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Evaluation of low power electric vehicles in demanding urban conditions: an application to Lisbon

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Abstract

This research paper analyses the use of four electric vehicles, two motorcycles (EM) and two small low powered electric vehicles (EV) in an urban environment with demanding topography and driving profile. The vehicles were compared with conventional technologies using a methodology that was developed to estimate its drive cycle (EV-DC) as well as the corresponding energy consumption, in a life-cycle approach. This methodology uses real-world driving cycles as input performed with conventional vehicles, in this case, on representative routes in Lisbon, and estimates the impacts on the driving cycle considering that an electric vehicle was used. The deviation between the original and the estimated driving cycles for electric vehicles was quantified considering the power and speed limitations of the electric vehicles and the average speed and trip time impacts were quantified. The results indicate up to 13% longer trip time for the vehicles and up to 25% longer trip time for motorcycles, resulting of reductions in average trip speed of up to 11 and 20% respectively. In terms of fuel efficiency, the electric technologies considered may reduce the Tank-to-Wheel (TTW) energy consumption in average 10 times for the vehicles and 4 times for the motorcycles. However, the reductions in a Well-to-Wheel (WTW) approach are reduced to a 5 times reduction in energy consumption for vehicles and a 2 times reduction for motorcycles. In all, this methodology corresponds to an innovative way of understanding how low-powered electric technologies, both vehicles and motorcycles, would perform in specific applications to replace conventional technologies, both in terms of trips statistics and of energy and environmental performance.

Keywords: electric motorcycles and small low-powered electric vehicles; drive cycle simulation; on-road monitoring; energy and efficiency impacts

1 Introduction

The transportation sector faces increasingly demanding energy consumption and emissions standards representing 33% of the final energy consumption, with the road transportation sector being responsible in 2011 for 82% of that energy consumption [1]. Two important possibilities of improving this situation are promoting vehicle efficiency improvements and the shift to alternative vehicle technologies and energy sources [2]. In terms of alternative vehicle technologies and energy sources, electricity powered vehicles are regarded as an opportunity for significantly reducing the amount of CO_2 emitted by the transportation sector and increased

renewable energy penetration [3-5]. Furthermore, the shift to electricity would have substantial impacts for urban systems due to their zero local emissions and noise reduction. However, such technologies still have significant weaknesses that prevent them from being true alternatives, such as purchase cost, performance, autonomy and recharging limitations [6]. Several electric vehicles are commercially available (e.g. Nissan Leaf, Mitsubishi iMiev, Renault Fluence, Renault Zoe). Moreover, in the Portuguese context, the Government has promoted in the past the deployment of a public recharging infrastructure, with 1300 slow public recharging points and 50 fast public recharging points. This strategy, together with the incorporation of high levels of renewable energy in its electricity generation mix, envisioned to strategically develop specific industries in Portugal such as wind power turbines, solar panel, battery production, etc. [7].
However, due to their high purchase cost, their market penetration has been low. In Portugal, the sales of EV have peaked in 2011 in Portugal with approximately 200 units being sold [8]. However, after that, the 5000 € government purchase benefits has been removed, lowering EV sales dramatically.
As a result, other electric vehicles with lower purchase cost may be more appealing in this first stage of electric vehicle penetration. In many developing countries, these vehicles are a first affordable step towards individual mobility, with more than 95% of all powered two-wheelers being produced in China, Southeast Asia and Japan [9, 10]. These vehicles often constitute low power electric mobility solutions, which, due to their power restrictions, may influence the driving patterns of their users.
Nevertheless, the impacts of these technologies impacts have not yet been fully characterized. A small-scale electric scooter trial was performed in Oxford, United Kingdom, to record their time of day usage and charging regimes [11]. The on-road monitoring of electric vehicles has also been performed but without focusing on the fulfillment of drive-cycles [12].
According to this framework, the objectives of this research work were, in a first approach, to develop a methodology to estimate the driving cycle of electric low power mobility solutions, on a given route, considering speed, acceleration and road topography. Moreover, an on-road characterization of small low-powered electric vehicles (EV) and motorcycles (EM) was performed. Consequently, this methodology allows evaluating if these alternative electric technologies can, in an urban driving environment, fully replace, in terms of driving profile, the conventional technologies and assess their energy and global pollutant emission performance, as well as travel time.

2 Methodology for energy characterization of vehicles

2.1 Electric vehicle drive-cycle simulation tool

The proposed methodology is based on Vehicle Specific Power (VSP) to estimate the power demand by vehicles, which combines speed (v), acceleration (a) and road grade (θ). This methodology allows comparing different technologies under similar power requirements. It is traditionally used on light-duty vehicles [13] and its generic definition is presented in Equation 1. The coefficients of the equation are adjusted according to the typology of vehicle monitored [14]. In this case, the two typologies of vehicles studied, small sized vehicles and scooters, the coefficients used are presented in Table 1.

$$\mathrm{VSP} = \frac{\frac{d}{dt}(E_{Kinetic} + E_{Potential}) + F_{Rolling}\cdot v + F_{Aerodynamic}\cdot v}{m} = \\ = v\cdot[a\cdot(1+\varepsilon_i) + g\cdot sen(\theta) + C_{Roll}] + C_{Aero}\cdot v^3$$

Eq. 1

Table 1: Coefficient values for the variables included in VSP

Variables	Coefficient			
	Vehicle		Motorcycle	
	Conven-tional	Electric	Conven-tional	Electric
Effect of translational mass of powertrain rotating components, ε	0.1		0.01	
Gravitational constant, g (m/s^2)	9.81			
Rolling coefficient, C_{Roll}	0.132	0.164	0.137	
Aerodynamic coefficient, C_{Aero}	0.000302	0.000957	0.0139	
Driver weight, m (kg)	70			

Considering the driving cycles performed with vehicles without power limitations as input, the VSP methodology is useful to evaluate in a second by second basis the electric vehicle performance (or lack of it) compared with the power demand imposed by the conventional vehicle. Therefore, it is possible to adapt the conventional vehicle driving cycle according to the electric vehicle limitations.

To assess the application of electric solutions, two routes in the city of Lisbon were selected, as presented in Table 2. One route comprehends traffic intensive avenues and side roads with very little traffic, and the other a demanding topography profile.

Table 2: Selected routes

Route	Distance (km)	Average positive slope (rad)	Average negative slope (rad)
R1	9.81	0.033	-0.033
R2	17.10	0.028	-0.024

This research evaluated if low-powered electric solutions, both for vehicles and scooters, are capable of performing at equal or comparable level than their conventional counterparts in a defined urban driving context. Therefore, a conventional vehicle (CV) and motorcycle (CM) were used to perform these routes, generating a real-world speed profile. The technical specifications of each conventional vehicle studied are presented in Table 3. Additionally, two low-powered electric vehicles (EV1 and EV2) and two electric motorcycles (EM1 and EM2) were considered.

Table 3: Vehicle specifications

Vehicle	Curb weight (kg)	Motor power (kW)		Battery type	Battery capacity (kWh)
		Conventional	Electric		
CM	150	6.7	-	-	-
EM1	83	-	2	Lead-acid	1.7
EM2	160	-	6	Li-ion	2.9
CV	1054	60	-	-	-
EV1	300	-	4.8	Lead-acid	2.4
EV2	754	-	10	Li-ion	7.7

The measured real-world driving cycles are used as input to estimate the adjusted EV1, EV2, EM1 and EM2 driving profiles, in order to identify situations where the electric vehicle is unable to perform according to what was demanded by the driver, due to its lower power and maximum speed limitations. In this approach, trip characteristics such as stops and stopping times are assumed not to be variable parameters and that they are distance dependent (and not time dependent).

For obtaining the simulated drive cycle, an iterative software named Electric Vehicle Drive-Cycle simulation tool (EV-DC) was developed in Matlab R2012a. This software tool verifies second by second if the electric vehicle is able to fulfill the power demands and speed limitations of the conventional vehicle performing the cycle. If it is not able to equal those requirements, the electric vehicle performs at it maximum power or speed (lower than the conventional vehicle speed) and, consequently, increases the trip time. This methodology results in a simulated drive cycle, with equal distance travelled, where the EV or EM are able to minimize time gains by maximizing the use of the available power. In the end the speed profile, average speed, maximum speed and energy consumption profile are computed.

2.2 On-road monitoring for characterization of energy consumption

To accomplish an energy consumption and environmental analysis independently of the drive cycle (generated by the EV-DC and based on a real-world conventional vehicle measurement), a detailed on-road monitoring of the 4 electric vehicles (2 motorcycles and 2 small vehicles) was performed. Over 5 hours of driving data were collected for these vehicles. To assess the impacts of vehicle usage on energy consumption and travel time, the driving cycle VSP time distribution was combined with the energy rates for each VSP mode.

All vehicles where monitored using a portable laboratory designed to characterize energy and environmental impacts associated with motorized vehicles (TEEL) [15]. TEEL is equipped with a GPS to record the dynamic profile of the trip (including location, altitude and speed) and voltage and current probes to measure electricity consumption. The data collected for the Conventional vehicle (CV) includes information from vehicle OBD, namely vehicle speed and engine data. All the components are connected to a laptop to record the data throughout the trips at 1 Hz. A brief description of the equipment used and of the data presented in this paper is presented in Table 4.

Table 4: Technical description of the equipment.

Monitoring equipment	Data acquired	Applied on
OBD port reader	Vehicle speed, engine parameters	CV
GPS (Garmin GPS map 76CSx)	Speed (km/h), altitude (m), location	CV, EM, CM, EV
Voltage and current probes (Fluke i1010)	Voltage, current	EM, EV

2.3 Life-cycle assessment

An additional layer of results is analyzed by considering a life-cycle assessment, which must be accounted when dealing with electric mobility. The Tank-to-Wheel (TTW) stage accounts for the emissions and fuel consumption that result from moving the vehicle through its drive cycle. The Well-to-Tank (WTT) impacts results from the expended energy and emissions from bringing an energy vector from its source until its utilization stages. Reference factors were used for each of the different energy pathways considered (in this case, gasoline production and electricity production in the Portuguese electricity mix) [3, 5]. The combination of the TTW and the WTT stages accounts for the Well-to-Wheel (WTW).

3 Results

3.1 Drive cycle simulation and trip statistics

Regarding the application case evaluated, the measured speed profiles performed with conventional vehicle and motorcycle in route 1 and 2 are presented in Figure 1 and Figure 2, respectively. Moreover, the simulated drive cycles performed by EV1, EV2, EM1 and EM2 are also presented. The differences between the conventional vehicle speed and the electric one are easily observed.

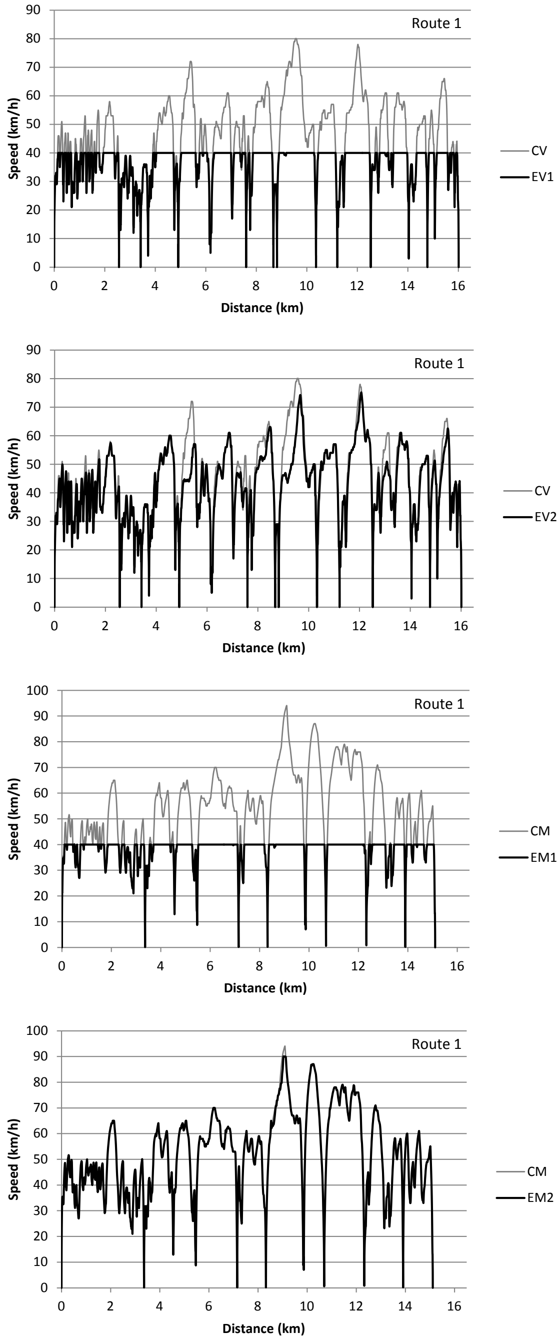

Figure 1: CV and CM drive cycles for the route 1.

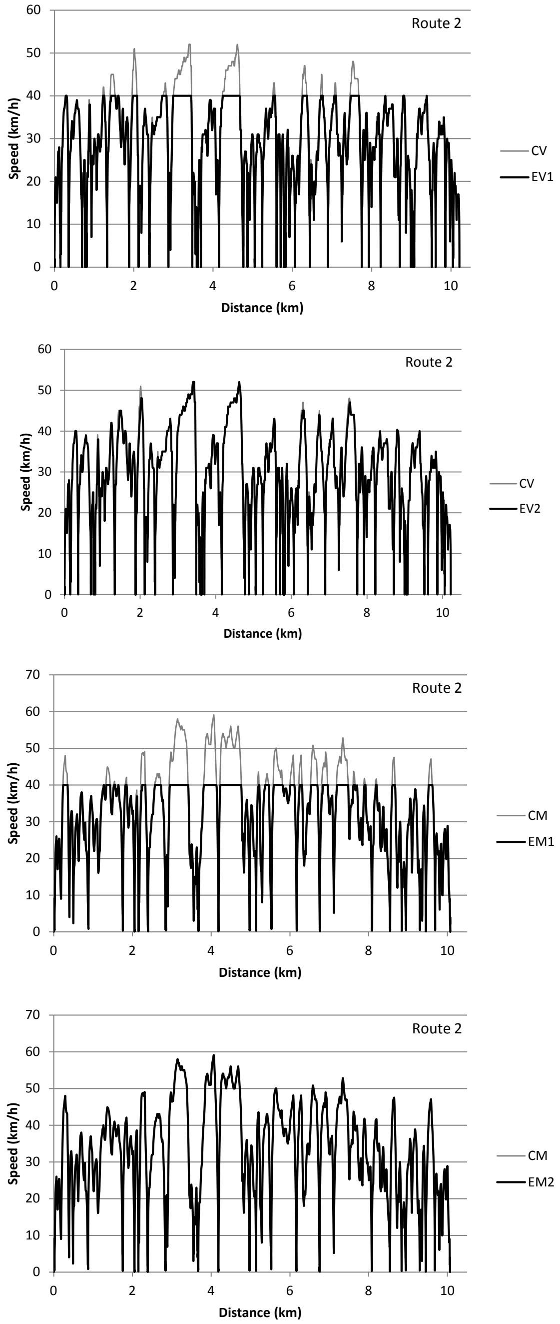

Figure 2: CV and CM drive cycles for the route 2.

These speed profiles are mainly limited by the surrounding traffic in both cases. However, the conventional motorcycle is less affected by that effect than the conventional vehicle, due to its ability to overcome traffic. This is reflected on a trip time ≈27% lower for the motorcycle compared to the vehicle. The main dynamic statistics for each of the vehicles is presented in Table 5 and Table 6.

Table 5: Statistics for the vehicles studied

Trip statistics	**Route 1**			**Route 2**		
	CV	**Variation Compared to CV**		**CV**	**Variation Compared to CV**	
		EV1	**EV2**		**EV1**	**EV2**
Trip time (min)	30	+12.8%	+2.8%	44	+0.8%	+0.2%
Average speed (km/h)	33	-11.4%	-2.7%	14	-0.8%	-0.1%
Maximum speed (km/h)	80	-50.0%	-6.0%	52	-23.1%	0.0%
Average positive acceleration (m/s^2)	0.56	+0.5%	-17.8%	0.59	+0.8%	-3.2%
Average negative acceleration (m/s^2)	-0.74	+2.9%	-5.3%	-0.64	+0.5%	0.0%

Table 6: Statistics for the motorcycles studied

Trip statistics	**Route 1**			**Route 2**		
	CM	**Variation Compared to CM**		**CM**	**Variation Compared to CM**	
		EM1	**EM2**		**EM1**	**EM2**
Trip time (min)	21	+24.5%	+0.1%	33	+2.5%	0.0%
Average speed (km/h)	43	-19.7%	0.0%	18	-2.4%	0.0%
Maximum speed (km/h)	94	-57.4%	-4.3%	59	-32.2%	0.0%
Average positive acceleration (m/s^2)	0.52	+6.5%	0.0%	0	-2.7%	0.0%
Average negative acceleration (m/s^2)	-0.53	-11.9%	-0.8%	0	-3.2%	0.0%

The trip statistics show that route 1 is more demanding than route 2, independently of the vehicle tested. Both speed and power limitations of electric technologies are more effective in route 1. In route 1, the low-powered vehicle and motorcycle present the highest increases in total trip time (12.8% in EV1 and 24.5% in EM1) compared with the conventional technologies. The electric technologies with higher power present total trip times comparable to the conventional solutions, suggesting that conventional solutions may be over-powered, particularly for these city driving profiles that were considered. Route 2 is a very congested avenue in the center of Lisbon and the speed profile is mainly dominated by traffic. Therefore, even the small powered electric solutions can follow the conventional solutions.

3.2 Energy consumption characterization

By adapting the driving profile according to the limitations of the electric mobility solutions, the energy and environmental impacts can be quantified. Therefore, the on-road monitoring of the electric and conventional vehicles was performed to build a database that allows to characterizing the vehicle's energy consumption profile per VSP mode.

For electric vehicles a modal analysis in a 1 W/kg basis was developed, while for conventional vehicles a 14 mode binning was adopted [16]. The energy consumption profiles of the measured electric vehicles (Figure 3 a), typical conventional vehicles (gasoline, diesel and hybrid, Figure 3 b) and conventional and electric motorcycles (Figure 3 c) are presented in the following Figure.

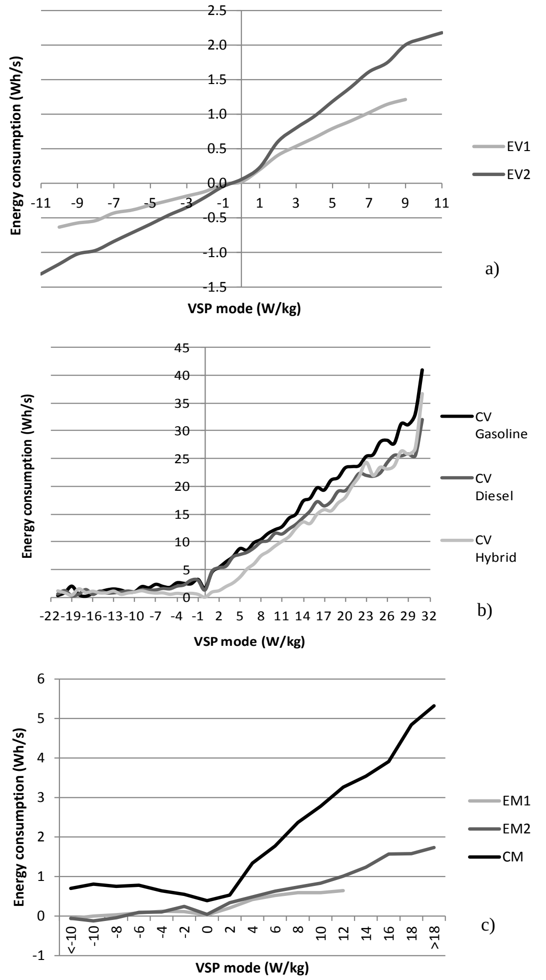

Figure 3: Energy consumption per VSP mode for EV1 and EV2 (a), typical conventional vehicles (b) and EM, EM1 and EM2 (c) resulting from the on-road monitoring.

Moreover, from the on-road monitoring, the time dirtibution in each VSP mode was obtained, as is presented in Figure 4. EV2 and EM2 tend to achieve higher power requirements, since they corrrespond to higher powered technolgies, when compared with EV1 and EM1, respectively. Furthermore, due to the conditions imposed by the EV-DC simulation tool, when the electric solutions are not able to follow the original driving cycle, they perform at its maximum power, hence the considerable amount of time spent on higher VSP modes.

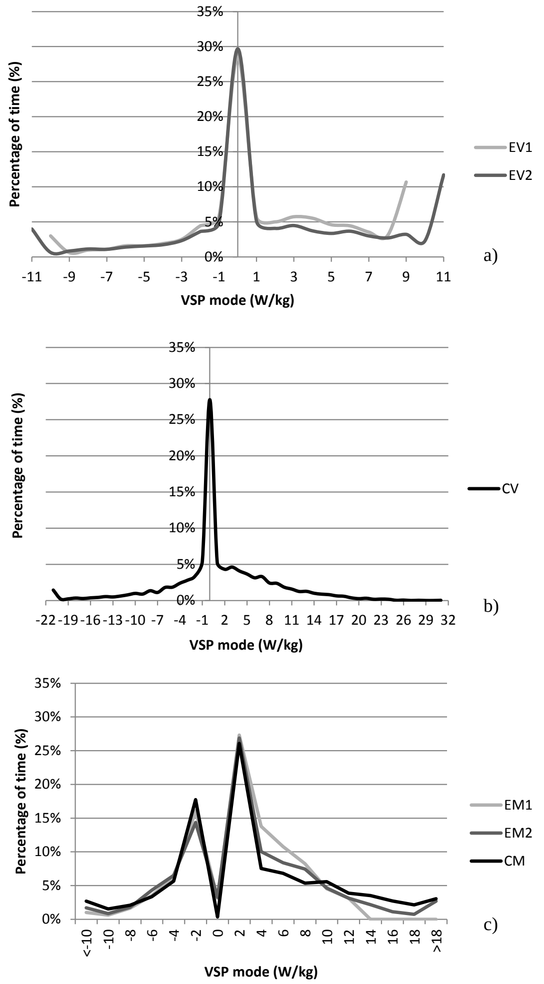

Figure 4: Time distribution (%) per VSP mode for EV1 and EV2 (a), conventional vehicle (b) and CM, EM1 and EM2 (c) resulting from the on-road monitoring.

Using the vehicles modal energy rates and the respective time in each mode, the total energy use is estimated, according to Eq. 2.

$$Total\ Fuel = \sum_{i=-21}^{31} Fuel_i \times t_i \qquad \text{Eq. 2}$$

Table 7 presents the energy consumption results for the studied routes. Five different vehicles were simulated: one spark-ignition (CV Gasoline), one compression-ignition (CV Diesel), one full hybrid vehicle (HEV) and the electric vehicles considered (EV1 and EV2).

Table 7: Energy consumption results for different vehicle technologies.

Vehicle	TTW Energy consumption					
	Route 1			Route 2		
	Wh/km	l/100km	MJ/km	Wh/km	l/100km	MJ/km
CV Gasoline	-	8.0	2.5	-	11.6	3.7
CV Diesel	-	6.1	2.2	-	8.8	3.1
CV Hybrid	-	5.2	1.7	-	5.0	1.6
EV1	54.7	0.6*	0.2	60.7	0.7*	0.2
EV2	91.3	1.0*	0.3	94.3	1.1*	0.3

Note: * gasoline equivalent

For the motorcycles, Table 8 presents the energy consumption results for considering the conventional gasoline motorcycle and the tested electric motorcycles.

Table 8: TTW Energy consumption results for different motorcycle technologies.

Motor-cycle	TTW Energy consumption					
	Route 1			Route 2		
	Wh/km	l/100km	MJ/km	Wh/km	l/100km	MJ/km
CM	-	2.3	0.7	-	3.3	1.1
EM1	47.6	0.5*	0.2	52.5	0.6*	0.2
EM2	70.4	0.8*	0.3	82.2	0.9*	0.3

Note: * gasoline equivalent

From these results, it stands out that route 2 presents the highest fuel consumption for all the vehicles considered, except the HEV. Due to its low average speed and low power profiles, the conventional vehicles are very affected by the amount of time spent under low engine loads. The HEV benefits from these conditions, where it takes advantage of the electric propulsion to power the vehicle (it should be noticed that electricity use is not considered in the HEV).
Comparatively, for vehicle technologies considered, the electric vehicles present a 9 and 11 times reduction in route 1 and 2 respectively. For the motorcycles, the shift from the conventional technology to the electric versions would represent a 4 and 5 times reduction in energy consumption in route 1 and 2, respectively.

3.3 Life-cycle comparison results

For a life cycle energy and environmental analysis of these technologies, the average performance in routes 1 and 2 was considered.
As a result, the TTW and WTT impacts of these different technologies are presented for energy consumption and CO_2 emissions in Figure 5 and Figure 6.
As seen in the previous section, electric drives are more efficient in the TTW stage. However, the electricity production stage must also be considered, since a shift in the energy production and consumption sectors is being performed.
The comparison of technologies allows concluding that in a WTW analysis, the use of EV1 and EV2 would reduce energy consumption in 7 and 4 times respectively. For CO_2 emissions, the reductions would be of 10 and 6 times, taking advantage of the zero local emissions in the TTW stage.
When analyzing the motorcycles, the reductions are not so high, with a 2 times average reduction for energy consumption and a 4 times reduction for CO_2 emissions.

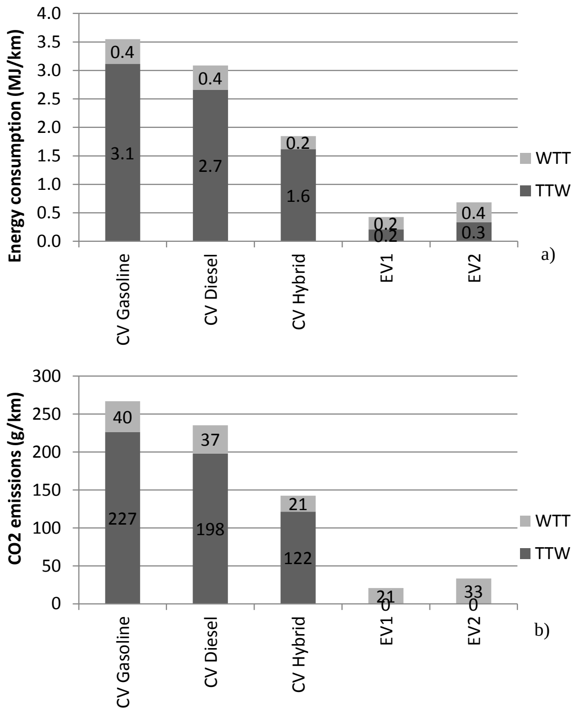

Figure 5: Life-cycle energy consumption (a) and CO_2 emissions (b) impacts for the vehicles considered.

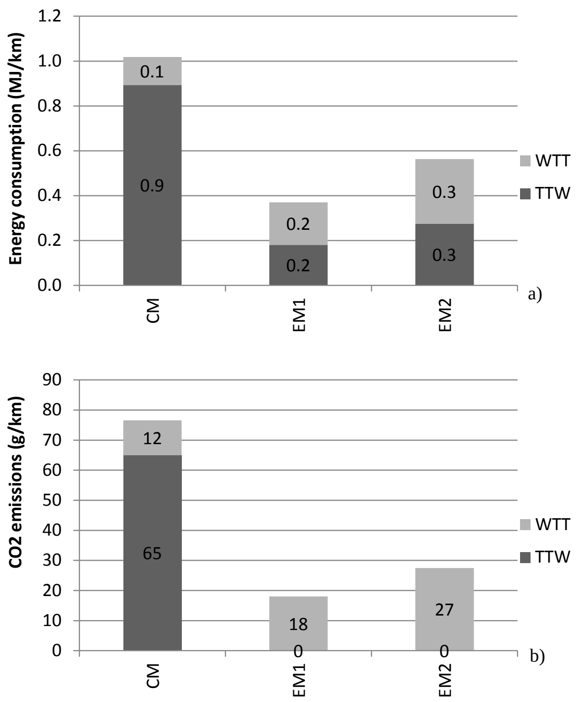

Figure 6: Life-cycle energy consumption (a) and CO_2 emissions (b) impacts for the motorcycles considered.

4 Conclusions

This research paper addresses the effect that low powered electric solutions have on urban driving cycles by taking as a starting point the driving cycles of conventional vehicles. Low power electric vehicles may be more attractive to the market due to its lower purchase costs. In this sense, a methodology and a software tool, Electric vehicle drive-cycle simulation tool (EV-DC), were developed to assess the applicability of these low-powered electric vehicles to replace their conventional counterparts, estimating the impacts on travel time and the associated benefits on energy and environment.

The results indicate that for the more demanding route the low-powered electric vehicle would lead to a reduction in average speed of up to 11%, increasing the trip time in 13%. For the low-powered motorcycles, in the more demanding route, reduction of up to 20% in average speed and, consequently, up to 25% increases in trip time.

Additionally, the energy consumption associated to these technologies was estimated, based on on-road monitoring data. The VSP methodology was used, in order to characterize the vehicles' power requirements time distribution and energy consumption profiles. From the technologies analyzed, EV2 and EM2 tend to comply with higher power requirements, since they corrrespond to higher powered technolgies, when compared with EV1 and EM1, respectively. Additionaly, in terms of route comparison, route 2, due to its lower speed profile, has higher fuel consumption for all the vehicles considered, except the HEV. In terms of fuel efficiency, the electric technologies considered may reduce the TTW energy consumption in average 10 times for the vehicles and 4 times for the motorcycles. However, the electrification of the transportation sector must be addressed in a WTW approach, considering both the usage and the production of electricity. In that sense, these reductions in energy consumption in WTW account for 5 times reductions for vehicles and 2 times for motorcycles. If this analysis if performed for CO_2 emissions, this reduction reaches 8 times for vehicles and 4 times for motorcycles.

This methodology corresponds to an innovative way of understanding how low-powered electric technologies, both vehicles and motorcycles, would perform in specific applications, both in terms of trips statistics and of energy and environmental performance. The application market of these low-powered technologies will most probably deal with city logistics operations (such as mail and groceries deliveries, garbage collection, parking collection, among others) with low vehicle range or speed requirements.

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References

1. EUROSTAT, *Environment and Energy, EUROPA Eurostat – Data Navigation Tree*, http://ec.europa.eu/eurostat, 2013 [cited May 2013].
2. IEA, *Energy Technology Perspectives, scenarios & strategies to 2050 by International Energy Agency*, 2010.
3. Baptista, P., Tomás, M., Silva, C., *Plug-in hybrid fuel cell vehicles market penetration scenarios*, International Journal of Hydrogen Energy, 2010, 35(18), p. 10024-10030.
4. Pina, A., Ioakimidis, C., Ferrão, P., *Introduction of electric vehicles in an island as a driver to increase renewable energy penetration*, in *IEEE International Conference on Sustainable Energy Technologies 2008*, 2008, Singapore
5. Baptista, P., C. Silva, T. Farias, and J. Heywood, *Energy and environmental impacts of alternative pathways for the Portuguese road transportation sector*, Journal of Energy Policy, 2012, 51, p. 802–815.
6. Berger, R., *Powertrain 2020 - The Future Drives Electric* 2009.
7. MEI, *Electric Mobility, Portugal - A pioneer in defining a national model by Ministry of Economy and Innovation*, 2009, Lisbon.
8. ACAP, *Statistics - Vehicle sales*, 2012, Automobile Association of Portugal.
9. Weinert, J., J. Ogden, D. Sperling, and A. Burke, *The future of electric two-wheelers and electric vehicles in China*, Energy Policy, 2008, 36(7), p. 2544–2555.
10. IEA, *World Energy Outlook 2010 by International Energy Agency*, 2010.
11. Bishop, J., et al., *Investigating the technical, economic and environmental performance of electric vehicles in the real-world: A case study using electric scooters*, Journal of Power Sources, 2011, 196, p. 10094–10104.
12. Duarte, G., G. Gonçalves, and T. Farias, *Development of a Portable Laboratory for On-Road Measurement of Hybrid Electric and Battery Electric Vehicles*, in *21st CRC Real World Emissions Workshop*, 2011, San Diego, USA.
13. Jiménez-Palacios, J., *Understanding and Quantifying Motor Vehicle Emissions with Vehicle Specific Power and TILDAS Remote Sensing*, 1999, Massachusets Institute of Technology.
14. Baptista, P., et al., *Scenarios for electric bicycle use: from on-road monitoring to possible impacts of largeintroduction*, in *NECTAR Conference on Dynamics of Global and Local Networks*, 2013, São Miguel Island, Azores (Portugal).
15. Duarte, G., G. Gonçalves, and T. Farias, *Vehicle monitoring for driver training in bus companies - Application in two case studies in Portugal*, Transportation Research Part D: Transport and Environment, 2013, 18, p. 103-109.
16. Zhai, H., et al., *Comparison of Flexible Fuel Vehicle and Life-Cycle Fuel Consumption and Emissions of Selected Pollutants and Greenhouse Gases for Ethanol 85 Versus Gasoline*, Journal of the Air & Waste Management Association, 2009, 59(8), p. 912-24.

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