# Impacts of Electric Vehicles - Deliverable 1

## An overview of Electric Vehicles on the market and in development

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# Contents

# Summary

Electric Vehicles (EVs) are a promising technology for reducing the GHG emissions and other environmental impacts of road transport. It is important for EU policy makers to get an overview of the possible impacts of the introduction of Electric Vehicles. Therefore DG CLIMA commissioned CE Delft, ICF and Ecologic to carry out a study on the potential impacts of large scale market penetration of EVs in the EU, with a focus on passenger cars and light commercial vehicles. This study includes an assessment of both the transport part (e.g., composition of vehicle fleet) and electricity production and the impacts on well-to-wheel GHG emissions, pollutant emissions, other environmental impacts, costs, etc. This report is the first deliverable of this project and provides an overview of current market developments, i.e., mostly EVs coming to the market by 2011-12, but also covering vehicles up to 2015 as well as genuine show cars.

We analysed 106 different passenger cars and a smaller number of non-passenger cars. The relatively limited data in the sample, together with the speculative nature of the topic and the fact that some of the vehicles are still announcements or prototypes of which some specifications might change in the coming year(s), results in a limited statistical robustness of the findings, calling for caution when drawing conclusions building on the analysis.

Presently there is no clear indication for a real shift in terms of vehicle mass or design. The fact that the forecasted electric cars are on average not significantly heavier than today's European cars implies either that the heavy battery weight will be compensated with weight reduction in other elements or that there will be more small cars in the market than currently. No fundamental shift in the short term towards light weight composite materials as in aircraft design could be observed. This may not hold true in the long term as composite materials may become market-ready in the future.

Vehicle prices will be considerably higher for Full Electric Vehicles (FEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) compared to today's cars powered by Internal Combustion Engines (ICEs).

Judging from the available data, battery capacity correlates very directly with battery mass. Thus, more battery capacity implies a heavier and larger car. Ranges are therefore still very much limited and pure electric driving will be limited to short and medium range applications for the near-term future. In the long run, the ranges of FEVs might increase significantly and extend the cars' typical fields of application beyond city-only use. Based on electric urban drive ranges, FEVs are primarily in the 100-200 km ranges, PHEVs in the ranges below 100 km. This is linked both to vehicle mass and battery performance.

In terms of maximum speed and acceleration, Electric Vehicles (EVs) will not differ significantly from today's cars. However, it has to be noted that EVs can only run at top speed for a very short time due to overheating issues. Their performance will increase over time, which will also allow electric driving beyond urban and local traffic.

The gathered information seems to indicate that the actual body will not differ much from today's mid-sized European cars, at least until 2015. On average, the chassis will be significantly lighter than today's US cars and slightly lighter than today's European cars. This seems to indicate a trend towards smaller cars.

When comparing directly an ICE model with its electric sister-model, EV models almost always perform weaker against their ICE versions. In particular, vehicle price and range – two essential purchase criteria – are significantly less advantageous for the EVs. As a consequence, the market penetration of EVs might remain below expectations as potential buyers could rather stick to the lower-priced ICE version with a better overall performance.

Apart from passenger cars, many different vehicle types will be electrified in the future. Generally, these vehicles are very heterogeneous and can be subdivided into several variable subgroups: city cruisers, racing and off-road motorbikes, city bicycles ('Pedelecs'), trucks and vans. Their specifications largely depend on the type and use of the vehicle (i.e., the subgroup) and need to be compared more profoundly to receive meaningful results. As many of the vehicles are not produced in large quantities, individual modifications are often possible.

In some countries, non-passenger-car EVs already represent market shares of up to 10%, as do electric bicycles in the Netherlands, indicating a significant market potential for non-car electric mobility. Further concrete current signs of burgeoning market penetration can be observed as postal and messenger services and other companies are increasingly equipping their inner-city fleets with short-range electric vans and trucks. These fields might be a potential key application of EVs with a much higher potential than for passenger cars.

The further uptake of EVs – passenger cars and other vehicles – will tend to be heavily supported by government and industry programs and, thus, also be threatened by national austerity programs. The majority of total global government and industry investments (€ 21.6 billion) have been initiated in the US and the EU. The tendency has been to support subsidy programs for EVs dispersion, where the USA is the world leader. Indication of increasing political will to promote EV technologies is evidenced by the fact that large sums are spent by government institutions or are part of national economic stimulus programs to support EVs. Similarly, most of the countries within the EU and beyond have introduced $CO_2$-based car taxes favouring EVs. Tax incentives, rebates and circulation restrictions are additional measures and have been instituted in many countries.

Generally, the types of programs for electric mobility (target numbers, infrastructure, pilot projects, traffic rights, etc.) vary globally, but also within the EU. Infrastructure for EVs is often developed and installed in cooperation with private companies and in public private partnership, revealing that there is not only a public interest in EV technology, but also economic potential.

Research activities are abundant in the USA and the EU, but also in Japan and China. Research activities in virtually all areas of electric mobility are highest in the United States, especially in universities and national laboratories, while all other countries trail significantly in both categories.

Japan remains the world leader in battery research and development. National-level research activities within the EU often coincide with huge subsidies originating from national economic stimulus packages. Most projects are pilot and demonstration projects and include companies, universities, research institutes, and public institutions.

The 7th Framework Programme for Research and Technological Development (FP7) represents the largest arena in which EU-wide research on Electric Vehicles is currently taking place. FP7, which has a total budget of over € 50 billion and lasts from 2007 to 2013, includes a number of research projects directly related to Electric Vehicles; particularly prominent are energy efficiency, battery and drive train technology as well as developing transport systems and scenarios.

A number of government programs are limited in duration and will run out by 2012, thus raising the question of the continuity of government and private industry commitment to Electric Vehicles.

**Key Findings**

In the near-term future, the market penetration of EVs will remain fairly low compared to conventional vehicles. The estimation based on several government announcements, industry capacities and proliferation projects sees more than five million new Electric Vehicles on the road globally until 2015 (excluding two- and three-wheelers), the majority of these in the European Union. The main markets for Electric Vehicle are in order of importance the EU, the US and Asia (China and Japan). Some further target markets like Israel and the Indian subcontinent are also expected to evolve.

In the long term, the share of EVs will most likely increase as additional countries adopt technologies and initiate projects.

1. It can be assumed that in the short run, i.e., until 2015, EVs will not differ significantly from today's cars concerning their outward appearance and function, albeit with shorter ranges than conventional ICE cars.
2. Until 2015, the market penetration of EVs will remain fairly low: compared to global sales forecasts of 53 million conventional cars in 2010 alone, EVs will account for over five million cars until 2015. The main markets for EVs still being the EU, the US and East Asia (China and Japan).
3. As research activities and investments are relatively high, EV technology may advance rapidly and might account for greater shifts in the future than our findings suggest.
4. There is a significant risk of electric 'depression' after 2012 if expectations are not met and market penetration remains low.

# 1 Introduction and aim of the report

## 1.1 Introduction to the project

Electric Vehicles (EVs) are a promising technology for drastically reducing the environmental burden of road transport. More than a decade ago and also more recently, they were advocated by various actors as an important element in reducing $CO_2$ emissions of particularly passenger cars and light commercial vehicles as well as emissions of pollutants and noise.

At the same time, EVs are still far from proven technology. There exist many uncertainties with respect to crucial issues like:
- The battery technology (energy capacity in relation to vehicle range, charging speed, durability, availability and environmental impacts of materials).
- Well-to-wheel impacts on emissions.
- Interaction with the electricity generation.
- Cost and business case of large scale introduction.

For EU policy makers, it is important to get a reliable and independent assessment of the state of the art of these issues in order to develop targeted and appropriate GHG reduction policy for transport. Therefore DG CLIMA commissioned CE Delft, ICF and Ecologic to carry out a study on the potential impacts of large scale market penetration of EVs in the EU, with a focus on passenger cars and light commercial vehicles. This study includes an assessment of both the transport part (e.g., composition of vehicle fleet) and electricity production and the impacts on well-to-wheel GHG emissions, pollutant emissions, other environmental impacts, costs, etc.

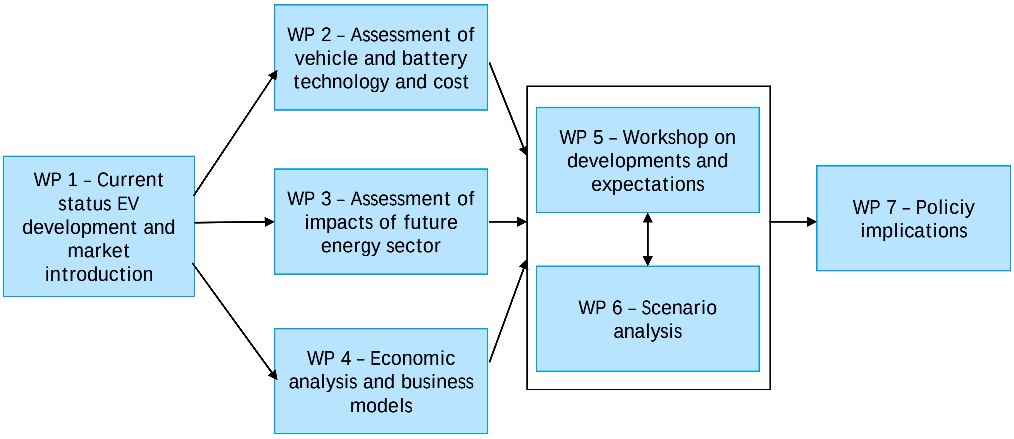
In this study three types of EVs are distinguished:
- Full Electric Vehicles (FEVs) that have an electric engine and no internal combustion engine (ICE).
- Plug-in Hybrid Electric Vehicles (PHEVs) that have both an ICE and an electric engine, with a battery that can be charged on the grid.
- Electric Vehicles with a Range Extender (EREVs) that have an electric engine and an ICE that can be used to charge the battery and so extend the vehicle's range. The battery of an EREV can be charged on the grid.

The results of the study should help the Commission with developing GHG policy for transport, in particular in the field of EVs and in relation to the wider EU transport policy and EU policy for the electricity sector.

The project is organised around seven work packages (WPs):
WP 1 Current status EV of development and market introduction.
WP 2 Assessment of vehicle and battery technology and cost.
WP 3 Assessment of impacts on future energy sector.
WP 4 Economic analysis and business models.
WP 5 Workshop on developments and expectations.
WP 6 Scenario analysis.
WP 7 Policy implications.

The following graph (Figure 1) gives an overview of the main interactions between the various WPs. The approach for each WP is explained in the following paragraphs.

**Figure 1 Project overview**




The results of this project are presented in five deliverables: Deliverables 1 to 4 presenting the results of WP 1 to 4 and a final Deliverable 5 with the results of WP 5, 6 and 7. In addition there is a summary report, briefly summarizing the main results of the entire project.

This report is the first deliverable of the project and includes the results of WP 1.

## 1.2 Objective

The aim of WP 1 is to provide an overview of the current status of EVs and PHEVs in the market. This overview includes:
– The current **industry activities**, by car makers, electricity utilities, parts suppliers (motors and batteries), including joint ventures, product announcements and pilot projects.
– Announcement and projections by **analysts, policy makers, experts**, etc.
– Gather and summarise conclusions of the most important existing **research projects** in the EU and elsewhere.
– Assess these forecasts and predictions.

The scope of this deliverable is:
– Worldwide developments.
– Data was taken into consideration until the end of the Geneva Auto Show, 14.03.2010.

The study primarily focuses on passenger cars. Other types of road transport and non-road transport modes are only included in a qualitative assessment.

## 1.3 Approach

Currently, Electric Vehicles (EVs) represent only a small fraction of car sales. While the market share of pure Electric Vehicles remains microscopic throughout the EU (Eurostat 2010), milder forms of electrification start to penetrate the car market:

- Micro hybrids essentially are standard ICE based cars with a start-stop mechanism to reduce idling of the engine at for example traffic lights.
- Mild hybrid concepts use an electric drive to support the ICE when additional torque is needed.
- Full Hybrids, feature both an ICE and an electric drive train, where the electric drive train can operate independently and allows emission free propulsion for short distances at low speeds. The battery is charged by the ICE component and not through an external charger.
- PHEVs feature both an ICE and an electric drive train. They can be charged through a power outlet or other external charger and can thus run independently of the ICE for a limited distance after which the combustion engine again charges the battery. Once the battery is depleted, the vehicle runs on the ICE.
- EREVs have an all electric drive train and drive on battery electricity only. Their ICE serves solely to charge the battery and thus extends the vehicle's range.
- Full Electric Vehicle (FEV): an all-Electric Vehicle without ICE.

While all the above mentioned car categories share the similarity that they use electric batteries to power the drive train to various degrees, the complexity of the configuration varies significantly: From a purely systems engineering perspective, PHEVs showcase a higher degree of complexity than FEVs or EREVs as they include two fully functional drive train systems. Moreover, PHEVs are conceptually closer to classical ICE-powered cars than both EREVs and FEVs, as PHEVs present both the features of ICE cars and EVs.

This report focuses on the following types:

- PHEVs, Plug-in Hybrid Electric Vehicles.
- FEVs, Full Electric Vehicles (no ICE).
- EREVs, EVs with Range Extender.

For each class, we define three vehicle categories:

- Small – i.e., a car that would fit into the European small car segment.
- Medium – i.e., a car that would fit into the European mid-size segment.
- Large – i.e., a car that would fit into the European full-size segment.

This categorisation will guide us in our analysis of the data and will allow us to link closely with the following tasks in the project.

This work package gives an overview of current activities by car manufacturers, electric utilities and public entities including joint ventures, product announcements and pilot projects. Furthermore, we have included assessments by experts, policy makers and analysts.

To assess the different approaches, we will review each of them in a similar way. Our first step is, thus, to develop the assessment framework. In a subsequent step, we will then apply this framework to currently available products, industry research and finally publicly funded research.

All data and information for this work package has been obtained from readily available literature, press releases, leaflets, newsletters, company websites and through personal communication. In particular, work built on recent studies commissioned by the European Commission.

# 2 Manufacturer forecasts for passenger cars

## 2.1 Introduction

In this chapter, we gather and review data on car manufacturer developments in electric mobility. The chapter focuses primarily on passenger cars as these constitute currently the most relevant vehicle market. The next section (Section 2.2) will address how data was gathered and compiled, followed by an analysis of the raw data (Section 2.3), which will then be analysed in more detail (Section 2.4). This analysis draws statistical comparisons on drive train configuration, vehicle mass, pricing, range, batteries, maximum speed and acceleration.

Furthermore, future EVs are directly compared to their ICEV equivalents. In a final section, we look into developments in the non-passenger car segment, including two- and three-wheelers and commercial vehicles (Section 2.5). The chapter closes with a summary of the main findings (Section 2.6).

## 2.2 Methodology for data gathering

We build our assessment of current and near-future EV passenger cars on forecasts made by car manufacturers.

The EEA report 'Environmental impacts and impact on the electricity market of a large scale introduction of electric cars in Europe - Critical Review of Literature' (ETC/ACC Technical Paper 2009/4, July 2009) was a main source of information.

Furthermore, we contacted several experts in the field of electric mobility. Their personal assessments contributed to the findings presented in this report.

Another main source was the internet. The homepages of the different car manufacturers provided much necessary information on vehicle specifications.

The major model database used was http://www.pluginamerica.org/vehicles/. The http://evworld.com – newsletter regularly updated us on current developments in the EV-scene. Further websites on developments in the car industry and especially in the area of alternative compulsion were:
– http://www.autoblog.com.
– http://green.autoblog.com.
– http://www.wired.com.
– http://www.hybridcars.com.
– http://www.greencarcongress.com.
– http://ww2.autoscout24.de.
– http://blogs.edmunds.com/greencaradvisor.

In addition, car magazines (such as AutoMotorSport, Autobild, etc.) and their web pages provided inside reports and missing data. Car purchase prices are indicated in Euro. All prices are final retail prices and taxes are included in the purchase prices. We used the official exchange rates of April 23rd, 2010 for prices quoted in other currencies. If a price span was given, we took the arithmetic mean as the purchase price.

## 2.3 Raw data analysis

The full list of cars assessed can be found in Table 1.

**Table 1 Announced EV**

| | | |
|---|---|---|
| Aptera 2h | Fisker Project Nina | Renault Kangoo ZE |
| Audi E-tron | Ford Escape | Renault Zoe Z.E. Concept |
| Audi Metroproject Quattro | Ford Focus EV | Renault Zoe Z.E. |
| Audi A1 Sportback | Ford Transit Connect | REVA NXG |
| BAIC BE701 | General Motors Cadillac Converj | REVA NXR |
| BMW 1 Series Concept Active E electric coupe | GM Saturn Vue Green Line | Rinspeed UC? |
| BMW Megacity | Green Vehicles Moose | RUF Stormster |
| BMW Mini-E | Green Vehicles Triac | Saab ZE 9-3 |
| BMW Vision | Herpa Trabant nT | SABA Carbon Zero |
| Bright Automotive Idea | Heuliez Mia | SAIC Roewe 750 |
| BYD Auto e6 | Hyundai Blue-Will | SEAT Ibe |
| BYD F3DM | Jaguar XJ | SEAT León 'Twin Drive Ecomotive' |
| Capstone CMT-380 | Kia Ray | Suzuki Swift |
| Chery Auto Co. S18/M1 | Kia Venga | Tata Indica |
| Chevrolet Volt | Land Rover Range Rover Sport | Tata Nano |
| Chrysler GEM | Lightning UK Electric Lightning GT | Tazzari Zero |
| Chrysler Town & Country | Lotus Evora 414E hybrid | Tesla Motors Roadster |
| Chrysler 200C | Mercedes Benz F 800 | Tesla S Electric Sedan |
| Chrysler Jeep Patriot | Mercedes Benz F 800 | Th!nk City C |
| Chrysler Jeep Wrangler Unlimited | Mercedes Benz SLS eDrive | Toyota 1/X |
| Citroen C-Zero | Miles Electric (ZX40S) | Toyota FT-EV city car |
| Citroen C-Zero City Car | Mindset AG Mindset | Toyota Prius Plug-in |
| Citroën REVOLTE | Mitsubishi iMiEV | Valmet EVA |
| Coda Automotive CODA | Mitsubishi PX-iMiEV | Velozzi Solo crossover |
| Commuter Cars Tango | Nissan Leaf | Velozzi Supercar |
| CT&T United e-Zone with lead-acid battery | NLV Quant | VentureOne/Persu Mobility |
| CT&T United e-Zone with lithium polymer battery | Opel Ampera | Venturi Fetish |
| Daimler Smart ED | Opel Flextreme | Visionary Vehicles/Bricklin Collection |
| Daimler Mercedes Benz Blue Zero | Optimal Energy Joule | Volkswagen Twin Drive |
| Daimler Mercedes Benz S500 Vision | Peugeot ion City Car | Volvo C-30 electric car |
| Detroit Electric e63 | Pininfarina/Bollore BlueCar | Volvo ReCharge |
| Detroit Electric e64 | Porsche 918 Spyder | Volvo V70 |
| EWE-E3 | Protoscar SA Lampo2 | VW Up! (E-Up!) |
| e-WOLF e2 | Renault Fluence Z.E. Concept | XR-3 Hybrid |
| Fiat 500 | Renault Fluence ZE EV | |
| Fisker Karma | Renault Kangoo Z.E. Concept | |

The data of our study comprises 106 different EVs of 66 different car manufacturers, including models of the 15 biggest vehicle manufacturing groups worldwide such as Toyota Motor Corporation, General Motors Company, Volkswagen AG, etc. While Honda has been sluggish and explicitly renounced Electric Vehicles and PHEV technology until recently[1], changes in the California tax code have made them reconsider their stance, implying that Honda may develop a PHEV in the near future[2].

While all of the above were developed with the aim of finally producing a final product, we are very much aware of the fact that a considerable number of the proposed concepts will not come to see completion. Furthermore, show-cars usually demonstrate state-of-the-art technology. Hence, the results of a comparison with cars that are already on the market have to be judged with caution. Even without them being introduced to the market, the conceptual design of show cars reveals statistically meaningful information on construction and performance possibilities and constraints of Electric Vehicles.

The relative limited data in the sample, together with the speculative nature of the topic, results in a limited statistical robustness of the findings, calling for caution when drawing conclusions building on the analysis.

Most manufacturers are serving the ‘classical’ (West) European, North American and East Asian markets and also originate from these regions. However, there is a significant share of Chinese and Indian car manufacturers, and even one South African company. Chinese, South American, South Asian (esp. India) and Middle East markets play an increasingly important role for EV penetration, whereas African, Central American and Central Asian markets are considered marginal.

30% of all researched models have been or will be released in 2009/2010, the remaining 70% in 2011+ (if at all). We have included available information up to the Geneva car show, i.e., 14.03.2010.

## 2.4 Current and future developments by car manufacturers

We will refrain from analysing each proposed model separately and instead opt for a statistical analysis of the models. This allows us to exclude some of the uncertainties due to missing or incorrect data. Some uncertainty will nevertheless remain as the number of assessed cars is relatively small, especially in the sub-samples.

We analyse developments according to a set of criteria that overlaps as much as possible with the data requirements for the subsequent development of vehicle platforms within WP 2: drive train configuration and vehicle size, weight, purchase costs, electrical drive train (EDT) range and battery property. We will analyse these parameters for all cars and separately for 2009/2010 versus 2011 and later car releases. This will allow us to establish an indicator for trends in the EV market. Comparing short-term and long-term releases, we run the risk of providing an overly optimistic trend towards the latter, but the categorisation proves to be comparatively reliable.

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1 According to: http://online.wsj.com/article/SB119313344275568239.html?mod=googlenews_wsj.

2 Bloomberg 26.04.2009 http://www.bloomberg.com/apps/news?pid=20601103&sid=aD0dW_P92jeU&refer=us.

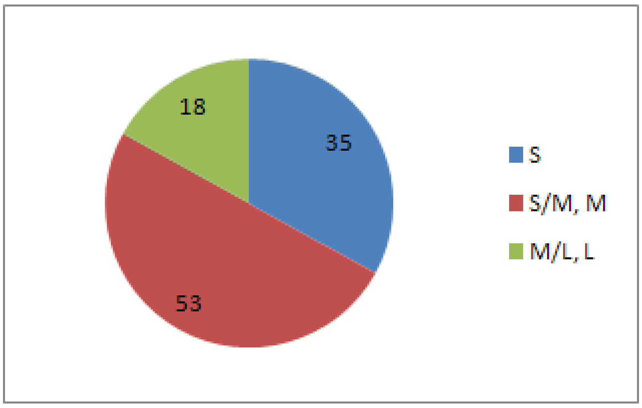
### 2.4.1 Drive train configuration and vehicle size

In comparison with the average car of today, the near-future EV does not seem to be very different regarding the body, as lower-medium size sedans will most likely be the preferred model even in the future.
It seems that 50% of the cars will belong to the small-medium or medium sector, while less than 20% of all EVs will be mid-large or large.

According to JD Powers forecasting (Bonhoff, 2009), compact cars represent the largest share of the European car market, followed by mid-size cars. Large cars represent a much smaller part of the car market.

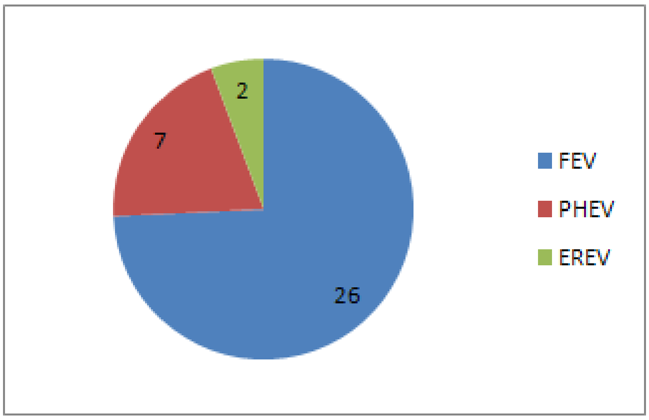
Looking at current trends (see Figure 2), it seems that the future EV market will follow the same pattern and have an emphasis on small and mid-size vehicles, the latter alone embodying 50% of all announced vehicles.

**Figure 2** **Share of car segments in the data set (with actual number of vehicles, n=106)**



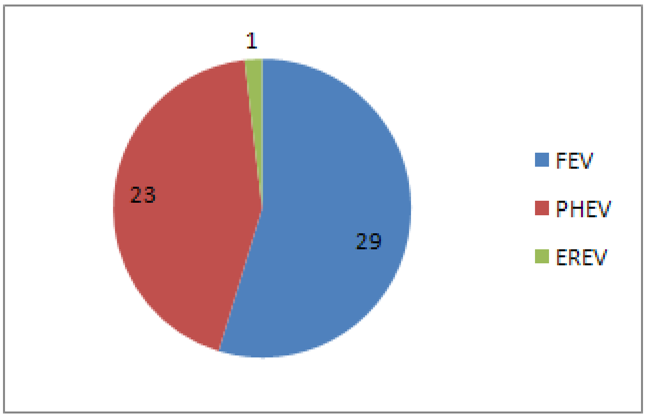

When looking at the power train configuration in the different vehicle classes, we find that among the small vehicles, FEVs dominate with almost 75%, see Figure 3. EREVs have no high relevance in this segment.

**Figure 3** **Small vehicles drive train configuration (with actual number of vehicles, n=35)**



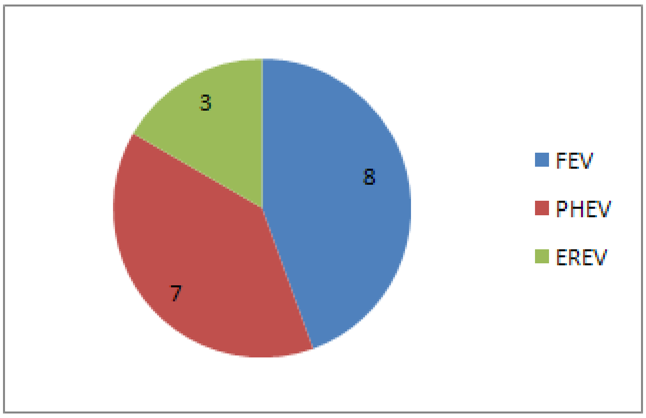

In the medium and large vehicle sector, however, FEVs and PHEVs balance more evenly, see Figure 4. We found only one vehicle with a Range Extender in this segment.

Figure 4 **Medium vehicles drive train configuration (with actual number of vehicles, n=53)**




EREVs predominately appear among the large vehicles, see Figure 5.

Figure 5 **Large vehicles drive train configuration (with actual number of vehicles, n=18)**




The larger the car, i.e., the heavier, the less likely it is to be a Full Electric Vehicle. Also, PHEV concepts are rarely proposed for small cars.

Furthermore, we separated our database into two classes (cars to be released 2009/2010 and cars to be released 2011+) and subsequently compared these subgroups with each other.

Strikingly, 73% of the EVs to be released in 2009 or 2010 are FEVs with only one EREV (3%) among them. However, in later years, the PHEV share will increase and reduce the share of FEVs to 54% (PHEVs 39%, EREVs 7%). The data thus indicates a shift towards PHEVs.

### 2.4.2 Vehicle mass

If a distinction was made for different weights of the vehicles, we opted for curb weight data. We were not able to differentiate between gasoline and diesel cars concerning the US and EU ICE cars.
The average Electric Vehicles will weigh 1,289 kg, 83 kg lighter than the average European car today (1,372 kg[3]), but significantly lighter than today's

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[3] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0001:0015:EN:PDF.

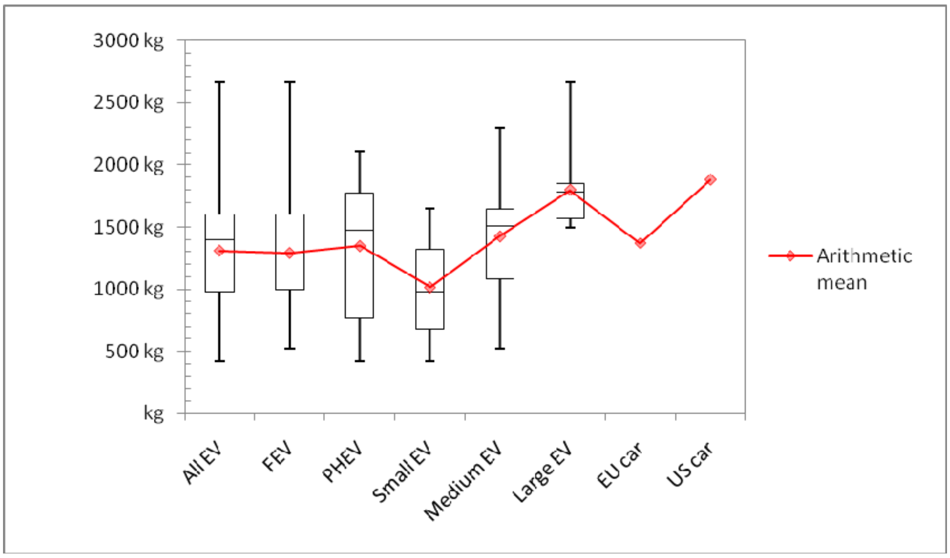
average US-car (1,879 kg[4]). Despite of the fact that PHEVs rely less on electric compulsion and thus could have lighter batteries (that account for a great share of the vehicle's complete mass), they weigh 1,349 kg on average and, thus, almost 90 kg more than FEVs (1,262 kg), see Figure 6. This indicates that PHEVs tend to be larger cars compared to FEVs.

The median for FEVs only amounts to 1,240 kg (hence FEV mass dispersion is slightly skewed to the right) as compared to 1,471 kg for PHEVs (hence PHEV mass dispersion is notably skewed to the left).The median for all EVs is 1,400 kg, so the dispersion here is also skewed to the left.

The fact that the announced cars are on average not significantly heavier than today's European cars implies that the additional weight caused by the battery will be offset by weight reductions in other vehicle components such as the chassis. It could also be caused by a higher share of EVs in smaller and medium cars instead of large vehicles. So far, however, there seems to be no fundamental shift towards light weight composite materials as has been observed in aircraft design, see the upcoming Boeing B787 Dreamliner and the Airbus A350. However, BMW is currently investing heavily in developing composite components for its future cars.[5]

When comparing the average vehicle mass to the vehicle size, a clear and logical picture evolves: Small vehicles weigh on average 1,019 kg, medium vehicles 1,425 kg and large vehicles 1,618 kg.

**Figure 6** **Vehicle mass comparison: whiskers show the range, bars show the 25-75% distribution, centre line is the median value and red dot is the mean; n=106, All EV=106, FEV=63, PHEV=37, Small EV=35, Medium EV=53, Large EV=18**




In summary, there is no evidence that the overall average weight of EVs and PHEVs will differ significantly from today's European cars in the short term.

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4 http://www.msnbc.msn.com/id/14187951/.

5 http://www.handelsblatt.com/unternehmen/koepfe/klatten-steigt-bei-sgl-carbon-ein;2203845.

However, taking into consideration the significant weight of the vehicles' battery, it becomes apparent that the chassis and body itself must be somewhat lighter compared to today's cars.

### 2.4.3 Price

The price of the vehicle is a crucial point in the question whether one day EVs will be able to fully penetrate the car market. In this subtask, if possible, we opted for prices including taxes.

The average vehicle purchase price of future EVs (€ 45,316) is almost three times higher than the average European price for a new car today (€ 15,313, as of 2001[6]), and it more than doubles the 2009 US price (€ 20,826.56[7]) for a new vehicle, see Figure 7. Although it is understood that these values do not directly compare, it has to be pointed out that actual vehicle purchase price data is not readily available.

Within the different sub-groups, the average EV purchasing costs vary from € 157,500 for an EREV (high price caused by the fact that there are only two EREVs with information on price in the dataset, thereof one of € 280,000). compared to € 29,883 for an average new PHEV, while the average FEV price of € 46,626 comes close to the overall average.

The median FEV purchase price amounts to € 28,500, even below the arithmetic mean for PHEVs, implying that some extremely high-priced cars (e.g., Venturi Fetish, Mercedes Benz SLS, etc.) augment the average FEV purchase price. For PHEVs, the median shows no significant aberration.

The cars with Range Extender are skewed towards the very high price segment by just one car, the Capstone CMT with a retail price of € 280,000.

Again, the median price for all Electric Vehicles is € 28,750 and thus significantly below the average price, even below the average PHEV price. The reasons are the same as for FEVs only: a few high-priced FEVs distort the overall average.

In summary, FEVs will be on average more expensive than PHEVs, even comparing median values (€ 28,500 for FEVs and € 25,505 for PHEVs). In any case, both will be more expensive than the average ICE car of today. It is still widely unknown how prices will be affected by higher production volumes, so there might be some potential for lowering the purchasing price of FEVs and PHEVs. Besides, an increasing number of countries worldwide offers subsidy programmes and tax relief for Electric Vehicles that might encourage higher production and compensate purchasing prices. Nevertheless, the data shows an overall upward move in purchase price.

Surprisingly, the average vehicle purchase price decreases with the car's size. This seems to be mostly due to the number of outliers, i.e., cars that are significantly more expensive than comparable cars: The number of outliers was highest among the small EVs, still significant for the medium EVs and nil for large EVs. This can be observed in Figure 7.

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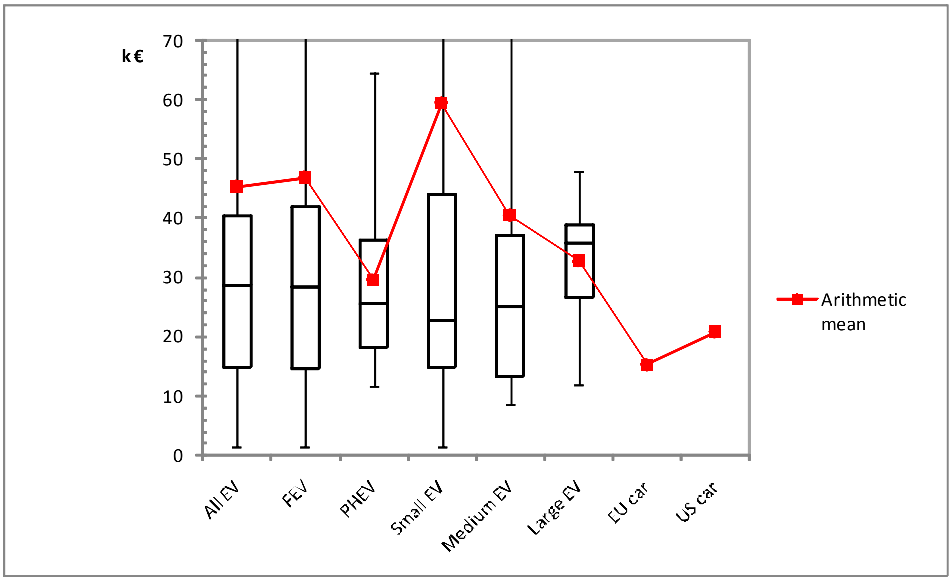
[6] http://www.autoindustry.co.uk/articles/31-08-01_1.

[7] NADA (2010): NADA DATA 2010, http://www.nada.org/Publications/NADADATA/2010/default.

While small vehicles cost € 59,383 on average, medium vehicles can be purchased for € 40,400 on average, and large vehicles even for € 32,728. Median prices, however, correct for this discrepancy by avoiding significant biases (a few extremely high-priced cars in the small and medium section). Here, the car prices increases with size, starting at € 22,750 for small cars, € 24,948 for medium cars and € 35,700 for large cars. The difference between small and medium cars is considerably smaller than between medium and large cars (over € 10,000).

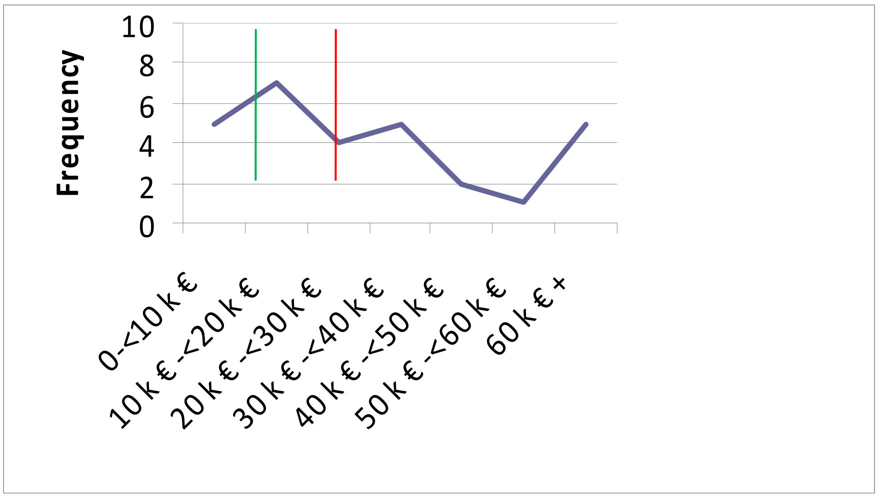
This data can be interpreted in several ways: For one, FEVs tend to be small cars, as we observed earlier (Section 2.4.1). Moreover, PHEVs tend to be large cars. Thus, it becomes apparent that FEV technology will be more expensive than PHEV technology, even though FEVs are smaller compared to PHEVs.

**Figure 7** **Vehicle purchase price comparison: whiskers show the range, bars show the 25-75% distribution, centre line is the median value and red dot is the mean; n=106, All EV=106, FEV=63, PHEV=37, Small EV=35, Medium EV=53, Large EV=18**



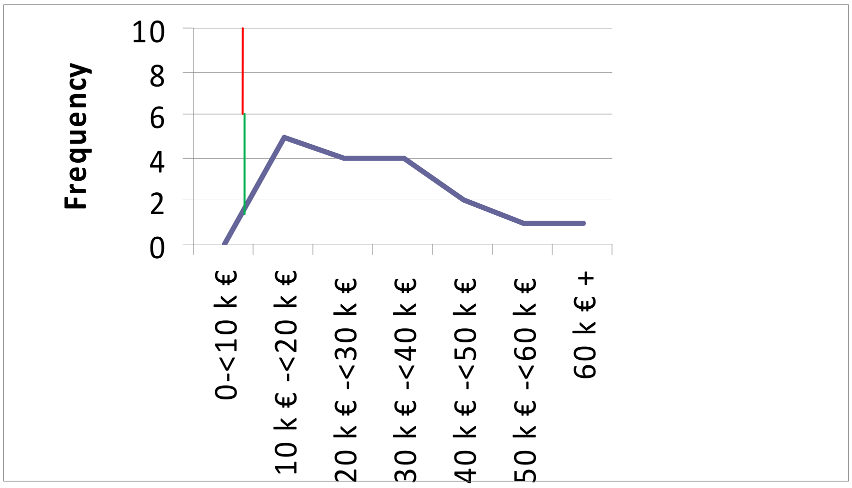

Looking at the segments of FEV purchase price, the largest number of cars (seven out of 29) is in the € 10,000-20,000 group (just like the average EU price for a new car), while a few extremely expensive cars skew the arithmetic mean (red) to the right of the median (green).

Figure 8 **Distribution of FEVs in different price classes with median (green) and arithmetic mean (red)**




For PHEVs, the arithmetic mean (red) and the median (green) are almost identical. The largest number of cars falls in the € 10,000-20,000 group as well (5 out of 22), but the vehicles are distributed more equally.

Figure 9 **Distribution of PHEVs in different price classes with median (green) and arithmetic mean (red)**




## 2.4.4 Range

One of the most relevant criteria for future market penetration ability is without doubt the range of the EDT.

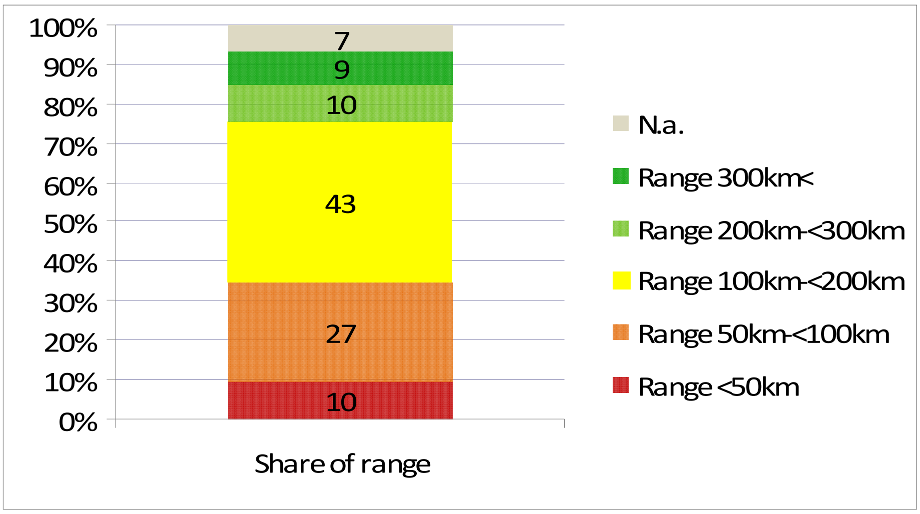
The data we used is manufacturer data of the models that were announced when we gathered information, in comparison with which the real life statistics might differ. Firstly, these data might not appropriately show the status quo in research and technical development. Secondly, real life values depend on charging patterns (charging kills batteries, and quick charging reduces life time and requires more energy), temperature (the lower the temperature, the shorter the range) and on auxiliaries like air conditioning/heating (range reduction). Lastly, most of the vehicles we analysed were introduced on car shows that again often follow certain trends in the car industry. As a consequence, ‘fashionable’ cars or models following

new trends might be overrepresented in our analysis compared to actual sales volumes.
Nevertheless, we analysed the existing dataset corresponding to our statistical analysis model, as data on actual ranges, taking into consideration different heating/cooling patterns and/or charging systems are hardly available.

The future EV's electric urban driving ranges are mainly (75%) in the 200 km or less region, with the majority (41%) of the cars having a range between 100 and 200 km. Cars with an electric drive train (EDT) range of over 200 km will be rather seldom (18%). Even though there are some expensive cars in this group, there is no strong correlation between price and range: The correlation coefficient is at 0.39. Put together, the ranges of 0 to 100 km and 100 to 200 km amount to a comparable share (35 resp. 41%). For 7% of the cars, no EDT range was indicated, see Figure 10.

The median EDT range of 130 km also fits into the main 100-200 km category.

**Figure 10 Share of EDT range (with numbers of vehicles, n=106)**




The driving range is a crucial point in the question whether EVs will one day be able to fully penetrate the world's car markets and therefore has been examined in detail. We focus our analysis on urban driving range, as we expect that near-future EVs will be designed mainly for urban transport due to limitations on charging and range. Contrary to ICEVs, EVs have only small efficiency gains from driving on highways: the electric engine can run at almost efficient levels even in stop and go (recuperating energy from braking). Most manufacturers do not report separate range scenarios for highway and city use except for two cases: the Opel Ampera shows a slightly lower highway range compared to urban (66 vs. 55 km); while the Tata Nano promises 160 km on highways vs. only 120 in urban use. Thus, the data remains inconclusive on whether urban ranges will be lower or higher than highway ranges.

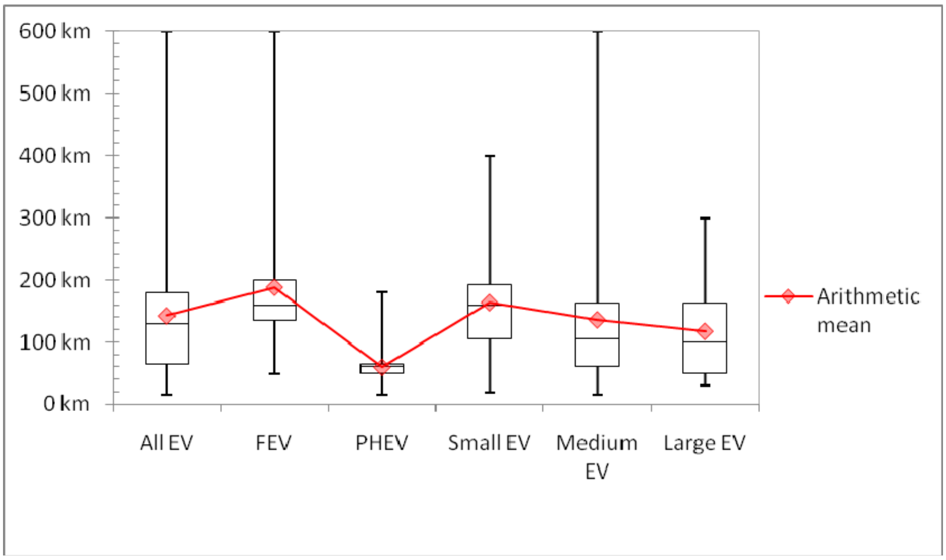
The average EDT range for Full Electric Vehicles amounts to 189 km, while the average PHEV EDT range is considerably lower at 60 km. The median shows a corresponding picture of 160 km EDT range for FEVs (revealing several maximum outliers in this subset) and again 60 km for PHEVs. Thus, not surprisingly FEV EDT ranges are on average about three times higher than PHEV ranges.

Splitting up the EDT ranges by vehicle size, the ranges are evidently decreasing with an increasing size. Small vehicles – regardless of their type – on average have an EDT range of 164 km (median: 160 km). Medium vehicles have a significantly lower range of 136 km on average (median: 104.5) and on average large vehicles only have ranges of 118 km (median 100 km).
This might be explained by the fact that the smaller a vehicles is, the more likely it is to be a FEV, which have higher electric ranges than PHEVs or EREVs (see above).

Considering FEVs only, there is no clear trend: Small Full Electric Vehicles have an average EDT range of 177 km, medium vehicles of 203 km and large vehicles of 181 km. For PHEVs only, however, the EDT ranges are decreasing with the car's size, due to an outlier in the small car section: Small Plug-in Hybrid EVs on average can drive up to 75 km, medium up to 58 km and large vehicles up to 55 km. Again, FEVs possess two to over three times higher EDT ranges.

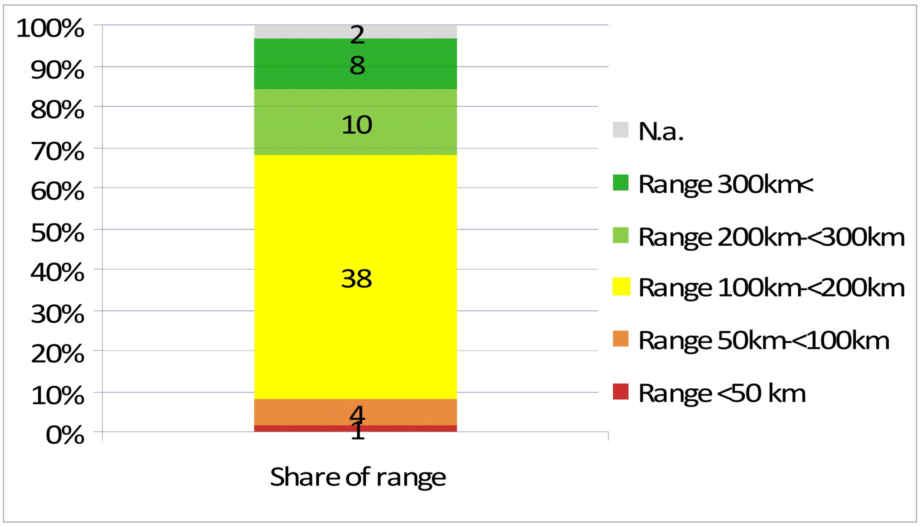
The maximum outlier with an EDT range of 600 km is the Mercedes Benz F 800, affecting the whiskers of medium EVs, FEVs and all EVs. GM's Saturn Vue Green Line (a medium-sized PHEV) has the shortest EDT range of 16 km (see Figure 11).

**Figure 11** **EDT Urban Range: whiskers show the range, bars show the 25-75% distribution, centre line is the median value and red dot is the mean; n=106, All EV=106, FEV=63, PHEV=37, Small EV=35, Medium EV=53, Large EV=18**



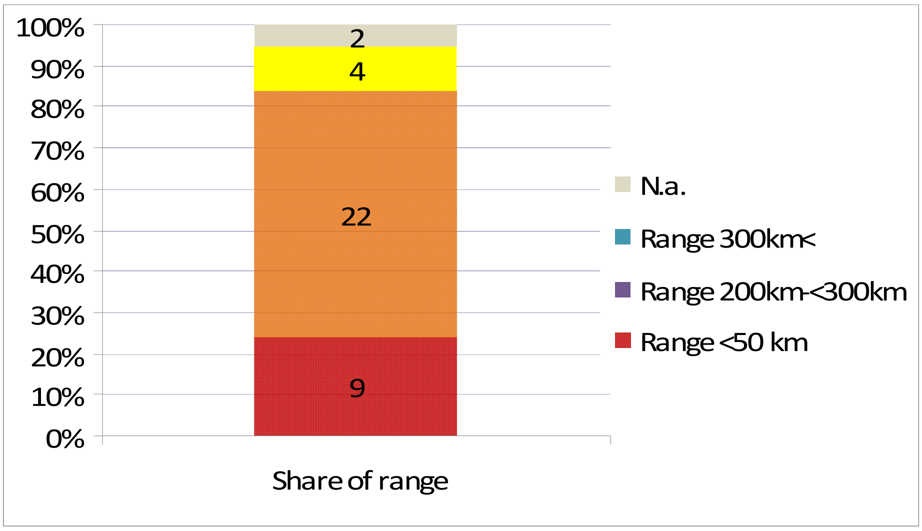

Looking at the EDT driving ranges for FEVs only, 69% of the vehicles claim a range between 100 and 200 km. 28.6% of all cars surpass the 200 km range and only 8% of the cars have a range below 100 km. For two FEVs, that is 3%, no data was found, see Figure 12.

Figure 12 EDT urban range for FEVs (with numbers of vehicles, n=63)




Taking a look at the PHEV's in greater detail, an opposite trend becomes visible. The average EDT ranges for PHEVs show that a striking 84% of all cars have a range up to 100 km only, almost one quarter (24%) even below 50 km. Four cars (11%) are in the 100-200 km area, which is not exceeded at all. There was no data available for two cars; see Figure 13.

Figure 13 EDT urban range for PHEVs (with numbers of vehicles, n=37)



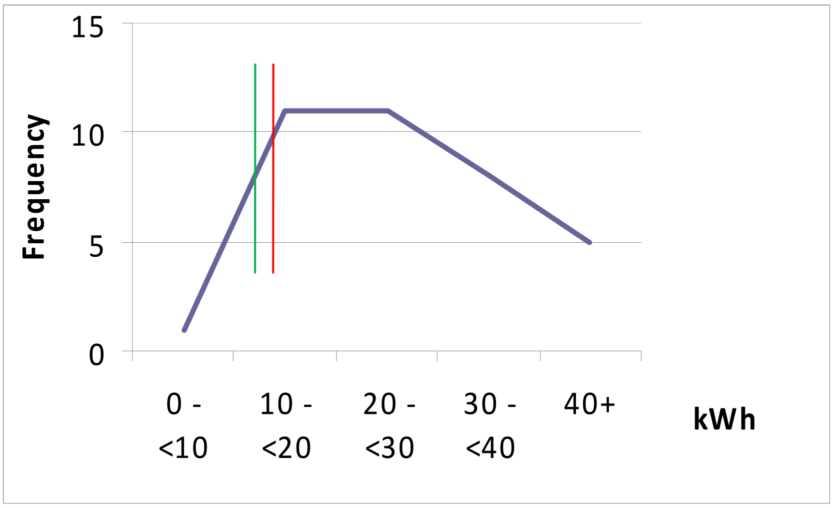

For EREVs, the existing dataset was too small to be separated into range or time categories.

Based on EDT urban drive ranges, FEVs are primarily in the 100 km+ ranges (89%), PHEVs in the ranges below 100 km (84%). This is linked both to vehicle mass and battery performance.

### 2.4.5 Battery

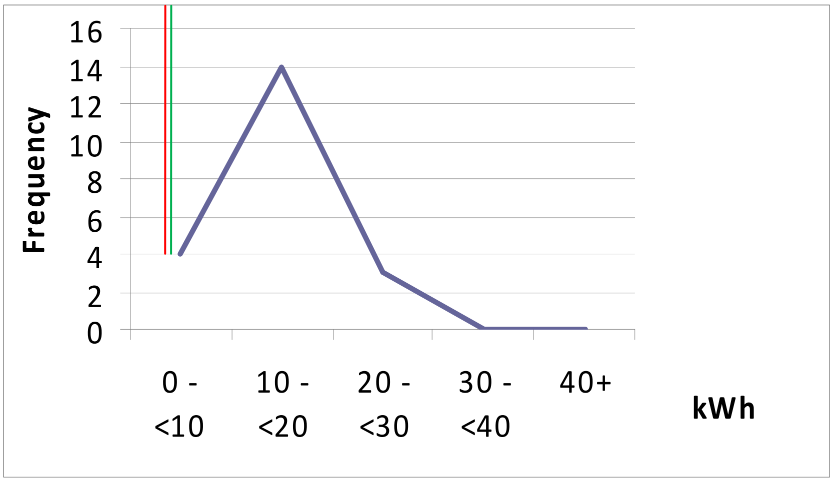
EV battery capacity will be 23.2 kWh on average.
Most FEV batteries have capacities between 10 to 20 and 20 to 30 kWh. The median (green) is at 24 kWh, the arithmetic mean at 26.7 kWh; see Figure 14. Nevertheless, there is a significant share of cars with capacities between 30 and 40 kWh and even above. The BYD Auto e6 showcases by far the highest battery capacity (72 kWh).

**Figure 14 Distribution of FEV battery capacity in kWh with median (green) and arithmetic mean (red)**



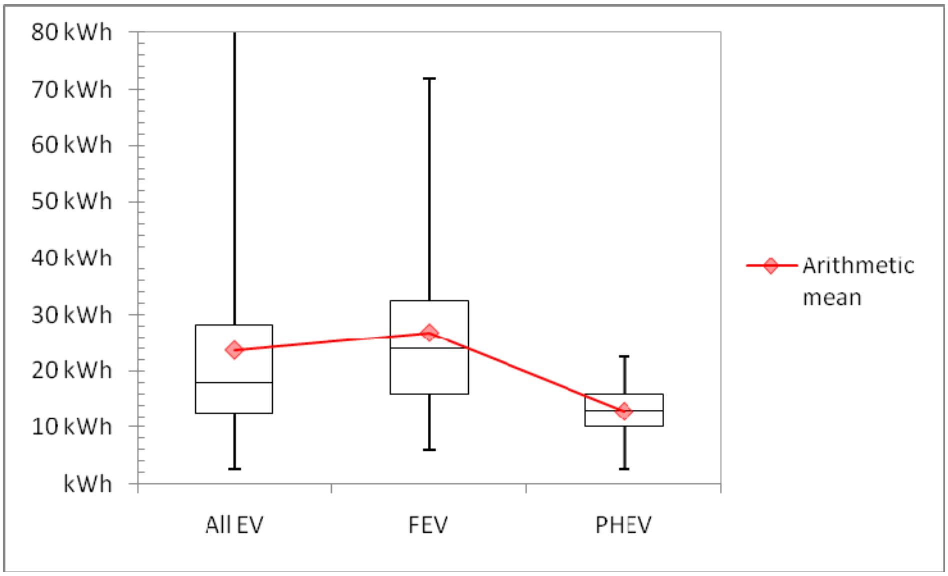

The vast majority of PHEV battery capacities can be found in the area of 10 to 20 kWh. There are no capacities exceeding 23 kWh. Median and arithmetic mean are almost equal (13 kWh and 12.8 kWh); see Figure 15.
There were only two EREVs with an indicated battery capacity, making a distribution curve rather meaningless.

**Figure 15 Distribution of PHEV battery capacity in kWh with median (green) and arithmetic mean (red)**



The overall battery capacity for all Electric Vehicles is 23.6 kWh, slightly less than 26.7 kWh for FEV only and notably more than 12.8 for PHEVs only. Median calculation shows a more balanced image, however with the same trend (EV 18 kWh, FEV 24 kWh, PHEV 13 kWh), see Figure 16.

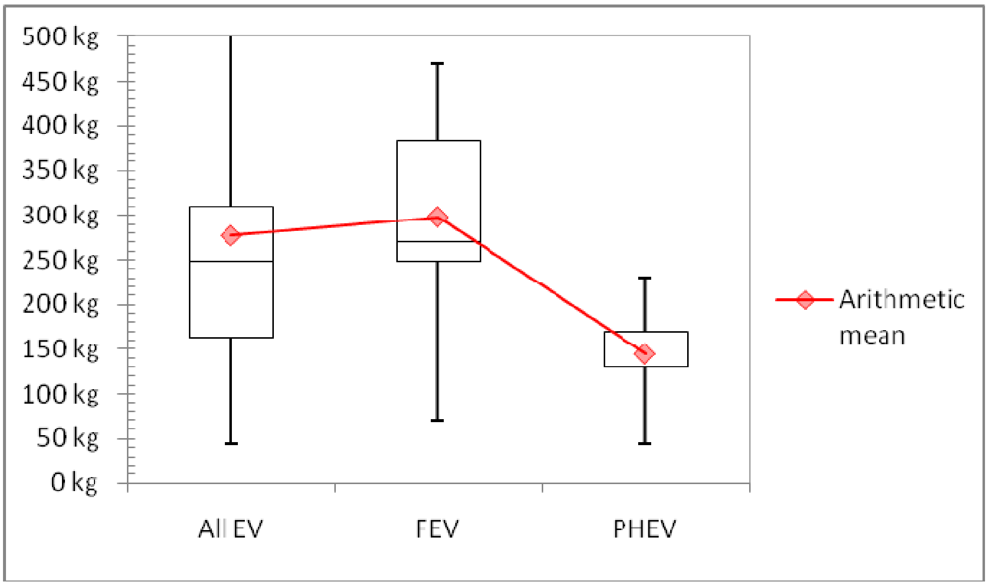
**Figure 16 Battery capacity: whiskers show the range, bars show the 25-75% distribution, centre line is the median value and red dot is the mean**




The usable energy of an EV is actually lower than the battery capacity (especially for FEV), depending also on outside temperatures, charging patterns and use. Thus, battery capacities will remain relatively confined, limiting EV applications in the near-term future.

Average battery mass for EVs is 278 kg (median at 249 kg). Looking at FEVs, battery mass is considerably higher at 299 kg (median at 270 kg), whereas PHEV batteries weigh 145 kg (median at 155 kg), see Figure 17.

Figure 17 Battery mass: whiskers show the range, bars show the 25-75% distribution, centre line is the median value and red dot is the mean




A wide range of different battery technologies can be observed:

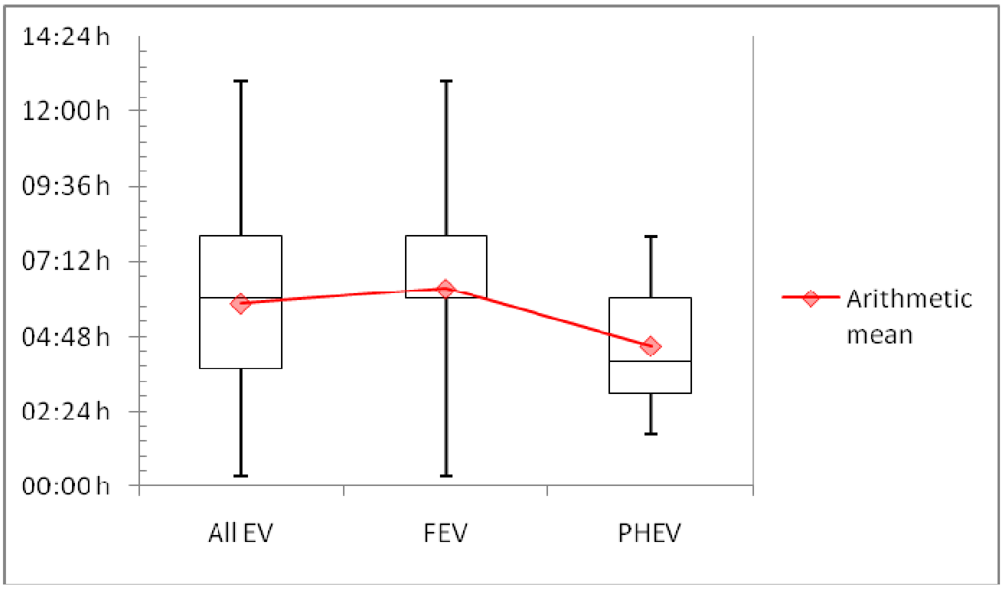
- Lead-acid.
- Lithium-ion phosphate.
- Lithium-ion polymer.
- Lithium-ion, ferric phosphate.
- Lithium-ion, manganese spinel.
- Lithium-ion, nickel-cobalt-aluminum (NCA).
- Metal-air.
- Redox (reduction-oxidation) flow.

Nevertheless, there is a very strong correlation between battery weight and battery capacity. The correlation coefficient is at 0.90, implying that more battery capacity necessitates more battery weight for the average battery. This does not preclude any significant advances in battery technology, but shows that physical limitations prevail.

The average charging time for a PHEV amounts to 4:30 h and therewith, it is almost two hours shorter than the average FEV charging time of 6:20 h. For all EVs, the average charging time is 05:51. All medians show a very similar picture; see Figure 18.

The median overall EV charging time is 06:00 h.

**Figure 18** **Charging time: whiskers show the range, bars show the 25-75% distribution, centre line is the median value and red dot is the mean**




### 2.4.6 Maximum speed

We found that the average top speed of all EVs is 159 km/h, 148 km/h for FEVs alone and 172 km/h for PHEVs. Only 23 cars out of 108 claimed a top speed above 180 km/h (21%). 46 cars claimed a top speed of 160 km/h or more (42.6%). That is, the top speed average is skewed due to high-value sports cars.

The median can be found at 160 (a number of cars had no available data at all, hence the median at 43%). The slowest car (Chrysler GEM) only had a maximum speed of 40 km/h, while the fastest car (NLV Quant) claims to drive up to 377 km/h; thus, the span amounts to astonishing 337 km/h.

For most EVs, the quoted top speed must not be mistaken for the cruise speed due to battery and motor overheating. The stated top speed can only be maintained for a short period of time, unless complex cooling systems are in place.

### 2.4.7 Acceleration

Acceleration from 0 to 100 km/h: The total EV average was 7.9 seconds; 8.5 seconds for FEV alone. Only five cars had slower acceleration values than 13 seconds (BYD Auto e6, Citroen C-Zero, BAIC BE701, Citroen C-Zero City Car, EWE-E3). 75% of all cars have an acceleration of 10 seconds or less.

### 2.4.8 Comparison EV - ICEV

In order to avoid the mistake of only comparing separate Electric Vehicles with general averages for ICE cars, we also tried to have a direct comparison of an EV model with its ICE equivalent. Six cars of different size and propulsion system were chosen and compared on the basis of the most significant specifications for both electric and non-Electric Vehicles.

**Table 2 Comparison ICE - EV**

| Name | Type of Vehicle | Size | Price (in €) | Vehicle mass (kg) | Battery capacity (KWh) | Maximum speed (in km/h) | Acceleration (0-100 km/h in s) | EDT driving range | ICE driving range | Number of seats | Horsepower (kw) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **BMW Mini One** | ICE | S | 14,600 | 1,135 | / | 186 | 10.5 | / | 741 | 4 | 72 |
| **BMW Mini-E** | FEV | S | N.a. | 1,465 | 35 | 153 | 8.5 | 175 | / | 2 | 150 |
| **2010 Ford Escape XLS** | ICE | L | 15,780 | 1,496 | / | N.a. | 8.9 | / | 585 | 5 | 128 |
| **Ford Escape EV** | PHEV | L | 20,000 | 1,769 | 10 | 164 | N.a. | 48 | N.a. | 5 | N.a. |
| **Volvo V70 2.4** | ICE | L | 44,300 | 1,570 | / | 205 | 10.5 | / | 778 | 5 | 103 |
| **Volvo V70 EV** | PHEV | L | 48,000 | 1,955 | 11.3 | 161 | 9 | 50 | 1,150 | 5 | 107 |
| **Renault Kangoo Authentique 1.6 8V 90** | ICE | ML | 14,990 | 1,412 | / | 159 | 15.8 | / | 741 | 5 | 64 |
| **Renault Kangoo Z.E. Concept** | FEV | M | N.a. | 1,520 | 24 | 130 | N.a. | 160 | / | 5 | 70 |
| **Toyota Prius ZHW3** | Hybrid | M | 25,450 | 1,445 | / | 180 | 10.4 | / | 1,125 | 5 | 100 |
| **Toyota Prius Plug-In** | PHEV | M | 34,750 | 1,380 | 5.2 | 170 | 10.9 | 23 | N.a. | 5 | 82 |
| **Ford Focus 1.4** | ICE | S | 15,500 | 1,229 | / | 164 | 14.1 | / | 803 | 5 | 59 |
| **Ford Focus EV** | FEV | S | 28,500 | 1,552 | 23 | 100 | 8 | 160 | / | N.a. | 105 |

## Drive train configuration and vehicle size

In this sub-segment, out of the six cars, two are small, two medium and two large. Thus, there will be less data from small cars than in the general database which might bias the results slightly.
Among the cars, three are FEVs and three are PHEVs, none being an EREV. The two large vehicles are PHEVs, just as the general analysis would suggest, while the medium cars are both FEVs and PHEVs and the small cars FEVs only.

## Vehicle mass

Five out of the six vehicles are heavier than their ICE counterparts. Added weights range between 108 kg (Renault Kangoo) and 385 kg (Volvo V70). Only the Toyota Prius PHEV is lighter than the regular Prius (65 kg). This seems to indicate that FEVs and PHEVs both tend to be heavier than conventional ICE cars, suggesting that the fact that the data analysis showed no increase in vehicle weight is not linked to weight reductions in the specific cars, but rather to a dominance of small cars in the announcements.

## Price

In all of the cases where data exists, the EV is notably between € 4,220 and 13,000 more expensive than the ICE version of the car. This finding is absolutely in line with the general analysis.

### Range

The urban EDT ranges in the group go from 23 km for the Prius (explaining the low weight) to 175 km for the Mini E. PHEV ranges in the sub-sample are lower than FEV ranges and all ranges are limited to under 200 km, considerably lower than any of the ICE ranges. This supports the findings from the general analysis.

### Battery

Battery capacities are relatively low in the sub-sample. FEVs have higher battery capacities (max. 35 kWh for Mini E, min. 23 for Ford Focus) than PHEVs (max. 11.3 for Volvo V70, min. 5.1 for Prius). This supports the assessment from the general analysis that PHEVs have smaller batteries than FEVs.

### Maximum speed

All EVs in the sub-sample have significantly lower maximum speeds than their ICE counterpart (between 29 km/h and 80 km/h lower). FEVs are slower than PHEVs.

### Acceleration

In terms of acceleration, however, the EVs are faster in three cases (by 1.5 to 6.1 s), and only the Prius PHEV is negligibly slower. In four out of five cases, the engine performance is higher for the EV version, especially for the MINI and the Ford Focus. Again, the Toyota Prius is the exception (100 kW ICE – 82 kW PHEV).

In summary, within the crucial areas for future market penetration, the EV model almost always performs weaker against the ICE version. In particular, vehicle price is higher and range is lower for EVs – two essential purchase criteria.
As a consequence, the market penetration of EVs might remain lower as potential buyers could rather stick to the lower-priced ICE version with a better overall performance.

## 2.5 Non-passenger car vehicles

A number of FEVs and PHEVs are being developed in non-passenger car vehicle segments as well. This category includes light- and heavy-duty trucks and vans, but also scooters, motorcycles, and three-wheel vehicles, as well as golf carts and recreational vehicles. Uses vary from load hauling to shopping and recreational activities.

The data we analysed for non-passenger car vehicles originates from 32 different non-passenger car vehicles by 24 different predominantly small manufacturers. Half of the companies are registered in the USA (mainly California and Oregon), the other half in Europe (mainly UK, Germany, Italy). Piaggio and KTM are the most known and established firms, the former being the European market leader for scooters. All of the vehicles are either already available or will be released during 2010, almost exclusively on European and North American markets. 87.5% of the vehicles are FEVs, 12.5% PHEVs. We did not investigate electric models destined exclusively for Far-Eastern markets.

**Table 3** **Non-passenger car vehicles**

| | | |
|---|---|---|
| Aptera Motors Aptera 2e three-wheel | Mavizen TTX02 two-wheel | Smith Edison |
| Aptera Motors Aptera 2h three-wheel | Mega Van | Smith Newton (12t) |
| Arcimoto Pulse Electric three-wheel | Mission Motors Mission One two-wheel | Smith Newton (7,5t +10t) |
| Brammo Enertia two-wheel | Modec | TTW One three-wheel |
| City Bike Gocyle | Myers Motors Duo three-wheel | Ultra Motor A2B Hybrid |
| Electric Motorsport Electric GPR-S two-wheel | Myers Motors NmG three-wheel | Ultra Motor A2B Metro |
| E-Motorbike GRACE | Persu Mobility Persu Hybrid three-wheel two-seats | Vectrix VX-1 two-wheel |
| Eped Sport/City | Persu Mobility Persu Hybrid three-wheel two-seats | Xtreme Green Products X Rider |
| Green Vehicles Triac three-wheel | PG-Bike 'Black Book' | Zero Motorcycles Zero S two-wheel |
| KTM Enduro | Piaggio MP3 Hybrid three-wheel | Zero Motorcycles Zero X two-wheel |
| KTM Supermoto | Quantya Track & Strada two-wheel | |

Generally, the vehicles are very heterogeneous and can be subdivided into several subgroups: city cruisers, e-scooters, racing and off-road motorbikes (even participating in international contests), city bikes ('Pedelecs'), trucks and vans. Up to two passengers can travel on the vehicles, of which most are powered by lithium-ion batteries. Price and weight vary broadly between € 1,700 and 50,000, and respectively 16.2 and 4,210 kg; the majority of the EDT ranges are between 20 and 160 km. The further specifications also depend largely on the type and use of the vehicle (i.e., the subgroup) and need to be compared more profoundly to receive meaningful results.

At first glance, though, we find that two- and three-wheelers come usually with a full electric configuration and a relatively low range. Vans and trucks, in comparison, showcase higher ranges (even exceeding 200 km), but lower maximum speeds than the city or racing motorbikes.

The larger or faster a vehicle is, the more expensive it gets (i.e., racing bikes and vans). Besides, the city bikes are significantly more expensive than normal bicycles are today, with prices between € 1,700 and 4,200. They also have the – comparatively – shortest ranges and lowest battery capacities. A peculiarity is the E-bicycle GRACE that does not rank among the Pedelecs, but is an accredited motor vehicle for road traffic – the first of its kind.

As many of the vehicles are not produced in large quantities, individual modifications are often possible (e.g., different sizes of the vans). Furthermore, most of them cannot be bought in ordinary vehicle shops, but have to be exclusively ordered at the manufacturer or in rare specialist shops.

While there clearly is a trend towards electric bicycles and two- and three-wheelers in Asian markets, the uptake is much more sluggish in European and North American markets at this time. In the Netherlands, however, electric bikes account for a 10% market share[8] with an upward trend. Electric trucks and vans currently gain media attention, importance and market shares, especially for postal and messenger services and other company fleets (see Section 3.5), but the cost disadvantage keeps them in a niche existence. Ultimately, it could be possible that this market segment even has a higher potential than the passenger car market, because in the case of non-passenger car EVs, driving ranges do not necessarily have to be as significant and the required ranges might be easier to anticipate by the vehicle owners.

## 2.6 Summary

Our research provided insight into the Electric Vehicles of both today and tomorrow, i.e., Plug-in Hybrid Electric Vehicles (PHEV), Full Electric Vehicles (FEV) and Electric Vehicles with Range Extender (EREV). This review did not include mild hybrids and regular hybrid cars without plug-in capability.

- Just as in today's car markets, the majority of Electric Vehicles sold in the future will be small and mid-sized cars. FEV concepts dominate in the small car segment, while PHEVs and EVs with Range Extender (EREV) are more prominent for larger cars.
- PHEVs become more dominant compared to FEVs over time; nevertheless, FEVs account for a higher total share of the market. EREVs are only a secondary element.
- The average Electric Vehicle (EV) will be slightly heavier than today's European cars, but significantly lighter than today's US cars. Given the high additional weight penalty by the batteries, this indicates a shift towards small and medium cars. We cannot confirm a fundamental shift towards light weight composite materials as has been observed in aircraft design – see the upcoming Boeing B787 Dreamliner and the Airbus A350.
- FEVs and PHEVs will both be significantly more expensive than today's cars. The average EV will cost more than twice as much as today's cars.
- FEV EDT ranges are on average about three times higher than PHEV ranges. Based on EDT urban drive ranges, FEVs are primarily in the 100 km+ ranges (89%), PHEVs in the ranges below 100 km (84%).
- FEVs' main use is urban traffic and commuting, not inter-city travel.
- In terms of acceleration from 0 to 100 km/h, EVs will not differ significantly from today's cars. Although indicated maximum speeds do not differ significantly from today's ICE cars, top speeds can only be maintained for a very short period of time by EVs due to battery and motor overheating.
- In comparison with its respective ICE version, the EV model almost always performs weaker. In particular, vehicle price and mass – two essential purchase criteria – are significantly higher for the EV. As a consequence, the market penetration of EVs might remain low as potential buyers could rather stick to the lower-priced ICE version with a better overall performance.
- Near-term future non-passenger car Electric Vehicles are very heterogeneous and can be subdivided into several subgroups: city cruisers, racing and off-road motorbikes, city bikes ('Pedelecs'), trucks and vans.

[8] http://www.bike-eu.com/news/4030/in-holland-one-out-of-eight-bikes-is-electric.html.

- As many of these vehicles are not produced in large quantities, individual modifications are often possible.
- While there clearly is a trend towards electric bicycles and two- and three-wheelers in Asian markets, this does not necessarily apply for European and North American markets at the time (with the exception of electric bicycles in the Netherlands). Electric trucks and vans currently gain media attention, importance and market shares, especially for postal and messenger services and other company fleets, but the cost disadvantage keeps them in a niche existence.

# 3 Government and industry investment decisions

## 3.1 Introduction

In this chapter, we will summarise government and industry investments and commitments into electric mobility both in Europe and globally. The first section (Section 3.2) focuses on government and industry investments, followed by an overview of government development plans and programmes (Sections 3.3 and 3.4). A next section summarises existing tax incentives and subsidy schemes in several countries (Section 3.6). Information on non-car industry investment decisions (Section 3.5) form the next section followed a brief outline of industry research activities (Section 3.7). The chapter concludes with a summary of the main findings (Section 3.8).

## 3.2 Government and industry investments

Governments in many countries support the introduction with investments in research and implementation.

Past, present and future government and industry investment programs into EV technology predominately began in 2008 and 2009. The overall sum of € 21.6 billion over a period from 2008 to 2011 is divided almost identically between the USA (€ 8.6 billion) and the EU (€ 8.5 billion), with a majority of the funding already having been distributed. East Asia accounts for approx. one fifth of the share (€ 4.6 billion or 21%).
The average spending is € 540.0 million, whereas median spending is only € 256 million. This deviation can be explained by the fact that a few countries have invested large sums, stemming mainly from national economic stimulus packages, which skew the arithmetic up.

Gathering and collecting the data has been quite difficult as for example the companies' and industry's investments in electric mobility partially stem from national economic stimulus programs, which has not always been separately indicated in our sources. Hence, a few sums might potentially overlap.

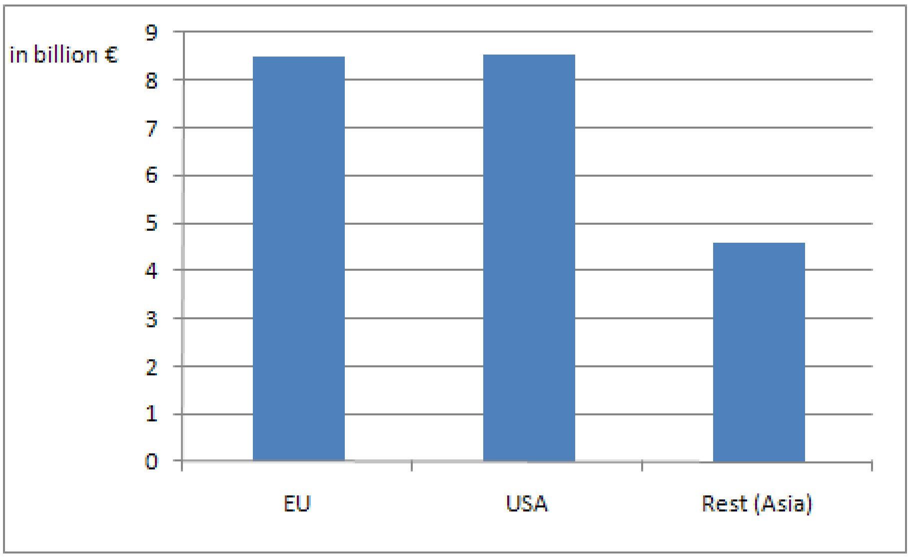
Most programs and spending are focused on the near term and lack long term funding. It is important to notice the coincidence of EV programs and stimulus spending in the 2008/2009 financial and economic crisis. In the following austerity mood, further continued spending on EV technology is less likely which fuels substantiated fears in the research community that research and development will be curtailed significantly after 2012.[9] This trend, combined with possibly modest progress in market penetration up to then and slow technological progress might jeopardise the development of EVs and lead to a knock-out for EVs not only in Europe, but globally.

[9] Such as Proposition 23 in California aiming to end spending on green technologies, to be voted by the public in November 2010.

Table 4 Government and industry investments

| Country | Sum (in mil. €) | Year (start) | Source |
|---|---|---|---|
| Belgium | 2.0 | In place | Transport Minister in Wallonia |
| Denmark | 100.0 | 2009 | DONG and Better Place |
| | 5.6 | 2009 | EDISON R&D project |
| | 4.0 | 2009 | Danish Energy Authorities |
| France | 400.0 | 2008 | France government |
| | 1,500.0 | 2010 | France government |
| | 1,494.0 | 2009 | AESC (with Japan) |
| Germany | 500.0 | 2009 | German government |
| | 60.0 | 2008 | German government |
| | 360.0 | 2008 | German government |
| | 2,000.0 | 2010+ | Daimler |
| | 77.0 | 2008 | Li-Tec |
| | 385.0 | 2011 | SB LiMotive (with South Korea) |
| Sweden | 1.5 | In place | Swedish government |
| UK | 440.4 | Committed | British government |
| | 21.9 | Committed | British government |
| | 60.0 | Committed | City of London |
| Netherlands | 3.0 | 2010 | City of Amsterdam |
| | 65.0 | 2010 | Dutch Cabinet |
| EU | 1,000.0 | 2009 | European Green Cars initiative |
| USA | 3,275.6 | 2009 | United States Department of Energy |
| | 2,197.0 | 2009 | US government (Car Exchange Program) |
| | 73.1 | 2009 | US government (Car Exchange Program) |
| | 0.04 | 2009 | California, US (solar charging stations) |
| | 1,025.3 | 2010 | US Department of Energy to Nissan |
| | 0.3 | 2010 | California, US (Bay Area Air Quality Management) |
| | 462.0 | 2009 | JCI-Saft (with France) |
| | 713.0 | 2009 | Ener1 |
| | 807.0 | 2009 | A123 |
| Japan | 85.0 | 2009 | Panasonic EV Energy |
| | 144.0 | 2008 | Lithium Energy Japan |
| | 202.0 | 2009 | Blue Energy |
| | 214.0 | 2010 | Toshiba |
| | 242.0 | 2009 | Sanyo |
| | 351.0 | 2010 | Hitachi Vehicle Energy |
| | 769.0 | 2009 | Sony |
| South Korea | 87.0 | 2009 | SK Energy |
| | 846.0 | 2009 | LG Chem |
| | 269.0 | 2009 | Dow/Kokam |
| China | 1,357.0 | 2009 | China, State Council |
| **Total** | **21,598.7** | | |
| **EU** | **8,479.4** | | |
| **USA** | **8,553.3** | | |
| **Rest (Asia)** | **4,566.0** | | |
| **Average sum** | **540** | | |
| **Median sum** | **255.5** | | |

Figure 19 Sum of investments per region




## 3.3 Government development plans

A large number of governments have made announcements as to how many Electric Vehicles they aim to have on the road by certain dates.

Concrete announcements and estimations that have been made recently suggest that within the next five years, i.e., until 2015, more than five million new EVs could hit the road globally, the majority of these in Europe, see Table 5. Afterwards, the number of new EVs (2016+) is announced to increase by a further 1.7 million. By 2020, total announced cars sum up to 7.2 million cars, see Figure 20. The vast majority of these cars (5.1 million, i.e., 71%) will probably be driven in the EU, while the USA accounts for almost one seventh (1 million; i.e., 14%). Approximately 1.4 million can be produced or will be driven in the rest of the world, which means Asia (East Asia and Israel). Especially in Japan and South Korea, the numbers do not figure as announcements, but rather as production capacities. This suggests that Europe will be by far the most relevant market for EVs in the world.

Still, this analysis captures only one aspect of future market development and does not constitute a market forecast. Many other aspects are relevant for EV penetration besides the sheer commitment in numbers. Among them are: willingness to pay and existence of a customer base, access to charging infrastructure and other influences.

**Figure 20 'Promised' future cars by region in million vehicles (total 7.2 million vehicles)**

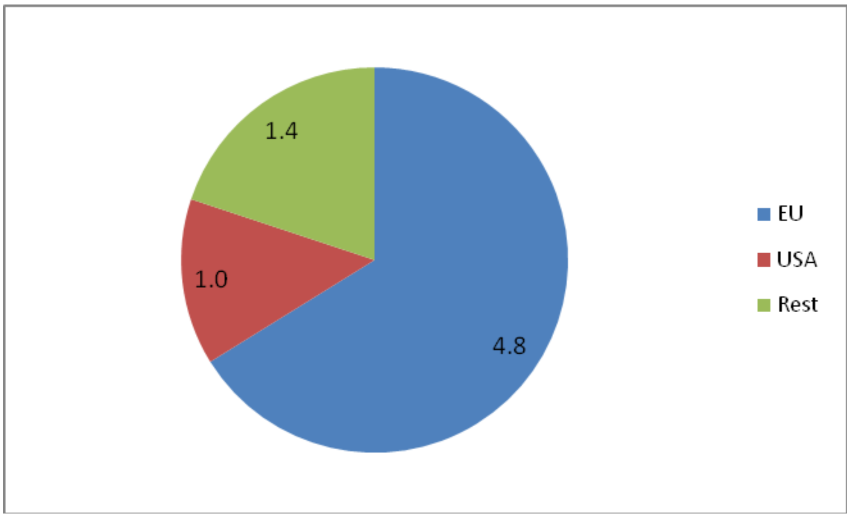



**Table 5 Announcements concerning future EVs and PHEVs**

| Country | Number of cars | Year | Parties involved | Type | National fleet | Year | Share of EVs (in %) |
|---|---|---|---|---|---|---|---|
| Denmark | 100,000 | 2011 | BetterPlace, DONG | FEV | 2,120,322 | 2010 | 4.72 |
| France | 5,000 | 2008 | French government (Hybrid and FEV) | Hybrid and FEV | 30,850,000 | 2008 | 6.48 |
| | 500 | 2010 | PSA Peugeot Citroen | Probably FEV | | | |
| | 5,000 | 2011 | PSA Peugeot Citroen | Probably FEV | | | |
| | 10,000 | 2012 | French Post | Probably PHEV | | | |
| | 100,000 | 2015 | French government, Renault | Probably FEV | | | |
| | 420,000 | 2015 | AESC capacities (with Japan) | Both | | | |
| | 2,000,000 | 2020 | French government | | | | |
| Germany | 25 | 2010 | Municipality of Cologne, Ford, RheinEnergie | FEV | 41,183,600 | 2008 | 2.43 |
| | 40,000 | 2015 | Lic-TecSB capacities | Both | | | |
| | 149,000 | 2015 | LiMotive capacities (with South Korea) | Both | | | |
| | 250,000 | 2020 | Municipality of Cologne, Cologne Region, Ford, RheinEnergie | | | | |
| | 1,000,000 | 2020 | German government, Volkswagen, Daimler, Tesla Motors, RWE, etc. | | | | |
| Spain | 2,000 | 2009 | Spain's Ministry of Industry, MOVELE project | Both | 22,145,364 | 2008 | 4.52 |
| | 1,000,000 | 2014 | Spanish government (Hybrid and FEV) | Both | | | |
| Israel | 30,000 | 2010 | Israeli government (30,000 cars p.a.) | FEV | 1,875,765 | 2009 | 1.60 p.a. |
| Ireland | 250,000 | 2020 | Irish government | | 1,924,281 | 2008 | 13.00 |
| UK | 100 | 2010 | British government | | 28,459,044 | 2009 | 0.35 |
| | 100,000 | 2015 | City of London, several companies | | | | |
| Netherlands | 200,000 | 2020 | Dutch government | Both | 7,542,331 | 2009 | 2.65 |
| EU | 100,000 | 2010 | Mitsubishi, Peugeot, Citroen | | 223,590,513 | 2008 | 0.04 |

| Country | Number of cars | Year | Parties involved | Type | National fleet | Year | Share of EVs (in %) |
|---|---|---|---|---|---|---|---|
| USA | 4,700 | 2010 | Nissan, eTec | FEV | 137,079,843 | 2008 | 0.73 |
| | 140,000 | 2015 | JCI Saft capacities (with France) | | | | |
| | 195,000 | 2015 | Ener1 capacities | Hybrid vans | | | |
| | 294,000 | 2015 | A123 capacities | Both | | | |
| | 1,000,000 | 2015 | Government of the USA | FEV | | | |
| Japan | 9,000 | 2015 | Panasonic EV Energy capacities | Both | 57,682,000 | 2008 | 0.93 |
| | 55,000 | 2015 | Lithium Energy Japan capacities | Both, mainly PHEV | | | |
| | 30,000 | 2015 | Blue Energy capacities | Both | | | |
| | 60,000 | 2015 | Toshiba capacities | Focus on HEV | | | |
| | 110,000 | 2015 | Sanyo capacities | Both | | | |
| | 70,000 | 2015 | Hitachi Vehicle Energy capacities | | | | |
| | 200,000 | 2015 | Sony capacities | PHEV | | | |
| South Korea | 25,000 | 2015 | SK Energy capacities | | 11,417,807 | 2006 | 4.29 |
| | 405,000 | 2015 | LG Chem capacities | Hybrid | | | |
| | 60,000 | 2015 | Dow/Kokam capacities | Both | | | |
| China | 48 | 2009 | F3DM Plug-in Hybrids to government and corporate customers | Both | 24,380,000 | 2008 | 1.54 |
| | 100 | 2010 | Fleet of 100 taxis for BYD's hometown of Shenzhen, China | PHEV | | | |
| | 15,000 | 2010 | Beijing's municipal commission of reform and development | FEV | | | |
| | 360,000 | 2015 | Chine capacities | Both | | | |
| **All** | **7,181,248** | | | | | | |
| **EU** | **4,752,100** | | | | **223,590,513** | **2008** | **2.13** |
| **USA** | **1,000,000** | | | | **137,079,843** | **2008** | **0.73** |
| **Rest** | **1,429,148** | | | | | | |
| **Up to 2015** | **5,094,473** | | | | | | |

Most of the announcements did not specify whether FEVs or PHEVs were to be introduced. In most cases, both car types will probably be delivered. Some battery suppliers concentrate on a battery type suitable only for one car type as indicated in the table. However, it would be too fast to draw any conclusions from the data, as the information on the type is only marginal and not always confirmed.

Again, the estimated number of EVs might be different in reality and partly overlap with government announcements that refer in their estimations to industry’s production capacities. Government target announcement and estimations cannot be exact, but are rather national goals of the respective national development plans for electric mobility. In particular, estimates for the EV potential which are based on lithium reserves show that the overall number of cars is limited (FISI, 2009).

Global sales forecasts for conventional cars in 2010 alone amount to 53 million passenger cars (GOMES, 2010).

Based on the above numbers, market penetration will remain fairly low in the short-term future.

## 3.4 Government development programmes

Governments have introduced a wide array of programmes and structures that foster the introduction of Electric Vehicles in their respective markets.

The information from the following sources has also been accounted for in Table 4 and Table 5.

**Table 6** **Electric mobility development plans/programs**

| Country | Electric mobility development plans/programs | Source |
|---|---|---|
| **Austria** | Different electric mobility pilot projects enable access to the so-called 'mobility card' car leasing and maintenance and free charging for individuals using these cars | KLFO, 2008 |
| **Belgium** | The Transport Minister for Wallonia made available € 2 million for municipalities planning to buy Electric Vehicles (cars, bicycles and vans) | ACEA, 2009 |
| **Denmark** | EVs can park for free in Denmark | AVERE, 2007 |
| | In collaboration with the US company Better Place the Danish energy corporation DONG plans to invest € 100 million ($ 135 million) to build up infrastructure in the country for electric cars. Charging the battery of an Electric Vehicle should become as fast as filling up a tank of gas. The overall number of EVs in Denmark is estimated to increase to up to 100,000 within two years | DEWE, 2009 |
| | An international consortium carries out the EDISON R&D project on intelligent integration of EVs and their optimal interaction with wind power, being budgeted with € 5.6 million | XU, 2009 |
| | Finally, a € 4 million EV fleet trial program is funded by the Danish Energy Authorities | XU, 2009 |
| **France** | 5,000 Hybrid and fully Electric Vehicles were ordered in the course of a 2008 public procurement programme | AVERE, 2007 |
| | The French government plans to set-up a public-private procurement plan that coordinates the demand of EVs for public and private use (e.g., French post planning to procure 10,000 Electric Vehicles by 2012) | Chatel and Jouanno, 2009 |
| **Germany** | The development of a common plug standard (400 V, 63 A, European wired applicable) has been announced by major energy and automotive companies in March 2009 | Schraven, 2009 |
| | At the 'Nationale Strategiekonferenz Elektromobilität' in November 2008 in Berlin, the German government announced a national target of 1 million Electric Vehicles by 2020 | BUND, 2008 |
| **Greece** | Electric and hybrid vehicles are excluded from circulation restriction in metropolitan areas, where these are applied | HIEV, 2009 |
| **Ireland** | The government aims for 10% of the national fleet (250,000 cars and vans) to be electric. The first significant number shall hit the road within the next two years. It has signed a deal with Renault-Nissan accordingly. The government hopes that by boosting renewable energies, like wind, and improving the electricity grid, the introduction of electric cars will lead to a significant drop in carbon emissions in the transport sector | RTÉ, 2009 |

| Country | Electric mobility development plans/programs | Source |
|---|---|---|
| **Italy** | The region of Lombardy is to install 270 EV charging points in two major cities as it prepares to test some of the first EVs to arrive in the country. The pilot project 'E-Moving' will start in June in the two cities of Milan and Brescia and is scheduled for one year. The two cities are to be the first in Italy to boast a complete charging structure for EVs, allowing them to participate in the one-year trial of commercial and personal EVs. French carmaker Renault and Italian utility firm A2A will make 60 EVs (including the Renault Fluence Z.E. and the Renault Kangoo Z.E.) available to rent for costumers on a monthly basis at a rate comparable to a similar diesel model. A 'point-to-point' charging network across the main cities of Lombardy shall be installed in the near future | IND, 2010; EDM, 2010 |
| | Car manufacturer Daimler and Enel, Italy's largest power company launched the project 'e-mobility Italy' which will test more than 100 Smart and Mercedes EVs under real-life circumstances in Rome, Milan and Pisa in 2010. Enel will be responsible for developing and setting up over 400 charging stations in the three cities especially for this purpose | DAIM, 2008 |
| | An Italian private equity manager plans to build electric cars in Sicily when Fiat stops producing cars at a plant on the island next year. The € 900 m ($1.2bn) proposal aims to combine Italian money and design flair with Indian technology to produce cars as well as a network of recharging facilities powered by the island's most obvious and underused energy source – the sun. The Indian car manufacturer Reva might produce its next generation of EVs for the European market there | FTIME, 2010 |
| **Nether-lands** | Dutch companies will be financially incentivised to invest in the sector. Both national and local governments will be doing their bits by electrifying their own fleets as soon as is possible. A total of € 10 million worth of grants will also be available for practical testing via tendering schemes. Grid operators have agreed to build at least 10,000 charging stations around the country by about 2012 | MINDS, 2009 |
| **Norway** | Drivers of EVs are allowed to use bus-lanes and are exempted from congestion charges and public parking fees. Norway has enabled the free use of ferryboats connecting national roads since 2009 | OEN, 2009 |
| **Portugal** | Portugal plans to have 320 charging stations by 2010 and 1,300 by 2011 | GCC, 2008 |
| **Spain** | One measure to achieve Spain's goal to have one million electric or hybrid cars on the roads by 2014 is to provide consumers who buy an electric car in Spain with a rebate of 15% off the price of the vehicle | BUGR, 2008; BERR, 2008a |
| **UK** | Alternatively fuelled' vehicles, including EVs, are exempt from paying the central London congestion charge (£ 8 p.d.), while future revisions of the scheme most likely will even increase the charges for high emission vehicles | KING, 2008 |
| | London's Mayor, a strong advocate of EVs, attempts to make London the European capital for EVs and therefore wants to deliver 25,000 charging points in the city's workplaces, retail outlets, streets, public and station car parks by 2015 (est. cost: € 60 million) | WWF, 2008 |
| | Employers and company car drivers are encouraged to choose a low carbon vehicle through the company car tax scheme's financial incentives | EDIE, 2009 |
| | In the London Borough of Richmond and Manchester, the costs of parking permits depend on the vehicle's emission level EVs being exempted from all parking fees | ETEC, 2007 |

| Country | Electric mobility development plans/programs | Source |
| --- | --- | --- |
| **EU** | The European Green Cars initiative (launched in July 2009) is included in the Commission's recovery package as one of the three private and public partnerships (PPP).<br>It includes three streams of action:<br>1 R&D, mainly through FP7 grants for research on greening road transport (budget: € 1 billion, of which € 500 million from the Commission, matched by € 500 million from industry and Member States).<br>2 Support to industrial innovation through EIB loans (budget: € 4 billion in addition to existing loans).<br>3 Demand side measures and public procurement, such as reduction of circulation and registration taxes for low-$CO_2$ cars | |
| **USA** | The first zero-emission vehicle (ZEV) mandate was introduced by the California Air Resources Board (CARB) in 1990 as part of the Low Emission Vehicle Program. The ZEV-mandate – aimed at enabling a large scale introduction of ZEVs - initially required that 10% of new cars sold in California to be zero-emissions vehicles by 2003, but the timeframe was abandoned as it became apparent that the technology was not mature enough to compete in the market. Nevertheless, the ZEV mandate has been partly successful in the past and lead to the development and low-scale deployment of several FEV | CARB, 2008; ITS, 2004; MIT, 2007; WWF, 2008 |
| | Today, car manufacturers are required to introduce ZEVs by 2014, independent of their fleet emission levels within the zero-emission mandate, but the number of required pure-ZEVs has been significantly reduced compared to earlier regulations. Assumedly, further U.S.-states will adopt comparable regulations in the near future | UCS, 2008; Roland Berger, 2008 |
| | The U.S. Government focuses on supporting public-private partnerships between US OEMs, government agencies, national laboratories, and developers of low-carbon technologies. ‘Partnership for Next Generation Vehicles’ – the first program - started in 1993 and has been replaced by the Freedom CAR program in 2002. In California and Virginia, EV drivers are even offered access to high-occupancy lanes regardless of the number of passengers. Generally, the use and development of PHEVs is encouraged by further state and local policies | MIT, 2007; ABERN, 2006; EPA, 2007 |
| | Federal fleets are required to select the most fuel-efficient vehicles, in some states even hybrid vehicles. A $ 2.5 billion programme for the development of electric-powered cars and the improvement of battery technology has been released by the States Department of Energy. Another $ 2 billion programme for battery development has recently been set-up as part of the economic stimulus programme enacted by the U.S. Congress | ABERN. 2006; TNYT, 2009; WBCSD, 2009; FAST, 2009 |
| | In cooperation with Better Place (mentioned above) and the Renault-Nissan group, the government of Hawaii will transform the state’s transportation infrastructure to renewable sources of energy: About 100,000 charging stations ($1 Billion) for EVs are to be built; renewable energy sources should meet 70% of the state's needs by 2030 | |

| Country | Electric mobility development plans/programs | Source |
|---|---|---|
| **Australia** | Better Place in collaboration with AGL Energy and Macquarie under the authority of the government will construct an EV network capable of supporting the switch of Australia's 15 million gas cars ZEVs (budget of $ 25 million). The first city-wide roll-out of EV infrastructure will take place in Canberra. The construction of charge spots and battery swap stations will begin in 2011, the support for customers in 2012 | |
| **China** | Gasoline two-wheelers were banned from the city-centres, which could also happen to conventional passenger cars as soon as Electric Vehicles become widely available, according to Roland Berger (2008) | Roland Berger, 2008 |
| | Additionally, the state electricity grid started the set up of electric charging stations in Beijing, Shanghai and Tianjin | TNYT, 2009 |
| **Israel** | In collaboration with Better Place, Israel will start the large-scale introduction of EVs in 2011/2012. In the course of the Better Place project, about 500,000 charging and several battery exchange stations are planned to be established all over the country until 2012. All in all, a long-term annual purchase of 30,000 vehicles is expected | SYRO, 2008 |

The type of the separate development plans and programs for electric mobility vary broadly on a worldwide, but also on a European level.

In many countries, EV infrastructure – charging stations, standard plugs, etc. - will be developed and installed, often in collaboration with private companies as a public private partnership (PPP). At this point, Better Place is the only non-car manufacturer that operates on a global scale. Several national, regional and city governments announce target numbers of future car market penetration by EVs. In some countries, drivers of EVs even possess additional rights in road traffic (free parking, no circulation restrictions, etc.).Concrete numbers or sums spent on EV-technology development are predominately limited to the main players, i.e., USA, Germany, UK, France, and Spain.

On an European level, the European Green Cars initiative stands out as a high-budget initiative involving virtually all subtopics and areas of electric mobility.

In addition, the Communication from the European Commission of 16 July 2008 on Public procurement for a better environment (Green Public Procurement) highlights the Commission's aim to encourage green public procurement as an effective instrument to promote environmentally-friendly products and services and to encourage eco-innovation, thus contributing to sustainable development. This Communication covers all public procurement procedures, both above and below the thresholds defined by European public procurement Directives (e.g., 2004/17/EC and 2004/18/EC). The Commission has identified ten priority sectors for GPP, among which can be found transport and energy as the sectors strongly related to electric mobility.
According to the Directive, governments have to take into consideration the full life cycle costs of vehicles, putting EVs – assessed as $CO_2$-neutral – into a better position compared to conventional ICE, potentially compensating the higher price.

In addition to that, the legislation on $CO_2$ emissions of passenger cars has been adopted in form of Regulation (EC) No 443/2009, which includes the following key elements:

- "Limit value curve: the fleet average to be achieved by all cars registered in the EU is 130 grams per kilometre (g/km). A so-called limit value curve implies that heavier cars are allowed higher emissions than lighter cars while preserving the overall fleet average.
- Phasing-in of requirements: in 2012, 65% of each manufacturer's newly registered cars must comply on average with the limit value curve set by the legislation. This will rise to 75% in 2013, 80% in 2014 and 100% from 2015 onwards.
- Lower penalty payments for small excess emissions until 2018: If the average $CO_2$ emissions of a manufacturer's fleet exceed its limit value in any year from 2012, the manufacturer has to pay an excess emissions premium for each car registered. This premium amounts to € 5 for the first g/km of exceedance, € 15 for the second g/km, € 25 for the third g/km, and € 95 for each subsequent g/km. From 2019, already the first g/km of exceedance will cost € 95.
- Long-term target: a target of 95g/km is specified for the year 2020. The modalities for reaching this target and the aspects of its implementation including the excess emissions premium will have to be defined in a review to be completed no later than the beginning of 2013.
- Eco-innovations: because the test procedure used for vehicle type approval is outdated, certain innovative technologies cannot demonstrate their $CO_2$-reducing effects under the type approval test. As an interim procedure until the test procedure is reviewed by 2014, manufacturers can be granted a maximum of 7g/km of emission credits on average for their fleet if they equip vehicles with innovative technologies, based on independently verified data."[10]
- Moreover, EVs are counted as zero emission vehicles, i.e., the emissions from energy production are waived.
- For low emissions vehicles, i.e., vehicles with emissions below 50g $CO_2$/km, so-called super-credits apply: in 2012-13 each such car counts with the factor 3.5, in 2014 with 2.5, in 2015 with 1.5.

Especially these last two assumptions encourage manufacturers to sell a certain amount of EVs from 2012 on and enter them into their accountable fleet.

This regulation might also favour the uptake of Electric Vehicles as $CO_2$ emission targets are being tightened over time and thus new innovations to limit emissions must be found by car manufacturers.

The US provides the most massive amounts of subsidies for electric mobility – mainly as part of the national economic stimulus programme – but account only for approximately one fourth of the future announced EVs.

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10 http://ec.europa.eu/environment/air/transport/co2/co2_home.htm.

### 3.5 Non-car industry investment decisions

In addition to the above mentioned announcements by governments, several companies have declared an intention to electrify their fleet. These include:

- Postal services
  - The French post plans to procure 10,000 Electric Vehicles by 2012 (Chatel and Jouanno, 2008).
  - The United States Postal Service (USPS) is considering converting its 140,000 distributing long life vehicles fleet into all-Electric Vehicles with the support of Eckhaus Fleet, REVConversion and Fort Peck Tech Services.[11]
- Messenger services
  - The UK Electric Vehicle manufacturer Smith Electric Vehicles equips the fleets of many well-known messenger services, e.g.,[12]:
    - DHL, the global market leader of the international express and logistics industry, purchased the 9T Smith Newton as its first EV ever for use in its revolutionary consolidation centre (in April 2007).
    - Since September 2006, the express, mail and logistics operator TNT ordered over 100 7.5 tonne high performance electric Newton vehicles.
    - After a successful one-year trial of Smith EVs in its home shopping delivery applications in and around Central London, Sainsbury's plans to convert its whole online delivery fleet to EVs.
    - Having one of the largest commercial delivering fleets in Europe, Royal Mail has ordered both the Smith Edison and Newton higher function delivery vehicles to be deployed in London.
  - In the Netherlands, Urgenda, TNT, Eneco and Tendris launched a tender for 3,000 EVs in 2012. Together with the pioneering consortium partners ABN AMRO, Delta, Essent, Facilicom, the Municipality of Rotterdam, the Municipality of Leeuwarden, ING, JCDecaux, the Dutch Ministry of Housing, Spatial Planning and the Environment, the Dutch Ministry of Transport, Public Works and Water Management, NUON, Philips, Port of Rotterdam, the Province of Friesland and Triodos Bank almost 3,000 cars were ordered for the well-known messenger service TNT.[13]
- Taxi companies/associations
  - Better Place and Nihon Kotsu, Tokyo's largest taxi operator, will bring the world's first electric taxis with switchable batteries to Japan (was scheduled to begin in January 2010 and last 3-6 months, now postponed). A battery switch station will be installed in the Roppongi Hills area of Central Tokyo. The project receives funding from Japan's Ministry of Economy, Trade and Industry's Natural Resources and Energy Agency.[14]

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11 http://www.government-fleet.com/Message/Error.aspx?aspxerrorpath=/News/Story/2009/07/USPS-to-Go-Electric-with-Eckhaus-Fleet.aspx.

12 http://www.smithelectricvehicles.com/casestudies.asp.

13 http://corporateuk.eneco.nl/News_and_Media/pressreleases/Pages/Urgenda,TNT,EnecoandTendrislaunchatenderfor3000electricvehiclesinthreeyears.aspx.

14 http://www.betterplace.com/global-progress/japan/.

## 3.6 Tax incentives and subsidies

Table 7 summarises the tax incentives and subsidies for EV in the various EU Member States.

**Table 7** **$CO_2$ tax incentives/subsidies**

| Country | $CO_2$ tax incentives/subsidies | Source |
|---|---|---|
| **Austria** | Car consumers pay a one-time penalty (malus) of € 25 for each gram $CO_2$ emitted in excess of 180 g $CO_2$/km | ACEA, 2009 |
| | Purchasers of alternative fuel vehicles receive a one-time € 500 bonus | |
| **Belgium** | Consumers who purchase cars with emissions of less than 105 g $CO_2$/km receive a reduction of 15% of the purchase price up to a maximum of € 4,540 | ACEA, 2009 |
| | Consumers who purchase cars with emissions between 105 and 115 g $CO_2$/km receive a reduction of 3% of the purchase price up to a maximum of € 850 | |
| | Walloon region: A bonus-malus system pays consumers up to € 1,000 for cars below 105 g $CO_2$/km and charges a penalty of up to € 1,000 for cars emitting more than 195 g $CO_2$/km | |
| **Cyprus** | Consumers who purchase cars with emissions of less than 120 g $CO_2$/km receive a 30% reduction in registration tax | ACEA, 2009 |
| | Consumers who purchase cars with emissions of less than 150 g $CO_2$/km 15% reduction of the annual circulation tax | |
| | Consumers receive a discount of € 683 for purchases of new electric cars | |
| **Denmark** | All clean cars are freed of all taxes before 2025 (Considering the particularly high car registration tax of 180% and a VAT of 25%, the announced tax exemption represents a considerable subsidy for EVs) | AVERE, 2007 |
| **France** | France introduced a yearly eco-label on new vehicles with a cost-neutral bonus-malus system (tax deductions and tax penalties) which favours low-emission vehicles on the basis of the car's tank-to-wheel $CO_2$ emissions (since January 2008) | CLBZ, 2006 |
| | Consumers who purchase cars with emissions of less than 60 g $CO_2$/km receive a bonus of € 5,000 for new cars and new light commercial vehicles; since 2009, applicable until 2012 for the first 100,000 low carbon vehicles purchased | PDLR, 2009; Chatel and Jouanno, 2009 |
| | Vehicles with emissions of 100 g $CO_2$/km or less (€ 2 per gram) to emissions of more than 250 g $CO_2$/km: € 19 per gram qualify for a progressive company car tax | ACEA, 2009 |
| **Germany** | Since July 2009, Germany implements a new vehicle tax system, transforming the annual car tax into a base tax and a $CO_2$ tax<br>(€ 2 per g $CO_2$/km) | ACEA, 2009 |
| | Cars with emissions below 129 g $CO_2$/km as well as EVs in the first five years after purchase are exempt from taxation | COIN, 2009; TAGE, 2007 |
| **Greece** | Electric and hybrid cars are exempted from the special consumption tax and from the yearly circulation taxes | HIEV, 2009 |

| Country | $CO_2$ tax incentives/subsidies | Source |
|---|---|---|
| **Ireland** | Registration tax rates vary between 14% and 36% of the purchase price depending on emissions with the lowest rate at 120 g $CO_2$/km and the highest rate at 225 g $CO_2$/km | ACEA, 2009 |
| | EVs are tax exempt until December 1st 2010 | BERR, 2008a |
| | A relief of maximum € 2,500 is applicable for hybrid and flexible fuel vehicles | ACEA, 2009 |
| | Annual circulation rates vary from € 104 (up to 120 g $CO_2$/km) to<br>€ 2,100 (above 225 g $CO_2$/km) | ACEA, 2009 |
| **Nether-lands** | EVs are exempt from road tax and registration tax | MINDS, 2009 |
| | Up to € 8,000 rebate available for companies purchasing EVs | |
| | Businesses developing EV charging infrastructure will benefit from a twenty per cent tax break | |
| **Norway** | EVs are exempt from registration tax, VAT and annual car tax | MAYO, 2009 |
| **Portugal** | EVs and other alternative propulsion systems should be exempt from circulation and registration tax by now | DOMB, 2008; IMPO, 2007 |
| | Consumers who purchase cars with emissions of less than 140 g $CO_2$/km receive a bonus of up to € 1,000 | ACEA, 2009 |
| **Sweden** | SEK 10,000 are given to individuals buying a new green car, including electric and hybrid cars | SWE, 2007 |
| | An annual circulation tax of SEK 360 base rate plus SEK 15 for each gram $CO_2$ emitted above 100 g $CO_2$/km; this sum is multiplied by 3.15 for diesel cars bought in 2008 or later or by 3.3 for other diesel cars is used | ACEA, 2009 |
| | The tax for alternative fuel vehicles is SEK 10 per gram emitted above 100 g $CO_2$/km | |
| | Hybrid and EVs are exempt from the Stockholm congestion charge | ABERN, 2006 |
| **Spain** | Consumers who purchase cars with emissions below 120 g $CO_2$/km are exempted from the registration tax | ETAP, 2009 |
| | Consumers who purchase cars with emissions between 121 and 161 g $CO_2$/km receive a reduced tax of 4.75% | ETAP, 2009; BBC, 2009; DFT, 2009; BERR, 2009 |
| | Consumers who purchase cars with emissions between 161 and 200 g $CO_2$/km receive a reduced tax of 9.75% | |
| | Consumers who purchase cars with emissions over 201 g $CO_2$/km pay a tax of 14.75% | |
| | The electric car incentive program (starting 2011) provides subsidies of £ 2,000 to £ 5,000 to motorists who intend to buy Electric or Plug-in Hybrid Cars | |
| **UK** | The annual circulation is £ 0 for cars emitting less than 100 g $CO_2$/km but can augment up to £ 400 for cars emitting more than 225 g $CO_2$/km | ACEA, 2009 |
| | Since 2006 federal tax credits are provided for low-emission vehicles (US Energy Act); several state governments give further state tax credits | MIT, 2007; ABERN, 2006 |
| **USA** | A Federal tax credit of between $ 2,500 and 7,500 is available per Plug-in Vehicle purchased based on the size of the battery. Batteries with capacity of 16 kWh qualify for the full $ 7,500 credit. This tax credit will decrease in dollar amount after 200,000 Plug-in Vehicles per automaker are sold and the credit expires at the end of 2014 | WBCSD, 2009; EEA, 2009; http://www.irs.gov/businesses/article/0,,id=214841,00.html |
| | Various additional state and local incentives and subsidies such as in California and in Georgia | ABERN, 2006 |
| | Tax incentives for fuel efficient vehicles were introduced in | GLOB, 2009 |

| Country | $CO_2$ tax incentives/subsidies | Source |
|---|---|---|
| | 2001. They have led to an accelerated penetration of fuel efficient vehicles already fulfilling the 2010 fuel efficiency standards in 2004 | |
| **Japan** | Hybrid buyers had the chance to benefit from tax credits of up to<br>$ 3,500, but the scheme is now being phased out | ABERN, 2006 |
| | Subsidies of up to $ 8,800 are provided for Electric Vehicles purchased by taxi fleets and local government | Roland Berger, 2008 |
| **Israel** | Relating to the collaboration with Better Place, the Israeli Government reduces the purchase tax for electrically driven vehicles from 79 to 10% until 2014, and to 30% after 2019, as a fiscal measure to stimulate the purchase of EVs | SYRO, 2008 |
| China | Taxi fleets and local government agencies that purchase Electric Vehicles are offered subsidies of up to $ 8,800 | TNYT, 2009 |

Most of the countries within the EU and beyond have introduced $CO_2$-based car taxes. The exact structuring - i.e., the amount of $CO_2$, the type of tax (registration tax, annual tax, etc.), the design of the tax (progressive, in clumps, bonus-malus system, etc.), the sum, etc. - differs between the respective countries. In many countries (e.g., Norway, Denmark, Greece), EVs are exempted from all or some taxes. Furthermore, many countries implement subsidy programs (discounts, etc.) for EV dispersion.

In summary, many programmes within and beyond the EU refer to $CO_2$ emission levels and tax incentives to stimulate green vehicle purchasing. Concrete rebates and subsidies vary within the different countries, as do reference and target amounts of $CO_2$ emissions. Tax exemptions for EVs and circulation restrictions for fuel-consuming cars are also used frequently to boost the market penetration of EVs.

## 3.7 Industry research activities

Apart from battery research, where Japan is world leader (see Section 4.6), industrial research activities mainly focus on drive train and control technologies. Most of the relevant companies are working on this (e.g., Continental, Bosch, ZF, VDO, etc.).
However, actual investment figures in terms of Research and Development are hardly accessible or specific for EV technology, as details on spending might be helpful for possible competitors.

## 3.8 Summary

In this chapter, we have provided an estimate of total announced market penetration. We investigated the volume of government sponsorship programs to promote Electric Vehicles and the numbers of cars governments and companies dedicated to have on the road in the time horizon of our study. Here, briefly, are the key findings.

- Government and industry EV investment programs predominately began in 2008 and 2009. Considerably less investment is foreseen for 2010 or beyond. This fuels fears of a funding dry-up after 2012.
- The majority of total funding, € 22 billion, has been initiated in the USA and the EU (mainly Germany, France, UK, Spain).

- According to announcements, more than five million new Electric Vehicles (without two- and three-wheelers) globally could hit the road by 2015, the majority in Europe. By 2040, total announced cars sum up to almost 7 million cars. This ‘slowing’ of market penetration can be easily explained by the fact that most announcements relate to the near-term future.
- The main markets are (in order of importance): EU, USA, East Asia (China and Japan).
- Compared to global sales forecasts of 53 million conventional cars in 2010 alone, market penetration will remain fairly low in the near-term future. Current EU fleet amounts to 213 million passenger vehicles.[15]
- Many subsidy programmes within the EU refer to $CO_2$ emission levels and tax incentives to stimulate green vehicle purchasing. Tax incentives, rebates and circulation restrictions also seem to be applicable measures in other regions of the world.
- Most countries within the EU and beyond have introduced $CO_2$-based car taxes, but the exact structuring differs between the respective countries.
- Many countries implement broadly varying subsidy programs for Electric Vehicle dispersion.
- The US provides the most subsidies for electric mobility. On the other hand, the announcements of new EVs sum up to just one fourth of the global market. On a cars per € comparison basis, the EU fares more efficiently, at first glance.
- Infrastructure for EVs is often developed and installed in cooperation with private companies.
- At the European level, the European Green Cars Initiative stands out as a high-budget initiative involving virtually all subtopics and areas of electric mobility.
- Postal, messenger services and other companies increasingly equip their inner-city fleets with short-range electric vans and trucks, starting from very marginal levels. The overall market share of EVs in the commercial fleet is still miniscule.

[15] Eurostat tables demo_pop_esms and tsdpc340.

# 4 Public research programmes

## 4.1 Introduction

This chapter lists and summarises public research activities. A first section (Section 4.2) addresses European research, followed by a survey of national research programmes of EU Member States (Section 4.3).This is followed by a special focus section on US university and laboratory research activities (Sections 4.4 and 4.5). Moreover, international research activities in other countries are investigated (Section 4.6). All the before-mentioned activities are summarised in a general overview (Section 4.7), complemented by a literature overview (Section 4.8). The chapter closes with a summary section (Section 4.9).

## 4.2 EU-wide research activities

The 7$^{th}$ Framework Programme for Research and Technological Development (FP7) represents the largest arena in which EU-wide research on EVs is currently taking place. FP7, which has a total budget of € 50 billion and lasts from 2007 to 2013, includes a number of research projects[16] directly related to EVs (EC, 2009b; EC, 2009c; EC, 2009a).

The first of these projects is **EE-VERT** (Energy Efficient Vehicles for Road Transport), which will develop strategies for overall energy management (thermal and electric) in conventional and hybrid vehicles to reduce fuel consumption and emissions. The project began on January 1$^{st}$ ,2009 and will last a total of 36 months, costing approximately € 6.5 million. The end goal of the project is to develop technologies that will help the European Commission meet its target of having average $CO_2$ emissions of new vehicles be 120g $CO_2$/km by 2012, and of reducing emissions from light passenger vehicles by 40% by 2020.

The second related project funded under FP7 is **POLYZION** (Fast rechargeable zinc-polymer battery based on ionic liquids). This project will create a new class of fast rechargeable zinc-polymer battery for hybrid and small EVs that should overcome current technological, cost and environmental limitations. The project includes research and development in the fields of ionic liquids, rechargeable zinc electrodes, ultra-fast pulse charge injection techniques and conducting polymers. The resulting battery should be low cost, have minimal environmental impacts and be able to power electric and hybrid vehicles as well if not better than current battery technology. POLYZION began on August 1$^{st}$, 2008 and will last three years, costing approximately € 3.5 million.

The third relevant project is **VIETA** (Vehicle Independent Electric Transmission Architectures), which concerns the rapid development of electric drive trains for low-carbon vehicles in Europe, with specific focus on urban Electric Vehicles and commercial vehicles. The proposed electric drive train is based

16 All data on project was retrievd from Cordis at http://cordis.europa.eu.

on a vehicle-independent electric transmission architecture system. The project, which began on September 1st, 2009, will last 36 months and cost approximately € 330,000.

In addition to these research activities occurring within the context of FP7, the European Commission Joint Research Centre is currently conducting a number of projects directly related to EVs. These include HySaST (Hydrogen Safety for Storage and Transport), ETEA (Energy and Transport Techno-Economic Assessment), SYSTEM (Energy Systems Technology Modelling), TransTech (Transport Technologies and Emissions) and AIRMODE (Air Quality and Transport Modelling). TransTech and AIRMODE are detailed below.

The purpose of **TransTech** is to research energy efficiency, fuel consumption innovative technologies, alternative vehicle concepts (e.g., electric and hybrid) and alternative fuels to see how these might contribute to reducing pollution and the $CO_2$ emission that result from transport. It seeks to provide technical and scientific support to the development of technological and non-technological measures in Europe. In doing so, it should improve European energy security and aid the European Commission in achieving its sustainable transportation goals.

**AIRMODE** researches transport emissions, fuel consumption and air quality modeling. Amongst other goals, it aims at improving transport emission inventories in support of the EU Air Quality and Climate Change strategies, and the relevant Action Plans and policies. In 2010, emphasis is being put especially on the modeling of fuel consumption and $CO_2$ emissions. As part of AIRMODE, a report on the economic and environmental impacts of possible future scenarios about the penetration of Electric and Plug-in Hybrids will be drawn up and submitted.

Recent additions are **OVERSEE** and **G4V. OVERSEE** (Open vehicular secure platform) aims at realising an open IT platform for protected and standardised communications. **G4V** (Grid for vehicles) develops an analytical framework for the planning of technological developments in grid infrastructure in order to accommodate a mass introduction of EVs.

Apart from that, the **European Green Car Initiative** also has earmarked money for EV research.

## 4.3 National-level research activities (EU)

The national development plan for electric mobility **Germany** - supports eight pilot projects with a total of € 115 million as part of the German recovery act until 2011. Further funding will follow. A € 500 million programme as part of a national economic stimulus package has been set up to accelerate the development and deployment of EVs within the next years, being dedicated to several pilot projects and to major German manufacturers of cars and battery systems as well as to utilities and scientific institutes to do the accompanying research (WWF, 2009). The money should cover research and development of battery technologies and EVs, as well as the financial support of several demonstration projects with EVs that were launched in 2009 in several German cities (e.g., BMW, Daimler with Vattenfall; RWE in Berlin, Munich) (FOCUS, 2008; TAGS, 2009). In addition, a lithium-ion battery research programme (LIB, 2015) is funded € 60 million (2008-2015) by the government and € 360 million investments by an industry consortium (BMU, 2008; BMBF, 2009).

The University of Duisburg-Essen[17] is also conducting its own EV tests, while the Ruhr University of Bochum[18] is conducting advanced battery tests.

The ADAC in collaboration with the energy provider RWE took into operation 25 charging stations for EVs nationwide in 1999, which provide free power until the end of 2011.Further stations will follow until the end of 2011.

The group of municipal utilities 'Trianel' founded the 'competence centre for electric mobility' in Aachen, enabling the participating parties (29) to benefit from advantages in transfer of knowledge as well as in the purchasing of infrastructure and vehicles.

**Austria**'s Climate and Energy Fund of the Ministry of Transport, Innovation and Technology funded the project 'e-connected'[19] which aims to link different stakeholders and to provide information on ongoing projects and initiatives in the context of e-mobility. Within e-connected, several expert panels with representatives from research institutes, industry and NGOs come together in order to identify and eliminate obstacles to facilitate the deployment of EVs in Austria (LUGMAIER, 2009).

For example, in the course of the VLOTTE-project[20] in the Vorarlberg region that was launched in 2008, 78 EVs were deployed, 32 charging station installed and a distance of 150,000 km was covered. In 2010, the second round of this project, VLOTTE II, started.

In **France**, a € 400 million funding for R&D and demonstration projects on low carbon vehicles (vehicle development, charging infrastructure) over 2008-2012 has been established, thereof € 90 million for the research on EV technology. An interministerial fund will finance two national research platforms on the development of battery technology and electric and hybrid vehicles (Chatel and Jouanno, 2009). In February 2009, the government installed a special working group responsible for the coordination and installation of a standardised national charging network for PHEVs and battery powered EVs (CARN, 2009; Chatel and Jouanno, 2009). The strategy includes the empowerment of local governments to set up public charging infrastructure, a quota of parking areas in work places and shopping areas for EVs and charging spots, an obligation for builders of collective residences to set up charging facilities at parking places upon request of inhabitants as well as an obligation for local governments to equip public parking areas with charging facilities (Chatel and Jouanno, 2009).

In addition to these public-funded activities, the École des Mines de Paris[21] is researching hybrid and EV systems and components.

In the course of the French car-sharing public-private partnership 'Autolib'[22] between AVIS car rental, the French National railway Company SNCF and the French Transit Authority RATP, 4,000 Electric Vehicles will be deployed in

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17 http://www.uni-due.de/index.shtml.en.

18 http://www.ruhr-uni-bochum.de/index_en.htm.

19 www.e-connected.at.

20 http://www.vlotte.at/index.asp.

21 http://www.ensmp.fr/Accueil/.

22 http://www.autolib.fr/autolib/.

Paris and two dozen surrounding cities. In addition, 1,400 charging stations will be installed in Paris and its suburbs.[23]

In **Spain**, the Ministry of Industry through the IDAE (Institute for Energy's Diversification and Saving) supports the MOVELE-project to introduce 2,000 electric cars and install 500 recharging points in 2009 and 2010 (IDEA, 2009).

In the **UK**, the government plans to spend £ 400 million to encourage the development and support of ultra-low-emission vehicles (BERR, 2009), including a demonstration project with 100 EVs in several UK towns and cities (funded with £ 10 million). Additionally, £ 20 million are dedicated to UK research into improving EV technologies and infrastructure, coordinated by the Government-funded Technology Strategy Board (BERR, 2008b; BERR, 2009). A commitment to promote EV technology, to facilitate the establishment of charging infrastructure and to collaborate multilaterally regarding the development of international standards (BERR, 2008b) has been made by the government. Further £ 20 million will support the demonstration and use of low carbon vehicles in the public sector with the aim to encourage the mass production of electric vans (BERR, 2008b).

National-level research activities within the EU often go along with huge subsidies originating from national economic stimulus packages. Most projects are pilot and demonstration projects and include companies, universities, research institutes and public institutions.

## 4.4 University-affiliated research activities (USA)

The **Davis Plug-In Hybrid Electrical Vehicle Research Center** of the University of California[24] aims to serve as a magnet for research on consumer response, environmental impacts, and vehicle technology, including EVs.

The **Sloan Automotive Laboratory** at the MIT Center for 21st Century Energy[25] focuses on research on technologies for energy conversion and utilisation, encompassing existing and emerging technologies and systems. These include developing fuel cell and advanced battery systems.

The **Clemson University International Center for Automotive Research[26]** conducts research on ultracapacitors used for automotive energy storage.

Development and implementation of new materials, monitoring techniques, designs and applications as well as alternative fuels research, specifically in the areas of Plug-in Electric Vehicles and the development of a future hydrogen infrastructure, is being researched by the **Missouri Transportation Institute** at the Missouri University of Science and Technology[27].

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23 http://www.businessweek.com/globalbiz/content/aug2009/gb2009087_330677.htm.

24 http://phev.ucdavis.edu/.

25 http://web.mit.edu/c21ce/index.html.

26 http://www.clemson.edu/centers-institutes/cu-icar/.

27 http://mti.mst.edu/.

The Department of Materials Science and Engineering at **Carnegie Mellon**[28] wants to improve the efficiency of batteries, motors, generators and other energy conversion devices.

The College of Engineering at **Michigan State University**[29] researches motor and generator technology that can dramatically improve efficiency and reduce costs of electric and hybrid vehicles.

The **University of Wisconsin Madison**[30] is dealing with control and conversion of electric power for applications ranging from EVs to fuel cell power converters.

The **Precourt Energy Efficiency Center (PEEC)**[31] at Stanford University carries out EV research and assesses prototype building capabilities.

**Georgetown University Advanced Vehicle Development**[32] integrates tests and demonstrates electric drive systems and specialises in fuel cell buses.

The Hybrid Electric Vehicle Team at **San Diego State University's College of Engineering**[33] is developing a medium duty, modular, reduced-weight hybrid-powered urban delivery fleet. The work includes design, energy management and control technologies.
The Vehicle to Grid (V2G) Technology Research Group at the **University of Delaware**[34] is developing vehicle to grid technology.

The Advanced Power Systems Research Center of **Michigan Technological University**[35] carries out research on hybrid and electrical vehicles and alternative fuel use in HEVs.

The **University of Michigan Transportation Research Institute**[36] has wide research capabilities concerning advanced technology vehicles.

The **University of Michigan-Dearborn**[37] specialises in modelling and simulations of hybrid and Electric Vehicles.

**Purdue University**[38] is developing cooling systems for EV components, including batteries.

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28 http://www.materials.cmu.edu/research/materials_energy.html.

29 http://www.egr.msu.edu/research/areas/energy.

30 http://www.engr.wisc.edu/ece/.

31 http://peec.stanford.edu/index.php.

32 http://fuelcellbus.georgetown.edu/.

33 http://www.engineering.sdsu.edu/~hev/statement.html.

34 http://www.udel.edu/V2G/.

35 http://www.me.mtu.edu/research/power/.

36 http://www.umtri.umich.edu/about.php.

37 http://www-personal.engin.umd.umich.edu/~chrismi/publications/2007_95_4_IEEE_Proc_Modeling_HEV.PDF.

38 http://www.purdue.edu/.

**West Virginia University**[39] focuses on automotive engineering, hybrid electrical vehicles, as well as EcoCar development and testing.

**Ohio State University's Center for Automotive Research**[40] has launched a new program called SMART@CAR: Sustainable Mobility – Advanced Research Team. SMART@CAR partners with 12 organisations in a new program focused on PHEVs, EVs and intelligent charging.

## 4.5 Laboratory research activities (USA)

The **Los Alamos National Laboratory** serves as the conduit for laboratory collaborations with private industry. In doing so, it promotes the transfer of technology from the laboratory to external sectors. Its Technology Transfer Division[41] (TT) is responsible for helping move technologies from the lab to the marketplace to benefit the US economy and society. The TT recently submitted a proposal to the Advanced Research Projects Agency-Energy (ARPA-E) to conduct research on low-cost, ultra-high-energy-density batteries for PHEVs and EVs, amongst other topics.

The Transportation Technology R&D Center at **Argonne National Laboratory**[42] is developing and testing various Hybrid Electric Vehicles and their components to identify the technologies, configurations and engine control strategies that would provide the best combination of high fuel economy and low emissions.

The **Idaho National Laboratory**[43] provides capability in testing and evaluating advanced battery, fuel cell and ultra-capacitor technologies. This testing activity provides data for the Department of Energy's technology, modelling, simulations and R&D programs, as well as by private industry. The stated goal of the Idaho National Laboratory's research in this field is to develop and test technologies that can lead to emission- and petroleum-free vehicles so as to reduce consumption of foreign oil.

**Brookhaven National Laboratory**[44] is conducting research into solid-state hydrogen storage and lithium batteries to make alternative modes of transportation more feasible and safe, as well as to reduce oil dependency. Brookhaven scientists are conducting basic electrochemical research to improve the efficiency and reliability of fuel cells and batteries. Accordingly, they are performing basic and applied research for the improvement of energy-storage materials and systems with high energy densities.

The **National Renewable Energy Laboratory (NREL)**[45] is conducting research in the fields of battery thermal management, modelling and systems solutions for Fuel Cell, Hybrid Electric and Electric Vehicles. It is also working to develop hybrid technology for the next generation of trucks and other heavy

39 http://www.cemr.wvu.edu/research/center-details.php?&id=87&type=lab.

40 http://car.eng.ohio-state.edu/node/84.

41 http://www.lanl.gov/orgs/tt/.

42 http://www.transportation.anl.gov/.

43 https://inlportal.inl.gov/portal/server.pt?open=512&objID=255&mode=2.

44 http://www.bnl.gov/world/.

45 http://www.nrel.gov/.

transportation vehicles. The NREL's hydrogen and fuel cells research focuses on hydrogen production, delivery and storage; fuel cells; technology validation; safety, codes, and standards; analysis; education; and manufacturing.

The Center for Transportation Analysis (CTA) in the **Oak Ridge national Laboratory (ORNL)**[46] seeks to develop integrated inter-modal transportation solutions. CTA's activities encompass transportation energy and environmental concerns, planning and policy issues, systems engineering, amongst others. More specifically, CTA is currently researching energy storage and automotive electrical drive development.

The research activities of the Transformational Materials Science Initiative at the **Pacific Northwest National Laboratory**[47] focus on the synthesis and assembly of multifunctional nanomaterials. It studies such materials with the goal of optimising the transportation and storage of charged species within them.

The **Rocky Mountain Institute (RMI)**[48] is currently leading a non-profit initiative called Project Get Ready, which will provide a database of US and international plug-in readiness activities, and will bring together relevant stakeholders from around the world on a regular basis to discuss lessons learned and best practices. RMI is also conducting advanced vehicle concept development research.

From June 2004 to May 2005, the **Motor Vehicle Fire Research Institute**[49] was contracted by the Southwest Research Institute to conduct a project entitled 'Electrical Vehicle Battery Abuse Testing'. This project entailed performing abuse research on 36V batteries to investigate the possibility of them self-igniting in the case of an accident.

Research activities in virtually all areas of electric mobility are highest in the United States, especially in universities and national laboratories.

## 4.6 International research activities

**Japan** remains the world leader with regard to the research and development of battery technologies showing the highest R&D budget for the development of lithium-ion batteries. Recently, the Government of **China** announced plans to turn the country into one of the leading producers of EVs within three years. Government research subsidies for electric car designs have already increased significantly. An interagency panel is planning tax credits for the purchase of alternative energy vehicles.

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46 http://cta.ornl.gov/cta/.

47 http://www.pnl.gov/.

48 http://www.rmi.org/rmi/.

49 http://www.mvfri.org/.

## 4.7 General overview

The following listing is intended to give a general overview on the different measures and on the different levels where these measures were taken, including the information of Chapters 3 and 4. It is neither absolute nor finished, as new programs, development plans, research activities and joint ventures are being created, developed and initiated all the time. Especially the pilot projects in some countries are diverse and partly overlap with national programs or stimuli, so that a definite classification and demarcation is hardly possible.

Please note that tax incentives and subsidies have been counted as national measures.

**Table 8 General overview of research activities**

| Country | National Program | University | Laboratory | Pilot Projects | Sum (in mio. €) |
|---|---|---|---|---|---|
| Austria | 2 | | | 2+ | |
| Belgium | 3 | | | | 2 |
| Cyprus | 1 | | | | |
| Denmark | 3 | | | 2 | 109.6 |
| France | 3 | 1 | 2 | Several | 400 |
| Germany | 2 | 2 | | 8+ | 920 |
| Greece | 2 | | | | |
| Ireland | 2 | 1 | | 1 | |
| Italy | | 1 | | 3 | |
| Netherlands | 4 | | | 1 | 68 |
| Norway | 3 | | | | |
| Portugal | 2 | | | | |
| Spain | 2 | | | | |
| Turkey | | 1 | | | |
| UK | 5 | | | 3 | 522 |
| EU | 9 | | | | 1,000 |
| Australia | | | | 1 | |
| China | 3 | | | | 1,357 |
| Israel | 1 | | | 1 | |
| Japan | 1 | | Battery research | | |
| Russia | | 1 | | | |
| USA | 6 | 17 | 12+ | 1 | 6,571 |

The US conducts by far the most research activities in national laboratories and universities, while all the other countries are left behind in both categories. As stated before, Japan remains the world leader in battery research and development.

Many countries of the EU have at least one national program supporting the market penetration of EVs, most of them in the Netherlands and the UK. Pilot projects are mainly held in France and Germany, the latter being also comparatively strong in university research.

The EU itself has launched several high-budget research projects on almost all subareas of electric mobility, thereof particularly prominent energy efficiency, battery and drive train technology as well as developing transport systems and scenarios.

## 4.8 Literature Overview

Table 9 provides a list of sources utilised in the project related to the various production aspects of FEVs and PHEVs. The different categories refer to the types of information gleaned from each source.

**Table 9 EVs, PHEVs and electricity production aspects**

| | Long term transition | Business case | Battery development | Emissions and energy use of vehicles | Impact EVs on electricity production | Charging | Smart grid | Electricity production and emissions | Electricity grid and infrastructure | Renewables grid integration | Vehicle 2 Grid |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AER, 2009 | X | | | | | | | | X | | |
| BERR, 2008a | X | X | X | X | | | | | | | |
| CE, 2008 | | | | X | | | | | | | |
| CE, 2009 | | | | X | X | | | | X | | |
| DB, 2008 | | X | | | | | | | | | |
| EA, 2009 | | | | X | | | | | | | |
| EEA, 2008 | | | | | | | | X | | | |
| EEA, 2009 | X | X | X | X | X | | | X | | | |
| Greenpeace, 2009 | | | | | | | | | X | X | |
| IHS Global Insight, 2009a | | X | | | | X | X | | | | |
| IHS Global Insight, 2009b | | | X | | | X | | | | | |
| IEA, 2006 | | | | | | | | X | | | |
| JRC, 2008 | | | | X | | | | X | | | |
| Lund and Kempton, 2008 | | | | | | | X | | | | X |
| NREL, 2010 | | | X | | | | | | | | |
| OECD/IEA, 2008 | X | | X | | | | | | | | |
| PBL, 2009 | X | | X | X | | | | X | | | |
| TNO, TWTH & ECN, 2009 | | | | X | | | | | | | |
| UK ERC, 2006 | | | | | | | | | | X | |
| UMMELS, 2009 | | | | | | | | | | X | |
| WWF, 2008 | X | | X | X | | | | X | | | |
| WWF, 2009 | | | | X | | | | | | | |

## 4.9 Summary

In this section, we looked at various research initiatives around the world related to Electric Vehicles, components, etc. The following are the key findings.

- Research activities in virtually all areas of electric mobility are highest in the United States, especially in universities and national laboratories, while all the other countries are left behind in both categories.
- Japan remains the world leader in battery research and development.
- National-level research activities within the EU often go along with huge subsidies originating from national economic stimulus packages. Most projects are pilot and demonstration projects and include companies, universities, research institutes and public institutions.
- The 7$^{th}$ Framework Programme for Research and Technological Development (FP7) represents the largest arena in which EU-wide research on Electric Vehicles is currently taking place (2007-2013).
  Many countries of the EU have at least one national program supporting the market penetration of EVs, most of them in the Netherlands and the UK. Pilot projects are mainly held in France and Germany.

# 5 Conclusions

## 5.1 The nature of the future EVs

Presently, there is no clear trend visible towards real shifts in terms of vehicle mass or design. The fact that the announced cars are on average not significantly lighter than today's European cars indicates that there will be a significant shift towards small cars. There is no clear evidence of light weight composite materials as has been observed in aircraft design, see the upcoming Boeing B787 Dreamliner and the Airbus A350. This conclusion may not hold true in the long term as composite materials may become market-ready in the future. However, vehicle prices will be considerably higher for FEVs and PHEVs compared to today's ICE cars, which will certainly affect customer purchasing behaviour and thus might limit the number of sales.

Judging from the available data, battery capacity correlates very directly with battery mass. Thus, more battery capacity implies a heavier and larger car. Ranges are therefore still very much limited and pure electric driving will be limited to short and medium range applications for the short-term future. Based on EDT urban drive ranges, FEVs are primarily in the 100-200 km ranges (89%), PHEVs in the ranges below 100 km (84%). This is linked both to vehicle mass and battery performance. As only 28.6% of FEVs have a range above 200 km, their main use is urban traffic and commuting, but not travel. In the long run, however, the ranges of FEVs might increase significantly and extend the cars' typical fields of application beyond only city use.

In terms of acceleration from 0 to 100 km/h, EVs will not differ significantly from today's cars. Although indicated maximum speeds are lower than for today's ICE cars, these top speeds can only be maintained for a very short period of time by EVs due to overheating.

In comparison with its respective ICE version, the EV model almost always performs weaker. In particular, vehicle price and range – two essential purchase criteria – are significantly less advantageous for the EVs. As a consequence, the market penetration of EVs might remain lower since potential buyers could rather stick to the lower-priced ICE version with a better overall performance.

Apart from passenger cars, many different vehicle types will be electrified in the future. Generally, these vehicles are very heterogeneous and can be subdivided into several variable subgroups: city cruisers, racing and off-road motorbikes, city bicycles ('Pedelecs'), trucks and vans. Their specifications largely depend on the type and use of the vehicle (i.e., the subgroup) and need to be compared more profoundly to receive meaningful results.

The function and outward appearance of these non-passenger car vehicles are mainly based on already existing vehicle types and thus do not represent fundamental changes in vehicle construction. However, a few vehicles (Aptera, TTW One) look rather futuristic and are built out of light weight materials.

As many of the vehicles are not produced in large quantities, individual modifications are often possible.

## 5.2 Trends and market penetration in the near future

Until 2015, the market penetration of EVs will remain fairly low compared to sales forecasts of 53 million conventional cars in 2010. The estimation based on several government announcements, industry capacities and proliferation projects sees over five million new EVs on the road globally by 2015, the majority of these in the EU. The main markets for EVs are in order of importance the EU, the US and East Asia (China and Japan), also representing today's main markets for ICE passenger cars in a different order. Some further target markets like Israel and the Indian subcontinent will evolve as well.

In the long term, the share of EVs will most likely increase as additional countries adopt technologies and initiate projects themselves. On the other hand, there is also a likelihood that Electric Vehicles might fail to reach mass markets and will remain a niche product for technology leaders.

In some countries, non-passenger car EVs already hold market shares of up to 10%, as do electric bicycles in the Netherlands. In East Asia, especially in China, there is also a clear trend towards electric bicycles. These examples highlight the potential for electric mobility in non-car applications. Additionally, concrete beginnings of existing market penetration can be observed as postal and messenger services as well as other companies increasingly plan to equip their inner-city fleets with short-range electric vans and trucks. In these cases, the EVs are used in their typical urban field of application where they prove to be profitable and attractive also for private companies.

Generally, non-passenger car market penetration in the short term might have more impact than passenger cars as postal and messenger services as well as other companies increasingly equip their inner-city fleets with short-range electric vans and trucks, however starting from very marginal levels.

## 5.3 Government and industry investment

The further uptake of EVs – passenger cars and other - vehicles is heavily supported by government and industry programs.

Government and industry investments have predominately been high during the past 24 months. A majority of the total funding of € 21.6 billion has been distributed in the US and the EU. The money often went into subsidy programs for EV dispersion, where the US is the world leader. The fact that large sums have been spent by government institutions and as part of national economic stimuli programs can be construed as an increasing political will to promote EV technologies. Accordingly, most of the countries within the EU and beyond have introduced $CO_2$-based car taxes favouring EVs. Tax incentives, rebates and circulation restrictions are further measures and can be found in many nations. Compared to these measures that predominantly already became operative, EV distribution has remained relatively low yet, but an increasing number of available cars in the market during the next years will most likely lift up the market share of EVs.

Generally, the types of programs for electric mobility (target numbers, infrastructure, pilot projects, traffic rights, etc.) vary broadly on a worldwide, but also on a European level. Infrastructure for EVs is often developed and installed in cooperation with private companies and in public private partnerships, revealing that there is not only a public interest in EV technology, but also economic possibilities. Here, too, the US holds the leading position.

There is considerable scepticism as to the long term continuity of government and industry investment schemes and there is a perceived fear that these programs might dry-up after 2012, especially if progress remains below the expected outcome.

## 5.4 Research efforts

Research activities in virtually all areas of electric mobility are highest in the US, especially in universities and national laboratories, while all the other countries are left behind in both categories. This goes along with the US providing the highest investment sums and initiating the largest subsidy programs, even though they form only the second largest future EV market.

Japan remains the world leader in battery research and development, often attached to familiar electronics companies.

National-level research activities within the EU often go along with huge subsidies originating from national economic stimuli packages. Most projects are pilot and demonstration projects and include companies, universities, research institutes and public institutions. Especially the main players (Germany, France, and UK) are active in this field.

The 7$^{th}$ Framework Programme for Research and Technological Development (FP7) represents the largest arena in which EU-wide research on EVs is currently taking place. FP7, which has a total budget of over € 50 billion and lasts from 2007 to 2013, includes a number of research projects directly related to EVs, thereof particularly prominent on energy efficiency, battery and drive train technology as well as developing transport systems and scenarios.

Further research into the long term potential for EV market penetration will be needed. This task will be carried out in WP 4 (Economic Analysis) and WP 6 (Scenario Analysis).

In the near-term future, the market penetration of EVs will remain fairly low compared to conventional automobiles. The estimation based on several government announcements, industry capacities and proliferation projects sees over five million new Electric Vehicles on the road globally by 2015, the majority of these in the EU. The main markets for EVs are in order of importance the EU, the US and East Asia (China and Japan). Some further target markets like Israel and the Indian subcontinent will evolve, too.

In the long term, the share of EVs will most likely increase as further countries adopt technologies and initiate projects themselves.

1. It can be assumed that in the short run, i.e., until 2015, EVs will not differ significantly from today's cars concerning their outward appearance and function, albeit with shorter ranges than conventional ICE cars.

2. In the near-term future, the market penetration of EVs will remain fairly low: compared to sales forecasts of 53 million conventional cars in 2010 alone, EVs will account for over five million cars until 2015. The main markets for EVs still being the EU, the US and East Asia (China and Japan).
3. As research activities and investments are relatively high, EV technology may advance rapidly and in future might account for greater shifts than our findings suggest.
4. There is a significant risk of electric 'depression' after 2012 if expectations are not met and market penetration remains low.

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# Annex A Website List

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| Country | Websites |
| --- | --- |
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# Annex B Database excerpt

**Table 10** **Excerpt of the database with or existing and announced EVs**

| Vehicle Number | Name of Vehicle | Type of vehicle | Size | Vehicle Purchase Cost (€) | Vehicle mass (kg) | Battery mass (kg) | Maximum speed (km/h) | 0-100 km/h (sec.) | EDT urban range (in km) | Charging time (hrs:min) | Battery capacity (kWh) | Battery type | Battery life expectancy (years) | Number of seats | Expected Release Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Chevrolet Volt | PHEV | M | 29,347 | 1,588 | 170 | 161 | 9 | 64 | 08:00 | 16 | Lithium-ion battery | 10 | 4 | 01.11.2010 |
| 2 | BYD F3DM | PHEV | M | 11,784 | 1,560 | 230 | 150 | 10.5 | 100 | 08:00 | 13.2 | Lithium iron phosphate battery | 10 | 5 | 01.01.2010 |
| 3 | Fisker Karma | PHEV | M | 64,490 | 2,109 | N.a. | 201 | 5.8 | 80 | N.a. | 22.6 | Lithium-ion battery | 10 | 4 | 01.05.2010 |
| 4 | Volvo V70 | PHEV | L | 48,000 | 1,955 | 150 | 161 | 9 | 50 | 03:30 | 11.3 | Lithium ion battery | 10 | 5 | 01.01.2012 |
| 5 | Ford Escape | PHEV | L | 20,000 | 1,769 | N.a. | 164 | N.a. | 48 | 07:00 | 10 | Lithium ion battery | 10 | N.a. | 01.01.2012 |
| 6 | Audi A1 Sportback | PHEV | M | N.a. | N.a. | N.a. | 100 | 8 | 50 | N.a. | 20 | Lithium-ion battery | 10 | 4 | 01.01.2011 |
| 7 | Volvo ReCharge | PHEV | L | 40,000 | N.a. | N.a. | 160 | 9 | 100 | 03:00 | N.a. | Lithium-polymer battery | ... | N.a. | N.a. |
| 8 | Citroën REVOLTE | PHEV | S | N.a. | N.a. | N.a. | N.a. | N.a. | N.a. | N.a. | N.a. | Lithium-ion battery | N.a. | 3 | Not yet announced |
| 9 | Opel Ampera | PHEV | M | 30,000 | 1,900 | 180 | 160 | 9 | 60 | 03:00 | 16 | Lithium-ion battery | 10 | 4 | 01.01.2011 |
| 10 | Hyundai Blue-Will | PHEV | M | N.a. | N.a. | N.a. | N.a. | N.a. | 61 | N.a. | N.a. | Li-ion polymer battery | 10 | 4 | 01.01.2012 |
| 11 | BMW Mini-E | FEV | S | N.a. | 1,465 | 259 | 153 | N.a. | 175 | 03:45 | 35 | Li-ion battery pack with 5000+ laptop-style batteries | N.a. | 2 | 22.05.2009 |
| 12 | Tesla Motors Roadster | FEV | S | 84,000 | 1,238 | 450 | 183 | 3.9 | 393 | 03:30 | 56 | Microprocessor-controlled lithium-ion battery pack | ... | 2 | N.a. |
| 13 | BYD Auto e6 | FEV | M | N.a. | 2,295 | N.a. | 140 | 14 | 330 | ... | 72 | BYD Li-ion Fe battery | N.a. | 5 | 01.01.2010 |
| 14 | Citroen C-Zero | FEV | S | N.a. | 1,100 | N.a. | 130 | 15 | 130 | 06:00 | 16 | Lithium-ion battery | N.a. | 5 | 01.01.2010 |
| 15 | Daimler Smart ED | FEV | S | N.a. | N.a. | N.a. | 100 | ... | 135 | N.a. | 14 | Li-Ioan battery from Tesla | N.a. | 2 | 01.01.2012 |
| 16 | Mitsubishi iMiEV | FEV | M | 37,767 | 1,080 | 200 | 130 | N.a. | 160 | 07:00 | 16 | Lithium-ion | N.a. | 4 | N.a. |
| 17 | Venturi Fetish | FEV | S | 297,000 | 980 | 248 | 160 | 5 | 250 | 01:00 | N.a. | 31 modules of Li-ion LIV-7 batteries | ... | 2 | 01.07.2010 |
| 18 | Renault Zoe Z.E. Concept | FEV | S | N.a. | 1,400 | N.a. | 140 | N.a. | 160 | 06:00 | 24 | Lithium ion | 6 | 2 | 01.01.2011 |

| Vehicle Number | Name of Vehicle | Type of vehicle | Size | Vehicle Purchase Cost (€) | Vehicle mass (kg) | Battery mass (kg) | Maximum speed (km/h) | 0-100 km/h (sec.) | EDT urban range (in km) | Charging time (hrs:min) | Battery capacity (kWh) | Battery type | Battery life expectancy (years) | Number of seats | Expected Release Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | Renault Kangoo Z.E. Concept | FEV | L | N.a. | 1,520 | N.a. | 130 | N.a. | 160 | 06:00 | 24 | Lithium ion | 6 | 5 | 01.01.2011 |
| 20 | Renault Fluence Z.E. Concept | FEV | M | N.a. | 1,600 | N.a. | N.a. | N.a. | 160 | 06:00 | 24 | Lithium ion | 6 | 4 | 01.01.2011 |
| 21 | Mindset AG Mindset | PHEV | S | 50,000 | 800 | N.a. | 140 | 7 | 180 | 02:30 | 20 | Lithium-ion battery | 10 | 4 | 01.01.2010 |
| 22 | Mitsubishi PX-iMiEV | PHEV | L | N.a. | N.a. | N.a. | N.a. | N.a. | 50 | N.a. | 16 | Lithium-ion battery | N.a. | 4 | 01.01.2013 |
| 23 | Suzuki Swift | PHEV | S | N.a. | N.a. | N.a. | N.a. | N.a. | 20 | N.a. | 2.66 | Lithium-ion battery | N.a. | 5 | N.a. |
| 24 | Toyota Prius Plug-in | PHEV | M | 34,750 | 1,380 | 155 | 100 | 10.9 | 23 | 01:40 | 5.2 | Lithium-ion battery | N.a. | 5 | 01.01.2012 |
| 25 | Volkswagen Twin Drive | PHEV | M | N.a. | N.a. | 160 | 170 | N.a. | 50 | N.a. | 8 | Lithium-ion battery | N.a. | 4 | 01.01.2013 |
| 26 | BMW Vision | PHEV | M | N.a. | 1,360 | 85 | 250 | 4.8 | 50 | 02:30 | 10.8 | 98 Lithium-polymer batteries | N.a. | 4 | No plan announced for mass production |
| 27 | Daimler Mercedes Benz Blue Zero | PHEV | M | N.a. | N.a. | N.a. | 150 | 11 | 50 | 06:00 | 18 | Lithium-ion battery pack | 10 | 5 | No model specified, announced low volume production of the EV version in 2010 |

| Vehicle Number | Name of Vehicle | Type of vehicle | Size | Vehicle Purchase Cost (€) | Vehicle mass (kg) | Battery mass (kg) | Maximum speed (km/h) | 0-100 km/h (sec.) | EDT urban range (in km) | Charging time (hrs:min) | Battery capacity (kWh) | Battery type | Battery life expectancy (years) | Number of seats | Expected Release Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | Daimler Mercedes Benz S500 Vision | PHEV | L | N.a. | N.a. | 130 | 250 | 5.5 | 30 | 04:30 | 10 | Lithium-ion battery | 10 | N.a. | Not yet announced, expected with next generation S-class |
| 29 | General Motors Cadillac Converj | PHEV | M | N.a. | N.a. | N.a. | 161 | 9 | 64 | 03:00 | 16 | 220 Lithium-ion cells (w/liquid-controlled thermal management system) | 10 | 4 | 01.01.2014 |
| 30 | Bright Automotive Idea | PHEV | L | N.a. | 1,452 | N.a. | N.a. | N.a. | 64 | 06:00 | 13 | Lithium-ion battery | N.a. | N.a. | 01.10.2012 |
| 31 | SEAT León 'Twin Drive Ecomotive' | PHEV | M | N.a. | N.a. | N.a. | 100 | N.a. | 50 | N.a. | N.a. | Lithium-ion battery | 10 | 5 | 01.01.2014 |
| 32 | VentureOne/ Persu Mobility | PHEV | S | 13,115 | 680 | 45 | 160 | 7 | 32 | N.a. | 3 | Li-ion battery pack (60 cells) | N.a. | 2 | 01.01.2009 |
| 33 | XR-3 Hybrid | PHEV | S | 18,215 | 671 | N.a. | 130 | N.a. | 64 | N.a. | N.a. | Lithium-ion battery | N.a. | 2 | N.a. |
| 34 | Audi Metroproject Quattro | PHEV | M | N.a. | N.a. | N.a. | 201 | 7.8 | 100 | N.a. | N.a. | Lithium-ion battery pack | 10 | 4 | 01.01.2010 |
| 35 | Visionary Vehicles/ Bricklin Collection | PHEV | M | 25,505 | 1,769 | N.a. | N.a. | 5.9 | 72 | N.a. | N.a. | Lithium-ion battery | N.a. | variable | N.a. |
| 36 | Chrysler Town & Country | PHEV | L | 36,420 | N.a. | N.a. | 160 | 8 | 64 | N.a. | N.a. | N.a. | N.a. | 7 | Not yet announced, recently closed ENVI group |

| Vehicle Number | Name of Vehicle | Type of vehicle | Size | Vehicle Purchase Cost (€) | Vehicle mass (kg) | Battery mass (kg) | Maximum speed (km/h) | 0-100 km/h (sec.) | EDT urban range (in km) | Charging time (hrs:min) | Battery capacity (kWh) | Battery type | Battery life expectancy (years) | Number of seats | Expected Release Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37 | Chrysler Jeep Patriot | PHEV | M | 13,110 | N.a. | N.a. | 160 | 8 | 64 | N.a. | N.a. | N.a. | N.a. | 5 | Not yet announced, recently closed ENVI group |
| 38 | Chrysler Jeep Wrangler Unlimited | PHEV | M | 32,775 | N.a. | N.a. | 145 | 9 | 64 | N.a. | N.a. | N.a. | N.a. | 5 | Not yet announced, recently closed ENVI group |
| 39 | Chrysler 200C | PHEV | M | N.a. | N.a. | N.a. | 200 | 7 | 64 | N.a. | N.a. | N.a. | N.a. | 4 | Not yet announced, recently closed ENVI group |
| 40 | Opel Flextreme | PHEV | M | N.a. | N.a. | N.a. | 200 | 9 | 60 | 03:00 | 16 | Lithium-ion (manganese spinel) | N.a. | 4 | N.a. |
| 41 | Toyota 1/X | PHEV | S | N.a. | 420 | N.a. | N.a. | N.a. | N.a. | N.a. | N.a. | Lithium-ion battery | N.a. | 4 | Not yet announced |
| 42 | GM Saturn Vue Green Line | PHEV | M | 18,000 | N.a. | N.a. | N.a. | 7.3 | 16 | 04:30 | N.a. | Lithium-ion battery | N.a. | N.a. | 01.01.2011 |
| 43 | Aptera 2h | PHEV | S | 22,500 | 680 | N.a. | 144 | 10 | 80 | N.a. | 11.5 | Lithium iron phosphate battery | N.a. | 2 | 01.10.2010 |
| 44 | BAIC (Beijing Automotive Industry Holding Company) BE701 | FEV | M | N.a. | N.a. | N.a. | 160 | 15 | 200 | N.a. | N.a. | N.a. | N.a. | N.a. | 01.01.2011 |
| 45 | Chery Auto Co. S18/M1 | FEV | S/M | 12,000 | N.a. | N.a. | 120 | N.a. | 150 | 05:00 | 40 | Ferric phosphate lithium battery pack | N.a. | 5 | 01.06.2010 |

| Vehicle Number | Name of Vehicle | Type of vehicle | Size | Vehicle Purchase Cost (€) | Vehicle mass (kg) | Battery mass (kg) | Maximum speed (km/h) | 0-100 km/h (sec.) | EDT urban range (in km) | Charging time (hrs:min) | Battery capacity (kWh) | Battery type | Battery life expectancy (years) | Number of seats | Expected Release Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46 | Miles Electric Vehicles (ZX40S) | FEV | M | 14,500 | 1,066 | N.a. | 40 | ... | 72 | 08:00 | ... | Advanced sealed, absorbed glass mat (AGM), valve regulated, maintenance free lead-acid | ... | 4 | 01.01.2009 |
| 47 | Velozzi Supercar | EREV | S | N.a. | N.a. | 939.5 | 320 | 3 | 320 | N.a. | N.a. | Lithium ion polymer | 7 | N.a. | 01.10.2010 |
| 48 | Velozzi Solo crossover | EREV | L | N.a. | N.a. | 491.5 | 210 | 6 | N.a. | N.a. | N.a. | N.a. | 7 | N.a. | 01.10.2011 |
| 49 | Fisker Project Nina | EREV | M/L | 35,000 | N.a. | N.a. | 161 | N.a. | N.a. | N.a. | N.a. | N.a. | N.a. | N.a. | 01.01.2012 |
| 50 | Kia Ray | PHEV | M | N.a. | N.a. | N.a. | 175 | N.a. | 80 | N.a. | N.a. | Lithium ion polymer | N.a. | 4 | N.a. |
| 51 | Capstone CMT-380 | EREV | S | 280,000 | N.a. | N.a. | 201 | 3.9 | 130 | N.a. | N.a. | Batteries and 30 kW (bio)diesel microturbine | N.a. | 2 | N.a. |
| 52 | Jaguar XJ | EREV | M/L | N.a. | N.a. | N.a. | 180 | N.a. | N.a. | N.a. | 145 | Lithium-ion battery | N.a. | N.a. | 01.01.2011 |
| 53 | Tazzari Zero | FEV | S | 42,000 | 544 | N.a. | 164 | N.a. | 140 | 10:00 | N.a. | Lithium-ion battery | N.a. | 2 | 01.03.2010 |
| 54 | Tesla S Electric Sedan | FEV | M/L | 42,000 | 1,814 | 270 | 100 | 5.6 | 260 | 03:00 | N.a. | Lithium-ion battery | 10 | 5 | 01.10.2011 |
| 55 | Pininfarina/Bollore BlueCar | FEV | M | ... | N.a. | N.a. | 160 | N.a. | 250 | 08:00 | 30 | Lithium metal polymer battery | ... | 4 | 01.01.2011 |
| 56 | Renault Fluence ZE EV | FEV | M | N.a. | 1,600 | N.a. | N.a. | N.a. | N.a. | 06:00 | N.a. | Lithium-ion battery | N.a. | N.a. | 01.01.2011 |
| 57 | Renault Kangoo ZE | FEV | M | N.a. | 1,520 | N.a. | 130 | N.a. | 160 | 06:00 | ... | Lithium-ion battery | N.a. | N.a. | 01.02.2012 |
| 58 | Renault Zoe ZE | FEV | S | N.a. | 1,400 | N.a. | 140 | N.a. | 160 | 06:00 | ... | Lithium-ion battery | N.a. | 4 | 01.02.2012 |
| 59 | REVA NXG | FEV | S | 22,999 | 825 | N.a. | 130 | N.a. | 200 | 06:00 | 14 | Lithium ion phosphate battery pack | N.a. | 2 | 01.02.2011 |
| 60 | REVA NXR | FEV | M | 14,995 | 850 | N.a. | 104 | N.a. | 160 | ... | N.a. | Either lead-acid or lithium-ion batteries | N.a. | 4 | 01.01.2010 |
| 61 | SABA Carbon Zero | FEV | S | N.a. | N.a. | N.a. | 147 | 5.1 | 192 | N.a. | N.a. | N.a. | N.a. | 2 | 01.06.2010 |
| 62 | SAIC Roewe 750 | FEV | M | N.a. | N.a. | N.a. | 150 | N.a. | 200 | 07:00 | N.a. | Lithium-ion battery | N.a. | 4 | 01.01.2012 |

| Vehicle Number | Name of Vehicle | Type of vehicle | Size | Vehicle Purchase Cost (€) | Vehicle mass (kg) | Battery mass (kg) | Maximum speed (km/h) | 0-100 km/h (sec.) | EDT urban range (in km) | Charging time (hrs:min) | Battery capacity (kWh) | Battery type | Battery life expectancy (years) | Number of seats | Expected Release Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 | Coda Automotive CODA | FEV | M | 56,000 | 1,660 | N.a. | 103 | 11 | 169 | 06:00 | 33.8 | Lithium ion (LiFePO4) | 8 | 4 | 01.01.2010 |
| 64 | BMW 1 Series Concept Active E electric coupe | FEV | S/M | N.a. | 1,800 | N.a. | 145 | 9 | 160 | 03:00 | N.a. | Lithium-ion battery | N.a. | 4 | N.a. |
| 65 | Toyota FT-EV City Car | FEV | S | 14,700 | N.a. | N.a. | 160 | N.a. | 90 | N.a. | N.a. | Lithium-ion battery | N.a. | 4 | 01.12.2012 |
| 66 | Citroen C-Zero City Car | FEV | S/M | N.a. | N.a. | N.a. | N.a. | 15 | 130 | 06:00 | 16 | Lithium-ion battery | N.a. | 4 | 01.10.2010 |
| 67 | Chrysler GEM | FEV | S | 5,280 | 600 | N.a. | 40 | N.a. | 48 | N.a. | N.a. | Lead acid | N.a. | 2 | 01.01.2009 |
| 68 | Commuter Cars Tango | FEV | S | N.a. | 1,428 | 448 | N.a. | 4 | 192 | N.a. | 30 | Lead-acid or lithium ion | N.a. | 1 | 01.01.2009 |
| 69 | Green Vehicles Triac | FEV | S | 18,330 | N.a. | N.a. | 140 | N.a. | 160 | 06:00 | N.a. | Lithium-ion battery | N.a. | 2 | 01.10.2010 |
| 70 | Green Vehicles Moose | FEV | L | 12,000 | N.a. | N.a. | N.a. | N.a. | 100 | ... | N.a. | Lithium-ion battery | N.a. | 2 | 01.10.2010 |
| 71 | Th!nk City C | FEV | S | N.a. | 1,038 | 252.5 | N.a. | ... | 180 | 13:00 | 28.3 | MES DEA - Zebra, sodium; Enerdel (lithium-ion); A123 (lithium-ion) | N.a. | 2 | 01.01.2011 |
| 72 | Ford Focus EV | FEV | S | 28,500 | 1,552 | N.a. | 100 | 8 | 160 | 06:00 | 23 | 98, air-cooled, 60 A-h Lithium-ion batteries | N.a. | N.a. | 01.01.2011 |
| 73 | Fiat 500 | FEV | S | 37,000 | N.a. | N.a. | 170 | N.a. | 100 | N.a. | N.a. | Lithium-ion battery | ... | N.a. | 01.12.2010 |
| 74 | Audi E-tron | FEV | S/M | 115,000 | 1,600 | 470 | 250 | 4.8 | 250 | 07:00 | 42.4 | Lithium-ion battery | N.a. | 2 | 01.10.2011 |
| 75 | Saab ZE 9-3 | FEV | S | N.a. | N.a. | N.a. | 150 | 6.5 | 150 | N.a. | 26 | N.a. | N.a. | N.a. | Currently building trial models |
| 76 | RUF Stormster | FEV | L | N.a. | 2,664 | N.a. | 250 | 10 | 190 | 08:00 | N.a. | Lithium-ion battery | N.a. | 5 | 01.06.2010 |

| Vehicle Number | Name of Vehicle | Type of vehicle | Size | Vehicle Purchase Cost (€) | Vehicle mass (kg) | Battery mass (kg) | Maximum speed (km/h) | 0-100 km/h (sec.) | EDT urban range (in km) | Charging time (hrs:min) | Battery capacity (kWh) | Battery type | Battery life expectancy (years) | Number of seats | Expected Release Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 77 | Land Rover Range Rover Sport | PHEV | L | N.a. | N.a. | N.a. | 161 | N.a. | 32 | N.a. | N.a. | N.a. | N.a. | 5 | 01.01.2012 |
| 78 | VW Up! (E-Up!) | FEV | S/M | 8,500 | 1,085 | 240 | N.a. | 11.3 | 130 | 05:00 | 18 | Lithium-ion battery | N.a. | 4 | 01.01.2013 |
| 79 | Peugeot ion City Car | FEV | M | N.a. | N.a. | N.a. | 130 | N.a. | 130 | 06:00 | N.a. | Lithium-ion battery | N.a. | 4 | 01.10.2010 |
| 80 | Tata Indica | FEV | M | N.a. | N.a. | N.a. | 160 | ... | 200 | 08:00 | 26.5 | Super polymer lithium ion | N.a. | 4 | N.a. |
| 81 | Herpa Trabant nT | FEV | M | 20,000 | 1,050 | N.a. | 130 | N.a. | 250 | 08:00 | N.a. | Lithium-ion battery | N.a. | 4 | 01.01.2012 |
| 82 | Volvo C-30 electric car | FEV | L | N.a. | N.a. | 280 | 201 | 10.5 | 135 | 08:00 | 24 | Lithium-ion battery | N.a. | 4 | 01.01.2011 |
| 83 | Ford Transit Connect | FEV | L | 35,700 | 1,791 | 272 | 120 | N.a. | 129 | 07:00 | 28 | Lithium-ion battery | 10 | 2 | 01.01.2010 |
| 84 | Lightning UK Electric Lightning GT | FEV | M | 155,000 | 1,350 | N.a. | 160 | 5 | 300 | 08:00 | 36 | Lithium-ion battery | N.a. | 2 | 01.01.2010 |
| 85 | Nissan Leaf | FEV | M | 32,722 | N.a. | 250 | 160 | 10 | 160 | 08:00 | 24 | Lithium-ion battery | N.a. | 5 | 01.12.2010 |
| 86 | EWE-E3 | FEV | L | 37,500 | 1,492 | N.a. | 140 | 15 | 170 | 08:00 | 31.7 | Lithium-ion battery (nickel-cobalt-aluminum; NCA) | N.a. | 4 | 01.01.2012 |
| 87 | e-WOLF e2 | FEV | S | N.a. | 900 | N.a. | 250 | 3 | 400 | 00:30 | N.a. | Patented integration | N.a. | 2 | 01.09.2011 |
| 88 | CT&T United e-Zone with lead-acid battery | FEV | M | 9,000 | 520 | N.a. | 70 | N.a. | 66 | N.a. | 12 | Lead acid | N.a. | 2 | N.a. |
| 89 | CT&T United e-Zone with lithium polymer battery | FEV | M | 9,000 | 520 | N.a. | 70 | N.a. | 109 | N.a. | 10 | Lithium-polymer | N.a. | 2 | N.a. |
| 90 | Heuliez Mia | FEV | S | 14,990 | 620 | 70 | 110 | N.a. | 90 | 02:00 | 6 | Lithium-phosphat | N.a. | 3 | 01.01.2010 |

| Vehicle Number | Name of Vehicle | Type of vehicle | Size | Vehicle Purchase Cost (€) | Vehicle mass (kg) | Battery mass (kg) | Maximum speed (km/h) | 0-100 km/h (sec.) | EDT urban range (in km) | Charging time (hrs:min) | Battery capacity (kWh) | Battery type | Battery life expectancy (years) | Number of seats | Expected Release Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 91 | BMW Megacity | FEV | S | N.a. | N.a. | N.a. | 145 | 9 | 160 | N.a. | N.a. | Lithium-ion battery | N.a. | N.a. | 01.01.2015 |
| 92 | Mercedes Benz F 800 | PHEV | M | N.a. | N.a. | N.a. | 250 | 4.8 | 30 | 06:00 | 10 | Lithium-ion battery | N.a. | 5 | 01.01.2012 |
| 93 | Mercedes Benz F 800 | FEV | M | N.a. | N.a. | N.a. | 180 | 11 | 600 | 06:00 | N.a. | Lithium-ion battery | N.a. | 5 | 01.01.2015 |
| 94 | SEAT Ibe | FEV | M | N.a. | 1,000 | N.a. | 160 | 9.4 | N.a. | N.a. | 18 | Lithium-ion battery | N.a. | 4 | 01.01.2014 |
| 95 | Porsche 918 Spyder | PHEV | M | N.a. | 1,490 | N.a. | 320 | 3.2 | 25 | N.a. | N.a. | Lithium-ion battery | N.a. | 2 | N.a. |
| 96 | Mercedes Benz SLS eDrive | FEV | M | 145,169 | N.a. | N.a. | 200 | 4 | 164 | 08:00 | 48 | Lithium-ion battery | N.a. | 2 | 01.01.2015 |
| 97 | Rinspeed UC? | FEV | S | N.a. | 980 | N.a. | 120 | N.a. | 105 | N.a. | 12 | Lithium-ionen Li-Tec | N.a. | 2 | N.a. |
| 98 | Optimal Energy Joule | FEV | L | 29,000 | | N.a. | 135 | N.a. | 300 | 08:00 | N.a. | Lithium-ion battery | 10 | 5 | N.a. |
| 99 | Protoscar SA Lampo2 | FEV | S | N.a. | 1,650 | 320 | 200 | 5 | 200 | 07:00 | 32 | 2 Brusa EVB1 lithium-ion battery packs (each 16 kWh) | N.a. | 2 | N.a. |
| 100 | Detroit Electric e63 | FEV | S | N.a. | 1,240 | N.a. | 180 | 8 | 180 | 08:00 | N.a. | Lithium-ion polymer | N.a. | 4 | N.a. |
| 101 | Detroit Electric e64 | FEV | S | N.a. | 1,225 | N.a. | 180 | 8 | 320 | 12:00 | N.a. | Lithium-ion polymer | N.a. | 4 | N.a. |
| 102 | Tata Nano | FEV | S | 1,500 | N.a. | N.a. | 110 | ... | 120 | N.a. | 12 | Lithium-Polymer-(LiPo)-Battery | N.a. | 4 | 01.01.2012 |
| 103 | Lotus Evora 414E hybrid | EREV | M | N.a. | 1,460 | N.a. | N.a. | 4 | 56 | ... | 17 | Lithium polymer | N.a. | 2 | N.a. |
| 104 | Kia Venga | FEV | M | N.a. | N.a. | N.a. | 140 | 11.8 | 180 | 08:00 | 24 | Lithium-ion polymer batteries | N.a. | 5 | N.a. |
| 105 | NLV Quant | FEV | M | N.a. | 1,680 | 450 | 377 | 2.8 | 483 | 00:20 | N.a. | Flow Accumulator Energy Storage (FAES) | N.a. | 2 | N.a. |
| 106 | Valmet EVA | FEV | M | N.a. | N.a. | N.a. | 120 | N.a. | 160 | N.a. | 35.5 | Lithium-polymer battery pack | N.a. | 4 | N.a. |