The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION.
Barcelona, Spain
17th-20th November 2013

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

Patrícia Baptista, Gonçalo Duarte, Gonçalo Gonçalves, Tiago Farias
IDMEC - Instituto Superior Técnico, Universidade de Lisboa,
Av. Rovisco Pais, 1 - 1049-001 Lisboa – Portugal

Organized by
Hosted by
In collaboration with
Supported by

Research areas

Tiago Farias

Vehicle Simulation and Energy Sources	Energy and environmental impacts and Behavior	Urban Transport	Urban Accessibility	User/Technology Interaction
Carla Silva	Patrícia Baptista	Sandra Melo	Ana Vasconcelos	Gonçalo Gonçalves
Vehicle simulation, energy management optimization, LCA	Fleet impacts, LCA, Electric mobility, ICT in urban mobility, Policy implications, Driver behavior	Alternative Modes, Intermodal Transport, Freight Transport and Distribution	Local accessibility indicators Soft mode's accessibility PM Exposure	Trip monitoring and analysis, driver training, impacts quantification

TEEL – Transport, Energy and Emissions Lab:
monitoring softmodes (pedestrians, bicycles, etc.), conventional and alternative vehicle technologies

Software and numerical tools: Ecogest, RVS, PATTS, CleanDrive, Gabi, LAI, AIMSUN, Legion

Introduction

- Transportation sector faces increasingly demanding energy consumption and emissions outcomes
  - 33% of the final energy consumption, with the road transportation sector being responsible in 2011 for 82% of that energy consumption

- Alternative vehicle technologies and energy sources
  - Electric mobility (EV, PHEV…)

Introduction

evs 27

TÉCNICO LISBOA

idmec

- Portuguese context:

National charging grid

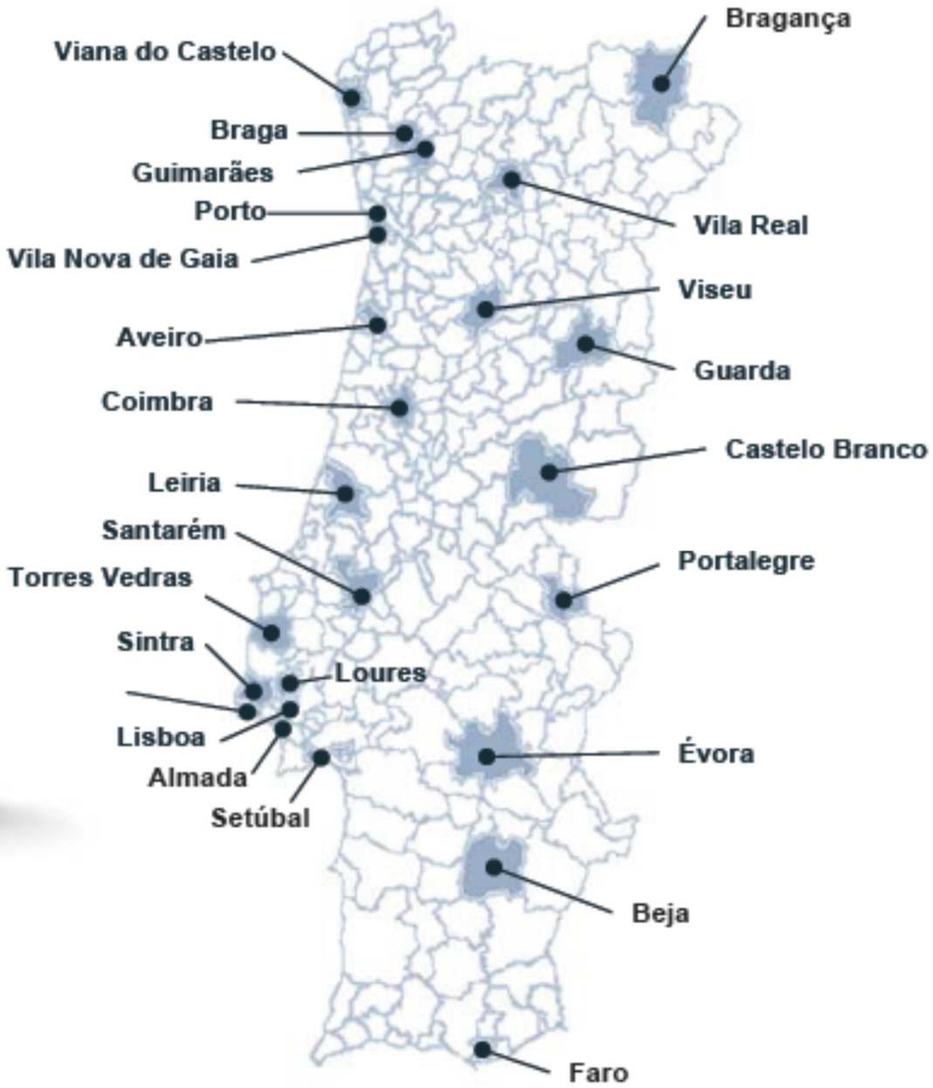
MOBI.E
MOBILIDADE ELÉCTRICA

1.300 slow charging stations

50 fast charging points

25 pilot cities

25 Cities



Organized by

Fira Barcelona avele

Hosted by

AVERE

Ajuntament Barcelon

Introduction

- Portuguese context:

National charging grid

ca. <u>550 charging stations</u>

Lisbon charging points network, Project MOBI-E

Introduction

- Portuguese context:

  National charging grid

  High penetration of renewable energy in electricity mix (45% RER in 2012)

Introduction

- Portuguese context:

  National charging grid

  High penetration of renewable energy in electricity mix

  Green Parking Permit for EV users that join the project
  (ca. 40 members joined the program)

EVS27

Introduction

TÉCNICO LISBOA

idmec

- Portuguese context:
  - **National charging grid**
  - **High penetration of renewable energy in electricity mix**
  - **Green Parking Permit for EV users that join the project**
  - **Electrification of Lisbon Municipal Fleet**

Introduction

- Portuguese context:

National charging grid

High penetration of renewable energy in electricity mix

Green Parking Permit for EV users that join the project

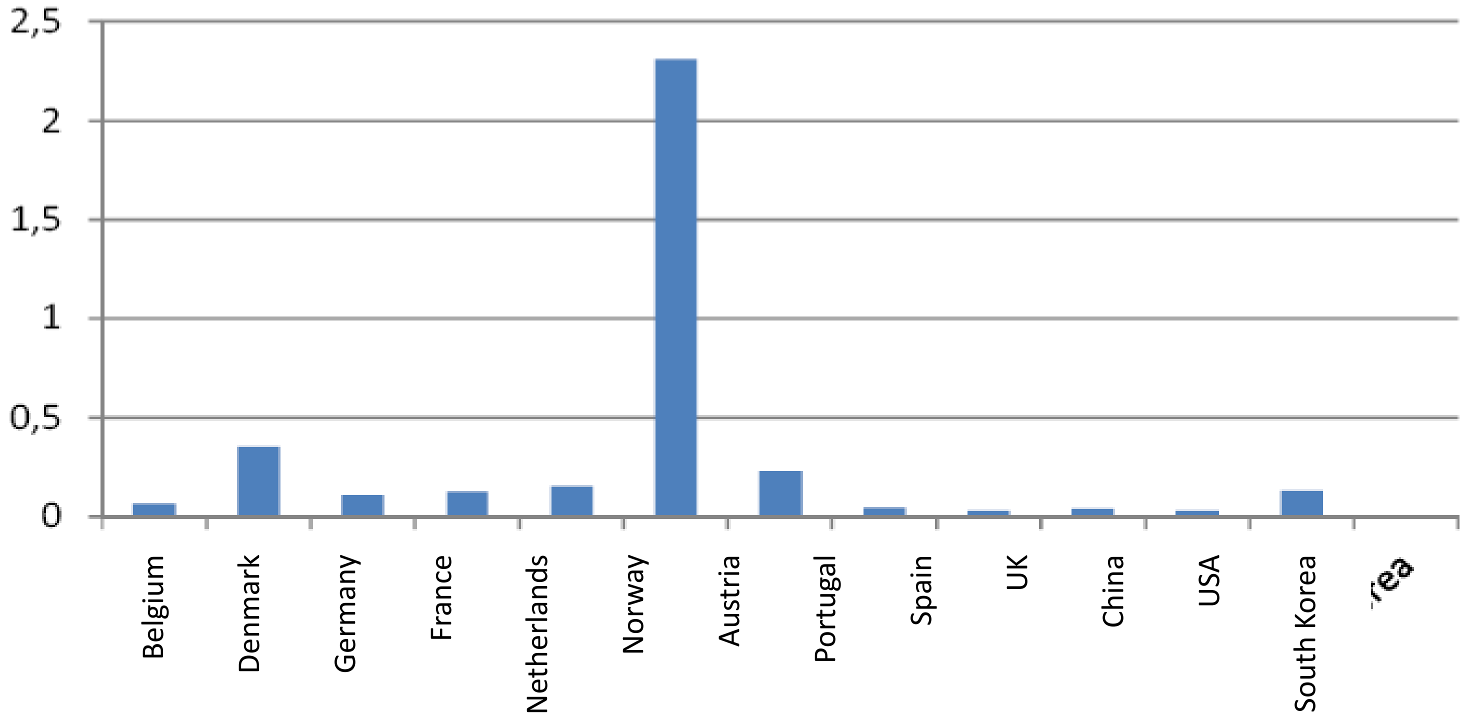
Electrification of Lisbon Municipal Fleet

Electrification of Lisbon Taxi Fleet

(20 electric taxis)

Introduction

- Number of electric cars per 1000 passenger cars (2012)



Adapted from Weeda, M., P. Kroon and D. Appels (2012) Elektrisch vervoer in Nederland in internationaal perspectief, ECN/Agentschap NL, Petten

Introduction

- Due to high purchase cost, little market availability, and type of early adopters vehicle utilization/applications:

Low powered electric vehicles

Vehicles (Toyota Coms, REVA, etc.)

Motorcycles (Guewer, Ekoway, etc)

Will they have the same performance?

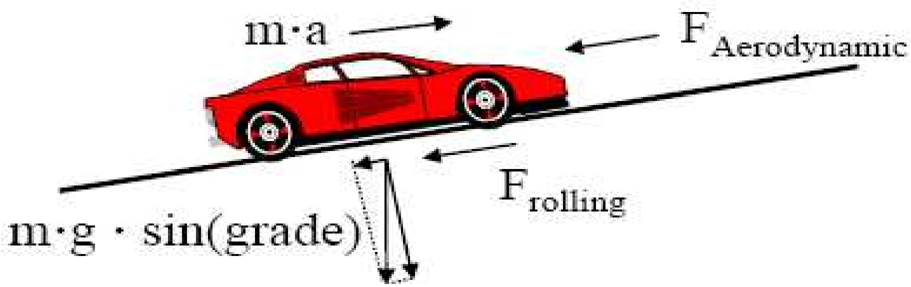
Objectives

- Develop a methodology to **estimate the driving cycle of electric low power mobility solutions**, on a given route, considering speed, acceleration and road topography

- **Evaluate if these alternative electric technologies can fully replace**, in terms of driving profile, the **conventional technologies** and assess their energy and emission performance, as well as travel time

Methodology

- Vehicle Specific Power (VSP) - estimate the power demand by vehicles, which combines speed (v), acceleration (a) and road grade (θ).



$$VSP = \frac{\frac{d}{dt}(E_{Kinetic} + E_{Potential}) + F_{Rolling} \cdot v + F_{Aerodynamic} \cdot v}{m}$$

$$VSP = v \cdot (1.1 \cdot a + 9.81 \cdot grade + 0.132) + 3.02 \cdot 10^{-4} \cdot v^3$$

Table 1: Coefficient values for the variables included in VSP

Variables	Coefficient			
	Vehicle		Motorcycle	
	Conventional	Electric	Conventional	Electric
Effect of translational mass of powertrain rotating components, ε	0.1		0.01	
Gravitational constant, g (m/s²)	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			

Methodology

- 6 vehicles analyzed: conventional vehicle (CV) and motorcycle (CM); two low-powered electric vehicles (EV1 and EV2); and two electric motorcycles (EM1 and EM2)

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

eVS 27

Methodology

TÉCNICO LISBOA

idmec

- 6 vehicles analyzed: conventional vehicle (CV) and motorcycle (CM); two low-powered electric vehicles (EV1 and EV2); and two electric motorcycles (EM1 and EM2)

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




Methodology

- 6 vehicles analyzed: conventional vehicle (CV) and motorcycle (CM); two low-powered electric vehicles (EV1 and EV2); and two electric motorcycles (EM1 and EM2)
- 2 routes in the city of Lisbon were selected: One route comprehends traffic intensive avenues and side roads with very little traffic; another with 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

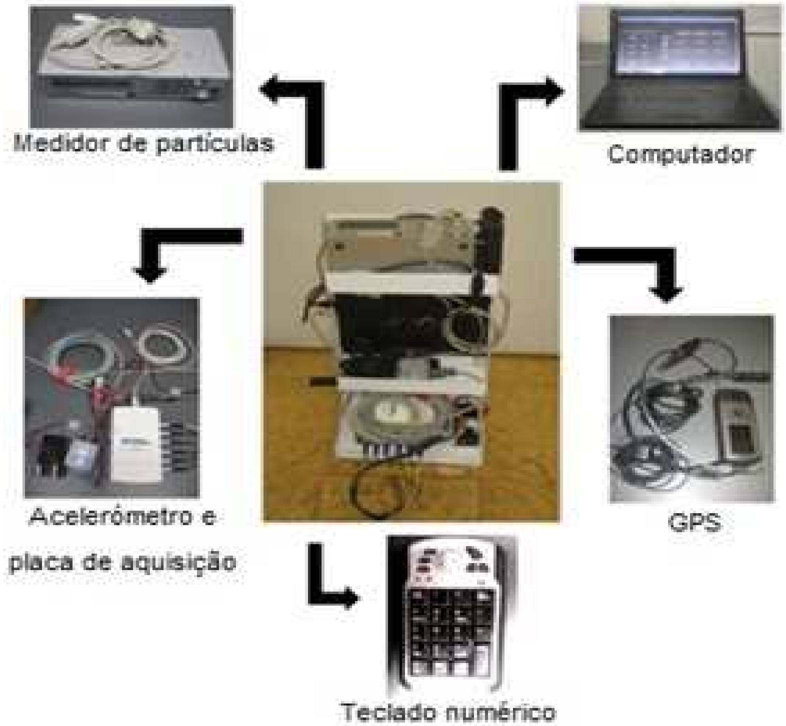
Methodology

- 6 vehicles analyzed: conventional vehicle (CV) and motorcycle (CM); two low-powered electric vehicles (EV1 and EV2); and two electric motorcycles (EM1 and EM2)
- 2 routes in the city of Lisbon were selected: one route comprehends traffic intensive avenues and side roads with very little traffic; another with a demanding topography profile

On road monitoring with portable laboratory

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



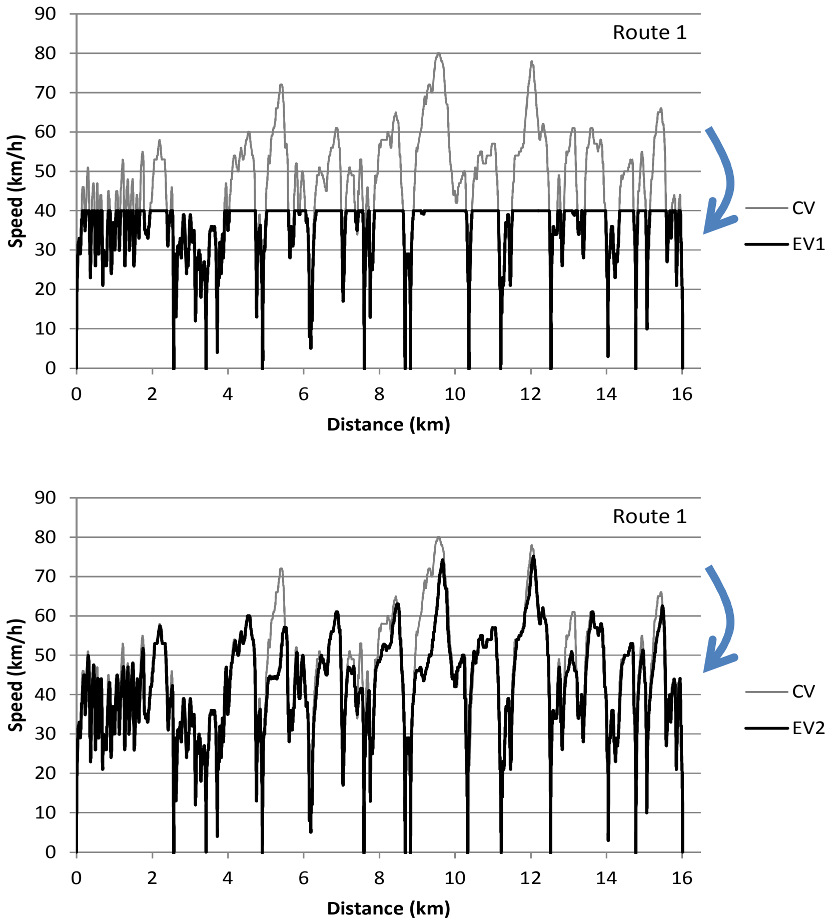
Methodology

- **Electric Vehicle Drive-Cycle simulation tool (EV-DC)**
  - **Iterative software** for obtaining the simulated drive cycle
  - This software tool verifies second by second if the **electric vehicle is able to fulfill the power and speed demands** of the conventional vehicle. If it is not able to equal those requirements, the electric vehicle performs at its **maximum power or speed**.
  - 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.

Results

Application of EV-DC

Influence on drive cycles for the route 1 - vehicles

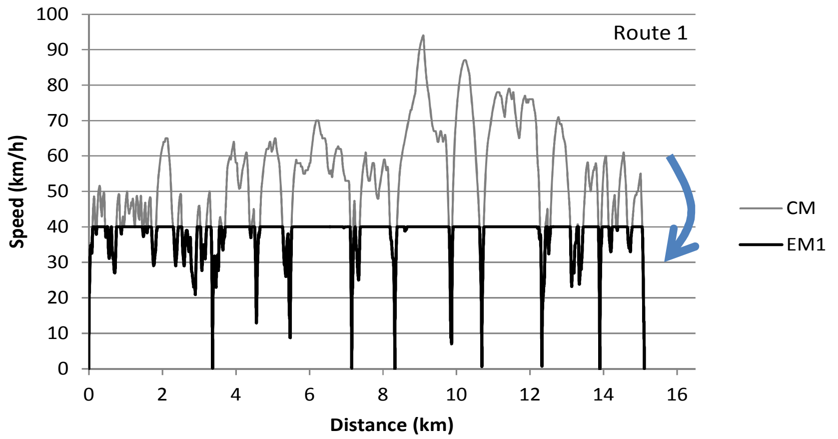


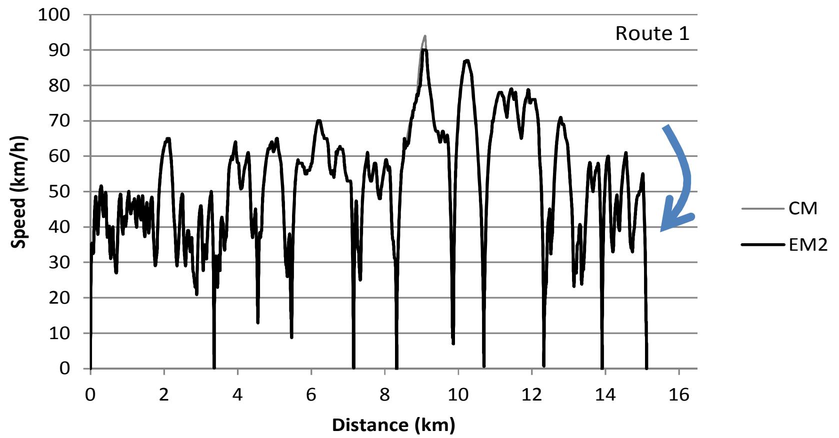
- 3 to 12% increase in trip time and similar reduction in average speed
- 6 to 50% reduction in maximum speed

Results

Application of EV-DC

Influence on drive cycles for the route 1 - motorcycles



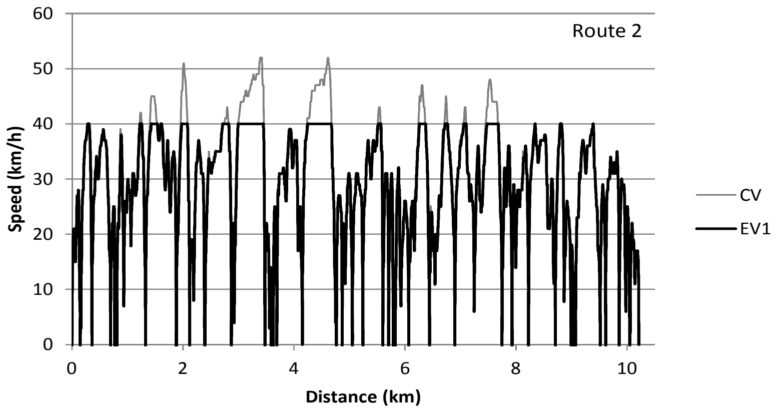


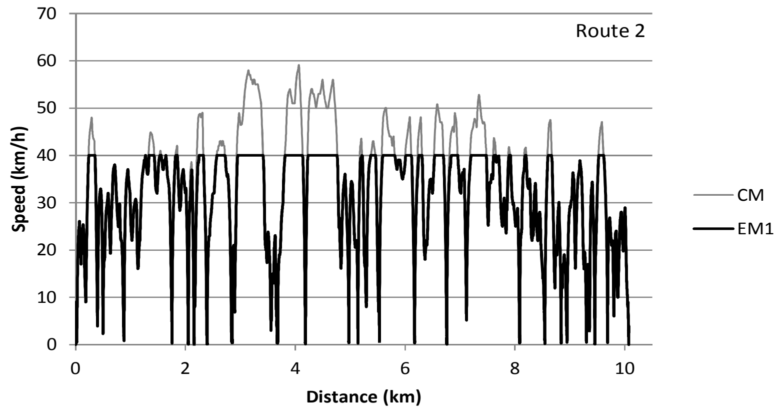
- Up to 25% increase in trip time
- 4.3 to 57.4% reduction in maximum speed

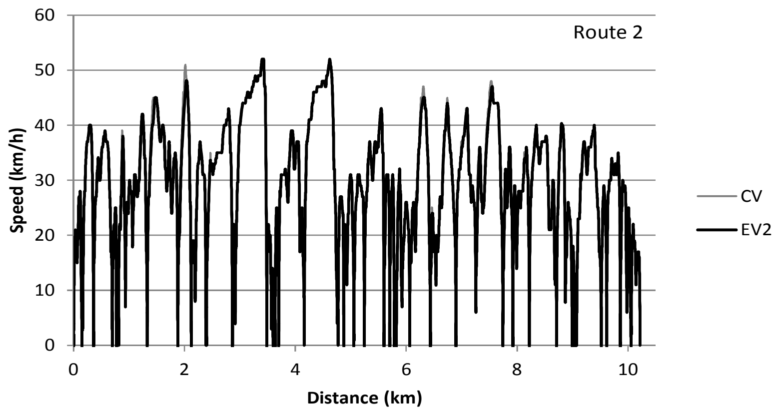
Results

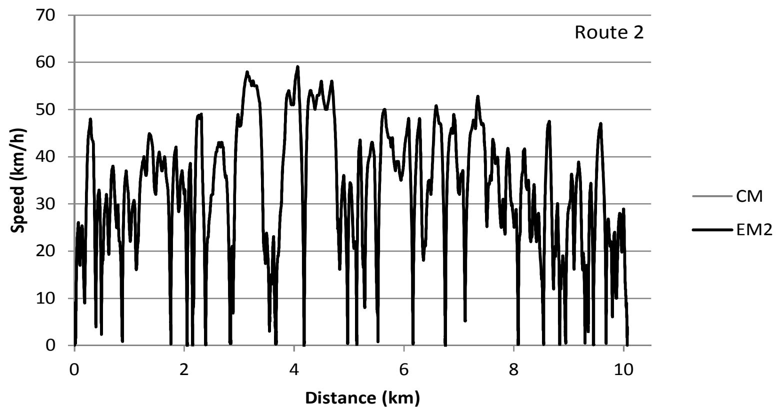
Application of EV-DC

Influence on drive cycles for route 2









Organized by Fira Barcelona avele
Hosted by AVERE
In collaboration with Ajuntament de Barcelona
Supported by European Commission

evs27

Results

Application of EV-DC

TÉCNICO LISBOA

idmec IST engenharia mecânica

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%

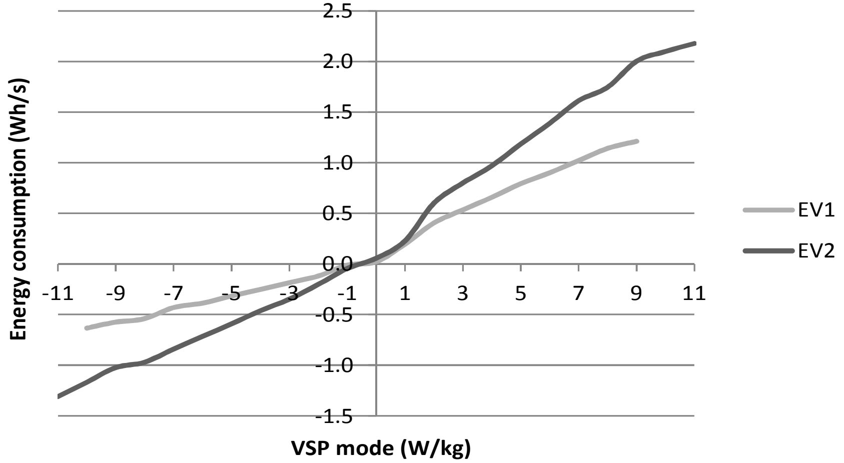
Table 6: Statistics for the motorcycles studied

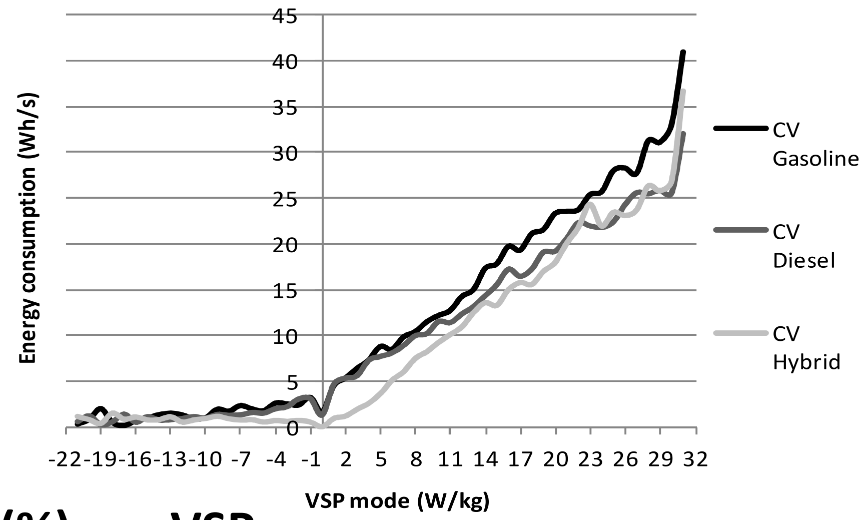
Trip statistics	Route 1			Route 2		
	CM	Variation Compared to CM		CM	Variation Compared to CM	
		EM1	EM2		EM1	EM2
Trip time (min)	21	+24.5%	+0.1%	33	+2.5%	0.0%
Average speed (km/h)	43	-19.7%	0.0%	18	-2.4%	0.0%
Maximum speed (km/h)	94	-57.4%	-4.3%	59	-32.2%	0.0%
Average positive acceleration (m/s^2)	0.52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

Results

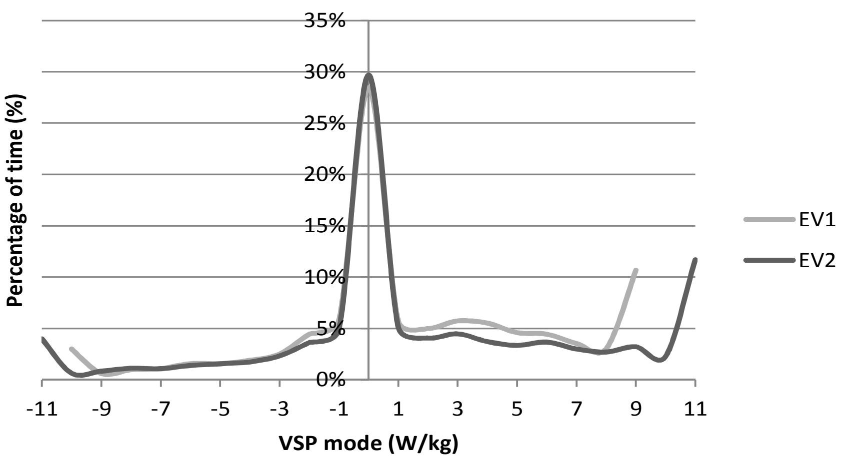
On-road monitoring - vehicles

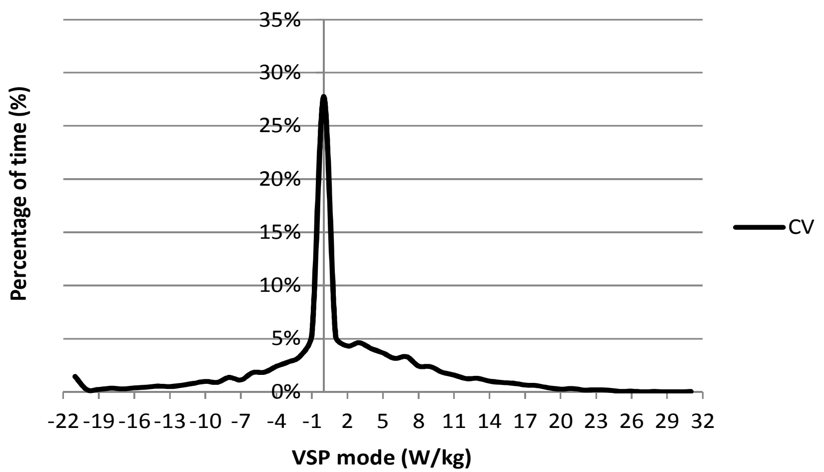
Energy consumption per VSP





Time distribution (%) per VSP





Results

Energy impacts - vehicles

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

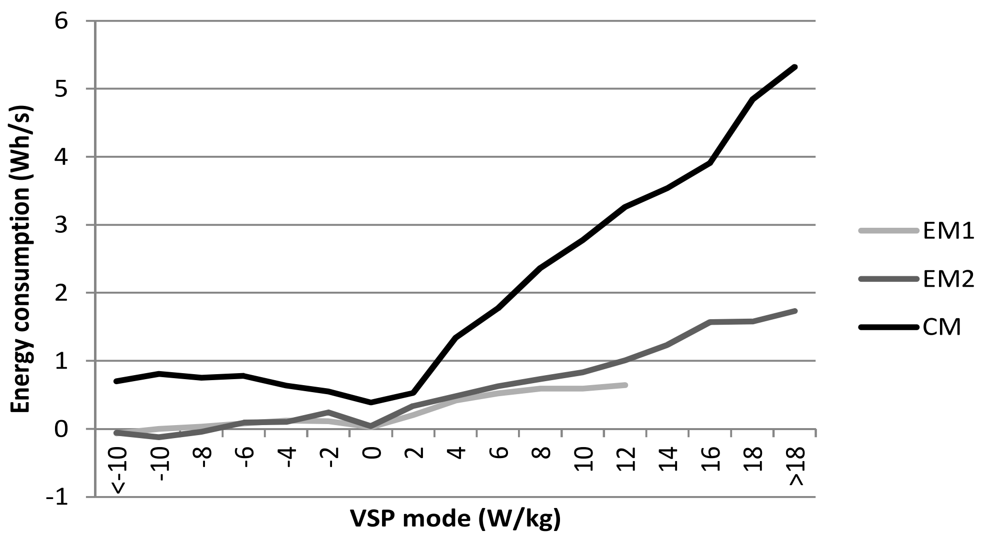
Note: * gasoline equivalent

- 86 to 93% reduction in TTW energy consumption

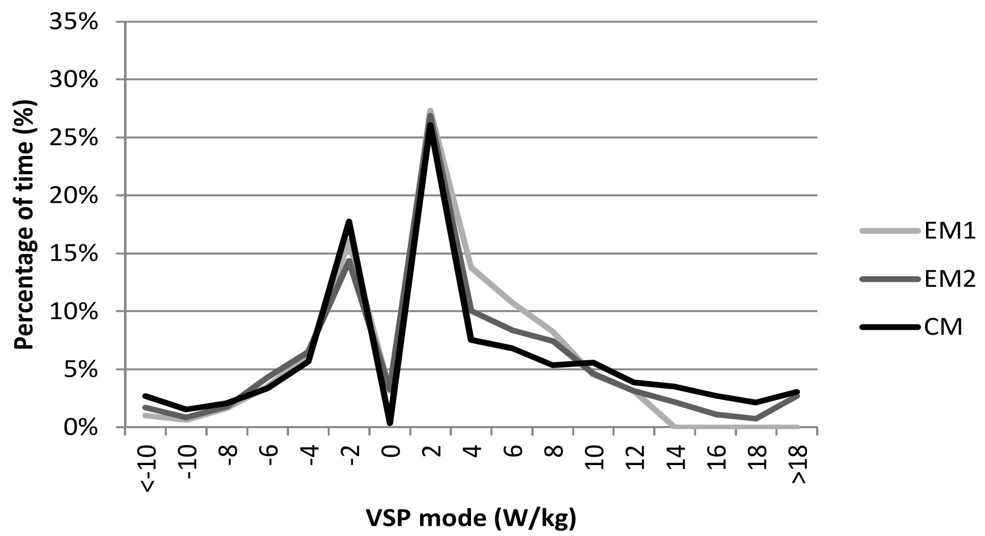
Results

On-road monitoring - motorcycles

Energy consumption per VSP mode



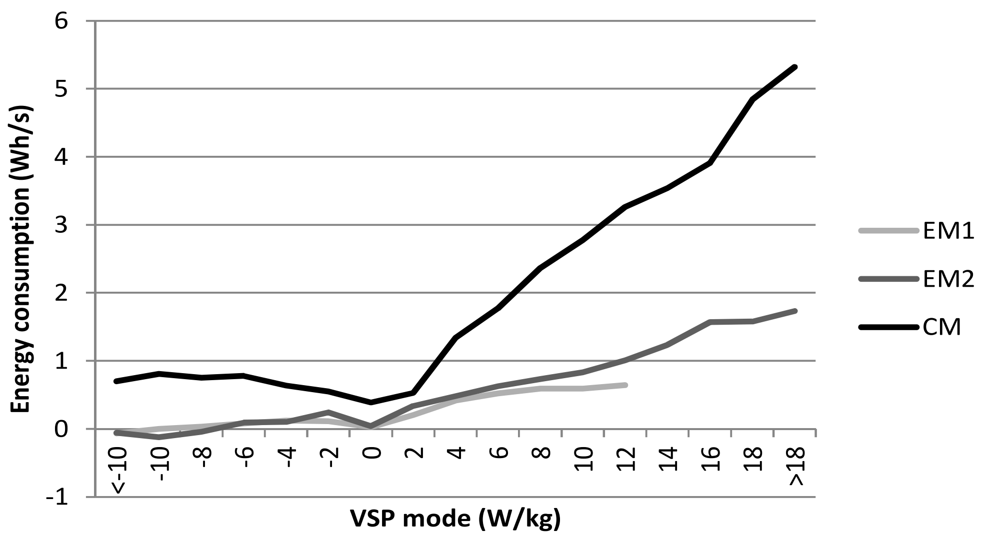
Time distribution (%) per VSP



Results

On-road monitoring - motorcycles

Energy consumption per VSP mode



Time distribution (%) per VSP

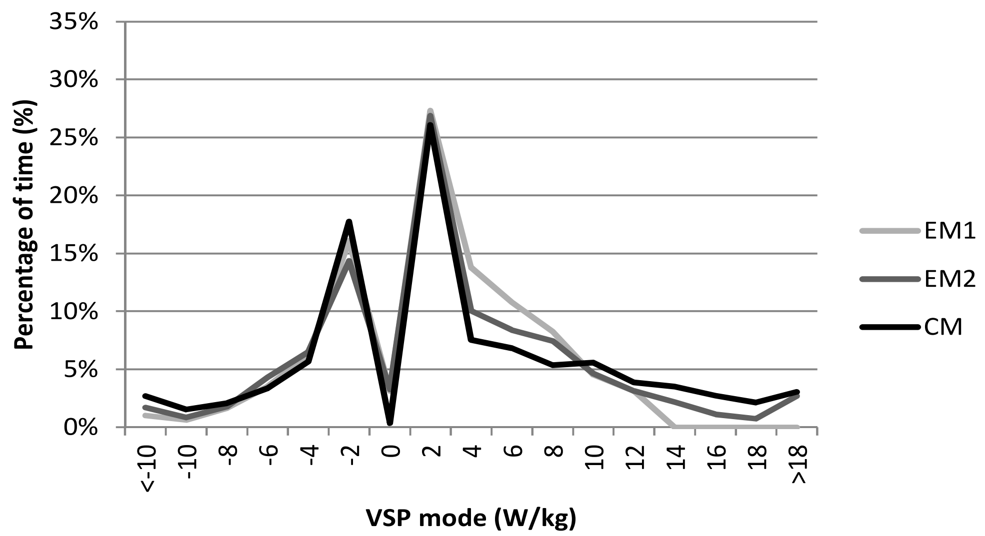


Table 8: TTW Energy consumption results for different motorcycle technologies.

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

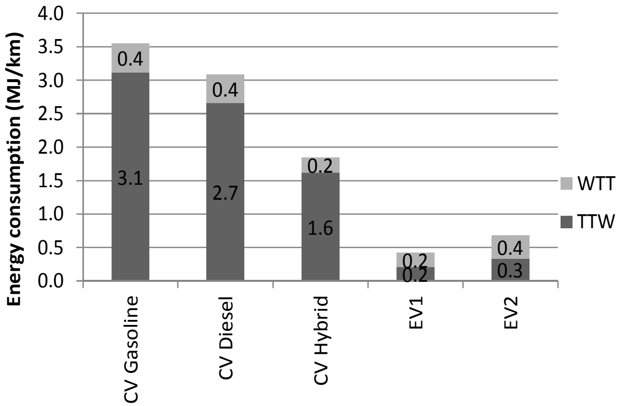
Note: * gasoline equivalent

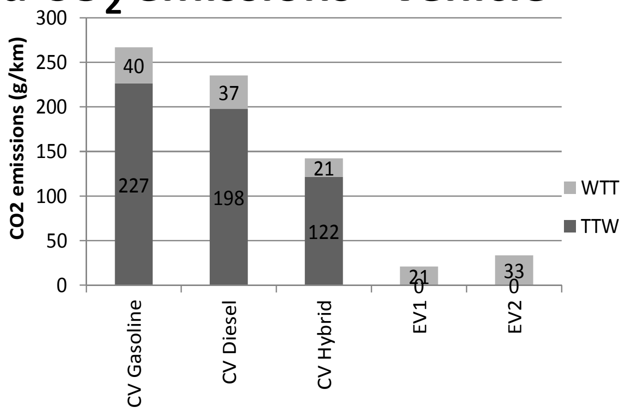
- 57 to 82% reduction in TTW energy consumption

Results

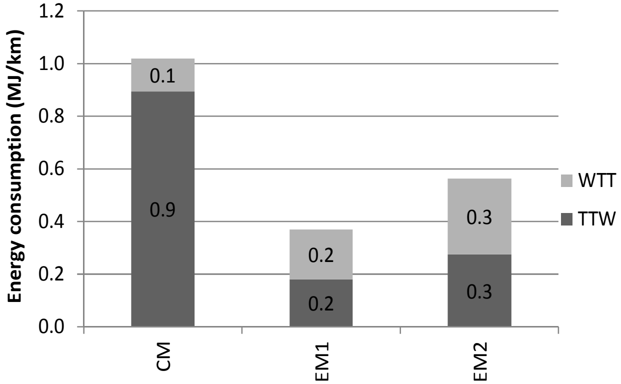
LC impacts

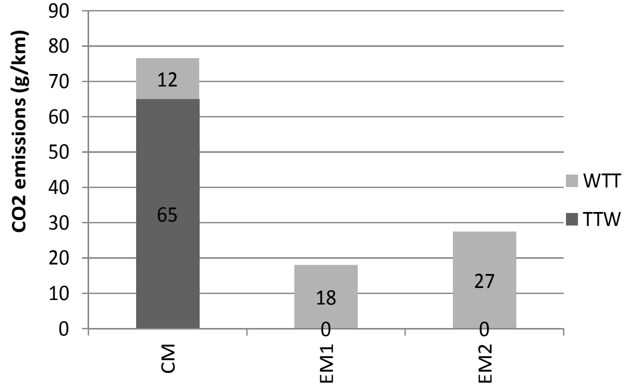
Life-cycle energy consumption and CO_2 emissions - vehicle





Life-cycle energy consumption and CO_2 emissions impacts - motorcycles





Conclusions

- 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. -> **Electric vehicle drive-cycle simulation tool** (EV-DC)
- 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.

Conclusions

- Trip impacts for the more demanding route:
  - Low-powered electric vehicle would lead to a **reduction in average speed of up to 11% and increasing the trip time**
  - Low-powered motorcycles would allow **reductions of up to 20% in average speed and, consequently, increases trip time**
- Energy impacts
  - The electric technologies considered may **reduce the TTW energy consumption in average 10 times for the vehicles and 4 times for the motorcycles**
  - 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.**

evs 27

Acknowledgments

TÉCNICO LISBOA

idmec

- The authors would like to acknowledge the sponsors of the research: **Toyota Portugal, Eco-critério and EMEL**.

- Thanks are also due to **Fundação para a Ciência e Tecnologia** for the PhD and Post-Doctoral financial support (SFRH / BPD / 79684 / 2011, SFRH / BPD / 62985 / 2009, SFRH / BD / 61109 / 2009).