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The Electric Vehicle in the Climate Change Race
Tortoise, Hare or Both?

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January 2011

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Gouvernance européenne et géopolitique de l'énergie

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ISBN: 978-2-86592-868-2

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Executive Summary

Europe is seeking ways to decrease the growing negative impact of passenger cars on climate, currently responsible for up to 12% of total EU CO_2 emissions. After biofuels in the nineties and hydrogen in 2000, the new answer to climate change appears to be electric. But contrary to many marketing messages, electric cars are not zero emissions cars. They will not necessarily contribute to actual CO_2 emission reductions before 2020 and even then, not in every country. In EU Member States where the power sector is based on coal, they could actually make things worse. In others, bad management of the charging function could increase peak load requirements and cause investments in fossil-fuel-fired power plants. Finally, electric vehicles and related costs are very high. Not only does this cast doubts on the extent and timing of their eventual market breakthrough, but it may also mean that their CO_2 tone abatement cost is high.

Nonetheless, for the longer term, CO_2 emissions from conventional vehicles can only be reduced to a certain extent whereas the potential for electric vehicles plugged into a decarbonised electricity grid approaches zero. If electric cars are to help to reduce CO_2 emissions significantly in the future, Europe needs to start now to develop this promising mitigation tool. There is in theory almost no constraint on the electric vehicle becoming a “zero emission vehicle”, while conventional car will always have to burn fuel.

Main Findings

This paper finds that drawing firm conclusions on the real CO_2 savings potential of electric vehicles belongs to the myth of Sisyphus. We roll the heavy ball of electric vehicle technology work up the hill, only to have lack of progress in power generation, infrastructures, batteries, prices all or individually send it rolling back down: the number of variables bearing on the CO_2 abatement outcome is impressive, statistics often incomplete, methodologies for assessing net CO_2 emissions unclear, and circumstances vary greatly from place to place.

This paper also demonstrates that results of CO_2 savings studies cannot either be generalized to the entire European Union. Based on market forecasts for the state-of-the-art in power production, it appears that the electric vehicle is not a substantive way of reducing CO_2 as compared to other car technologies, and surely not a cost effective one. Even in some countries, such as France where the electric car could be a medium term solution, several challenges have first to be addressed.

This paper concludes that CO_2 abatement is not currently the main driver behind the push for electric vehicles, at least at the European Level or in particular in such countries as Germany or Poland. The support for electric vehicles can be seen for now to be as much or more an industrial rather than a climate change policy. Introduced in an sustainable system, the electric car could nevertheless be a critical long term, solution. This paper finds that green credits were too easily granted to the electric vehicle.

Main Recommendations

This paper encourages greater investment of public money in Research and Development instead of subsidizing immature products. It suggests to review the purpose of transportation policies and their carbon assessment methodologies thoroughly, to find a way of assessing the cost effectiveness of the electric vehicle as a climate mitigation tool. Finally, Europe should be clear about its policies. If this is more about propping-up Europe's shaken car industry using the label of green growth, or decreasing oil dependency, then policies would be more effective if they were tailored to those objectives. Announcing the electric vehicle as a winner hare in the race for CO_2 cuts, might end up being counterproductive and expensive.

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Introduction

To win a race, the swiftness of a dart
Availeth not without a timely start.
The hare and tortoise are my witnesses.
Jean de La Fontaine, 1668

The fully electric car and its younger cousin the Plug-in hybrid, have recently met with success both in the public and private sphere. At the 80th Geneva Motor show in 2009, car manufacturers advertised a broad range of electric cars. A year later in the 2010 Paris Motor Show, electric vehicles were allocated an entire warehouse equipped with a car track -impressive. One could drive a sample: it runs, it brakes, it turns and it is pleasantly silent; in sum it has now became a real car. Even German carmakers, previously very cautious about promoting this new technology, not really suitable to large and powerful cars, have apparently changed their strategies towards electric cars, or at least talking the talk. Last but not least, governments support the trend in their communications and budget without hesitation. Billions of Euros are indeed being invested by some EU Member States on research programmes, sales subsidies, project demonstrations or infrastructure development. Similar initiatives are taken on the world stage. China is strongly pushing for the development of the electric vehicle in its market with no less than $15 billion. The US is focusing on research programmes, and Japan targets a 50% share of green vehicles in its internal market for 2050. But why is the electric vehicle recently meeting with such success?

In fact, electric cars are not new. They were invented well before internal combustion engines came into existence. But already by the late 19th century they were replaced by gasoline-fuelled engines running long distances on cheap oil. Several unsuccessful attempts were made to push them back on the market after the 70s oil crisis and in response to US air pollutions laws in the 90s. In Europe even, the repeated attempts to invade the niche market of captive utilitarian fleets in the 80s and again in the 2000s were set backed. Why are we trying yet again?

There is now a new policy driver: climate change. And, in Europe, at least, electric vehicles are presented in the public discourse as a solution to the world's raising CO_2 emissions. The fact that Europe needs to cut emissions from transport if it wants to reach its Kyoto objectives, and more, is a commonplace. The transport sector now accounts for a quarter of EU CO_2 emissions, and passenger cars alone for 12% of total EU emissions. CO_2 emissions from transport will almost double in Europe by 2050. Hence transport looks like a good place to start if emissions are to be decreased. However, while public money starts to flow into a new technology development with the stated objective to reduce CO_2, it needs to be worth the effort. Europe is struggling with the side effects of the 1990s biofuels wave, which did not deliver on its CO_2 promises, and the 2000s hydrogen has gone out of fashion. If all players have entered the electric vehicle game, it is time to look at the menu.

This study focuses on "new generation" electric vehicles, i.e. those which can be connected to the grid. Two types in particular are examined: Battery-electric vehicles (BEVs), vehicles running solely on a battery charged from the grid, and Plug-in Hybrids (PHEVs), relying both on power from the grid and internal fuel combustion. Hybrids (HEVs) have already been introduced on the market; they consist of an internal combustion engine backed by a small battery. Yet the technology is quite different, and they are not considered as electric vehicles in this report.

This paper focuses on the EU level. As electricity is not fully integrated at the European level, the impact of an EV on CO_2 emissions will yet vary from a country to another. In this respect, a few countries have been chosen for review on the basis of their electricity mix, their electric vehicles forecast if any and the availability of data on transport, power etc.: France which benefits from its nuclear park of low CO_2 emissions and has an ambitious plan to support the roll out of EVs; Spain, active in the debate and investing huge amounts in renewable; Poland a new member state running mainly on coal; Germany running mainly on gas, coal and lignite and home to a large vehicle park; the UK was chosen for its interesting data and gas fired power sector; and finally Sweden is also included as it benefits from a low emitting power sector.

The first part assesses the CO_2 abatement of electric cars as of today which depends on the electricity mix of countries, the numbers of cars forecasted. The second part presents the future potential of electric cars despites a still very long list of uncertainties. The third and last part develops policy recommendations.

Is the electric vehicle reducing CO_2 emissions?

Electric cars are often referred to as “zero emission” cars, just as displayed recently on labels at the October 2010 Paris Motor show. They also offer low fuel consumption levels, an interesting attribute when energy security is at the top of political agendas. In this vein, conventional cars look like the transport bad boys that should urgently be replaced.

This chapter assesses this green argument. The total amount of CO_2 to be potentially saved by electric vehicles is not easy to estimate as a large number of variables have to be taken into account. Introducing electric vehicles is not only about replacing conventional cars; it is also about integrating them into the electricity network. To put things simply, driving a car on zero CO_2 emissions electricity is great for the climate but if old coal fired power plant has to be restarted to meet an increase in electricity demand for electric vehicles, is CO_2 really going to be reduced?

This chapter does not pretend to fully answer the question. Technologies and markets are not always predictable, nor is detailed information or reliable data available. It may be imprecise to judge future developments; it is nevertheless not too soon to explore the intricacies hidden in a simple political idea of cleaner transport, in order to draw some constructive conclusions.

What is an electric vehicle?

The electric vehicle is a complex technology to assess as it encompasses a variety of options. Generally, an electric vehicle (EV) is a car benefitting of an electrified power train -electrified to various degrees- and a battery - more or less powerful. The different types of electric vehicles respond to different mobility demands, and are matched by specific infrastructure needs. This section offers a brief description of technologies at their current state.

Different Car Concepts

At the lower end of electrification stand the already known hybrid vehicles. *Hybrid vehicles (HEV)* actually consist of a conventional engine assisted in its consumption performance by a small battery pack. It typically encompasses “start-stop” systems useful in urban modes. This start stop system is regenerating electricity from the braking energy system where the heat emitted by the breaks is stored in a small battery, and a small electric motor provides acceleration assistance (the consumption of fuel is higher during acceleration than at constant speeds). The small battery pack is recharged by the conventional engine solely. HEVs can achieve a 10-15% consumption reduction compared to ICEs. This study will not focus on this type of vehicle as they were introduced about ten years ago, and as their cost and CO_2 contribution is already known. Hybrids vehicles are not considered as « electric vehicles » as they cannot be plugged into the electricity grid.

At the other end of the electrification path, some vehicles have been fully electrified. *Full-electric vehicles (FEV)* run solely on a battery, charged from the power grid. They are seen as highly energy efficient, up to 85%. They offer the prospect of zero emission vehicles, as they do not emit local pollutants themselves through the burning of fuels.

At present state full electric cars offer very low driving ranges – around 100 km on average (see Annex 1 for and overview of marketed and forthcoming electric cars models). This type of car has been designed mainly for urban use. The concept fits European driving patterns: traffic statistics across Europe reveal that there are a large proportion of short trips (an average daily distance of 26km)[1].

The key element of this type of vehicle is the battery on which its costs and driving range mainly depend. Whereas past electric vehicles were less complex technologies than conventional vehicles, optimum electric power-trains (i.e. the integration of the battery in the power-train) remain today an expensiveand complex technological challenge. Current batteries do not offer long driving range at a competitive price, on average EVs offer 120km autonomy. This problem could be partially offset by increasing the density of the charging infrastructure - although not completely as charging times are still too long. The second chapter will present the technology development for the second or third generation of electric cars.

Finally, an in-between concept is the *plug-in hybrid electric vehicle (PHEV).* The PHEV stores energy in a battery on-board which can be recharged from the electricity grid, but it also has an internal combustion engine that starts either when the battery is down or when additional power is needed. The battery can also be recharged by a 'start and stop' system which stores the vehicle kinetic energy from braking.

There are nevertheless currently no clear technical definitions for Plug-in hybrids. The concept encompasses a large variety of possibilities. PHEVs can be either "series hybrids" or "parallel hybrids". In the first option, the conventional engine is used exclusively to recharge the battery; it works as a kind of generating set and cannot activate the wheels. In "parallel" driving trains, wheels can be activated by both the battery power and the engine directly (see figure below). Finally range extenders[2] can be used in addition to an electric power-train to increase by a few kilometers the driving range of a full electric car. This technology is not very well developed at present.

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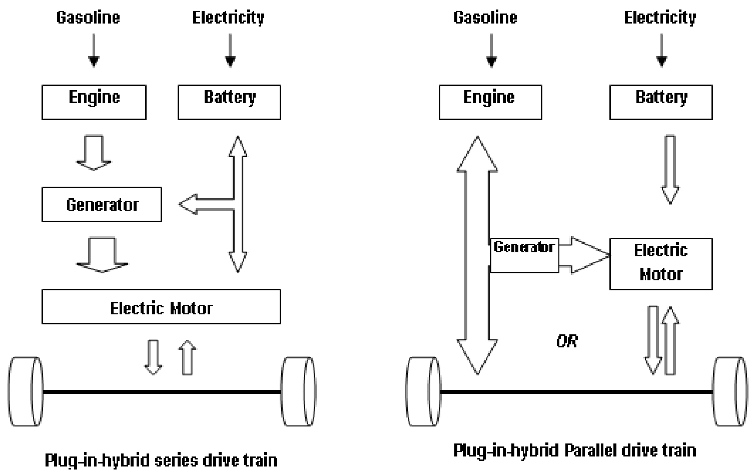
[1] [EUROSTAT 2009 bis], p102

[2] A range extender today is a very basic and small conventional motor, nothing comparable to the *developed* conventional motor used in ICE cars, or series or parallel hybrids

Plug-in hybrids are also heavier than their full electric or conventional equivalents and therefore consume more power. PHEVs show fuel consumption benefits of 25 to 30% compared to ICEs. They can cover longer distances in a purely electric mode than HEVs, but less than EVs, typically ranging from 20 to 50km[3], in some cases up to 60km.

Figure 1: Plug-in Electric Vehicles Drive trains



Batteries: The Lung of the Electric Vehicle

The main characteristics of an electric car, i.e. its price, power, life, and driving range, and ultimately its successful market introduction, depend mainly on its battery. Above all, batteries define the energy consumption of the vehicle and therefore its impact on the environment.

The basic principle of a battery is to store and release electric energy through a chemical process. In each cell of an electric vehicle's battery pack, reactions of oxidation or reduction occur between two interfaces, the anode and the cathode. Ions, positively or negatively charged circulate in the so called "electrolyte" from the cathode to the anode when charging, and the other way round when releasing energy. This process is managed by the battery management system, the so called BSM. Different electro-chemical couples have been developed and offer different characteristics.

Batteries differ in terms of their storage capacity:

- power density (w/kg) corresponds to the amount of power per unit of mass, and determines for instance the acceleration potential;

[3] [IEA 2009], p135

- energy (power over time) density determines the autonomy of the vehicle according to its battery pack weight (Wh/kg) or volume (Wh/l).

- Batteries also differ in terms of discharge cycle capacity (life expectancy).

Typically hybrids need batteries with good power density, as the battery provides mainly a periodic back up to the ICE, while on the contrary the energy capacity of a battery (autonomy) is decisive for EVs. HEV batteries also need to be able to endure thousands of partial charge and discharge cycles due to regenerative braking and providing short support in acceleration. PHEV's batteries need the two. The challenge is therefore to optimize a model providing high energy and power density for a low weight, volume and cost. Until now, battery technologies were adequate for the first generation of hybrids, further and significant development prospects were needed in particular for full-electric vehicles. Lithium based batteries offer a significant breakthrough in this respect. Please refer to Annex 2 for an overview of current (and future) batteries technologies.

The size of an electric vehicles' battery is directly linked to both its energy consumption, and its electric driving range: two key variables of an electric car CO_2 emissions. These variables are not yet regulated and they vary greatly according to the vehicle considered. Generally, the longer the driving range, the bigger the battery and the more it costs.

In its report on transport, energy and CO_2 from 2009, the IEA estimates that the average consumption of FEVs at the current technological status is estimated at 0.2KWh/km (for a 5l Volkswagen golf type of car) likely to evolve to 0.1KWh/km for small urban vehicles4. Full Electric Vehicles therefore need a lithium battery pack of roughly 30KWh for a 150km driving range, and PHEV an 8KWh battery pack for a 30 to 40 km pure electric driving range5.

As most electric vehicles, are still far from commercialization, and in particular PHEVs, there is very little data on battery performance of the vehicles. It is also therefore very difficult to give an accurate estimation of cost. Annex 3 gives some examples of batteries currently used in the new generation of electric vehicles6. In the long term substantial decreases of battery costs are expected, as well as significant improvements in battery consumption. For an overview of battery characteristics and costs in the near and long term, see the table below.

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[4] Ibid, p149

[5] [IEA 2010] International Energy Agency, Transport, *Energy and CO2,* p147

[6] Please note that as most of these cars are not commercialised yet, numbers given are estimates available in the press, mainly found on the following website: www.greencarcongress.com. For the full list of sources, please refer to Annex 1.

Table 1: Types of Batteries and Costs

	Battery	Timeline	Energy (KWh)	Power (kW)	Weight (kg)	Battery Cost/KWh	Total Battery Price
Conventional Hybrid (HEV)	NiMH	Near term	1.0	45	35-50	750-830	750-830
	NiMH	Long term	0.5	45	30-40	560-640	250-290
	Li-ion	Near term	1.0	45	15-25	760-1000	760-1000
	Li-ion	Long term	0.5	45	10-20	460-700	210-320
Plug-In Hybrid (PHEV)	Li-ion	Near term	8	75	45-65	570-755	4600-6000
	Li-ion	Long term	6	75	30-50	420-645	2500-3900
Full electric (FEV) – 150 km range	Li-ion	Near term	33	75	180-240	470-620	16000-20000
	Li-ion	Long term	27	75	130-200	350-530	9000-14000
Full electric (FEV) - 200km range	Li-ion	Near term	44	75	235-315	445-590	20000-26000
	Li-ion	Long term	36	75	170-270	330-505	12000-18000
Full electric (FEV) – 400 km range	Li-ion	Near term	88	75	415-555	405-535	36000-47000
	Li-ion	Long term	72	75	310-470	300-460	22000-33000

Source: IEA (2009), Transport Energy and CO_2

Various charging systems

The most basic, and currently most widespread form of charging, consists of plugging the car into standard residential or commercial sources of electricity, i.e. at home or in a parking place. The domestic electric capacity of households usually starts around 3KW and goes up to 12KW. A normal domestic plug can provide up to 3 KW. The more powerful the electricity network, the faster the vehicle will be charged. The voltage and amperage of a plug determine the amount of electricity transmitted (KW), which in turn therefore directly defines charging times. This type of charging uses 230V at 16-Amps. This means that a 150 km driving range electric vehicles, with a battery capacity around 30 KW will take around 6 to 8h to be fully charged.

Semi-fast charging requires a higher power capacity; usually about 7-10 KW (230 V; 32 Ampere). It allows the vehicle to be charged in 2-4 hours. This higher voltage can be provided either by a tri-phased alternative current or direct current. This is a mode favored in Germany, where many homes have tri-phased alternative current contrary to France where homes are equipped with mono-phased plugs (up to 3KW).

Finally, fast charging systems allow vehicles to be charged in less than 30 minutes thanks to a very strong electric current. However the fast charging curve is not linear. This means that fast charging is optimum until 80% of the battery charge. The remaining 20%

charging take much longer. This explains why many manufacturers announce only partial fast charging time (80% charge in 20 minutes for instance). Labeling might be misleading for the consumer, charging may take 10 minutes for 80% but it does not mean that it will take about 12 minutes to fully charge the car[7].

See Annex 4 on the duration of charging for a sample of cars. Three observations can be made.

First, the labeling of charging systems is not clearly defined yet. While the European Commission uses standard – semi fast – fast charging categories, the reality is different across the Atlantic. In the US, standard charging uses domestic plugs with a 110 voltage.

Second, the driving ranges of the current generation of electric vehicles are still low as battery capacities are still limited. Having access to a dense network of charging stations cannot be an appropriate solution to overcome this bottleneck as long as charging times are more than a few hours. In this respect new and faster charging technologies have been developed. There are nevertheless serious challenges associated with these developments, be they cost or technology related.

Thirdly, each of these systems present benefits and limits.

The cheapest and most practical is probably the standard type. This requires no significant additional distribution infrastructure. Despite the fact that this charging process is slow, if not very slow, considering that a car is parked about 90% of the time this could still be a viable option. However, the European Joint Research Centre estimates that only 10% of car purchasers currently have access to a parking facility containing a plug at home. Moreover some equipment will still be needed. Technically the charging of a battery is done with a direct current (DC) while in Europe electric current is distributed in an alternating form (AC). A power converter (such as chargers for mobile phones for instance) -combined with a cooling system- is therefore needed if the vehicle is plugged into a normal plug.

Fast charging is much more problematic. This type of charging requires significant energy - around 50 kWh against 3kWh for a home charge. This is expensive as it requires specific DC connections. A large amount of heat is also produced due to the high voltage involved. Specific cables and chargers are consequently needed to ensure security. Additionally, batteries are vulnerable to severe damage, and techniques to offset this problem usually affect battery life-time.

Some inventive business models are proposing alternative technologies. Better Place, a Palo Alto, California-based company, invented a battery swap process. The car depleted battery can be

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[7] Elegie for instance is a European project encompassing several companies (Renault, Siemens, Fiam ABB, Sagem and EDF the French power company) studying a fast semi fast charger that could recover 50% of the battery autonomy in less than 15 minutes. A Japanese based company JFE has also developed an ultra fast charging station able to recharge a 16KWh battery pack up to 50% in only three minutes. This means that a small car could be recharged up to 70% in 5 minutes and a larger car in about 10 minutes [CARS 21 6 july 2010]

replaced by a freshly charged one in less than 3 minutes[8]. However, there are doubts whether EV companies would be ready to standardize their core competitive feature i.e. their batteries. Indeed the forms and connections of batteries would need to be similar. Secondly, swapped-batteries will most probably be charged with a fast charge, therefore this solution confronts the same problem mentioned above.

Examining the realms of electric and conventional vehicles CO_2 emissions

Compared to the conventional internal combustion engine, full electric cars driven on European roads appear as environmental winners for the next decades.

Automobile CO_2 emissions rate (in g per driven km), are usually evaluated tank-to-wheel. This method looks only at the CO_2 emissions produced through the vehicle fuel consumption i.e. it considers mainly the energy efficiency of the car. Contrary to conventional vehicles, electric vehicles present the advantage of emitting no CO_2 on a tank-to-wheel basis, as power is provided to the wheel without the internal combustion of fuel. Tank to wheel, a car can be considered as “zero emission vehicle” when it runs solely on electricity.

Electric cars, in particular full electric vehicles, also appear much more efficient than conventional vehicles. For the same distance, a report conducted for the French prime minister in 2008 concluded that conventional cars need up to three times more energy than lithium-batteries electric cars[9].

The CO_2 emissions of plug-in hybrids are more difficult to estimate. Indeed, there is a large range of PHEVs, the number of kilometers driven on electric mode can fluctuate (the longer the journey, the more the car will be driving on conventional fuels and the more it will pollute), the consumption -on electric mode- will probably be higher than for a full electric car (if only because the car is heavier), and it is not clear whether its conventional engine will be efficient.

As it is almost impossible to define a small bracket in which to place Plug-in hybrids, most studies assessing new vehicles technologies contribution to CO_2 reduction efforts have mainly focused on pure electric vehicles as compared to conventional ones, assuming that plug-in hybrids technologies should score in between.

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[8] Renault-Nissan already signed a partnership to equip some of their vehicles (Zoé, Leaf and Fluenz) with this technology. Demonstration projects will take place in Israel and Denmark.

[9] According to the report, Gasoline, NGV, Hydrogen and LPG vehicles are the least efficient tank to wheel (around 30-35%); diesel vehicles have an energy efficiency average of 40-42%. Electric vehicles achieve efficiency levels up to 80-85% [SYROTA 2008, p48].

An electric car has neither tailpipe emission nor smell of unhealthy gases - but it would be too easy to think that emissions simply don't exist. In fact they come from elsewhere: in the process of bringing that electrically charged vehicle to the road. A meaningful comparative assessment of CO_2 emissions from different types of cars has to include both emissions from the vehicle itself and emissions generated by the production and distribution of the fuel needed to drive this car, i.e. the carbon factor of the fuel (gasoline, diesel, biofuels or electricity). This full assessment is called a *well to tank* assessment. The entire methodology is called a *well- to-wheel* assessment.

In order to calculate the CO_2 emissions of an electric vehicle, its (electric) consumption (in Wh by km) has to be multiplied by the CO_2 gases emitted to produce the kWh of electricity consumed (the carbon factor of electricity in g/kWh). There is a variety of estimations for the EU carbon factor of electricity. The most well known are the Primes model and Eurelectric, the federation of power companies, own estimates. For 2007, it was estimated at 390.2g CO_2/KWh by Eurelectric[10] and estimates for 2010 will be probably lower.

Tables below show the CO_2 emissions of electric vehicles. The first table gives approximate CO_2 emissions level of electric cars based on standardized consumption levels (as set by the International Energy Agency); the second displays the CO_2 emissions of electric cars samples (in different categories), for which consumption levels are already known[11].

These approximate results reveal that full electric cars, with the current power structure of the EU27, will emit little CO_2 (from 58 to 70gCO_2/KWh). This represents only half of the current average conventional vehicle, and still less than binding fleet emissions levels set for 2020[12].

However, despite being widely used to promote the electric vehicle as a green car, the results obtained in the two tables above should not be taken for granted. Several elements presented in the following parts challenge this conclusion. Firstly, averages distort the reality; secondly the standardized test to evaluate vehicle fuel consumption is biased in favor of electric vehicles; moreover if the CO_2 assessment is extended to the car production and recycling (i.e. a life cycle assessment), the electric vehicle slips a bit off its green podium.

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[10] [EURELECTRIC 2010] 4th Environment and Sustainable development report 2007-2008 (EU 27 emission factor of electricity is available two years after. Therefore, only 2007 estimates have yet been released). The European Commission forecasts a slightly slower estimate for 2010 386gCO2/KWh reflecting more renewable and gas.

[11] Only a few manufacturers have released consumption level up to date.

[12] The CO2 emissions average of the European car fleet is around 160gCO2/km[12] and about 203gCO2/km for vans. The evolution of the European car fleet is guided by the European Commission new compulsory CO2 emissions targets for passenger cars: 130gCO2/km by 2015 and 95gCO2/km by 2020. Likewise emissions from vans have just been fixed at 175gCO2/km by 2017 and 147gCO2/km by 2020 to be confirmed in a review set for 2013.

Table 2: CO_2 emissions per km for Full Electric vehicles based on the current power sector emissions estimates (in gCO_2/km)[13]

	Average Power Sector CO_2 Emissions (g CO_2/kWh)*	FEVs* emissions (consumption 0.15kWh/km) (g CO_2/km)	FEVs emissions (consumption 0.2kWh/km) (g CO_2/km)
PRIMES 2008 Baseline Scenario	465 (2005)	70	93
PRIMES 2009 Baseline Scenario[14]	386 (2010)	58	77.2
Eurelectric Baseline Scenario	**410 (2005)**	**61.5**	**82**
Eurelectric	**390.2 (2007)**	**58.5**	**78**

Source: author calculation based on Eurelectric 4th environment and sustainable development report 2007-2008 [EURELECTRIC 2009], Eurelectric Power Choices [EURELECTRIC 2010], European Commission [PRIMES 2008]

Table 3: Emissions for selected Full Electric Vehicles

Vehicle	Consumption KWh/100km plant-to-wheel	Driving Range km	CO_2 emissions g/ CO_2 (based on EU electricity mix 410gCO2/KWh)	CO_2 emissions g/ CO_2 (if electricity is produced by a coal fired plant over 100g CO_2/km)
Reva-i (small urban car)	**11**	**80**	**45**	**110**
EV1	**11**	**120**	**45**	**110**
QUICC! (van)	**39**	**100**	**175.5**	**390**
Tesla Roadster (sport car)	**34.4**	**220**	**141.04**	**344**

[13] Estimates of EVs consumption are given in the first part. A battery-electric car similar to a Volkswagen would consume about 20KWh/100km according to a study published by the European Topic Centre on Air and Climate Change. The IEA bases its technology roadmap on an average fuel efficiency of 0.2KWh/km this means a 150km powered by a 30KWh lithium battery [IEA 2010, p16], evolving to 0.15kWh/km. These numbers appear taken as basis for the following estimations.

[14] Results obtained by the conversion of the PRIMES 2009 baseline scenario average emission factor for electricity in tCO2/TJ, data presented in [JRC 2008, p21]

The problem of inadequate European Energy Efficiency Standardization Tests

Consumption estimates, and therefore CO_2 estimates, are made on the basis of New European Driving Cycle test (NEDC), standard to all EU countries. This standard test was initially set up to permit standardized comparisons of conventional vehicle consumption under simulated driving conditions supposed to reflect those found on European roads. On the basis of their consumption levels, their CO_2 emission rate was established.

However, these tests do not actually reflect reality. Specialized engineers have long been the only players selected to play this simulation game, so as to score as well as possible by adjusting their driving. Under real driving conditions with less experienced drivers, cars are definitely less efficient. The test conditions are also biased in favor of electric vehicles.

Firstly, they do not take into account the consumption of on-board appliances, which could in the case of an electric car significantly alter the results. In total, appliances could add up to 10% onto the final consumption (20% in extreme cases)15. For instance, in a traffic jam with an external temperature above 30°C, the autonomy of a berline, such as the Nissan Leaf, could be reduced from 160km to less than 80km because of the use of air conditioning16. Recent press announcements confirmed this problem by revealing that the Leaf driving range could fluctuate from 100 to 260 km17.

Secondly, the test format appears inadequate. In these tests, extra urban cycles represent only one fifth of the test time while plug-in hybrid consumption on motorways is almost double that in urban settings18. This is also the case for battery electric vehicles, although to a lesser extent. These consumption fluctuations are confirmed by manufacturer's data. According to Renault, an electric vehicle's consumption on highways is twice that in cities. This loophole should however not be exaggerated, as long as full-electrics and plug-ins are considered for urban use.

Thirdly, tests are performed on cars with a fully charged battery. Charging losses are therefore excluded from the fuel consumption evaluation, whereas according to interviewed experts chargers for EVs lose about 15 to 20% of the total energy required for a full battery charge. This means that in total, EVs consumption is in reality 20-40% higher than under the NEDC cycle, against 20% higher for ICEs.

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[15] on-board appliances could in the case of an electric car significantly alter the results: air-conditioning or heating of the vehicle requires from 1 to 3KWh, and other types of equipments (radio, lighting etc.) from 0.6 to 1KWh [SYROTA 2008, p48].

[16] Source: http://www.automobile-propre.com/2010/06/21/autonomie-de-la-nissan-leaf-fait-aussi-du-bruit/

[17] (62 to 138 miles) Source: Nissan USA at http://www.nissanusa.com/leaf-electric-car/tags/show/performance#/leaf-electric-car/range-disclaimer/indexhttp://www.nissanusa.com/

[18] In 2007, the IEA estimated that the consumption of PHEV on motorways was around 26-27KWh/100km, while being only 12-13KWh/100km in inter-urban cycles and 14-15KWh/100km in urban settings.

Finally, these tests are conducted with new vehicles. This does not reflect the fact that electric vehicle efficiency decreases significantly over their life time due to the wearing of the battery.

To conclude, NEDC tests based on standardized conditions rather instead of in field tend to distort the green competition between electric - in particular plug-in hybrids - and conventional cars in favor of the former.

Electric cars batteries are polluting to produce and hard to recycle

A life cycle assessment of a product includes the raw material extraction and production, the manufacture, its distribution, and its use and end-of-life. The production and disposal of current conventional vehicles account for a significant 15% of their life time CO_2 emissions[19], this number could be higher in the case of electric vehicles. In particular, battery production and recycling are the core issues. A study conducted for the UK department of transport concluded that 13% of life cycle emissions were due only to battery materials extraction[20].

Lithium battery production seems also to have a higher impact on water use and quality. Last but not least, they are more difficult to recycle than other types of batteries. Laptop batteries, using nickel cadmium or lithium, have quite a low recycling rate. Lead acid batteries used in conventional cars are on the top-ten list of recycled batteries with a rate of 97% recycling according to Johnson Control, the leader company in the area. Nickel Metal Hybrid batteries actually contain highly valued metals such as nickel and cobalt that can be used in the steel industry. The process of recycling lithium is unfortunately more complex and there is little market opportunity as these batteries contain little raw material. Consequently, there is limited battery recycling capacity in Europe, in particular for lithium batteries (please refer to the table in Annex 5).

To complement their electric vehicle strategies, governments are therefore subsidizing the development of recycling facilities21. In

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[19] The production of a 1-tonne vehicles emits about 5.5 tonnes of CO2 according to the ADEME [ADEME 2007]

[20] This depends on type of lithium extraction process, as there are more or less carbon intensive techniques for producing lithium, from mining to sea water extraction. Please refer to [ETC/ATC 2009, p 30] and *to Toyota 2005 life cycle assessment of hybrids versus conventional cars.* The report finds out that in the case of hybrids, production represent 13% of CO2 life cycle emissions added to 32% due to material production, in the case of conventional diesel cars production accounts for 6% of total emissions added to 12% of material production [A.I. february 2005] *data available at* http://findarticles.com/p/articles/mi_m3012/is_2_185/ai_n12937459/.

[21] In the United States, *Toxco Inc.* was awarded $9.5 million by the US Department of Energy (DoE) for its facility in Ohio in February 2010. The firm initially recycles large format lead acid batteries and nickel metal hybrid batteries used for hybrids and for the second generation of electric vehicles [GREENWIRE 21 June 2009] Nissan also recently signed a joint venture with *Sumimoto Corporation* to recycle precious metals of EV batteries http://www.sumitomocorp.co.jp/english/news/2010/20100915_090010.html. Through its LIFE project, the European Commission allocated €380 000 to a joint French-Belgium research project on lithium battery recycling. Some small facilities or research projects are currently present in Europe: In October 2003, AEA Technology

Europe, producers are held responsible for processing batteries under the 2006/66/EC directive. This European law does not include specific provisions for lithium batteries. It states that 50% of average battery weight should be recycled, excluding energy recovery. If no end market use is found, batteries components can either be stored or exported22.

Electric car batteries could require more frequent changes than conventional ones. On average lithium batteries have a life expectancy of 10 to 15 years, and their capacity decreases over time as a battery can only tolerate a finite number of cycles. Their life expectancy is also a function of driving patterns and weather conditions23. Life cycles of lithium batteries range from 500 to 1000cycles only half of the NiMH batteries, used in hybrids24. Numbers also vary greatly according to the model considered. For instance, the Tesla Roadster, a sport car model, has a battery expectancy of only 7 years (160 000km). The batteries run at 70% of capacity after 5 years of 160 000km driving range25; this is far from the current ICE life expectancy. The frequent renewal of the fleet will have an impact on the product CO_2 life cycle assessment.

Comparing Apples and Oranges: small urban electric car versus the European car fleet average CO_2 emissions

Comparing an electric car CO2 emissions pattern with an average of the European car fleet is like comparing apples with oranges. The European car fleet is composed of old, big and long-driving-range vehicles while electric vehicles are small urban vehicles. An overview of existing conventional car models shows that car emissions range from 86g CO_2/km to more than 460g CO_2/km[26]. Moreover, if full electric vehicles and plug in hybrids were to achieve the same driving range as conventional cars, the picture could well shift. In the current technological state, increasing the autonomy of FEVs and PHEVs would add significant weight to the battery and therefore not only to the price of the vehicle but also to its consumption. This led Evert Geursten and Julian Wilford to state that the “call for real electric cars

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(AEAT) launched a £2 million research and development facility in Sutherland, north Scotland for lithium-ion and lithium-polymer; Citron and Recupyl in France

[22] [EU Directive 2006/EC/66]

[23] ERTRAC states that the lifetime of a battery is halved every 10°C of temperature increase, requiring therefore complex conditioning systems [ERTRAC 2009], p7

[24] [SYROTA 2008] p74. Lithium phosphate batteries have greater life expectancies, around 2000 cycles; but lithium polymer achieve only around 200-300 cycles.

[25] Source : http://www.teslamotors.com/blog2/?p=39

[26] To give some examples: The urban car smart fortwo (86gCO2/km) or other small cars such as the Nissan Pixo (103gCO2/km), the new VW Polo Blue motion (87gCO2/km), the ford fiesta ecoetnic (98gCO2/km) or the opel corsa ecoflex.. The French governmental agency established a classification of low polluting cars available on the French market, available on the following link: http://www.ademe.fr/auto-diag/transports/rubrique/CarLabelling/Top10dies.asp. For larger cars, Hybrid vehicles like the Honda Insight (80gCO2/km) or the Prius (89 to 104gCO2/km), or the forecasted Peugeot 308 with less than 90gCO2/km. or the also score well According to the ADEME, 50% of new car sales in 2009 emits less than 120gCO2/km, 75% of new vehicles are under the 140gCO2/km threshold. France is leading in terms of low emissions vehicles in Europe, with an average sale of 133gCO2/km. Three manufacturers are almost already complying with the 2030 average CO2 emissions of fleet: Toyota and FIAT with a 127g average, followed by PSA (130gCO2/km) and Renault (131gCO2/km). The German ADAC

should be resisted" from a commercial, societal and environmental perspective[27].

A fair comparative assessment of cars CO_2 emissions, should consider cars equivalent in terms of size, weight, consumption and range.

Plugging electric vehicles into European grids

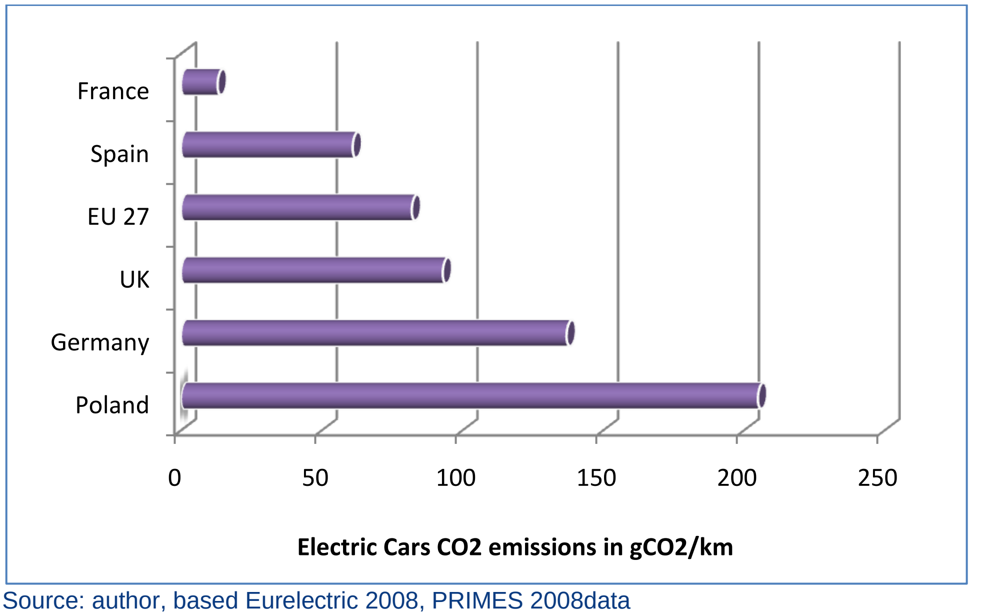
Electricity mix and electric cars: green or grey?

To compare the carbon benefits of car technologies against the average conventional car is biased, but it is also wrong to calculate electric vehicle carbon factors on the basis of the average *European* electricity carbon factor as there is in reality no such thing as a European electricity carbon factor because the power structure varies so much among and within Member States, and because the European electricity grid is not well integrated. The well to tank carbon assessment will therefore shift from one country to the other (please refer to figure 2 below and Annex 6).

In France where most of the electricity is produced with nuclear power, CO_2 emissions low. In Poland on the contrary, where electricity is mainly coal-based, and in particular brown coal, an average electric car in Poland has a worse carbon footprint than the European conventional car fleet average (205gCO_2/km compared to 160gCO_2/km).

Figure 2 below reveals that, introduced on the market now, the same electric car pollutes twenty times more in Poland than in Sweden. In some EU member states, electric vehicles will aggravate emissions rather than provide a solution.

Figure 2: Comparing electric vehicles CO_2 emissions for the Power sector across EU Member States



Source: author, based Eurelectric 2008, PRIMES 2008data

[27] [AVERE 2009]

Emissions are calculated on the basis of a 0.2kWh/km consumption.The power sector carbon factor data used for the graph is available in Annex 7.

Targeting the right charge timing

The extra electricity demand for electric vehicle charging will be produced by different types of power plants according to when people charge their vehicles. Across Europe, the carbon factor of the power sector at peak, medium or base load varies considerably[28].

The carbon factor of peak, medium and base load power plants varies across EU Member States

Different types of power plant are used to cover the different level of demand (peak, medium and base load). In case of a demand peak, plants which can be switched on faster and whose production can be easily adjusted are used[29]. They include fuel fired power plants; gas and coal thermal power plants as well as oil fired power plants as a last resort. Conventional gas turbine power plants have a lower thermal efficiency than combined cycle power plants and higher running costs (offset to some extend by low capital cost). These Gas combined cycle turbines as well as pumped storage power plants can also be used. Last but not least, some wind turbines can eventually be switched on to cover peak demand, but wind cannot be ordered. The intermittency of renewable makes it difficult to use as primary source to cover peak periods. On the other hand, Hydropower, coal and nuclear power plants are used for base load or intermediate power requests (in particular older coal plant).

The types of power plants used to cover the different levels of demand vary across countries (please see the graphs in annex 6).: in Germany coal, lignite and wind are used as base load electricity sources while gas is still the preferred source for peak load management though increasingly used for base load too. French base load is mostly nuclear, while pumped storage hydro, gas, coal and oil are all used in cases of peak demand. The UK uses nuclear, coal and wind while gas is the main source for peak load management. It is yet very difficult to know the exact electricity mix of a member state at a specific point in time, due to the sensitiveness of this data for companies. Some utilities though do reveal it, as for instance RTE the French distribution network or RED electrica, the Spanish electricity grid, annual statistics. Yet there is no sufficient data to make a precise comparison of how much a car will pollute

[28] Electricity demand varies according to seasons, time of the week and time of the day. The electricity consumption is usually higher in winter due to heating, lower during week-ends as many industries run at a slower pace, and lower at night and in summer. Electricity demand is divided into different levels: base load demand, middle load demand and peak load demand. In winter, peak demand loads usually occurs between 6pm and 8pm and in the early morning. In summer, consumption is lower in summer due to a lesser need for heating and lighting; and the demand curve is also more flat. In some countries however, the tendency is reversed. Spain for instance reflects the southern reality, where air conditioning leads to higher demand consumption in summer.

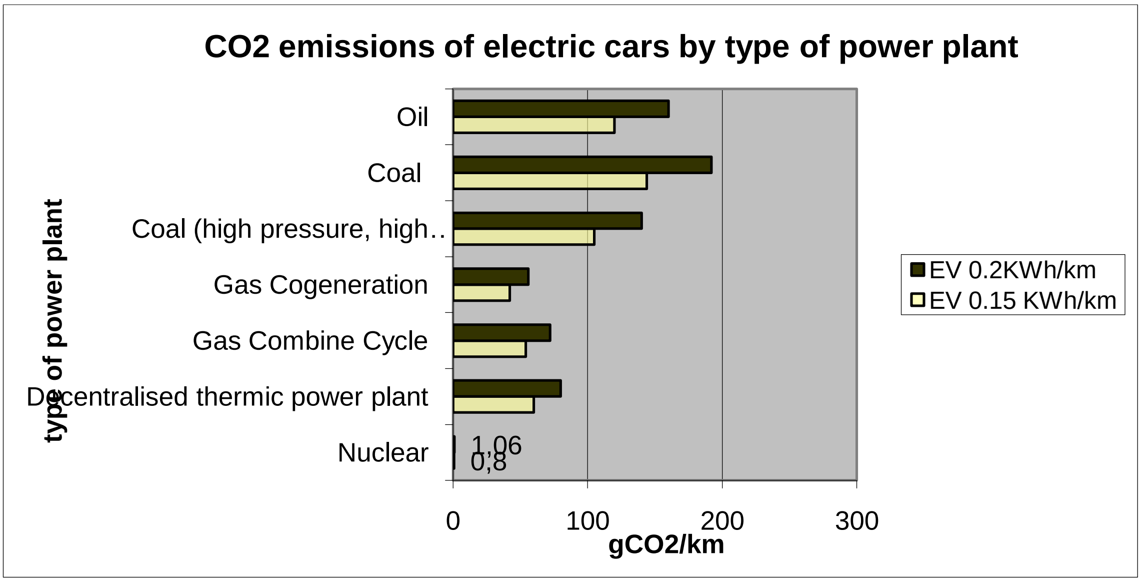
[29] Some types of hydroelectric plants (pumped and storage) are also operated to cover peak demand for electricity. Conventional hydro plants (using the energy potential of dammed water to activate a turbine) can also be used punctually, mainly in emergency situations so as to avoid electric black out but water then have to be stored again).

while being charged at peak hours in Germany, France, UK, Sweden and Poland. ENSTO-E gives some data of annual demand coverage across countries.

Depending on the grid mix at a given point in time, the introduction of electric vehicles could decrease or increase CO_2 emissions as compared to conventional cars. In general, the CO_2 emissions of peak load power plants are higher than base-load power plants. Therefore if cars are being charged at peak load, they will emit more CO_2 than if they are charged during the night. However, this is only true in countries with low emitting base load power, such as France or Sweden. In countries with highly polluting base load power, like in Germany or in Poland, charging at peak load could generate less CO_2. If the primary source of electricity is coal, and in particular low efficient coal power plant, CO_2 emissions could actually be increased by the use of electric vehicles[30]. And yet an electric car charged at peak load in Germany emits less than an electric car charged at peak load in the UK, in France or in Spain, and of course less than if it were charged during base load in Germany.

The figure below reflects the CO_2 impact of an electric car according to the primary source of the electricity used for charging. It appears that an electric car running on coal will actually exceed the 130gCO_2/KM threshold fixed by the European Commission as a mandatory fleet average for 2015, and pollute as much as 100 times more than a vehicle running on nuclear electricity.

Figure 3: Electricity Primary Source and Electric Cars Emissions



Source: RTE 2010, ADEME 2008, FRANCE SCEE 2010[31]

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[30] Studies published by WWF reveals that if EVs are runing on electricity produced by coal power plants, the CO2 benefits would actually be negative up to -38% [ETC/ATC 2009], p96.

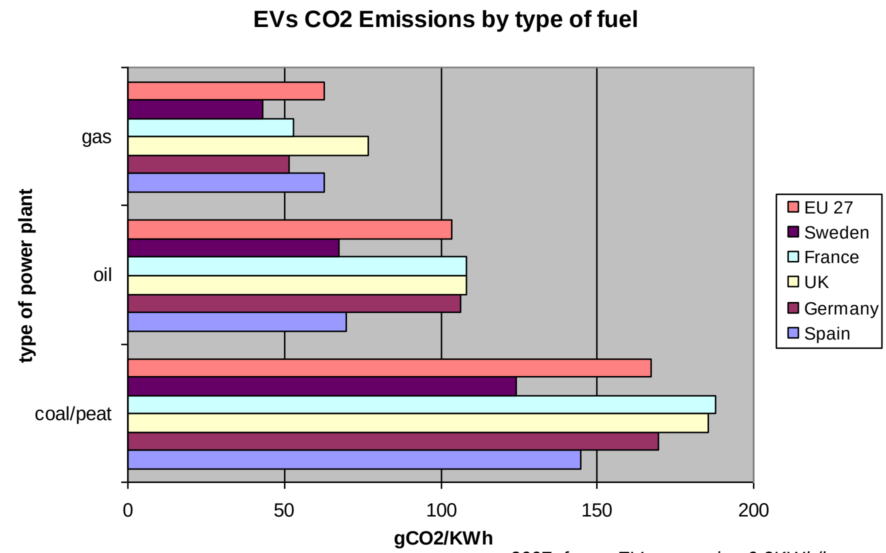
[31] There are some data for the CO2 content of fuels. However it is more difficult to find estimations of CO2 emissions by the type of power plant. RTE the French distribution company publishes some estimates on its website: http://www.rte-france.com/fr/developpement-durable/maitriser-sa-consommation-electrique/consommation-production-et-contenu-co2-de-l-electricite-francaise. Other sources include Eurelectric 2005 data and GEMIS 2005. For the Gas Cogeneration

Additionally, the same types of power plants have different efficiency levels across EU Member States. A vehicle running on electricity made out of gas is likely to pollute more in France, where gas power plants have low efficiency levels, than in Germany.

France for instance has a very low average CO_2 emission factor for electricity, yet its fuel fired power plants score quite poorly in terms of efficiency. The emission factor of French electricity for peak periods is consequently twice that of its base load, i.e. 85gCO_2/KWh against 45gCO_2/KWh[32].In Germany on the contrary, electricity in base load hours comes mainly from coal and lignite fired power plant while gas, a less polluting source, is used for peak load power generation. Some countries are also importing electricity with a higher electricity CO_2 emission factor to cover peak load. This is for instance the case of Austria.

The impact of conventional power plant efficiencies on electric vehicles CO_2 emissions EU Member States is visible in the table below. A vehicle charged with electricity produced out of gas in France is more polluting than a vehicle running on gas in Germany.

Figure 4: Conventional Power Plants and Electric vehicles CO_2 Emissions



Source: on the basis of IEA CO2 emissions by fuel consumption for 2007, for an EV consuming 0,2KWh/km

CO2 emissions factor, two numbers are given by ADEME which depend on the turbines technique and efficiency: 230gCO2/KWh and 280gCO2/KWh. The second value is taken in consideration in this graph. Renewable electricity emissions factors are not included as they largely vary. Yet they should not be considered as zero emission sources. Depending on their location, according to a life cycle assessment, Solar photovoltaics emits from 60 to 58gCO2/KWh; Wave and tidal from 25 to 50gCO2/KWh; hydro dams (storage) from 10 to 30gCO2/KWh; hydraulic run of river less than 5gCO2/KWh; onshore wind 4.64gCO2/KWh and offshore wind 5.25gCO2/KWh; nuclear about 5gCO2/KWh [UK PARL 2006, p3]. The following link also gives estimates of renewable life cycle assessment of CO2 emissions: http://www.nirs.org/climate/background/sovacool_nuclear_ghg.pdf

[32] [KHT 2009], p86

If the charging of electric vehicles is unmanaged, the CO_2 outcome could shift dramatically, even in countries where the power mix is not emitting much CO_2. The most likely times for vehicle charging (in the evening and at midday) actually correspond to peak electricity demand.

The first conclusion is that the electric vehicle cannot be assessed without knowing the energy mix and electricity grid context. No sustainable environmental electric vehicle policy is possible without a sustainable power sector.

Saving CO_2 in niche markets

The potential of CO_2 savings to be achieved with electric vehicles is also limited by sales forecasts. The full electric vehicle in particular is expected to be a niche market, and the first plug in hybrids will not be ready before 2015. Before 2030, sales will probably remain low and the fleet share thereof. This is proven by the small numbers of models developed by carmakers, and confirmed by serious forecasts and governmental targets.

Carmakers target niche markets

The short term market for pure electric battery vehicles is a niche. This is clearly reflected by the type and the small range of models presented by manufacturers. Few manufacturers, perhaps only Renault and Nissan, are developing several models of EVs, including family cars. Nor do the majority of manufacturers seem to target mass production in the long term. The market has nevertheless seen the popping up of small, companies specialized solely in electric vehicles like the Swedish Th!nk, or the French Bolloré. Yet their production announcements have been rather limited, and companies are still bound to offer new types of business model to make their vehicle attractive, such as rental services.

Markets targeted by manufacturers have been chosen to reflect product limitations, i.e. their high price and low driving range. They concentrate accordingly on the so called "second vehicle market" of small urban vehicles (small to medium size cars for urban or to a limited extend inter-urban use), city car sharing projects, vans, and sport cars[33].

Companies could be interested to buy electric cars for their employees, in particular to increase their green image. Vans, currently representing 12.6% of the 230 million EU car fleet[34], are an

[33] This is actually due to the fact that EV motors deliver full torque from zero revs. They can accelerate quickly without the help of a gearbox. This makes them interesting to the sport segment of the automotive industry. For this luxury market segment, the significant additional cost of EVs compared to ICEs is of less relevance.

[34] The potential of the delivery van market is now reduced as the market was badly hurt by the crisis. **In 2009**, sales decreased dramatically and new van registrations totalled 1,375,856 units, or 30.5% less than in 2008.
AECA, March 2010, Economic Report. http://www.acea.be/images/uploads/files/20100520_2010_KEY_FIGURES_4_Vehicles_in_Use.pdf

interesting market segment from a CO_2 perspective. These kinds of vehicles have a higher mileage than normal car and as their charge can be managed in an appropriate manner. For instance, postal routes are short, constant and identical every day. Service companies, such as the French postal service who created a group for the purchase of electric vehicles, or the German railway Deutsche Bahn, have already shown an interest in electric vehicles, as it helps them reduce their energy bill.

Maybe surprisingly, electric sport car models are being developed by carmakers. This is actually due to the fact that EV motors deliver full torque from zero revs. They can accelerate quickly without the help of a gearbox. This makes them interesting to the sport segment of the automotive industry. For this luxury market segment, the significant additional cost of EVs compared to ICEs is of less relevance.

For the Plug-in hybrids, the cars benefit from a longer driving range (500km on average). A much more rapid market uptake than FEVs can be expected for this segment notwithstanding its high price. They would compete mainly with hybrids. Consequently, a larger range of PHEV models has been announced, including small cars and delivery vans (such as Daimler *Sprinter* already tested in the US). This model has been developed in certain countries, such as the US by General Motors with its Chevrolet Volt; the daily car mileage being much higher than in the EU (around 60km), it would have been more difficult to roll out full electric cars. Plug-In vehicles have also been adopted by European manufacturers as they allow them to make use of their knowledge in conventional gasoline and diesel technologies, while being able to label this vehicle “electric”. Parallel Plug-In concepts are also derived from hybrid technology. In this respect Toyota developed a PHEV (Prius III) from its hybrid Prius, and Ford from its hybrid Escape. This type of vehicle will not be rolled out before 2015; the earliest models are announced for 2013. As their CO_2 advantage is not defined, it is not clear to what extent they could contribute to CO_2 savings by 2020.

Carmakers production announcements are generally quite low (please refer to annex 8) although opinions are divided as well among manufacturers depending on their industrial strategies. Renault announced by far the biggest production levels for 2012, and its CEO Carlos Ghosn announced that by 2020 more than 10% of the European Car fleet will be fully electric. Renault more recently forecasted 5 million in sales per year by 2020. ERTRAC, the European representative platform for automotive research, estimates that 5 million EVs and PHEVs *on European roads* by 2020, a consensual estimate among industry players.

Major studies confirm low market penetration rates before 2020

The International Energy Agency, forecasts that in ‘OECD Europe’[35] the share of electric vehicles will remain fairly limited by 2020 (3% of

[35] A group including the EU, EFTA and Turkey with the exception of some member states (the Baltic states, Cyprus and Slovenia) as well as Liechtenstein

the total car fleet in the most optimistic scenario)[36]. The IEA forecasts, even the optimistic Blue Map scenario, predict the dominance of conventional fuels progressively and massively hybridized.

The European Commission Joint Research Centre also published its own estimates in 2010. It designed four market penetration scenarios for the European Union based on the evolution of battery costs and the development of infrastructure. The most aggressive scenario forecasts that market share of electric vehicles, all technologies considered, will remain under 3% by 2020. (For more details about these scenarios please refer to the Annex 9).

The electric vehicle: an industrial policy

Uncertain CO_2 abatement

The CO_2 saved through the introduction of electric cars by 2020 or 2030 is highly uncertain. It is unlikely they will in any way contribute to the EU 2020 climate change objective of reducing CO_2 by 20%: Market penetration forecasts are low, and the total mileage that will be driven on electricity will be limited. The electric vehicle also has to be considered in the context of the energy mix and its interface with the electric grid, if electric vehicles are running on coal electricity made out of low efficient gas or coal fired power plants, they will be worse than the average conventional vehicle. Therefore even in best case countries, such as France, where the electric vehicle is highly supported, where market share forecasts are quite high and the carbon factor of electricity is rather low, the introduction of electric vehicles will definitely not lead to massive CO_2 reductions by 2020.

Improvements of internal combustion engine efficiency are indeed already in the pipe. They include improvements to the engine and the power-train, the use of light materials and the ongoing hybridization of vehicles. Some of the available techniques are mentioned in Annex 12. Some of these technologies will also be of benefit in the development alternative fuel vehicles. This could be a sure path to achieve the needed climate effort. As a whole, experts estimate that internal combustion engine consumption could be reduced by 20% and eventually 40% on the basis of technologies already available in 2010[37]. This could help to decrease the European fleet CO_2 emissions average from 160gCO_2/km to 96gCO_2/km. In other words, the optimization of conventional powertrains, and in particular progressive hybridization could be sufficient to reach the European commission's CO_2 emission target for 2020. The reality is the optimisation of conventional cars through a progressive electrification, rather than a radical shift to pure electric vehicles. Optimized conventional car will still represent the large majority of vehicles by 2030. Furthermore, today's automotive

[36] For the IEA findings and overview of scenarios please refer to annex8

[37] [SYROTA 2008, p64]. The international panel on climate change found in 2007 that hybrids could save up from 20% to 57% of GHG emissions compared to standard cars [FINANCIAL TIMES 26 May 2008]. According to Philippe Ungerer from the IFP (French Petroleum Institute) Hybrids coupled with low carbon fuel (second generation biofuels) could make savings up to electric cars levels.

performance is well above what is actually used and needed. Decreasing car size, power, range and improving design could be a fast and economic way to achieve the CO_2 reductions. Two to 3 liter engines could be created for urban and inter-urban use. In the Frankfurt Motor show, Volkswagen already presented a 1 liter diesel hybrid car, weighting 380kg and able to drive 100 km and emitting 39gCO_2/km[38]. This is half a FEV's CO_2 emissions given the current EU27 electricity mix.

Hence, the second conclusion is that CO_2 abatement cannot be the main and immediate driver behind the push for electric vehicles, at least at the European Level or in countries such as Germany or Poland.

- **Green growth: a working concept?**

The fact that there is no estimation of the CO_2 reduction potential of EVs is in itself instructive.

EU member states' governments have set sales or market share targets but not CO_2 emission reduction targets (see table below). The few targets announced already amount to more than 6 million electric vehicles (PHEVs included) by 2020. This is in line with the IEA blue map predictions (6.5 million electric cars for 2020).

Table 4: EU Member States fleet targets for the introduction of Electric Cars

Country	Number of EVs*	Timeline
Denmark	200 000	2020
France	2millions	2020
Germany	1 million – 5 millions	2020-2050
Ireland	250 000**	2020
Spain	1 million	2014
Sweden ***	600 000	2020
UK	1.5millions	2020
Total	6.55 millions	2020

*These targets include both full electric vehicles and plug-in hybrids
**The Irish target is 10% of the total car, van and truck fleet by 2020
*** Sweden governmental target is to have 15% of FEVs and PHEVs by 2020
**** Cities can additionally introduce their own targets (e.g. Amsterdam plans the introduction of 10 000 EVs by 2015). In this respect the total target is in fact above 6.5 millions

The lack of consistency from an environmental perspective is because the main reason behind electric vehicles, from the policy side, is to enhance the competitiveness of the European car industry. The first policy move towards supporting electric vehicles at the

[38] http://www.volkswagen.com/vwcms/master_public/virtualmaster/en2/unternehmen/mobility_and_sustainability0/technik___innovation/Forschung/1_Liter_Auto.html

European level took place in 2008 in the heart of the economic crisis. At the time manufacturers were facing serious difficulties.

The car industry is indeed an important part of the European economy as Europe wide it implies about 2.2 million direct jobs and 10 million indirect jobs for nearly 4% of European GDP - according to the federation of automotive industries in Europe (AECA). It is even more so in particular Member States: Germany is the third producer of cars worldwide behind the USA and Japan. Its 2005 turnover was about €226 billion (the equivalent of 10% of its GDP), and over 880 000 people are employed. France is number 5 in the ranking of world producers, cars are representing 15.4% of the country's exports where 258 304 people are employed[39].

At the European level, no money can be given directly to industry. Strict EU competition policy, is in particular forbidding that state aids and subsides are given to companies. They were relaxed on the basis of this environmental case. This led Member States to support the industry from the supply side (direct support) but also from the demand side, through car scrapping programmes, *bonus malus* systems, where green cars benefited of an additional subsidy. To quote a few, subsidies given for the purchase of a new car amounted to €5000 in France, €6000 in Spain or £5000 in the UK. Many countries also plan to financially support the take off of the electric vehicle market by the governmental purchase of cars for public services, governmental investments in charging infrastructures (€1.5billion in France).

The December 2008 "Green Car Initiative", a €5 billion package supporting research and development in particular and designed by the European Commission, was part of the European economic recovery plan. Later on the European council competitiveness formation, under the Spanish presidency, gave a mandate to the European Commission Directorate General for Enterprise Industry to draw an electric vehicle strategy, relabeled in the end "green car strategy". Out of 27 Member States, 5 were pushing for such a strategy: France, Germany, Spain, Denmark and Portugal. Out of five, clearly three have a direct interest in protecting the car industry. The European Commission can invest in the framework of its research and development policy.

The European car industry is struggling to stay competitive. Before the crisis, the industry already faced huge restructurations due to its decreasing competitiveness in Europe. This is due do a very slow renewal rate of the European car fleet compared to a rapidly expanding Asian market (the Chinese car fleet alone is expected to double by 2050) and a mounting international competition. European governments were also keen to support the development of future technologies at a time when China is investing $15 billion in the electric car industry; when Japan is constructing a leadership on electric cars on the basis of its battery sector, one of the biggest world-wide, and its lead on hybrids, is pressing on charging stations and standards; and when even the US department of energy willing to reduce is providing support to battery technologies and manufactures while states are giving subsidies to electric vehicles.

[39] [ACEA 2009]

By 2020, Electric vehicles are not expected to provide significant CO_2 reductions, even if massively introduced. Yet the present can lock in the future. There is in theory almost no limit for the electric vehicle to be a “zero emission vehicle”, while conventional car will always have to burn fuel. Therefore Europe may have a long term interest in developing this climate mitigation tool.

Future opportunities and challenges

Technologies will improve, the power sector is on its way to lower carbon emissions, and the electric car is predicted to grow out of its niche market. Forecasts of studies confirm the future potential of electric vehicles.

Why not optimise conventional cars? The evolution of car technologies and power sector emissions

As described in part 1, the optimization of conventional cars and in particular the ongoing hybridization of cars could lead to substantial improvements in fuel efficiency and CO_2 emissions reduction. The European Commission target of 95gCO_2/km by 2030 is only reachable for small vehicles; therefore new technologies are already being developed for more powerful and bigger cars but the target will be harder to reach. Today's electric car technologies can improve as well; they will also benefit from power sector greening. They could offer interesting technology solutions to CO_2 emissions regulation for cars and vans.

If sufficient investments are made, batteries and electric vehicle technologies could improve significantly. Most electric vehicles presented in motor shows are just conventional ones, where the electric motor replaces the internal combustion engine. As described in the first chapter, there is neither a single concept nor a defined quality type of electric vehicle. Only a few present some interesting technology innovations, such as flat batteries under the seats, solar panels integrated in windows offsetting the major issue of air conditioning and heating, electric drive train are being placed in wheels to decrease weight. Range extenders40 could also be further improved as they do not yet alter significantly the driving range of a vehicle.

Some cars are already a step ahead. For instance, the Swedish Koenigsegg Quant sport car electric version was one of the EVs with the longest driving range presented at the Geneva Motor Show in 2009. The car offers a 500km autonomy for a weight of 1780kg, thanks to a 75KWh battery pack and solar technologies.

[40] This technology which consist in adding a small motorisation to pure electric vehicles, was already developed in 2003 by Renault under the Elect'road project

Lithium battery technologies are further developed. The energy efficiency of lithium-ion batteries, the most frequently used type of batteries for pure electric vehicles, is improving. Other types of lithium batteries such as lithium-ion phosphate[41] or lithium-iron-polymer offer some benefits such as improved safety, a slightly lower energy density, a very high life cycling, and reduced charging times. They will be complementary to other new grid technologies that have positive CO_2 impacts such as vehicle-to-grid, or new types of charging. Lithium sulphur batteries also based on metallic lithium, offer the highest energy density yet. Lithium-iron-polymer pack could be 5 times lighter than lead-acid batteries, and present significant cost reduction prospects. Nanomaterials are also being used to increase power density and decrease charging times. (See annex 2 for an overview of electric vehicle battery technologies).

Other new technologies are being developed, but they are not for tomorrow. For instance Metal-air batteries, initially developed for military applications in the US, could potentially extend pure electric vehicles driving range up to 800km. St Andrews, a British university is being financed by the UK government for its research program on a carbon-air battery. The STAIR (St Andrews Air) battery has an energy density of 2000-3000Wh/kg; ten times the current energy density of lithium batteries, at a lighter weight and a lower cost[42]. PolyPlus Battery Company replaced the liquid electrolyte by a solid one, therefore offsetting the problems of dry out[43]. In the near future, lithium-iron-phosphate batteries could also help significantly decrease costs compared with lithium-cobalt batteries[44].

Major energy efficiency improvements will come from the optimization of the vehicle such as solar panels, reduced friction on wheels, improved start stop systems etc. These technologies are already being developed for hybrids. Experts believe that electric car energy efficiency could be increased up to 40% in the coming years. The path is one of progressive electrification rather than a dramatic shift towards full electric vehicles.

The future electric vehicle will also benefit from a greener power sector.

The established EU climate policy to achieve a 20% reduction in CO_2 emissions by 2020 compared to 1990s levels will indeed hopefully be driven in part by results in the power sector. A large number of compulsory measures have recently been adopted at the EU level such as the development of renewable energy, the setting of a carbon exchange market and energy efficiency measures. The share of renewable energy has been fixed to 20% for 2020, which will lead to an actual 30% increase of renewables in power production; the European Trading Scheme cap was tightened for the period 2013-2020 in order to achieve a 21% reduction from 2005 levels. The long standing subsidies to the coal industry should be phased out by

[41] The cathode is made of iron phosphate instead of cobalt for Lithium ion.
[42] [THE TELEGRAPH 20 May 2009]
[43] http://www.polyplus.com/company.html
[44] From the targeted €300/kWh to €200/kWh Eric Lemaitre, CEA, directorate for technology research, in [CONFRONTATIONS EUROPE 2010], p27

2014 as proposed by a recent regulation. Additionally some specific technologies, such as Carbon Capture and Storage (CCS), are being promoted. These measures are likely to impact the EU energy mix and accelerate the development of green technologies.

The impact of European energy and climate policies on power sector CO_2 emissions over the next ten to twenty years have been worked out in a number of models[45].

According to the table below and depending on the evolution of the power sector, the potential of electric vehicles looks very promising: electric car emissions could decrease *EU wide* to 80-45gCO_2/km by 2020, 73-20gCO_2/km by 2030 and up to 5gCO_2/km by 2050.

Table 5: Future CO_2 emissions of a standard EV based on the power sector's carbon factor forecasts (in gCO_2/km)

	2010	2020	2030	2050
PRIMES 2008 Baseline Scenario		**398gCO_2/KWh**	**365gCO_2/KWh**	**n.a.**
PRIMES 2009 Baseline Scenario[46]	**386gCO_2/KWh**	**335gCO_2/KWh**	**214gCO_2/KWh**	
PRIMES 2008 NSAT scenario		**278gCO_2/KWh**	**204gCO_2/KWh**	**n.a.**
NSAT-CDM scenario		**307gCO_2/KWh**	**246gCO_2/KWh**	**n.a.**
RSAT Scenario		**282gC0$_2$/KWh**	**182gCO_2/KWh**	**n.a.**
RSAT-CDM		**305gCO_2/KWh**	**245gCO_2/KWh**	**n.a.**
Eurelectric Baseline Scenario	**304gCO_2/KWh**	**250gCO_2/KWh**	**175gCO_2/KWh**	**130gCO_2/KWh**
Eurelectric Power Based Scenario	**304gCO_2/KWh**	**225gCO_2/KWh**	**100gCO_2/KWh**	**25gCO_2/KWh**
Emission estimates for an average FEV*	**77-61gCO_2/km**	**80-45gCO_2/km**	**73-20gCO_2/km**	**26-5gCO_2/km**

Source: PRIMES, EURELECTRIC
*consumption of 0.2kWh/km. According to the IEA this consumption will decrease by 0.15kWh/km by 2020. In this respect, emissions could be even lower than these presented in the table. Annex 7 explains assumptions behind these power sector emissions scenarios in more details.

[45] The most well-known is the PRIMES model reported every year to the European Commission's Directorate General for the Environment. This model analyses the impact of EU policies on the European Union electricity mix. Eurelectric, the European federation of electric companies, also issues forecasts for the achievement of a carbon-neutral power sector by 2050 compared to a baseline scenario (see Annex6).

[46] Results obtained by the conversion of the PRIMES 2009 baseline scenario average emission factor for electricity in tCO_2/TJ, data presented in JRC, p21

But in the short term - as we have seen in Chapter 1 - the electric vehicle is not necessarily better than conventional cars regarding CO_2 emissions – the EV would only win the race in 20 to 30 years. The European Environment Agency forecast that by 2050, penetration rates of 50% to 80% electric vehicles could help reduce CO_2 emissions from vehicles by 35% assuming renewable in the EU energy mix at that time meet their target.

New technologies to manage vehicles interface with the grid: a win-win CO_2 situation?

Plugging millions of cars into European power grids

The introduction of millions of electric cars raises the issue of their interface with power grids. Indeed while the introduction of one electric vehicle is trifling in terms of additional electricity needed, as it requests only a few MW per year. But can the electric system cope with millions of cars? In particular if they are all plugged at the same time?

In the short term, i.e. until 2020, the additional electricity required to power electric vehicle is not expected to be a challenge, even at peak load.

The aggregate demand can be met by using existing capacity. If this were to be insufficient, an increase in the overall capacity through the construction of new or extension of existing power plants can be considered.

The introduction of electric vehicles will apparently not require additional capacity unless it is massive, which is highly unlikely in the short and medium term. In the long term however, this will become more challenging. The massive introduction of electric vehicles could totally distort the load curve, even more so if their charging remains unmanaged[47].

[47] A study supervised by RTE concluded that, for France, the introduction of 1 million vehicles by 2015 would only add 1000MW. With the introduction of 3.5 million vehicles (the governmental target is 2 million EV) by 2020 the load curve could be 4 to 5% higher. By 2025, the introduction of 6.5 million vehicles would totally distort the load curve by adding between 2 to 6 GW. This range is actually very large, revealing the difficulty of properly assessing the impact on the electricity sector [RTE 2010].

How much additional electricity will be needed to fuel electric cars?

The power needed by an electric vehicle fleet can be calculated on the basis of vehicle mileage and electric consumption[48]. On average, an electric car consumes 1.898 MWh per year. Whether electric vehicle demand is significant on a national level depends on the size of the country consumption, its fleet target and total electric vehicle mileage. These national impacts should smooth as the European grid integrates.

With an average consumption of 0.2KWH/km (IEA average estimation) and 26km daily car mileage on average in the EU (Eurostat), 1 million cars would only add 1.898 TWh per year. Depending on the size of the country consumption and its fleet target, this would be more or less significant.

In France, with a target of 2 million electric cars by 2020 (the highest national target up to day), this would represent an increase of 3,796 TWh i.e. 0.7% f France annual final electricity consumption[49], and probably less if this target is matched by a mix of full electric and plug in hybrids.

In Spain, with a target of 1 million vehicles by 2014, this would represent 0.27% of Spanish final electricity consumption[50].

In Germany and Sweden, the introduction of 1 million and 700 000 electric cars respectively, would also amount to less than 1% of the total energy consumption.

These estimations are very approximate to draw solid conclusions. In particular due to the fact that there is a lack of data regarding annual car mileage and Eurostat gives data on passenger per kilometres data but no data on kilometres per car.

Several studies estimated aggregate additional electricity consumption on the basis of different scenarios, forecasts and hypothesis[51]. The majority of studies confirm that achieving announced governmental electric vehicle market shares targets will not impact substantially the power sector; requiring less than1% of the total production[52].

48 Please refer to Chapter 1 data. EVs average consumption is about 0.2KWH/km as estimated by the IEA and Eurostat estimates that the daily car mileage in the EU is 26km.

49 The French electricity consumption in 2008 amounted to 527,1 TWh. For data on French electricity consumption please consult the French national statistical office INSEE at http://www.insee.fr/fr/themes/tableau.asp?ref_id=NATTEF11309).

50 Spanish final consumption was 276.1TWh in 2008, according to Eurostat. *Available at*: http://www.energy.eu/stats/energy-electricity-consumption.html

51 The French electricity consumption in 2008 amounted to 527,1 TWh. (data on French electricity consumption available at http://www.insee.fr/fr/themes/tableau.asp?ref_id=NATTEF11309).

52 The ETC's literature review confirms the minor impact of electric vehicles introduction on electricity demand in the short and medium term. For Germany 1 million electric vehicles, for an average consumption of 1500kWh per year, would result in an additional demand of 1.5 TWh, hence represent only 0.25% of the German electricity consumption (586TWh) according to a Delft study conducted for WWF [ETC/ATC 2009].

These numbers are calculated on the current and projected electricity demand. In 2020 electricity consumption will be higher and therefore the additional demand driven by the introduction of electric vehicles would represent an even smaller share. However, these "home made" estimations are very approximate; particularly due to the fact that there is a lack of data regarding annual car mileage[53]. It is therefore difficult to draw solid conclusions on this basis.

Electric utilities and studies nevertheless confirm that there should be sufficient power capacity in Europe to meet the demand driven by forecasted EVs sales. For 2009, for the remaining available capacity was over 20% of the net generating capacity[54], hence largely sufficient to cover a 1% annual increase in consumption[55]. According to Eurelectric's chairman of the electric vehicle task force, Thomas Theisen, the current European power structure could accommodate a 10% EVs introduction, and a theoretical complete shift towards electric vehicles with only an increase an of 470TWh, 15% of current electricity consumption[56].

Increasing the peak load

More difficult to cope with than an increase in aggregate electricity consumption, is the risk that all that demand will be concentrated in periods of peak load. Indeed, vehicle charging most probable patterns (in the evening and at midday) actually correspond to peak electricity demand. This can affect the security of power supply and increase CO_2 emissions.

The amount of load at a point in time will vary with the number of vehicles plugged into the grid, and their type of charging. Slow and standard charging requires about 3KWh stretched out over 6 to 8 hours, but fast charging stresses the electricity network with a demand of 50KWh for 20 minutes, hence more than 30 times higher[57]. Millions of cars 'fast charging' at peak hours would become a nightmare for utilities. The potential pressure fast charging can impose on the network, the subsequent additional costs resulting from increased capacity needs and the negative impact on CO_2 explains why utilities are not enthusiastic about this type of charging.

In the short term, the number of vehicles is too small, and fast charging at peak hours is too limited to pose a risk. Currently, EVs

[53] Eurostat gives yearly passenger per kilometres data but no data on kilometres per car. The 26km per day is just an average of all EU country, likely to differ from one country to another.. It is also difficult to predict whether consumer would use their electric vehicle to cover the same distances than with a normal car.

[54] This 20% reserve is not enterily available, as some % is needed for instance for maintenance (about 5%) or to secure the grid [ENSTO-E 2010].

[55] Some experts consider that in France, by 2020 9MW capacity would be available fors electric vehicles, i.e. the capacity needed to charge about 4 million EVs, twice the governmental vehicle penetration target [ETC/ATC 2009], p101.

[56] [ETC/ATC 2009], p98 & http://www.eurelectric.org/Highlights/EUSustainableEnergyWeek/Sector1.htm.

[57] A WWF study reveals that the introduction of 20 million vehicles in Germany would increase the load capacity by 30 000MW (around 60TWh per year); if a system of fast charging in two hours were introduced an additional load capacity of 80 000MW would be required [EEA 2008, p105].

are charged at night with a slow charge. Fast charging stations are not yet being rolled out, and semi fast charging stations are mainly thought of as reassuring stations rather than for extensive use. Most studies therefore foresee that the impact on the peak load will be negligible[58].

In the medium to longer term however, electric vehicles could start to significantly impact the load curve amplitude and to aggravate the peak load. In France, a worst case scenario consisting of charging quickly 3.5 million vehicles at peak hours would increase the consumption by about 4GW and create a second peak at midday (!)[59]. This shows that unmanaged charging could potentially alter the dynamics of the electricity system.

Whether or not national grids will actually be able to face an increase in peak load is not clear, even in the short term.

The network is much more sensitive to black outs than it used to be. While previously, national (state owned) companies were controlling the electricity markets, the European Commission's liberalization packages called for the opening of gas and electricity markets in Europe. The task of covering the peak to avoid electricity black outs is now therefore left to the market. This entails problems as it is not always in the economic interest of companies to have surplus generation capacity to cover large demand fluctuations or quick surges of demand. European countries are not equally concerned by this problem. But recent incidents advise caution. In 2009 both France and UK reached historical peak loads which they had to cover with significant imports[60].

The question of generation capacity is also a concern at the local level. Indeed, full electric vehicles and plug-in hybrids are targeting the niche markets of urban and peri-urban cars, respectively. Increasing electricity demand in cities is problematic as some local networks are already close to capacity.

Apart from the increased risk of black out, the unmanaged charging of electric vehicles after 2020 has a twofold environmental impact. As already mentioned, electricity is generally more polluting at peak load than at base load; but worse increasing the peak could direct power sector investments into higher emission flexible power plants.

58 In the UK for instance, unmanaged charging of 10% EVs would only lead to an increase of 1GW in the daily peak load (about 2%) [ETC/ATC 2009], p109

59 [KHT 2009]

60 In France, a historical peak of 96350MW was reached on the 15 of Decembre 2010. During a lower peak in 2009, France even had to import electricity from German coal power plants. RTE, the French transmission company, explains the 2009 peaks as the result of cold weather, the development of electric heating, network maintenance and strikes. In fact, the French electricity grid is adapted to an increase in base load demand but not in peak load. Recent investments have also been driven towards an increase in nuclear capacity.

Unmanaged charging of Electric Cars could direct power sector investments into expensive and polluting gas-fired power plants

The unpredictable charging time and power needs of an increasing number of electric cars, will lead to greater variations in electricity consumption. Power production will need to be more flexible. Because electricity cannot be stored, the network, the generation capacity and the production structure (base load or peak load power plants) have to be adapted to the fluctuation of demand in order to avoid black-outs. To maintain the reliability of the system, the balance production-consumption must be respected at all times. Therefore peak load management is to some extent shaping the whole electricity system. An increase in peak consumption would therefore be translated into greater power needs, entailing heavy investments in the grid and production infrastructure.This could increase the power sector CO_2 emissions and increase its reliance on conventional fuels. As a matter of fact, this pattern has already been observed with the penetration of renewable energy[61]. Unmanaged charging would require different generation capacity than distributed or base load charging[62]. The deployment of a large quantity of such power plants just for use a few hours per day or even per year would increase the price of electricity.

On the contrary better managed charging would promote investments in base load power plants even as it drives some investments into peak load power plants. This issue is of paramount interest to power companies.

How to manage the charge: price mechanism, smart grids and interconnections

Ideally, unused capacity in off-peak periods could be used for charging. This would flatten the demand profile, decrease electricity costs, and thereby improve generation efficiency and marginal CO_2 emissions. This “valley filling” process would balance daily variation in electricity demand. Base load generators could in this respect increase their production. In particular, countries with low emitting base load power plants, such as nuclear, would gain in orienting vehicle charging to off peak periods from a CO_2 perspective. On the contrary, if no incentives are introduced, electric vehicle charging patterns can hardly be monitored.

Several solutions on the power sector side can address the increase in electricity demand variability without increasing CO_2

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[61] In Denmark for instance, the massive promotion of intermittent wind power had to be backed up with flexible sources of production such as gas fired power plants. As a result, the country power sector paradoxically ranks among the highest polluter across the EU.

[62] According to a study conducted by Delft Consultancy based on three market penetration scenarios, distributed charging will require an extra capacity of 0.2 to 2.2 GW, based load charging 0.7 to 6.7 GW, and 0.5-4.4GW in case of peak load charging. This will result respectively in a total capacity demand of 25-55GW during base load hours or 55-100GW during peak load hours. The study is based on three electric vehicle penetration scenarios for 2020: a moderate/medium uptake scenario (0.4 million cars), a fast uptake scenario (3.2 million) and an ultra-fast uptake scenario (6.3 million) [DEL 2010], pp 68-70.

emissions: improvement of interconnections and the development of smarter grids[63] to better distribute the power generated, pricing systems such as seasonal or hour pricing, smart meters[64] or interruptible clients. The development of a system of communication via the electricity network subsequently needed will be facilitated by the European directive on the liberalisation of electricity markets, which should leave consumers with more freedom to choose their electricity provider.

EVs currently have at their disposal on board equipment useful in load management: specific charging plugs made up a communication spin, and Battery Management Systems (BMS). Battery Management Systems control the charge and its timing, helping to lower the peak significantly[65].

Electric Cars and Renewables: mutually reinforcing developments?

The introduction of electric vehicles can also be seen as a solution for grid management rather than as an additional burden. The electric car battery can be used as a storage device for the grid, or buffer storage for electricity surpluses[66]. EV batteries could withdraw or add electricity to the grid to balance electricity demand and production. This technology is called **Vehicle-to-Grid (V2G).**

This system is able to take advantage of the batteries' size. Batteries actually exceed real mileage needs, as they offer on average a driving range between 100 and 160 km while the average daily journey is around 26km (please refer to chapter 1)[67]. A part of

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[63] Demand-Response mechanisms are a market tool based on pricing aimed at smoothing grid variations and easing grid management. Smart grids, a "clever" distribution network, are using communication technologies to optimise consumption and production. This in turns should help to secure the electricity supply, decrease transmission losses, prices and CO2 emissions and enable the integration of renewable into the grid. Smart grids would provide real data at real time.

[64] At the consumer level, the price can be used to manage the vehicle charge's timing through smart meters. These meters connect electricity tariffs to grid demand. Charging times and tariffs for electric vehicles could be automatically selected via this system

[65] Melaine Rousselle estimates that the peak induced by 3.5 million vehicles on the french electricity grid could be lowered by 25% at 8pm, if 80% of them are equipped with BMS [KHT 2009].

[66] The amount of electricity stored in electric cars batteries could serve as a regulation reserve. There are different types of reserves in electricity networks. The *operating reserve* is composed of the spinning reserve (increasing the power output of generators already connected to the grid) and the non spinning reserve (extra generating capacity not currently connected and that can be brought in rapidly either through imports or fast start power plants). The *regulation reserve* is the automatic regulation of power plants according to the demand; it is also called the frequency response reserve and is smaller than the later. Finally, the *contingency reserve,* under which the activation of generators, is taking between 30 to 60 minutes). As electric vehicles can release energy stored in the battery rapidly (depending on the connection), they could be considered as a regulation reserve (frequency response reserve). A study concluded that 1 million pure electric vehicles would provide a 3GW regulation reserve (with a 10 KWh battery and a low load connection of 3KWh). In 2020, on this basis, the UK would benefit of a 4.5GW regulation reserve. [ETC/ATC 2009] p114.

[67] The study done by the Belgium regulatory commission for gas and electricity consider that about 6KWh per car per day could be use. Vehicule usually run 41.4km

the charge not used during the day could therefore serve for other purposes. This interaction with the grid could therefore not only smooth the impact of electric vehicles on the system but would also avoid network congestion as vehicles are spread across the entire grid. Finally, the ability to store electricity on the margins of the grid serves as a way to integrate renewable energy and decrease prices and their volatility on the spot market[68].

Electric cars and renewables are thus seen as mutually enforcing developments. Truly, where electric cars are fuelled by wind energy, their CO_2 emissions while running on their batteries will be close to zero, quite an attractive idea. Electric vehicles batteries could work as a solution for the problematic intermittency of renewable energy[69].

The potential of this new technology explains the enthusiasm of some European countries for the promotion of the electric vehicles. In some Member States, like Germany, Poland, Spain, or Denmark, the electric car is seen as part of the solution to the problems faced in the introduction of renewable[70].

The concept is interesting but does it actually work? The system has to be thought through carefully. The results of demonstration projects launched in Europe are awaited, but some challenges are already visible.

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per day, which implies a consumption of 6.03KWh plus a safety margin of 30% out of 15KWh. The rest of the battery (about 6KWh) could be use for grid „valley filling" [ENER 2010].

[68] Electricity prices on the spot market are usually defined by their high volatility. It is up to ten times the average €/MWh price. The CREG (Belgium regulatory Commission for electricity and gas) estimates the price of the spot market in Belgium to peak at 500€/MWh, while the annual Belgium average price is about 40-90€/MWh [ENER 2010], pVII. As a matter of comparison, the EU27 average annual electricity price for 2008 was 0.102 €/KWh, and the cheapest annual average was found in France at 0.1164€/KWh including VAT [FRANCE 2009].

[69] The recent massive development of renewable energy causes major issues for electric utilities because of their intermittent nature. Substantial amounts of renewable electricity were recently lost by Spain and Italy, where wind turbines finally had to be turned off. The wind was not blowing at the right time for the grid to be able to integrate the resulting electricity production. Please refer to Maïté Jaureguy „Wind Power: A victim of policies and politics", Ifri Note, Octobre 2010 *available at* http://www.ifri.org/?page=detail-contribution&id=6246&id_provenance=97 [JAUREGUY 2010]

[70] In Denmark, on the island of Bornholm, there is a project to introduce electric cars in order to maximize the capacity production ratio (the so called capacity load factor). Although the installed wind power capacity amounts to 40% of electricity consumption, the wind supplies only 20% of the island needs. The reason is that as wind is intermittent, to operate at 20%, at least the same capacity of conventional power has to be available and switched off when the wind is stronger. A project for the introduction of electric cars to increase the share of wind power up to 50% is currently under consideration. The EDISON project is developed jointly by Copenhagen utility DONG Energy, the regional energy company of Oestkraft, the technical University of Denmark, Siemens, Eurisco, the Danish Energy Association and IBM.

Other countries developed electric car programme so as to smooth the integration of renewable on their power grid: The polish government programme is entitled 'electric cars and renewables'; the German government supported a four year programme; the "Flottenversuch Elektromobilität" aimed at testing the potential of PHEV to stabilize the grid. Some companies are also involved in testing: Volkswagen is providing 20 Golf Twindrive in partnership with EON, the energy company and six other partners. This is part of the company strategy to catch up in the race of electric car development.

The first challenge associated with the Vehicle-to-Grid technology (V2G), is **systemic.** V2G can be used as an arbitration tool or as a free market mechanism.

In the first case utilities pay for the use of EV storage, and a regulatory power has to be set up to oversee electricity exchanges. This tends to benefit producers as they can then enhance their production efficiency and reduce volatility, as well as all electricity consumers because prices could accordingly be reduced. This would clearly be to the advantage of base load and semi base load power plants and renewable, as the need for peak production would be decreased.

V2G can also thought of as a free market mechanism, hence be based on prices. In this case, the main indicator would be the price and not the regulation nor the security of production. The electric vehicles owner's behavior would also be less predictable. While electricity should in their interest of the system only be sold when prices are high during peak hours at midday or in the evening, it could end up being sold at night and bought during the day to benefit from small prices fluctuations. This could make the system even less predictable, increase the need for peak power plants and the cost of electricity. The first limit to this V2G system is therefore its complexity.

Additionally, driver's mileage, movements and behaviors are uncertain; thus the amount of storage that could be made available with a V2G storage system is unclear. This is an estimate almost impossible to make as the storage capacity depends not only on the number and type of electric vehicles sold and the behavior of their drivers but also on the size of their batteries (PHEV batteries will be smaller than pure FEVs), and their load connection.

Other limits are more at a ***technology level.*** They are first the charging loss coefficient, secondly the wearing rate of the battery. In case of intensive use, the lithium battery life cycle (approximately 1000 cycles – see previous sections) could be significantly decreased, in particular in the case of deep charging and discharging for grid management purpose. Electric Cars have a shorter life time than conventional ones, and this could be worsened if their batteries are used as electricity storage. Only a small part of the battery can therefore be used in such a system (The Belgium regulatory commission considers that if only 3% of the battery is used, the impact on its life cycle could be limited). Such a limit would need to be fixed and would clearly depend on future battery technology developments and price evolution. V2G, with the current battery technologies, would actually penalize electric cars life CO_2 assessment.

By increasing the number of actors in the sector, system integrity is brought into question. In this respect, will this system be a reliable source of energy? Or will it just contribute to increasing system intermittency? And is it cost effective?

These shortfalls lead to the conceptualization of another system, Vehicle-to-House (V2H). This system eases the demand on the house rather than on the grid. It has the advantage of avoiding transmission and distribution charges and the need for complex communication systems. It could serve as emergency power and electricity could at some point even be exported to the grid. Small house renewable installations such as solar panels on rooftops have been developed. Thinking local could be a first step. However the integration of homemade electricity in the grid and heavy subsidies make it difficult to assess from a cost efficiency perspective.

The Electric vehicle storage potential has to be further assessed as many uncertainties remain on its feasibility and cost.

Given the current state of technologies and power grids, it is ambitious to state that renewable and EVs are complementary. Without the support of new grid technologies, their simultaneous development could actually be worse in CO_2 and cost efficiency terms.

Thanks to interconnections, smart grids and smart meters, EVs impact on the load curve could be smaller than expected. The development of these technologies represents a prerequisite for the “zero emission” label wrongly attributed to electric vehicles.

Pricing the uncertainties of a long term potential

The first issue was to understand whether the electric car (or the different type of electric cars) can reduce CO_2 emissions. The second question is at what price? Indeed there is limited rational for investing public money and driving research into costly ways of reducing CO_2, even more so at a time of economic crisis.

A high price...

(1) Expensive cars

First and foremost current EVs are still expensive cars. While they offer significantly lower driving range, the majority of existing and forthcoming models are uniformly more expensive than their conventional equivalent, up to twice the price (see Annex 10 for an overview of marketed electric cars prices).

To face this major bottleneck, either carmakers target urban areas, fleet companies and fans of expensive and fashionable sport cars, or they find a different business model such as battery leasing. Another solution is to build a charging infrastructure network. This is also quite expensive, in particular if it also has to be subsidized by states at a time of crisis.

(2) The cost of a new system

Added to the vehicle cost, the systemic costs are also tremendous.

At a conference in Paris, the head of the French Union for Electricity estimated that 90% of the overall cost of the EV will be **infrastructure**[71]. Infrastructure costs are huge as everything is still to be built[72]. For urban use, the European Commission Joint Research Centre (JRC) estimates that 13 chargers will be needed for every 1000 inhabitants, for an annual cost of 3billion€ EU wide. For use on motorways, charging places will be needed every 40 km, for an additional annual cost of €56million per year[73]. For France alone, the infrastructure costs have been estimated at more than €3 billion[74].

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[71] Nicolas Bouley (Delegué General de l'Union Française de l'Electricité), Conference organised by Confrontation Europe, Paris, 14-15th April 2010

[72] Europe wide, the current charging facilities are not sufficient. For instance, in Paris *intra-muros*, 80 public charging points were developed by the French electricity company for around 1 million inhabitants, and there are only 200 charging spots for the whole country.

[73] [JRC 2010], p14

[74] [LA TRIBUNE 8 October 2010]

Additionally, a communications system with the electric grid (such as Vehicle to Grid or Vehicle to House), and the supporting smart grids, would have to be introduced to secure CO_2 savings. The cost hurdle would then be quite significant.

This cost will be paid partly by states and municipalities supporting the development of electric cars[75], and ultimately by electric car owners themselves, as national plans rely mainly on home and work plugs. Captive fleets could benefit from private company investments in parking plugs. The need for significant investments in infrastructure could be significantly offset by the introduction of plug-in electric cars, but these do not contribute equally to CO_2 savings.

Customer services, in particular the repair of EVs will be quite expensive to the consumer, as the complex handling of batteries requires specific training.

Last but not least, to achieve a positive CO_2 outcome, EV batteries will have to be recycled. As noted previously, there is no business case at the moment for this sector. As lithium batteries are not composed of expensive metals, like for instance NiMH batteries used in hybrids, little or no profit can be made. This sector will require governmental subsidies. This is already happening: Germany will financially support a pilot recycling plant as part of its electro mobility strategy; worldwide similar trends can also be noticed, like for instance the US government which provided a $9.8 million subsidy to the battery firm Toxco to develop a recycling factory.

(3) Low electricity prices

A lot of electric cars enthusiasts argue that if one shifts price considerations from the vehicle to the lifetime price, electric vehicles will be competitive with conventional cars in a few years.

It is indeed **currently cheap to drive on electricity**, and it could even be cheaper in the future. The marginal cost of running an electric car is much lower than conventional ones. Running 100 km with a battery electric vehicle (BEV) with a high consumption level of 0.2KWh/Km, would cost 3€ for 100km. The same distance costs 4.2€ with the most efficient diesel-hybrid existing today (consuming about 4l/100km)[76]. On average, running a car on electricity is less than a third of the cost for conventional cars. A report issued for the UK department of transport, even estimated that in off peak period, fuelling EVs was 1/7 the cost of fuelling ICVs[77]. Furthermore oil prices will most probably rise, at a faster rate than electricity.

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[75] The French government plans to invest €1.5 billion to install 400 000 electric plugs by 2020 on public roads and parking places. This is only a part of the €4 billion infrastructure cost estimated to correspond to the governmental objective of 2million EVs by 2020. The Spanish government agency IDAE (Institute for Energy's Diversification and Saving) is currently installing 500 charging stations.

[76] These prices are calculated on the basis of 2007 diesel and electricity prices for household, given in the European Commission Statistical Pocketbook on Energy and Transport [COM 2009 ter]. The electricity price for household was estimated at 0.01466€cents/KWh in 2007 for the EU27; diesel oil prices were at the time 1.030€/l, and petrol 95 prices at 1.126€/l. In 2008, with oil prices peak, the difference would have been even greater.

[77] [BERR 2008], p37

But at present, the low marginal costs of operating EVs are offset by the high fixed costs of the battery. The Peugeot Ion, a small urban vehicles, is sold at a price of €35 000, while its conventional equivalent, the Peugeot 107 costs €10 000. The cost of use is announced at 1.5€/km, but 20 000 to 22 000km have to be driven per year for the vehicle to become competitive[78]. This is a big challenge for a small urban car, when the annual European mileage average is already less than 10 000km. There is a debate on the oil price at which electric cars reach cost parity with conventional cars[79], but it appears clear that if oil prices do not rise significantly and battery prices do not decrease, it will be challenging.

.... For a long list of uncertainties

EV prices are mostly a function of their battery, which can represent up to 70% of the total vehicle cost[80].

(1) Will the market take off?

All **market forecasts predict a jump by 2030.** The IEA predicts a jump in market share from 3% to more than 20% between 2020 and 2030 (and sales values from 3% to 30%) in its blue map scenario; the European Commission Joint Research Centre forecast a similar outcome in its highest range scenario; McKinsey assumed that globally about half of transport CO_2 emissions could be reduced by 2030 and that EVs and PHEVS could contribute about 7% with drastic power sector greening[81].

This possible dramatic success is reinforced by several observations. The first is the possible decrease of battery prices. The IEA based its blue map scenario assumption mainly on a 400$/kWh battery price, which is already in sight. The second is growing urbanization. About 80% of Europeans live in cities, and this will increase up to 84% by 2050 according to the European

[78] [La tribune, 8th October 2010].
[79] The IFP, the French Petroleum Institute, found that for a battery price of 300€/kWh and a stable fuel oil price of 1.5€/l (the current gasoline price at a Belgian petrol station), the total life cost of an EV would be about 2500€ less than a conventional car; a PHEV would be around 5000€ less. This is if the car is driven 200 000km, or kept for 21 years at the current European average mileage. The PRTM consultancy believes that with higher oil prices parity with conventional vehicles could be achieved by 2020. The BERR consultancy consider 2015-2016 as possible depending on the evolution of oil, electricity and battery prices. Charging at night, with low electricity tariffs, would allow faster parity. Each 200£ difference, brings the EV/ICE price parity crossover date by approximately two years.
[80] The market for hybrids batteries NiMH remains small, around $900 million, and is dominated by PEVE a Toyota subsidiary [T&E 2009], p35. Companies involved are American such as the newcomers A123 system which uses the lithium-ion-phosphate technology initially developed by Valance a Texan company or Boston Power specialised in fast charging lithium battery for consumer goods (including computers), Asian companies include in particular the Chinese BYD (owned at 10% by Warren Buffet) and traditional Japanese battery makers. Finally, European companies include SAFT and Renault-Nissan in partnership with NEC. The picture may be changing in the near future as revealed by the current expansion of the market which is growing at a rate of 8% per year. The market for large format batteries could explode and reach $50 bilion by 2020 [PRTM 2009]
[81] [MCKINSEY 2009], p6

Commission[82]. The electric vehicle could fit the mobility needs as daily distances are shorter in big cities (in London 84% of car trips are under 20km), it could also target a large share of emissions as 40% of CO_2 emissions from transport are emitted in a urban environment. These trends could support the success and the political need for a small urban vehicle. Last but not least, the interest of public administrations is encouraging. They represent 17% of car purchase EU-wide.

However ***there are still uncertainties regarding this impressive jump in market share.***

One of the biggest bottleneck for the penetration of electric vehicles, is their high price and low driving range, both for which the battery is directly responsible. *The evolution of battery prices is uncertain.* On the one hand the fast evolution of the technology at a rate of 5% per year matched by productivity gains of 10 % is encouraging[83]. The IEA estimates that EVs, and in particular BEVs, could become competitive with a cost factor of 300$/KWh. This seems a realistic path as some manufacturers have already managed to significantly decrease prices. Generally though, experts agree that a €200-240/kWh is a necessary and achievable target in the medium term for an average BEV with 150-160km autonomy (2015-2020)[84]. This still means a price of €4 000 for a 160km driving range battery. On the other hand, as little technology breakthrough is to be expected, decrease in large lithium battery pack prices will most probably come from mass production and the improvement of manufacturing processes[85]. In sum, technological developments for batteries are expected for BEVs, yet this will also depend on their initial commercialization. This is a chicken and egg situation.

Secondly, the predicted jump appears highly optimistic when compared to usual green vehicle technologies market penetration rates. In comparison, hybrids only took a 2-3% share of new sales ten years after their roll out since1990, and currently account for about 1% sales in the EU i.e. around 140 000 units. EVs and PHEVs will therefore most probably be introduced as substitutes for conventional cars. This means that to get to the Blue Map forecasts or any other optimist scenario, a very rapid growth and market penetration of technologies will be necessary. It will be difficult for electric vehicles to achieve a more rapid penetration. This is underpinned by the low fleet renewal rate in Europe, estimated at 6.8% for 2007 by Eurostat, and a slow-down in sales across Europe. New passenger cars sales are on a decreasing path, at least in Western Europe.

Thirdly, there are uncertainties regarding market penetration forecasts. The table below evaluates the average variation among forecasts. Above a 30% standard deviation, values are not considered credible. The table shows that for 2020 scenarios the variation in numbers is rational (12, 2%), but for 2030 it starts

[82] [COM 2009]

[83] In 2000 a lithium battery cost twice a NiMH battery, but reached parity in price in 2005.

[84] ETRAC, estimates that in the medium term, batteries could reach affordable values below 200€/KWh [ERTRAC 2009], p7

[85] The Boston Consulting Group estimates that 75% of the battery cost is volume dependent [BCG 2010], p7

becoming problematic (28, 5%). Arguably, these scenarios are based on different assumptions, such as vehicle prices and driving range, the maturity of business models, the density of the electric charging infrastructure, energy prices and the scope of government support. The IEA Blue Map scenario indeed forecast a decrease in the total car fleet, while the JRC forecasts a total car fleet increase of around 30%. Yet in both their most optimistic forecasts, there are still differences in sales.

2030 looks like the crucial date at which one can determine whether electric vehicles will be or not successful. It clearly appears here that it is still highly uncertain. Data in the table are in values of sales. This means that in vehicle real numbers, fluctuations would be even greater. Uncertainty of market penetration forecasts is quite problematic as it is difficult to know how much CO_2 can be saved, and to what extent governments should support this development.

Table 6: Variation in world electric vehicles' sales Scenarios

Variance Calculation – Standard Variation			
as a % of total sales of cars in EU	2020	203 0	2050
IEA Act Scenario	n.a	8,0 %	10,0 %
IEA Blue EV scenario	8,6 %	50,0 %	90,0 %
Renault, Carlos Goshn	10,0 %	n.a	n.a
McKinsey Mixed Technology scenario	6,0 %	17,0 %	n.a.
McKinsey Hybrid and Electric scenario	8,0 %	32,0 %	n.a.
McKinsey Optimised ICE	-	-	-
BCG slowdown scenario	1,0 %	n.a	n.a
BCG Steady pace scenario	6,0 %	n.a	n.a
BCG Acceleration scenario	16,0 %	n.a	n.a
IEA Blue Map scenario	9,0 %	31,0 %	57,0 %
EPRI low PHEV	n.a	n.a	20,0 %
EPRI Medium PHEV	n.a	n.a	62,0 %
EPRI high PHEV	n.a	n.a	80,0 %
Eurelectric scenario 1	n.a	8,0 %	n.a
Eurelectric scenario 2	n.a	20,0 %	n.a
Frauenhofer Institute modest scenario	n.a	7,0 %	15,0 %
Frauenhofer Institute ambitious scenario	n.a	24,0 %	90,0 %
Deloitte consulting	2,0 %	19,2 %	34,6 %
Deloitte consulting	10,0 %	n.a	n.a
PRTM	10,0 %	n.a	n.a
Deloitte Consulting US Market	3,1 %	1,4 %	76,0 %
EIA Berkley US market baseline scenario	18,0 %	64,0 %	n.a
EIA Berkley US market high energy price scenario	32,0 %	85,0 %	n.a
EIA Berkley US market operator subsidized scenario	47,0 %	86,0 %	n.a
Japanese Government	n.a	50,0 %	n.a
Average	11,7 %	30,2 %	48,6 %
Standard deviation	12,2 %	28,5 %	33,8 %

Source: author's own estimates

(2) Gaps in statistical data

Some other variables make it very difficult to have an idea about the CO_2 abatement potential of electric vehicles. Gaps in data on mileage, CO_2 emissions at peak load, on plug-in possible contributions as compared to pure electric vehicle make it even more difficult. Last but not least, the point in time at which the electric car will outstrip the optimisation of power trains in terms of costs or technology is not clear. There are big uncertainties about real electric vehicles consumption. Institutes are now comparing vehicles emissions using their fuel energy equivalences. This is problematic in particular as there are loopholes in legislation (this will be addressed in the last chapter).

(3) Evolution of power sector: ever greener?

The contribution of EVs to climate change objectives will depend on the evolution of the EU electricity mix. At present, the ETS system has just been revised and tightened until 2020 and the power sector should be on a greener way.

The evolution of EU and Member States electricity supplies will depend on a large variety of factors such as the building of new gas pipelines, the stability of suppliers and transit routes, the availability of resources, new technologies development such as Carbon Capture and Storage or unconventional oil and gas exploration techniques, interconnections and infrastructures. Policies could have an impact on power prices, set binding objectives and support green technologies development. Yet, these variables make the future EU electricity mix very hard to forecast. Some European objectives appear difficult to reach. A study from Pricewaterhouse Coopers cast doubts on an increase in the share of renewable to 20%. It appears that there was only a slight increase of 2% from 2000 to 2007 and that investments from companies in 2008 were directed mostly towards natural gas[86]. Finally, if electric cars' charging is not managed, the power sector could struggle to stay the course.

(4) The consumer's behaviour black box

Even more difficult to predict, will be consumers' behaviour. This in turn impacts charging patterns, infrastructure needs, and market uptake.

(5) The price of raw materials

***The evolution of the price of raw materials, needed to build batteries, remains uncertain*.**

Firstly, Lithium prices could be sensitive to an increase in demand driven by battery pack manufacturing. The market for batteries is expanding at 7% per year, and therefore may already drive up prices for lithium or other components of the battery (cobalt, manganese etc.). There is currently a debate on the impact of lithium prices, and their suspected evolution, on the EV market. Battery cost reduction will depend on raw material availability[87].

The current production rate is about 27400 metric tones per year and world reserves are thought to be around 11 to 30 million

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[86] [PWC 2009]

[87] For a 30kWh battery (160km range), about 9 kg lithium are needed on average. [ETC/ATC 2009],p23

tones[88]. Therefore the availability of reserves is not an issue. However the level to which the current production can be increased in a short period of time is not clear. Under announced programs, France alone would require nearly all of today's worldwide production of lithium in order to reach its governmental target of 2 million electric vehicles by 2020 (i.e. 18 000 t of lithium). Other methods of extraction (from ore or drained lakes) or substitutes (like cobalt) could over time available. However these other processes are more costly and CO_2 intensive than traditional production and cobalt is more expensive and presents a risk of overheating.

PRTM published a report stating that under a 'most probable scenario', battery manufacturing capacity will encounter a shortfall by 2016 if no significant investments are made in lithium production. According to PRTM, up to 4 times the capacity announced should actually be produced to meet the supply of 10% EVs and PHEVs by 2020[89].

On the other hand, costs will depend on how well supply responds to demand. The price of lithium has already exploded from $350 per ton in 2003 to $3 000 per ton in 2008[90]. Lithium prices are relatively low compared to other materials, and companies were even; yet speculation is now fierce precisely because it is based on future automotive demand[91].

(6) The price of electricity and oil

The affordability of electric cars, on which their market penetration depends, is said to be driven by high oil prices and low electricity prices. However these are subject to speculations as well.

Electricity prices could actually increase in the future. They could suffer from a decrease in subsidies, in particular for coal power plants, an increase of fixed cost related to standards (CO2 emissions, safety) and the introduction of renewable. It could also be affected by fast and unmanaged charging, or increased to meet infrastructures expenses, including the cost of storage in electric vehicles batteries.

In the VTG system, EV owners need to replace their batteries more often and obviously have to be compensated for it. The price would also be tremendously higher if the battery cannot be replaced.[92]. In this respect, for this vehicle to grid technology to be

[88] Chile is the biggest producer; China and Brazil have significant reserves (respectively 13% abd 5% of world reserves) According to the USGS, EEA p23

[89] http://www.greencarcongress.com/2010/03/prtm-20100322.html PRTM Analysis Finds Li-ion Battery Overcapacity Estimates Largely Unfounded, with Potential Shortfalls Looming; Total Market Demand in 2020 Will Require 4x Capacity Announced To Date *22 March 2010*

[90] E24 le lithium, future goulot d'etranglement pour le vehicule electrique, 15 decembre 2008

[91] Jaskula from the USGS quoted in [CLEAN TECH 2010].

[92] The final electricity price will be the initial cost of electricity (production and transmission) increased by the additional cost of battery storage i.e. the cost of the wear on the battery added to the cost of transmission. The wearing cost of the battery is calculated on basis of the total battery life cycles divided by the number of kilometres It was estimated at 0.533€ by KWh charged or discharged for a car consuming 0.15KWH/km, with a 1500 cycles 20 KWh battery, for a yearly mileage of 15000km by the Belgium Regulatory Commission for electricity and Gas. The price of electricity is currently around 0.10€/KWh in Belgium. This means that storing

functional, the marginal cost of electricity would have to exceed the cost of storing and retrieving the energy. According to the UK department of transport, the basic price of electricity could increase ten times if an 18000£ battery was used as storage device[93].This reveals that Vehicle-to-Grid is only interesting for use at peak load. The introduction of renewables in the European Member States power grids might create momentum for storage devices as it will most probably increase the cost of auxiliary services. But is this storage system as reliable as and more cost effective than other types of storage that are currently considered too expensive[94]?

(7) The price of CO_2, if any?

The cost-effectiveness of (different types of) electric cars as a climate change mitigation instrument will depend on the cost of CO_2 itself.

In twenty years the price of CO_2 might offset the price of investing today in new technologies, as it should increase substantially. A study commissioned by DG environment[95] estimates that for 2010 the cost of CO_2 is around 25€/t, while in 2050 it could increase to roughly 85€. The official PRIMES scenario forecasting the impact of EU policies on CO_2 prices confirms this increase:

Table 7: The evolution of CO_2 tone prices for the EU27

		2010	2015	2020	2025	2030
Carbon value €/tCO2	NSAT	20	33.8	42.7	45.6	48.5
	NSAT-CDM	20	23.7	30.0	32.0	34.1
	CES	20	31.0	39.2	41.9	44.5
RES value €/MWh	NSAT	0	35.1	44.5	47.5	50.5
	NSAT-CDM	0	39.1	49.5	52.9	56.2
	CES	0	35.4	44.8	47.8	50.8

**NB: In 2010, the price of the* CO_2 *tone is around €13*

Source: PRIMES 2008

Uncertainties are nevertheless high: estimations for 2050 range from 20€ to 180€ per tones, and the price of decreasing CO_2 with electric cars is most probably well above these estimates,

electricity in a car will in Belgium at least quintuple the price of electricity [ENER 2010].

[93] The price considered for the EV battery is quite high ([BERR 2008], pE1). At present, a lithium battery price of 10 000€-15000€ for 20KWh (800-600€ per KWh) appears as a good average price. Another study by the Belgium regulatory commission for electricity and gas estimates confirm that this Vehicule-to- Grid technology is currently quite costly. It would only become attractive for a battery cost of 400€/KWh. The study concludes that V2G technology will be only cost efficient if added to increase electric interconnections [ENER 2010].

[94] Currently the hydro electric dam is the only form of storage that is cost efficient, with the exception of a few demonstration projects such as the project developed in the state of Minnesota where Xcel energy inc. installed 1 100 MW wind turbines are supported by a giant 7 MW sodium-sulfur battery. Information available at http://www.scientificamerican.com/article.cfm?id=storing-the-breeze-new-battery-might-make-wind-power-reliable.

[95] [COM 2010 bis], pp.24-25

depending on the country considered[96].The CO_2 abatement cost of BEVs is estimated at more than 100€/t by 2030 for a rather limited abatement potential, around 79€/t for PHEVs with the higher abatement potential, and negative for ICE improvements[97]. A rough estimation of the French government pricing of a tone of CO_2 abated with Electric Vehicle is provided in Annex 10. It appears that reducing CO_2 with EVs; even with unlimited driving range is still costly.

Electric cars could actually have the reverse effect of increasing the cost of CO_2 abatement. Power sector emissions are capped under the European Trading Scheme and will have to be fully auctioned by 2013. If the introduction of electric vehicles does for some reasons, such as unmanaged charging or introduction in coal based countries, lead to an increase in CO_2 emissions from the power sector, this would have the reverse effect of driving up CO_2 prices. This also reveals the problem of sectoral CO_2 cap and trade systems.

(8) Who Should Pay?

Estimations can be given on the total amount of CO_2 that would-be-abated, yet a lot of uncertainties remain. Among others, variables include power sector emissions, battery capacity, market penetration rates, charging times, types of electric vehicles (FEV or PHEV?), the model considered and the location. To the price of introducing electric cars themselves, politicians should consider adding the price of uncertainties.

A major issue remains - who will pay for this technology? At present governments i.e. taxpayers, do – but for how long? Indeed government budgets are relying on taxes on fuels bought for use in conventional cars. The introduction of electric vehicles may decrease significantly these revenues, if taxes on gasoline are not compensated elsewhere. Added to the cost of promoting this new technology roll out itself, this could have long term negative impacts on member states budget.

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[96] McKInsey estimates that abating CO2 with electric vehicles is still more expensive than with improved combustion engines by 2030: it costs 3000€ to save 29% fuel on a gasoline car, 2600€ to save 36% fuel on diesel cars, and €4000 to save 44% fuel on hybrids. Fuel consumption can be further reduced on plug –in hybrids (65-80%) and full electric vehicles (70-85%) but the cost is tremendous and not compensated by fuel savings [MCKINSEY 2009].

[97] A study conducted for the European Commission Directorate General for Environment, *EU Transport GHG: Routes to 2050*, also concluded that EVs would have a limited impact on CO2 emissions for a relatively high price [COM 2010 bis]

Are short term industrial growth and long term CO_2 emissions reductions compatible?

The issue is political: how much is Europe ready to pay now to avoid paying in the future? And is Europe willing to take the risk of having to buy its new vehicle technologies abroad?

There is a rational behind promoting these two objectives at once. As the market share of electric cars directly depends on their prices and technology breakthroughs, supporting the development of the industry in the short term will optimise costs, help the market to expand, provide more potential for CO_2 savings, and decrease the abatement price of CO_2. In the long term CO_2 could thus be saved even if it is not the case in the first place. Both objectives should be pursued in a coherent way, there are unfortunately some loopholes in the legislation in that respect (see the following chapter).

There are nevertheless some trade-offs to be acknowledged.

States subsidise the electric vehicle product to keep jobs rather than really save CO_2; or in politically correct words they pay a high CO_2 price, but keep jobs at the same time. Companies have interests beyond borders. If the electric car is first and foremost an industrial strategy, policies have to address the following questions: will jobs be created or at least maintained? What is the timing to roll out subsidies? How to ensure that there are no barriers to technology spill-overs?

The market penetration of EVs would be strengthened by a public infrastructure network of semi fast or fast charging stations, while from a CO_2 perspective, vehicles should rather be charged at night or during off peak hours. Fast charging stations put pressure on the electric grids.

Thirdly, CO_2 does not appear to be the most relevant ground to justify public policy support. The electric car's real benefits can be found in other areas: it can lower the EU energy bill up to 15%[98], and decrease reliance on oil imports.

Another crucial benefit of Electric Vehicles, in particular as they target urban markets, is that they do not emit the gases and particulates harmful for human health linked to the burning of fossil fuels such as Carbon Monoxide, oxides of nitrogen (Nox), Particulate Matters and volatile organic compound (VOC)[99]. These emissions which are already regulated by fuel quality standards (the so-called "euro" norms), are very harmful for the health - for the lungs in particular. They are also responsible for photometrical smog and acid rains. The electric car could cut EU Member States' health bill at a

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[98] The European Commission joint research centre estimated that energy cost could be reduced up to 15% if EVs, including PHEVs, are introduced in significant numbers on the market [JRC, p27]

[99] In 2006, the the transport sector -as a whole- was responsible - for 36% of EU27 Carbon Monoxyde (CO) emissions, 40% of NOx (oxides of nitrogen) emissions, a mixture of oxygen and hydrogen produced by diesel vehicles, Particulate Matter (PM) emissions, small particles of unburned carbon, and about 18% of the EU 27 Volatile Organic Compounds (VOC), resulting from inefficient fuel combustion and the oxidation occurring in the catalytic converter [EUROSTAT 2009 bis], p169

time where national healthcare systems face the difficulty of an ever more ageing population. The American lung association found that in California, -which population of 40 million people is roughly equivalent to the Spanish one- a full switch to electric vehicles alone could save about €1.4 billion a year, prevent 300 cases of premature death, 260 cases of chronic bronchitis among others[100]. Finally, noise is reduced to a great extent. This is however not covered by many studies. One reason may be the fact that the European Commission does not have decision making authority in that area. The green marketing is perhaps usually more politically appealing than health.

[100] Financial times, may 27, 2008

Drawing conclusions: What is the way forward?

If the CO_2 outcome is negative or uncertain, with an undefined cost, and fluctuates across countries, what is the scope for political support, and in particular European policies? Under which conditions can the development of Electric Vehicles be promoted by governments with public money? And are current policies promoting a sustainable development of car passenger technologies? Are current policies consistent with their own objectives?

Increase policies coherence

Under the current European policy frameworks, EVs are promoted independently of their climate contribution, (at least in the short term). They contribute to achieve CO_2 reductions on paper and not in reality.

The CO_2 regulation for passenger cars

The CO_2 regulation for passenger cars, adopted in April 2009 by the European Commission[101], set CO_2 emission limits of 130gCO_2/km by 2015 and 95gCO_2/km by 2020. The limit is set for the average fleet of each manufacturer, and not at the car level (this would be impossible and would penalize bigger cars too strongly in the face of small cars). Penalties are set for small excess emissions (up to €95 per g/km by 2019).

To promote green technologies, the regulation gives "super-credits" for cars with emissions below 50gCO_2/km. Each car below 50g/km will count for 3.5 cars in 2012; 2.5 cars by 2014; 1.5 cars by 2015 and the credit is phased out by 2016 (article 5 of the regulation). This entails several problems

- With such a policy, the roll out of electric cars will not achieve CO2 emissions. The fact that electric cars are given super credits will just help manufacturers to reach their targets, instead of contributing to further CO_2 reductions. A consumer buying an electric car is actually paying the right to pollute of a bigger conventional car. Additionally derogations are given to small manufacturers. Sport cars for instance, could with one electric model maintain high emissions levels for their other cars.

- The CO_2 emissions of a carmaker fleet will ***in reality*** be higher than the "legal" and official one. The legislation is

[101] [COM 2009 bis]

not fully accurate[102]. Electric cars are not zero emissions vehicles. Given the current electricity mix of various European countries, they would in reality only be under the 50gCO_2/km in a limited number of countries; even with the European average emissions will likely be above the threshold. Differences between plug-in and pure electric cars are not clearly taken into account, although they contribute to a different extent to CO_2 savings.

- Should we also conclude that electric vehicles are 3.5 times more expensive to develop than CO_2 reduction technologies for conventional cars or than the penalties set?

Despite repeated warnings from several NGOs regarding the reverse effect of the CO_2 regulation for cars, the same pattern has been observed for the Van regulation (Light Duty Vehicles under 3.5 tones) decided later on. The biggest producers' countries were against the initial target proposed by the Commission. Super credits are also given to low carbon vehicles, and the limit is calculated for the fleet average too.

This regulation has been a driver behind the recent success of the electric car. Initially in favor of fuels cells, a lot of German companies finally reversed their strategies because this technology will not be ready by 2016, date at which subsidies will be rolled out. Additionally, carmakers afraid to face troubles meeting the CO_2 target, recently rushed into a number of joint ventures to develop electric vehicles.

There are nevertheless some good aspects to this regulation. In particular, this policy instrument helps in principle to give a clear signal to investors. Other systems, such as market based mechanism (the ETS) have suffered from a weak CO_2 price. Here the target and the deadline are clear. ***The support given to the electric vehicle at the expense of other technologies through super labeling or super credits is nevertheless distorting the objective: reducing CO_2 emissions***.

The renewable directive considers electricity consumed by the electric car as a renewable energy

The same distortion has been introduced in the 2008 renewable directive. The text sets a target of 10% renewable in transport for Member States by 2020 and gives a super credit of 2.5 to electric. Member States are additionally allowed to calculate CO_2 emissions of electric cars on the basis of the European power carbon factor (half the one of Poland for instance).

The fuel quality directive considers electricity a green fuel

The fuel quality directive sets a 6% target to reduce GHG emissions from transport fuels by 2020. By 2012, an additional 2% could be introduced so as to include electricity.

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[102] The approbation procedure under which a vehicle can be labelled as green innovation will be decided at the end of the year 2010 through the comitology procedure.

Measures to assess the fuel (electricity) life cycle impact on GHG emissions, would have to be adapted and measured before electricity is considered as a "green fuel". Recent results from bio fuels have proven to be negative, to quite an astonishing extent.

National Car scrapping schemes pushing for green cars sales are counterproductive

Some national measures also have been criticized for being counter-productive. This is the case of the scrapping scheme or the French type *bonus malus.* Subsidies were given to consumers replacing their old cars, or buying "green cars". The idea was smart: support the demand for car and maximize this public investment by decreasing the fleet CO_2 emissions. However, it appears that in the end, more CO_2 could be produced due to vehicles life cycle emissions, and even more so with electric vehicles: a new car must be produced, and the old car recycled, emitting more CO_2 in the end that if the old car would have been kept longer and replaced at a later stage with an even more advanced, and more efficient, new vehicle.

Recommendations:

This paper argues that policies have to be tailored to the technological stage of development of a given product while being coherent in its principles.

- Tailor subsidies and credits to real CO_2 savings. In particular differentiate the different types of electric vehicles.
- In the US for instance, car subsidies have been more strictly tailored and more focused on pure battery electric vehicles. Tax credits (up to $7500) are given to electric cars defined against battery pack above 15 kWh (which allows the Volt, General Motors Plug-in hybrid to be considered EVs). Some states, like California, condition their subsidies ($3 000 in that state) on the removal of engines and battery life cycle. The Volt is therefore only considered as an 'ultra low emission' vehicle which does not benefit from this financial rebate[103].
- Review standardization tests urgently and on a periodic basis to reflect adequately the fuel consumption of vehicles under realistic conditions. In particular they should be tailored to the vehicle's use (urban, inter-urban and motorway cycles), and include on-board appliances. Better information on electric car consumption will have the side benefit of reassuring consumers.
- Cars emissions are currently accounted for through new vehicles emissions standards; however this does not account for the existing fleet and the ever growing second hand market. Increased retro-fitting of the current car fleet would be a good way to achieve CO_2 emissions reduction.

[103] Global Insight, United States: the EVs are finally here: Chevrolet Volt enters production but is the world ready? 29 octobre 2010

Avoid bad surprises: why has there been no official impact assessment yet?

A large number of demonstration projects have been supported by the European Commission and Member states to fill data gaps, and in particular provide information on consumer behaviour. This effort reveals that it is very difficult to issue an impact and cost assessment now given the immature state of the technology. However it is urgently needed. The exercise is difficult; it could nevertheless be the backbone of an increased coordination of European policies and it is urgently needed.

Biofuels are going to make up 6 to 8% of road fuel globally in 2020 according to the European Environment Agency[104]. They have received a large support in the past, but today Europe is facing bad surprises. The IEA in its 2009 Transport Energy and CO_2, estimated that the first generation of Biofuels (sugar cane ethanol and CTL fuels produced with Carbon and Capture) to be the lowest-cost CO_2 reduction alternative to petroleum fuels for cars in the short and long term. However, a recent report conducted by the European Commission as part of its obligation under the fuel quality directive, reveals a different reality. The joint research centre estimates that actually up to 1 billion tones of GHG could be the secondary effect of such a policy if 7% of traffic is running on biofuels by 2020[105]. Second generation biofuels are a better although more expensive solution[106], as they use the non edible part of plants, or waste straw and forestry cuttings.

Target research and development

Europe could push for more coordination at the research level. This would also help Europe to reach it objective of 3% investment in R&D by 2020, as set out in the Commission president vision *Europe 2020,* and ensure a better use of public money.

Target green technologies benefiting to all types of vehicles

Electric cars will remain a niche market until at least 2030, and the product has not yet reached its technological maturity (second and third generation of electric vehicles are being worked out). Therefore this paper argues than instead of subsidising a given product, while the second and third generation will soon and progressively be rolled out, policies should for now rather target research and development.

Some technology progress could be shared amongst all types of vehicles. Public funding could in particular be orientated at the

[104] [EEA 2009], p18
[105] [JRC 2010]
[106] Second generation biofuels have a CO2 tonne abatement cost of 200$/t according to the IEA.

development of technologies useful to all types of vehicles. Thanks to binding CO_2 emissions, trends are finally changing at least in Europe. Most of the technologies mentioned in Annex 12 could be beneficial to any car. Some additional applications such as solar roof panels for thermal management, or driving assistance technologies improve the energy efficiency of all vehicles.

Increase research on battery technologies and recycling facilities

The European Union and Member States are supporting substantial research and development. The European Commission is already supporting research on batteries in its Green Car Initiative, and through its 7th framework programme.

Yet, research on batteries could benefit from benefit a more direct support. Some national plans set it as a priority however most of the research funds have until now been allocated to demonstration and infrastructure projects[107]. National plans are also still poorly coordinated in that area. Even the German national plan, which is the most ambitious to date on battery research, is only allocating €60 million out of €500 million to batteries[108]. Member States plans are still very much focused on lithium research and production, however breakthrough in battery technologies are also needed. Last but not least, these amounts fade in front of international competitors policies. The US, like China and Japan actually made it their top priority in the frame of electric vehicles policies (please refer to Annex 13).

Governments may be cautious to give their support to a limited sector. With the exception of the French company Saft, there is indeed a limited number of battery producers in Europe, very few lithium battery pack productions facilities in Europe and almost no recycling facilities for lithium batteries[109]. Hence, beyond batteries

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[107] In the European Commission 7th research framework programme, €940 million were allocated to fuel cells and hydrogen technology (a public-private research partnership), but there was no similar funding for EVs batteries. The green car initiative first call of proposal offered funding for safe and efficient vehicles (total cost of €7M, of which €4M from the EU, for 3 years) out of which two projects were mainly focusing on batteries technologies and management source. France has allocated a €200 million subvention to PREDIT (Innovation & Research Programme on land transportation). The French plan has included provisions for batteries. A €250 million loan is allocated to industrials, in particular for the development of lithium battery production. The first national network for research on battery technology has also been launched in July 2010. This is still less than money allocated to demonstration projects (up to €400 million). In Germany, €60 million out of €500 million of the German *national entwicklungsplan electromobilität* are allocated to battery research and development. Out of 15 defined research projects, two are directly targeting the development of battery technologies: projects targeting production technologies for Li-Ion-cells/Batteries, P10 Battery Centre and a pilot plant for recycling of Li-ion batteries. In particular, a six year project (LIB 2015) aims at developing safer, more efficient and cheaper batteries. Extraction of lithium is also promoted in Saxony and new agreements are to be signed with Bolivia. The ministry of environment also launched LITHOREC in 2009, a project of €18 million on the recycling of batteries.

[108] [MICHAUX 2010], pp.9-13

[109] France is one of the sole European countries to benefit from some production facilities. The French battery firm SAFT, one of the main world battery companies, entered a joint venture with Johnson Control, a top American automobile supplier in 2006 to enter the EV market for hybrids and electric. In 2007, the first Li-ion batteries

where Europe has little production capacity, work should be done on the system. Other fields of research include in particular electronic systems for cars and ways to link batteries with the power-train in an efficient way and the battery connection with the electricity grid as well as new communication technologies. Technologies such as Vehicle to Grid or Vehicle to House, offer an energy storage potential for renewable energy and a buffer to polluting peak power production.

Recommendations

- Spend money on research rather than finished products.
- Increase coordination of Member States research policies
- Support research on batteries, recycling facilities and consolidate Europe position in electronics. Introduce research on batteries in the forthcoming European commission 8th framework research programme (2014-2020) and forthcoming call for proposals.

Help the market to kick off, halt the member states cacophony

Even as the first cars are being rolled out, no European standards have yet been defined[110]. Some efforts have already been made: the April 2010 European Strategy on Clean and Efficient Vehicles[111], a communication drafted by Antonio Tajani, Commissioner for enterprise and industry, acknowledges the need to standardize. In its roadmap on regulations and standards, in particular the second version of the document released in October 2010, the European Commission lists the different standards needed. The last version in particular insists more on charging interfaces and recycling. The Action Plan adopted in May by European Council for competitiveness gave a mandate to do so to UNECE and CEN-CENELEC. A French German group on electro-mobility is working on the standardization of charging infrastructure and billing.

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for EVs were inaugurated in Nersac. Renault is building a factory in Flins with a short term production capacity of 100 000 batteries per year. Bolloré, a small electric car company, is also building its own in Britain. Nissan and Renault are considering building a partnership on a possible joint company to recycle lithium batteries. Johnson Controls-Saft batteries equip the first series-produced hybrid vehicle, the Mercedes S400, since April 2009, and the BMW 7 Series hybrid vehicle on the market since early 2010. http://www.saftbatteries.com/MarketSegments/HybridandelectricvehiclesJCS/tabid/400/Default.aspx. For an exellent overview of national EV development plans please refer to François Michaux report for Confrontation Europe on the 26th of April 2010. The website www.eagar.eu, created in the frame of the EU 7th Research Framework Programme, also benchmarks electric vehicles research activities worldwide

[110] For a more in-depth analysis on the problems of charging standards please refer to a previous publicaton *available at* www.ifri.org/downloads/actuelledeboncourtchargingstandardsev.pdf

[111] [COM 2010 ter] European Commission, communication from the commission to the european parliament, the council and the european economic and social committee**,** A European strategy on clean and energy efficient vehicles, COM(2010)186 final, Brussels, 28th April 2010.

But despite the set 2011 deadline, the way seems chaotic. German companies have already been successful defending the Mennekes plug on vehicles (a seven pin plug including a communications pin), French companies are now fighting to impose their standards for the interface plug. At the level of the charge itself, Germans home plugs allow higher voltage to charge vehicles than French ones. And the clock is ticking.

In general standards contribute to economies of scale and minimize production costs; they will enhance the sustainability of the electric car as means of transport. They can help to prevent any safety incident to have a dramatic negative impact on consumer acceptance. They are needed for cars to promote their mobility. Electric cars are unlikely to cross artificial infrastructure borders in the short term because of their low driving range, but research targets an increase in driving distance for the longer term. Charging infrastructure and communication systems therefore need to be harmonized. In particular they should facilitate interaction with the electric grids. This will for instance be necessary for the development of vehicle to grid technologies, which requires the development of communication among different actors (utilities, car makers, consumers, car owners). Recycling should also be standardized across EU countries. Last but not least, standards will increase competitiveness.

The fragmentation into national schemes or into different charging systems could also hamper European competitiveness on the global stage. Japan is already well advanced in infrastructure and seeking global leadership through standardization. The fastest charging systems have recently been created by the Japanese ChAdemo association regrouping electric utilities, car manufacturers and research centers. The United States has already aligned on the Japanese semi fast charging standards. Given the impact of infrastructures on market penetration rates, delays in standardization are problematic. Standards for charging infrastructure are but one example among many.

Recommendations:

Standards should be set that will promote the faster take off of electric cars, promote European competitiveness increase the potential of CO_2 that can be saved -thereby decreasing the cost of electric cars as mitigation tool.

Look at the vehicle in its context: Ensure a sustainable connection with the power sector

Most CO_2 impact assessment studies on the introduction of electric vehicles do not take into account the electricity load curve as a key variable. The JRC scenario, developed in partnership with the European Commission, is based on the average CO_2 emission factor of power generation in the EU, and therefore does not consider the variations induced by the charge timing, and barely the one resulting from the place of charging[112].

Recommendations:

- Include electricity as a variable in electric vehicle CO_2 assessment studies,
- support the development of EVs in countries where it will be beneficial in terms of CO_2
- assess the need for smart meters, interconnections and smart grids

Look at mobility in general

A comprehensive approach towards CO_2 reductions should target the most cost efficient ways and build sustainable paths into carbon neutral technologies. Conventional vehicles will remain a large share of the European vehicle fleet in the short and medium term (at least until 2030). CO_2 reduction from ICE should be encouraged. Given the fact that EV cost parity with ICEs is uncertain, other technological breakthroughs could offer interesting alternatives.

The European Commission Clean and Efficient vehicle strategy, initially pushed by the Spanish presidency targeted only the electrification of cars - it lacks the balance. A strategy subsequently later on approved by the Council, follows a two track approach: encouraging CO_2 reductions from ICE on the one hand, and promoting alternative technologies on the other, with a "positive discrimination" towards electrification. Conventional cars can also be adapted to real consumer needs: decreasing size and power trains offer an interesting CO_2 reduction potential. This technology neutral approach allows the development of more cost efficient technologies. This is necessary as EVs do not score equally in all the EU Member States.

In terms of CO_2 savings in the short and medium term, more is therefore likely to come from the white paper on transport than from electric vehicle policies.

Other tools might indeed be more efficient for decreasing CO_2 emissions from land transportation than focusing on the technologies of cars such as, speed limits, the re-orientation of demand towards other transport modes, multi-modal transportation, mileage targeted measures etc. Some measures are nevertheless facing fierce political opposition, such as proposals to establish speed limits of 80kmh for Lorries and 110-130km/h for cars or the proposals to include transport fuels in the European Energy Taxation Directive.

Finally, ICT solutions offer a great potential and Europe is quite advanced in the process. Traffic management with ICT solutions could account for up to 25% reductions, for a ridiculously low price compared to the electrification of power-trains.

[112] [JRC 2010], p. 15.

Recommendations :

- ICT solutions could be a growth strategy for Europe and should be considered in the forthcoming guidelines on transport infrastructure TEN-T.
- The white paper on transport should include electric vehicle as a long term instrument
- Ensure a fair price for CO_2 as the basis of green growth. With a clear target, the price of CO_2 is sufficient to sustain investments in the right direction. Global picture cannot be avoided. Sectors cannot be viewed separately, and in particular the electric vehicle.

Conclusion

The electric car is making the front lines of newspapers where it is often presented as an innovative solution to the CO_2 emitted by the expansion of the transport sector. However it appears that by 2020, Electric vehicles will barely contribute to CO_2 reductions in Europe, even if massively introduced. On the contrary, the optimization of conventional fuel power trains and the progressive hybridization of cars can, until then be a less costly and more efficient way of decreasing CO_2. Conventional engines will yet always have to burn fuel, whereas electric vehicles are not only potentially "zero emissions vehicles" but also offer interesting perspectives in terms of energy security as electricity can be produced variety of sources. By supporting its development now, Europe can thus secure the potential of a future mitigation tool.

Expectations might nevertheless have been pushed too high in the public debate as the product and its surrounding system have not yet reach their mature state. In order to achieve its promises, the electric car will first need to overcome several bottlenecks: price, technological shortcomings and its interaction with European power grids. It will have to be introduced in a sustainable framework made of a greener power sector, electric interconnections, smart grids and smart meters. Either these complementary technologies are to be introduced at the same time, or we face the risk of locking electric vehicles into a non sustainable CO_2 path. It remains also to be seen whether this is illusionary or feasible; the appropriate answer may be different across EU Member States.

The main concern behind the promotion of the electric vehicle until now has actually mainly been industrial: it is about saving jobs in Europe by maintaining the competitiveness of the car industry. In this respect, little has been done so far to ensure the sustainability of policies promoting this new technology. The issue of how to support best Europe competitiveness has been left beside too, as it was not openly mentioned in the public debate. The main problem is not therefore the electric vehicle in itself but the political discourse around it which lacks coherence. The electric vehicle is a tortoise publically announced as a hare in the climate change debate. This may end up being counterproductive.

Lord Dunsany, an Anglo-Irish writer from the 20th century wrote an alternative end to the well know French fable: The Hare did not lose the race, it actually just refused an absurd challenge of waiting hundreds of years for the tortoise to finish the circuit; but, the author proceeds, "the reason that this version of the race is not widely known is that very few of those that witnessed it survived the great forest-fire that happened shortly after. It came up over the weald by night with a great wind. The Hare and the Tortoise and a very few of the beasts saw it far off from a high bare hill that was at the edge of the trees, and they hurriedly called a meeting to decide what messenger they should send to warn the beasts in the forest. They sent the Tortoise." In the climate change race, the electric vehicle is currently not the best solution, nor is it the cheapest option. It can become an interesting long term potential, in particular as a third generation now emerge on the market, and policies should be tailored thereof

Annexes

Annex 1: Overview of some marketed and forthcoming electric cars' models

	Manufacturer	Model	Type Car	driving range km	Battery Type	Battery Size KWh	Vehicle Consumption	Market Introduction
BEV	BYD	E6	family car	400	Lithium-iron-phosphate	48	18kwh/100km	2010
	Mercedes	SLS edrive	sport	180	Li-ion	48		2015
	Audi	E-tron	sport	248	Li-ion	12		2013
	Tesla Motors	Roadster	sport	350	Lithium-ion blades	56		2009
	Renault - Nissan	Twizy Ze Concept	three-wheeled	100	Li-ion	15-20		2012
	Daimler - Smart	Fortwo ED	urban	135	Li-ion	14		2010-2012
	Fiat & Micro-Vett	E 500	urban	120-145	Li-ion polymer	20-22		n.a
	Mitsubishi	I-Miev	urban	160	Li-ion	16	12,5*	2010
	Renault - Nissan	Zoe	urban	160	Li-ion	20		2012

	Ford	Ford Transit Connect Electric	van	110	Li-ion	28		2011
	Renault - Nissan	Kangoo BE ZE	van	160	Li-ion	22		2011
PHEV	General Motors	Volt	compact	500	Li-ion	16	0.2 kWh / mile 3.9l/100km	Production November 2010 US, 2011 Europe/ Canada Opel Ampera
PHEV	Toyota	Prius III	family car	14,5	NiMH	9	0.25 kWh / mile	tbc
PHEV	Volvo	V70	break	1200	Li-ion	11,3		2012
PHEV	VW	Golf Twin Drive	compact	50	NiMH	12	8Kwh/100km	2011
PHEV	Mercedes	Vision S 500	executive car	30	Li-ion	15	3,2l/100km	
HEV	Toyota	Prius III	family car	13	NiMH or Li-ion	5	4.3l/100km	2009

Annex 2: Outlook on current and future technologies for electric cars batteries

Lead acid battery: the first available batteries, which are relatively cheap as as they are produced massively for the past hundred years, with albeit limited performance. Small lead-acid packs are used as starters in almost all ICE cars, and almost all small electric machines (golf cart…). Power is stored and discharged rapidly, but the autonomy is very low. They are in this respect not fitted for Electric Vehicles.

Nickel-cadmium (Ni-Cd) batteries: This technology initially used in telecoms and aeronautic, was developed for electric vehicles in the 90s. It was finally dumped because of the toxicity of cadmium, which is banned by European regulation on heavy metals, and their limited energy density. A new metal was then introduced to replace the cadmium giving birth to the **nickel-metal hybrid (NiMH) battery**. NiMH batteries offer a high power, large cycle capacity, and a favorable energy to weight ratio. In this respect they can be broadly used for both HEV and PHEV. The Toyota Prius II and the Honda Civic IMA are equipped with this technology. However NiMH battery energy density is still insufficient for full electric cars. Moreover the cost of nickel which is required in large amounts in the battery (5-10kg / kWh) remains high and is unlikely to decrease[113]. Additionally, these packs suffer an exothermic reaction during charging and from unpredictability in their life expectancy.

Zebra batteries, patented in 1975 were progressively developed. Thanks to their ceramic electrolyte, they demonstrate good reliability and an energy density two times higher than nickel cadmium batteries; yet the low conductivity of this material handicaps their power density[114]. In this respect, while being tested for buses in Italy or France, they are usually not used for EVs or HEVs with the exception of Daimler and Microvett utilities or the THINk! new EV.

Contrary to NiMH batteries, **lithium technology** offers a promising ratio of energy storage and power and for a lower weight. Lithium batteries can in this respect be adapted either for PHEVs, where the battery is optimised for power, or for EVs needs, i.e. energy density. Lithium technologies include a wide range of configurations, hence characteristics. Until now, lithium batteries were largely used for electronic consumer goods. Their use for high power applications remained limited as it is difficult to control the charge/discharge cycles.It is therefore necessary to associate them with electronic controls.

Lithium batteries, currently used in most of the electric vehicles, are being optimised as there as still some problems regarding their chemical and thermal stability. Technologies to improve the components of the battery pack are being developed. Cooling components are therefore essential but they add weight and use energy themselves, reducing thereby the autonomy of EVs. To address this, Nissan has formed a joint venture with NEC to produce batteries using a laminated structure to improve cooling[115]. Other lithium technologies are also being developed to adress their shortcomings. Lithium-ion phosphate[116] or lithium-iron-polymer show benefits of improved safety, a slightly lower energy density, and a very high life cycling, and charging times could in this respect be reduced up to 30minutes[117].

Lithium sulphur batteries also based on metallic lithium, offer the highest energy density in theory, yet its excessive cost, low cycling life and possible cell discharge reactions hamper its commercialisation in the near term.

Lithium-iron-polymer pack could be 5 times lighter than lead-acid batteries, and present significant cost reduction prospects. Nanomaterials are used to increase power

[113] Data found in [T&E 2009], p37
[114] [SYROTA 2008],pp.71-72
115 [ECONOMIST 2009]
116 The cathode is made of iron phosphate instead of cobalt for Lithium ion.
117 [T&E 2009], p38

density and decrease charging times. This technology is currently produced by A123, an American newcomer backed by general electric[118], and Electrovaya.

Third generation batteries are being developed, but they remain very far from commercialization. This is the case for metal-air batteries which could potentially extend pure electric vehicles driving range up to 800km. Initially developed for military applications, a large variety of technologies could be applied to electric vehicles. The cathode is replaced by incoming air and the anode is usually made of zinc, aluminum or even lithium in some cases. An American firm, fluidic energy, recently received a 5.13 million$ loan from the US government to develop its prototype. In Europe, projects are developed as well[119]. The British university, St Andrews is financed by the UK government for its research program on a carbon-air battery. The STAIR (St Andrews Air) battery has an energy density of 2000-3000Wh/kg, ten times the current energy density of lithium batteries, at a lighter weight and a lower cost[120]. PolyPlus Battery Company replaced the liquid electrolyte by a solid one, therefore offsetting the problems of dry out[121]. In the nearest future, lithium-iron-phosphate batteries could also help significantly decrease the batteries costs against lithium-cobalt batteries, from the targeted €300/kWh to €200/kWh[122].

118 [ECONOMIST 2009]
119 http://www.futura-sciences.com/fr/news/t/technologie-1/d/batterie-metal-air-800-km-dautonomie-pour-les-voitures-electriques_21308/
120 [THE TELEGRAPH 20 May 2009]
121 http://www.polyplus.com/company.html
122 Eric Lemaitre, CEA, directorate for technology research, in [CONFRONTATIONS EUROPE 2010], p27

Annex 3: Samples of Hybrids and Electric Cars, Batteries Capacity and EV Electricity Consumption Well to Wheel

	Manufacturer	Car Model	Type of Car	Driving Range km	Battery Technology	Battery Size in KWh	Vehicle Consumption in kWh/km	Market Introduction
Full Electric Vehicle	IEA - 150 km electric driving range	5 liter Volkswagen type of car	urban	150	Lithium-ion	33	0,2 kwh/km	current
	IEA	future small urban vehicles	urban	150	Lithium-ion	15	0,1 kWh/km	long term
	BYD	E6	family car	400	Lithium-iron-phosphate	48	0,18	2010
	Mercedes	SLS e drive	sport	180	Li-ion	48	n.a.	2015
	Audi	E-tron	sport	248	Li-ion	12		2013
	Tesla Motors	Roadster	sport	350	Lithium-ion blades	56		2009
	Renault - Nissan	Twizy Ze Concept	three-wheeled	100	Li-ion	15-20		2012
	Daimler - Smart	Fortwo ED	urban	135	Li-ion	14		2010-2012
	Fiat & Micro-Vett	E 500	urban	120-145	Li-ion polymer	20-22		n.a
	Mitsubishi	I-Miev	urban	160	Li-ion	16	12,5*	2010
	Renault - Nissan	Zoe	urban	160	Li-ion	20		2012
	Ford	Ford Transit Connect Electric	van	110	Li-ion	28		2011
	Renault - Nissan	Kangoo BE ZE	van	160	Li-ion	22		2011
	IEA - 30/40 km electric driving range				Lithium-ion	8	0,2 kWh/km	current
Plug-In Hybrid PHEV	Volvo	V70	break	1200	Li-ion	11,3		2012
	VW	Golf Twin Drive	compact	50	NiMH	12	0.8	2011
	Mercedes	Vision S 500	executive car	30	Li-ion	15	3,2l/100km	
	Toyota*	Prius III	family car	13	NiMH or Li-ion	5	n.a.	2012
	General Motors	Volt	compact	500	Li-ion	16	0.32 (0.2kWh/mile)	nov 2010
HEV	Toyota	Prius III	family car	14,5	NiMH	9	0.40 (0.25 kWh /	

* Japanese 10-15 mode urban driving pattern

Annex 4: Duration of electric vehicles charging, car samples

Manufacturer	Model	Type	Segment	Electric Driving range (km)	Battery Type	Battery Charging	Battery Size (kWh)
BMW	Mini-E	EV	urban	250 -160	Li-ion	4h30 (43kW); 7h (220V plug)	35
Renault - Nissan	Twizy Ze Concept	EV	tricycle	100	Li-ion	3h30	15-20
Renault - Nissan	Zoe (urbaine)	EV	urban	160	Li-ion	4-8h standard plug 80% in 20mn fast charging (station) 3 minutes quick drop	20
PSA	Peugot Ion (urbaine)	EV	urban	130	Li-ion	50% in 15 minutes; 80% in 30 minutes (three phase 380V triphased); 6h (220V plug)	16
Daimler - Smart	Fortwo ED	EV	Urban	115-135	Li-ion	3h (20-80% with 220V plug); 8h (220V plug)	14
Citroen	Berlingo First Electric	EV	van	120	ZEBRA - NiMH	8h; 5h for 50%	23,5
Renault	Kangoo BE ZE	EV	van	160	Li-ion	4-8h standard plug 80% in 20mn fast charging (station) 3 minutes quick drop	22
Mercedes	SLS edrive	EV	sport	180	Li-ion	8h	48
Tesla Motors	Roadster	EV	sport	350	Lithium-ion blades	3h30 (plug 240V/70A); 48h (120V-15A)	56
Audi	E-tron	EV	sport	248	Li-ion	6-8h	24
BYD	E6	EV	Compact	400	Lithium-fer-phosphate	100% in 8h; 50% in 10min (fast charging station)	48
Renault - Nissan	Leaf	EV	Berline	150	Li-ion	80% in 30 min; 24km in 5 min; 8h with 220v	24
General Motors	Volt	PHEV*	Compact	60	Li-ion	50% in 1h	16

*data not available for a lot of PHEVs. The start stop system should help recharge the battery.

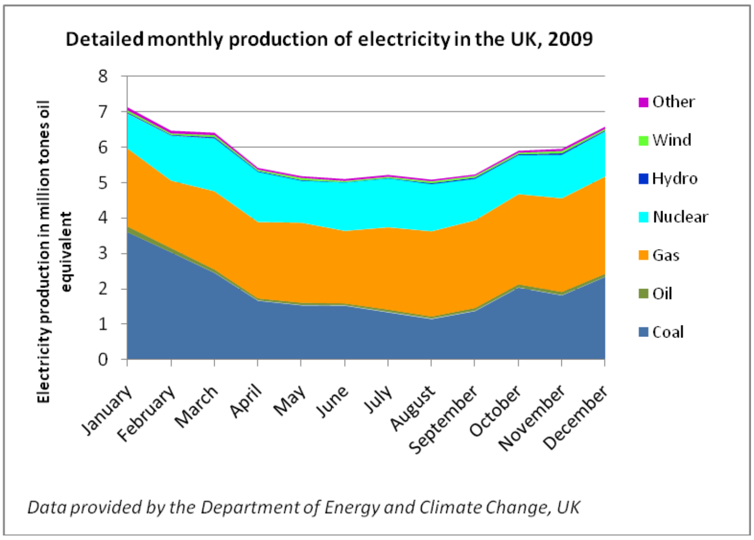
Annex 5: Lithium Batteries Recycling Facilities Worldwide

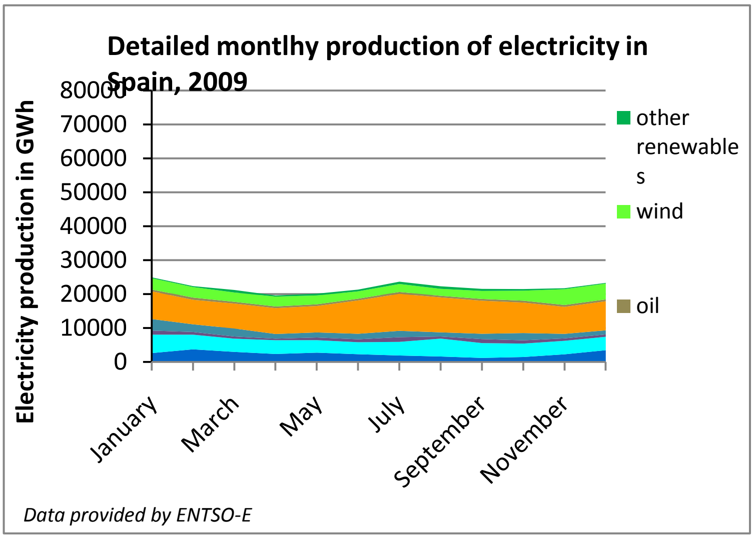
COMPANY	FACILITIES	MATERIAL RECYCLED	CAPACITY in tonnes/year
CITRON (Centre International de Traitement et de Recyclage des Ordures Nocives)	Le Havre (Port), France	Li-Ion et NiMH	n.a.
PILAGEST	El Pont de Vilomara i Rocafort, Barcelona, Espagne		2000
RECYPILAS	Bizkaia, Espagne	Li-Ion, NiMH	n.a.
REDUX RECYCLING	Dietzenbach, Allemagne	NiMH	6000
REVATECH	Liège Area (Egis / Monsin), Belgium	Li-Ion, NiMH	3000
SAFT BATTERIES	Oskarsham, Sweden,	NiMH	n.a.
SNAM	Viviez, France	Li-Ion, NiMH	n.a.
UMICORE	Sweden	Li-Ion	n.a.
KMK Metals Recycling	Tullamore, Ireland	Li-Ion, NiMH	n.a.
POLYECO	Aspropyrgos, Attica, Greece		n.a.
Batrec AG	Switzerland	All types of batteries	2000
AEA TECHNOLOGY	Scotland,UK	Li-ion	n.a.
Nissan-Sumitomo	Japan, Usa, Europe (Renault)		n.a.
Toxco	USA, Canada	All types of batteries	n.a.
Kinsbursky Brothers	USA	All types of batteries	n.a.
Raw Materials Company	USA	All types	n.a.
Doe Run	USA	Lead-acid batt.	13.5 million batteries/year
Exide Technologies	USA (10), Europe (3), New Zealand (1)	Lead-acid	n.a.
Inmetco	USA	Mostly Ni-Cd	n.a.
Gopher Resource	USA	Lead-acid	10 million Batteries/ year
Sanders Lead Company	USA	Lead-acid	n.a.
Universal Metal & Ore	USA	Ni-Cd, Li-ion	n.a.
Dowa Holdings	Japan	Li-ion	1000
Toyota Chemical – Sumitomo	Japan		n.a.

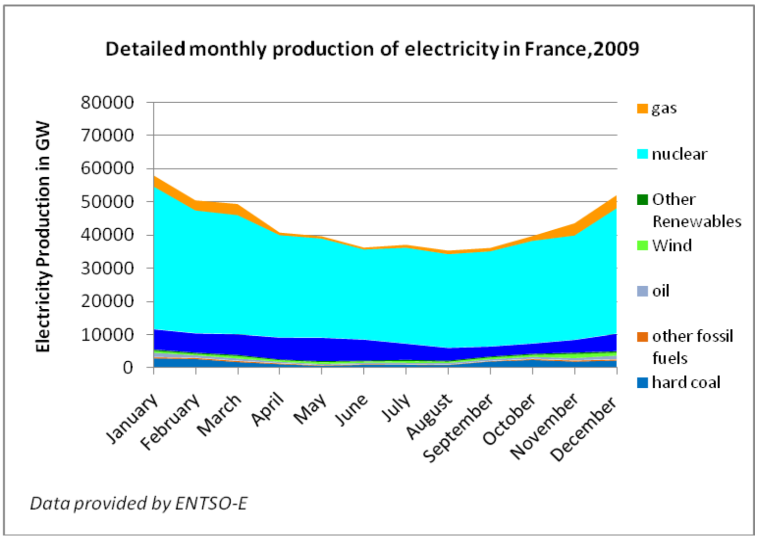
Source: Author

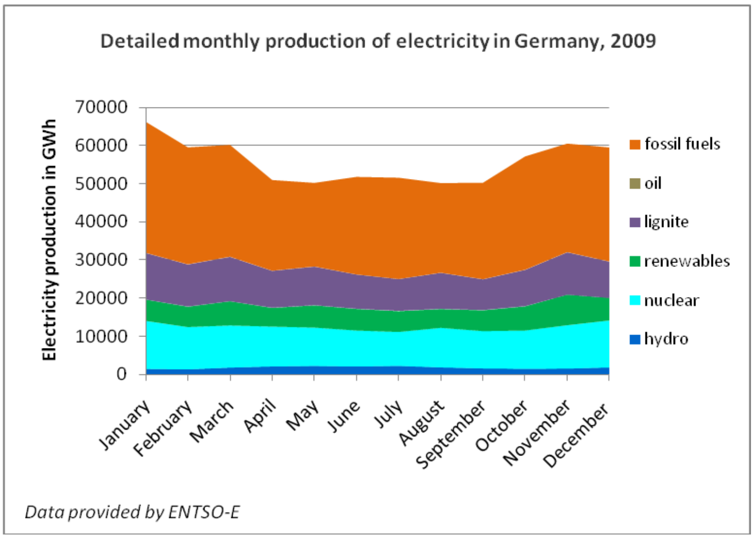
Annex 6: Power demand coverage by primary source of electricity across EU Member States

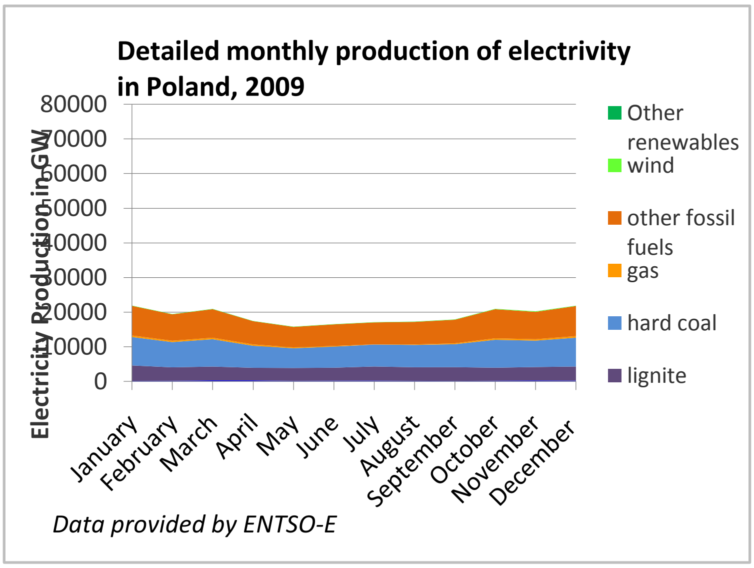
The graphs below give an indication of the type of power plants used to cover peak load demand as opposed to base load demand in Spain. For Spain at least, it appears that relatively more CO_2 is emitted at peak load than during base load hours.











Annex 7: Electricity Carbon Emission Factor in Selected EU Member States

Country	CO_2 Emissions	EV CO_2 emissions*	Source
EU 27	$410gCO_2/KWh$[123] for 2008 $385gCO_2/KWh$ for 2010	$82gCO_2/km$	**[EURELECTRIC, 2008]** **[PRIMES 2008, p21]**
Poland	$1025gCO_2/KWh$ for 2010	$205gCO_2/km$	**[PRIMES 2008, p21]**
Germany	$686gCO_2/KWh$ for 2010	$137gCO_2/km$	**[PRIMES 2008, p21]**
UK	$467gCO_2/KWh$ for 2010	$93gCO_2/km$	**[PRIMES 2008, p21]**
Spain	$307gCO_2/KWh$ for 2010	$61gCO_2/km$	**[PRIMES 2008, p21]**
France	$64gCO_2/KWh$ for 2010	$13gCO_2/km$	**[PRIMES 2008, p21]**
Sweden	**$43gCO_2/KWh$ for 2010**	**$9gCO_2/km$**	**[PRIMES 2008, p21]**

**on the basis of 0.2kWh/km consumption level (IEA representative value estimate)*

The PRIMES Scenario

PRIMES model calculates the emissions of the power sector in 2020 according to impact of the 20-20-20 objectives: 20% renewable in electricity, 20% energy efficiency and the 20% CO_2 emissions reduction target enforced through the European Trading Scheme. They assess several scenarios.

- The baseline scenario issued by DG TREN in 2007,
- The RSAT scenario that exclude trading of electricity produced from renewable energy sources among member states (each Member State will have to comply to their renewable target domestically),
- The RSAT-CDM scenario where electricity from renewable trading from Member States is also excluded but where member states are allowed to benefits from CO_2 emissions credits through the UN-CDM flexibility mechanism
- The NSAT scenario: trading of electricity from renewable is allowed, but not CDM.
- The NSAT-CDM scenario: both renewable and CDM Trading are allowed.

Source: [PRIMES 2008, p20]

Electric Power Choice Scenario

Eurelectric, the European federation of electric companies, also issues forecasts for the achievement of a carbon-neutral power sector by 2050 compared to a baseline scenario. The power choice scenario predicts that emissions from the power sector will be cut by 40% by 2030 and 90% by 2050, including a domestic 75% cut, relative to 1990s levels. This target should enable the EU to respect the 450ppm scenario developed by the UN to mitigate climate change. A large penetration of Electric Vehicles is assumed in the power choice scenario (11.1% of EVs in 2030 and up to 90.3% stock share by 2050) [EURELECTRIC 2009 bis, pp.35-51].

[123] EEA, p92

Annex 8: Available electric vehicle production levels announced by carmakers

Carmakers	Production Level	Year
General Motor – Volt (PHEV)	10 000 – 15 000	1st year of production[124]
Renault/Nissan – (FEVs all included 5models)	800 000	1st year of production
Renault – Zoé (FEV)	150 000	2012
PSA – Ion (FEV) and Citroen C-Zero	8000	2011
Bolloré – Blue Car (FEV for leasing)	40 000	First year of production

[124] Source: [IHS 2010] IHS Global Insight

Annex 9: Electric Vehicles Market Penetration Forecasts

IEA Forecasts of Electric Vehicles Market Penetration

The IEA has considered three types of possible scenarios. The Blue Map scenario forecast the number of electric car needed in order to reach the overall world target of 50% reduction in CO_2 emissions by 2050. It includes forthcoming technologies and strong government support. This is the idealistic scenario. The baseline scenario (ACT) is on the contrary simply based on current available technologies.

The IEA developed its scenarios on the following assumptions:

- In the Baseline scenario, worldwide sales of LDV (cars, sport cars and vans included) triple from 60 millions/year to 150millions/year in 2050. This is not the case in the Blue Map scenario where sales are much lower, reaching only 110millions in 2050 due to the development of public transportation.

- The sales forecast of the Blue Map Scenario is based on the assumption that the cost of the battery will drop to under 400$/kWh for FEVs and 450$/kWh for PHEVs by 2020. The latter assumption appears in line with carmakers forecasts.

[IEA 2010] International Energy Agency, *Transport, Energy and* CO_2, p125.

	2010		2020		2030		2050	
	EVs	PHEVs	EVs	PHEVs	EVs	PHEVs	EVs	**PHEVs**
Baseline Scenario World	0.1% max	0.4% max	n.a.	n.a.	n.a.	n.a.	n.a.	**n.a**
Blue Map Scenario World			2.5mln	4.7mln	9.3mln	24.6mln	52.2 mln	**49.1mln**
Baseline Scenario OECD Europe	1600	3200	1700	3400	1600	3200	1700	**3400**
Blue Map Scenario OECD Europe* SALES	7230 (0.0005 %)	3050 (0.0002%)	439 590 (2.5%)	1mln (0.05%)	1.5mln (9%)	4mln (24%)	4.5m ln (27%)	**5 mln (29%)**
Blue Map Scenario OECD Europe CAR FLEET	**18070 (0.08%)**	**12610 (0.05%)**	**1.5mln (0.8%)**	**5mln (2%)**	**10.6mln (4.2%)**	**42.4mln (16.6%)**	**54.2 mln (22.5 %)**	**122mln (50.6%)**

Source: author on the basis of IEA technology Roadmap, 2009

* The IEA new LDV sales forecasts in the Blue Map Scenario are as follow (in millions): 15.6446 for 2010; 17.4724 for 2020; 16.4707 in 2030 and 16.7948 for 2050.

European Commission Joint Research Centre Scenarios' Forecast

Initial assumptions of the JRC scenario include

- the decrease of battery costs of 700€/kWh to 203€/kWh (less than the IEA assumption),
- an initial 100km real autonomy for EV (against 160km under the NEDC cycle for the IEA scenario),
- and an existing starting basis for infrastructure in 2010 (10% in garages and 0.5% in other places).

The lowest range scenario forecast a low progress of battery technology and a continuous cost reduction up to 300€/kWh. Infrastructure consists solely of those announced in national plans. In the higher range scenario, battery technology evolves rapidly and prices reach 200€/kWh by 2030.

The European Commission Joint Research Centre Scenario FEVs and PHEVs Sales per year by 2020 and 2030

	2020		2030	
	FEVs	PHEVs	FEVs	**PHEVs**
JRC Lowest Range Scenario SALES	107 500 (0.05%)	1 million (4.7%)	420 000 (1.9%)	**3 million (13.3%)**
JRC Lowest Range Scenario FLEET SHARE	800 000 (0.3%)	1.1million (0.4%)	3millions (1%)	**19millions (6.3%)**
JRC Highest Range Scenario SALES	0.6million (2.9%)	2.5million (11.4%)	6.5million (29%)	**7.3million (32.6%)**
JRC Highest Range Scenario FLEET SHARE	**3.3 million (1.2%)**	**5.8million (0.9%)**	**26.1 million (8.7%)**	**54million (17.9%)**

Source: JRC2010; % are approximate and author own estimations[125]

[125] Percentage are approximate and based respectively on new car sales and car fleet forecasts. These were computed with sales estimates of around 21.5million in 2020 rising to 22.5millions by 2030 (Source: [JRC 2010], p.24). Fleet shares are calculated on the basis of table 10 (source: [JRC 2010], p.26). The EU fleet (total number of cars on EU roads) is raising 230 million in 2010, to 275 million in 2020 up to 300 million by 2030.

Annex 10: Samples of Electric Cars Prices

	Type of Car	Car & Price	Existing Conventional "Equivalent" & Basic Price
Battery Electric Vehicles (BEV)	**SMALL URBAN CARS**	Peugeot I-on €35 000*	**Peugeot 107** **€6420 (French Price)**
		Smart Fortwo ED $599/month lease	**Smart** **€10 000 (German Price)**
		Citroen C Zero €35 350	
		REVA NXR* €15 800, €120/month battery	
		REVA L-ion €23 890	
		Renault Zoé € 15 000 €100/month battery	
		MINI –E Test only, Leasing $600/month, installation costs included	**MINI** **€15550 (German Price)**
	COMPACT CAR	Volvo C30 Electric £22,500 (€26 314)	**Volvo C30 Diesel** **€21 420 (Belgium Price)**
	FAMILY CAR/ BERLINE	Nissan Leaf €30 000*	
		BYD E6 $40 000 (2009 est.)	
		Renault Fluence €21 300* €79 per month for batteries	
	UTILITARIAN VEHICLE	Renault – Kangoo Be Bop ZE €15 000-€20 000 VAT excl. €72/month for the battery leasing VAT excl.	**Renault Kangoo Express** **€11 000**
		Citroen Berlingo First Electric €37 500*	
	SPORT CAR	Tesla Roadster $103 000	
Plug-in Hybrids Vehicles (PHEV)		Audi A1 E Tron Hybride €16 000	**Audi A1 Diesel** **€18 950 (Belgium Price)**
		Chevrolet Volt $32 780***	
		BYD FEDM €13 000	
		Honda Insight €19 990	
		Toyota Prius €28 190	
		Exagon Furtive e-GT €200 000	
		Audi Q5 Hybrid **€ 59 000**	

*5000€ French government subside included
*** $7500 US gouvernement tax credit
Source: Ifri

Annex 11: How much does the French government values the reduction of a tonne of CO_2 with an electric vehicle by 2020?

In France the power sector CO_2 emissions are amongst the lowest in Europe, thanks to nuclear power. France could therefore be one of the most probable European Member State places where EVs could contribute to CO_2 mitigation efforts. The governmental plan is also quite clear in terms of the amount allocated to the development of EVs. This makes it a good sample to make rough estimations of costs. It is interesting therefore to estimate the money likely to be spent on a tonne of CO_2.

The graph is based on the following assumption and data:

- It takes as reference for calculation the average power sector emissions of 64g CO_2/kWh (Source: PRIMES 2008). Electric Vehicles are therefore assumed not to be mainly charged in peak periods, where emissions are higher.

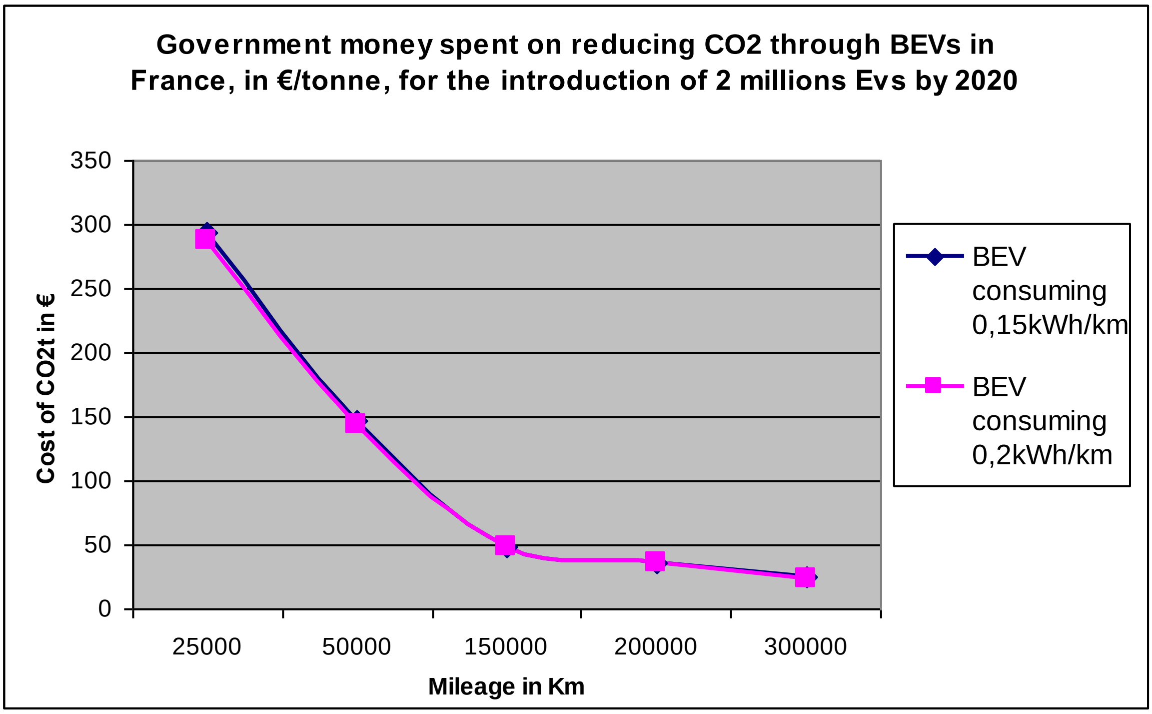
- The 20 million vehicle fleet is assumed to be entirely composed of battery electric vehicles. As the French government is funding electric vehicles, be they BEVs and PHEVs, the 2 million vehicle fleet is likely to include some plug in as well. BEVs are likely to reduce more CO_2 than PHEVs and efficient ICEs, if they cover the same number of kilometres. In this respect, the amount of emissions saved will in reality probably be lower than those assumed in the graph. This assumption decreases the probable price of a CO_2t.

- Two types of Electric Cars are taken into consideration: BEVs consuming 0.2kWh/km and BEVs consuming 0.15kWh/km.

- The BEVs emissions are compared to ICEs emissions for the same mileage. ICE emissions are considered to be 146g CO_2/km; the French average fleet emissions for 2008 (source: ADEME). This is to the advantage of BEVs CO_2 credentials. Indeed, BEVs are more likely to replace small urban cars that usually emit less than 146g CO_2/km than big berlines.

- For France, the government will spend €1.5 billion out of the 4 billion allocated to the infrastructure needed for the introduction of 20 million EVs by 2020, €500 million direct subsides to vehicle prices (€5 000 each for the first 100 000 vehicles). This makes a total cost of 2 billion Euros, 1000€ per car, without taking into account money spent on research and demonstration projects.

The cost of a tonne of CO_2 is calculated on the basis of the CO_2 tonne saved per car, compared to the €1 000 invested by the government. All assumptions are favouring the largest CO_2 emissions possible by electric vehicles, hence reflecting the lowest cost option per tonne of CO_2.



Source : ADEME, PRIMES

According to the graph, for a mileage of 150 000km, already substantial given the electric battery limited battery life cycle, the government is paying a price of 50€/t of CO_2. This price is very approximate and in reality it will be more. Indeed EV driver themselves would have invested about one third more than for a normal vehicle (around €5 000 to 10 000 differential for a small urban vehicle), and the French government only pays for half of the public infrastructure prices. Additionally, the French government financial support to research and development in this field is not included.

Annex 12: New energy efficiency technologies for conventional vehicles

Type of Car	Technology	Energy Efficiency Gains in %*	Prototypes	Source
All	Start-Stop	5-7% mix cycle 10-15% urban cycle		IFP, June 2009
All	Battery Management System	2%		[SYROTA 2008], p63
All	Lightening (new materials)	7%		[SYROTA 2008], p64
All	Aerodynamics	4%		[SYROTA 2008]
All	Wheels with decreased rubbing	3%		[SYROTA 2008]
All	System of wheel pressure control	3%		[SYROTA 2008]
All	Air Conditioning System	5%		[SYROTA 2008]
All	Electric Driving Assistance	2%		[SYROTA 2008]
All	Electro-hydraulic pump for Gearbox	2%		[SYROTA 2008], p64
All	Automated Transmission	4 to 6%		[SYROTA 2008], p64
All	Lightening	3%		[SYROTA 2008], p64
ICEs HEV / PHEV	Downsizing (reduction of motor weight and cylinders): direct injection of fuel or air over-alimentation, air loop,	25%		[SYROTA 2008]
Diesel	Combustion techniques (HCCI: Homogeneous Charge Compression Ignition)	15%		General Motors, Opel Vectra [SYROTA 2008], p59
Gasoline	Combustion Technique: Controlled auto-ignition	10-15%	Mercedes F700 Diesotto 50% consumption reduction (from 10.5l/100km to 5.3l/100km, 123gCO2/km)	Mercedes F700 Diesotto [SYROTA 2008], p60 IFP, June 2009
ICEs	Electronic control : thermic management	4%	Valeo	[SYROTA 2008], p63
ICEs	Electronic control : Friction reduction	5%	Logan ECO2 gain 2gCO2/km (2%)	[SYROTA 2008], p63
ICEs	Supercapacitor : convert gas exhaust into electricity	2%	Logan ECO2 4gCO2/km	[SYROTA 2008] 63

*% cannot be always be summed up

Annex 13: Japan, US and China put batteries at the forefront of electric vehicle research

The US is pushing technology breakthrough on batteries. President Obama already paid 4 visits to lithium battery factories. In total almost $1.5 billion out of $2.4 billion are dedicated to battery production, including new generation batteries. The Department of Energy is subsidizing as part of its *recovery act award for electric drive battery and component manufacturing initiative* the construction of 35 factories[126]. Additionally the department of energy is supporting financially research projects on Li-Ion batteries, regarding their manufacturing process or their components. In particular universities are quite active. Recently progress on metal-air batteries has been announced; A 123 also owns the iron-phosphate technology (resistant to temperature). Recycling is also addressed, and the state recently subsidized Toxco for the building of a Lithium battery recycling facility in Ohio.

Japanese support for electric vehicles is surprisingly limited, with no specific plan to promote BEVs or PHEVS. Rather limited public money is focusing on batteries. This is despite a high target of 50% electric vehicles (HEV included) by 2020. However the country, currently enjoying the leadership in the "green" car market thanks to the development of hybrids, is definitely intending to stay ahead. The strategy to do so is to the benefit of its battery sector, one of the biggest worldwide. The Japanese government is spending money on the improvements of battery capacity and costs. It also promotes the forthcoming fuel cell technology, and is aggregating lithium purchase at the national level. To give an order of magnitude, NEDO (the organization for the development of new energy and industrial technologies) disposes of €160 million over 7 years – about €18 millions for 2009 alone Like China, Japan is attempting to secure the whole battery chain.

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126 http://www.whitehouse.gov/the_press_office/24-Billion-in-Grants-to-Accelerate-the-Manufacturing-and-Deployment-of-the-Next-Generation-of-US-Batteries-and-Electric-Vehicles/

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US department of energy: http://www.fueleconomy.gov/feg/evtech.shtml

UK government – department for transport – statistics: http://www.dft.gov.uk/pgr/statistics/datatablespublications/nts/.

French National Statistical Office : http://www.insee.fr/fr/themes/tableau.asp?reg_id=0&ref_id=NATTEF13629

International Transport Forum : http://www.internationaltransportforum.org/

Victoria Transport Policy Institute, Transportation Statistics, Transportation Information Sources, TDM Encyclopedia : http://www.vtpi.org/tdm/tdm80.htm

European Network of Transmission System Operators for Electricity: https://www.entsoe.eu/index.php?id=158

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Literature Highlights

[ETC/ATC 2009]The critical overview of literature commissioned by the European Environmental Agency is very comprehensive and an excellent basis to start with.

[SYROTA 2008] The report directed by Jean Syrota, commissioned by the French Prime Minister, and published by the French journal *Le Point,* which cast doubts the massive introduction of electric vehicles in the medium term, gives some interesting data on Internal Combustion Engines.

In terms of statistics, basic energy, environment and transport data can be found in the commission official statistics or Eurostat. Information on the sector is provided by the European Car Manufacturers Association [AECA 2009]

The IEA scenario and EV data are broadly used. They nevertheless do not focus on the EU as such. Market penetration scenarios are quite optimistic in particular the Blue Map scenarios because take the 450ppm as reference to estimate the CO2 emissions needed. In this respect the cost of electric vehicles is likely to decrease more significantly [IEA 2009]

Official European Scenarios are also useful. In particular the European Commission Joint Research Center Electric Vehicles market penetration scenario reveals the crucial role of infrastructure [JRC 2010]. The study on GHG 2050, commissioned by the DG Climate, transport routes give a quick overview of the potential contribution of electric vehicles. [COM 2010 bis]

Last but not least the French environmental and energy agency ADEME has also been quite active on this issue, and they recently released a comparative report on the realms of EVs as compared to ICEs. UK department for transport has also issued a large number of documents.

On the electricity sector as such, it is quite difficult to find appropriate data on the following aspects

- Capacity load of power plants (rate of utilisation) per country
- Daily load curve per country revealing the primary fuel used. In particular the coverage of peak demand in the EU.
- Average efficiency of type of power plants across Europe, and in given countries
- Impact of introducing EVs on the power sector

The main sources available are UCTE now ENTSO-E (organisation of transmission utilities), UKTSOA, Northerngrid, some national grid utilities (RTE, UK grid); Eurostat gives the total electricity generation output and electricity prices; IEA has done country studies and some information of peak demand.

Position papers are also a good signal. In particular:

[T&E 2009] Transport and Environment as well as WWF were among the first to cover the pitfalls of developing electric vehicles.

[ERTRAC 2009] ERTRAC position papers are always interesting to read, as they reveal the consensual view of the different actors of the automotive sector ranging from carmakers, suppliers, research centres and NGOs. Their assumptions are therefore realistic.