission performance standards for newly manufactured passenger cars as a part of the Community's integrated approach to reducing CO_2 emissions. The emission limit sets for this Regulation for new vehicles is 130 g $CO_2 \cdot km^{-1}$. By 2020, this emission limit will be reduced to 95 g $CO_2 \cdot km^{-1}$. If this limit is exceeded, manufacturers will face financial penalties from 2019. The field of electromobility is, therefore, an area that needs to be given increased attention (European Union).

The world is constantly trying to find clean energy sources to ensure the daily operation of a million different vehicles to be as environmentally friendly as possible. The automotive industry is a major contributor to the global volume of toxic emissions from internal combustion engines into the atmosphere. These toxic emissions contribute to climate change, air pollution and also have a negative impact on human health (Chu et al. 2019).

Electric vehicles (EVs) are considered environmentally friendly. The electricity for EVs is not completely emission-free and it always depends on the power source of the electricity for charging. Enhancing EVs is only meaningful if it is ensured that much of the electricity they use is produced from renewable sources. The aim of electromobility is not to increase the number of EVs, but to effectively reduce emissions (Ajanovic, Haas 2016).

The limited range represents a significant disadvantage of EVs compared to internal combustion engine

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vehicles (ICEVs). This significant disadvantage may discourage potential customers (Egbue, Long 2012; Dimitropoulos et al. 2013). However, technologies are still evolving and now there is a focus on Extended-range electric vehicles (EREVs). EREVs have become alternative options because they have a higher efficiency and greater range than lithium battery-manibased electric vehicles (Chu et al. 2019).

At present, electromobility is not just about cars. but it is also about agricultural technology. For example, the leading agricultural company John Deere presented its first high-performance electric tractor at Paris International Farm Show (SIMA) in 2017, whose designation is Sustainable Energy Supply for Agricultural Machinery (SESAM). The advantage of the SESAM tractor is not only in the extraordinary efficiency, but also in its possible use on a farm producing energy from renewable sources. The electric tractor produces no emissions and virtually no noise, which is an advantage when working at night or near populated areas. When the battery is fully charged, the tractor is able to work for four hours or travel up to 55 km.

The aim of this article is the comparison of selected electric vehicles and their driving characteristics.

MATERIAL AND METHODS

The measurement was performed with two fully electric vehicles. The first test vehicle was the Fiat 500e (Fiat, Italy), as a representative of a lower-class vehicle designed especially for urban traffic. The second test vehicle was the Volkswagen e-Golf (Volkswagen, Germany), which is a medium-class vehicle designed for normal operation. The detailed technical information on both vehicles has been summarised in Table 1. The Fiat 500e had a mileage of 35 600 km, and the Volkswagen e-Golf had a mileage of 3 500 km.

During the measurements, the vehicles were equipped with a system for communication with the vehicle control unit (electric drive control unit), by means of which the instantaneous values of the operating parameters (voltage and battery current, electric motor speed, vehicle speed, etc.) were recorded and stored.

For communication with the Fiat 500e, a TEXA diagnostic system (TEXA, Italy) was used, for communication with the e-Golf, a VAG-COM diagnostic system (Ross Tech, USA) with an HEX-V2 communication interface (Ross Tech, USA) was used. In addition, the vehicles were equipped with GPS 18x USB with a 1 Hz frequency to monitor their immediate position.

Ordinary roads (or tracks, see Figure 1) were selected with the aim to be composed of two different sections. The first section led from the University (CULS) to the Budějovická metro station (BUD) in Prague where a fast-charging station is located. It is a typical urban drive influenced by ordinary traffic conditions (congestions, signal lights, etc.).

Table 1. Technical information of the electric vehicles (EVs)

	VW e-Golf	Fiat 500e
Engine		
Design	synchronous AC electric motor with permanent magnets	synchronous AC electric motor with permanent magnets
Power	85 kW	83 kW
Torque	270 Nm	200 Nm
Fuel system	electric	electric
Battery		
Type	li-ion 323 V	li-ion 364 V
Capacity	24.2 kWh	24 kWh
Number of cells	264 cells in 7 modules	97 cells
Weight	312 kg	260 kg
Car body		
Service weight	1 585 kg	1 352 kg
Manufacture year	2018	2015
Drive performance		
Max. speed	150 $km \cdot h^{-1}$	142 $km \cdot h^{-1}$
Acceleration 0–100 $km \cdot h^{-1}$	9.6 s	9.1 s
Fuel consumption	12.7 $kWh \cdot 100\ km^{-1}$	18 $kWh \cdot 100\ km^{-1}$
Tank range	231 km	135 km

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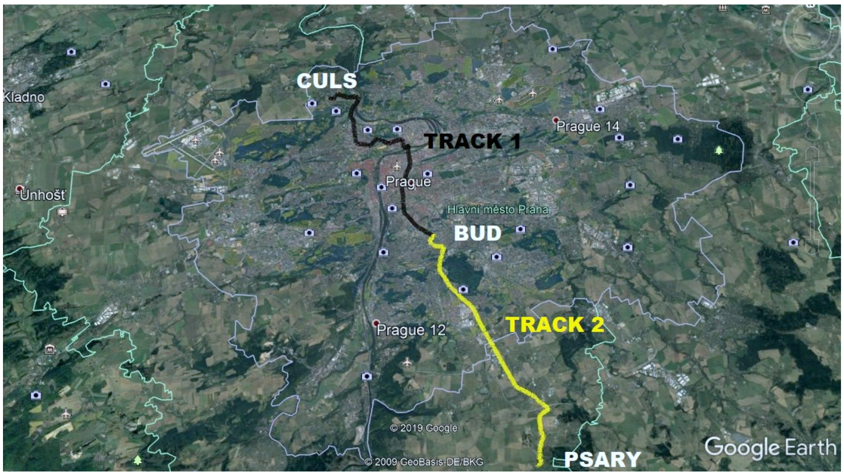

Figure 1. Test drive map
source: Google Earth (accesed June 1, 2020)

The second section was 15 km long and oriented out of the city. Its origin was placed on the parking lot next to the metro station Budějovická (BUD) and the final destination was in the suburban municipality of Psáry (PSARY). This section is considered to have semi-urban conditions.

The measurement took place this year (January 1, 2020). During the day it was 7 °C and it was partly cloudy. The car's interior air conditioning was set at 23 °C, the air conditioning was switched off.

RESULTS AND DISCUSSION

Table 2 summarises the resulting values of the achieved operating parameters. As can be seen from Table 2, in urban traffic (track 1), the vehicles reached lower average speeds and the driving was greatly influenced by frequent stops at traffic lights. This also corresponds to the achieved higher electricity consumption, because there is not such a large potential to use the electricity recovery phase. As expected, the smaller Fiat 500e achieved a lower power consumption than the e-Golf on both test tracks. Both tested vehicles achieved lower power consumption values than stated by the manufacturer. The evidently higher declared fuel consumption of the Fiat is probably due to the new world harmonised light-duty vehicles test procedure (WLTP) homologation methodology compared to the older New European Driving Cycle (NEDC) methodology used for the e-Golf.

The number of grams of CO_2 produced by the electric vehicles on the given tracks is calculated using the average electricity consumption per 100 km and the number of grams of CO_2 generated during the production of 1 kWh.

The number of grams of CO_2 in 1 kWh production depends on the country's energy mix. The energy mix is influenced by power plant's types of energy composition in the territory. In addition to the type of power plants, the weather (sun, wind, ...) also affects the number of grams of CO_2.

In this article, the carbon intensity on the 27th of January 2020 at 6 p.m. was used for the calculation. The unit CO_2 production·km^{-1} is mentioned in Table 3. The results show that the Fiat 500e is

Table 2. Results of the selected operating parameters on the tracks

	Unit	e-Golf		Fiat 500e	
		track 1	track 2	track 1	track 2
Driving time	min	28.73	36.34	33.45	33.86
Length of the route	km	14.84	16.07	14.97	15.82
Average speed	km·h^{-1}	31.5	26.6	27.0	29.5
Energy consumption	kWh·100 km^{-1}	15.16	14.15	13.80	13.33
Total energy	kWh	2.25	2.28	2.07	2.11
Total average power	kW	4.75	3.73	3.72	3.72

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Table 3. CO_2 production per 1 km

	Unit	e-Golf		Fiat 500e	
		track 1	track 2	track 1	track 2
	g CO_2·kWh^{-1}	502	502	502	502
Energy consumption	kWh·100 km^{-1}	15.16	14.15	13.80	13.33
CO_2 production	g CO_2·km^{-1}	76.10	71.03	69.28	66.92

Source of g CO_2·kWh^{-1} https://www.electricitymap.org/zone/CZ (accesed Jan 27, 2020)

more environmentally friendly than the e-Golf because it produces less indirect emissions. There is a difference of 6.82 g CO_2·km^{-1} on track 1 and 4.11 g CO_2·km^{-1} on track 2. The following graphs 1 and 2 show the instantaneous values of the selected endpoints of both vehicles on the first test track. The main monitored variable was the instantaneous current on the hybrid battery. The negative values show the consumed current, while the positive values show the regenerated current.

As shown in Figure 2, the average current consumed by the Fiat 500e was 18.9 A. It reached its maximum during the 152.5 A journey during the first climb in the Prague Suchdol district. The average recuperated current reached 16.3 A at a maximum value of 82.8 A. In the case of the e-Golf (Figure 3), the average current drawn was 31.77 A with a peak of 338.25 A again during the climb in Prague Suchdol. The average recuperated current was 22.71 A at a maximum of 134.5 A. As can be seen above, the e-Golf recuperated current was one-third higher in urban traffic.

Figures 4 and 5 show the instantaneous values of the operating parameters in the out-of-town traffic. The Fiat 500e reached an average current of 20.35 A with a maximum current of 77.9 A. During the recovery, the average current was 14.27 A at a maximum of 69 A. The e-Golf (Figure 5) achieved

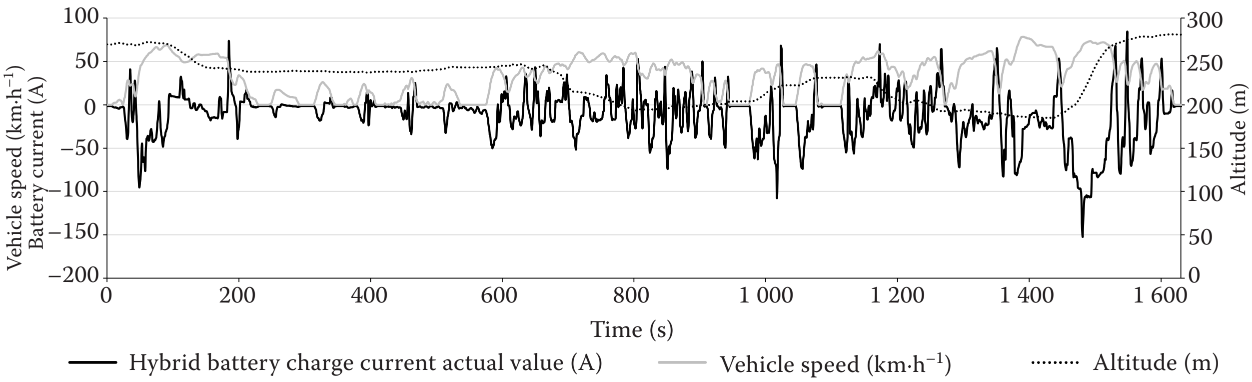

Figure 2. Operating parameters of the Fiat on track 1 (direction CULS → BUD)

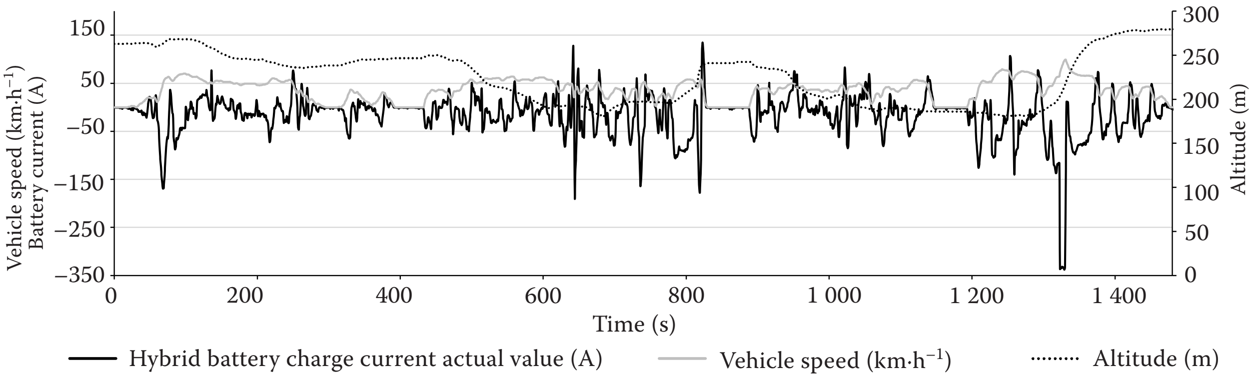

Figure 3. Operating parameters of the e-Golf on track 1 (direction CULS → BUD)

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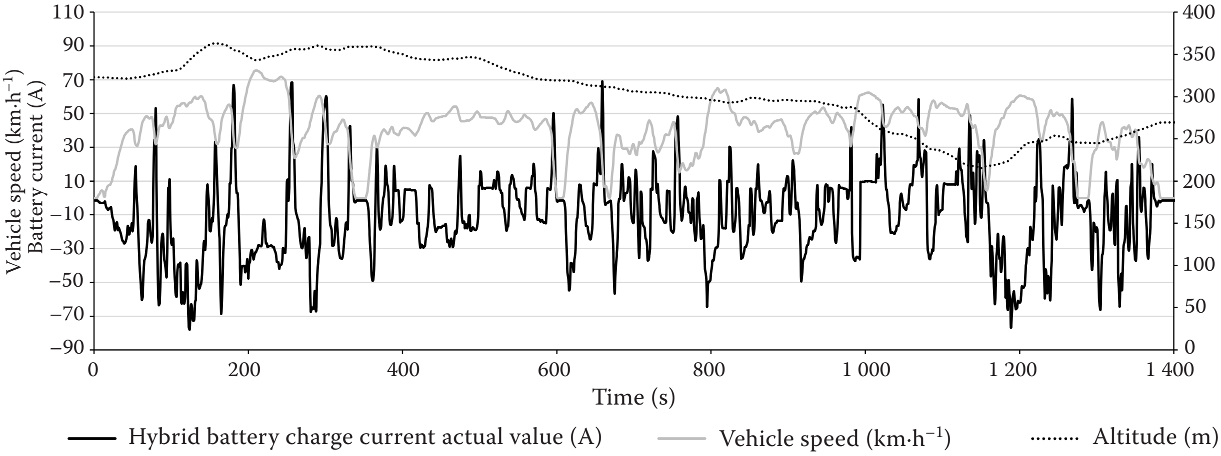

Figure 4. Operating parameters of the Fiat on track 2 (direction BUD → PSARY)

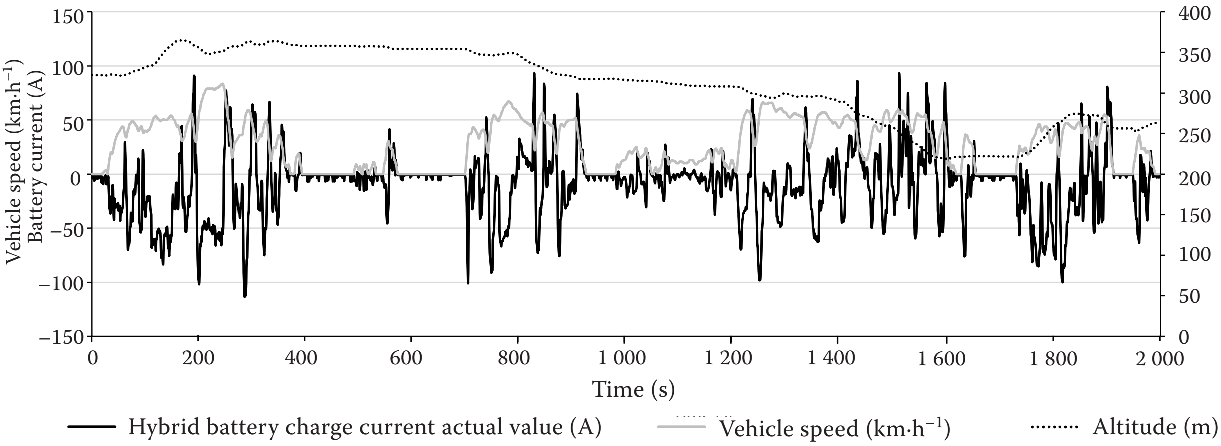

Figure 5. Operating parameters of the e-Golf on track 2 (direction BUD → PSARY)

an average current of 21 A in the extra-urban traffic. The average recovered current reached 21.5 A at a maximum of 93.25 A.

Thus, both vehicles achieved similar results in terms of the average current drawn in the extra-urban traffic. This is mainly caused by the profile of the track, which, in this direction, is mostly downhill and achieves a higher degree of recovery. Due to the fact that the limiting range is the main obstacle for the development of electromobility not only in the Czech Republic, but also elsewhere in the world, technological development in this area (range) is necessary. Many studies have dealt with extended-range electric vehicles based on ammonia (Awotwe et al. 2017). To improve the range of electric vehicles, a method that improves the range of the electric vehicle by using an effective cruise control is also being tested (Madhusudhanan 2019). Various ranges of electric vehicle are being explored in China (Zhou et al. 2020) and also in America (Tamor 2019) where data usage from fleets equipped with vehicles in several US cities is being used to study the potential cost, benefits and customer acceptance of battery powered electric vehicles.

Also, in the field of agriculture, they address the issue of a reduction in pollutant emissions and fossil fuel dependency. Thanks to the electrification of the tractor, which uses separate loads and drives from the engine, a high efficiency is possible. There is a reduction in the fuel consumption and a consequent reduction in CO_2 emissions (Moreda et al. 2016).

CONCLUSION

The use of an electric vehicles is always influenced by the vehicle's user. Electricity consumption is affected by the driving style, geography and, among other things, by the weather, which affects the need for air conditioning or heating.

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EVs do not produce local harmful emissions. However, it should be noted that EVs generate indirect emissions depending on how the electricity is produced, and it is also necessary to take the entire life cycle of an electric vehicle from production to disposal into account, when additional emissions are produced. The production of harmful emissions from an EV is strongly dependent on the electricity source, the type of power plant and its primary energy source.

The measurements show the suitability of the Fiat 500e for city traffic, while the e-Golf is a full-fledged vehicle for all types of traffic (even motorways, while the Fiat is not suitable for this operation). The measurements also show that the real consumption reached lower values than stated by the manufacturer, which is mainly caused by the defensive driving style. The Fiat 500e was more environmentally friendly during use because it produced less indirect emissions.

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