Green eMotion

Development of a European Framework for Electro-mobility

Deliverable 1.8

Second Report on EVs in Fleets

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List of Abbreviations

BEV	Battery Electric Vehicle
CMS	Charge management system
DoW	Description of Work (Annex I of Grant Agreement)
DSO	Distribution system operator
ESB	Electricity Supply Board
EV	Electric vehicle
EVCC	Electric Vehicle Communication Controller
EVSE	Electric vehicle supply equipment
EVSP	Electric vehicle service provider
FBEV	Fixed Battery Electric Vehicle
GeM	Green eMotion
ICT	Information Communication Technology
ICE	Internal Combustion Engine
KPI	Key Performance Indicator
MEWP	Mobile Elevated Working Platform
OEM	Original Equipment Manufacturer, i.e. Electric Vehicle manufacturer
PSV	Public Service Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
RES	Renewable energy source
RFID	Radio frequency identification
SBEV	Switchable Battery Electric Vehicle
SECC	Supply Equipment Communication Controller
TCO	Total Cost of Ownership
WP	Work Package
ZEV	Zero Emissions Vehicle

1 Executive Summary

This deliverable is the second interim report on the use of Electric Vehicles in fleets and as such builds on the first report setting the scene for more further tangible results in the final report (D1.9) due towards the end of the Green eMotion project. It will describe the types of EV's and their uses in fleet scenarios.

Documenting real life scenarios, the report shows successful use of EV technologies including any specific challenges encountered. These scenarios include office car pools, taxi services, urban bus routes and urban deliveries. The different types of electric transport are compared with alternative Internal Combustion Engine technologies.

The aim of the report is to provide detail of some of the existing fleets across Europe, for use by all actors in the EV industry to assist in further developing a sustainable EV fleet. Vehicle OEM's will gain a greater knowledge of the real life experiences, allowing more tuned response to customer demand. Policy makers both in member state countries and at European level can gain greater insight into the challenges of developing a cleaner transport infrastructure. Fleet managers will find the tools to better assess the appropriate introduction or expansion of an EV fleet, providing the main points to be considered.

Electric bicycles are seen to provide alternative means of transport over ICE vehicles where conventional bicycles are not always practical. The potential for wider exploitation of this method of transport is significant.

EVs as taxis have been assessed in Dublin and are seen to provide a good alternative to ICE vehicles. The range limitations and speed of battery replenish are limiting but not excluding factors, allowing substantial opportunity in this area. A modest range increase combined with wider access to fast battery replenish would greatly increase the penetration levels.

The report assesses the success of an urban bus route in Copenhagen and highlights the opportunity for fixed route uses, while acknowledging the limitations in available bus technology at this point in time. This route is operated solely with EVs driving back to back journeys for full day shifts.

Urban deliveries are seen to offer great opportunities for use of EVs. The importance of route and use assessment is highlighted to ensure that the chosen technology is sufficient for the use case. Once the right fit has been achieved the benefits are wide, including fuel and maintenance costs as well as the noise, emissions and comfort factors.

The success of a car pool scheme at companies in Ireland and Spain have been recorded, while the proven use has triggered steps to expand the scheme. The use case has been assessed for capital costs, running costs and emissions as against the alternative means of transport such as taxis. The opportunities in this area are great, particularly for medium to large companies where the employee base is sufficient to support the investment in EVs.

Fuel costs have been assessed, showing the trends over previous years, giving a clear indication of the future opportunity to control the cost of transport energy for fleet managers through the use of EVs. On top of this the cost of maintenance has been assessed, comparing ICE's with EV's. The expanding EV industry is acknowledged showing the trend towards further opportunities to reduce maintenance and repair costs due to the wide availability of EV service centres from an expanded number of suppliers.

The developing market and growing selection of vehicles is evident, providing confidence to the fleet purchaser in the commitment of policy makers, the auto industry and the other actors in the EV field. The growth in OEM built vehicles will also have a positive impact on the cost of running a 'stage' built EV, due to the wider availability of service expertise.

As the Green eMotion project continues, the data gathered is all the time increasing. In the final report this additional data will allow the project to describe in detail the overall EV fleet scenario in Europe, including the effect of climate on EV use in the demonstration regions. The indicators at this point in time show that the EV industry has reached a point where EV fleets are sustainable, while the identification of real life challenges through this report will support the industry in developing a road map to further facilitate the exploitation of this clean transport solution.

2 Definition

A Fleet Vehicle as described in this report refers to any vehicle, two wheeler or above used in connection with commercial or public business by a private company, public body or institute. It excludes any vehicle used solely for private purposes. The quantity of vehicles included within a fleet is not discriminated against.

3 Technologies

With partners drawn from 12 countries and 10 demonstration regions, GeM is evaluating and demonstrating a comprehensive range and variety of types of Electric Vehicle. Every vehicle type from Pedelec to cars, buses and Trucks are represented in the fleets being evaluated by GeM partners in Denmark, France, Germany, Ireland, Italy, Spain and Sweden.

It is necessary to present a definition of the various terms and to describe examples of vehicle types to demonstrate the added value being delivered by Green eMotion.

3.1 Drive Types

The following section describes the main drive types commonly found in fleet vehicles. The intention is to give a clearer understanding of the inclusions within technology types and the boundaries between them as used in fleet scenarios.

Zero emission vehicle (ZEV): A vehicle that has no regulated emissions from the exhaust pipe or tailpipe.

ZEV is one of the most important definitions from the point of view of developing enabling measures and legislation to support the uptake of EV’s. Both Climate Change strategies and the need to provide healthy cities for the future require reductions in CO_2 and Noise. Measures to address noise in cities are now being regulated by European Directive which has been transposed into national legislation throughout the EU.

European cities have a variety of ‘Toolkits’ available when it comes to regulation and the implementation of control measures to support the economic development of city centres. However, the potential enhancement offered by more widespread deployment of EV’s has yet to be exploited in support of declared objectives. The availability of a variety of Zero Emissions Vehicles across the range of vehicle types opens up a Virtuous Cycle as between the deployment of EV’s in fleets and Climate Change Strategies especially for cities.

A **Battery Electric Vehicle** (BEV): The Battery Electric Vehicle is a vehicle which is powered by battery energy store only. The vehicle has no internal combustion engine, it is propelled by an electric motor, powered by a battery pack. The vehicle is recharged by connection to an external power supply and has no on board generation capacity.

Hybrid electric vehicle (HEV): The 1990s definition of IA-HEA Annex 1 was “a hybrid electric vehicle (HEV) is a hybrid road vehicle in which at least one of the energy stores, sources or converters delivers electric energy”. The International Society of Automotive Engineers (SAE) defines a hybrid as “a vehicle with two or more energy storage systems, both of which provide propulsion power, either together or independently”. Normally, the energy converters in a HEV are a battery pack, an electric machine or machines, and internal combustion engine, ICE. However, fuel cells may be used instead of an ICE. In a hybrid, only one fuel ultimately provides motive power. One final definition is from the UN, which defines a HEV as “a vehicle that, for the purpose of mechanical propulsion, draws energy from both of the following on-vehicle sources of stored energy/power: a consumable fuel, and an electrical energy/power storage device (e.g.: battery, capacitor, flywheel/generator, etc.).”

Hybrid Electric Vehicle (HEV): - *Parallel configuration*: A parallel hybrid is a HEV in which both an electric machine and engine can provide final propulsion power.

Hybrid Electric Vehicle (HEV): - *Series configuration*: A series hybrid is a HEV in which only the electric machine can provide final propulsion power.

Plug in Hybrid Electric Vehicle (PHEV): A HEV with a battery pack with a relatively large amount of kWh of storage capability, with the ability to charge the battery by plugging into the electricity grid. This allows two fuels to provide the propulsion energy giving the possibility of extended ranges where necessary and at the same time benefiting from cleaner more efficient electrical energy from the electricity network.

Internal Combustion Engine (ICE): Historically the most common means of converting fuel energy to mechanical power in conventional road vehicles. Air and fuel are compressed in cylinders and ignited intermittently. The resulting expansion of hot gasses in the cylinders creates a reciprocal motion that is transferred to the wheels via a driveshaft or shafts.

3.2 Categories

Electric Bike: With an Electric bike, riding a bicycle is possible without pedalling. The motor output of an Electric bike is activated and controlled by using a throttle or button. Human power and the electric motor are independent systems. This means that the throttle and the pedals can be used at the same time or separately. This contrasts with the Pedelec which requires that the throttle and pedals must always be used at the same time. As a result, an Electric bike is more or less used in the same way as a scooter or motorcycle rather than a bicycle. UK, Swiss and Italian regulations define the maximum power that can be used for an Electric bike. More power makes it an electric scooter.

Pedelec: Pedelec stands for “pedal electric cycle”. While pedalling the cyclist gets additional power from the electric drive system. The control of the motor output of a pedelec is linked to the cyclist’s pedalling contribution by means of a movement or power sensor.

Electric Scooter or E-scooter: Small electric sit-down or stand-up vehicles ranging from motorised kick boards to electric mini motorcycles. Differences between the two types of small electric scooters are as follows: Stand-up scooters, instead of pushing the scooter forward with one leg, the rider simply turns the throttle on the handlebar and rides electrically. In contrast, sit-down scooters are small electric vehicles with a seat and are used much the same way as gasoline or petrol powered scooters. A throttle on the handlebar regulates the acceleration.

Car

Cars as described in this report are passenger vehicles up to 8 seats in addition to the driver, in accordance with European vehicle category M1. These can include ICE, or any of the electric drive configurations.

Van

Vans as described in this report are goods vehicles with a maximum weight not exceeding 3.5 Tonnes in accordance with European vehicle category N1. These can include ICE, or any of the electric drive configurations.

Truck

Trucks as described in this report will be larger goods vehicles greater in size than the category Van. This includes European vehicle category N2 and N3. These can include ICE, or any of the electric drive configurations.

Bus

Buses as described in this report refer to passenger vehicles described in European categories, M2 and M3. These can include ICE, or any of the electric drive configurations.

3.3 Vehicle Evolution

In the year 2010 the Mitsubishi iMiev came on the European market which became the starting point for the new generation of affordable electric cars in the EU. It was the first serious attempt to build an all-electric car based on the newest battery technology, Li-Ion. In the year 2011 the Nissan Leaf and the Renault Fluence ZE came on sale. All three cars offered good range at a reasonable price. For the new generation of electric cars the consumer can now look forward to longer range and lower prices on all-electric cars.

This new generation of electric cars offers a significantly higher standard for the building quality, compared to the previous models of electric cars on the market. The change from small scale production series up to large scale OEM production is one of the key changes in the electric car industry in recent years. More OEM built cars are on the way to the market and only a small amount of small scale producers of electric cars has survived and continue to provide reliable cost effective solutions.

The differences between the so called small scale production series or retrofit company cars and the OEM build cars are amongst others, that the small scale cars[1]:are often of poor quality– often with different types of malfunctions due to low quality management. Additionally, users experienced high maintenance costs due to limited service network and high prices on simple failures. Many of the vehicles exhibited limited range due to old battery technology and poor utilization of the battery capacity as well as long charging capabilities (mode 1 charging).

For the retrofit versions the gearbox was often reused and replaced by a standard industrial motor, but similar to the small scale producers making fully designed electric cars, simple motor control units and battery management systems were widely used in the business. Often causing imprecise indications of the state of charge and with-it difficulties in knowing how far you could go. The battery itself was, up till 2011-12, often Lead-Acid or Nickel-Metal-Hydride batteries that did not have the range and reliability as the Li-Ion now has.[2]

The new generation of electric cars is seen to have overtaken the small production series, as the OEMs can offer significantly lower price, better quality, higher safety and longer range.

Strengths and weaknesses - OEM build electric cars

There are three distinct groupings available across OEM based electric cars; The all battery electric vehicle (BEV), The plug-in hybrid (PHEV) and the range extended

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[1] http://www.ens.dk/DA-DK/KLIMAOGCO2/TRANSPORT/ELBILER/Sider/Forside.aspx

[2] http://www.tva.com/environment/technology/car_batteries.htm

electric vehicle (REEV) which alternates between a conventional engine and a motor. The BEV is in the majority with a small number of battery swap vehicles in circulation.
The technical set-up of the PHEV and REEV is very different from the BEV. In terms of range the biggest advantage for the PHEV/REEV is that they can be measured with the best diesel cars on the market, where the BEV has a total range of avg. 100 to 160 KM on one charge. Due to the fact that both drive technologies are placed in the PHEV/REEV the price itself is significantly higher than for other competing technologies which also reflects the service costs being higher than for both BEVs and conventional cars.[3]
Please also see the different car technologies in the overview below in figure 3.1.
Regarding the difference in charging methods (see figure 3.2) below and section 3.4 below).

	Micro-, mild & full hybrid	**PHEV** (Plug-in Hybrid Electric Vehicle)	**REEV** (Range Extended Electric Vehicle)	**SBEV** (Switchable Battery Electric Vehicle)	**FBEV** (Fixed Battery Electric Vehicle)
ICE	X	X	(X)		
Electric Drive Mode	(X)	X	X	X	X
Generator			X		
Recuperation	(X)	X	X	X	X
E-Boost Function	(X)	X			
Energy Source	⛽	⛽ 🔌	⛽ 🔌	🔌	🔄 🔌

Figure 3.1 Vehicle Technologies

3.4 Charging methods

There are a number of charging scenarios relevant across the existing range of electric cars on the market such as; AC slow, AC fast, battery swap, CHAdeMO, Combo Charging System (CCS) which includes AC slow as well as DC fast charge on one connector and inductive charging (not yet ready).

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[3] http://www.greencarreports.com/news/1018460_prius-repairs-cost-a-little-more-than-non-hybrids

On the AC connector side the Type 2 connector has been widely accepted as the norm, supported at EC level in the Clean Power for Transport directive. The directive also supports the CCS plug for DC fast charging, although the existence of a significant number of CHAdeMO vehicles on the road up until now, leaves the need to maintain a charging infrastructure for this technology.

AC charging

The most commonly used form for charging is the AC charging which can be facilitated in three modes.
Mode 1 charging: In this charging mode a 16A EC plug is used and mostly by the “first generation” (late 1980-2009) of electric cars, having a small battery density and short range. Mode 1 charging is still seen for retrofit cars and small scale production models but is not seen on the second generation OEM build cars - except from OEM build micro cars with a very limited battery density. This is partly due to the fact that a small battery can be charged relatively fast and that the power of a micro car battery is not exposing any overload to the current level when being charged. However, for an average sized ‘Mode 1 car’ the charging can put stress on the current level pulling all the current the car can get. Where the current scenario is max 10-13A, often seen in for instance summer houses, charging up to 12 hours of max peak can potentially lead to dangerous hazards, especially since the typical Mode 1 charging set-up has no system to control the charging in the other end – the household plug!

Mode 2 charging: This mode is facilitated by a so called Mode 2 cable with an installed control box unit that limits the level of amps to be used for charging for the ‘Mode 3 car’. Some boxes can be adjusted to a certain amp level and some can’t. The typical max amp load is normally set at 8-12 A which at some point ought to prevent dangerous hazards as the box does not see what the limitations at the site are.
All Mode 3 supporting cars OEM build BEVs (FBEVs and SBEVs) and PHEV/REEVs – (figure 3.3 below) can use this type of control box in charging sites where an EC industrial inlet is accessible.
The Mode 2 charging limits the max amps and can be even slower than the Mode 1 charging mode.

Mode 3 charging: All OEM built cars being delivered now are supporting Mode 3 -and a charging station all of which supports the IEC standards IEC 61851-1, 61851-21+22 and the 62196-2.

Single Phase Charging

This type of AC charging is and will be the most commonly used form for charging at home and at work as the car slowly, safe and controlled can charge up to 100 % state of charge.
The most commonly known plug on the car side for both types of BEVs and PHEV/REEVs is the Yazaki plug (SAE J1772/IEC 62196-2 type 1) facilitating single phase charging at 16 or 32Amps depending on the vehicle. On the charging station

side the Mennekes (IEC 62196-2 type 2) is the most used plug on the market in Europe (see also 3 phased charging).

The Mode 3 single phase charging is ideal for BEV car fleet owners with very little need for recharging during the whole workday, which can either be set to charge approx. 5-6 hours (0-100 % at 16A) without being interrupted or with fixed charging during longer visits or breaks, depending on the frequency, but not less than 20 minutes. The charging time of the PHEV/REEVs is due to the significant smaller battery equivalent faster than the BEVs using approx. 3-4 hours (0-100 % at 16A).

3 Phase Charging

To meet the requirements from the consumers to lower the charging time, when charging in the day time, a 3 phased solution is now available with some vehicles such as the Renault Zoe. With the introduction of 3 phase charging the plug on both the car and the charging station side predominantly seems to be the Mennekes plug (IEC 62196-2 type 2) which facilitates charging at max 63A 500V[4] and an easy to use interface in line with the CPT Directive.

Some charge spot operators have set-up their charging infrastructure to support 3 phases as this set-up appears to be required in parallel with the DC fast charging system supported by the fact that the AC equipment can be installed at a low marginal cost[5]. It will also give the car driver a remarkably higher service degree as a 3 phased mode 3 charging of an average sized electric car (22kWh) can lower the charge time to only 1 hour (and to 30 minutes with 80 % SOC) making it attractive for fleet usage.

DC charging

DC charging is used by a significant portion of BEV's, these vehicles are predominately CHAdeMO with CCS starting to take a share of the market. DC charging makes it possible for the driver to charge the car in approx. 25-30 minutes from 0-80 % state of charge. Initially the OEM's had included a limit of 1 DC fast charge a day in their warranties, however some of the OEM's have now removed this limitation, indicating better confidence in the battery performance. DC charging as with AC fast charging provides a means of increasing the practical range of the vehicle through the fast replenishment of the battery.

Here in Europe, CCS (IEC 62196) has received the backing of the CPT Directive.

Battery Swap

The introduction of the battery swap (or switch) technology is available in Denmark and in Israel covering both countries nationwide. Hereby the possibility of driving an SBEV at the time being the Renault Fluence ZE An unofficial record set by Better Place Denmark (July 2012) demonstrated that thanks to the battery switch technology 2,399 km could be driven in 24 hours (first attempt). This proves that the SBEV can act

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[4] The Smart ED has an onboard 22kW 400V charger

[5] And possibly increase the price of the car

as a normal car when the battery switch infrastructure is in place in the area you operate.

The cost of the SBEV is without the battery and thereby the risk and battery up-date is taken by the battery swap station operator. The battery swap station is able to handle multi battery pack sizes and can switch the battery in less than 5 minutes.

The battery cost for the fleet manager could be lowered by offering a battery pack which fits to the needs and which can be swapped to a higher density (same shape) at a higher price when needed.

At present, Battery Swap is in limbo with limited availability in any of the world markets.

	AC Charging				Inductive Charging		DC Charging		Fast Charge
Charging Power	3,7 kW	11 kW	22 kW	44 kW	3,7 kW	11 kW	<20 kW	< 50 kW	60 kW
Voltage	230 V	400V	400 V	400V	230V	400V	450 V dc	<450 V dc	400V dc
Current	16 A	16 A	32 A	63 A	16 A	16 A	32 A	< 100 A	150 A
From SOC min.	30%	30%	30%	30%	30%	30%	30%	30%	30%
To SOC max.	100 %	100 %	100 %	80%	100 %	100 %	100 %	80%	80%
Charging time for 20 kWh	230 min	80 min	40 min	20 min	230 min	80 min	40 min	20 min	12 min

Figure 3.2 Charging Technology

List of electric cars available on 2012 sale in EU

In alphabetic order	CAR PEDIGREE				CHARGING METHOD				
	FBEV	SBEV	PHEV	Service network	AC Mode 1 charging	AC Mode 2& 3 charging	AC/DC combo charging	DC charging	Battery switch
Bellier	■			1)	■				
BlueCar	■			1)	■				
FIAT/MicroVett e500	■			1)	■	2)			
FIAT/MicroVettFiorino	■			1)	■	2)			
FIAT/MicroVettDoblò	■			1)	■			2)	
FIAT/MicroVettDucato	■			1)	■	2)			
Fisker Karma			OEM	OEM		■			
Garia	■			1)	■				
MitubishiiMiev/Citroën C Zero/Peugeot Ion	OEM			OEM		■		■	
Mega City	■			1)	■				
Mercedes Vito e-Cell	OEM			OEM		■			
MyCar	■			1)		■			
Nissan Leaf	OEM			OEM		■		■	
Opel/Vauxhall Ampera			OEM	OEM		■			
Renault Kangoo/Maxi ZE	OEM			OEM		■			
Renault Fluence ZE		OEM		OEM		■			■
Renault Zwizy	OEM			OEM	■				
Reva	■			1)	■				
Smart ForTwo ED	OEM			OEM		■			
Tesla Roadster	OEM			OEM		■			
Think City	■			1)	■				
Toyota Prius Plug-In			OEM	OEM		■			
1) Small service network - if any									
2) Additional choice									

List of electric cars coming on sale in EU by end 2013

The above list is of vehicles which are on sale or reasonably expected by end 2013.

In alphabetic order	PEDIGREE	CHARGING METHOD

	FBEV	SBEV	PHEV	Service network	AC Mode 1 charging	AC Mode 2 & 3 charging	AC/DC combo charging	DC charging	Battery switch
BMW i3 (both as BEV and PHEV)	OEM		OEM	OEM		🟩	4)		
BMW i8 / i8 Spider			OEM	OEM		🟩	4)		
Ford C Max			OEM	OEM		🟩			
Ford Transit Connect	OEM			OEM		3)			
Ford Focus Electric	OEM			OEM		3)			
Honda Jazz EV	OEM			OEM		🟩		🟥	
Hyundai i30 Plug-in			OEM	OEM		🟩			
Mercedes A Class E Cell	OEM			OEM		🟩	4)		
Peugeot 508 Hybrid4			OEM	OEM		🟩			
Renault Fluence ZE (2nd gen.)		OEM				7)			🟪
Renault Zoe ZE		OEM		OEM		7)			🟪
Smart ForTwo ED (3 phased as optional)	OEM			OEM		🟩			
Tesla Model S		OEM		OEM		🟩		5)	6)
Toyota Prius C			OEM	OEM		🟩			
Volvo C30 electric	OEM			OEM		3)			
Volvo V60 plug-in			OEM	OEM		3)			
VW e-UP	OEM			OEM		🟩	4)		
VW Golf Blue e-Motion (both as BEV and PHEV)	OEM		OEM	OEM		🟩	4)		
QBEAK	▨					🟩			
3) Three phase charging not confirmed									
4) Combo charging not confirmed									
5) Near future possibility for super charging +90kW station									
6) No infrastructure solution yet mentioned									
7) 3 phased									

Figure 3.3 Vehicle Listings

4 Use cases

4.1 Electric Assisted Bicycles

Pedelec ‘Electric Assisted’ Bicycles CORK

Cork City Council has introduced a small fleet of bicycles for use by staff during the day. Members of staff apply to be users and they can get access to keys and the removable lights at the Reception Desk. In addition, the Transportation Division has been making use of a Pedelec ‘power assisted’ electric bike which was purchased at the end of 2011 by the Energy Agency Office. Cork City Council are also considering the purchase another Pedelec for the fleet this year to support the promotion of the benefits of GeM.

About the use:

The electric bike is now being used on a regular basis by a Cork City Council Technician to undertake site visits that previously required the use of a car. In fact, the site visits necessitated the use of a vehicle from the car sharing club facility operated by GoCar. Trips of in excess of 12 Km are being undertaken by electric bike to visit and inspect the installation of the Real Time Passenger Information (RTPI) system being implemented by the National Transport Authority (NTA). It has been noted by the user that in addition to extending the range of cycling, the enhanced ability to overcome the uphill gradients in Cork means this bike can be used were a standard bike would not be of interest. Details of the range and the battery capacity are provided with reference to the HERO eco Ultra Motor Hybrid A2B manufacturers brochure –http://a2b.ultramotor.com/en/a2b_hybrid_26 and Giant Cycles http://www.giant-bicycles.com/en-gb/bikes/model/twist.w/9359/55728/ also being considered for the cycle fleet by Cork City Council.

Electric Assisted Bicycles Malmö

Electric bicycles are now in use in Malmö and it is planned to start to track the bicycles in August 2012.

About the use:

City of Malmö has 30 electric assisted bicycles in its bicycle fleets. Those 30 bicycles are distributed at several departments of the city and used for various work related trips. The city is encouraging employees to use the electric bicycles instead of cars for trips within the city. In most of the cases the employee can make their own choice about what vehicle will be used for the trip. Malmö is a relatively small city with good bicycle roads and there is a good potential for increased use of electric bicycles for short / medium trips. Details of the range and the battery capacity are provided with reference to the Goodwheelmanufacturers’ brochure http://shop.goodwheel.se/se/grp/elcyklar.php

4.2 Bus Routes

Movia - the largest public transport company in Denmark - has a fleet of 11 electric busses which run a fixed route, route 11A, in the inner city zone 1 in Copenhagen. The 11A route is 10.1 km long. A ride takes about half an hour if you go from Copenhagen Central Station to the bus terminus. The busses run between 11-13 times per day. On average each bus thus runs 130 kilometres per 24 hours. The busses run 7 days a week during the following hours; on weekdays from 7am till midnight, on Saturdays and Sundays from 9am till midnight. The buses run every 10 minutes during the day and every 20 minutes in the evenings. There are no breaks in the day. The total energy consumption per month of all the busses is between 18,000 and 20,000 kilowatt depending on the weather conditions.

The busses have 9 seats and standing room for 12. They have been converted by an Italian manufacturer and are only charged by charging points at the bus depot. The buses do not require preheating in the winter. Only e-buses run on route 11A, and unfortunately it is rather difficult to give examples with fossil fuel buses on the same route. The traditional buses in the City of Copenhagen run on diesel, and below there is a chart with an overview of the differences between e-buses and traditional buses in terms of room, weight and durability.

Figure 4.1 E-buses vs. diesel buses

	Seats	**Standing room (for)**	**All-up weight (kg)**	**Dead weight (kg)**	**Load capacity (kg)**	**Km to the litre (on average)**
E-buses	9	12	5,950	4,150	1,800	
12 m diesel bus	34	37	18,000	11,175	6,825	2,5
13,7 m diesel bus	43	61	2,0925	13,400	7,525	2,5
14,7 m diesel bus	47	63	22,700	14,700	80,000	2,5

Maintenance costs

In this project, the operating costs of the e-busses have been more expensive than those of the diesel busses in all respects: The driving line cost per kilometre is higher, especially since the batteries are very expensive. There are 24 batteries in each bus, and the price of one battery currently amounts to EUR 3,500. Up to now, five batteries packs (i.e. 120 batteries) have been replaced. Furthermore, the cost price of e-busses is higher than that of diesel busses, as the supply is smaller. Repair costs are also higher due to the special technology, which is rather time consuming. Additionally, there is a much larger risk of breakdowns and slow fault clearance with e-busses, since the problems arising are not known. There is also a much larger residual risk when selling e-busses due to the fact that the e-technology is evolving rapidly, and therefore it is more difficult to sell an old e-bus compared to an old diesel bus. Lastly, the e-busses cannot tolerate water on a large scale.

Having mentioned the challenges above, it should be kept in mind that e-technology is constantly and rapidly evolving, which is why the price and product quality may do the same. E-busses should still be regarded and organised as a pilot project until sufficient experiences have been attained. However, this does not mean that there will not be an overall socio-economic benefit in the short term taking account of environmental pollution, noise etc.

Below there are two tables respectively indicating the e-buses' energy consumption per month and the distance travelled per month.

	Energy Consumption per month, all e-buses			**Since last reading**	
01-11-2009	**Electricity meter =**	**23,940**	kWh		
18-11-2009	**Electricity meter =**	**32,360**	kWh	**8,420**	
01-12-2009	**Electricity meter =**	**37,700**	kWh	**5,340**	kWh
01-01-2010	**Electricity meter =**	**51,680**	kWh	**13,980**	kWh
01-02-2010	**Electricity meter =**	**65,690**	kWh	**14,010**	kWh
01-03-2010	**Electricity meter =**	**77,740**	kWh	**12,050**	kWh
01-04-2010	**Electricity meter =**	**94,990**	kWh	**17,250**	kWh
01-05-2010	**Electricity meter =**	**109,480**	kWh	**14,490**	kWh
01-06-2010	**Electricity meter =**	**124,550**	kWh	**15,070**	kWh
01-07-2010	**Electricity meter =**	**140,710**	kWh	**16,160**	kWh
01-08-2010	**Electricity meter =**	**157,680**	kWh	**16,970**	kWh

01-09-2010	**Electricity meter =**	**174,600**	kWh	**16,920**	kWh
01-10-2010	**Electricity meter =**	**191,130**	kWh	**16,530**	kWh
01-11-2010	**Electricity meter =**	**209,060**	kWh	**17,930**	kWh
01-12-2010	**Electricity meter =**	**229,720**	kWh	**20,660**	kWh
01-01-2011	**Electricity meter =**	**250,300**	kWh	**20,580**	kWh
01-02-2011	**Electricity meter =**	**266,790**	kWh	**16,490**	kWh
01-03-2011	**Electricity meter =**	**283,100**	kWh	**16,310**	kWh
01-04-2011	**Electricity meter =**	**301,230**	kWh	**18,130**	kWh
01-05-2011	**Electricity meter =**	**325,210**	kWh	**23,980**	kWh
01-06-2011	**Electricity meter =**	**344,770**	kWh	**19,560**	kWh
01-07-2011	**Electricity meter =**	**363,510**	kWh	**18,740**	kWh
01-08-2011	**Electricity meter =**	**374,037**	kWh	**10,527**	kWh
01-09-2011	**Electricity meter =**	**384,280**	kWh	**10,243**	kWh
01-10-2011	**Electricity meter =**	**394,450**	kWh	**10,170**	kWh
01-11-2011	**Electricity meter =**	**406,300**	kWh	**11,850**	kWh
01-12-2011	**Electricity meter =**	**418,240**	kWh	**11,940**	kWh
01-01-2012	**Electricity meter =**	**431,060**	kWh	**12,820**	kWh
01-02-2012	**Electricity meter =**	**447,520**	kWh	**16,460**	kWh
01-03-2012	**Electricity meter =**	**461,070**	kWh	**13,550**	kWh
01-04-2012	**Electricity meter =**	**472,520**	kWh	**11,450**	kWh
01-05-2012	**Electricity meter =**	**482,560**	kWh	**10,040**	kWh
01-06-2012	**Electricity meter =**	**495,290**	kWh	**12,730**	kWh

Figure 4.2 e-Bus Energy Consumption

Kilometres per month

Dato:	**Bus 1**		**Bus 2**		**Bus 3**		**Bus 4**		**Bus 5**		**Bus 6**	
01-01-2012	64,709		82,410		98,891		88,442		61,969		62,592	
01-02-2012	64,709		85,276	**2,866**	98,891		92,196	**3,754**	61,969		66,605	**4,013**
01-03-2012	64,709		88,058	**2,782**	98,891		95,749	**3,553**	61,969		68,576	**1,971**
01-04-2012	64,709		90,910	**2,852**	98,891		98,680	**2,931**	61,969		71,662	**3,086**
01-05-2012	64,709		93,415	**2,505**	98,891		101,395	**2,715**	61,969		74,280	**2,618**
01-06-2012	64,709		94,782	**1,367**	98,891		104,324	**2,929**	61,969		77,955	**3,675**
01-07-2012		**-64,709**		**-94,782**		**-98,891**		**-104,324**		**-61,969**		**-77,955**

	Bus 7		**Bus 8**		**Bus 9**		**Bus 10**		**Bus11**	
01-01-2012	81,157		58,128		68,929	**2,254**	43,734		58,642	
01-02-2012	84,590	**3,433**	58,927	**799**	69,117	**188**	47,062	**3,328**	61,729	**3,087**
01-03-2012	87,529	**2,939**	62,167	**3,240**	69,984	**867**	50,089	**3,027**	63,641	**1,912**
01-04-2012	89,676	**2,147**	64,502	**2,335**	69,984		52,488	**2,399**	65,678	**2,037**
01-05-2012	91,234	**1,558**	66,688	**2,186**	69,984		54,720	**2,232**	67,757	**2,079**
01-06-2012	93,461	**2,227**	69,415	**2,727**	71,891	**1,907**	57,132	**2,412**	71,273	**3,516**
01-07-2012		**-93,461**		**-69,415**		**-71,891**		**-57,132**		**-71,273**
01-08-2012										

Figure 4.3 e-Bus km Driven

From Figure 4.3 above we can see that the buses were heavily utilised with average monthly usage of over 2500km. While energy consumption figures are included in Figure 4.2 above, these figures represent only a short overlap period and therefore while they give an indication of kWh/km they are as yet immature. It is intended to revisit this topic in the final report to establish a fuller and representative picture of energy consumption and related seasonal effects

4.3 Taxis

4.3.1 Ireland

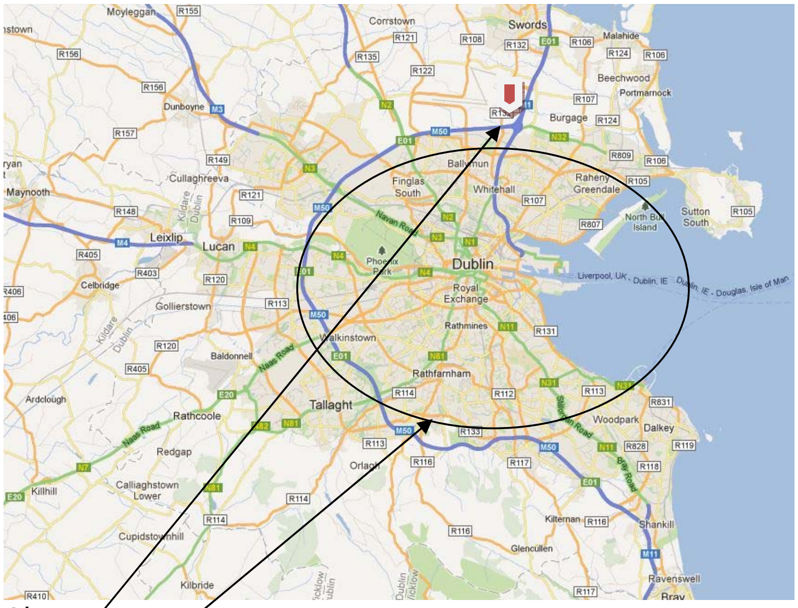
The Ireland demo region has monitored 2 Electric Taxi's. The vehicle type and the charging technologies were different in order to assist in assessing challenges and opportunity in operating an electric taxi. Neither vehicle is shared by a second driver. The vehicles have been monitored over a 12 month period which has been supported by an interview of both drivers in order to ensure a greater understanding of the full experience.

Taxi Regulation

There are 11,028 taxi's licensed in the Co. Dublin area at June 2012 of which 487 are wheel chair accessible. Taxi Regulation in Ireland specifies the load space required in the taxis. In the case of Taxi 1, special permission has been granted for use as a taxi, due to the undersized load space. A portion of taxi licences are granted for specific use as wheel chair accessible vehicles. These licences cannot be exchanged and must always include wheelchair accessibility.

Dublin Geographical overview

The Dublin area consists of approx. 920km^2. For both vehicles monitored the home area is south of the city, however clients can wish to travel outside this area. The airport is located to the north of the city and is likely to be the most regular long journey a taxi driver based in the south of the city will encounter. (See Figure 4.4)



Airport
Home Area
Figure 4.4 Dublin Area View

Taxi 1

Taxi 1 is operated between 5 and 6 days a week. It has both AC charge (3.5kW) and DC ‘fast charge’ (50kW) capability. The primary place of residence has been fitted with an AC charge point. Taxi 1 is charged each night at the home charge point with occasional use of a DC charge at a city centre location. Friday’s and Saturday’s are the days where fast charging is most important due to the quantity (and distance) of trips undertaken. Approximately 20% of requests are declined due to range limitations, where the driver is uncomfortable about the return journey. At no time has the driver declined a fare due to luggage space. The driver experience has been very positive with particular notes made on responsiveness and comfort. The car is much preferred to the previous fossil fuel vehicle and attracts positive feedback from passengers. The driver is aware of the difference in fuel costs between both vehicles and this is a significant factor in considering the vehicle type. The driver believes a range of 250km to be suitable for taxi use in the Dublin area.

Taxi 2 is also operated between 5 and 6 days a week. It has 3 Phase AC charge capability only, with a charge time of approximately 8.5 hours. Charge outlets are installed at both home and taxi office locations. Due to the duration required to charge, the only practical charging is overnight at the drivers home. Friday’s and Saturday’s are the days charging is the greatest problem due to the quantity (and distance) of trips undertaken. Approximately 40% of requests are declined due to range limitations, where the driver is uncomfortable about the expected distance. The driver experience has been generally positive with particular notes made on comfort and quietness, however charge times are a particular issue with this vehicle. The vehicle is more comfortable than the previous fossil fuel vehicle and attracts positive feedback from passengers. The driver is aware of the difference in fuel costs between both vehicles and this is a significant factor in considering the vehicle type. The driver believes a range of 300km to be suitable for taxi use in the Dublin area.

Vehicle ID	Taxi1	Taxi2	Comments
Type	Car, 5 Door	Van, Wheelchair Access	
Seating	5	6	
AC Charging	Yes	Yes	
DC Charging	Yes	No	
Charge Rate (AC)	3.5kW	5kW	
Charge Time (AC)	6.8 hrs	8.5 hrs	
Nominal Range	160km	160km	
Previous vehicle Engine Volume	Petrol, 2 Litre	Diesel, 2 Litre	
Average weekly km	900km	750km	
Weekly	€30	€35	Assuming €0.21 /kWh

electricity Cost			
Weekly fossil fuel cost	€140	€120	Assuming €1.60/l fuel
% Home Charge	85%	100%	
% Public AC Charging	0%	0%	
% Public DC Charging	15%	0%	
Savings per Annum	€5,280	€4,080	Assuming €0.21 /kWh and €1.60/l fuel, 48 weeks per year

Figure 4.5 Trial Taxi Comparison Chart

Findings

The ranges of the tested vehicle technologies are on the boundaries of practical use as taxi's in the Dublin area. Particular difficulties are experienced at peak times, while the vehicle operation is satisfactory at other days in the working week. The availability of DC fast charging significantly alleviates this obstacle and highlights the importance of fast energy replenish times by whatever method. The overall experiences of comfort and energy costs are very positive. Range extension and/or the accessibility of fast methods of charging or battery swapping are of particular interest to operators. After 3 years of operation in the Nissan leaf, the vehicle has covered over 100,000km, the battery level still shows a full battery charge on the gauge, indicating that the battery is still in a very healthy condition.

Future plans

The testing of induction charging on a Nissan Leaf as part of WP8, will consider the possible opportunities for range extension while parked between journeys. Furthermore the added value of 6kW AC charging available in the latest production Leaf's as against the 3kW AC available in the current Taxi will be considered with respect to the potential to increase the range of the vehicle.

4.3.2 Spain

The number of electric taxis in different cities of Europe is increasing quickly. According to IDTechEX[1], 119,000 electric taxis will be sold in the world market in 2014. Taxi companies see advantages in electric vehicles. Although the key disadvantages of electric taxis are the price of the vehicle and the limited range of autonomy (approximately 180km) on the other hand, they are an attractive alternative to the conventional car in many other respects. The price of petrol or diesel is about 5 times more expensive than electricity. Many city governments give incentives to the user when acquiring an electric car. But for drivers and managers of taxi companies there is an extra reason for replacing the conventional taxi with an electric model - to reduce the level of noise and improve the quality of urban air. When we consider the statistic that a taxi runs nineteen times more mileage than a private car, it can be seen as a perfect pilot car.

In this case we are analyzing the use of an electric taxi. This taxi was the first electric taxi circulating in Spain (November 2011). Specifically this taxi is operating in the city of Valladolid. The city of Valladolid is a city of medium size.

- The maximum distance from one point to another in a straight line is about 9 km.
- A very large number of villages in the periphery are within 20 km. The nearest city of Palencia is 50 km from Valladolid.
- The airport is located 13 Km from the city center.
- There are 34 charging points installed in public streets and parking, plus 2 fast charging points.
- The taxi usually travels a distance of 15 kilometers on its routes with a travelled distance between 120-150 kilometers daily, where it can cover the vast majority of journeys.

The electric taxi has the following characteristics: It has a capacity battery of 24 KWh, consumption approximately 173 Wh/km and a nominal range of 175 km, and it has an energy recovery system (regenerative braking).

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[1] www.IDTechEx.com

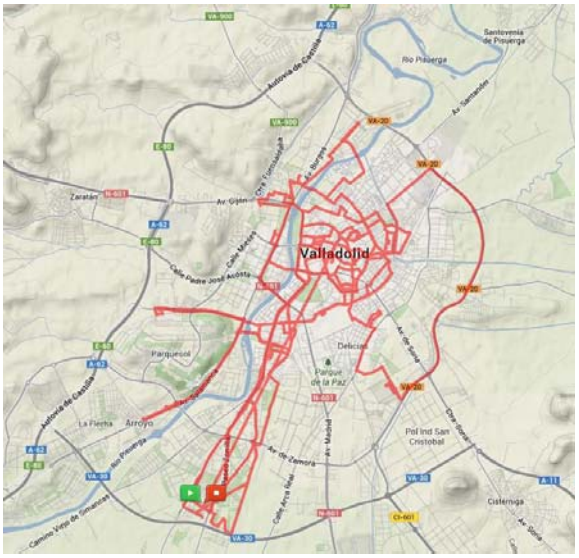

Figure 4.6 Daily route in urban area 150 Km

Figure 4.7 Daily routes in urban area with trip to a closer village 165 km

The taxi operates mainly in an urban environment, but sometimes it runs in extra urban routes to reach some villages near to the city including trips to the airport. The geographic area within which the taxi is used has been divided into three zones relating to the average speed reached by the taxi. In figure 4.8 the green area represents speed values less than 50km/h. Speed between 50km/h and 80 km/h correspond to the orange area. Finally, in the remaining areas the taxi circulates with speeds over 80km/h. The classification is made taking into account that this model of electric vehicle has an energy recovery system. This system comes into operation at the time when the driver lifts his / her foot off the accelerator pedal and also when applying the foot break. These systems work better in urban areas where the stops and starts are frequent, thus achieving increases in the autonomy of the vehicle. Another advantage is lower maintenance due to the car braking systems have less wear.

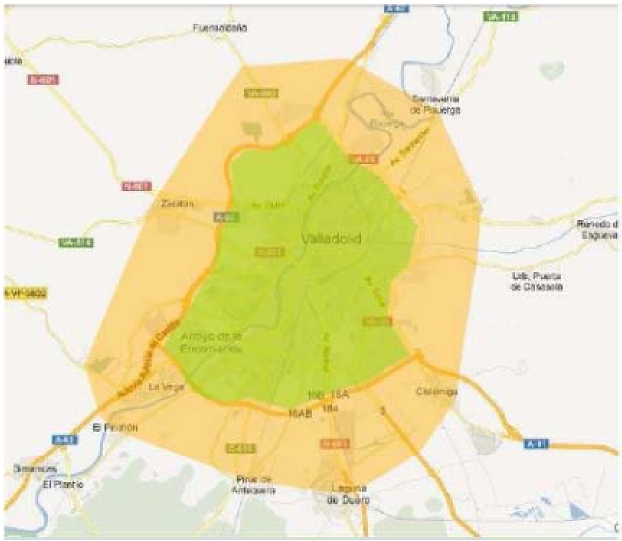

Figure 4.8 Map of Valladolid: Usual routes by area

From the data collected from the electric taxi, the efficiency estimation by speed has been calculated. Two different types of efficiency have been defined. The first corresponds to a use during seasons where the heating and air conditioning has not been necessary to activate. The second corresponds to a lower efficiency where the use of HVAC systems corresponding with winter and summer periods.

Speed	d< 50 km/h	50km/h<d<80km/h	D>80km
Efficiency	120%	100%	80%

Table 4.1. Efficiency type 1 (no HVAC)

Speed	d< 50 km/h	50km/h<d<80km/h	D>80km
Efficiency	110%	90%	70%

Table 4.2. Efficiency type 2 (HVAC)

In the next table, a total of eight daily routes have been selected in order to analyse the type of displacements most representative. These routes correspond to travelled distances in one day. The average distance travelled is approximately 100 kilometers as depicted in the table. Some of the daily routes necessitate intermediate recharges made during a lunch break.

	Distance	Speed < 50 km/h		50km<Speed<80km/h		Speed> 80km/h	
	Km	%	Km	%	Km	%	Km
Route 1	115,13	54,4	62,63	4,17	4,8	41,43	47,7
Route 2	125,14	86,57	108,34	9,43	5	4	11,8

Route 3	147,7	89,44	132,1	3,25	4,8	7,31	10,8
Route 4	190,93	89	169,93	3,04	5,8	7,96	15,2
Route 5	132,61	81,1	106,21	3,3	4,4	15,6	22
Route 6	69,08	100	69,08	0	0	0	0
Route 7	46,13	81,6	37,63	10,4	4,8	8	3,7
Route 8	73,96	84,31	62,36	4,33	3,2	11,36	8,4
Total	900,68	83,30	748,28	4,74	32,8	11,95	119,6

Table 4.3 Route classifications by speed

A total of 83% of the total distance travelled was made in an urban environment with speeds below 50 km/h. The fuel consumption over a distance travelled of 900 km of an electric taxi versus an internal combustion engine vehicle was compared. For the consumption of the electric taxi in contrast to an ICE vehicle, the efficiency depending on the area (Table 2) was taken into account. Furthermore data was taken from urban, extra-urban and combined consumption. The results clearly show that the consumption of an electric taxi is 5 times lower than that of an ICE vehicle on urban routes. As the average speed of travel increases, this difference becomes smaller due in part to lower consumption of an ICE taxi as well as the lower efficiency of the electric taxi.

	Speed < 50 km/h	50km<Speed< 80km/h	Speed> 80km/h	Total
Kilometers	748,28 (83%)	32,8 (4.74%)	119,6(11.95%)	900,68
EV consumption	11.43 (110 %)	0.61 (90%)	2.87 €(70%)	14.91€
Diesel consumption	61.81 €(5.9 l)	2.07 € (4.5 l)	6.53 € (3.9)	70.4 €
Saving Percentage	5.41	3.38	2.28	4.72
	Assuming prices :diesel (1.4 €/l), electricity (0.12 €/kWh) Assuming energy consumption (0.14kWh/km). Efficiency type 2			

Table 4.4 Fuel economy of the electric taxi compared to the ICE

In addition to the previous data, in the next graphic the driving distance and the energy consumption during the last two years is represented. Total other data is represented in Table 4.5. If we take into account an average energy consumption of 0.14 kWh/h and taking the cost of electricity based on night tariff of 0.12 €/kWh the total cost of fuel of the electric taxi during two years is calculated.

Year 2012 0.14kWh/km* 0.12 €/kWh* 35564 Km = 597.47€
Year 2013 0.14kWh/km* 0.12 €/kWh* 44664 Km = 750.35 €

Comparing the cost of a diesel fuelled taxi during this time taking the fuel cost of 1.4 €/l and an average consumption of 8.5 l/100km in urban environment, fuel economy

would be close to 8200€. This means that with use of nearly 300,000 km can pay back the initial investment of the electric taxi, which for this model electric car was about 30,600€.
Total electric cost =1347, 82 €
Total diesel cost 8.5 l/100 km*1.40 €/l*80228 = 9547, 13 €

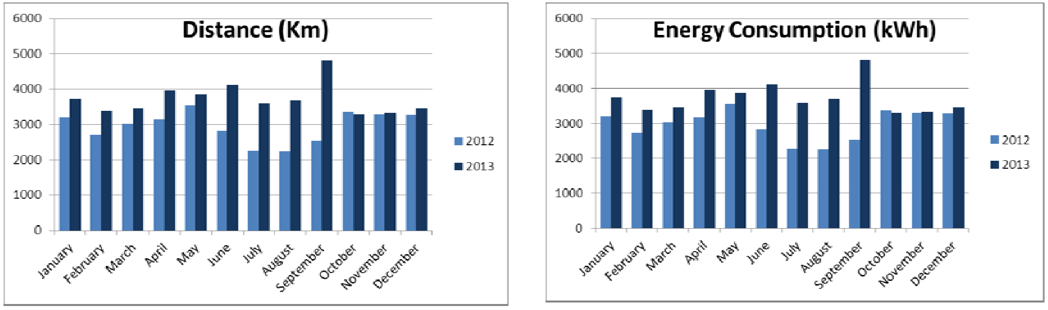

Figure 4.9. Km and consumption made by the electric taxi during the years 2012 and 2013

	2012	2013
Total driving distance	**35564,8 km**	**44644 km**
Average energy consumption	**0,14 kW/km**	**0,14 kW/km**
Power consumption	**5086,2 kW**	**6377,3 kW**
Driving time	**2345.5 h**	**4292,4 h**
CO_2 emission reductions	**6110 Kg**	**7670 Kg**

Table 4.5. Total data Taxi During 2012 and 2013

If we consider the maintenance costs of both vehicles the repayment period would be achieved in less time. Maintenance costs of the electric taxi have just reached less then 600 € while the costs in an ICE taxi would have easily overcomes the 1100 €. The cost differences would be greater in the case of corrective maintenance where the only fault in the electric taxi has consisted in the replacement of a light bulb. If in addition to the savings in fuel and maintenance we consider that the acquisition costs of the vehicle have dropped in the last year, we can estimate that using the car more than 200,000 km, and the car can be amortized.

Despite the advantages of electric taxi in relation to consumption, the taxi drivers are still wary of electric car use. Perhaps one of the biggest problems they argue is the lack of autonomy of the vehicle. Anxiety about running out of autonomy, called “range anxiety” could be avoided if there are enough recharging points and if the driver knows in advance their location. Another factor to consider is the efficiency of the batteries, it decreases with use, especially conditioned by the temperature and the number of fast recharges that have been performed.

It should be noted that some cities are more favorable than others to the use of electric taxi. For example, Valladolid is an appropriate city due to its topography and climate. It is a flat city with few slopes and the climate in summer is not too hot. Almost 80% of the routes can be performed in urban environment with average speeds less than 50 km/h. it is possible that cities with greater average distances and higher volumes of passengers are not as appropriate.

From the data analysed during the two and a half years that the electric taxi has been in use in the city of Valladolid the following conclusions can be obtained:

- The electric taxi is a good alternative to conventional car in cities with the size and geographical characteristics of Valladolid. The electric taxi is perfectly applicable for use in the majority of cities and towns in Spain and therefore in Europe.
- One of the biggest advantages to consider is the fuel economy, besides the low maintenance.
- There are also other environmental advantages such as the absence of noise inside the car or drivability in everyday use.

4.4 Courier & Urban delivery

4.4.1 Postal Fleet

In this section we will focus on the postal service in Europe, particularly in the Spanish public company "Correos". The fleet of these companies brings a set of characteristics that make it suitable for replacing internal combustion vehicles to electric vehicles. One such feature is the variety of its fleet with motorcycles, cars, vans and trucks of different tonnages. To this must be added the total distances that these fleets cover daily, by delivering letters and parcels to the users.

The Spanish postal fleet[8] has about 13,426 vehicles including cars, vans, trucks and motorcycles. This fleet daily travels more than 342,000 km, equivalent to travelling nine times around the world every day. The fleet is composed of approximately 10,000 motorcycles, 285 cars, 3,061 vans of different load and about 80 trucks.

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[8] www.postal.es

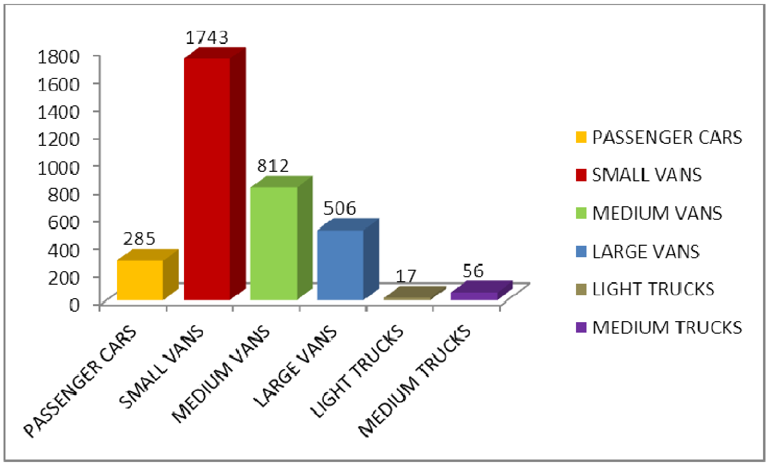


Fig 4.10 Vehicle numbers of Postal fleet by categories

The company has replaced 2% of its fleet, approximately two hundred, with electric vehicles comprising cars and motorbikes, with the goal of reducing pollution in cities, due both to noise and carbon dioxide emissions.

The current electric postal fleet is composed of a total of 209 vehicles (5 vans, 100 motorcycles, 89 bicycles and 15 four-wheel vehicles). Through the use of these vehicles 16,200 kilos of CO_2 emmissions per year will be avoided.

IThere are also provisions to replace between the 10% and 20% of its fleet of motorcycles, by electric bikes and between 30 and 40% of commercial vehicles of up to 400 kg load by electric vehicles.

The postal service EVs are distributed in about 80 locations, conducting routes not exceeding 50 kilometers per day. As there is no need to recharge en route, it may use the conventional charging points in postal facilities during nighttime hours when the vehicles are not in use.

In addition to fuel savings and reduced environmental impact, the postal service also notes a decrease in the electric motorcycle accidents compared to their combustion counterparts. Furthermore adaptation to EV's by the drivers has been smooth, with a very positive reception to the new technology.

In the graphic 4.11 and table 4.6, we can see the estimated average cost (€/km) of each type of conventional vehicle belonging to the postal fleet. This data have been calculated according to the average consumption of each type of car that uses the fleet, based on information obtained from IDAE[9]. Furthermore, the average consumptions for electric cars with similar characteristics to those already in operation, have been calculated[10]. Thus, the fuel economy by km related to replacing an ICE by a EV for the category of passenger car and van has been estimated.

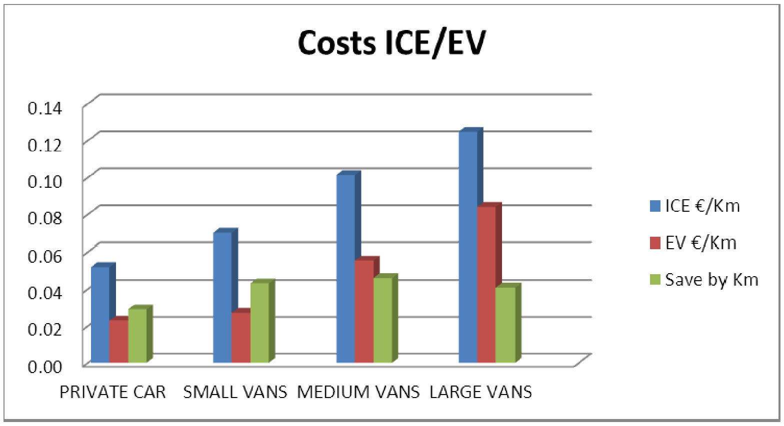


Fig 4.11 Fuel economy for introduction of EVs in Postal fleet

If we analyse the average fuel savings due to the replacement of a conventional vehicle belonging to the current fleet, by an electric vehicle, it would be around 2,0 € per day. For this calculation the following assumptions have been made: an average distance of 50 km per vehicle, an average cost of diesel price of 1.4 €/l and an average cost of electricity about 0.2 €/kWh. In Table 4.6, the savings in fuel costs for the lifetime of the vehicles taking into account that small vehicles are replaced at 150,000 km at most and vans greater capacity to 300,000 km are also analysed.

l	ICE €/km	EV €/km	Save by km	Save by car daily	Save by fleet daily	Save lifetime by car
PRIVATE CAR	**0.052**	**0.023**	**0.029 €**	**1.44 €**	**412 €**	**4338 €**
SMALL VANS	**0.070**	**0.027**	**0.043 €**	**2.15 €**	**3747 €**	**6450 €**
MEDIUM VANS	**0.101**	**0.055**	**0.046 €**	**2.29 €**	**1862 €**	**6882 €**
LARGE VANS	**0.124**	**0.084**	**0.041 €**	**2.03 €**	**791 €**	**12180 €**

Table 4.6 Comparative of VE versus ICE vans in postal fleet

[9] http://www.idae.es/Coches/portal/BaseDatos

[10] http://www.movele.es/index.php/mod.coches/mem.listado/relmenu.4

4.4.1.1 Ireland

As part of the Irish demonstration region a total of 6 vehicles have been monitored over a period of 12 weeks in urban delivery and courier scenarios. These vehicles have all been ICE vehicles, with the intension of assessing usage patterns and analysing suitability for EV alternatives. In addition 3 fixed route courier post-delivery electric vehicles are monitored.

Drive patterns of the monitored vehicles show varying distances in a working day. The monitored vehicles show only one work shift per day, after which the vehicle is idle. The duration of breaks witnessed during the day is short with few lasting for more than 1 hour. The vehicles are all mainly used in day time applications. Due to the nature of the routes, (i.e. the majority is city centre) the vehicles are in the best environment to achieve the maximum ranges specified for EV's.

For vehicles on fixed routes, AC (3.5kW) charging may be sufficient, once the distances travelled are within the practically achievable range of the vehicle. Due to the short breaks and relatively long distances covered by many vehicles, particularly those on variable distance routes, it would be necessary to consider the charging methods for EV urban delivery. Vehicles will often require fast charge or battery swap technologies to facilitate extensions in range during the short intervals between usages. This would be particularly important where vehicles are to be used in 'back to back' shift scenarios, that is, where a driver finishes a work shift and another driver takes the same vehicle for the next shift. Increased range capabilities would address the needs of single shift vehicles where they can be charged over longer periods of time, however the multi-shift vehicles will still require a fast replenish facility.

The nature of usage experienced across the vehicles monitored, would suggest that, if uncontrolled, the charging would take place mainly at the time of peak electricity demand. To best optimise this and to control energy prices for the user, there is opportunity to exploit scheduled charging, thus making use of night-time or other variable electricity rates. While this timing could be undertaken in the vehicle, it would be advantageous to consider centralised scheduling for larger fleets as this would alleviate, stresses to the electricity supply at a depot from large scale simultaneous charging.

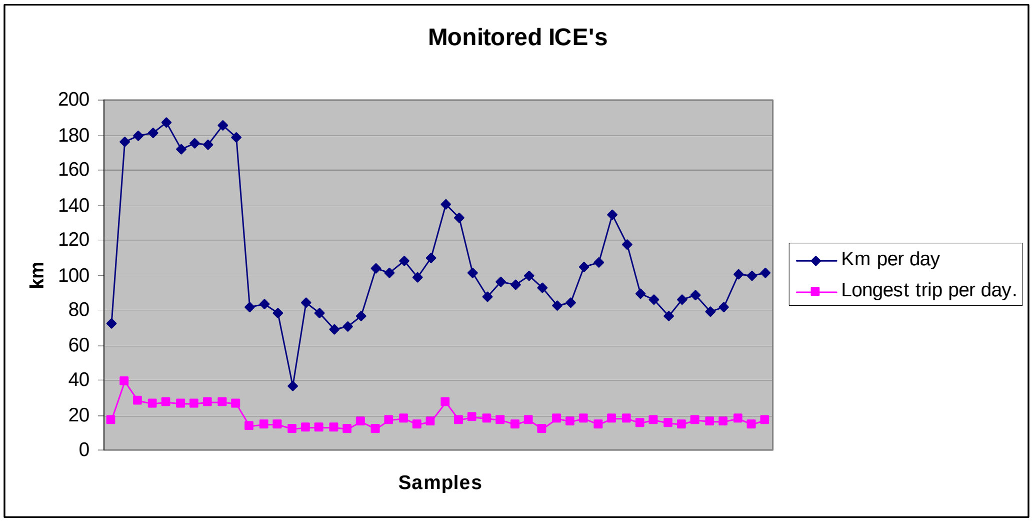


Figure 4.12 Urban Delivery Vehicle Usage

4.5 Car Pool

4.5.1 Ireland

Transport is a particularly significant overhead for many businesses, however it is not goods delivery alone that creates this drain on resources, in many cases it is transit of employees. Company vehicles can be utilised where particular members of staff such as sales or service engineers are regularly travelling on behalf of the business, however in cases where travel patterns are more sporadic, then taxi's or car mileage allowances are typically favoured. The use of personal vehicles is still a financial drain on the business however it has the added disadvantage of requiring the employee to commute to work in their personal car, where they might otherwise be able to utilise public transport. This situation clearly doesn't support the sustainable targets of modern business. A solution to the challenge may be found in a 'car pool' system, however migration to an ICE car pool holds none of the fuel saving benefits, nor does it benefit the sustainable targets of companies.

A fleet of 4 EVs were used in a car pool located at the head office of a Dublin based company. The office is the main workplace of approximately 800 employees from a variety of business units.
As the company has multiple offices within the region and conducts business with other industry partners, employees would regularly be required to travel to other locations as part of their work. This travel may require employees to walk, cycle, use their own vehicle or take a taxi.
The car pool has not yet been advertised throughout the company but relies solely on word of mouth, with the number currently using the car pool standing at 40 users and is provided free of charge. Following this pilot, it is hoped to supplement the number of vehicles available and advertise the service to a wider audience under a 'business shared service' scheme.
Users of the car pool can make bookings by contacting a member of staff responsible for vehicle management who can then view availability and enter bookings on behalf of the user. It is anticipated that the software would be made available to all staff once a wider deployment of the system commences. It is also anticipated that key management is upgraded to allow more automated access control.

Data was gathered from records of the company taxi account and the receipted taxi expenses of employees. The total combined value of receipted expenses from taxi usage and the invoices to the taxi account can be seen in Table 4.8 below.

Taxi Invoices 2011	
01 Jan 2011 - 31 Dec 2011	**Totals**
€ Total	€61,672
No of Trips	4,224
€ Average	€17.17
Av. Distance Km	2.98

Taxi Receipts (Personal Expenses)	
Total spend	€43,473
Total no of trips	2,058

Regulated Taxi Fair Structure	**Rates €**
Standing charge	€4.10
Charge / km	€1.03

Combined Taxi Costs	
Total Spend	€105,145
Total no of trips	6,282
Average Distance Km	12.27

Table 4.7 Taxi Invoices & Expenses

A cost comparison of owning 4 electric vehicles for 5 years against the cost of taxis over 5 years reveals that the taxi's would cost €525,724, while the cost of owning and maintaining the electric vehicles would cost approximately €132,213. See Table 4.9 below.

The TCO for the fleet of 4 EVs has been calculated using the parameters set out below. The distance travelled over the taxi journeys is calculated using the number of journeys and the regulated taxi fairs listed in Table 4.7 above. Currently in Ireland, the cost of a Nissan 'Leaf' is €25,500 with an electricity consumption of €1094 for 77,077km. Energy costs are calculated based on night time charging at a rate of 10.18 cent/kWh. Data acquired from the Nissan 'Carwings' monitoring system calculated energy consumption of 0.14kWh/km, (based on 900km of typical travel) therefore the calculation of fuel for the vehicles is:

0.14kWh x 10.18 cent x 77077km = €1098.50 per year.

The insurance for the four vehicles is estimated at €4000 per year, however for many fleet insurance policies this would be considered high. Vehicle road tax is €120 per vehicle per year and the maintenance costs have been consistent for 3 existing vehicles over 2 years at €105 per vehicle each year. A National Car Test applies to vehicles which are 4 years old, this test is only repeated after a further 3 years and therefore will only apply once during the evaluation period at a cost of €55 per vehicle.

	1 Year (€)	5 Years (€)
Cost of Taxi's	105,145	525,725
EV Ownership x 4		
Capex	20400	102,000
Fuel	1098.50	5492.50
Insurance	4000	20,000
Tax	480	2400
Maintenance	420	2100
National Car Test NCT (Required in Yr 4)		220
TCO	26,398.50	132,212.50

Table 4.8 Comparison Overview

A comparison of emissions showed that for the taxi's journey total distance of 77,077Km the taxis emitted 11.56 million grams of carbon, while the same journeys in an electric car would reduce it to 5.32 million grams (based on Ireland's electricity mix). This promotes sustainable travel and a reduction in their carbon footprint. These figures show that there is an opportunity to improve sustainable travel in the office. The replacement of taxi journeys with low emission electric vehicles not only reduces the companies carbon footprint, but also it's spend on staff transport. See Table 4.9 below.

Emissions		
Taxi carbon g / Km	150	
EV carbon g / Km		69
Taxi carbon g / total Km	11561621	
Millions grams of carbon	11.56	
EV carbon g / total Km		5318345.83
Millions grams of carbon		5.32

Table 4.9 Emissions comparison Taxi v. EV

Tables 4.10 and 4.11 give summary details and assumptions used in the pilot.

Summary Data	
Total number of bookings	1,074
Total distance driven (kms)	29,250
Average distance	27.2
No of bookings per car	358
Avg distance per car	9,750
Number of cars available	4
Working days in month	21

Table 4.10 Summary Data

Comparable monthly costs	
Equivalent cost in a taxi	€4,793.16
Cost to pay for fuel:	**Euro**
- petrol	514
- diesel	310
- electricity	56
Assumptions	
Cost of fuel per km (cent)	
- petrol	12.5
- diesel	7.5
- electricity - Night Rate	1.42
EV Purchase Cost	€25,500
Taxi costs	
Standing charge	€4.10
Charge / km	€1.03
Total distance km Taxi	4,177
No of Standing charges	-160
Total km remaining	4,017
Total cost of standing charges	€656
Total cost of remaining charges	€4,137
	€4,793

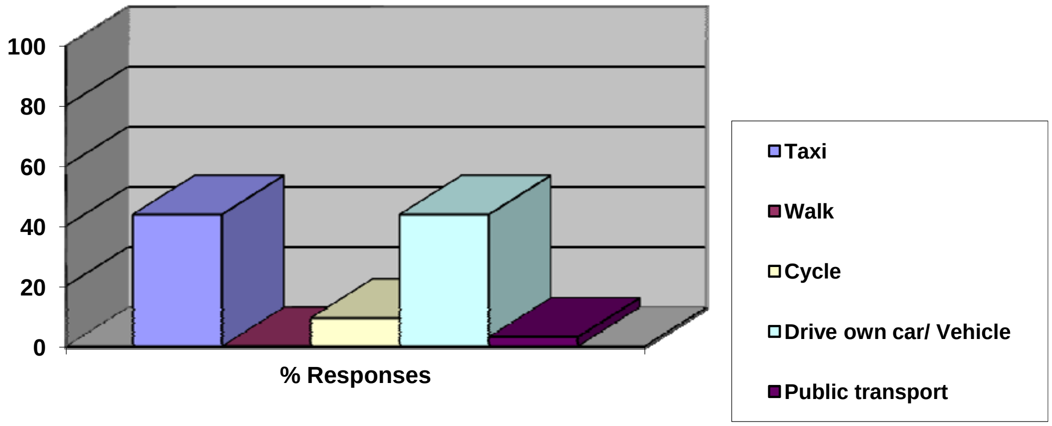
Emmissions	
Total distance for trips Km	4,118
EV carbon g / Km	69
Taxi carbon g / Km	150
Taxi carbon g / total Km	617,687
EV carbon g / total Km	284,136

Table 4.11 Monthly equivalents

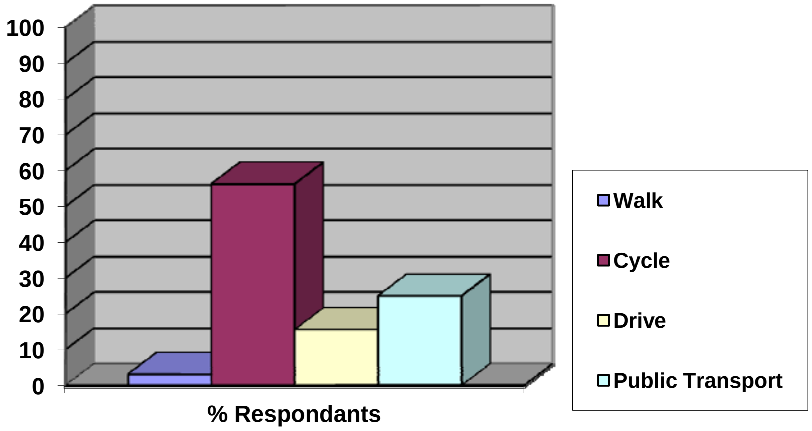
From the data gathered in this use case and validation with equivalent taxi usage, there is a clear benefit both financially and environmentally for the use of an EV car pool. The average return journey the cars were used for was 26Km and the cars were used on average, twice a day. This high number of uses of the vehicles and the high average distances augurs well for the cost benefit of using this type of car pool system in place of a taxi service or indeed a mileage system for personal vehicle usage.

In addition to this data a survey was carried out of registered users of the car pool in which questions were presented relevant to user acceptance. From the responses received it can be clearly seen that the EV carpool was mainly replacing ICE vehicles.
The high level of respondents who use either cycling or public transport to commute to work combined with the high number of users who would have used own transport as an alternative means of travelling to meetings indicates that there is a greater benefit to having EV car pools other than that simply calculated on the business journeys.
While the percentage of work related journeys which were possible with an electric vehicle was high, the main limitation was the range limitation of 70km available with the preproduction vehicles used in the pilot. It should be noted that the ranges available on many of the vehicles currently available is significantly higher, thus allowing almost all trips to be within the capabilities of the EV.

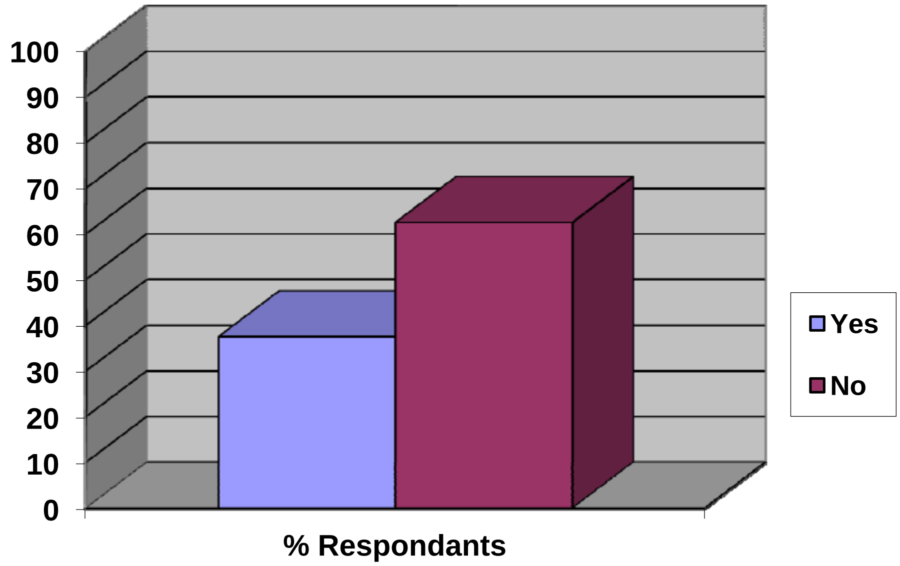
If the electric car was unavailable, what method of transport would you choose?



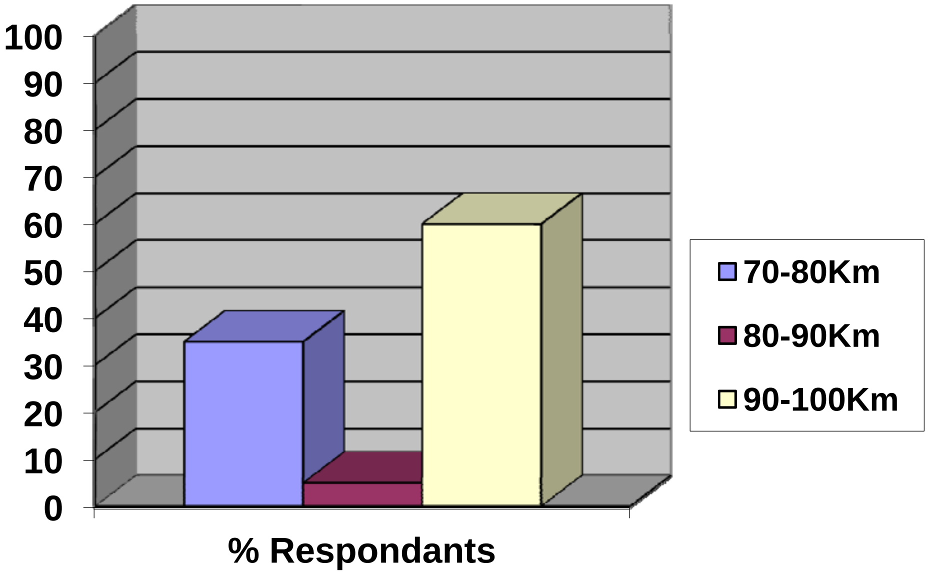
How do you usually commute to work?



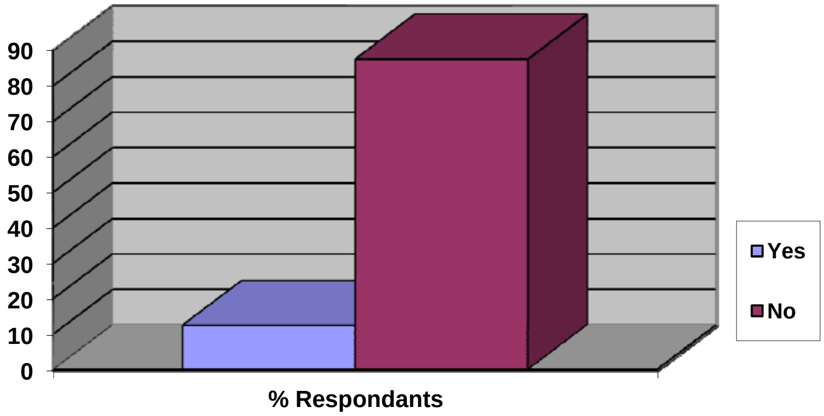
Have there been many work related journeys that the electric car could not facilitate?



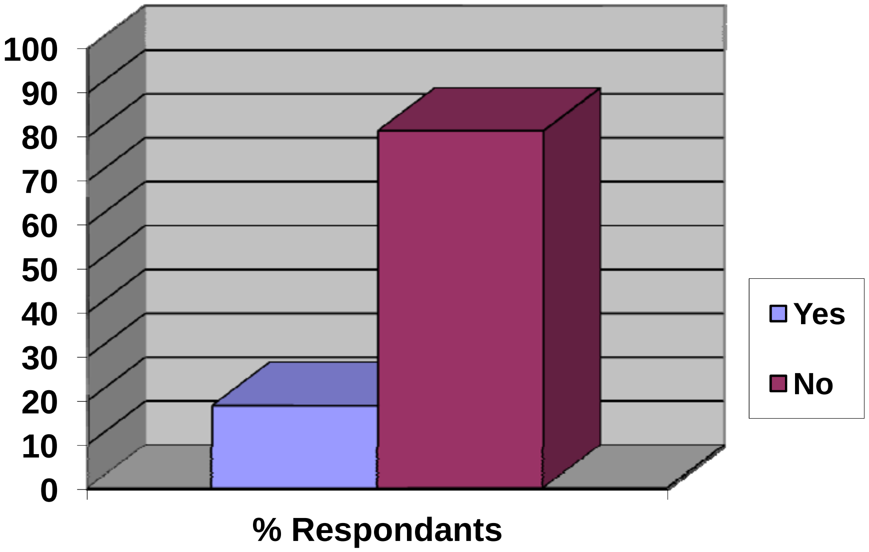
If yes, what distances were they, on average?



Are there any instances where you have recharged the car while using it away from head office during working hours?



Are there any journeys where you would choose a taxi over an electric car, given that the electric car was available?



The above data shows that a car pool system using Electric Vehicles is an acceptable and workable solution to the majority of the respondents. The main limitation of range which was experienced with the preproduction vehicles would not be a factor for many of the vehicles commercially available at this point in time.

4.5.2 Spain

The ES2 Demo Region in Spain has monitored a total of 13 electric vehicles: 8 of them belonging to Iberdrola car sharing. This is a private fleet used by Iberdrola employees in their daily work displacements. The other 5 vehicles constitute a public car sharing fleet located in Ataun and is supported by local authorities. The type of vehicle is a city car and its features are shown in Figure 4.13. Data from a 24-month period has been used in order to analyze the energy consumption and the charging process.

Electric Vehicle	Performance
Maximum speed	120 km/h
Power	40 HP
Acceleration 0-50km/h:	6.5 seg
Range	Up to 203 km (160 normal conditions)
Charging time 8(16A)	80% in 7h
Battery	28,2 kwh (23kWh)

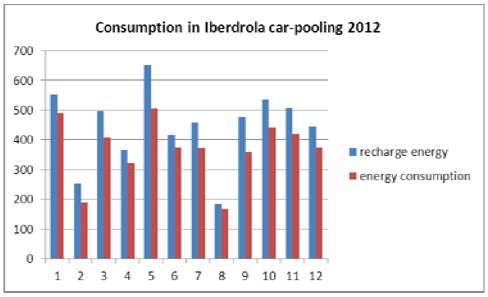
Figure 4.13 Electric city car features

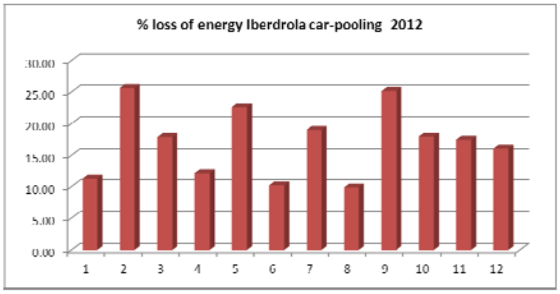
Reviewing the data monitored during the year 2012 (see Figure 4.14) in the two fleets, it can be seen that the consumed energy differs from the energy used for recharging. This is mainly due to the fact that if the electric car is used irregularly, the battery discharges over time. The manual specifies that under these conditions the battery lasts "over a week" and it is advised that you have always plugged the car in if it is not used.

[6] Report No.1: Integrating Electric Vehicles into a Commercial Fleet Feasibility & Deployment Strategy.

[7] European Vehicle Market Statistics Pocketbook 2013

As can be seen in the graphs, the energy loss in the vehicles from Iberdrola car sharing is greater than that from Ataun fleet. Reduced use of vehicles from Iberdrola car sharing causes the battery to become discharged more often. It can be concluded that an electric vehicle will be more efficient the more often it is used. This is also true when compared to a conventional vehicle.





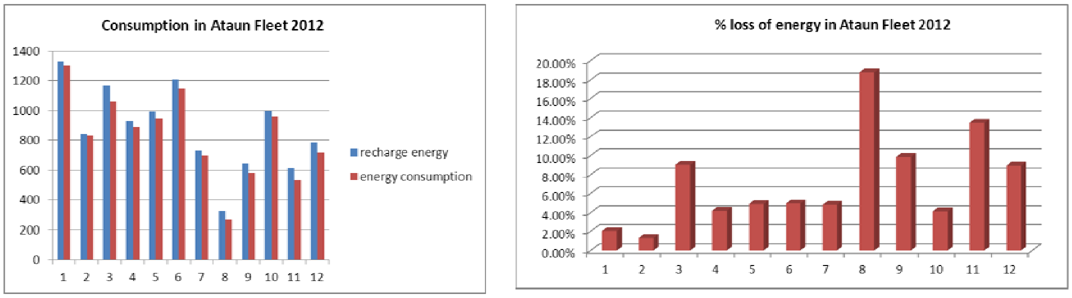


Fig 4.14 Comparative of consumption in Iberdrola car sharing and Ataun Fleet 2012

Routes

Madrid is the largest city of Spain and the third largest city in the European Union. The city spans a total of 604.3 km^2. There is a great number of extended suburbs and villages around the city. Madrid Airport is located 13 km from the city center. There are several orbital motorways: M30 is the innermost ring road of the city and the length is 32.5 km (maximum speed 90 km/h). It is almost inside the city being the busiest road. Outer rings are named M-40 (maximum speed 100 km/h), and M-50 (maximum speed 120 km/h).

Fig 4.15 Madrid Map

A fleet of EVs from Iberdrola car sharing has been used to perform this study. Data from the vehicles location during each journey was collected by a GPS navigation system. Analysing the data shown in figure 4.16, it can be seen that most of the trips were made to the metropolitan area of the city inside the area surrounded by the M30, mainly around the east of this area.

These journeys are made from the company's head office at Tomas Redondo Street (Fig 4.15) to other locations travelled by employees as part of their daily work (Fig 4.16). These routes correspond to the main avenues and streets of the city, such as the Paseo de la Castellana, Príncipe de Vergara, Avenida de Alberto Alcocer, Avenida de América, and Calle de Alcalá. To access these locations drivers usually use the fast roads of the city, like the M30 and M40.

There are also routes corresponding to remote parts of the city with the objective to reach nearby villages. Examples are the villages located around 50 km, like Colmenar Viejo 50 km, Torredolones 42 km, Alcorcón 35 km, Griñon 50 km and Pinto 33 km.

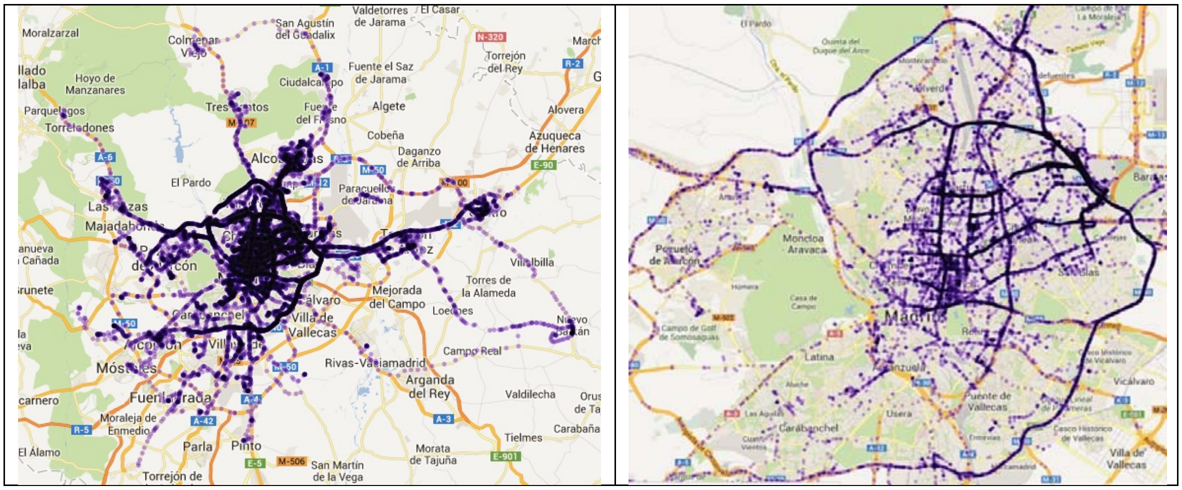


Fig 4.16 Usual routes of Iberdrola car sharing

The average distance travelled (figure 4.17) each month by Iberdrola car sharing in 2012 was around 10 km (figure 4.17). However, in the case of Ataun fleet, this value is approximately 16 km. Travel distances of less than 2 km have not been taken into account. This is due to the routine use of these cars that usually access business areas which are very close to the starting point of the vehicles. Moreover, the average total number of trips (figure 4.18) made monthly by Iberdrola car sharing fleet in 2012 is around 140 trips (0.88 uses/day) while in Ataun fleet it is around 314 trips (3.14 uses/day).

From the data analysed in this study it is possible to conclude there is an actual benefit related to the use of electric vehicles versus Internal combustion vehicles, mainly in big cities. Until the electric car has more uptake among private users, only the use of electric vehicles in fleets has greater advantages over other means of transport using fossil fuel.

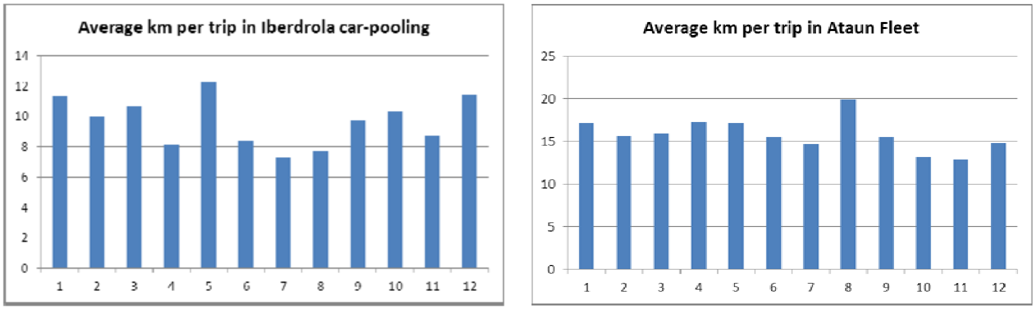


Fig 5.13 Comparative of km per trip in Iberdrola car-pooling and Ataun fleet 2012

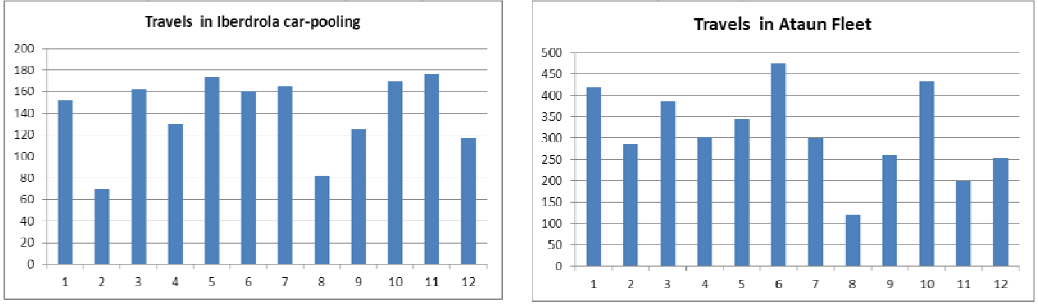


Fig 4.17 Comparative of travels in Iberdrola car-pooling and Ataun fleet 2012

In the graph below the estimated speed that vehicles have reached in their routes around the city is shown. As can be seen, the areas of use are clearly defined. In the downtown area of the city the speed is below 50 km/h. The sections comprising the M30 inner ring and the access to the outer ring M40 show that the speed is below 70 km/h due to the speed limit on those fast roads, and finally the speed is around 100 km/h in the outer ring road M40 and the exits from M40 to reach the closer villages.

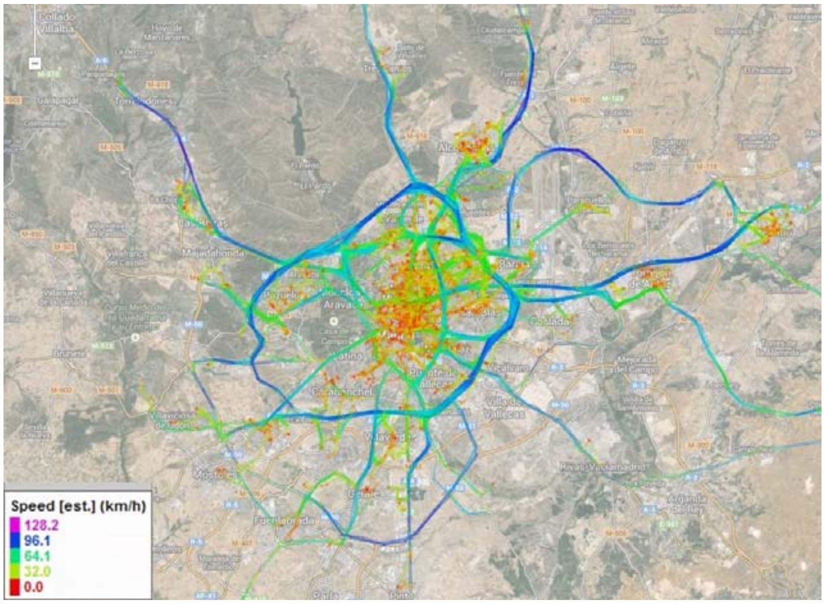


Fig 4.18 Vehicles speed in Iberdrola car sharing

Fuel Consumption

A theoretical energy cost comparison of electric vehicles against conventional ones of similar features to those from the ES2 Demo Region reveals that the ICE vehicle energy would cost about 0.0805 €/km, while that from the electric vehicle would be of approximately 0.02955 €/km. This equates to 3 times less energy cost in the EV. However, if we consider the actual monitored data throughout the year 2012 in Iberdrola car sharing and Ataun pilot, the actual cost of the power consumption of the electric car is significantly higher than expected when compared to the theoretical data. These data are not as advantageous as one would initially expect. The fuel savings of the electric car are reduced to 53% in the case of vehicles from Ataun and only about 30% in the case of those from Iberdrola car sharing.

The difference between real and theoretical consumption of the vehicle is determined among others, by the use of heating and air conditioning and the speed. The climate is not equal in the selected locations. Ataun climate is very soft. The lower usage of cars in Iberdrola car sharing, linked to the increased use of heating systems and conditioned areas contribute to lower the efficiency of the electric vehicle. Besides, the high speed of Madrid´s motorways demand more energy than Ataun´s roads.

EV Manufacturer	ATAUN 2012	IBERDROLA 2012	ICE (similar features)
0.02955 €/km	**0.03722 €/km**	**0.05579 €/km**	**0.0805 €/km**
Battery 28Kw Autonomy 180 kw	Diesel Price 1.4€/ l Electricity Prices 0.19 € kw/h		

Table 4.12 Consumption comparative of the different scenarios

Fleet-Month-Year	Energy consumption per month	Kilometers per month	Charging times per month	average €/kw
Iberdrola 1-2012	552.552	1812	77	0.0594
Iberdrola 2-2012	254.324	707	40	0.0602
Iberdrola 3-2012	496.748	1638	84	0.0543
Iberdrola 4-2012	366.1	1337	61	0.0511
Iberdrola 5-2012	652.12	2114	89	0.0549
Iberdrola 6-2012	416.164	1484	79	0.0579
Iberdrola 7-2012	457.66	1434	77	0.0587
Iberdrola 8-2012	185.584	674	40	0.0562
Iberdrola 9-2012	478.184	1502	68	0.0541
Iberdrola 10-2012	535.808	1839	87	0.0516
Iberdrola 11-2012	508.004	1601	84	0.0535
Iberdrola 12-2012	444.752	1397	60	0.0571
Ataun 1-2012	1330	6959	178	0.0402
Ataun 2-2012	842.8	4185	131	0.0438
Ataun 3-2012	1168.16	5952	174	0.0380
Ataun 4-2012	927.08	5077	134	0.0364
Ataun 5-2012	995.12	5857	152	0.0338
Ataun 6-2012	1207.64	7455	216	0.0328
Ataun 7-2012	730.8	4494	133	0.0336
Ataun 8-2012	326.76	1707	54	0.03002
Ataun 9-2012	642.6	3755	97	0.0342
Ataun 10-2012	997.92	5774	153	0.0361
Ataun 11-2012	613.48	2867	100	0.04313
Ataun 12-2012	788.2	3915	115	0.04427
Assuming Electricity Price 0.19€/kwh				

Table 4.13 Data by month of pilot fleets during year 2012

The total cost savings by month of city cars that have been used in both fleets throughout the year 2012 can be seen in the graph below. An average consumption of 5.75 l, for a conventional diesel city car and a fuel price of 1.4 €/l. (0.0805 €/km) has been considered. An average fuel price has been estimated, considering the price in Spain is different depending on the region (mainly due to rates of tax).

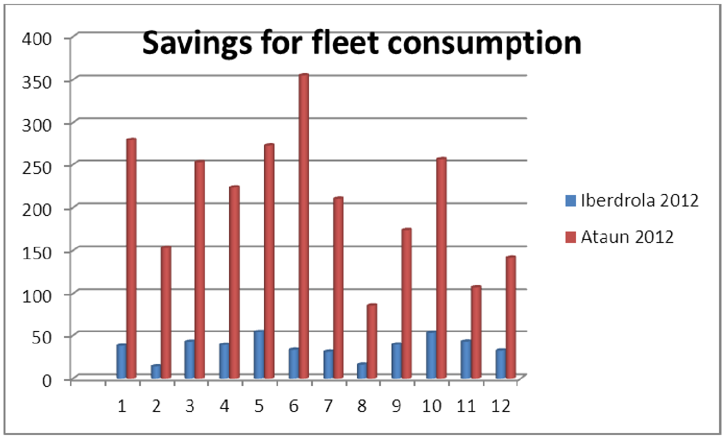


Fig 4.19 Estimated saving by the use of EV versus ICE in Iberdrola car-pooling and Ataun fleet

This data can be used to calculate the average total savings of an electric car versus conventional car considering the lifetime of the battery which can be estimated around 1,200 recharges, equivalent to 234,000 km.

(0,0805 €/km – 0,05579 €/km) * 234.000 km = 5.780 € Iberdrola car sharing
(0,0805 €/km – 0,03722 €/km) * 234.000 km = 10.126 € Ataun fleet

4.6 Electric Hoists

ESB Networks in 2009 set upon a program of reducing the Carbon emissions of their ‘yellow’ fleet. Targets of 30% by 2012, 50% by 2020 and100% 2035 have been set. Since then ESB have introduced two fully electric MEWPS (Mobile Elevated Working Platform), into their fleet with a further eight vehicles converted to-date. The diesel powered vehicles were fitted with lithium battery packs to operate the MEWP part of the vehicle.

These are ‘every day’ working vehicles fitted with hydraulic platforms that allow our network technicians to service and maintain the ESB overhead networks infrastructure.

Figure 4.20 Smith Newton Electric MEWP

For our assessment we are monitoring the power consumption of the Electric and Hybrid vehicles compared to similar vehicles fuelled by Diesel. Both sets of vehicles are in everyday usage and will be compared as part of routine activity rather than a laboratory style test.

The vehicles we are going to look at are a Smiths Newton 10t 120kW electric truck, which went into service in May 2012. The second vehicle is a 2009 Mercedes Atego 918, 11 tonne diesel powered engine with an output of 130kW (177hp) at 2,200 rpm which in turn operates a power take off (PTO) which when engaged by the driver operates the hydraulic system to power the MEWP.

The vehicle is based in Enniscorthy, Ireland and is operated by a network technician in the same location. The operator returns monthly reports via an hour meter fitted to the machine to capture its usage of the battery pack. To date the MEWP has a total of seven hundred and forty hours of working time on its battery pack.

In parallel we looked at the conventional diesel vehicle (Mercedes Atego) doing the same type of work and looking at its PTO/ idle time, to see what advantages/disadvantages the electric/Hybrid had over the diesel vehicle, and any savings that could be achieved.

The Smiths Newton has now been in service for 15 months and has travelled 2,500kms. The MEWP side of the vehicle has operated on average three hour per day and in that time it has a total reading to date of nine hundred hours.

The Mercedes Atego hybrid MEWP has a plug-in 220 volt system to charge the lithium battery pack. Charging took place at the end of the operator’s working day, and left charging over night ready for use the next day.

It takes eight hours to charge the battery pack to its full capacity this is indicated by means of a meter fitted to the battery pack unit.

As mentioned above we will consider the fuel usage of a conventional MEWP working at the pole with its engine idling and PTO engaged.

Hybrid Power Pack System.


Figure 4.21 Mercedes Atego Hybrid MEWP

Pilot study on battery operated Power Pack System.

Fleet & Equipment have carried out a pilot study using a battery power pack system to operate their mobile elevated work platforms (MEWPs) and truck mounted cranes. Fleet & Equipment is committed to fitting a battery power pack system to a MEWP and Crane before the end of 2009.
The Pilot study will focus on:

- Safety.
- Reliability
- Electric being the Primary Power
- Fuel use

The estimated cost of the battery power pack unit will be in the region of 15,000 to 20,000 Euros.
Working on the Motor industry average fitting power pack units to all our MEWPs and Cranes on our fleet the reduction of carbon emissions would be an estimated 1518 tons Co2 per annum (see calculations below).

- ESB avg. 3h per day idling and operating Crane/MEWP
- Industry avg. 2lt. Per hour = 5kg Co2
- 3h x 5Kg = 15kg Co2 a day per Vehicle.

- 260 hoists, 200 cranes, Total 460 units
- 44 weeks. 460 units. 75kg Co2 per week = 1,518,000 kg. Co2 per annum.
- 1518 ton Co2 per annum.

Example of power pack system currently under research and development by Versalift UK.

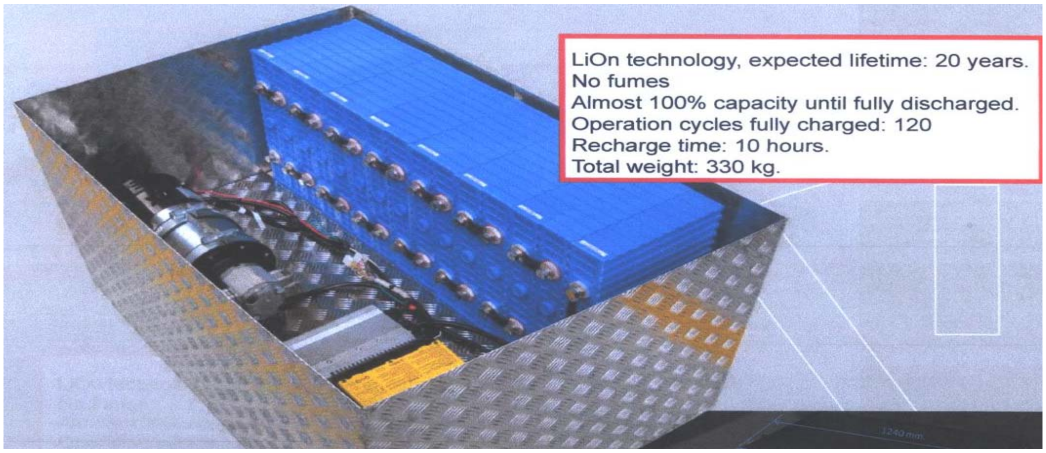


Figure 4.22 Truck Mounted Power Pack Versalift

4.7 European City Comparison

The nature of urban logistics is similar to many others where margins are extremely tight. To be competitive and win contracts the operator must trim all possible aspects of operating costs. Of high impact on the operating cost of urban delivery or logistics companies is fuel, therefore regular fuel savings are crucial for the competitiveness of operators.

One of the perceived concerns of logistics companies is the limited driving range of vehicles. If the vehicle cannot cover the required range then the fuel cost is irrelevant. The table below shows a selection of European cities, comparing the geographical layout of the region. Each of the cities has been considered in terms of its outer ring road which reasonably creates a boundary for the ‘urban’ zones.

While considering the use case of urban delivery, there are two distinct modes of operation. The first is fixed route and the second is the ‘job by job’ basis. Fixed route delivery holds massive potential for EV use. Fleet operators will have accurate data relating to each vehicle, where this data is not available historically it can easily be gathered by taking a daily reading from the vehicle’s odometer. It is important to consider, that with the increasing availability of fast charge infrastructure, the vehicle is not limited to the range achievable with one battery charge, but rather has the opportunity to achieve greater autonomy by making use of a charge on route or during natural break times or rest periods for a driver.

Country	City	Nth - Sth (km)	East - West (km)	Average diameter (km)	Size rank
Germany	Berlin	72	79	75.5	1
UK	London	76	66	71	2
Germany	Hamburg	42	42	42	3
Austria	Vienna	40	34	37	4
France	Paris	30	42	36	5
Italy	Rome	37	25	31	6
Lithuania	Vilnius	34	28	31	7
Germany	Munich	31	29	30	8
Spain	Madrid	35	24	29.5	9
Latvia	Riga	29	28	28.5	10
Germany	Frankfurt	26	30	28	11
Ireland	Dublin	30	22	26	12
Malta	-	26	23	24.5	13
France	Lyon	21	22	21.5	14
The Netherlands	Amsterdam	19	23	21	15
Belgium	Brussels	19	21	20	16
Estonia	Tallinn	18	22	20	17
France	Marseille	23	14	18.5	18
Spain	Bacelona	25	11	18	19
Switzerland	Zurich	19	17	18	20
Ireland	Cork	16	13	14.5	21
Demark	Copenhagen	15	13	14	22
Ireland	Belfast	16	10	13	23
Greece	Athens	11	14	12.5	24
Spain	Seville	14	10	12	25
Portugal	Lisbon	9	13	11	26
Sweden	Stockholm	10	9	9.5	27
Portugal	Porto	8	10	9	28
Switzerland	Geneva	9	8	8.5	29
Switzerland	Bern	8	8	8	30
Malta	Valletta	4	1.5	2.75	31

Table 4.14 European City Dimensional Overview

A selection of Europe’s larger cities have are presented in Table 4.14 above. While each potential Fleet EV adopter will need to assess their own fleet individually, the table assists in comparing these cities to the cities presented in the use cases. Each operator should also consider the rate of travel in their location as slower travel rates will mean greater diesel consumption and lower electricity consumption resulting in higher EV autonomy on a single charge.

5 Fleet EV Usage Patterns

The data from all vehicles registered under the category 'fleet' in each of the demo regions of Green eMotion has been correlated to provide some useful information on usage times and charge start times.

Figure 5.1 below shows the distribution of 'Plug in' times for the monitored vehicles. The chart shows the times of plug in predominantly across the standard day to evening time after a work shift. The data indicates that while there are significant plug in events arising during the typical evening energy electricity consumption peak, the number of events during the daytime is still very high. This differs significantly from the private vehicle household charge events monitored in GeM WP 1, which showed a much higher level of charge events started at or during the evening peak. This indicates that the effect on the electricity system could be significantly lower on fleet vehicles than an equivalent number of private use vehicles.

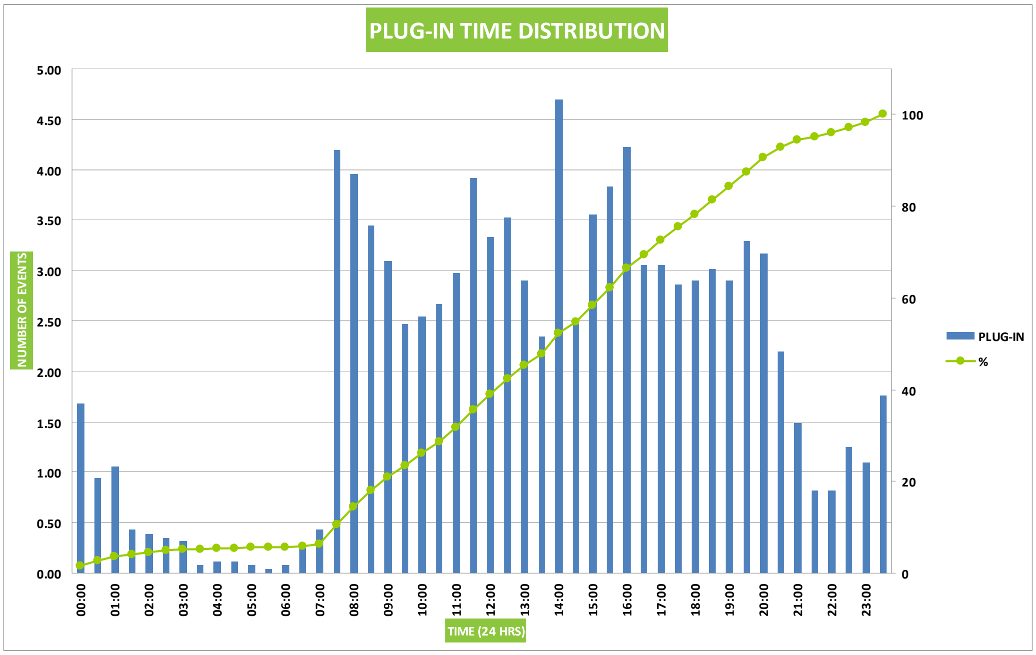


Figure 5.1

The distribution of start and finish times of fleets are shown in Figure 5.2 and Figure 5.3 respectively. These charts show that the distribution overlap is very close indicating that the journey times are generally short. The monitored vehicles started their daily activity at approx. 6.30 am. Last journey activity tapering off from 6pm with almost no activity after 11pm.

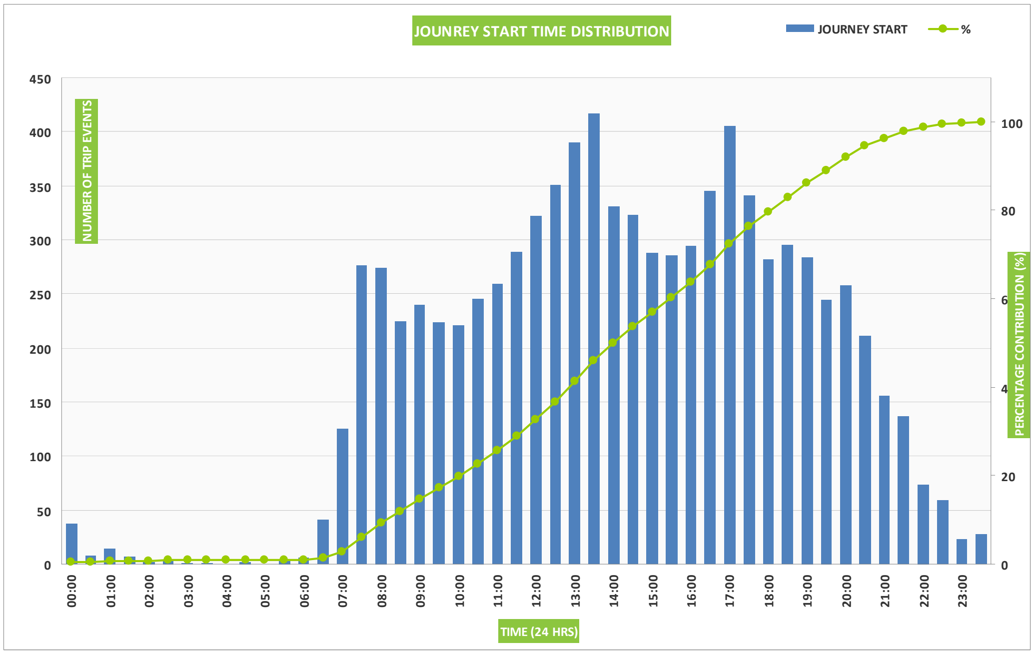


Figure 5.2

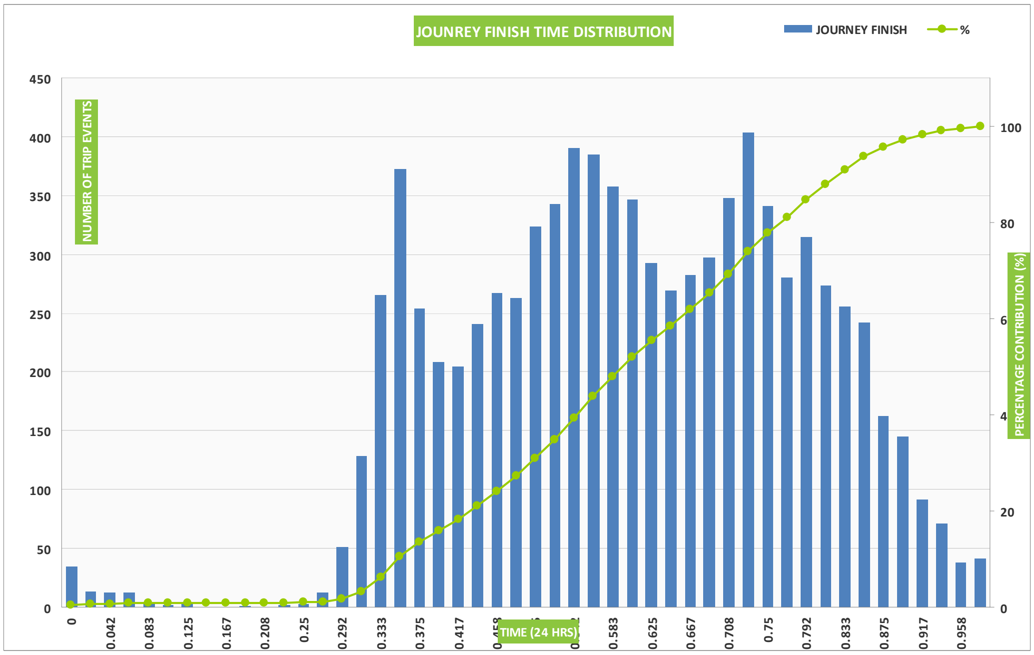


Figure 5.3

The combination of the chart event plug in times as well as the journey start and finish times show that fleet vehicles tend to use available opportunities for top up charging. This charging is spread out over a wide section of the day.

5.1 Vehicle Costs

Vehicle costs of EVs have reduced significantly over the last number of years. In many cases the initial investment is the same or little more than an ICE equivalent. This has been brought around by larger production quantities and the entrance of the vehicle OEM's to the EV market. It is now much simpler for a fleet manager to assess the costs of migrating some or all of a fleet to EV. Purchase /lease costs, fuel and maintenance are now straight forward to calculate. The reduced cost has made the proposal of EV's far more cost effective for potential customers in general, however due to the vehicles being offered this is particularly true when it comes to fleets.

5.2 Lease/Purchase models

There are two main models by which EV's are sold into the European market. These are Battery lease and outright purchase.

Battery lease is where the vehicle is sold to the customer however the battery is leased thereafter. This removes any perceived risk the customer may foresee regarding battery life or battery technology improvements. In the case of battery degradation vehicle supplier would be responsible for changing the battery. In a scenario where there was a significant advance in battery technology or efficiency, the supplier may offer an upgrade lease for the vehicle.

Outright sale is where the vehicle is sold to the customer including the battery. This leaves the customer responsible (after warranty) for the vehicle battery. Customers who do not perceive the risk to battery life or customers, who do not want a continuous payment scheme, may find this more attractive.

Currently the purchase models offered after singular by manufacturer; however the changing arena may prompt manufacturers to offer multiple purchase models. Furthermore there is no reason why manufacturers or leasing companies would not offer other alternatives.

5.3 Fuel Economy

Prices

One important aspect when assessing the advantages of EVs against conventional vehicles is the analysis of fuel consumption. The differences in consumption are determined mainly by the cost of electricity, compared to gasoline or diesel. Figure 5.1 shows the evolution of diesel and gasoline average prices in Europe over the last two years (2012-2013) based on the oil bulletin of the European Commission[1].

If these data are analysed, it can be observed that although the prices have increased during some months along the studied period, current gasoline and diesel prices are similar to those at the beginning of the year 2012. The differences in price in the last month of 2013 among the different countries of the European Union are striking with maximum values above 1.7 € / l and minimum values below 1.25 € / l as shown in figure 5.4

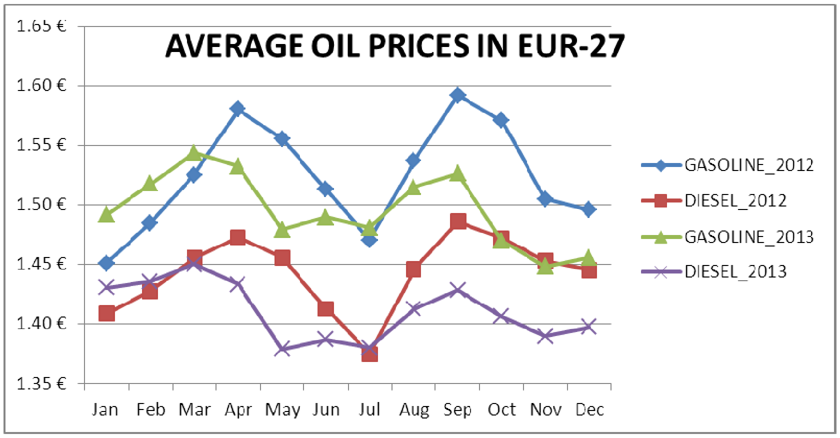


Figure 5.4 Oil prices evolution along the years 2012-2013 in Europe

In these graphics (Figure 5.4 and 5.5) all taxes and duties have been included in the price of gasoline and diesel. These taxes are high in the case of diesel or gasoline in most European countries, and this is reflected in the price paid by consumers. These taxes (Figure 5.6) have an average weight of 58% of the total price in the case of euro-super 95 and 50% in the case of diesel oil in the countries of the European Union at the end of 2013. The rising price of fuel is of concern not only to private consumers, but to fleet managers who see this as a problem when managing their fleets. Needless to say this increase has had a severe impact on cost, and in particular on the Total Cost of Ownership (TCO) of fleet. A recent study by GE Capital[2] showed that, on average across Europe, fuel cost represents 26% of a company car fleet´s TCO. Although better fleet fuel management can help mitigate the high costs of fuel, an option that more and more managers are taking is the replacement of part of the fleet with electric vehicles.

[1] http://ec.europa.eu/energy/observatory/oil/bulletin_en.htm

[2] Fleet Europe Magazine nº 66.October 2013

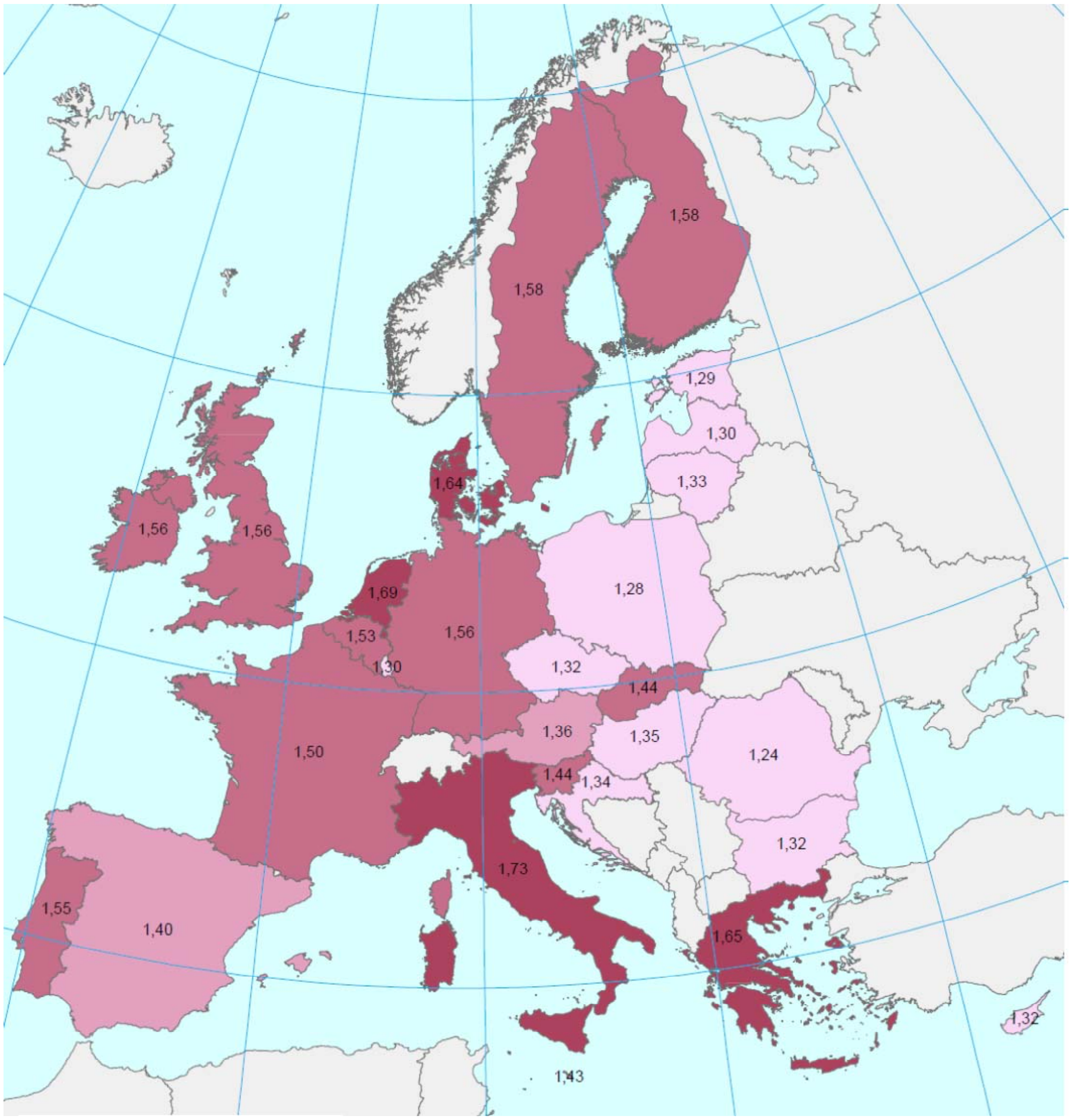


Figure 5.5 Consumer prices per litre of petroleum products at 9-12-2013

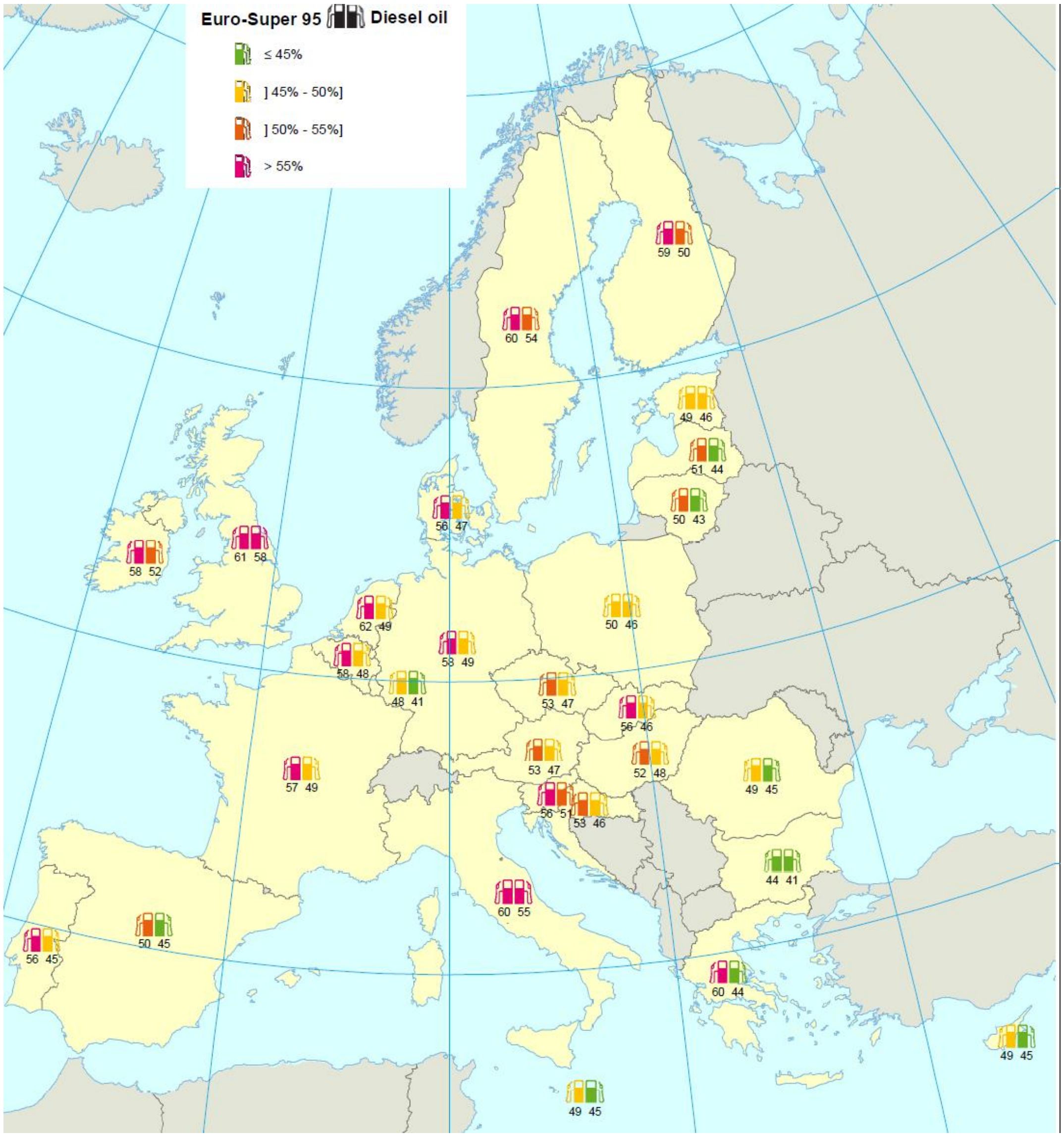


Figure 5.6 Total taxation shares in the end consumer price of euro-super 95 and diesel oil at 9-12-2013

On the other hand, the electricity prices follow an uptrend in the last years according to data from the European Commision[3]. Figure 5.7 shows the trend of the EU-27 electricity prices for household consumers over the last 6 years. Electricity prices for households increased in 2008, remained stable or even decreased in 2009, but went up again since 2010. From 2010 to 2013, the price has continued to rise.

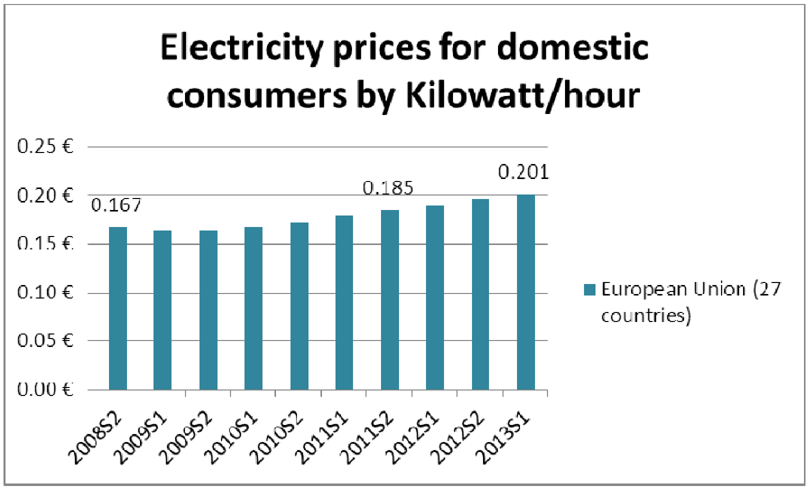


Figure 5.7 Electricity prices evolution along the years 2008-2013 in Europe

In the case of electricity the taxes are growing and the governments use them in order to increase generating revenues for the public budget. Although the electricity taxes[4] are not as high as in the case of diesel or gasoline tax, the trend in the coming years is that prices may increase, lowering the fuel economy advantage of the electric car. In the graphs (figure 5.8 and 5.9), the contribution of the base price (HT) and taxes on (Vat and other taxes and levies) the total price of electricity can be observed.

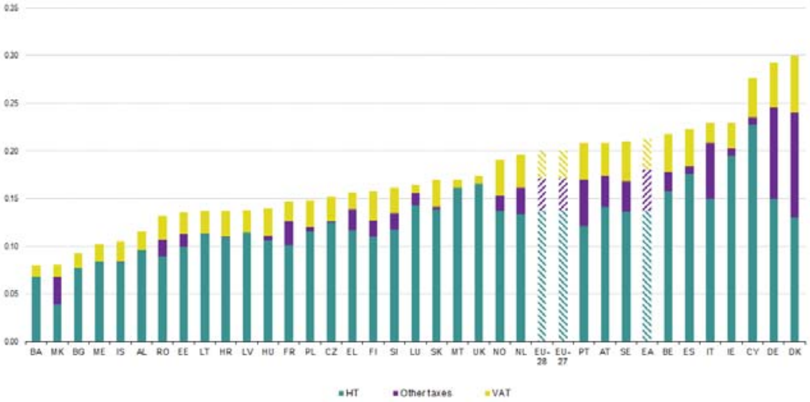
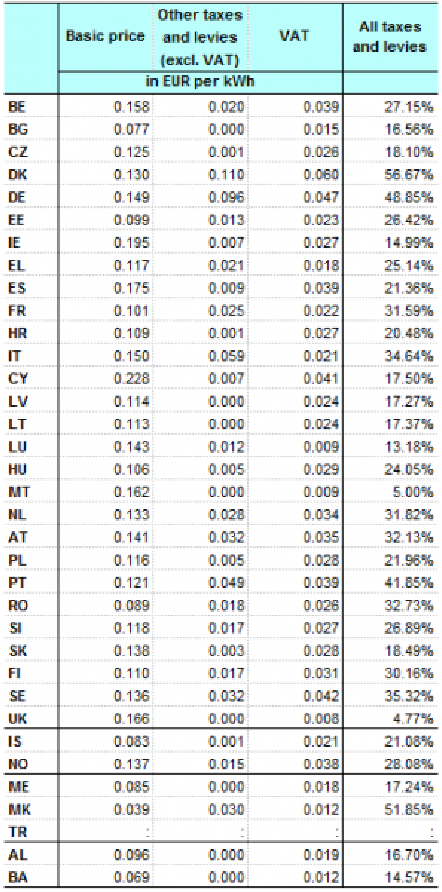


Figure 5.8 Electricity prices for household consumers 2013

[3] http://ec.europa.eu/energy/observatory/electricity/electricity_en.htm

[4] http://epp.eurostat.ec.europa.eu



	Basic price	Other taxes and levies (excl. VAT)	VAT	All taxes and levies
	in EUR per kWh			
BE	0.158	0.020	0.039	27.15%
BG	0.077	0.000	0.015	16.56%
CZ	0.125	0.001	0.026	18.10%
DK	0.130	0.110	0.060	56.67%
DE	0.149	0.096	0.047	48.85%
EE	0.099	0.013	0.023	26.42%
IE	0.195	0.007	0.027	14.99%
EL	0.117	0.021	0.018	25.14%
ES	0.175	0.009	0.039	21.36%
FR	0.101	0.025	0.022	31.59%
HR	0.109	0.001	0.027	20.48%
IT	0.150	0.059	0.021	34.64%
CY	0.228	0.007	0.041	17.50%
LV	0.114	0.000	0.024	17.27%
LT	0.113	0.000	0.024	17.37%
LU	0.143	0.012	0.009	13.18%
HU	0.106	0.005	0.029	24.05%
MT	0.162	0.000	0.009	5.00%
NL	0.133	0.028	0.034	31.82%
AT	0.141	0.032	0.035	32.13%
PL	0.116	0.005	0.028	21.96%
PT	0.121	0.049	0.039	41.85%
RO	0.089	0.018	0.026	32.73%
SI	0.118	0.017	0.027	26.89%
SK	0.138	0.003	0.028	18.49%
FI	0.110	0.017	0.031	30.16%
SE	0.136	0.032	0.042	35.32%
UK	0.166	0.000	0.008	4.77%
IS	0.083	0.001	0.021	21.08%
NO	0.137	0.015	0.038	28.08%
ME	0.085	0.000	0.018	17.24%
MK	0.039	0.030	0.012	51.85%
TR	:	:	:	:
AL	0.096	0.000	0.019	16.70%
BA	0.069	0.000	0.012	14.57%

Figure 5.9 - Share of taxes and levies paid by household consumers, 2013s1

Fuel and the energy price predictions in the next year isn´t an easy task (figure 5.10). According to energy analysts[5], the price of the oil barrel is going to stay stable in 2014 with similar prices to current. On the contrary, an increase in the cost of electric energy throughout next year is expected.

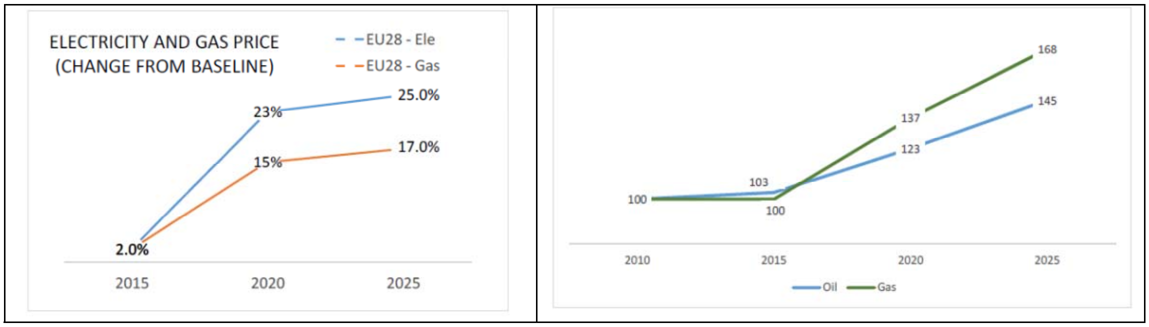


Figure 5.10 Electricity and Oil price predictions

[5] http://ec.europa.eu/energy/doc/2030/20140122_swd_prices.pdf

Fleet fuel economy will be analysed taking the example from the previous version of this document. Comparing the fuel consumption for a van and its electric counterpart, it is possible to obtain some conclusions. The savings of EV electricity costs against the cost of running conventional fuel can be accurately calculated as:

$$S_{EV-F} = \left(1 - \frac{C_E \frac{P_{EV}}{R_{EV}}}{C_F \frac{F_E}{100}} \right) \times 100$$

Where:

Parameter	Meaning	Units	Example
C_F	Fuel cost	€/l	1,4
F_E	Fuel efficiency	l/100km	5,9
C_E	Electricity	€/kWh	0,17
P_{EV}	Capacity of the battery	kWh	22
R_{EV}	Range of EV	km	170

If we compare the differences in the fuel economy between conventional and electric vans used in fleets along 2011-2013 years in the different countries of the European Union, when switching from ICE vehicles to EV ones (see Fig 5.11), savings are practically constant with a decline in 2013 of approximately 1% compared to 2011. The potential average savings in percent for the years 2011, 2012 and 2013 are 0.728, 0.731, and 0.714 respectively. Therefore, fuel savings derived of using EVs versus conventional vehicles can be estimated and they would keep almost constant in the next year. (Taking estimated prices of 1.4 €/l and 0.17 €/kWh).

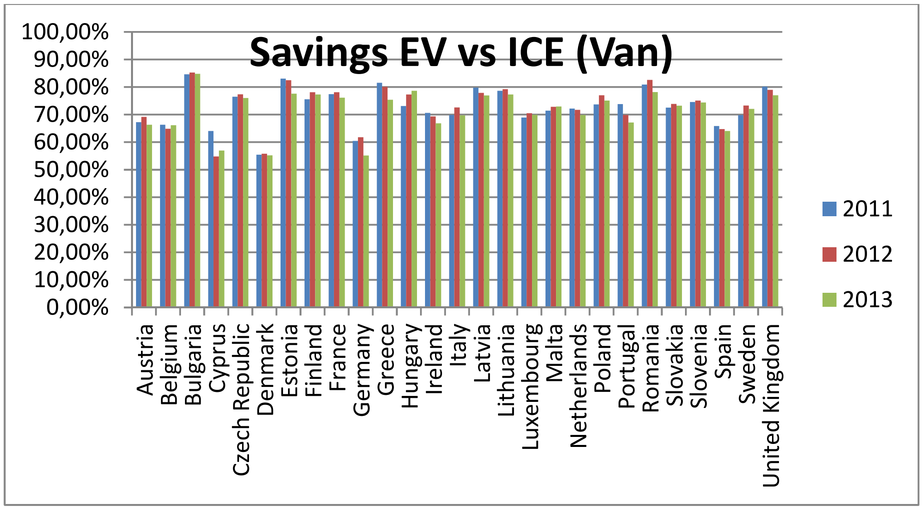


Figure 5.11 Savings of EV van vs. ICE van in European countries 2011-2013

Another important point to be analysed for the implementation of electric vehicles in fleets is the efficiency of both vehicles. According to the report from Ecology Foundation[6] the efficiency of diesel vehicles is 25% whereas that of electric vehicles is 75%. Allowing for the inefficiencies of power generation (45%) and transmission (90%), the overall efficiency of the electric vehicle (30%) is still better than that of the internal combustion engine (25%).

The average official fuel consumption of new cars in the EU[7] decreased from about 6.8 l/100 km in 2001 (1,500 €/year*) to 5.4 l/100 km in 2011 (1,200 €/year). Recent analysis [7] on nearly half a million vehicles show that on-road fuel consumption did not decrease to the same extent. Instead, the gap between official (laboratory tested) values and the 'real-world' driving experience of vehicle owners increased from about 7 % to 23 %. The target of the European Union in 2020 is that the average fuel consumption of new cars is around 3.8 l/100km or € 850 / year.

Therefore, in the coming years an improvement in the efficiency of power batteries will be necessary due to the future expected improvement in the efficiency of conventional vehicles. The member states should also consider ways to control the rise in cost of electricity.

* Assuming 15.000 km/year of driving and 1.5 €/l fuel price.

5.4 Maintenance Costs

In a similar manner to the cost of fuel for a conventional ICE car versus an EV, the cost of maintenance is also a factor to consider in relation to the total cost of a vehicle. There are various types of vehicle maintenance. Maintenance operations can be mainly classified into two types.

Routine or preventive maintenance: represents the maintenance associated with periodic operations according to the car manufacturer. Some of these operations, such as changing the oil or replacing the timing belt, are necessary to help prevent a major breakdown.

Corrective maintenance or repair is a system of maintenance that is performed after a fault or breakdown has occurred, with the goal of restoring operability to the system. In some cases, it can be impossible to predict or prevent a failure, making this type of maintenance the only option. In other instances, a system can require repairs as a result of insufficient preventive maintenance.

We can include a third type of maintenance based on replacement due to wear and aging of the vehicle parts. Such operations can be defined as **safety preventive maintenance** and usually are recommendations done by the car workshops based on visual inspections done in preventive or corrective maintenance operations. The tasks associated with this type of maintenance are focused on preventing the occurrence of unexpected breakdowns. (e.g. changing brake pads, tyres or windshield wiper blades).

In the next sections the different maintenance costs for ICE and electric vehicles will be analysed.

Many studies tend to confirm that the maintenance costs of an electric car are lower than those from an ICE vehicle. The current chapter is intended to analyse the maintenance costs for various types of vehicles to make an estimation of the corresponding maintenance costs for the same EV counterparts.

According to a study conducted by (IFA)[6] and published on 20 November 2012, maintenance and repair costs for electric vehicles will be around 35 percent below costs of a comparable internal combustion vehicle. The Institute calculated these numbers on the basis of a small car with a lifetime of 8 years and an annual mileage of 8,000km. For ICEs, running on gasoline or diesel, maintenance and repair costs will represent on average 3,650€, when owners of a battery-electric car will only have to pay 2,350€. The main reasons are:

- Elimination of oil changes
- No need for replacement of exhaust systems and couplings
- Regenerative breaking reduces brake wear
- Fewer moving parts
- Electrical systems do not require frequent maintenance

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[6] Institute for Management in the Automotive Sector (Institut für Automobilwirtschaft [IFA])

Routine Maintenance Costs

Firstly, the costs of preventive maintenance of ICE vehicles will be analysed. Four categories of vehicles have been chosen based on size and usage-based vehicle classification systems worldwide. Below the European classification is defined[7].

Euro NCAP Class (1997 2009)	Euro Market Segment
Supermini	B-segment small cars
Small family car	C-segment medium cars
Large family car	D-segment large cars
Small-Large MPV	M-segment multi-purpose cars

Table 5.1 European car classification (in the case of MPV, only small category has been considered)

- 'Supermini''' (also called '''B-segment''' across Europe) have three, four or five doors and are designed to seat four passengers comfortably. Current supermini hatchbacks are approximately 3900 mm long, while saloons and estate cars are around 4200 mm long. Today, superminis are some of the best-selling vehicles in Europe. In 2013, 22,4% of European sales were B-segment cars. Half of the sales are covered by five models such us Ford Fiesta, the recently renewed Renault Clio and Peugeot 208+, the VW Polo and the Opel Corsa.
- Small family refer (equating roughly to the C-segment in Europe) to the hatchbacks and shortest saloons and estate cars with similar size. They are approximately 4250 mm long in case of hatchbacks and 4500 mm in the case of saloons and estate cars. Compact cars have room for five adults and usually have engines between 1.4 and 2.2 litres, but some have engines of up to 2.5 litres. Popular small European family cars include the Ford Focus, Opel Astra, Renault Megane, Citroën C4+, Seat Leon, Toyota Corolla, VW Golf.
- Large Family class (described as D-segment in Europe), these cars have room for five adults and a large trunk (boot). Engines are more powerful than small family/compact cars and six-cylinder engines are more common than in smaller cars. Car sizes vary from region to region; in Europe, large family cars are rarely over 4700 mm long. Examples of large family cars include the Ford Mondeo, Opel Insignia, Peugeot 508, Volkswagen Passat and Citroen C5.
- Multi-purpose vehicles/Minivans (MPV). Also known as "people carriers", this class of cars resembles tall estate cars are versions of small family cars fitting between the mini MPV and large MPV sub-segments. Most compact MPVs

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[7] http://acdac.files.wordpress.com/2010/06/car_classification.pdf

have better "flexibility" than other body styles: for example, seats may be individually folded or even removed. Due to the multi-purpose architecture, the bonnet may be shorter and the passengers sit more upright than in regular cars, providing for a roomier interior.

Larger MPVs may have seating for up to eight passengers. Being taller than a family car improves visibility for the driver (while reducing visibility for other road users) and may help access for the elderly or disabled. They also offer more seats and increased load capacity than hatchbacks or estate cars. The first vehicle to be described by that term was the Renault Scenic Some later models include the Citroën C4 Picasso, Ford C-MAX, Opel Zafira, Renault Kangoo, Peugeot Partner.

For each category the best-selling cars in Europe in 2012 have been selected. The different OEM manufacturers specify their maintenance routines according to a predefined interval of kilometres. Typically this range varies depending on the type of vehicle and the brand. Currently the most recommended intervals are 15,000, 20,000 and 30,000 km.

The different ranges of costs for each vehicle kilometres have been obtained from [Cochesnet2013][8], which is a Spanish service dedicated to establishing the details of every preventive maintenance stop. It includes the list of spare parts to be substituted and the corresponding labour cost. In order to calculate the different costs per kilometre, all the maintenance costs carried out in the first 120,000 km realized by each vehicle have been taken into account.

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[8] Spanish prices without VAT (21%) as of December-2013, source: http://www.coches.net/servicios/costes-mantenimiento

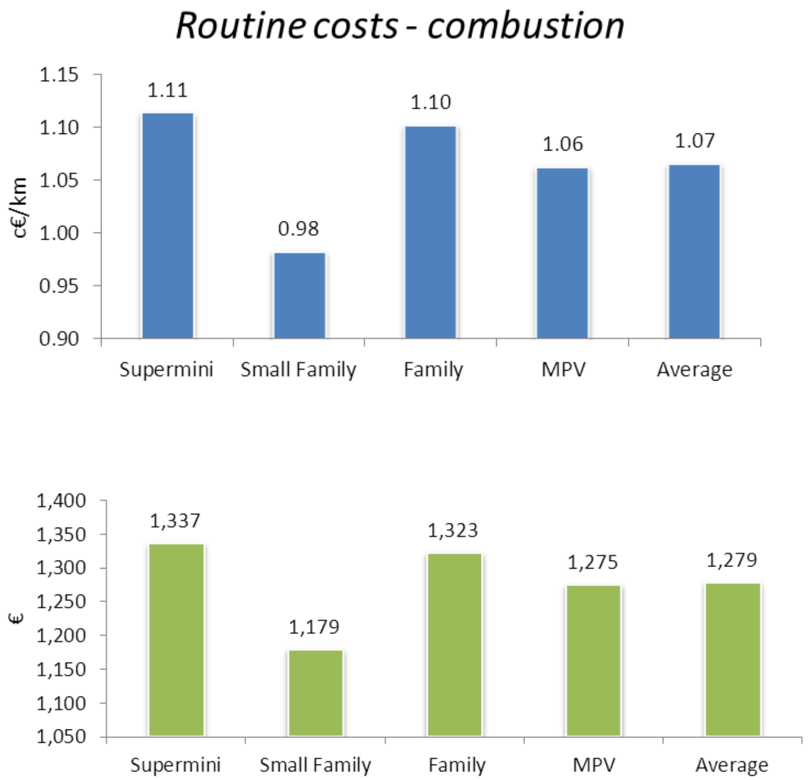


Figure 1 Routine costs for conventional cars

The set of spare parts that usually must be taken into account in such routine revisions are shown in the following list:

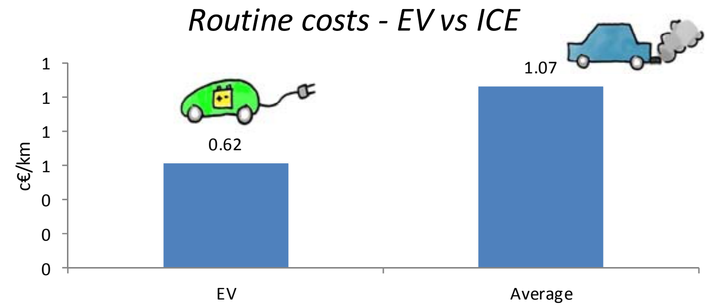
- Pollen filter
- Brake fluid
- Refrigerant fluid
- Oil
- Diesel Filter
- Oil Cartridge
- Spark Plugs.

The elements with the largest associated costs are oil changes and the manual labour due to the fact that they are more frequent. The cost differences of the various categories are due to the frequency of predictive maintenance performed and the cost of the different spare parts. According to Figure 1, the small family category has the lowest maintenance costs and the supermini category the highest costs.

The preventive maintenance costs of electric cars most commonly used in Europe have been collected using the same source of information used for the analysis of Internal combustion engine cars. The preventive maintenance costs of 7 electric vehicles have been analyzed (1 MPV, 4 Supermini and 2 Small Family cars) with batteries capacities ranging from 16 to 24 kWh and autonomy of 130-200 km. The results are the average of all available data regardless of classification because it is difficult to have cost data relating to the maintenance.

As shown in the figure 2, where the average maintenance costs of a conventional vehicle are compared against those of an electric car, the maintenance cost per kilometre of an EV car is 42% cheaper than the one from an ICE car. That's an average saving of 540 euros per 120,000 km travelled. The savings are mainly due to two reasons. Firstly, preventive maintenance of an electric car is quite simple and only requires changes in pollen filters and brake fluids. On other hand, the revisions are less frequent (figure 3) than in conventional cars so that manual labour is also cheaper.

We can conclude that the costs are lower in electric cars and that these costs remain virtually constant throughout the lifetime of the vehicle and this can be known in advance when we facing the decision of buying either vehicle.



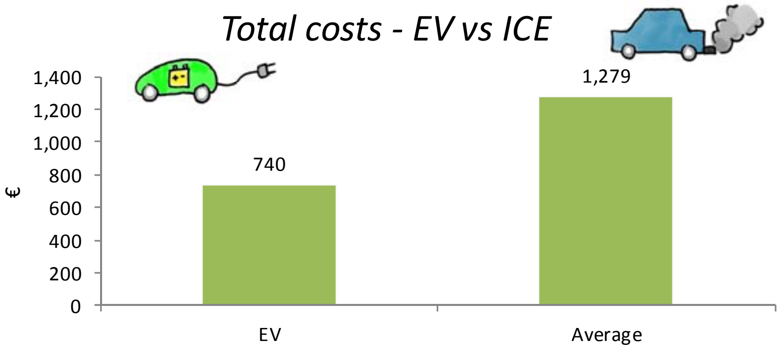


Figure 2 Routine maintenance costs (EV vs. ICE)

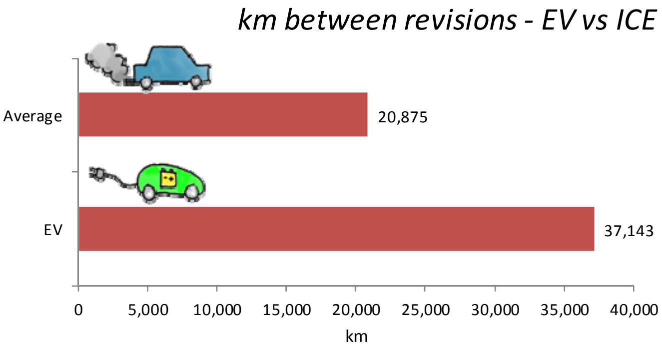
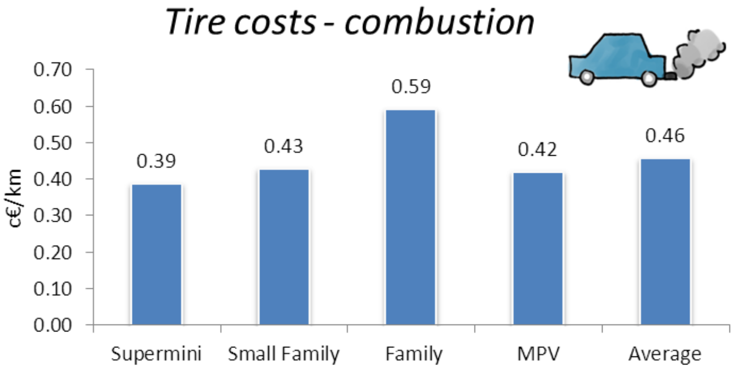


Figure 3 Distance between revisions (EV vs. ICE)

Replacement Tyre Cost

Another of the costs that we must consider when buying a car is the cost of changing tyres. The useful life of a tyre depends on many factors, driving style, tyre brand and maintenance. According to the study[9] the replacement of tyres is usually done about 35000-45000 km. In our case we have assumed a change of tyres every 40,000km which is about 2 additional sets of tyres for 120,000 km

Taking an average cost of tyres and the tyre size recommended by the manufacturer, in the figure 4 different replacement tyre costs are showed depending on the category of vehicle. The category named Family has the highest cost due to use larger tyre size.



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[9] http://www.ocu.org/coches/neumaticos/noticias/los-mejores-y-los-peores-neumaticos

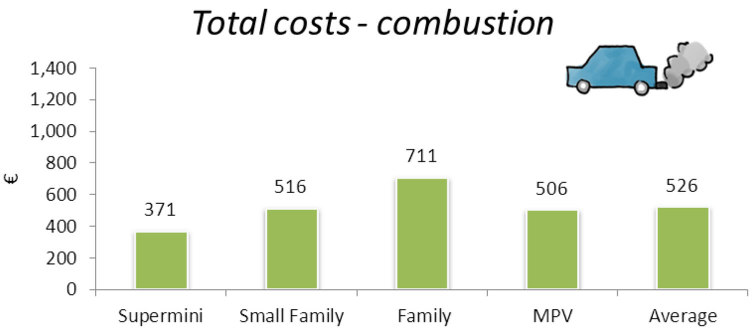


Figure 4 Replacement Tyre costs for conventional cars

In Figure 5 the comparison of replacement tyre cost for average EVs and average conventional cars is presented. If we assume that the selected electric cars mostly belong to the supermini and small family cars category, the replacement tyre cost would be slightly higher in internal combustion cars 0.41€ / km than in electric cars 0.32€ / km. This difference may be higher due to the fact that tyre wear is lower in electric cars because the load is better distributed throughout the car and therefore the frequency of tyre change can be greater than 40,000 km of conventional cars.

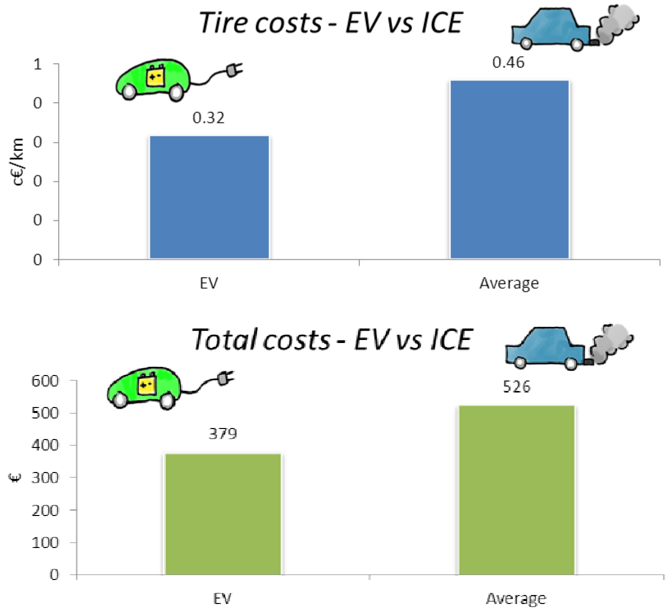
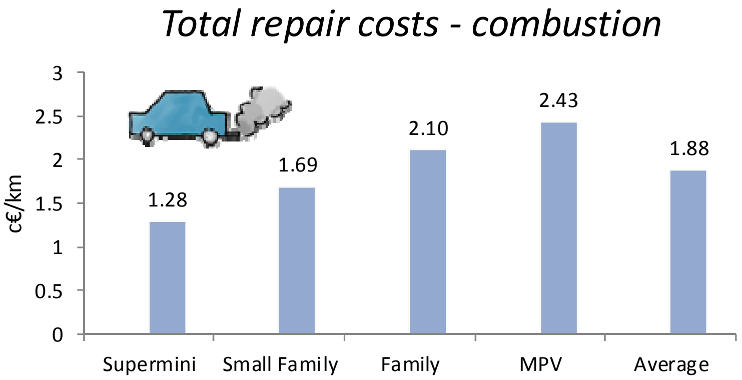


Figure 5 Replacement Tyre costs (EV vs. ICE)

Repair Maintenance Cost

Repair maintenance represents those tasks associated to the fixing of unexpected breakdowns. This type of maintenance is related to how reliable each car is. The repair maintenance cost is determined by how often a car needs repairing, and how much it will cost you to fix. According to [Reliability Index 2013][10] costs data has been extracted about repair of breakdowns of over 70 models of cars of different manufacturers belonging to different categories of cars and it also take account the more frequent fails. Reliability decreases as the size of the car is increased. So for example the supermini cars category is the most reliable and the MPV category cars are most likely to have faults.

The estimated cost of the replacement of wear parts that do not involve a breakdown has been also considered. Data provided by periodic technical inspections reports[11] can give us an estimation of these costs. From the data analyzed, these costs represent in most cases a value greater than the cost of corrective maintenance. In the following figure the average repair and wear costs are presented for the four categories of cars.



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[10] English prices source: http://www.reliabilityindex.com/

[11] TÜV reports, source http://www.anusedcar.com and MOT index source, http://www.motangel.co.uk

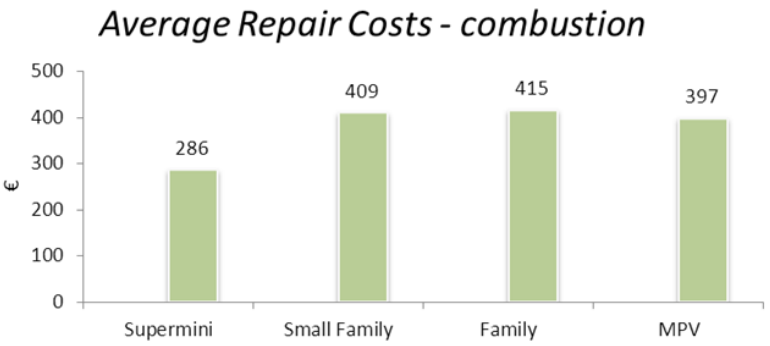


Figure 6 Average repair costs for ICE cars

In the following table the percentage of faults for each type of ICE is presented (calculations made from the data[5] of 15 cars in every category). Major breakdowns in conventional cars are associated with electrical problems (21.64%) and with faults in suspension systems (20.26%).

	Supermini	Small Family	Family	MPV	**Total**
Air Conditioning	2.77%	6.17%	4.14%	5.50%	**4.64%**
Axle & Suspension	25.60%	18.96%	15.68%	20.78%	**20.26%**
Braking System	6.35%	10.14%	10.16%	8.63%	**8.82%**
Cooling & heating system	10.96%	8.90%	7.01%	5.98%	**8.21%**
Electrical	26.39%	21.57%	18.24%	20.37%	**21.64%**
Engine	9.68%	13.97%	16.72%	14.79%	**13.79%**
Fuel System	6.51%	4.51%	11.88%	6.43%	**7.34%**
Gearbox	5.52%	6.34%	3.53%	6.02%	**5.36%**
Steering System	3.51%	5.47%	7.71%	7.08%	**5.94%**
Transmission	2.70%	3.98%	4.92%	4.40%	**4.00%**

Table 2 Typical faults of ICE car by categories

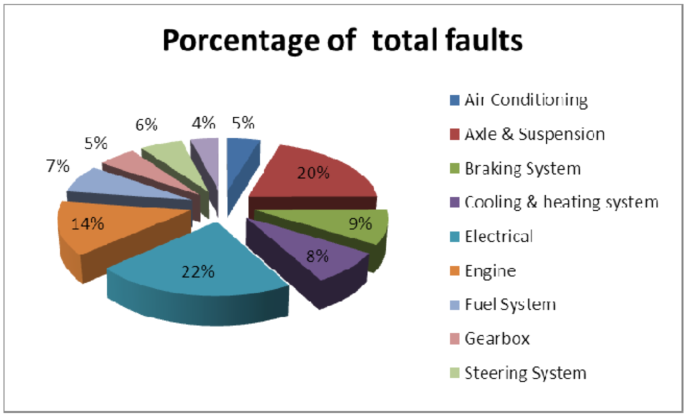
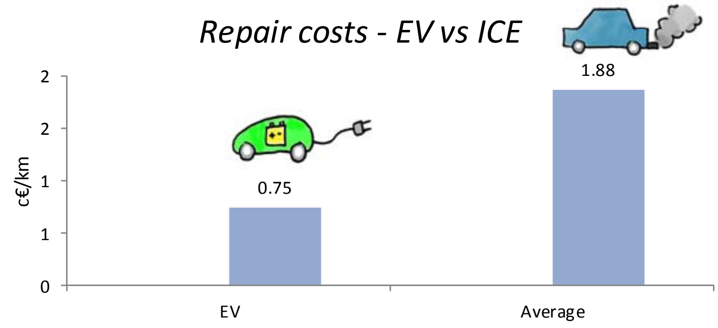


Figure 7 Percentage of faults in conventional car

In the case of the electric vehicle maintenance is cheaper compared to a traditional engine because it does not have elements whose maintenance involves its replacement with use. For example clutch, alternator, starter motor and timing belt. Furthermore, the recovery of energy in regenerative braking system of this type of cars, results in a lower wear in brake pad and brake discs than in a conventional car. Although it is difficult to have real data since most of the electric vehicles are under warranty and the repairs are carried out by authorised workshops, an initial estimation can be done. If we consider that in most electric cars certain type of breakdowns cannot occur, according to the table 2, we could estimate that the cost of maintenance of repair can be reduced by up to 60% in relation to conventional cars.

Consequently, comparing of the costs corrective maintenance per kilometre between the electric vehicle and the conventional one would be reflected in the chart below.



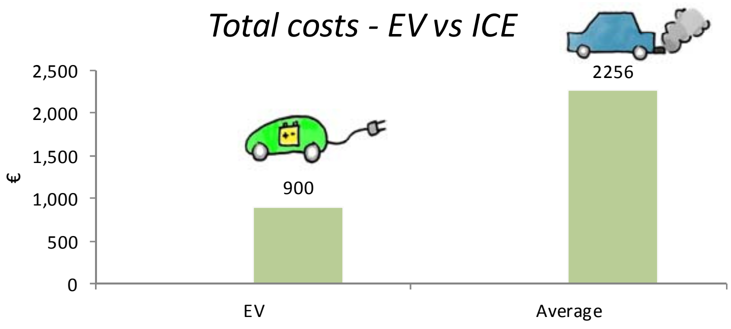


Figure 8 Repair mmaintenance costs (EV vs. ICE)

One of the current limitations of using an electric vehicle is the durability of the battery and therefore the high cost. The useful life of the battery depends mainly on the number of cycles of loading and unloading, in addition to other factors such as ambient temperature and management of the charging process. In table 3 we can see a comparative assessment of different battery technologies that includes the number of cycles, the expected service life and the cost per kWh

Battery type	Energy density Wh/kg	Service life		Cost EUR/kWh
		Cycles	Years	
Lead	30-50	500-1000	3-5	100-150
Nickel/Cadmium	40-60	>2000	3-10	225-350
Nickel/Metal hydride	60-80	500-1000	5-10	225-300
Zebra (Na-NiCl2)	80-100	800-1000	5-10	225-300
Lithium ion	90-120	1000	5-10	275
Lithium polymer	150	<1000	-	<225
Zinc/Air	100-220	-	-	60

Table 3 Battery technology assessment[12]

If we assume that a battery can last a maximum of 1000 cycles and the autonomy of a car is around 120 km, a battery useful life of about 120,000 km can be estimated. The total cost of the battery may be around 5000 euros for a 20kWh battery standard, with an average price of 250 € / kWh. If for example the useful life of an electric car was about 240,000 km, the cost of replacing the battery would result in the total maintenance cost of the electric car being higher than that of the conventional car. This extra cost would affect less to fleet cars as they are renewed very often. It should also be considered that the cost at the end of life of the battery may be for a reconditioned battery rather than a complete new battery, which should be considerably cheaper, however as the technology has not reached this level of maturity, it is impossible to predict what this cost might be.

Total Maintenance Cost

Finally in the following graphs the total maintenance costs in euros and the average cost per kilometer of both electric and conventional cars are reflected. It should be noted that the maintenance costs has been taken from sources in different countries where prices can vary from one another. In view of the mirrored data we can draw the following conclusions:

- An electric car is about 50% more economical to maintain than a conventional car. In part due to the lower amount mechanical components which means it does not require routine operations such as changing the oil, air filter, fuel, timing belt. Moreover, the breakdowns are much lower and the replacement of wearing parts is less frequent.
- The saving of the electric car can fade if replacement of the batteries when reaching a numbers performed recharge cycles is considered.

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[12] Internal Basshuysen R., Schäfer F., Combustion Engine Handbook: Basics, Components, Systems, and Perspectives, SAE International, 2004.

- The total maintenance costs area an average of different models and categories of vehicles for a mileage of 120,000 km. In the case of ICE cars these costs depend on many factors. It is obvious that the costs per kilometre will increase according to car mileage. The estimation of costs in the EV is more difficult to determine but overall are lower than ICE cars.

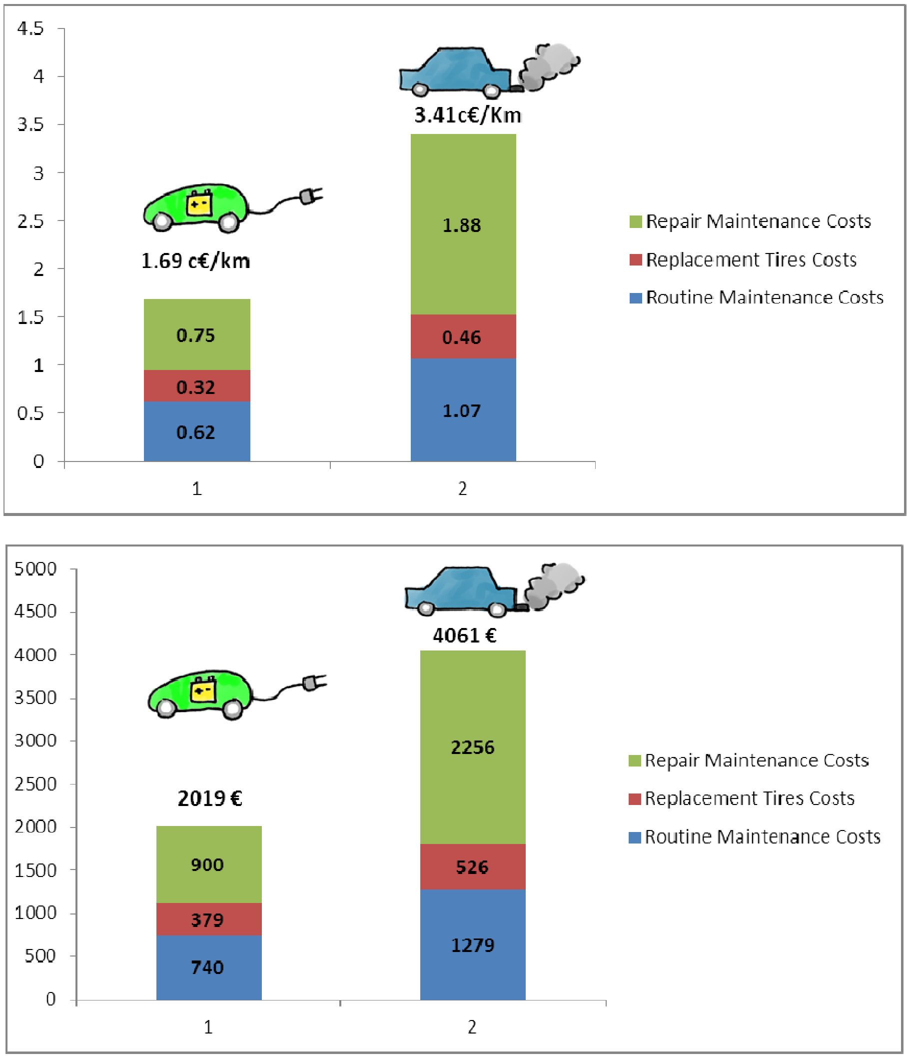


Figure 9 Total maintenance costs (EV vs. ICE)

5.5 Emissions

Electric vehicles are often dismissed as not being zero emissions due to the requirement to fuel electricity generation by fossil fuel resources. Sweeping statements are never an accurate reflection of the true state of the sector. Equivalent CO_2 emissions on EV's will vary from country to country and from minute to minute. We can see from the table below that the energy mix across these sample countries varies substantially. Many of the fuel sources contained in the generation mix offer lower CO_2 when it reaches the wheel than an equivalent ICE vehicle. With renewable sources offering close to zero CO_2, there is advantage in most member states in the utilization of EV's. Green eMotion Deliverable D9.5 will further evaluable the environmental impact of widespread shifting towards electricity based mobility.

% Generation Mix examples from across Europe.							
Country	Coal	Natural Gas	Oil	Nuclear	Hydro	Renewables	Diverse
Denmark	9	21	2	0	0	25	43
Spain	7.9	23.8	0	22.1	13.8	27.1	5.3
Germany	42.7	13.7	1.2	22.8	3.2	12.5	3.8
Sweden	4.8	0	0	38.3	45.6	11.3	0
Italy	12.8	43.1	1.7	1.2	0	35.2	6
Ireland	14.3	61.4	2.1	0	2.1	9.7	10.4

Figure 5.17 Green eMotion external Stakeholder Report

EC member state targets for generation by renewable sources are high agenda items and are steadily increasing the renewable generation share. This increase in sustainable energy goes further to driving down the equivalent CO_2 emissions of EVs. Furthermore development of smart charging systems which will allow increased preference of renewable sources while charging your vehicle can further facilitate renewable sources by allowing load balancing at times of renewable instability.

Fleet usage of EVs can assist substantially in the renewable goal. Particularly where there are a number of vehicles used at a single depot, charge management systems can be utilized to gain greater reductions in energy prices. This utilization of charge management can be very beneficial to electricity system control.

5.6 Noise

Noise has always been an environmental challenge to mankind. In many cities throughout Medieval Europe, it was not allowed to go by horse or in horse carriages during night hours because of the disturbance of sleep. Even in ancient Rome restrictions was made to prevent iron wheeled wagons to disturb nightly sleep.

In modern society, ambient noise, and traffic noise in particular, is louder and wider spread than ever before. It has huge effects on humans and wildlife alike and today it is a well-known fact that noise affects health and has a large impact on people's life and the wellbeing of the society in whole. Quiet areas are scarce and continuously grow smaller. Noise disrupts communication, sleep, concentration and rest and generally affect our quality of life. There are also indications that prolonged exposure to traffic noise can cause effects on the cardiovascular system and create stress. These effects on health not only affect the individual citizen, but also infer large social and economic costs.

Today, about 40 percent of the population in the European Union, about 200 million people, suffer from noise levels exceeding 55 dB, a level potentially dangerous to health. Additionally, 30 percent of the population, about 150 million people, are exposed to levels above 55 dB at night. One should then bear in mind that the recommendations from World Health Organization (WHO) is 33 dB during nighttime[1].

Some groups are more vulnerable to noise than others. Children are highly affected since they spend more time in bed than adults. To mention some examples, noise has an effect on learning, motivation and potentially blood pressure. Other groups that are more sensitive to noise are chronically ill, elderly, shift workers and less affluent citizens.[2]

Except from the severe costs of health and convenience of people, traffic noise also has a tremendous economic cost for society. In Europe, the social cost of traffic noise is estimated to be about 40 billion Euro each year, or about 0.4% of the Gross Domestic Product (GDP). In those estimates, 90 % of the noise comes from passenger cars and trucks. [3]

Studies calculate vehicle noise as the sum of noise produced by a number of factors, such as tyre contact to surface, aerodynamics, engine sound, horns and braking. At low speed, engine sound and drive train are the dominating factors, while aerodynamics and tyre noise are dominant in higher speeds[4]. This makes the relatively silent electrical motor interesting to have a real potential to reduce noise levels in our cities. In urban traffic, electric vehicles (EV) are less noisy than vehicles with combustion engines at slow speeds. However, when the speed exceeds about 20 kilometres per hour, an electric car is as noisy as a car with an internal combustion engine[2] since the tyre and aerodynamic noise factors take over.

In an urban environment, electrical vehicles may be one piece of the puzzle solving the traffic noise challenge. EVs together with technical advancements and efforts in areas such as more silent tyres, silent pavement and speed reductions, could challenge traffic noise in Europe in near future. In urban areas a commercial EV fleet could have large impact. This has been investigated and demonstrated before and the impacts of noise reduction are large [5, 6]. Exchanging heavy duty vehicles such as trucks and busses into low-noise electric alternatives could potentially reduce the noise pollution in urban environments, especially in noise sensitive situation such as in residential areas or deliveries in noise restricted areas.

[1] Hurtley, C., Bengs, D. ed., 2009, *Night noise guidelines for Europe*, World Health Organization, Regional Office for Europe, Denmark.

[2] Genuit, K., Fiebig, A., 2010, *Psychoacoustics for the creation of acoustically green city areas*, 23-27 August. Sydney, Australia, ICA 2010.

[3] den Boer, L.C, Schroten, A., 2007, *Traffic noise reduction in Europe.* CE Delft, March 2007.

[4] Victoria Transport Policy Institute, 2009, *Transportation cost and benefit analysis – Techniques, estimates and implications, sec. ed.* [pdf] Victoria, Canada. Available at: http://www.vtpi.org/tca/tca0511.pdf [Accessed 25 June 2012].

[5] McMorrin, F., Anderson, R., Featherstone, I., Watsoi, C. ed., *Plugged-in fleets – A guide to deploying electric vehicles in fleets*, EV20. Available at: http://www.theclimategroup.org/_assets/files/EV_report_final_hi-res.pdf [Accessed 1 august 2012].

[6] Douglas, C., *Quit deliveries demonstration scheme (QDDS), Final Project Report*, Department for transport, London. Available at: http://assets.dft.gov.uk/publications/quiet-deliveries-demonstration-scheme/quiet-deliveries-demo-scheme-final-project-report.pdf [Accessed 1 August 2012].

5.7 Other factors

Fleet Manager's and the Benefit of EV's

From a vehicle fleet point of view the GeM Project is focused on the deployment and use of Plug-in Hybrid and Battery Electric Vehicles, collectively referred to as EVs, across the full range of types or vehicle classes. The use of Hybrid Electric Vehicles that do not cater for plug-in charging from the grid do not form part of the GeM fleet as these vehicles do not require electrification of the transport infrastructure and more crucially would not contribute the quanta of energy savings being sought by 2020. Typically, ICE powered vehicles consume between three and five times more energy based on the full life cycle when manufacture, fuel consumption and disposal of the vehicle are calculated as compared to Plug-in hybrid and Battery EVs.

The energy savings associated with the full life cycle of EVs are not as yet fully reflected in projected cost of ownership as is always the case with an emerging technology and the associated market conditions. However, the incentives and benefits on offer to the purchasers of EVs seek to offset the initial capital cost for the early adopter.

EVs for Goods Deliveries in Cities & Urban Areas

The use of EV's for goods delivery in city centres and urban areas is one of the most attractive options from a fleet manager's point of view. Firstly, given the duty cycle and range associated with goods deliveries EVs are inherently more efficient in dealing with traffic congestion, stopping and starting and with the parking associated with loading and unloading. As with private users of EVs a capital grant or a refund is available to the purchaser of a new vehicle. However, in many jurisdictions an Accelerated Capital Allowance or write off is available to the business investing in the purchase of an EV or EVs for the vehicle fleet.

Accelerated Capital Allowances for Electric Vehicles

Capital Allowances allow a business to gain relief from Corporation Tax on money spent on capital equipment purchases such as vehicles. The relief is received by allowing the company to reduce its taxable income by an amount equal to the pre-tax value of the asset. The company therefore “writes down” the asset against profits. They normally must do this over an 8 year period so 1/8th or 12.5% of the capital value of the asset is written down each year until 100% write down has been achieved at the end of year 8.

The total value of the relief to the business is therefore equal to 12.5% of the pre-tax value of the asset. Under normal Capital Allowances, this total benefit accrues over an 8 year period so. 1/8th of the relief is received each year.

Under Accelerated Capital Allowance (ACA) schemes, 100% asset write down is permitted in year 1 allowing the full value of the tax relief benefit to be received in year 1 thus helping to stimulate a greater cash flow for the business. ACA is intended to stimulate businesses to buy more energy efficient products which include Electric Vehicles and their associated charging infrastructure.

GeM Project & Fleet Managers

Fleet Manager’s need to be appraised of the savings and benefits of a transition to EV’s in the vehicle fleet and vehicle dealers and energy agencies within the regions should consider special marketing and promotional initiatives to highlight the potential savings and benefits with reference to actual Case Studies on Goods Deliveries with EV’s such as:

Virtuous Sustainable EV Cycle for Cities: Climate Change Strategies – Reduction in CO2 emissions & Noise - EV’s in fleets –Liveable Urban Centres– Healthy Cities initiative – The benefit of a transition to widespread deployment of EV’s in fleets needs to be highlighted as a Virtuous Cycle for Cities

GeM is demonstrating the viability and economic costs associated with the deployment of EVs in fleets which can be seen to support the viability of City centre strategies based on Pedestrian Priority Zones, Restricted Access, Zero Emissions Zones, Low Emissions Zone, Clean Zones, Quiet Night-time Deliveries and Clean Air strategies as implemented throughout European cities. The need to extend these measures both in terms of range and impact requires a comprehensive deployment of EVs in both public and private fleets. A strategy of undertaking commitments by cities on CO2 emissions and Noise reduction would contribute to the uptake and deployment of EV’s to a very significant extent.

The more sustainable modes of transport comprising walking, cycling, Public Transport and EVs are essential to secure liveable and healthy cities for the future. If cities begin to commit to Climate Change reductions in CO_2 combined with reductions in Noise, the deployment and uptake of EV’s will increase in the manner envisaged by policy makers to deliver reduced unit costs for vehicle fleets.

The widespread deployment of EVs in vehicle fleets is an essential prerequisite to the establishment and maintenance of healthy cities for the future in Europe and globally. The electrification of transport infrastructure as reflected in the term ’electro-mobility’ is a key to a sustainable future in Europe as demonstrated by partners on GeM.

There is a clear advantage in terms of fuel economy for the EV vehicles versus the conventional vehicles. In terms of savings it is expected an average of 80% if we compare, for example, an EV van and a conventional van. In order to the assess the total impact in Europe economy it will be needed to undertake a deeper study that will take in to account the available EV technology capacities and ranges to be compared against their counterparts conventional vehicle. To estimate the total potential savings in fuel economy it will be required to estimate the figures of vehicles devoted to fleet operation, and their spending in fuel.

Potential in electric vehicle fleets

In spite of the decline in car sales across the main markets in Europe over last the years, the sale of electric vehicles is growing each year. According to [AID 04][1] the last global car year´s sales 2013 have fallen in levels by less than 2 per cent respect to 2012 (12.53 million units) with sales easing back to 12.30 million units. On the contrary, the sales of electric cars have continued to increase in 2013, especially in markets like, France, Germany, Norway, Netherlands and Great Britain where either geographical advantages or improvements in infrastructure promote the introduction of electric vehicles. The distribution by countries is shown in Figure 5.18.

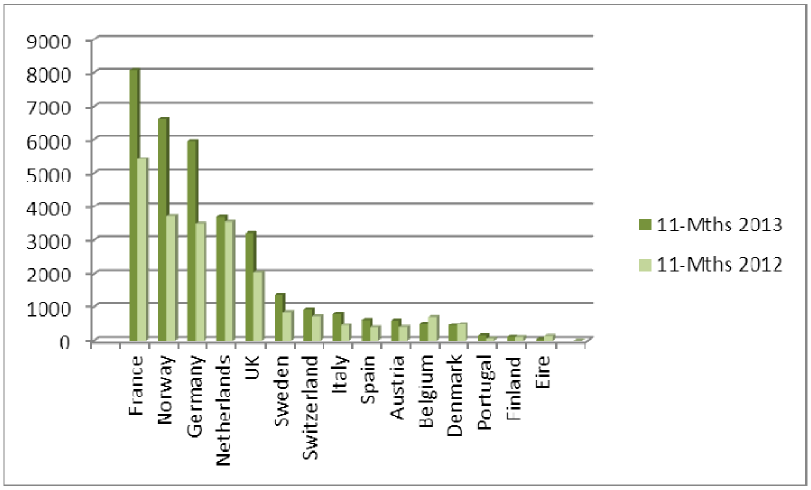


Figure 5.18: Electric Passenger car sales by market. Source AID

Looking at the information available [AID 04][1] now [January to November 2013] the sales of electric vehicles in Europe can be estimated around 33,133 units taking in account pure EV and extended EV, nearly 50% more than in the same period of 2012 with 22,589 units. This shows that the share of electric vehicle in comparison to conventional car has grown from 0.21% in 2012 to 0.31% in 2013.

If we analyse the sales evolution of electric cars by model obtained from [Ev-sales blog][2] we can see that a large portion of the models have increased in sales, reaching in some case over 16,000 units sold during these two last years, as is depicted in Figure 5.19.

[1][AID14] Europe´s leading automotive industry newsletter. January 2014

[2] http://ev-sales.blogspot.com.es/

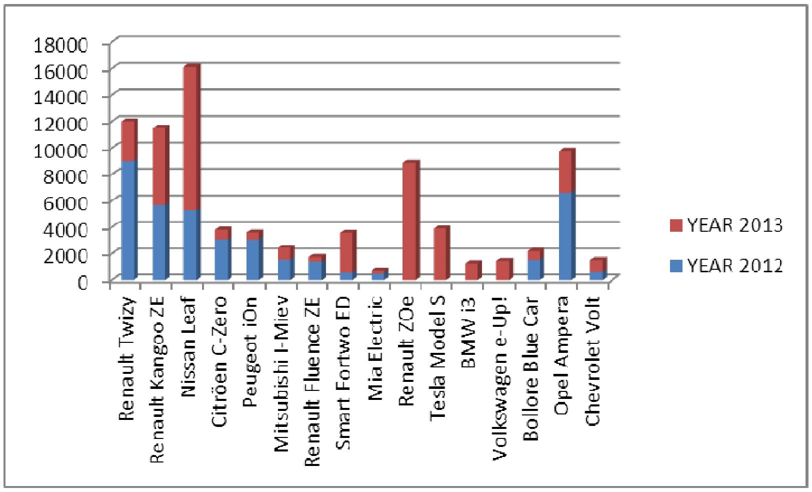


Figure 5.19: Comparative sales of electric cars by model in Europe 2012-2013

Comparing the sales of electric cars for fleets in relation to the global sales of electric cars in Europe in 2012 (table I)[3], 57% of the electric car relate to fleet purchases. For Pure EVs and extended range EVs, the registrations are almost exclusively fleet registrations in the main European markets, except France, where EV are more popular with private consumers due to the great support provided by the government for the purchase of an electric car.

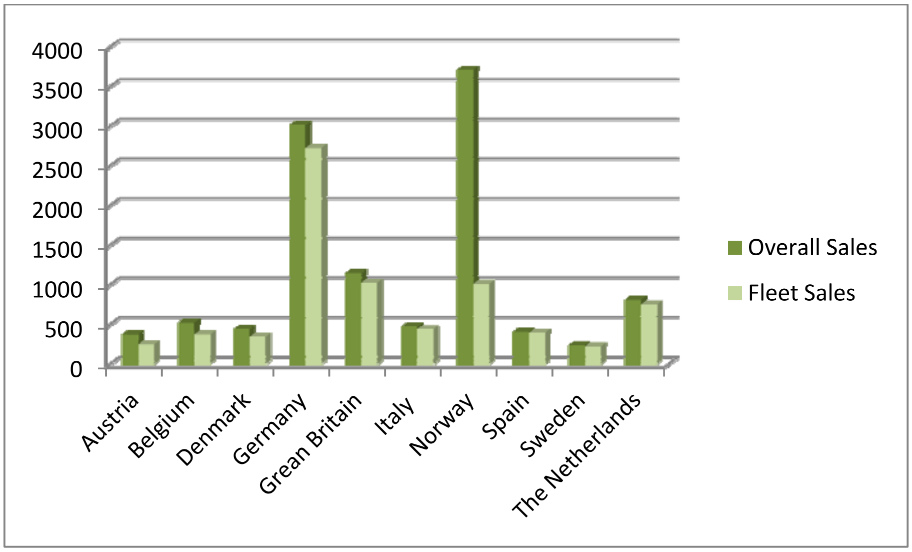


Figure 5.20: Sales of electric cars for fleets in Europe 2012 by countries

We can conclude that the “green fleets” have contributed significantly to the overall sales along year 2012. This trend has continued throughout 2013 given the increase in the sale of electric vehicles. Corporate fleets have to be the key to gradually introduce new technologies of the electric car. There is great potential in fleets to significantly contribute to increasing the sales of the electric car in Europe.

[3] Fleet Europe Magazine nº 62. January 2013. (Source: http://www.jato.com).

	2012 YTF Nov		2011	
	Overall sales	Fleet Sales	Overall sales	Fleet Sales
Petrol	4,585,492	1,691,633	5,285,754	2,016,950
Diesel	5,908,941	2,934,989	7,008,709	3,816,839
Hybrid	118,662	53,260	95,711	48,216
Plug-in Hybrid/Extended EV	6,099	4,824	368	356
EV	16,805	8,188	11,292	8,801
TOTAL	10,635,999	4,692,894	12,401,834	5,891,162

Table I: Overall sales of new cars and sales for fleets according to the type of power train[3].

Although the market for passenger vehicles attributes for the majority of all sales in Europe, the market for light commercial vehicles has great potential for the introduction of the electric vehicle. Total sales in Europe reached the 1,377,283 units in 2012 according to data from ACEA[4].

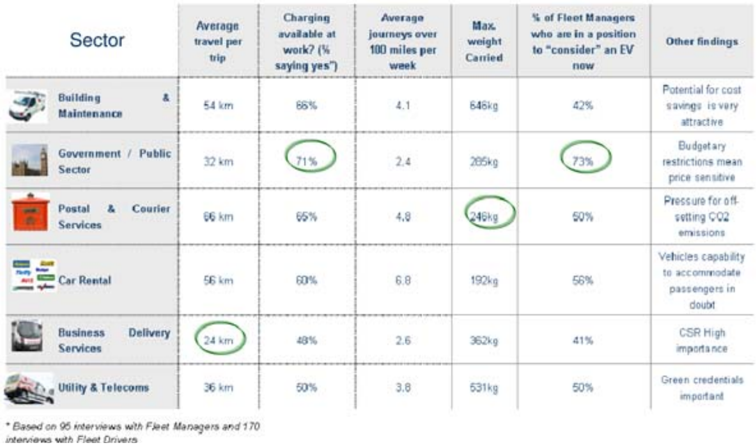
The main reasons why the electric commercial vehicle, mainly composed of vans and light-duty trucks, will grow in the coming years is due in part to that commercial vehicles regularly remain in service for far longer than the typical passenger car and kilometers on them will cost less than a conventional van based on the lower maintenance costs and lower consumption. Despite the fact that sales in the last years of vans and light trucks have been small, noting the Renault Kangoo ZE with more than 10,000 units sold, a study conducted by Frost & Sullivan[5] suggests that Europe´s demand for light commercial electrics, mainly companies and municipalities will reach the 165,000 units by 2016.

					TOTAL
AT	336,010	31,508	6,589	722	374,829
BE	486,737	54,607	8,474	701	550,519
BG	19,419	3,118	n.a.	n.a.	22,537
CY	10,967	1,293	88	n.a.	12,348
CZ	174,009	11,821	7,234	731	193,795
DK	170,763	24,109	3,770	506	199,148
EE	17,267	2,139	726	116	20,248
FI	111,251	11,469	3,252	533	126,505
FR	1,898,760	381,233	45,678	6,062	2,331,733
DE	3,082,504	219,422	86,937	5,139	3,394,002
GR	58,482	3,707	211	118	62,518
HU	53,059	10,900	4,158	51	68,168
IE	79,498	10,874	1,120	236	91,728
IT	1,402,089	116,112	13,741	2,131	1,534,073
LV	10,665	2,236	1,605	92	14,598
LT	12,170	1,598	2,759	145	16,672
LU	50,398	3,262	995	159	54,814
NL	502,528	56,576	12,002	779	571,885
PL	273,589	38,507	16,436	1,271	329,803
PT	95,290	16,011	1,892	223	113,416
RO	66,436	9,389	2,817	1,463	80,105
SK	69,268	5,103	3,511	307	78,189
SI	48,648	6,412	1,097	92	56,249
ES	699,589	76,933	12,827	1,642	790,991
SE	279,899	39,303	5,610	1,629	326,441
UK	2,044,609	239,641	42,280	7,233	2,333,763
EU[1]	**12,053,904**	**1,377,283**	**285,809**	**32,081**	**13,749,077**

Figure 5.21. Motor vehicle registrations in the EU- by country (in units) 2012

[4] The Automobile Industry. Pocket Guide 2013. European Automobile Manufacturers Association.
[5] Frost and Sullivan. www.frost.com

According to this study half of fleet managers would be willing to incorporate the electric vehicle in their fleet, being the public and government fleets the most interested in promoting the electric car.



Sector	Average travel per trip	Charging available at work? (% saying yes")	Average journeys over 100 miles per week	Max. weight Carried	% of Fleet Managers who are in a position to "consider" an EV now	Other findings
Building & Maintenance	54 km	66%	4.1	646kg	42%	Potential for cost savings is very attractive
Government / Public Sector	32 km	71%	2.4	285kg	73%	Budgetary restrictions mean price sensitive
Postal & Courier Services	66 km	65%	4.8	246kg	50%	Pressure for off-setting CO2 emissions
Car Rental	56 km	60%	6.8	192kg	56%	Vehicles capability to accommodate passengers in doubt
Business Delivery Services	24 km	48%	2.6	362kg	41%	CSR High importance
Utility & Telecoms	36 km	50%	3.8	531kg	50%	Green credentials important

** Based on 95 interviews with Fleet Managers and 170 interviews with Fleet Drivers*

Figure 5.22. Electric Vehicle Preferences: Fleet Profiles and Interest in EV in Europe

6 Conclusion

The EV has made large strides in technology, availability of infrastructure and price points over the last number of years. Many member states have made significant steps to facilitate and encourage the use of EVs. Vehicle manufacturers are expanding their ranges and are offering improved driving autonomy in newer models. All of these factors combined with rising fuel prices have made EVs more attractive to fleets than ever before. The use cases assessed also identified clear advantages of EVs in fleet while many of the obstacles encountered are being addressed already. The use cases provide a good basis to assist the fleet manager in making an informed choice as to suitability of the technology.

This second report sees an expansion of the uses cases set out in D1.7. The additional areas where taxi's, car pools and urban deliveries have been explored demonstrate how the technology works effectively in both the moderate climates as well as the more temperate climates across Europe. Fuel efficiencies are less favourable where heating or air conditioning is used, however even here the benefits are still clear above the internal combustion alternative.

An expansion of the analysis of both fuel consumption and maintenance costs establishes that on both counts the EV is a clear winner over petrol or diesel vehicles. Maintenance costs are significantly less over the lifetime of the vehicle, with fewer moving parts and no engine oils to change. Furthermore the cost of maintenance is far more linear for EVs over the lifecycle of the vehicle, making fleet budgeting a more straightforward prospect.

Further vehicle offerings with the capability of fast battery replenish mean that the effective range requirements of more fleets fall into the operating parameters of an EV. Having identified the clear reduction in cost, and understanding the tight margins that most logistics companies encounter, the choice of EV has become a real opportunity for competitive edge.

An overview of a selection of large and recognisable cities across Europe sets a measure by which potential adopters can gauge the demonstration cities with that of their own location.

At this point, the application of fixed route buses shows high potential, however the cost of operation and maintenance is still an obstacle, posing a challenge to bus operators when considering migration to electric technologies. Cars and small vans have reached a point where the fleet manager can easily assess the suitability of the application and identify the clear benefits of adopting the EV technology.

It is clear from the use cases demonstrated that many of the myths and perceptions commonly associated with EVs are no longer true to the current offerings. The time has come where EVs are practical, reliable and cost effective in fleets.