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ECONOMIC AND SCIENTIFIC POLICY **A**

Economic and Monetary Affairs

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# CHALLENGES FOR A EUROPEAN MARKET FOR ELECTRIC VEHICLES

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DIRECTORATE GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY

INDUSTRY, RESEARCH AND ENERGY

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**Abstract**

The introduction of the electric vehicle to European industry is seen important for many reasons. It will bring new market opportunities and new jobs. At the same time it would provide better energy efficiency and reduce greenhouse gas emissions. The development of electric vehicle industry requires considerable RTD investments, support for the creation of new markets and new business models but also changes in the mobility behaviour of both individual people and the society as a whole.



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## DISCLAIMER

# CONTENTS

# LIST OF ABBREVIATIONS

| | |
|---|---|
| **BEV** | battery electric vehicle |
| **CENELEC** | European Committee for Electrotechnical Standardization, |
| **EREV** | extended-range electric vehicle |
| **FCV** | fuel cell vehicle |
| **FEV** | Full Electric Vehicles |
| **GHG** | green house gas |
| **HEV** | full hybrid vehicles |
| **ICE** | internal combustion engine |
| **IEC** | International Electrotechnical Commission |
| **ISO** | International Standardization Organisation |
| **LCA** | Life Cycle Assessment |
| **OEM** | Original Equipment Manufacturer |
| **PHEV** | plug-in hybrid electric vehicle (including range extenders) |
| **RTD** | Research and technological development |
| **TCO** | Total Cost of Ownership |
| **UNECE** | United Nations Economic Commission for Europe |

# EXECUTIVE SUMMARY

Electric vehicles still represent a small niche market hardly exceeding 1% of the passenger car market today. However, due to major progress in battery technology, more vehicles with an electric operation mode are expected to enter the market within the next few years.

New concepts and new technologies need to be developed to launch electrically chargeable vehicles suited for both individual and public mobility and for goods distribution in urban areas. Electrically chargeable vehicles promise many benefits to towns and cities, such as very low (plug-in hybrid electric vehicle - PHEV) to zero (battery electric vehicle - BEV) tailpipe emissions and reduced noise. It has been estimated that with current average European energy supply the greenhouse gas (GHG) emissions of electric vehicles would be less than 50% compared with conventional vehicles.

Despite great opportunities and rapid development it has to be noted that diverse transportation needs call for a strategy based on the complementary use of electric vehicles instead of simple substitution of the existing combustion engine. It is therefore estimated that a realistic market share for new, electrically chargeable vehicles would be 3 to 10% by 2020 to 2025. However, the market penetration can be further increased if current technological and economic barriers are addressed, adequate infrastructure for power supply is developed and new mobility patterns are accepted by potential customers.

This briefing note summarises the current state of affairs and the most important policy issues calling for European coordination. These are:

- Further RTD efforts are needed to prepare large scale production of affordable batteries
- Industry needs to develop new business models but at the same time these need to be supported by corresponding public decisions of supporting the development of these models e.g. through the creation of lead markets and support for pilot projects
- Grid capacity is not considered a problem as the energy consumption of electrically chargeable vehicles is predicted to be only a fraction of the total energy consumption. However, due to the primary energy mix used to produce electricity the level of emissions from generating electricity for electric cars depends on the energy policy decisions at the European and national levels.
- The development of appropriate infrastructure needs a European harmonised approach (standards and norms) for the charging system of batteries used in electric vehicles as well as decisions that make sure that customer-friendly operation and billing systems are created
- Standardisation is needed especially to ensure the vehicles can be easily connected to the power network in order to recharge the energy storage system. The goal should not be just European but worldwide standards to avoid market fragmentation and to reduce overall costs. Standards and common interfaces also need to be agreed upon quickly as this would enable the European car industry to establish themselves in the market for electric vehicles.

Coordinated collaboration between the industry, the research community, governments and customers is needed for the development of a lead market for electric vehicles in Europe. Other governments in countries such as the USA, Japan and China already support the new technology intensively, which means there is a need for rapid action.

Overall, the findings from this briefing could be summarised as follows:

- Electric vehicles will be a radical innovation offering global market opportunities for European automotive industry, requiring not only new technological and infrastructure solutions but also significant changes in the mobility behaviour of our society.
- Electric vehicles can be regarded as a key option for reducing GHG emissions of the transport sector due to the existing energy mix in Europe.
- Significant RTD efforts are needed in order to enter mass production of electric vehicles (“industrialisation of electromobility”), especially for improved reliability and cost reduction of batteries.
- European car manufacturers (recently) became aware of the opportunities and challenges and started significant investments.
- Such investments would need to be coordinated in order to prepare a European lead manufacturing market for electric vehicles.
- Normalisation and standardisation at European and global level are of crucial importance for technology and market preparation of electric vehicles.

To support joint decision making there is also a need for more reliable data on, technological requirements, lifetime costs and environmental impact of electric vehicles, as well as customers’ acceptance of new mobility patterns. Additional studies are also needed to better assess both markets and the environmental impact of electric vehicles. Specific issues to be addressed in future studies:

- Impact of a developing electric vehicle market on energy efficiency and $CO_2$ emissions in the EU (based on recent field data).
- Potential of ongoing and planned support schemes on regional and national level in the EU and the potential for synergies through better coordination.
- New mobility patterns supporting the use of electric vehicles, taking into account constraints in autonomy and speed versus environmental benefits.

# 1. INTRODUCTION AND CURRENT SITUATION

## 1.1. Introduction

New propulsion systems gain increasing attraction in the context of long-term emission targets. Vehicles with electric propulsion are considered as an attractive option on the pathway towards low-emission vehicles that could enable the transport sector to reduce sectoral emissions by a significant degree. Therefore, during the last years electric vehicles gained increased interest in national and European policies and public awareness raised significantly.

Due to major progress in battery technology, vehicles with electric operation mode are expected to enter the market within the next few years. Electric vehicles are characterised by the highest engine efficiency of existing propulsion systems and zero tailpipe emissions. The use of electricity as an energy carrier for these vehicles offers the opportunity to broaden the range of primary energy sources in road transport.

But it has to be kept in mind that well-to-wheel[1] emissions of electric vehicles are strongly dependent on the carbon-intensity of power generation. If carbon emissions from electricity generation are fundamentally reduced over time, considerable emission reductions of the transport sector relying on a large share of electric vehicles could be achieved in the future.

The development of the electric propulsion system represents a radical innovation with respect to technological concepts and production methods but to mobility behaviour and business models as well. Therefore, in contrast to incremental innovations the successful market introduction of electric vehicles and related infrastructure needs specific and synchronised policy measures. At the informal meeting of EU Ministers for Competitiveness in San Sebastián on 9 February 2010 the need for a well-structured coordinative approach has been stated in order to stimulate a European lead manufacturing market for e-cars.

Recently, the European Commission published a communication on a European strategy on clean and energy efficient vehicles[2] and a Roadmap on Regulations and Standards for the Electrification of Cars[3]. An action plan covering the regulatory framework, support of research and innovation, market uptake and consumer information including specific actions for electric vehicles in line with the EU 2020 strategy aims at the creation of a platform to coordinate efforts between European, national and regional actors.

## 1.2. The current situation

Today electric vehicles represent a very small niche market[4] which is dominated by low-performance light electric vehicles for particular applications. The first major activities of several vehicle manufacturers (OEMs[5]) were carried out in the 1990s and resulted in the development of several electric vehicles in the United States and Europe. A growing activity in electric vehicle development can be observed as a result of recent major advances of

[1] Well-to-wheel is the specific Life Cycle Assessment (LCA) of the efficiency of fuels used for road transportation.
[2] For details see http://ec.europa.eu/enterprise/sectors/automotive/competitiveness-cars21/energy-efficient/communication_en.htm
3 For details see MEMO/10/153 http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/10/153&format=HTML&aged=0&language=EN&guiLanguage=fr
[4] For example the market share of hybrid passenger cars, the biggest electric vehicle market today, was estimated to be 1.28% in 2009 (Asia Pacific Region Propels Growth of Hybrid Market. Polk View March 2010).
[5] In the automotive sector the notions „vehicle manufacturer“and „Original Equipment Manufacturer“(OEM) is used synonymously.

battery technologies. Some smaller manufacturers have already introduced electric vehicles at small production volumes into the market. Several major OEMs[6] have announced the development and the commercialisation of electrically driven vehicles within the next years. The development activities comprise full electric and plug-in hybrid electric vehicle concepts and passenger cars as well as delivery vans. Some vehicle manufacturers started already a small scale production of electric vehicle prototypes that are tested in several (national funded) projects (Box 1). The pilot projects concentrate mainly on urban areas and include the installation of charging infrastructure.

**Box 1**: Fleet tests with electric vehicles

> 100 **Smart ED**s (electric drive) were tested in London since 2007, tests with improved **Smart ED**s are started 2009 in Berlin (100 vehicles), 2010 in Rome, Milan Pisa (100 vehicles), Stuttgart Region (100 vehicles); In Spain tests are designed with 2,000 electric vehicles in Sevilla, Barcelona, Madrid from 2009-2011; Daimler starts tests with Vito vans (FEVs) in Berlin (50 vehicles) and Stuttgart Region (50 vehicles); EDF and Toyota start a test in Strasbourg with 100 PHEVs; EnBW runs a test with 600 two-wheelers in Stuttgart Region. All these fleet tests are accompanied by high numbers of public and private charging stations. Globally, only US (500 BMW e-mini in LA, New York and New Jersey) and Japan (300 EVs announced for Tokyo) show similar efforts.

Globally, the market of electric two-wheelers is highly dynamic, dominated by an increased demand of zero-emission two-wheelers in Asian metropolitan areas. Whereas electric propulsion systems mainly are discussed in the context of passenger cars, plug-in hybrid and fully electric vehicles represent only a niche market. However increased demand and corresponding activities of major OEMs to develop corresponding vehicles can be already observed. Hybrid electric and full electric delivery vehicles (vans) are under development and tested in several pilot schemes. First series-production plug-in buses have been recently introduced to the market.

With a fund totalling approx. EUR 1 billion, China promotes technological innovations in more efficient drive technologies. Moreover, the Chinese Ministry of Science and Technology is supporting the development of over 10 pilot regions with more than 10,000 vehicles and approx. EUR 2 billion between 2009 and 2011.

The US Government plans to invest US$ 150 billion dollars in energy technology over the next 10 years and another US$ 2 billion to promote advanced battery technology and components for electric vehicles. Demonstration projects will also be promoted with a total of US$ 400 million dollars in infrastructure for electromobility. US$ 25 billion has been earmarked as loans for motor-vehicle manufacturers and parts suppliers to equip or extend production centres for fuel-saving vehicles (Advanced Technology Vehicles Manufacturing Loan Programme - ATVM). It will also introduce fuel economy regulations for passenger cars and some other types of vehicle for domestic sale in the model years 2012 -2016 with a target average $CO_2$ emission by 2016 of approx. 155 g/km.

Japan supports the development of improved traction batteries with US$ 200 million over five years, aimed at halving cell costs by 2010.

France intends to promote research and development for hybrid and electric vehicles with an overall budget of EUR 400 million over the next four years. Under a bonus-malus arrangement, purchase subsidies of EUR 5,000 are to be granted for vehicles with low $CO_2$ emissions below 60 g of $CO_2$/km. Under its Low Carbon Vehicle Programme in 2009, the

[6] These include Daimler AG, BMW AG, Toyota Motor Corp., BYD Auto, General Motors Corp., Renault SA and Mitsubishi Corp., Nissan Motor Company and Volkswagen AG.

United Kingdom is to promote research and development in subcomponents for electric and hybrid vehicles and grant purchase subsidies for the first electric and plug-in hybrid vehicles.[7]

The Green Cars Initiative implemented as a public-private partnership between the European Commission and industry as part of the European Economic Recovery Plan at the end of November 2008 aims at promoting research and development activities in safe and energy-efficient mobility, in particular electromobility. The Initiative includes both a lending programme by the European Investment Bank and the provision of subsidies through additional calls to tender pending publication in 2009 and 2010 under the 7th Research Framework Programme. It will be dovetailed with relevant programmes in the Member States, preferably by an ERA-NET+ action.

**Box 2**: Examples of FP 7 funding for electric vehicles

**FP7 calls under the Green Cars Initiative**

The Commission's Directorates-General for Research, Transport and Energy, and Information Society will each launch calls that focus on electrification of road transport, along with a fourth, joint call on Electric Batteries. The funding for road transport projects under FP7 in 2010 will all be focused on the electrification of road transport and research into hybrid technologies; a critical mass which is expected to produce a step change in innovation in these technologies.

In the following FP7 Calls, in 2011, the topics for projects to be funded should broaden to the other areas of the Green Cars Initiative: research into trucks, internal combustion engines, logistics, and intelligent transport systems. In 2011, there could be also a Joint Call on “smart grid and recharging systems” between several services of the Commission.

Calls for 2010 were published in July 2009 and focused on

- GC.SST.2010.7-1 to 7-7 "European Green Cars Initiative - RTD Pillar" as part of the Work Programme Sustainable Surface Transport (SST). Call Identifier: FP7-SST-2010-RTD-1
- GC.SST.2010.7-8 "Green Cars - Integrated EU demonstration Project on Electromobility" as part of Sustainable Surface Transport (SST). Call Identifier: FP7-TRANSPORT-2010-TREN-1
- GC.SST.2010.7-9 "Materials, Technologies and Processes for Sustainable Automotive Electrochemical Storage Applications" as part of Sustainable Surface Transport (SST). Call Identifier: FP7-2010-GC-ELECTROCHEMICAL-STORAGE
- GC.ICT.2010.10-3 "ICT for the Fully Electric Vehicle" as part of Information and Communication Technologies (ICT). Call Identifier: FP7-2010-ICT-GC

[7] See [NEP 2009]

# 2. IDENTIFICATION OF CURRENT MAIN CHALLENGES

An easy answer to the challenges of future traffic cannot be given. Electrification of both the mobility and transport system is one possible answer. Consequently, new concepts and new technologies need to be developed to realize efficient electric vehicles suited for both individual and public mobility and for goods distribution in urban areas. Electrification most probably will be ending up with pure electric vehicles powered by batteries or hydrogen fuel cells. Both fuel cell (FCV) and battery electric vehicles use similar technologies in the drivetrain[8] and thus there are many synergies in component development for the drivetrain, such as high voltage systems, E-Drives and battery technology. In contrast to the hydrogen fuel cell vehicle, all plug-in electric vehicles can build on an existing infrastructure for distributing electric energy, which however needs to be adapted and extended.

## 2.1. Batteries - latest technological developments/challenges

The successful market introduction of vehicles with electric driving mode is highly dependent on the availability of a battery technology that allows reliable on-board storage of electric energy. The key component for both performance characteristics and costs of an electrically chargeable vehicle is the energy storage system. Today it is expected that the energy storage system will be a lithium based battery system[9]. Large Li-Ion battery systems for automotive application have not achieved commercialisation yet. The following can be assumed for passenger cars:

- Today's costs of a Li-Ion battery system are about € 600 – 800/kWh. In the long-term (2020 to 2030) a price of € 150 – 200/kWh is regarded to be very challenging[10].
- The expected typical driving range requirements, based on current driving patterns, for electrically chargeable vehicles will be up to 150 km which will require an electric energy consumption up to 20kWh (small/compact car). It follows that the battery costs for an electrically chargeable vehicle can add € 6,000 – 16,000 to the cost per vehicle.
- The additional costs are compared to a vehicle with an internal combustion engine and without electrification. Further components to be considered are costs for power electronics (e.g. performance control unit), cooling, wiring, etc.

The extent of additional costs mentioned above cannot be fully compensated by industry's cost reduction efforts (economies of scale, learning curve) in the mid-term, even in the long-term additional costs of € 3,000 – 4,000 must be accepted (see Box 3). Therefore, subsidies and incentives are necessary to foster the market introduction of such vehicles.

[8] Drivetrain refers to all the components between the engine and driving wheels and including the clutch and axle, as well as the components of the driveline.

[9] Battery technologies include: ZEBRA batteries, characterised by low power density and thus applicable in small battery electric vehicles only. Lithium-ion polymer battery systems and the lithium iron phosphate battery are further technologies that are currently under development and could become available for automotive application in the near future. Other options, such as flywheels, ultracapacitors and magnetic energy storage are not considered to be available for electric vehicle application in the near term, but should be further investigated in order to develop long-term alternatives.

[10] Roland Berger Automotive inSIGHTS 1/2009 or http://www.arb.ca.gov/msprog/zevprog/zevreview/zev_panel_report.pdf

**Box 3**: Total Cost of Onwership[11]

**Total Cost of Ownership (TCO)**

More and more buyers of cars take into account costs of ownership instead the pure price of the car. Total cost of ownership take into account all costs arising from the time of purchase by the owner, through its operation and maintenance to the time it leaves the possession of the owner (price of the car, fueling, taxes insurances, maintenance etc.).

Full electric vehicles are becoming competitive in the light of a 5 years TCO at oil prices of 110 – 120 US$ per barrel, if batteries could be sold at 500 US$ per kWh. If battery prices stay at 700 US$ this becomes true for an oil prie of 280-300 US$.

It has to be taken into account that a battery system includes, besides the battery cells, components for interconnections and packaging as well as electrical and thermal management equipment. All these additional components have a significant influence on the overall volume, weight and cost of a battery system.

Even if a lot of progress has been made in terms of energy content related to volume and weight of a modern battery, the energy density remains about hundred times lower than that of fuels for combustion engines. This fact is one of the main challenges for electric mobility, as it influences both costs and usability.

To overcome, in the long term (8 to 10 years), the performance hurdles of Li-ion technologies, it is necessary to continue investing in R&D for further improvement of the overall comfort and performance of electrically chargeable vehicles.

Recycling and disposal for Li-Ion batteries of electric vehicles is not common and there are currently no recycling facilities in Europe able to recycle lithium for use in new batteries. However, first lithium-ion battery recycling plants are already announced.[12]

## 2.2. Availability and preparedness of relevant industry capacity

The successful introduction and market penetration of electrically chargeable vehicles depends on many factors such as customer acceptance, market incentive systems, attractiveness of alternative mobility solutions, vehicle energy storage system, etc.

### 2.2.1. Market penetration

Most stakeholders assume a realistic market share for new, electrically chargeable vehicles in the range of 3 to 10% by 2020 to 2025. The market penetration will depend on the extent to which the tasks and requirements are addressed and fulfilled as well as on how fast the technology develops and on the way customers perceive/accept electric mobility.

Based on today's new vehicle sales of app. 15 million vehicles in the EU-27 in 2009 (passenger cars and commercial vehicles), this would result in new electrically chargeable vehicle registrations of between 450,000 and 1,500,000 units by 2020 to 2025. The total amount of electrically chargeable vehicles (in units) in the whole vehicle park would by then be higher due to increased market penetration of the vehicles from the near future onwards.

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[11] Figures extracted from „Strukturstudie BW$^e$ mobil – Baden-Württemberg auf dem Weg in die Elektromobilität", Fraunhofer-Institut für Arbeitswirtschaft und Organisation (IAO), 2010.

[12] The German Ministry of Education and Research recently published a call in order to prepare technology and outline a recycling plant, see http://www.bmbf.de/foerderungen/14611.php, the US Department of Energy granted $9.5M to Toxco Inc, a battery recycling company, to develop lithium battery recycling technology

Today there is no electric car on the market which offers the capabilities of existing fully-homologated cars. Any forecast of figures therefore is based on specific scenarios, described by key variables able to address policies, economy and energy, society and mobility, as well as industrial and technological issues. In general, one could distinguish four groups of key variables addressing $CO_2$ limits, marketing strategies of OEMs, total cost of ownership (TCO) and user acceptance of innovative drive technologies. Table 1 gives an example of such calculations for three scenarios[13]:

- Scenario 1 is based on the assumptions, that there will be no globally binding climate policy, oil prices increase moderately, gas will be accepted as fuel, 2nd generation bio-fuels remain expensive, cars will remain the basis of individual mobility, in urbanised areas acceptance of models like car sharing increases, and OEMs' strategies follow customer requirements.
- Scenario 2 assumes an agreement of the most important industrialised and emerging countries on $CO_2$ limits, policies including incentives and penalties will be designed accordingly, investments in nuclear power and renewable energies, continuously increase of oil prices, diversification of energy infrastructure, utility companies invest in charging infrastructure, cars remain the basis of individual mobility, electric two-wheelers become "trendy" and gain interest in urban areas.
- Scenario 3 is based on the assumptions, that in 2015 a globally binding Climate Convention will be closed, calling for 50% reduction of GHG emissions in 2030, oil prices increase to $200 per barrel, utility companies as well as OEMs invest in charging infrastructure and hydrogen fuelling stations, car use will be reduced to its transport function, car sharing models increasingly are accepted, most urban areas only allow locally emission free transport, and new business models gain interest (mobility providers).

**Table 1**: Technology scenarios 2030

| Share of total volume per year (%) | 2010 | Scenario 1 | | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|---|---|---|
| | | 2020 | 2030 | 2020 | 2030 | 2020 | 2030 |
| ICE[14] | 95.0 | 79.0 | 65.0 | 77.0 | 59.0 | 67.0 | 20.0 |
| HEV[15] | 5.0 | 15.0 | 20.0 | 15.0 | 13.0 | 20.0 | 28.0 |
| PHEV | 0.0 | 4.0 | 10.0 | 5.0 | 20.0 | 8.0 | 40.0 |
| BEV/FCV | 0.0 | 2.0 | 5.0 | 3.0 | 8.0 | 5.0 | 12.0 |
| Market volume in Mio Cars | 51.95 | 69.8 | 85.1 | 66.5 | 77.2 | 63.5 | 69.9 |

[13] IFA Technologie-Szenarien 2030, to be published July 2010.
[14] Vehicles with internal combustion engine (ICE) include „mild hybrids" as well.
[15] Full hybrid vehicles.

### 2.2.2. Business models

Commercial success of electric vehicles could be fostered by new business models:

- High investment costs related to batteries could be coped through new leasing concepts
- Battery exchange stations (e.g. Better Place Project, the model of a US based start-up company) are discussed as a viable option in Israel, Australia, California, Tokyo and Denmark
- Vehicle-to-grid interfaces may emerge in new grid management strategies resulting in more efficient grid integration of renewable energies.

Most of the pilot projects mentioned in box 1 involve cooperation between vehicle manufacturers and utility companies. While the first provide a considerable number of electric vehicles, the latter are in charge of the energy supply infrastructure. As a consequence, a limited number of charging polls will be established in the testing areas that will enable the frequent charging of the test vehicles. Those co operations reflect the altered stakeholders with regard to the available infrastructure and charging of electrically driven vehicles compared to conventional vehicles. The pilot projects mainly focus on reliability and user acceptance of electric vehicles, layout of charging infrastructures and billing systems. Few of them include analysis of different mobility and related business models. A cross sectional analysis may allow deeper conclusions for policy interventions and coordination needed across the EU.

The pilot tests with recharging stations at private and public places will provide evaluation data for the potential future need to extend the charging infrastructure in case of an increased demand of electrically driven vehicles. Furthermore, data on the customer acceptance of vehicles with low performance, limited driving range and the requirement of frequent recharging will be acquired in order to better evaluate the future market potential of electric vehicles. Valuable data will be collected from those pilot projects with regard to real-world energy consumption under different driving and external conditions, battery self-discharge losses and the energy demand of auxiliaries. Data on driving and charging behaviour could provide valuable information on the potential of electric vehicles to substitute conventionally driven mileage. Therefore, a cross sectional analysis of these tests is highly recommended.

## 2.3. Charging infrastructure

Without an appropriate recharging infrastructure electrically chargeable vehicles cannot successfully be introduced in the market. The energy sector will have to build up a recharging infrastructure as a prerequisite for customer's acceptance of electrically chargeable vehicles. An encouraging framework e.g. with clear targets for market penetration and standards for chargers and billing systems is required to build-up an infrastructure.

An appropriate infrastructure provides the availability and necessary density of recharging possibilities. In a first phase, recharging places should be installed in parallel at strategic locations – including homes, workplaces and truck or bus depots - and on main roads:

- Identification of the early adopter hotspots and build capacity there
- Public recharging stations (parking garage, shopping mall, Park & Ride, dedicated parking spots along streets…)
- Home/depot recharging
- Workplace recharging.

Frequency and numbers of charging points needed are matter of investigations in many of the pilot test listed above.

The European Commission announced to mandate within the framework of Directive 98/34/EC22 the European standardisation bodies in 2010 to develop by 2011 a standardised charging interface to ensure interoperability and connectivity between the electricity supply point and the charger of the electric vehicle, to address safety risks and electromagnetic compatibility and to consider smart charging.[16]

A harmonised European approach would be able to speed up the market preparation for infrastructures and lower the risk of investments:

- Customers should have the free choice between different energy suppliers (from which utility they get their electricity) and access to all charging stations independent of the charging station provider or energy provider (e.g. national/international roaming).
- Customer-friendly operation and billing systems need to be harmonized at EU and global level. This includes different payment systems such as coin based, credit card, prepaid card, electric vehicle identification with monthly bill, etc.

## 2.4. Electrical grid capacity and connectivity

The first generation of electrically chargeable vehicles will not offer vehicle-to-grid communication capabilities, i.e. any facility for intelligent recharging. In the future, it will be important to recharge vehicles in an intelligent manner in order to prevent charging at the peak loads for the power networks and to allow customers a recharging at low costs (variable pricing of electricity in order to control electric power market demand). The tariffs for recharging electrically chargeable vehicles should not be higher than those for normal household appliances.

Once a large volume of electrically chargeable vehicles will have reached the market, it is likely that some extra supply of electric energy will be needed. However, additional electricity demand generated by the introduction of electric vehicles will have only little impact on the overall electricity supply in the short- and mid-term. Even broad introduction of electrically chargeable vehicles would not meet limitations in terms of generating capacity: assuming the future energy consumption of a electrically chargeable passenger cars to be in the order of 100-120 Wh/km and taking into account on average 10,000 km travelled per year, it follows that 1 million vehicles will require about 1 TWh of energy which is only a minor fraction of the annual electricity output of the EU (2006: 3,400 TWh, source Eurostat) i.e. +0.03% of annual electricity output of the EU  It has been also estimated that e.g. for Germany 1 Million FEVs would increase the total amount of electricity by less than 1%.

At a later date, the vehicle battery could also be used to feed energy back into the grid whenever the price for control energy or balancing energy is particularly high. This will require the future generation of batteries to be designed in such a way that this kind of operation has no effect on the energy storage systems' service life. Many technological issues still have to be resolved until then, as it is crucial to ensure there will not be negative effects on the durability of the battery, the power grid and consumer convenience. Priority of the automobile industry is to charge the vehicle while optimizing battery life. However, vehicle batteries might one day be able to serve as bi-directional energy storage devices that will compensate for fluctuations in wind energy, for example.

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[16] For details see [COM 2010]

Research on the critical mass of vehicles needed (minimal total volume of storage needed) and design of control systems allowing to take care of the interest of utility companies without affecting consumers needs to have the battery full to drive is still at an early stage and needs to be further developed.

## 2.5. Regulation and Standardisation issues

Comprehensive standards and norms have to be created to ensure the vehicles can be easily connected to the power network in order to recharge the energy storage system. The goal must be to establish worldwide standards in order to avoid market fragmentation and to reduce costs (economies of scale).

Standards and common interfaces (e.g. vehicle-to-infrastructure) need to be agreed upon quickly for Europe as a whole to avoid a fragmented pattern of local competing and incompatible solutions. This would provide European industry with a unique opportunity to establish themselves as world leaders in electrically chargeable vehicles and related transport systems.

Technical issues with a need for EU-wide harmonization:

- Standardization (plug, phases, data protocol)
- Cross-national compatibility (re-charging abroad should not be different to re-charging at home)
- Data protection (personal, business)
- Safety requirements for recharging/discharging places
- Safety requirements while recharging/discharging the battery, e.g. short circuits
- Charging cable at the car or at the recharging station
- Technical approval body for recharging places
- Periodic inspections & maintenance of recharging places
- Liability clarification
- Convenient billing systems.

Meanwhile there is an intensive international standardisation work running at ISO, IEC and CENELEC with regard to the relevant standards for connectors, charging stations and the communication interface.

On 10 March 2010 the revised UNECE Regulation 100 was adopted[17] ensuring the safety of electric cars by setting out how users of cars shall be protected from the high voltage parts of cars. The EU and Japan have already indicated that they intend to incorporate the new UNECE Regulation in their respective rules on technical standards for vehicles.[18]

In February 2010 French and German carmakers have agreed to harmonise their plugs and to create a uniform billing system. They recognised that billing infrastructure and communication from the vehicle to the charge spot directly are dependent on local infrastructure but will be subject to regulation from the European Union.

[17] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/10/260&format=HTML&aged=0&language=EN&guiLanguage=en and http://www.unece.org/press/pr2010/10trans_p06.htm

[18] UNECE Regulation No. 100 covers “Uniform provisions concerning the approval of battery electric vehicles with regard to specific requirements for the construction and functional safety”. The revised text is available at: http://www.unece.org/trans/doc/2010/wp29/ECE-TRANS-WP29-2010-52e.pdf

The European Commission recently announced several actions on regulations and standards[19]:

- To mandate the application of UNECE Regulation 100 for the type-approval of electric vehicles.
- To amend the Framework Directive (Directive 2007/46/EC) by a Commission Regulation to specify the applicable requirements for electric vehicles regarding specific type-approval provisions, including the mandatory application of certain UNECE Regulations.
- To mandate the European standardisation bodies to adopt a European harmonised approach for the charging system of batteries used in electric vehicles.

## 2.6. Impacts on energy efficiency and green house gas emissions

While conventional vehicles with internal combustion engines create the largest proportion of the fuel life-cycle emissions during driving, full electric vehicles do not produce any local air pollutants and green house gas emissions during vehicle operation. In contrary, electricity supply for electric vehicles may cause considerably higher emissions at the power plant level (depending on the source of energy production) compared to only little emissions caused during production and distribution of conventional fuels. Overall, the environmental benefits of electric vehicles significantly depends on what type of electricity (fossil, nuclear, renewable) is used for charging. Furthermore, in the long term and based on a significant volume of batteries, intelligent vehicle-to-grid solutions and load management (charging / discharging) may allow more efficient use of fluctuating energy production by “valley-filling” and “peak reduction”. In this sense, electric vehicles could become part of an overall energy (storage) strategy.

Considering different average grid mixes, well-to-wheel GHG emissions of electric vehicles are up to 70% lower compared to conventional vehicles (high share of renewable e.g. in Austria) but could be worse (10-20% higher) when electricity is based on coal-fired power plants. Assuming current average European energy supply would reduce GHG emissions by more than 50%.[20]

Electrically chargeable vehicles have the potential to be a sustainable long-term solution for mobility. Significant progress has been made over the last few years, but some breakthroughs are still required. $CO_2$ savings will be maximized if the well-to-wheel impact is clearly addressed at all stages of the fuel and energy chain – low carbon energy production such as renewable energy production is a key to realize $CO_2$ savings potential. Any framework needs to clearly identify and address the stakeholders’ responsibility and sphere of influence (e.g. vehicle manufacturers do not have any influence on the well-to-tank chain (emissions)).

While battery electric power does not create any tailpipe emissions, it is important to also improve the well-to-tank impact, i.e. the level of emissions from generating electricity by the energy sector. More renewable electricity production will automatically increase the benefits of electrically chargeable vehicles. It should be noted, that the well-to-tank emissions are determined by the national energy mix which cannot be influenced by the manufacturers. Thus, the automotive industry sees the need for a framework which clearly identifies/addresses the stakeholders’ responsibilities. EU vehicle manufacturers are open to discuss a range of policy instruments supporting such an approach.

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[19] Roadmap on Regulations and Standards for the Electrification of Cars. 26.4.2010.
[20] Compare [KINSEY 2009], [BCG 2009] and [EABEC 2009]

# 3. CONCLUSIONS

A European lead manufacturing market for electric vehicles can only happen based on a coordinated collaboration and competitive-neutral guidelines of all key players (industries, scientific institutes, governments, customers).

A number of barriers need to be overcome in order to prepare market penetration for electric vehicles:

- Technology ability in terms of range, durability, reliability, costs mainly related to battery technologies and development of an adequate charging infrastructure.
- Society is used to highly-developed internal combustion engines and associated filling-station infrastructure. Potential users and customers have, therefore, expectations and routines in line with their individual mobility needs and habits that need to be met, involving issues such as affordability of mobility as well as convenience of driving and recharging.

Immediate action needs to be taken in standardisation (type-approval of vehicles and standardization of charging infrastructure) and regulation (e.g. rules on the methods for the collection of excess emissions premiums) to ensure safe framework conditions for investments in technologies and infrastructure.

Furthermore, coordination of market incentives for electric vehicles will be of crucial importance to avoid market distortion across the EU. As production of vehicles is announced for 2011/12 onwards, this needs to be organised before end of this year. Furthermore, such incentives need to take into account not to hamper other means of greening transport (e.g. bio-fuels, hydrogen, further improvement of internal combustion engines).

## 3.1. Complementarity instead of substitution

Characteristics of electric vehicles call for a market penetration strategy which is more based on complementary use of electric vehicles than simple substitution of existing combustion engine cars. While urban areas create specific mobility needs due to often congested conditions and a typically limited travelling distance, other transport needs do require larger daily driving distances at higher speed. All these diverse transportation needs will lead to further diversification of future vehicle types and their propulsion, and electrically chargeable vehicles will cover a certain area in this application map for passenger transport.

Regulations like restricted access to metropolitan areas in favour of locally emission free vehicles represent a viable instrument to stimulate the development and deployment of electric vehicles. Current and future directives for stringent emission levels for new vehicles reward production and demand of low-emission and low carbon vehicles. Any policy framework and its time frame should be clearly defined and predictable in order to reduce risks for investments. In combination with a dense infrastructure network this could become an instrument for a successful market penetration especially in urban areas. Further investigations are needed in order to compare potential impact of different instruments and identifying the most appropriate mix.

## 3.2. The need for more reliable data

Existing studies rely on theoretical assumptions but there are no standardised data on the real-world energy consumption under different driving and external conditions available.

These may be gathered in the context of ongoing and announced pilot schemes all across Europe. Both lifetime costs and environmental impact of electric vehicles should be carefully analysed based on experiences gathered in these fleet test. A cross sectional study could take into account different dimensions (driving patterns, topography, charging cycles, long-term battery performance, ...) and result in better understanding the needs of customers and technological requirements.

Such data are essential for reliable market penetration scenarios and an assessment of the environmental impact of electric vehicles. In the mid-term, data compilation between these initiatives could be facilitated by one or more of the European institutions.

## 3.3. Better European coordination

The EU is asked to define a clear roadmap for the market introduction of electric vehicles with all stakeholders involved. To this end CARS21 could be re-launched with a revised mandate and extended stakeholder involvement to in particular address the barriers to market uptake of electric vehicles and other alternative technologies.

A clear policy framework including provision of adequate infrastructure and incentives and the definition of a reliable time frame could reduce investment risks and foster the deployment of electric vehicles. Incentives like long term agreements on $CO_2$ deduction for electric vehicles could contribute to an improved market take-up. Voluntary agreements with the relevant public bodies and the different industries involved contribute to reduce upfront investment risks in infrastructure and vehicle production. Public procurement could play a significant role in the market development for electric vehicles.

First of all, European standards for the type-approval of electric vehicles are a must for the market preparation of electric vehicles. Standardisation is needed for the charging infrastructure, the vehicle to grid connection, safety standards and test cycles. International standards reduce uncertainty for car manufacturers and energy providers and could lead to higher investments and an accelerated market penetration. EU wide harmonization of customer-friendly operation and billing systems are needed to guarantee free choice between different energy suppliers and access to all charging stations independent of the charging station provider or energy provider. A standardised charging system of batteries used in electric vehicles could prepare the ground for the roll-out of a European charging infrastructure. Further standards (e.g. for on-board high-voltage connectors) could reduce parallel development of modules and parts and thus reduce RTD investments of the European automotive industries. Overall, standards need to guarantee interoperability of technology not only in the car but in the wider infrastructure.

As in many European Member States already funding schemes and fleet tests are in place or are announced (see Box 1 and Annex), better coordination of RTD efforts could be reached through an ERA-Net like scheme. Europe should make research on affordable and safe battery systems including post Lithium-ion technologies a top priority. This research should include basic cell research on materials in order to ensure availability with lower costs and higher energy density, manufacturing issues, cell design and packaging, and recycling and life-cycle aspects according to the operational requirements and usage of the vehicles. Further research topics include electric machines, power electronics, auxiliaries (like heating and cooling), as well as system architecture (including AUTOSAR integration). Furthermore, the support of cross-border pilot initiatives could stimulate market preparation and infrastructure investments.

## 3.4. Alternative transport scenarios

Electro-mobility might change mobility behaviour of our society far beyond those scenarios underlying the recent discussions. Limitations of battery performance could lead to a rethinking of established car concepts and mobility patterns. New vehicle concepts and mobility services could be established matching to individual mobility needs and transform mobility significantly versus car concepts and mobility patterns such as car sharing in combination with public transport.

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# ANNEX: POLICIES AND INITIATIVES

The following overview is based on Florian Hacker, Ralph Harthan, Felix Matthes, Wiebke Zimmer: Environmental impacts and impact on the electricity market of a large scale introduction of electric cars in Europe - Critical Review of Literature, ETC/ACC Technical Paper 2009/4 and amended by own research.

## Austria

In Austria the fuel consumption tax is $CO_2$ based. As a result alternative fuelled vehicles attract a € 500 bonus whereas cars emitting more than 180 g/km pay a penalty of € 25 for each gram emitted in excess of 180 g/km (160 g/km as from 1st January 2010). Some electro mobility pilot projects include access to the so called "mobility card", car leasing and maintenance and free charging for individuals using these cars.

## Belgium

Tax incentives are granted to private persons purchasing a "green" car. Cars emitting less than 105 g/km get a reduction of 15 % of the purchase price up to a maximum of € 4,540 and cars emitting between 105 and 115 g/km receive 3 % of the purchase price up to a maximum of € 850.

In the Walloon Region a bonus-malus system is in placed paying up to € 1,000 for cars below 105 g/km and charging a penalty of up to € 1,000 for cars emitting more than 195 g/km. Furthermore the Transport Minister in Wallonia made available € 2 million for municipalities that plan to buy electric vehicles (cars, cycles, vans).

## Cyprus

In Cyprus the rates of the registration tax and the rates of the annual circulation tax are $CO_2$ based. For cars emitting less than 120 g/km there is a 30 % reduction in registration tax. Also the annual circulation tax gets reduced by 15 % for cars emitting less than 150 g/km. Furthermore, there is a discount of € 683 for purchases of new electric cars.

## Denmark

The Danish Government has released a National Energy Plan onwards 2025 where clean cars are freed of all taxes. Considering the particularly high car registration tax of 180 % and a VAT of 25 %, the announced tax exemption represents a considerable subsidy for EVs.

The Danish energy corporation DONG and the American company Better Place are planning to invest € 100 million ($ 135 million) to build up infrastructure in the country for electric cars. The idea is to make it just as fast to charge up a battery as it is to fill up a tank of gas and to grow the numbers of electric cars up to 100,000 within two years. The EDISON R&D project on intelligent integration of EVs and their optimal interaction with wind power is carried out by an international consortium and comprises a budget of 5.6 million €. A 4 millon € EV fleet trial programm is funded by the Danish Energy Authorities.

## France

With regard to the average $CO_2$-emissions of passenger cars, the French Government recently set up a yearly eco-label on new vehicles with an auto-financed bonus-malus system which favours low-emission vehicles. The national bonus/malus scheme sets tax deductions (bonus) and tax penalties (malus) at the purchase of new vehicles on the basis of their tank-to-wheel $CO_2$ emissions. The scheme applies to new cars sold on the French market since January 2008. Since 2009, the scheme sets a new bonus of € 5,000 bonus for new cars and now new light commercial vehicles emitting less than 60 g $CO_2$/km (covering hence full electric vehicles). It will be applicable till 2012 for the first 100 000 low carbon vehicles purchased.

France's progressive company car tax is based on $CO_2$ emissions. Tax rates vary from € 2 for each gram emitted for cars emitting 100g/ km or less to € 19 for each gram emitted for cars emitting more than 250 g/km.

Furthermore, the France government announced to dedicate € 400 million for R&D and demonstration projects over 2008-2012 on low carbon vehicles. This budget covers many R&D and demonstration activities for the development of vehicles and charging infrastructure. Part of this budget (57 million €) was recently attributed for 11 projects; another call will be followed by another set of funded projects for an additional 50 million €. The research on electric vehicle technology is funded by 90 million €. Two national research platforms on the development of battery technology and electric and hybrid vehicles will be financed by an interministerial fund.

In February 2009 a specific working group was installed by the government in order to coordinate installation of a standardised national charging network for plug-in hybrid electric vehicles and battery powered EVs. The strategy already foresees the following provisions: local governments will be empowered to set up public charging infrastructure; a quota of parking areas in work places and shopping areas will have to be set for electric vehicles and charging spots; builders of collective residences will be obliged to set up charging facilities at parking places upon request of inhabitants; local governments will be obliged to equip public parking areas with charging facilities.

A 2008 public procurement programme includes a mass ordering of 5,000 hybrid and fully-electric vehicle. The French government plans to set-up a publicprivate procurement plan that coordinates the demand of electric vehicles for public and private vehicle fleets. In this context, the French post plans to procure 10,000 electric vehicles by 2012.

## Germany

The German Government announced at the “Nationale Strategiekonferenz Elektromobilität” in November 2008 in Berlin a national target of 1 million electric vehicles by 2020 and 5 million electric vehicles by 2030.

As part of the national Economic Stimulus Package II, a 500 million € programme has been set up to accelerate the development and deployment of electric vehicles within the next years. The money is dedicated to several pilot projects and to major German manufacturers of cars and battery systems as well as to utilities and scientific institutes to do the accompanying research. It covers research and development of battery technologies and electric vehicles, as well as the financial support of several demonstration projects with electric vehicles that will be launched in 2009 in several German cities.

The lithium ion battery research programme (LIB 2015) is funded by the German government with 60 million € between 2008 and 2015 and complemented by further investments of 360 million € by an industy consortium. From July 2009 a new vehicle tax system will be implemented. The annual car tax will consist of a base tax and a $CO_2$ tax. The $CO_2$ tax will be linear at € 2 per g $CO_2$ per km. Cars with $CO_2$ emissions below 120 g//km will be exempt from taxation as well as EVs in the first five years after purchase.

In terms of infrastructure and industry standards, some of the major energy and automotive companies announced the development of a common plug standard in March 2009. The plug has a capacity of 400 voltage and 63 ampere, can be applied European wide and was presented at Hannover trade fare end of April 2009.

In May 2010 the German government and industry established the National Platform Electric Mobility. Industry announced annual investments in RTD of 20 billion € of which a high share will be dedicated to efficient drive technologies and electric vehicles as well as other energy saving measures. Seven working groups will be established to elaborate detailed roadmaps to reach the targets of the National Development Plan for Electric Mobility. The government announced to exlarge funding of research and innovation for batteries (mainly preparation of industrial production), electric engines and electronics, grid integration, storage management and charging systems, recycling, but further development of (existing) pilot regions as well.

## Greece

In Greece electric and hybrid cars are exempted from the special consumption tax and from the yearly circulation taxes. Furthermore they are excluded from circulation restriction in metroploitain areas, where these are applied.

## Ireland

By 2020 the Irish government aims for 10 % of the national fleet (250,000 cars and vans) to be electric, with the first significant number shall hit the road within the next two years.

In April 2010, the Irish Government, the ESB and the Renault-Nissan Alliance announced a comprehensive partnership to position Ireland as a European leader in electric transport. The Definitive Agreement includes the development of a nationwide electric car charging infrastructure by ESB, the supply of electric cars by the Renault-Nissan Alliance from 2011, as well as Government policies and incentives that will support the widespread adoption of such vehicles.

Those who purchase electric cars can avail of the €5,000 grant, Irish buyers of electric vehicles will be exempt from Vehicle Registration Tax.

The registration tax is based on $CO_2$ emissions. Rates vary from 14 % of the purchase price for cars with $CO_2$ emissions of up to 120 g/km to 36 % for cars with $CO_2$ emissions above 225 g/km. Hybrid and flexible fuel vehicles benefit from a tax relief of maximum of € 2,500. EVs are exempt from vehicle registration tax until December 31st 2010. The annual circulation tax is also based on $CO_2$ emissions. Rates vary from € 104 (up to 120 g/km) to € 2,100 (above 225 g/km).

## Norway

Electric cars are exempted from registration tax, VAT and annual car tax. Furthermore drivers of electric cars are allowed to use bus-lanes. Also they are exempted from congestion charges and parking fees on public parking places. Norway planes to enable the free use of ferryboats, connecting national roads by 2009.

## Portugal

Electric cars and other alternative energy propulsion systems are planned to be exempt from circulation and registration tax. Furthermore, people buying a new car emitting less than 140 g CO/km receive a bonus of up to € 1,000. Portugal plans to have 320 charging stations by 2010 and 1,300 by 2011.

## Sweden

Electric and hybrid cars are covered by a green car rebate which allocates SEK 10,000 to individuals who buy a new green car. Furthermore the taxation system is $CO_2$ based. The annual circulation tax consists of a SEK 360 base rate plus SEK 15 for each gram $CO_2$ emitted above 100 g/km. This sum is multiplied by 3.15 for diesel cars bought in 2008 or later or by 3.3 for other diesel cars. For alternative fuel vehicles, the tax is SEK 10 per gram emitted above 100g/km. The Stockholm congestion charge exempts hybrid and electric vehicles.

## Spain

The government is committed to have one million electric or hybrid cars on the Spanish roads by 2014 and announced a total investment of 590 Mio €. One measure (with a total of 240 Mio. €) to achieve this goal is to provide consumers who buy an electric car in Spain with a rebate of 15 % of the price of the vehicle (up to 6,000 €).

Additionally the registration tax is based on $CO_2$ emissions and all cars with emissions below 120 $CO_2$ g/km are exempted from such a charge. Cars with between 121 and 161 $CO_2$ g/km benefit from a reduced tax of 4.75 %, while those with between 161 and 200 $CO_2$ g/km pay 9.75 %. Vehicles with more than 201 $CO_2$ g/km must pay a registration tax of 14.75%. A pilot project to introduce 2000 electric cars and install 500 recharging points in 2009 and 2010 (called MOVELE) has already started by the IDAE (Institute for Energy's Diversification and Saving, belongs to Ministry of Industry).

## United Kingdom

The British government outlined its ambition to be a world low carbon transport leader in its Ultra-Low Carbon Vehicles in the UK: The Challenge. There the UK announces a £ 400 million commitment to encourage development and support of ultra-low-emission vehicles. As part of this effort a demonstration project with 100 electric vehicles will be launched in several UK towns and cities to gather first practical experiences with electrically driven cars. The demonstration project is funded with £ 10 million by the British government. At the same time, up to £ 20 million has been dedicated to UK research into improving electric vehicle technologies and the infrastructure needed. These activities will be coordinated by the Government-funded Technology Strategy Board.

Furthermore, the British government announced a commitment to promote electric vehicles, to facilitate the roll-out of charging infrastructure through the planning system and to collaborate with other countries in the development of international standards. A £ 20 million procurement programme supports the demonstration and use of low carbon vehicles in the public sector with the aim to encourage the mass production of electric vans.

The British government unveiled the plan of an electric car incentive program. Motorists will be offered subsidies of £ 2,000 to £ 5,000 encourage them to buy electric or plug-in hybrid cars. The program is planned to start in 2011 and is part of the government's € 250 million plan to promote low carbon transport over the next five years.

The UK tax system for vehicles is based on $CO_2$ and is in favour of cars emitting less than 100 g/km. The annual circulation for example is £0 for cars below this value but can augment up to £ 400 for cars emitting more than 225 g/km.

With regard to the local level, the London congestion charge requires car drivers to pay £ 8 for each day they travel in central London. 'Alternatively fueled' vehicles, including electric vehicles, are exempt from paying the charge. Foreseeable revisions of the scheme likely increase the charges for high emission vehicles. Also London Mayor Boris Johnson advocates electric cars and said he wants to make the city the European capital for electric vehicles by delivering 25,000 charging points in London's workplaces, retail outlets, streets, in public and station car parks by 2015. The estimated cost of this program is €60 million. The company car tax scheme provides financial incentives for employers and company car drivers that choose a low carbon vehicle.

## United States (California)

In 1990, the California Air Resources Board (CARB) introduced a zero-emission vehicle (ZEV) mandate as part of the Low Emission Vehicle Program. Its main motivation has been to enable the large scale introduction of ZEVs. The ZEV-mandate initially required that 10 % of new cars sold in California to be zeroemissions vehicles by 2003. The time of introduction has been abandoned when it became apparent that the technology was not mature enough to compete in the market. However, the ZEV mandate approach has enjoyed some success in the past and finally led to the development and the low-scale deployment of several fullyelectric vehicles. Today, the Californian Government requires car manufacturers to introduce zero-emission vehicles by 2014, independent of their fleet emission levels within the zero-emission mandate. However the number of required pure-ZEVs has been dramatically reduced compared to earlier regulations.

Governmental efforts focus on the support of public-private partnerships between US OEMs, government agencies, national laboratories, and developers of low-carbon technologies. A first programme started in 1993 (Partnership for Next Generation Vehicles) which has been replaced by the Freedom CAR program in 2002.

The US Energy Act of 2006 offers federal tax credits for low-emission vehicles. Several state governments give further state tax credits. President Barack Obama recently unveiled a plan to give a 7,500 dollar tax credit to people who buy plug-in hybrid vehicles. Some state and local governments provide reduced parking, registration and toll fees or exempt low-carbon vehicles from emissions testing. The States of California and Virgina offer access to high-occupancy lanes regardless of the number of passengers. Further state and local policies are encouraging the use and development of plug-in hybrid vehicles.

US federal fleets are required to select the most fuel-efficient vehicles. Several states also mandate the purchase of hybrid vehicles.

The United States Department of Energy released a $ 2.5 billion programme for the development of electric-powered cars and the improvement of battery technology. As part of the economic stimulus programme enacted by the U.S. Congress, another $ 2 billion programme for battery development has been set-up in 2009.

## Japan

Tax incentives for fuel efficient vehicles were introduced in 2001 and have led to an accelerated penetration of fuel efficient vehicles that fulfilled the 2010 fuel efficiency standards already in 2004. Tax credits of up to $ 3,500 have been available to hybrid buyers, but are now being phased out. Japan remains the world leader with regard to the research and development of battery technologies showing the highest R&D budget for the development of lithium-ion batteries.

## China

Individual Chinese municipalities ban gasoline two-wheelers from the city-centres. There are first hints that conventional passenger cars could also be banned from the inner city as soon as electric vehicles become widely available. Recently, the Chinese Government announced plans to turn the country into one of the leading producers of electric vehicles within three years. Government research subsidies for electric car designs have already increased significantly. An interagency panel is planning tax credits for the purchase of alternative energy vehicles. Today, subsidies of up to $ 8,800 are already offered to taxi fleets and local government agencies that purchase electric vehicles. Further, the state electricity grid started the set up of electric charging stations in Beijing, Shanghai and Tianjin.

## Israel

Israel will start the large-scale introduction of electric vehicles in collaboration with Better Place in 2011/2012. As a fiscal measure to stimulate the purchase of EVs, the Israeli Government reduces the purchase tax for electrically driven vehicles from 79 % to 10 % until 2014, and to 30 % after 2019. Until 2012, about 500,000 charging and several battery exchange stations are planned to be established all over the country. At the long-term an annual purchase of 30,000 vehicles is expected.

# NOTES

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