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WP 3	**Technology portfolio to meet the 2050 scenarios**		
D3.1	**Technology assessment from 2030 to 2050**		

Annex to D3.1 - Technology Assessment Report

Demand-side Technologies: Electric Vehicles

Revision	Organisation	Date
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Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	X

Document information

General purpose

This document is an annex of deliverable **D3.1** focusing on the technology assessment (technical and economic performances) of generation, storage, transmission and demand-side technologies. It deals with electric vehicles technologies within the end use "Electromobility (vehicles)" on the time horizon set by the e-Highway2050 project, i.e. from today until 2050.

The present document is complemented by an attached Excel file providing the data compiled according to the methodology described in the in the next sections.

Change log

Revision	Date	Changes description	Authors
V1.0	05/07/13	Creation of the document and associated Excel file	Technofi
V1.1	31/07/13	Integration of comments received from KU Leuven Integration of comments received from Eurelectric Contextualisation of data	Technofi
V1.2	14/08/13	Integration of new data from KU Leuven (CIRED paper)	Technofi
V1.3	26/08/13	Updating of the contextualisation of the data	Technofi
V1.4	19/09/13	Integration of comments received from RSE and RTE	Technofi
V2.0	29/08/14	Integration to the D3.1 after final project review	Technofi

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Table of content

Electric vehicle technology

1 Introduction

1.1 Scope

The vast majority of PHEV (Plug-in Hybrid Electric Vehicle) and BEV (Battery Electric Vehicle) technologies are used in vehicle types included in the Passenger-Vehicle (PV) segment. This report focuses on the PV segment, which is defined as including passenger cars, SUV/CUVs[1], and minivans/MPVs.

BEV and PHEV have been considered separately. Extended range electric vehicles (EREV or REEV) have been included in the BEV category as the power train is more similar to that of a BEV, as well as the battery capacity.

1.2 Rationale for selection

As mentioned in the M3.1a deliverable, electrical vehicles have been selected for the following reasons:

- EV typically represent a new use with a strong potential impact on electricity demand,
- under massive deployment (e.g. 150 million BEV and 120 million PHEV in 2050), plug-in EVs could generate an additional demand of from 350 to 500 TWh/year[2],
- if no demand-side management measures are implemented, the charge of plug-in EVs will have a major impact on the demand load profile, as most of the charges will take place at the same time, i.e. when people go back home in the evening, which would add up to the existing evening peak,
- the development of fast charging points, which are likely to draw a power of about 100kW per outlet in the near future, will represent an additional constraint for the distribution grid,
- smart charging[3] is essential to optimise the use of the distribution grid by coordinating and managing electrical loads. Electric vehicles represent controllable mobile loads that can prepare the ground for smart-grid deployment. Henceforth, EVs represent a vast potential for demand response: their charge could easily be adjusted or delayed during the night, and ‘vehicle to grid’ applications (i.e. EV delivering electricity to the grid when the electricity system needs it) are promising (provided that the benefits justify the required investments to enable V2G).

1.3 Underlying assumption

Most of the references used in this report are based on a ‘business as usual’ scenario with regards to the global size of the European passenger vehicle fleet, i.e. total number of cars on the road (internal combustion engines, hybrid, plug-in hybrid and battery electric vehicles altogether). The different studies will then differ on the share of EVs within that fleet

[1] SUV: sport utility vehicle. CUV: crossover utility vehicle. MPV: multi-purpose vehicle.
[2] Hypothesis: driving behaviour of 12 000km/year on average, consumption in 2050 assumed to vary from 0.1 to 0.15 kWh/km.
[3] EURELECTRIC position paper, April 2011, p. 10

In that 'BAU' scenario, the size of the fleet is likely to evolve as presented in Table 1.

Table 1 : Evolution of the number of registered vehicles in EU-27

	2008	2020	2030	2040	2050
Number of registered vehicles in EU-27 (in million)	235[4]	270	300	325	350

The consequence of this assumption is that no hypothesis is made with regards to a potential decrease of the European car fleet, reflecting an evolution (…or even a revolution) of the way mobility is considered within the next 40 years, with a potential change of the 'mobility paradigm' by 2050.

The whole automobile concept might also be revised, with a complete switch from heavy vehicles inherited from the internal combustion engine 'tradition' towards lightweight innovative vehicles designed for a specific use to optimise the benefits of electric drive. This change, which is closely related to the way people will approach mobility in the future, is complex to take into account but may heavily impact on the penetration of the EVs.

2 Methodology

The methodology implemented is described below. In case a specific approach is used for a certain data type, the corresponding methodology is described in the paragraph dedicated to that data type.

2.1 Methodology for data collection

Mode	Type of data collection	Nature of data processing	Comment
Own expertise	informal knowledge captured by interviews with internal experts	Modelling	
		Data collection	
	knowledge formalized in published articles	Modelling	
		Data collection	
Other experts of the field	informal knowledge captured by interviews with external experts or workshops	Modelling	
		Data collection	Interview of ADEME experts
	knowledge formalized in published articles	Modelling	
		Data collection	Cf list of references
	knowledge structured in State of the Art studies	Modelling	
		Data collection	Cf list of references
Other mode (please describe)		Modelling	
		Data collection	

Figure 1 : Modes for data collection. The colored cells in column three display the nature of the data processing.

As displayed in Figure 1, all data has been collected from publications of experts. No data modelling has been performed.

[4] http://www.acea.be/news/news_detail/vehicles_in_use

2.2 Robustness of the produced data

Data taken from an external source (expert or report):

The data used in these report have been found in various reports, publications and websites of trusted origin, listed below.

Source

- Deutsche Bank (2008) Electric Cars: Plugged In.
- Deutsche Bank (2009) Electric Cars: Plugged In 2.
- Boston Consulting Group (2009) The comeback of the electric car?
- Boston Consulting Group (2010). Batteries for Electric Cars: Challenges, Opportunities, and the Outlook to 2020.
- Merge project (2011) Deliverable D3.2 - penetration scenarios.
- European Commission (2011) Study on Clean Transport Systems.
- Eurelectric (2009) Power Choices - Pathways to Carbon-Neutral Electricity in Europe by 2050.
- JRC (2010) Plug-in Hybrid and Battery Electric Vehicles - Market penetration scenarios of electric drive vehicles.
- JRC (2013) Projections for Electric Vehicle Load Profiles in Europe Based on Travel Survey Data.
- IEA (2011) Technology Roadmap - Electric and plug-in hybrid electric vehicles.
- IEA (2013) Global EV Outlook - Understanding the Electric Vehicle Landscape to 2020.
- McKinsey (2012) A portfolio of power-trains for Europe: a fact-based analysis - The role of Battery Electric Vehicles, Plug-in Hybrids and Fuel Cell Electric Vehicles.
- McKinsey (2012) Profiling Japan's early EV adopters. A survey of the attitudes and behaviors of early electric vehicle buyers in Japan.
- RTE (2010) Développement des véhicules électriques - Impact sur le système électrique.
- CE Delft (2011) Impacts of Electric Vehicles - Deliverable 5, Impact analysis for market uptake scenarios and policy implications.
- European Climate Foundation (2013) Fuelling Europe’s Future - How auto innovation leads to EU jobs.
- Commissariat Général au Développement Durable (2011) Les véhicules électriques en perspective - Analyse coûts-avantages et demande potentielle.
- University of Duisburg-Essen (2012) Competitiveness of the EU Automotive Industry in Electric Vehicles - Final report.
- Google.org (2011). The Impact of Clean Energy Innovation: Examining the Impact of Clean Energy Innovation on the United States Energy System and Economy.
- Ricardo-AEA et al. (2013) Fuelling Europe's Future in press.
- AVERE (2012). DATA COLLECTION – from June to August 2012.
- PPP European Green Cars Initiative (2012). European Roadmap Electrification of Road Transport, 2nd Edition.
- Renault website.
- Chevrolet website.
- Peugeot website.
- Nissan website.
- Ford website.
- Toyota website.

Experts from the car industry and the French agency ADEME have also been consulted.

Data resulting from a modelling or computation process

No data modelling has been performed so as to temporally extrapolate or interpolate data.

However, in some cases data have been processed, for example to convert number of new sales into stock, or percentage of stock into number of vehicles on the road. In those cases, the assumptions made are presented in the corresponding paragraph, along with an index of confidence.

3 Technology performance characteristics

3.1 Variables selected

Variable : ***technology performance characteristics***	**Unit**	**Definition**	**Computation**
maximum power	kW	maximum power of electrical engine of typical EV	Average of 3 types of cars (city cars, such as Citroen C-zero; compact cars, such as Renault Zoé, and sedans, such as Nissan Leaf)
battery capacity	kWh	battery capacity of a typical EV	
consumption	kWh/km	consumption of a typical EV	= battery capacity/autonomy

3.2 Underlying assumptions

The overall expectation of the electric car industry is to get an increasing share of the new vehicle market, the ambitions being variable among OEMs[5]. New electric car models have recently been introduced, with varying level of success (below expectations so far).

With regards to the characteristics of the EVs in 2012, the data on the performances of the vehicles have been derived from commercial information for vehicles available on the market today.

- For the BEVs, these data have been averaged for 3 types of vehicles: city cars, such as Citroen C-zero (alias Mitsubishi iMiev alias Peugeot iOn); compact cars, such as Renault Zoé, and sedans, such as Nissan Leaf.
- For the PHEVs, the plug-in Toyota Prius and the Ford C-max Energi (which should be commercialised in Europe during the second half of 2013) have been taken into account.

Consumption was estimated by dividing the battery capacity[6] by the autonomy given by the car manufacturer. It has to be noted that the autonomy is assessed by the mean of a specific standardised bench test, it is therefore a theoretical value and real autonomy is likely to be lower, depending on the use of auxiliaries (heating, cooling), topography, climate and speed. As a consequence, a range instead of a single figure has been provided.

Although data are rather easy to obtain for the present time, it is more difficult to predict how the performances of the EVs will evolve until 2050, as technological breakthrough may or may not

[5] OEM: original equipment manufacturer. OEM sometimes means the company that sells the component to the Value Added Reseller (VAR), and other times it refers to the VAR who is acquiring a product from an OEM, i.e. the company that purchases for use in its own products a component made by a second company.

[6] The specific energy of the resulting battery pack is typically 30 to 40% lower (e.g. 110 Wh/kg) that the individual battery cell (e.g. 150 Wh/kg), according to (13).

happen. Incremental improvement consists in regenerative braking and deceleration, improvement of auxiliary energy equipment (heat pump for heating and cooling), weight reduction.

References (1) and (2) provide projections of consumption (efficiency) by 2050.

Regarding battery capacity, according to (3), there are two main ways to improve the actual battery technology (illustrated Figure 2) to increase the range of electric vehicles with unchanged or even reduced battery weight. On one hand, an improvement potential with regards to the Li-Ion technology (improvement up to 40% of energy density – 250 Wh/kg – thanks to optimisation of the anode and cathode materials) and on the other hand, a major breakthrough to develop completely new battery technologies (for lithium sulphur technology, a future performance of nearly 500 Wh/kg is assumed, and up to 5000 Wh/kg for lithium-air batteries[7] (3)).

Potential future battery capacities (kWh) from 2020 to 2050 have been derived from (2).

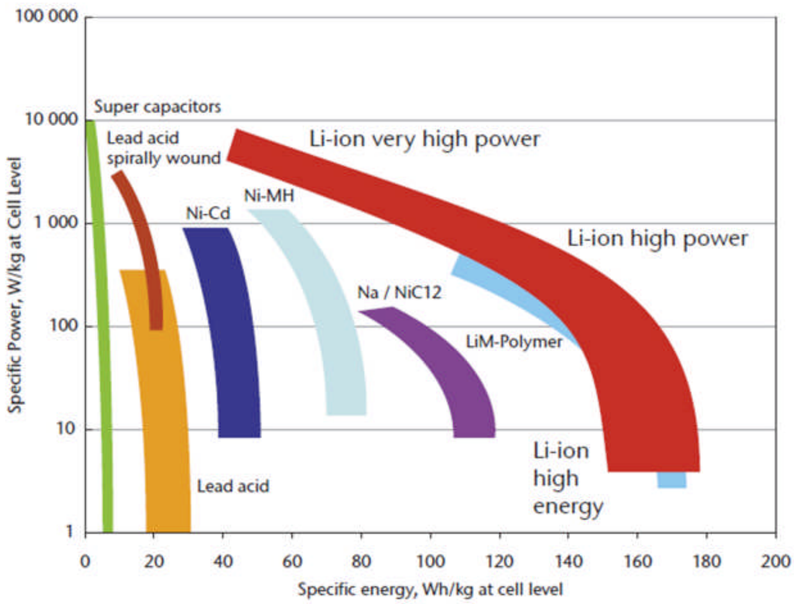


Figure 2 : Specific energy and specific power of different battery types (Source: IEA, 2011)

[7] The lithium-air battery, Li-air for short, is a metal-air battery chemistry that uses the oxidation of lithium at the anode and the reduction of oxygen at the cathode to induce a current flow. Originally proposed in the 1970s as a possible power source for electric vehicles, Li-air batteries recaptured scientific interest in the late 2000s due to advances in materials technology and an increasing demand for EVs.

4 Charging characteristics and charging infrastructure

4.1 Variables selected

Variable ***technology performance characteristics***	**Unit**	**Definition**	**Computation**
slow charging power	kW	typical power of a slow charging station	
fast charging power	kW	typical power of a fast charging station	
Typical slow charging profile	-	charging profile (for a single unit) (hourly time resolution)	
Typical fast charging profile	-	charging profile (for a single unit) (hourly time resolution)	

4.2 Underlying assumptions

The present power of slow charging is estimated at 3.3 kW (with a 16A current, or 2.07 kW with 10A)[8]. Considering that in the future specific "Mode 3" plugs will be generalised for electric vehicle charging, it seems that car manufacturers expect to push up to "6 kW" this "slow charging value".

It is important to note that this is the maximum value, since actual power drawn by a car depends on its design and actual condition. Smart charging will allow controlling the actual maximum power according to time by enabling an intelligent communication between the electric vehicle and the grid.

Fast charging is currently delivered at 43kW (AC, compatible with Renault, Smart) to 50 kW (DC, compatible with Nissan, Peugeot-Citroen, Mitsubishi). Renault is now working on a 86 kW fast charge (the battery has to be conditioned to avoid being damaged by the increase in temperature caused by the fast charging). Tesla already provides 120 kW fast charging today in the US, but the service is limited to properly equipped Tesla Model S[9]. We assume that fast charging will not go over 150kW. Fast charging is also completely dependent on battery technology and car design.

The availability of both slow and fast charging is necessary to meet customers' requirements and alleviate the 'range anxiety' of the driver. While it is difficult to predict market developments, the bulk of the charging can be done through low-power charging when the vehicles are plugged into the grid every time they are parked, i.e. to charge predominantly in domestic locations (home and office)[10] *(see section 6, Possible implementation constraints).*

Individual charging profiles:

- example of typical charging profiles have been found in an RTE report (4). They have been normalised so that the total charge equals 1 kWh. These charging profiles are maximum power envelopes, not real ones, as actual charging profiles are dependent on the EV status (State of Charge), its charging strategy (e.g. charging at reduced power at the end of fast charge to balance battery-cells) and charging signature. Charging profiles will be in fact controlled through smart charging.

[8] The present « 3 kW » power is related to the rated power of domestic plugs (more precisely the peak rated power is 3.7 kVA): the « kW » is under this value and it depends on the design of the car. EURELECTRIC and ACEA respectively define "normal power" and "basic charging" as up to 3.7 kVA

[9] http://www.teslamotors.com/supercharger

[10] Nonetheless, infrastructure differences between EU member states may influence charging possibilities e.g access to charging possibilities in private locations is not common in all countries/cities e.g. the Netherlands

- Actual charging profiles for 50kW fast charge and 25kW medium charge are provided in (5) and demonstrate the influence of the initial State of Charge (SOC) (see Figure 3)

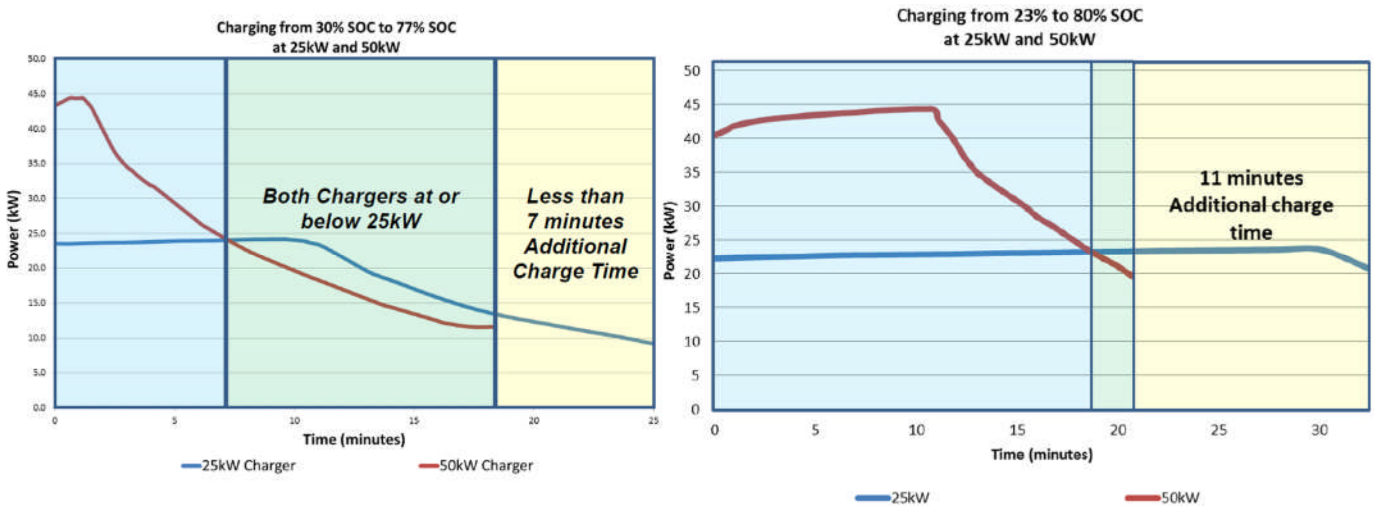


Figure 3 : Individual charging profiles of an EV with 25kW and 50kW chargers, depending on the initial and final State of Charge. Source: Fuji Electric, 2012 (5)

- The charging profile of a Renault Zoé (slow charging at 16A, with an initial SOC of 46%) metered by a French user with a 10min-resolution is illustrated Figure 4.

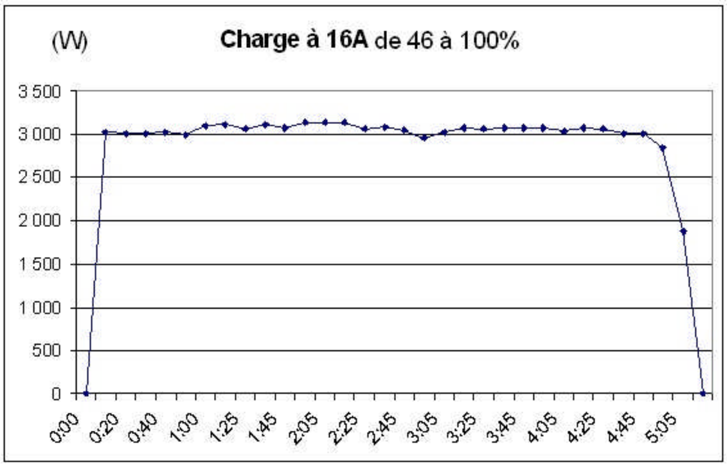


Figure 4 : Charging profile at 16A metered by a Renault Zoé user[11]

- With a high-resolution metering, it appears that the charging signatures vary greatly between different types of electrical vehicles, in particular for normal/slow charging (6), as shown in Figure 5. **This indicates that charging of electrical vehicle can be a challenge and cause poor voltage quality in locations with a weak grid.** However, as underlined by (6), the most challenging charging signatures (e.g. vehicle C) could easily be avoided if the manufacturers of electric vehicles were to focus on improving the charging signature of their vehicle.

[11] http://renault-zoe.forumpro.fr/t1653-voici-comment-charge-la-zoe-en-fonction-de-lintensite

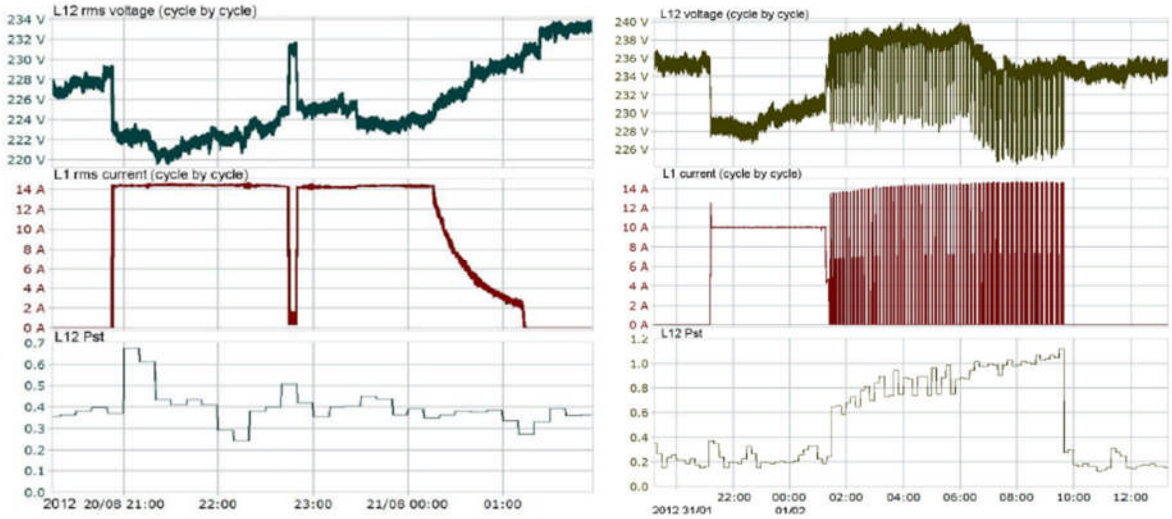


Figure 5: Load current, voltage variations and flicker level (Pst) during charging of Electric vehicle A (left side) and vehicle C (right side). Source: (6).

- Regarding PHEV, it appears difficult to report data on a typical load profile, due to the fact that the charging pattern of these vehicles is dependent on the amount of utilization of the "conventional" fuel, it is therefore rather complex to foresee a standard user behaviour.

Aggregated load profiles

Aggregated charging profiles simulated by RTE are provided in the Excel file for information only, as they are based on assumptions that may not be valid at EU-27 scale.

Aggregated load profiles for EVs based on car-use patterns in six European countries have been calculated by (7) and provide interesting results. The conclusions of the reports are the following:

> *"The load profiles obtained reveal that some differences between countries do exist, but it is the assumptions concerning when and where individuals can/want to recharge EDV[12]s that explain the amount of electricity demanded from the grid over time. For instance, discounted electricity tariffs are often available at night-time, and it is assumed that people are willing to postpone their recharge in order to exploit the lower electricity rates. Under this assumption, a strong peak of energy demand in late evening might be expected. The results of the scenarios suggest that peaks could be avoided only if there is no reason for preferring certain periods of the day over others. Also, widespread availability of recharging stations does not seem to be a sufficient condition for evening out the peaks. The reason is that cars are generally parked at home longer than in any other place, and therefore in most cases, an EDV will be charged while parked at home (which is also what individuals would prefer, according to the literature).*
>
> *Importantly, what this means in policy terms, is that providing the possibility to recharge at home is a key factor for promoting the diffusion of EDVs. Since many individuals do not own a private garage or rent a private parking space, but instead park their cars on the kerbside, the challenge lies in finding means for these EDVs to be recharged.*
>
> *The infrastructure challenge regarding the charging stations is not the only one suggested by the simulated scenario.* ***Even with a limited number of EDVs in the fleet (a 10 % share is assumed in the scenario), the total energy demanded in an evening peak like the one***

[12] EDV: electric drive vehicle.

shown in the simulated profiles (i.e. when many motorists would start simultaneously to charge their car in order to exploit the reduced power tariffs) could be a significant share of the available power capacity (i.e. net of existing load). In some cases, it might be even above the current residual capacity.

In comparing the estimated load peak with the available capacity, one must consider the worst conditions: the simulations warn about the possible need for additional electricity capacity (more so in some countries than in others) to accommodate a significant share of EDVs.

*From the perspective of electric cars replacing most of the conventional ICE[13] vehicles, all countries would probably need to increase their available capacity****. In other words, a policy for promoting the diffusion of EDVs might need to be complemented with a policy for expanding the capacity of electricity supply, and in particular of electricity supply from renewable or low-carbon sources (otherwise most of the rationale for replacing ICE vehicles with EDVs would disappear). If the charging time and rate is managed through smart charging, it can be ensured that the EDV-induced loads are planned mainly during periods of lower general electricity loads, thus mitigating the need for capacity expansion."***

5 Technology readiness and maturity

5.1 Variables selected

Variable *technology readiness and maturity*	**Unit**	**Definition**	**Computation**
increased autonomy	km	autonomy of EVs	
fast charging batteries	kWh/min	availability of fast charging batteries	
light weight cars	kg/kW	weight in relation to maximum power	=weight/maximum engine power

5.2 Underlying assumptions

The predicted autonomy is highly dependent on battery improvement and potential technology breakthroughs which are complex to foresee.

Beyond the improvement of battery capacity, there are other ways of improving the vehicle autonomy: optimised regenerative braking and deceleration to charge the battery (already implemented in recent models), improvement of auxiliaries (heat pump for heating and cooling – e.g. Renault Zoé), and most of all weight reduction[14].

Reference (1) provides projections of the evolution of BEV autonomy by 2050, depending on various scenarios of battery improvement:

- Scenario 1: Battery success -strong competitive advantage of vehicle technologies based on batteries (EV become viable alternatives to current ICE technologies)
- Scenario 2: Battery and fuel cell success - great improvement in costs and performance of fuel cell technologies (FCEV become viable alternatives to current ICE technologies)

[13] ICE: internal combustion engine.

[14] Companies such as BMW, VW and Daimler are already investing in cooperation in the field of lightweight materials, especially carbon (e.g. BMW with SGL Carbon) (2).

- Scenario 3: Dominant biomass - the developments of battery based vehicles and fuel cell based vehicles is not as impressive and optimistic as assumed in the dominant electricity. The market prospects drive higher improvements in energy efficiency for ICEs and hybrids, with production and market diffusion of new generation biofuels
- Scenario 4: 'renew' battery success - a combination of elements of the previous scenarios (i.e. assumes parallel development of the required infrastructures for all alternative fuels), with two variants, one with higher success in battery driven vehicles and one with higher success in fuel cells

Other studies report BEV driving range of up to 300 km in the long-term (3; 8) unless there is a major technology breakthrough (e.g. Li-air batteries become viable). Reference (2) is more optimistic and foresees a driving range of about 650 km in 2050.

A study by McKinsey (9) also provides projections on driving ranges for PHEV and BEV at 2050, with a rather conservative figure for BEV (around 200 km in 2050).

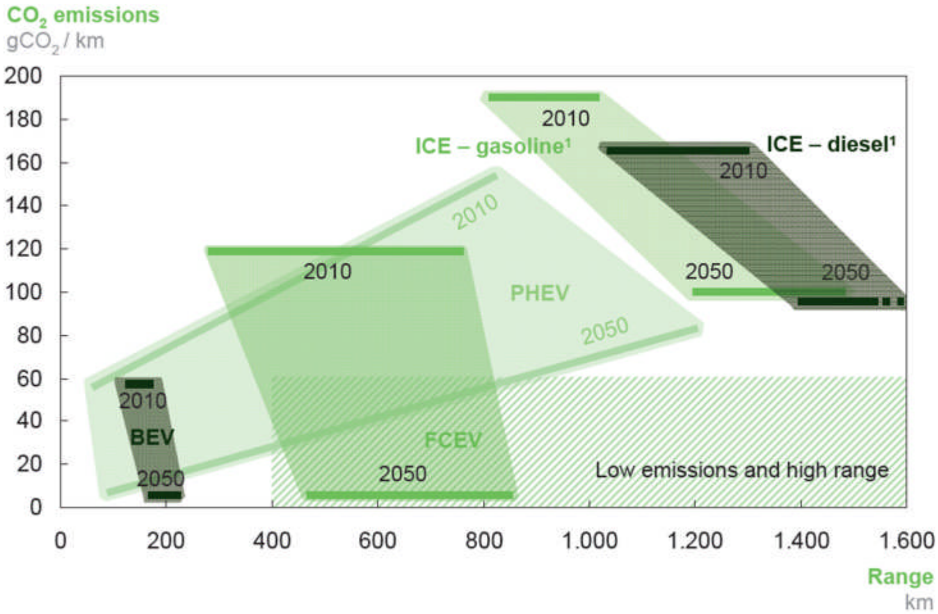


Figure 6 : Driving ranges and CO2 emissions for different types of vehicles, in 2010 and 2050 (Source: McKinsey, 2012)[15]

These various figures have been synthesised as a range.

No specific data has been found with regards to weight reduction.

6 Possible implementation constraints

6.1 Variables selected

Variable *possible implementation constraints*	Unit	Definition	Computation
autonomy of vehicles	%	autonomy of vehicles compared to fuel cars	= autonomy of EV / autonomy of ICE
number of private (home/work) slow charger per EV	unit/EV		
number of public slow charger per EV	unit/EV		

[15] ICE: Internal Combustion Engine, FCEV: Fuel Cell Electric Vehicle

number of public fast charger per EV	unit/EV		
security issues	TRL	availability of skilled workforce	

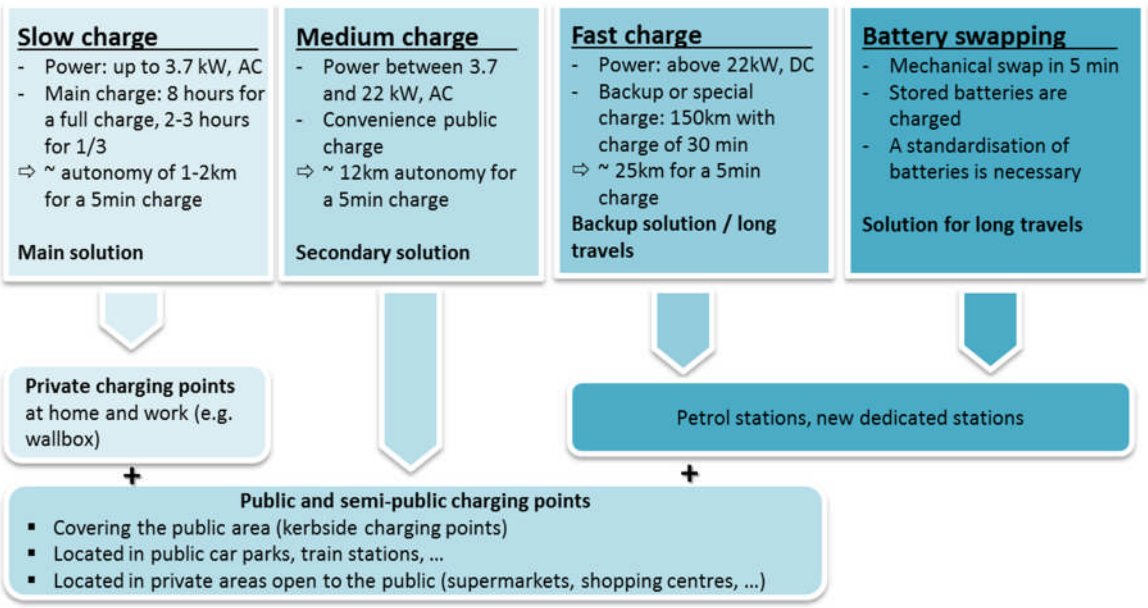
6.2 Underlying assumptions

The most important implementation constraint is the driving range, which is related to the intrinsic autonomy of the vehicle (efficiency and battery capacity), but also to the accessibility of charging points (in terms of geographical coverage and time availability). As highlighted by (10) and (11), most of EV potential buyers are indeed deterred by 1) the price, 2) the limited number of charging stations, and 3) the limited driving range.

The autonomy of EVs has therefore been expressed as a percentage of the autonomy of ICE, which is considered to be a 'standard' driving range by most of the drivers.

With regards to charging infrastructure:

- The different types of charging points in use today are illustrated below.



According to EURELECTRIC, although domestic and industrial plugs and sockets were not originally designed to charge electric vehicles, their availability should be seen as a bridging solution to facilitate initial market uptake. In the near future when electric vehicles have reached market development, new e-mobility infrastructure should be equipped for mode 3 charging which paves the way for controllable charging process and load management within a smart grid context.

- Ratios of slow and fast public chargers (number of chargers per EV) for 2012 are given in (12).
- Statistics on the current number of European charging points and plugs, and their location, are provided by chargemap.com, as illustrated in Figure 7, Figure 8,
-
-
- Figure 9 and Figure 10.

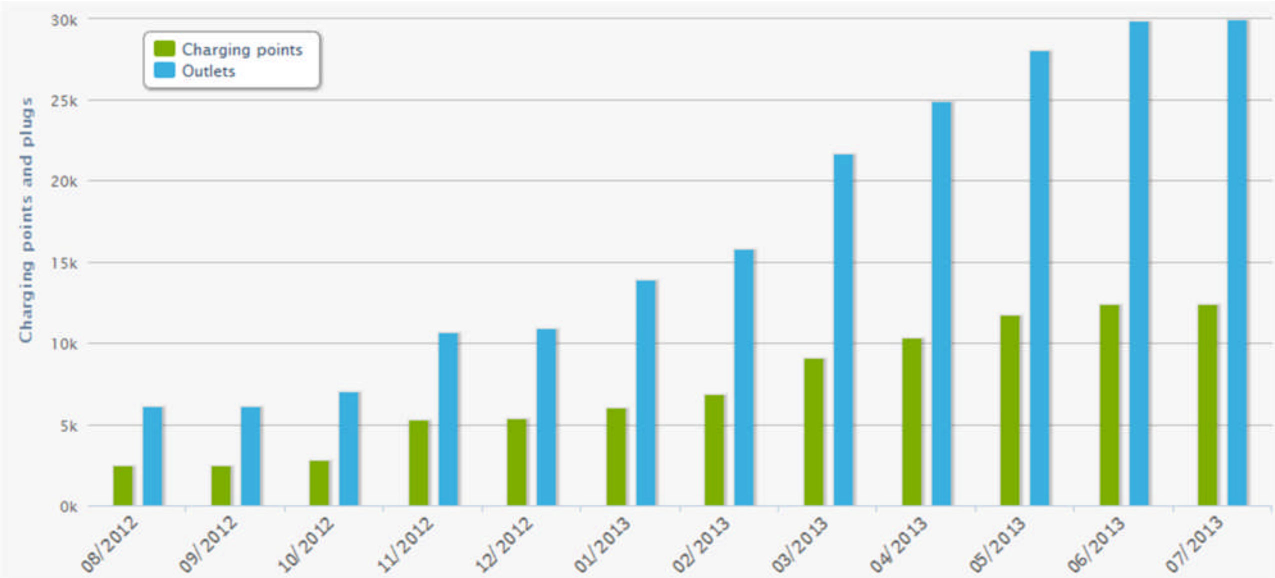


Figure 7 : Number of charging points and plugs in the last 12 months. Source: chargemap.com

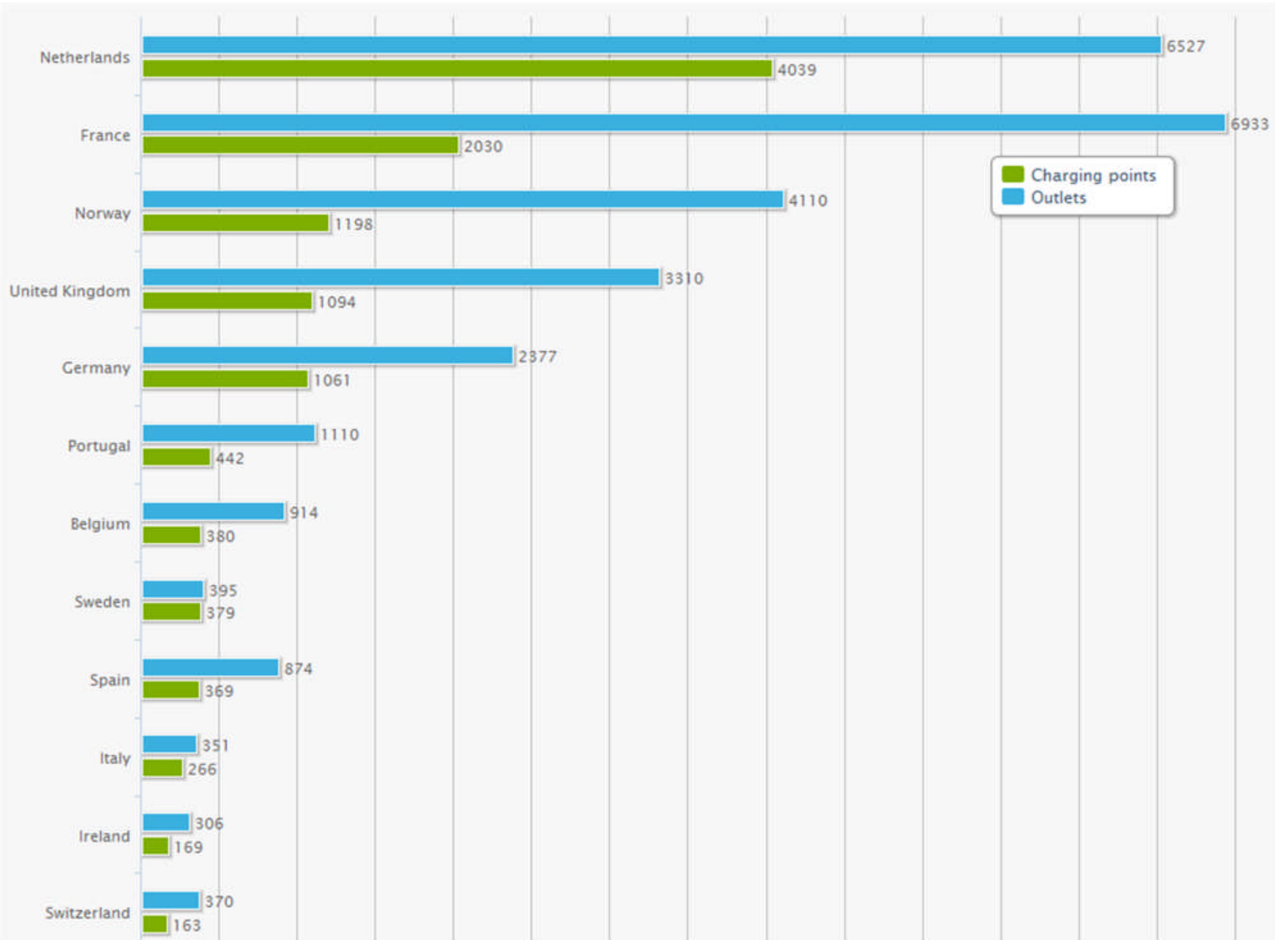


Figure 8 : Charging points per country. Source: chargemap.com

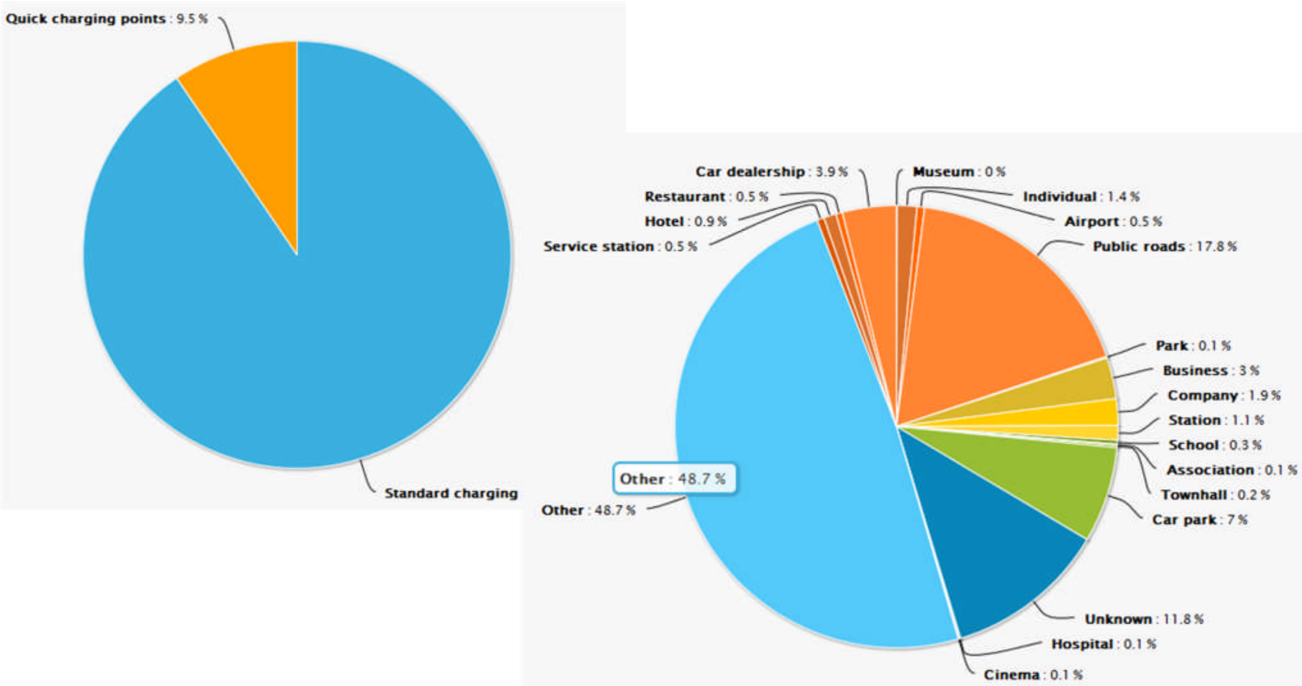


Figure 9 : Plugs, by charging speed type (left), and charging points, by location type (right). Source: chargemap.com

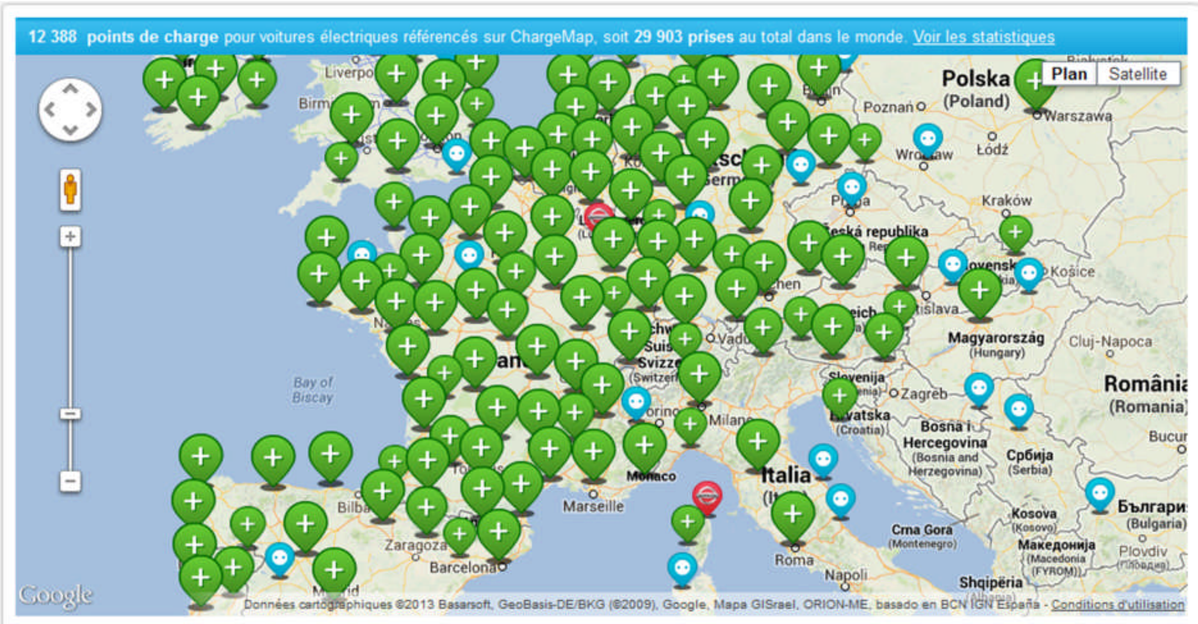


Figure 10 : Location of charging points. Source: chargemap.com

- Recommended ratios of private and public slow chargers and ratios of fast charging points are proposed in (13), and are consistent with (12).
- (3) provides assumptions for the future roll-out of public charging stations:

> *"The wider roll-out of the first generation of public charging stations will take place at a time, when the average charging process to recharge the battery of a BEV at a public charging station will take about 2 hours to perform. The recharge of an EREV will take about 1.25 hours and the recharge of a PHEV will take about 0.5 hours. This leads to an*

average charging time of 59 minutes for the plug-in electric vehicles which are likely to use public charging stations in 2020. To calculate the number of public charging stations necessary to satisfy demand, it is assumed, that in the time between 8 a.m. and 10 p.m. a public charging station faces an unoccupied time of 15 minutes between the charging processes. At night, between 10 p.m. and 8 a.m. an average of only 2 users is estimated to use the possibility to recharge their vehicle. These assumptions would lead to 8.2 users a day per public charging station.

For 2030 it is estimated that the time to recharge a battery will have decreased significantly and the batteries of the new generation of electric vehicles will be able to cope with superfast charging technology. As charging stations with the "old" technology will still be in use by 2030, the average time to recharge an electric vehicle (BEV) at public charging points is assumed to be about 1 hour. Overall, the average time to recharge an electric vehicle (BEV, PHEV and EREV) decreases significantly to 31 minutes. Using the same assumptions as before, the number of users per public charging station can be calculated to 23.6 users a day.

The roll-out of an area covering public charging infrastructure is rather hard to perform, as it holds a high economical risk and is insecure in relation to its technological implementation. While users can charge their cars at home without facing major problems or costs and may also be able to charge their car at their company's or at semi-public charging stations (e.g. supermarkets) in the near future, users who live in inner cities and therefore – in most cases – do not possess their own parking place are dependent on the availability of public charging stations."

- Potential trends for the deployment of charging infrastructure by 2050 are presented in (14), according to three different scenarios ("low cost deployment", i.e. home and work charging dominate ; "grazing", i.e. convenience public infrastructure plays an important role ; "high technology", where fast charging and battery swapping are more densely deployed than in the other scenarios)

  These trends have been translated into ranges of potential ratios for 2050.

The availability of skilled workforce and spare parts is also sometimes mentioned as a potential constraint for the fast roll-out of a Europe-wide electric fleet, but no quantitative data has been found on this topic.

7 Costs

7.1 Variables selected

Variable ***costs***	**Unit**	**Definition**	**Computation**
total investment costs	€		
total O&M costs	€/km		
investment cost for batteries	€/kWh		
O&M costs for batteries	€/kWh		
lifespan of vehicle	km		
lifespan of batteries	cycles		

7.2 Underlying assumptions

With regards to the costs of EVs in 2012/2013, the data presented in the Excel sheet have been derived from commercial information for vehicles available on the market today.

- For the BEVs, commercial information on retail price of the Renault Zoé has been used in particular, as it is more or less at the centre of the range of the cars available today (from city cars, such as Citroen C-zero to sedans, such as Nissan Leaf).
- For the PHEVs, only the Plug-in Toyota Prius has been taken into account.

Data on the evolution of BEV capital cost (battery and car body) by 2050 are provided in (2) and are consistent with (14). For PHEV, approximate figures have been taken in Figure 11 next page.

At present, BEVs and PHEVs can compete with ICE[16] only thanks to governmental subsidies (e.g. 7000€ for Renault Zoé in France) that give EVs a competitive advantage by ensuring that their Total Cost of Ownership (TCO) is close to the one of Internal Combustion Engines. However if EVs are to penetrate more significantly the market in the future, their TCO will need to be competitive in the absence of subsidies: this decrease in TCO is expected as the technology matures, see Figure 11. The TCO of EVs should become even more advantageous compared to ICE's TCO if fuel prices increase.

The TCO is calculated as follows:

$$TCO = Investment\ cost + \sum_{1}^{N} \frac{(O\&M\ cost)_n}{(1+x)^n}$$

where x is the discount rate, and N is the lifespan of the vehicle (assumed to be 10 years here).

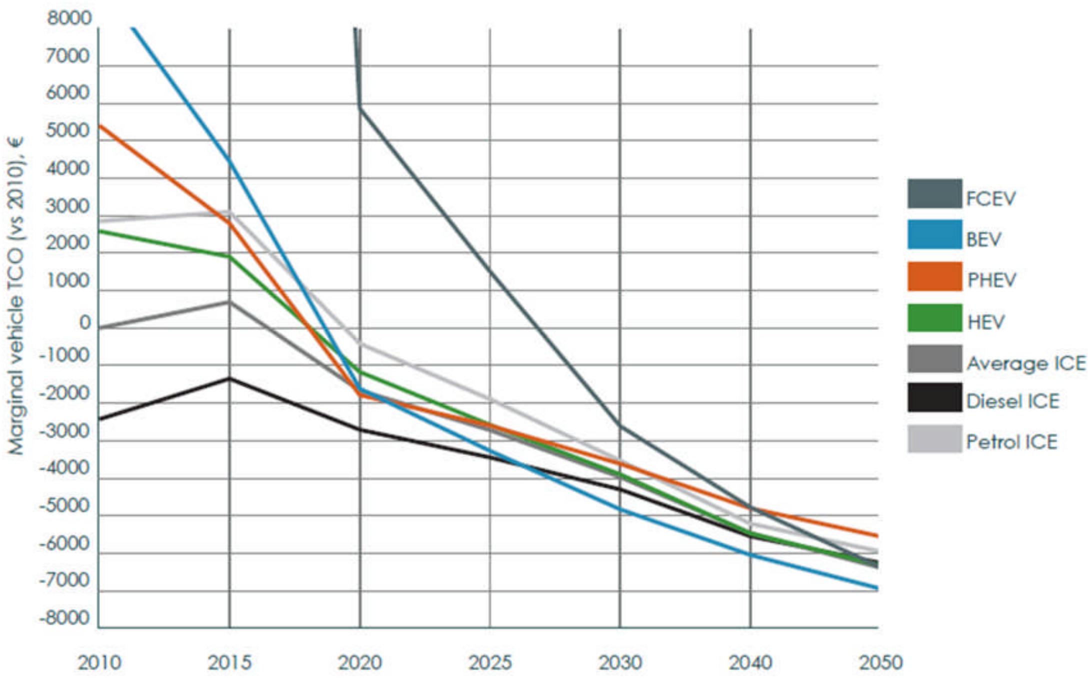


Figure 11 : Car Marginal Vehicle TCO (Discount Rate =3.5%, Central Fuel Prices). Source: Fuelling Europe's Future (2013)

Operation and Maintenance costs (O&M) include:

- fuel / electricity (calculated for an average annual distance of 15 000 km/year, with an electricity price of 0.01 €/kWh and fuel price of 1.6€/L),

[16] Internal Combustion Engine

- insurance,
- servicing and vehicle test.

The costs of insurance, servicing and vehicle test are assumed to amount to an annual cost equalling 10% of the initial investment for BEV and 14% for PHEV (14% for ICE according to (13)).

In the case of BEV, for which the fuel price (electricity) is low and maintenance costs are expected to be lower than for ICE (e.g. no filters or oil to be changed), the TCO is close to the initial investment. It may however depend on the business model, as some car manufacturers prefer to sell the car without the battery and lease the battery with monthly fees calculated according to the contract chosen by the client: in that case the structure of EVs' TCO will be similar to that of ICEs' TCO.

The investment cost also has to take into account the installation of a charging point, as detailed below. It is likely that these prices will decrease in the coming years as they become more widespread. Operational and maintenance costs for domestic charging spots should be close to zero. They are estimated to remain low in locations such as offices and commercial sites but they will vary depending on the network use.

Figures on the investment costs for batteries have been obtained from experts and commercial information, and projections (along various technological scenarios) have been found in (1) and (3).

O&M costs for batteries are unknown except in the case of battery leasing (the monthly fee including maintenance costs and potential replacement if the battery in case of failure). The data provided in the Excel file for 2012 is obtained from the monthly fee for Renault Zoé with a contract of at least 3 years and up to 15000 km/year (86 €/month), assuming a travelled distance of around 15000 km/year with an average consumption of 0.17 kWh/km.

MAIN APPLICATION	CHARGING POINT FEATURES	POWER (KW)	CHARGE TIME	PRODUC-TION COST (€)	INSTALLA-TION COST (€)	OPERATING COST (AS % OF CAPITAL COST)
Residential	Wall box One plug Mode 1 or 2 User protection during charging Options for individual metering system	3kW	4-8 hours	400	1,000	1%
Workplace	Ground mounted Two plugs Choice of access control systems e.g. cards, keypad with code.	7kW	4-8 hours	800	1,000	5%
Car parks and street-sied parking, shopping centers , hotels etc.	Ground mounted High resilience 2 plugs or more Different access options	22kW	1-2 hours	6,000	3,000	5%
Stations on highways	Fast charging Mode 3 and 4 2 plugs or more High resilience	43kW	30 min	22,000	25,000	5%

Figure 12 : Technical features and costs of EV charging points. Source: Fuelling Europe's Future

As the commercial models of BEV and PHEV considered in this report have recently been put on the market, it is complex to assess the real lifespan of these vehicles; 150 000km (according to ADEME) and 200 000km (IEA) have been used for BEV and PHEV in 2012 respectively. It is unlikely this lifespan will increase in the future if one takes into account the evolution of ICE's lifespan.

The lifespan of batteries is stated in number of cycles. OEMs sometimes rather mention a duration (8 years for example for Renault Zoé) or a distance (125 000 km according to ADEME experts). 800 cycles is a commonly cited figure today to express a Li-ion battery lifespan (i.e. number of complete cycles to 80% of original rated capacity, the battery being then available for 'static' usage such as storage). However, this number strongly depends on the technology, and some Li- configurations have a lifetime above 2000 cycles (Lithium titanate for example[17]) according to KU Leuven. The battery lifespan might be strongly influenced by the type of charge, as fast charge may impact negatively the battery (research is on-going on that topic). The lifespan also depends on the depth of discharge and the temperature at which the battery is used: it is suspected that batteries will degrade faster in hot climates (experimentation is underway by Renault in La Réunion island).

The evolution of batteries lifespan by 2050 is expected to increase (2.5 times by 2050 according to (2)).

[17] The lithium-titanate battery has the advantage of being faster to charge than other lithium-ion batteries. Titanate batteries are used in Mitsubishi's i-MiEV electric vehicle: Toshiba stated that its SCiB batteries can withstand 2.5 times more charge/discharge cycles than a typical lithium-ion battery.

8 Environmental impact and public acceptance

8.1 Variables selected

Variable ***environmental impact and public acceptance***	**Unit**	**Definition**	**Computation**
CO2 content	gCO_2e/km		= gCO_2e/kWh x consumption in kWh/km
Recyclability	%	% of materials recycled	

8.2 Underlying assumptions

The CO_2 content is here considered to be the CO_2 emitted 'from well to wheel', i.e. from electricity generation to the car wheels, and does not take into account the full life cycle (a study has recently been commissioned by ADEME in France on EVs Life Cycle Analysis and is still underway).

For the calculation of the CO_2 emissions in 2012, the following data have been used:

- EU27 mix : 369.7 gCO_2e/kWh in 2009,
- average BEV consumption: 0.15 to 0.2 kWh/km,
- carbon emissions of PHEV: 49 gCO_2e/km according to Toyota.

The figure provided in the excel file (and pasted below) is based upon calculations made by IFP, ADEME and AT Kearney (see original pictures in the attached file).

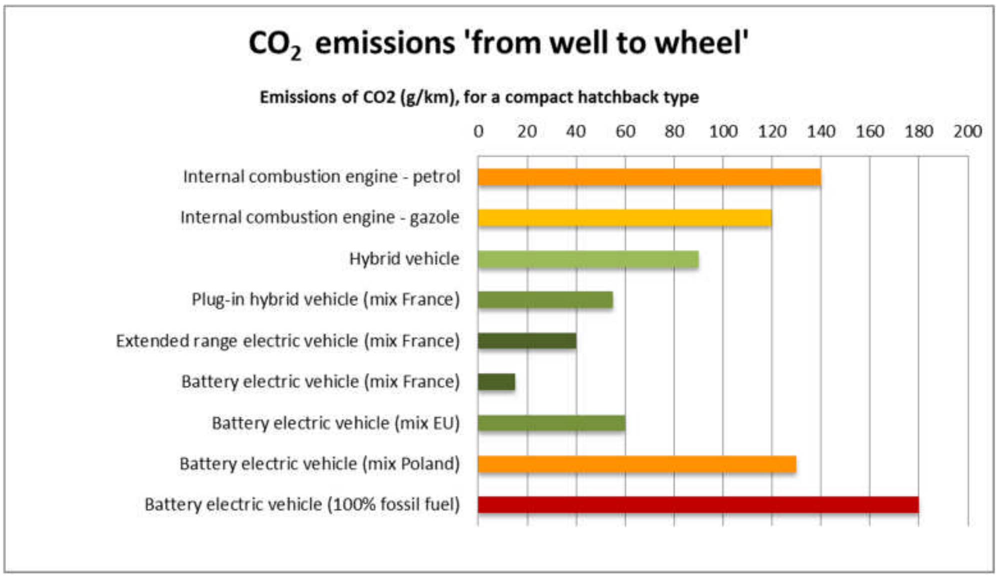


Figure 13 : CO_2 emissions from well to wheel for a compact hatchback type (own compilation from different sources)

The evolution of these CO_2 emissions by 2050 will be highly correlated to the evolution of the European electricity mix.

McKinsey (9) provides some projections on CO_2 emissions for PHEV and BEV in 2050 (see Figure 6).

9 Supply chain issues

9.1 Variables selected

Variable ***market and supply chain issues***	**Unit**	**Definition**	**Computation**
Cumulative market - medium	million	number of EVs at the European level according to different scenarios	See 'data processing'
Spare parts availability	weeks/ months	mean time to repair in case of failure	
Materials	high/low/ medium	risk of shortage of materials in manufacturing process	

9.2 Underlying assumptions

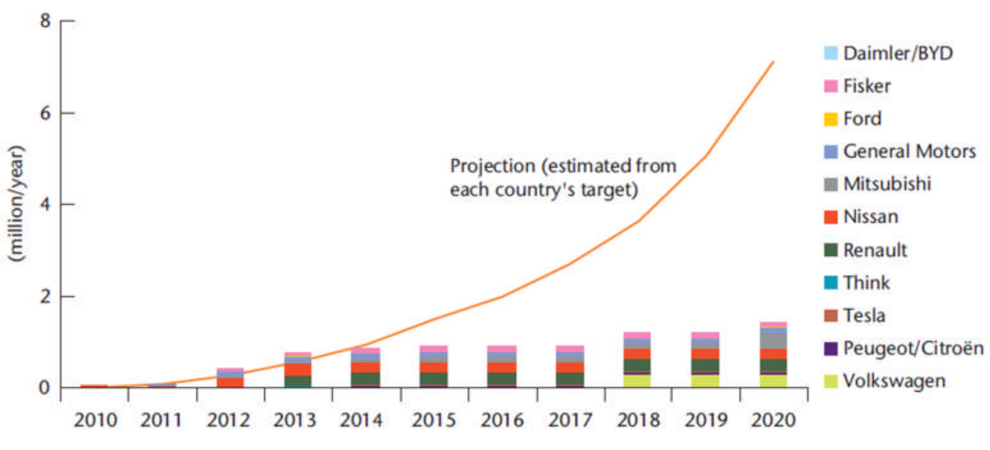
The present report has focussed on market penetration of Electric Vehicles. No information has been found on spare parts availability (which is likely to be highly dependent on the location), and the only information on materials is that mass production could cause lithium scarcity as its proven resources are limited (1) and because demand for lithium from portable electronics sector will compete with demand for lithium for BEVs' battery manufacturing.

As for the number of electric cars currently on the road in Europe, the source of data is Avere (15) (47 734 electric 4-wheelers in August 2012).

Although data are rather easy to obtain for the present time, it is more difficult to predict how the market penetration of EVs will evolve until 2050.

PHEVs and BEVs are now starting to penetrate the market and several studies (16; 1) anticipate that PHEV sales will rapidly exceed those of BEV. After 2040, sales of PHEVs are expected to begin declining as EVs (and fuel cell vehicles) achieve even greater levels of market share.

It should be noted that the international, European and national targets are usually more ambitious than those of the OEMs, as illustrated in Figure 14 from the International Energy Agency (16) below, although production capacities should rise after new plants enter in service. The comparison of these targets beyond 2020 is more problematic as OEMs do not wish to give any forecast or make any statement on what would be an "educated guess", since technological breakthroughs cannot be predicted.



* *Production/sale capacity levels shown here are assumed to remain constant after year of construction. In practice, capacities may rise after plants enter service.*

Figure 14 : Government target and EV/PHEV production/sales reported by OEM*. Source: IEA, 2011.

The second point to be taken into account is that most of the scenarios for EV deployment are target-oriented: for example the Blue Map scenario of the IEA sets the goal of halving global energy-related CO2 emissions by 2050 (compared to 2005 levels) and examines the least-cost means of achieving that goal through the deployment of existing and new low-carbon technologies, the electric car being one of them.

The pitfall of these target-oriented scenarios is that they are de-correlated from the current trend and recent news claiming that the EVs have difficulties in penetrating the market (mostly because of their limited driving range) and that their relative success in some countries (e.g. France) only relies on high volume purchases for car-sharing programmes (i.e. Autolib in Paris and other big cities) and commercial fleets. As a consequence, the penetration of EVs might be slower than expected. The target-oriented scenarios also assume that the main barriers to EV penetration will be addressed and that major technological breakthroughs will be reached by 2050, as illustrated Figure 15 (17).

With this in mind, eight different reports (some of them presenting up to 3 different scenarios) have being analysed to compare the available scenarios of EV penetration (BEV on one hand, PHEV on the other hand) (18; 19; 20; 21; 1; 22; 23; 16).

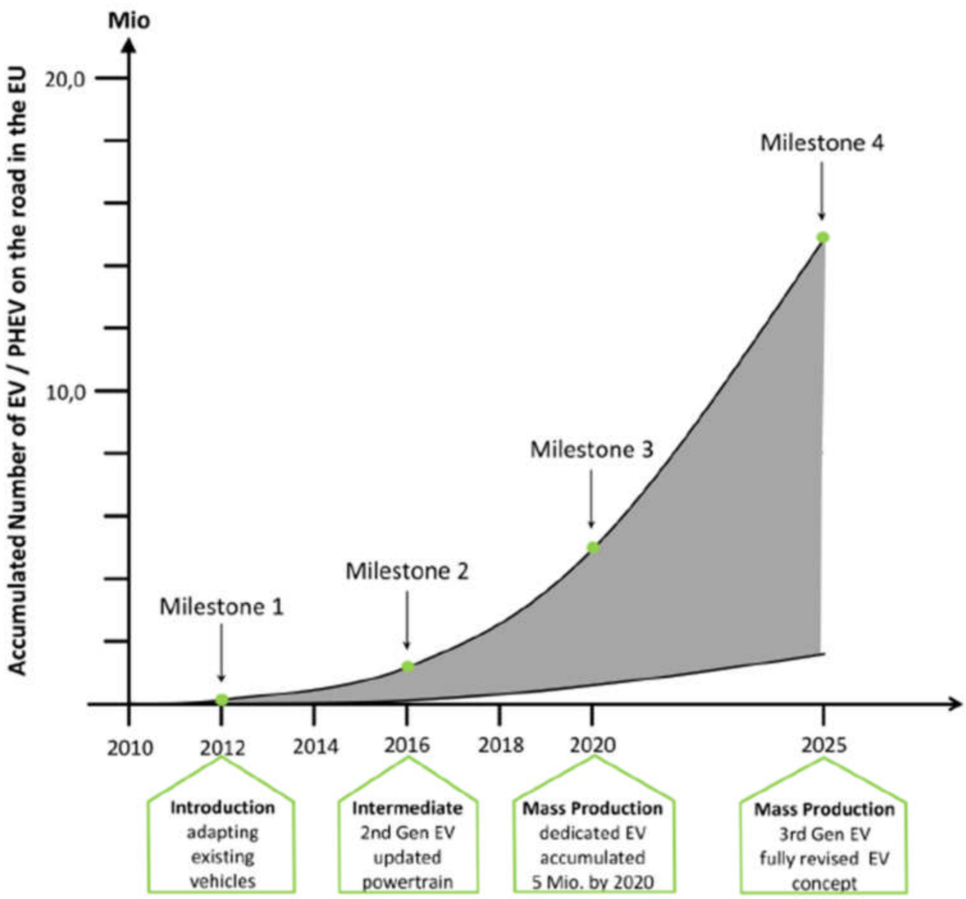


Figure 15 : Milestones of the European Industry Roadmap for Electrification of Road Transport. Lower black curve: evolutionary development of accumulated number of EV/PHEV. Upper black curve: expected development under assumption of reaching the major technological breakthroughs. Source: European Roadmap Electrification of Road Transport, 2nd Edition, 2012.

9.3 Data processing

The analysed reports do not all provide values of the number of vehicles in use in Europe: some provide estimates of market shares or number of sales, other give worldwide figures or figures for a few European countries only. It has therefore been necessary to process the data provided in most of the reports in order to obtain a single type of data (number of vehicles on the road in EU-27 at different time horizons) so that the various scenarios can be compared.

9.3.1 Blue Map scenario (16)

In its technology roadmap (16), the EIA gives figures on global sales of PHEV and BEV (number of vehicles) at worldwide scale from 2015 to 2050 with a 5-year time resolution.

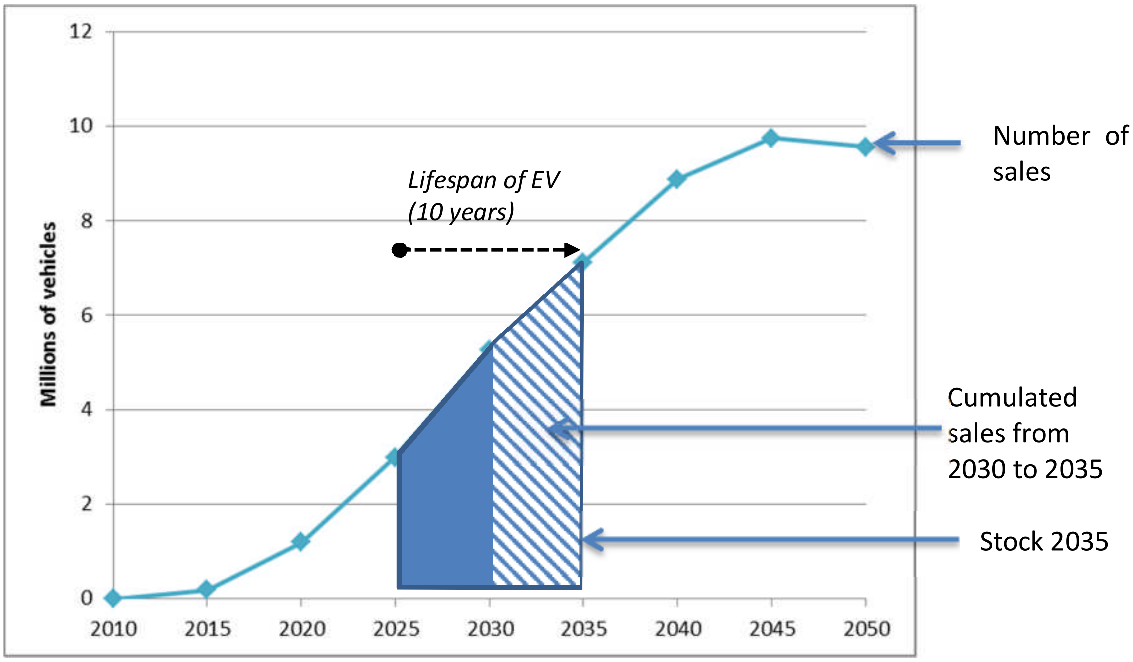
- These data have been translated into European sales with the following assumptions:

Table 2 : Evolution of the European share of global vehicle sales

	2010	2015	2020	2025	2030	2035	2040	2045	2050
European share of global sales	27%	25.6%	24.2%	22.8%	21.4%	20%	18.6%	17.3%	16%

The shares for 2010 has been considered as being equal to the rate calculated by (3) in 2011. The percentage then decreases linearly down to 16% in 2050 to take into account the fact that from 2030, the Chinese new vehicle market will probably be as large as the EU-27 and U.S. markets added together ((3), (16)).

- The data obtained for European sales of BEV and PHEV have then been converted to a number of vehicles on the road, as illustrated below.



$EV\ stock\ (year\ Y) = \sum_{n=Y-10}^{Y} new\ sales\ (year\ n)$ (assuming a lifespan of 10 years for EVs)

Assuming a linear increase of sales (see figure above), we approximate the stock as:

$$EV\ stock\ (year\ Y) = \frac{new\ sales\ (year\ Y-10) + new\ sales\ (year\ Y-5)}{2} \text{x}\ 5 + \frac{new\ sales\ (year\ Y-5) + new\ sales\ (year\ Y)}{2} \text{x}\ 5\ .$$

➲ ***Confidence index[18] of data processing: 3.5***

9.3.2 Deutsche Bank scenario I and II (18; 19)

No processing has been necessary.

9.3.3 Boston Consulting Group (20)

Values for BEV and PHEV stocks in 2020 have been derived from sales forecasts for 2020, with the same approach as in 9.3.1.

➲ ***Confidence index of data processing: 4***

9.3.4 Merge studies (21)

The Merge project investigated five European countries: Germany, UK, Spain, Portugal and Greece. In 2008, the 5 investigated countries accounted for 43.7% of the European fleet. It has been assumed that this rate would remain rather stable by 2050, and this rate has been used to convert the Merge's study into a European assessment.

Three types of EVs have been taken into account in the study: BEV, EREV, and PHEV. Due to the characteristics of EREV (only one electric engine - no ICE as in hybrid, battery almost the size of the BEV ones), this type of vehicle has been combined with BEVs.

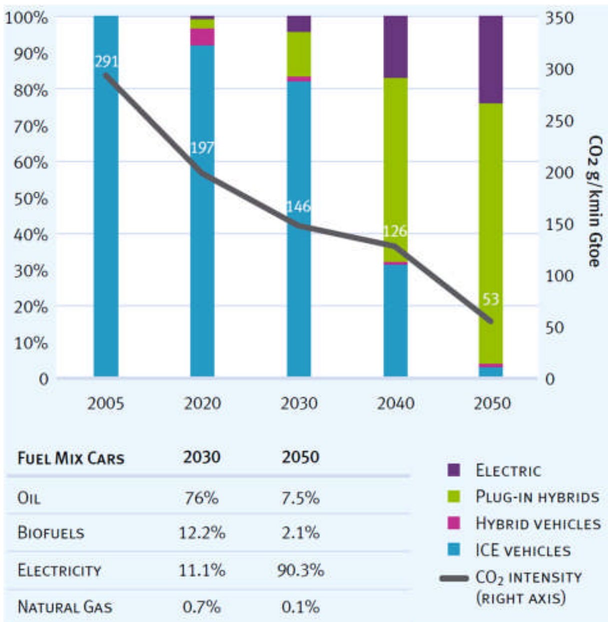
➲ ***Confidence index of data processing: 3.5***

9.3.5 European Clean Transport System (1)

Data have been taken directly in the report.

9.3.6 Eurelectric Power Choices (22)

Data on shares in passenger vehicles stock have been derived from a graphic, hence some imprecisions might be expected.



Fuel Mix Cars	2030	2050
Oil	76%	7.5%
Biofuels	12.2%	2.1%
Electricity	11.1%	90.3%
Natural Gas	0.7%	0.1%

Figure 16 : Shares in Passenger Vehicles Stock (source : Eurelectric, 2009)

[18] qualitative index on a 1 to 5 scale (5 being the best), assessed by TECHNOFI who has collected and processed the data.

These data have then been converted into number of vehicles on the road using the following figures, based on an average increase of around 1% per year:

Table 3 : Evolution of the number of registered vehicles in EU-27

	2008	2020	2030	2040	2050
Number of registered vehicles in EU-27 (in million)	235[19]	270	300	325	350

➲ ***Confidence index of data processing: 3.5*** (qualitative index on a 1 to 5 scale, 5 being the best)

9.3.7 Fuelling Europe's Future

This report provides percentages of new fleet shares for BEV and PHEV, and the corresponding number of vehicles on the road for EVs in general. Data have therefore been processed to distinguish the numbers of PHEVs on the road from those of BHEVs.

➲ ***Confidence index of data processing: 4*** (qualitative index on a 1 to 5 scale, 5 being the best)

9.3.8 JRC (23)

The JRC study provides shares in the European car fleet for 2020 and 2030 for BEV and PHEV separately. These data have been converted into number of vehicles using Table 3.

➲ ***Confidence index of data processing: 4*** (qualitative index on a 1 to 5 scale, 5 being the best)

9.3.9 Resulting ranges

Ranges of values have been derived from all these studies (16 scenarios in total). The mean of the available values and the standard deviation in 2020, 2030, 2040 and 2050 have also been calculated to highlight 'extreme' scenarios that are not consistent with the other scenarios (e.g. scenario of (22) for PHEV – this scenario has not been taken into account when calculating the range)

10 Dynamic performance of technology

10.1 Variables selected

Variable ***dynamic performance of the technology***	**Unit**	**Definition**	**Computation**
Controllable fleet	-	% of cumulative market controllable through active demand response	
Typical modulation profile (slow charging)	-	modulation profile (for a single unit) for two typical days (hourly time resolution, in % of typical load)	

[19] http://www.acea.be/news/news_detail/vehicles_in_use

10.2 Underlying assumptions

No electric vehicle is currently controlled within a demand-side management programme. No information has been found so far on the percentage of controllability by 2030 and 2050. An example of modulation profile is available in (4).

11 Contextualization of data

In a parallel task of the e-Highway2050 project, a scenario building approach has been defined to characterize five scenarios covering the time period 2020-2050 and taking into account technological, financial/economic, environmental and socio-political issues.

A key question for the downstream simulations to be performed in WP2 is the following:

How to adjust the typical range of technology data according to the five selected scenarios?

To that purpose an approach is proposed for the needs of WP2. This approach is called **data contextualization** and aims to allocate, for a given technology, typical values to key variables descriptive of this technology, at the 2050 time horizon, and this for each of the five considered WP1 scenarios.

The key assumption used is that the main driver for contextualization is the penetration rate of the technology (cumulated number of units at a given time). It is indeed assumed that the cost and performance trends of the technology by 2050 are directly correlated to its level of deployment.

The next diagram (next page) summarizes the successive steps to build such adjusted values:

1. A given scenario is a combination of :
    - a "future" characterized by a set of quantified "uncertainties" and
    - a "strategy" characterized by a set of quantified "options".

    The future deployment of EVs by 2050, i.e. its penetration level, is impacted by some of these uncertainties and options. A selection of uncertainties and options is therefore made according to their potential impact on future EV deployment: uncertainties and options are assessed in terms of their potential support or barrier to EV deployment. Only uncertainties and options with a significant impact (i.e. incentive/barrier to penetration) are retained.
2. Depending on the considered future and strategy, each uncertainty or option has a specific value. The potential impact related to this value on EVs deployment is assessed for the selected uncertainties and options. This assessment is qualitative (text description, see Table 4).
3. By aggregating these individual assessments of each selected uncertainty and option, an overall qualitative assessment is made, which reflects the impact of the given scenario on the deployment level of EVs, on a three degree scale (Low, Medium, High).
4. In parallel, a subset of key technology variables describing EVs is selected. The selection focuses on penetration level (number of units by 2050), performances (efficiency) and costs (battery and vehicle).
5. From the value ranges attached to the selected EV key technology variables are extracted the minimum, average, and maximum values, which will then be allocated to the market penetration assessment scale (Low, Medium, High –see point 3)

6. By combining the scenario assessments made at step 3 and the EV value tables built at step 5, specific values are allocated to the subset of EV variables (key technology variables) according to each given scenario.

Uncertainties and options selected for the contextualization process:

With regards to uncertainties describing the 'future' of each scenario, the following ones are retained as the most impacting:

- Variable u4 (*fuel costs*): the difference between electricity and fuel costs is assumed as a driver for EV adoption.

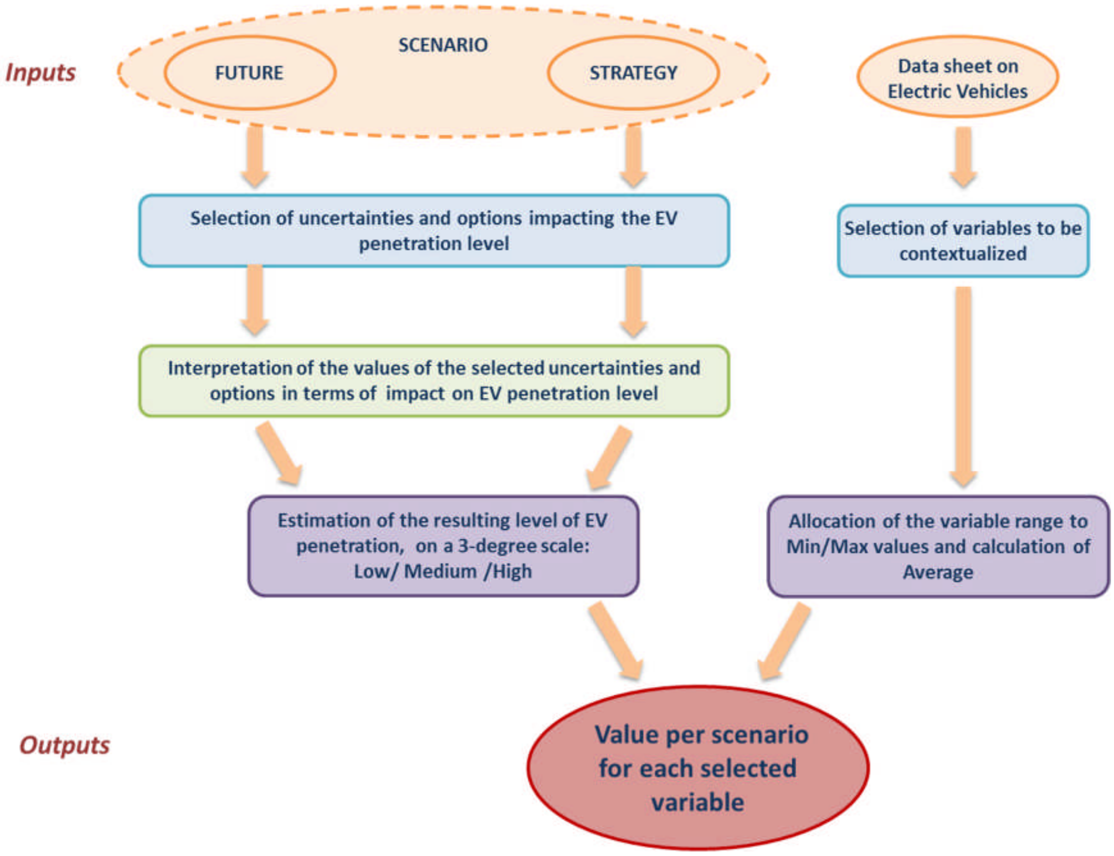


Figure 17 : Contextualisation process

- Variable u8 (*electrification in transport*): this variable directly reflects the deployment (market segment/scale) of the technology.
- Variable u14 (*shift towards greener behaviours*): this variable is assumed to be correlated to the "technology switch" effect towards the EV technology.

With regards to options describing the 'strategy' of each scenario, the following one is retained:

- Variable o7 (*increased energy efficiency (including DSM & flexibility of EV use)*): it is assumed that the support to DSM deployment will favor the BEV technology rather than PHEV, as BEV present a high flexibility potential.

Variable o4 has not been retained: although the *deployment of de-centralised storage* may have an influence on the evolution of EV battery performances and costs, it is considered that this impact would be very limited compared to those of the other selected variables. Indeed, battery storage is only a component of de-centralised storage, and as batteries used for (stationary electricity) storage do not have the same characteristics /performances as EV batteries, the two topics are difficult to relate. Conversely, it is likely that the deployment of battery storage will be the one impacted by EV deployment, instead of the opposite: EV batteries could indeed get a second life in grid storage, which would drive costs down and could change the economics of community-scale and grid-scale energy storage[20].

The table next page displays the analysis of each selected scenario parameter (i.e. option and uncertainty) in terms of its potential impact on the EV market penetration level, and the resulting mark given to each scenario to this regard.

[20] http://www.greentechmedia.com/articles/read/Chevy-Volt-Batteries-to-Get-Second-Life-in-Grid-Storage

Table 4: Contextualisation of values

	Scenario X5 Large scale RES & no emissions	**Scenario X7 100% RES**	**Scenario X10 Big & Market**	**Scenario X13 Large fossil fuel with CCS & Nuc**	**Scenario X16 Small and local**
Future	**2**		**4**		**5**
Fuel price	High ⇨ *incentive to use an EV, and BEV in particular*		Low ⇨ *no incentive to use EVs. Business as usual*		High ⇨ *incentive to use an EV, and BEV in particular*
Electrification in transport	All transport ⇨ *large development of EVs*		Large scale (freight) ⇨ *very limited development of EVs for passenger vehicles*		Personal vehicles ⇨ *large development of passenger EVs*
Greener behaviour	Major ⇨ *incentive to use an EV, and BEV in particular (green behaviour overcomes the drawback of limited driving range)*		Minor ⇨ *no incentive to use EVs. Business as usual*		Major ⇨ *incentive to use an EV, and BEV in particular as the driving range is not a problem here ('small & local')*
Strategy	**2**	**4**	**1**	**5**	**3**
Increase of energy efficiency – DSM & flexibility	Low ⇨ *the absence of DSM may imply that electricity price for EV charging is high to deter its intense use and reduce impact on the grid, PHEV are therefore favoured. Respective share is however difficult to assess.*	High ⇨ *incentive to use BEV thanks to 'vehicle to grid' applications*	Medium ⇨ *no influence given the future described above*	Low ⇨ *no influence given the future described above*	High ⇨ *incentive to use BEV thanks to 'vehicle to grid' applications to support local smart grid*
Resulting scenario for deployment of EVs, from 2020 to 2050					
- ***BEVs***	***Medium to high***	***High***	***Low***	***Low***	***High***
- ***PHEVs***	***Medium to high***	***Medium***	***Low***	***Low***	***Low***

Table 5 and Table 6 below display the selected variables relative to the EV technology (BEV and PHEV are considered separately), and the values attached to each penetration level (Low/Medium/high) at different time horizons.

Some calculations have been made to complete the ranges found in the literature *(see Excel file, 'Contextualisation' sheet for more details).*

- Costs (battery and vehicle) are assumed to be low when penetration level is high.
- With regard to the retail price of BEV, as only a figure corresponding to a high penetration level was available for 2040 and 2050, a range has been derived, based on the range of 2020 (cross-multiplication).
- With regard to the retail price of PHEV, as only figures corresponding to a medium penetration level were available, estimations of price ranges for the low and high scenarios have been interpolated from the medium values using the following calculation:

$$Price(penetration\ level = high)_{year\ N} =$$
$$mean\ (Price(penetration\ level = medium)_{year\ N};\ Price(penetration\ level = medium)_{year\ N+10}\ )$$
$$Price(penetration\ level = low)_{year\ N} =$$
$$mean(Price(penetration\ level = medium)_{year\ N-10};\ Price(penetration\ level = medium)_{year\ N}\ )$$

As a consequence,

$$Price\ (penetration\ level = high)_{year\ N} =\ Price\ (penetration\ level = low)_{year\ N+10}$$

Note: Although this approach may seem approximate and rather arbitrary, similar results (i.e. difference of less than 200€) are obtained using the battery cost range to estimate the vehicle retail price for the low and high penetration scenarios (assuming that the differences of vehicle cost among the scenarios depend only on the battery cost, with a constant battery capacity of 10kWh).

- Numbers of public and private chargers have been calculated by multiplying the median ratios provided in the attached Excel sheet by the estimated number of BEVs *(see Excel file, 'Contextualisation' sheet for the details of calculation)*.

How to read the tables?

Example: for the scenario X16, the levels of penetration of BEV and PHEV are expected to be high and low respectively, and the selected technology variables are expected to have the following values in 2050:

	Value – 2050
Number of BEVs	157 million
Battery cost	140 €/kWh
Retail price of BEV	15 000 €
Driving range of BEV	650 km
Nb of private (home/ work) slow charger	141.3 million
Nb of public standard charger	47.1 million
Nb of public fast charger (>46kW)	7.85 million
Number of PHEVs	65 million
Retail price of PHEV	29 750 €
Driving range of PHEV	1 200 km

Table 5: Contextualisation of BEV

Time horizon	Unit	2012	2020			2030			2040			2050		
Penetration level		/	*low*	*medium*	*high*	*low*	*medium*	*high*	*low*	*medium*	*high*	*low*	*medium*	*high*
Number of BEVs	Million	0.05	0.1	3.7	7.2	3.0	21.5	40.0	29.0	65.0	101.0	**52.0**	**104.5**	**157.0**
Battery cost	€/kWh	450	384	300	210	360	265	170	250	200	150	**250**	**195**	**140**
Retail price BEV	€/unit	30 000	27000	23500	20000	27000	22000	17000	21600	18800	16000	**20250**	**17625**	**15000**
Driving range of BEV	Km	150	200	260	320	200	340	480	250	405	560	**250**	**450**	**650**
Nb of private (home/ work) slow charger	Million	0.04	0.09	3.33	6.48	2.7	19.35	36	26.1	58.5	90.9	**46.8**	**94.05**	**141.3**
Nb of public standard charger (25kW)	Million	0.016	0.03	1.11	2.16	0.9	6.45	12	8.7	19.5	30.3	**15.6**	**31.35**	**47.1**
Nb of public fast charger (>46kW)	Million	0.003	0.005	0.185	0.36	0.15	1.075	2	1.45	3.25	5.05	**2.6**	**5.225**	**7.85**

Table 6: Contextualisation of PHEV

Time horizon	Unit	2012	2020			2030			2040			2050		
Scenario of penetration		/	*low*	*medium*	*high*	*low*	*medium*	*high*	*low*	*medium*	*high*	*low*	*medium*	*high*
Number of PHEVs	Million	0.00	0.4	9.9	19.4	10.0	35.5	61.0	70.0	85.0	100.0	**65.0**	**92.5**	**120.0**
Retail price PHEV	€/unit	39 000	36 000	33000	32250	32250	31500	30750	30750	30000	29750	**29750**	**29500**	**29000**
Driving range of PHEV	Km	900											**1200**	

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13 Attached document

See Excel file : data_electric vehicles_Technofi