Chapter 9
Electrical Vehicles Activities Around the World

Gerd Schauer and Rodrigo Garcia-Valle

9.1 Introduction

Mobility has always been a basic need, using more and more sophisticated means as the present car industry shows. Highly developed cars provide comfort, safety, and powerful and efficient drives—standards far away from the first motorized vehicles. Research and development is more and more driven to create an ecofriendly car. Under the boundary conditions of increasing dependency on fossil fuels, rising oil prices, the necessity for emission reduction, and increasing efficiency, electrically powered vehicles are experiencing a renaissance. The European Commission endorses these goals through legislation for eco-friendly transport systems. But the electric vehicle (EV) is not a present-day invention and it is worthwhile to give an overview of the development of the EV and the lessons learned.

The development of electrically driven cars can be divided into four phases:

- The early beginnings of development in the 1880s to around 1930;
- Development up to the 1990s;
- Renaissance of the EV, preparing and beginning with EV roll-out (around 2010) by offering the customer adequate cars;
- Significant market penetration to 2020.

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Fig. 9.1 Three-wheeler electric drive. *Source*: http://de.wikipedia.org/w/index.php?title=Datei:Trouve_trike_1881a.jpg&filetimestamp=20110815090503

9.1.1 The Early Beginnings of EV Development

The development of the electric car in Europe and in the U.S. goes back to the early 1900s. The basis was the development of the electric motor and the lead-acid battery for storing energy. First constructions go back to pioneers such as Thomas Davenport who operated an electric vehicle using a primary cell battery (not rechargeable) in 1834, Gustave Trouvé, who presented a three wheeler with an electric drive in 1881 (see Fig. 9.1), and Werner von Siemens who presented the electrically driven carriage in 1882. The Belgian engineer and racing driver Camille Jenatzy constructed the “La Jamais Contente,” which already in April 1899 achieved a top speed of nearly 106 km/h (Fig. 9.2).

The first highlight of the dissemination of the EV was its easy handling in comparison to the loud and difficult-to-start combustion engine. The Austrian engineer Ferdinand Porsche (1875–1951) developed the electric hub motor in 1897, and together with Ludwig Lohner (1858–1925), the owner of the largest horse-drawn carriage factory in Austria-Hungary, jointly constructed the “Lohner-Porsche” and presented that sensation at the World Exhibition in Paris in 1900 (Fig. 9.3). They soon realized its limits in terms of range as the weight of the battery had already reached half of the weight of the car. This barrier could be broken by combining the range advantage of the gasoline motor and the advantages of the easily controlled electric drive in a serial hybrid system.

In 1912 around 20 manufacturers produced 34,000 electric vehicles. For example, Detroit Electric produced electric vehicles from 1907 to 1939.

Fig. 9.2 Camille Jenatzy with his "La Jamais Contente." *Source*: http://de.wikipedia.org/w/index.php?title=Datei:Jamais_contente.jpg&filetimestamp=20061018082520

Fig. 9.3 Lohner-Porsche Electric car. *Source*: http://de.wikipedia.org/w/index.php?title=Datei:TMW_1428_Lohner-Porsche-Elektromobil.jpg&filetimestamp=20110318212547

Fig. 9.4 Sigfried Markus Car

Conversely, Siegfried Marcus (1831–1898) for example identified benzene as a useful energy source, constructed a carburetor, an electromagnetic ignition, and constructed a modern car with a four-stroke cycle engine in 1875 (Fig. 9.4). It is well known that the development of the electric starter around 1910 blazed the trail of success for gasoline motors. Electrically driven systems remained in niche markets such as, for example, for the postal service.

Manufacturers recognized in the 1910–1920 period that electric vehicles with their limits in terms of range and power will not represent the future of vehicular transport. As an example, Studebaker Electric, which had produced electric vehicles since 1902, switched in 1912 to production of gasoline motor cars. The dominant role of the upcoming gasoline vehicle can be seen in their sales figures; 15 Mio Ford Model T, also called the Tin Lizzy, were sold between 1908 and 1927 in the USA. The construction was simple, durable, and designed for mass production. Thus, electric vehicles remained in niche markets.

9.1.2 Development up to the 1990s

Oil shortage, *rethinking after the years 1973 and 1979*: The first drastic change in mobility behaviors was caused by the Jom Kippur war (6–26 October 1973). The organization of oil exporting countries, OPEC, reduced their production to assert pressure on western countries, thus leading to an increase in the oil price from 3$/barrel (159 L) by 70 % to 5$/barrel. Several governments in Europe limited demand for example via car-free days. A second peak in oil price was reached in 1979 during the Iran-Iraq war leading to a price of 38$/barrel. In the later 1980s the price decreased again to 20$/barrel, but later on a more continuous increase in oil price can be seen driven more by increased demand than by conflicts.

It's not astonishing that in 1973 ambitions began to move away from oil. E-mobility moved back into focus as one of several possibilities to reduce emissions with the initiation of an array of research and development projects; especially utilities increased their investments in this field.

Electric vehicles, technological progress: Cars were usually converted to use of electrical power, and only a few manufacturers presented light-weight vehicle prototypes. There was research progress in the improvement and development of battery systems and different types of motor drives.

Batteries: Formerly, most cars were equipped with lead-acid batteries in different designs (pasted plate, gel-type, absorbed glass mat [AGM]). Few cars used nickel-cadmium batteries with much better performance in power, energy density, and cycle stability. Although the sodium-sulfur battery seemed to be promising, later production of the Na-S battery was stopped because of serious manufacturing problems. The zinc-bromine battery could show suitable performance, but could not perform in terms of lifetime. Later, tests were performed with the zinc-air battery system.

Battery management: To reach adequate performance and lifetime, battery management helps to avoid deep discharge and overcharge, and thermal management maintains the variously located batteries at the same temperature. Charge equalizers help to avoid divergence of the batteries or cells.

Motor drive systems: The cars were equipped with DC-motors (series and shunt excitation) or AC asynchronous motors, and a few with the permanent magnet type and rare earth magnets for excitation.

Vehicles: In this phase development was more concentrated on the development of key electric components such as the battery, charger, and drive system, so most engineers converted existing cars, vans, buses, and transporters to electrically driven ones and few built specific light-weight vehicles.

9.2 Examples of Electric Vehicles

In several countries around the world different electric vehicles were manufactured and tested. Some examples are given below; however, it is not possible to present a detailed and complete list.

The Volkswagen Golf was converted to the "CitySTROMER" with a top speed of 100 km/h and a range of 60 km. Limited quantities were built by Volkswagen for testing at utilities.

FIAT produced in small production numbers the "Panda E" as depicted in Fig. 9.5. One of them was modified by VERBUND AG to test the Zinc-Flow-Battery® (Zinc-Bromine) with a 20 kWh capacity.

Nevertheless, few inventors tried to optimize performance with light-weight vehicles. In 1981–1982 one example of a newly constructed car, a pure electric vehicle with gullwing doors was the Pöhlmann EL. The project was financed by RWE. The car was equipped with two series of excited DC motors driving the rear

Fig. 9.5 FIAT Panda

Fig. 9.6 Pöhlmann EL. *Source*: http://www.traumautoarchiv.de/html/2671.html

wheels separately. The motors were normally operated in series achieving good acceleration and climbing ability. For higher speeds they could be switched in parallel achieving a top speed of 120 km/h. The car had a weight of 1,300 kg and passed a crash test, a novelty at that time. The range was about 60–90 km. The production price was relatively high, with low demand, and in total only 18 units was built.

One car was even exported to Tohoku Electric Power Company, Sendai, a utility in the northern part of Japan. At the first "Grand Prix Formel E" in 1986 the car won the race and was a real eye catcher (Fig. 9.6). In 1988 Erich Pöhlmann looked into a

Fig. 9.7 Horlacher GL-88 “EGG,” 1988. *Source*: http://www.horlacher.com/products_services/ev_development/gl_88_egg.htm

conversion of the Audi 100 Avant. He modified the back axle of the Quattro with an additional electric motor, replaced the spare wheels with batteries, and created the first Audi Duo, a hybrid car which was presented at the Internationale Automobil-Ausstellung (IAA) in 1989.

Another pioneer should be mentioned: Max Horlacher developed and built the GL-88 EGG in 1988 (Fig. 9.7), a car with a carbon-reinforced plastic body with dimensions of 2.55 m length, 1.31 m width, and 1.42 m height. The car had a weight of only 300 kg, was equipped with an 8-kW asynchronous motor, and reached a top speed of 80 km/h. The energy consumption was only between 3 and 4 kWh (DC).

One should mention that many other prototypes were designed at this time, for example the Twike (a light-weight three wheeler), the BMW series 3 and BMW E1, the Hotzenblitz with limited production, and Norway developed the city car Think.

In 1991 the Peugeot S.A. (PSA) group started with electric vehicles. The Peugeot 106 electrique had a weight of 980 kg, a top speed of 90 km/h, and a range of 80 km. The Peugeot 106E and Citroen Saxo, equipped with the Ni-Cd battery, had a quite acceptable performance for the customer. Over 1995–2005 PSA produced 10,000 EV. A big change was brought in by an EU environmental law concerning the restricted use of cadmium.

A very good example of how strict regulations and law can influence the development of technologies is the EV1 from General Motors (GM) presented in 1996. EV1 was primarily brought to market in order to accomplish the zero-emission vehicle mandate introduced in 1990 in California. As California is one of the biggest markets for cars the new mandate was quite a shock for the car industry and they had to rethink propulsion concepts. GM did a lot of development in electric vehicles and after the concept car “Impact” produced the EV1 in series. EV1, a two-seater, set new levels. For charging a paddle was used which worked via induction and the remarkable car shape enabled the lowest air resistance ever seen on a series vehicle. First, two separate motors where placed at each front wheel, but these were later replaced by a single AC induction motor. A top speed of 130 km/h, an acceleration of 9 s from 0 to 100 km/h, and a driving range of 220 km could be reached. Initially 26 lead-acid batteries were used and later these were replaced by nickel-metal-hydride batteries. They had a capacity of 16.3 kWh and a nominal voltage of 312 V. EV1 was first introduced in Los Angeles and San Diego for a price of $33,995, although the production price was much higher. Similar to today's business models the EV1 was only offered as a leasing car with monthly rates of $349–$640. The last piece of news relating to the EV1 was in 2006 when the film "Who killed the electric car" was released. The filmmakers criticized the takeover of GM's patents by Texaco.

9.3 Demonstrations at Electric Vehicle Races

Car racing events provided a good possibility to present technical developments to a broader audience, including the participation of technicians at technically orientated conferences. Safety aspects have great importance; races organized under FIA (Federation Internationale de L'Automobile) rules had to receive expert technical approval before races and the FIA promotes moves towards e-mobility. Some of these races are mentioned below.

Tour the Sol: It was the intention of solar pioneer Josef Jenni to demonstrate that solar energy works also in the middle of Europe and not only in sunnier areas. An essential impulse to the public came from the first "Tour the Sol" in 1985 in Switzerland. Aimed at demonstrating sustainable vehicles, light-weight concept vehicles demonstrated their performance and charged their batteries directly using onboard photovoltaic (PV)-modules. In another class, additional human power via pedals was allowed. Later, EV charging was allowed from stationary batteries energized by PV modules and later again charging using 230-V AC mains was allowed under the condition that the amount of energy used was provided by a grid-connected PV-system.

As the cars drove on public roads, they achieved good visibility and positive reaction in the media. Several reports, books, articles in newspapers were written and reports transmitted by television. Thousands of people observed the event and visited the cars in the daily camps over the 5 days of the first race from June 25 to June 30, 1985. This race was held until 1993 and it is worth mentioning that similar activities were organized (Fig. 9.8). It was fascinating that these prototypes could drive the routes required with minimal energy.

World Solar Challenge: This Australian solar-powered car race covers a distance of 3,021 km. The route starts north of Darwin, goes through the Australian outback travelling south to Adelaide. The first race was held in 1987, and until 2011 a total of 11 car races took place. As the name suggests, the solar-powered cars have to be powered by PV modules on the car. It is a challenge for participating teams from

Fig. 9.8 Tour the Sol 1987, solar cars at the goal in Arosa, Switzerland. *Source*: http://de.wikipedia.org/w/index.php?title=Datei:1987_TdS_Arosa.jpg&filetimestamp=20110523014223

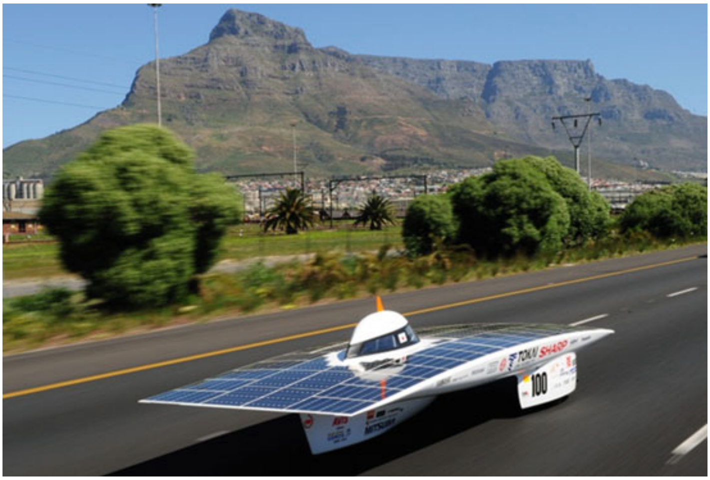


Fig. 9.9 Tokai Challenger, winner of the World Solar Challenge. *Source*: http://en.wikipedia.org/wiki/File:Sasc2010_tokai_challenger_table_mountain.jpg

universities and companies to optimize the car in terms of an efficient drive, high solar cell efficiency, and finding an effective energy management system to calculate the right driving strategy. The first race in 1987 was won by the GM sun racer with an average speed of 66.9 km/h, and after a few races the average speed was up to around 100 km/h. Figure 9.9 shows the winner of the race in 2001, the Tokai Challenger of Tokyo university.

Similar car races were organized, for example the North American Solar Challenge, The Solar Car Challenge, and the South African Solar Challenge.

Grand Prix of Formula E: The first “Grand Prix Formel E” was held in 1986. From 1987 this race was held at the airport area of Interlaken. Cars divided into different weight categories had to demonstrate performance, perform acceleration tests, a long time-period test, and had to drive the course three times quickly.

Austro Solar: The first Austro Solar took place in 1988 and aimed to demonstrate that EVs are suitable for daily use. Under conditions of a car race different tests for measuring range, acceleration, skills, and slalom had to be undertaken. Over the years different routes through Austria were chosen to include important cities in the regions of Austria. In 1989 a special challenge was the route over the Glockner pass, because of the many hills and huge altitude difference, meaning climbing up to 2,500 m above sea level. The Austro Solar was organized ten times—annually until 1999 except for 1998.

12 Electric Hours: Test demonstrations organized by Citelec. As there were constraints imposed by energy density and power at that time, a successful approach was the implementation of electric vehicles for cities which usually needed a low daily range. In this regard, regenerative braking, high efficiency of the electrical drive system, and minimal standby losses during waiting time at signal lights are great advantages. They can bring solutions to urban areas in relation to a cleaner environment. Citelec is the Association of European Cities interested in Electrical vehicles and was founded in 1990 as an international non-profit organization under Belgian law. It promotes hybrid and electrical vehicles by participating in research and demonstration projects, executing testing with involvement in standardization.

At the fifth “12 electric hours” in Namur, September 27–28, 1991, 20 vehicles of different type such as passenger cars and vans with different drives and battery systems demonstrated their suitability for daily use. At this time lead-acid batteries were the most commonly used followed by four cars by with nickel-cadmium. Two cars were prototypes with high-density batteries, one using the high-temperature sodium-sulfur (NaS) battery and one was a converted FIAT Panda E using the zinc-bromine battery developed by Powercell at Mürzzuschlag, Austria.

In total, many of the cars demonstrated successfully the ability for 6 h continuous daily operation. The average speed of most of the cars was around 20–22 km/h (limited by traffic), half of the cars needed less than 1 h for recharging within the 12 h.

9.4 Renaissance of the Electric Vehicle

As already mentioned, the battery is the key element for the performance of an electric vehicle. As slight improvements were made to conventional lead-acid batteries, a new battery type has in recent years captured the market, lithium-based batteries. Lithium systems offer high specific energy and power. Conversely, lithium is highly reactive and poses a fire danger. Significant help came from the information and communication technology side. Mobile phones and notebooks achieved high market shares; powering these devices brought Li-battery development into the mass market, replacing the former Ni-Cd and Ni-MH battery systems. Also other key factors such as improved drive systems, the ability of new batteries to charge quickly, and the development of new electric vehicles brought a breakthrough.

9.4.1 Li-Battery for the Mass Market

The power density of the Li-Ion battery is 40–70 % higher compared with Ni-MH batteries and at the same weight energy is about 20–80 % higher and provides a better efficiency. The goal for EV-batteries is to reach some thousand cycles though they could reach the life time of car. After this, there is the opportunity use them as stationary storage system (2nd life of battery). Depending on the composition of the positive and negative electrodes, different characteristics could be achieved. For application in vehicles there are five key factors that are most important: energy density, power density, safety, life time, costs. By choosing different components, characteristics can be tuned in terms of higher power or energy, better safety features, life time or costs. For EV in principle four typical technologies were developed.

Lithium nickel cobalt aluminum (NCA) cathodes demonstrated an extremely long life time and have the highest energy and power density. Conversely, they have disadvantages in terms of costs and safety as there is a danger of thermal run away at high charge level. Lithium manganese spinel (LMO) and Lithium manganese polymer cathodes are safer, though their energy density is lower. Capacity fading during cycling at temperatures greater than 40 °C was measured. Lithium titanate (LMO/LTO) cathode/anode materials feature more stability, high life time, and allow a wide use of the capacity. Conversely, they store comparably less energy (they operate at 2.5-V cell voltage in comparison to the 3.7–4.0 V of other chemistry systems). Lithium iron phosphate (LFP) batteries are relatively safe, more resistant against overcharge and have low production costs; however, their low temperature performance is weaker.

9.4.2 New Image of Electric Vehicles

Using the latest technologies, Tesla Motors created a sophisticated sports car. They used light-weight components from the Lotus Elise for the car, about 6,831 high-power Li-batteries from the mass market, and a powerful drive. The laptop batteries of the 18650 type are connected to a nominal voltage of 375 V, store 56 kWh, and have a weight of about 400 kg. A battery management system monitors each cell.

Fig. 9.10 Tesla Roadster

The Tesla Roadster was presented for the first time in July 2006 at Santa Monica Airport, California, and it took 2 years for production of the Tesla roadster to start in 2008. With a peak power of 225 kW (302 PS) and a torque of 370 Nm from the asynchronous motor, developed by AC Propulsion, the car offered a new dimension, an acceleration from 0 to 100 km/h in 3.9 s and a top speed of 200 km/h. This sporty, pioneering Tesla roadster, depicted in Fig. 9.10, changed the image of electric vehicles entirely concerning range, acceleration, and top speed.

9.4.3 Fast-Charging Possibility Changes Minds and Created Acceptance

Of interest is the experience made in Japan after provision of the “possibility” for fast charging. The result, shown in Fig. 9.11, was impressive. The psychological barrier of limited range on people using an EV can be seen clearly. Before the fast charger was installed (Fig. 9.11a) only 20–50 % of the available battery capacity was used, after installation of the fast-charging station, drivers made extensive use of the EV and used up to 70 % of the available capacity (Fig. 9.11b). The barrier and fear of running out of electricity no longer counted because of the possibility of fast charging. On the whole, acceptance increased dramatically; the monthly range was seven times higher than before installation of the fast charger.

9.4.4 EV Availability

In discussions the “chicken” or “egg” problem is often mentioned, cars need charging posts, but they will only be erected, if there are enough cars on the market.

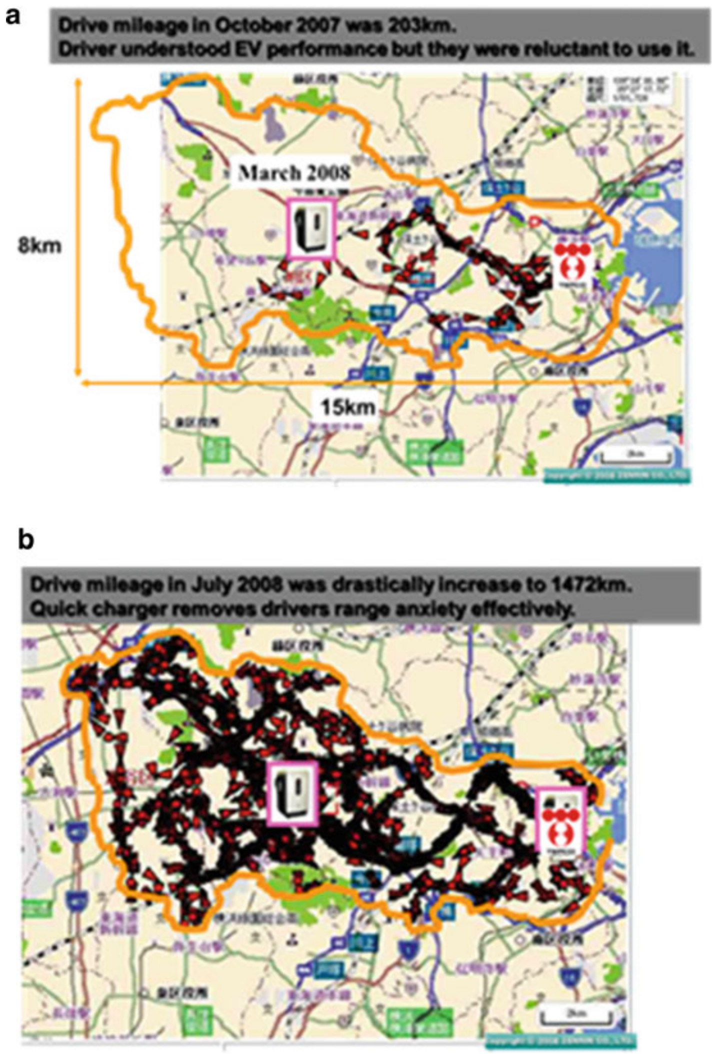


Fig. 9.11 Use of EV before (**a**) and after (**b**) installation of quick chargers (*Source*: H. Aoki, Tepco; CHAdeMO)

It was therefore of great interest to investigate the availability of electric vehicles. An investigation, initiated by Verbund showed interesting results. After several months of research a data base could be created, documenting 151 EV [1]. It could be seen that 81 different vehicle manufacturers were recorded in the vehicle database. Figure 9.12 illustrates the distribution in terms of continents.

Europe has with an identified 42 EV companies the most vehicle manufacturers compared to other continents. Asia is the next with 21 EV manufacturers, followed by North America with 17 EV manufacturers. In Africa activities in developing

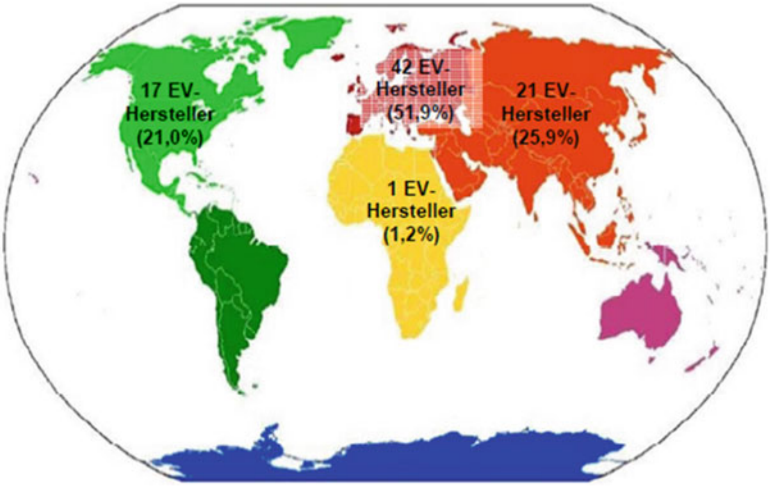
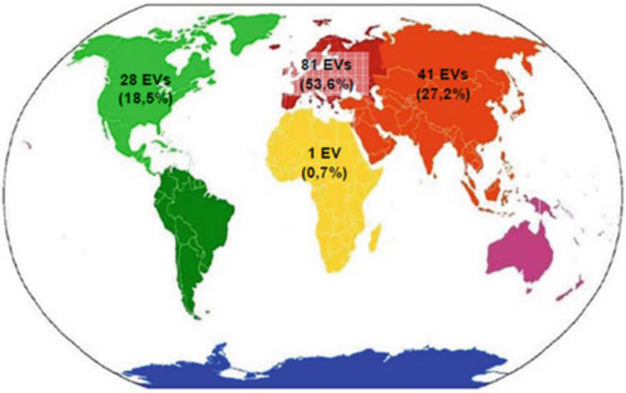


Fig. 9.12 Distribution of EV manufacturers

Table 9.1 Worldwide EV manufacturers

Region	EV Manufacturer
Africa	Optimal energy
Asia	BAIC, Brilliance, BYD, Chery, Dongfeng, EuAuto Technology Limited/Hong Kong Polytechnic University, Geely, Great Wall Motor, Haima, Honda, Hyundai, Japan Automobile Research Institute, Luis, Mitsubishi, Nissan, Reva Electric Car Company, Subaru, Tata, Tianjin Qingyuan, Toyota, Zotye
Europe	Audi, Bellier, Bluebird Automotive, BMW, Brabus, Citroen, Citycom AG (now Smiles AG), Comarth Engineering, Courb, Duracar, Effedi, elbilNorge, E-Wolf, Fiat, Heuliez, HSR, Kamoo AG, Karmann, Koenigsegg, Lightning, Loremo, Lotus, Magna, Mercedes, MES-DEA, Microcar, Modec, Nice, Peugeot, Piaggo, Pininfarina, Protoscar, Renault, Rinspeed, Ruf, Tazzari, Think, Trabant, Twike, Venturi, Volvo, VW
North America	AC Propulsion, Aptera, Chrysler, Commuter Cars, Corbin Motors, Dodge, Energetique, Ford, Myers Motors, Phoenix Motorcars, Shelby, Smith Electric Vehicle, Steenstra, Tesla, Universal Electric Vehicle, Zab, Zenn

electric vehicles could be seen. In Australia and South America research in this area was not found; this could be caused by the relatively small automobile industry in those continents or other key aspects of activity such as for example the use of ethanol as a fuel in Brazil, South America. Table 9.1 provides an overview of the manufacturers involved with EV. Besides the well-known large automotive manufacturers from around the world, there are some, which are not well known in Europe. Even small manufacturers pursue the field of electric mobility and develop their own concepts. But it is questionable in which dimension the smaller companies will prevail against the bigger ones in the future.



Korea	1
Niederlande	1
S-Afrika	1
Österreich	1
Schweden	2
Kanada	3
Norwegen	4
Schweiz	7
Spanien	2
Indien	6
Großbritannien/UK	9
Italien	12
Japan	16
China	18
Deutschland	18
Frankreich	25
US	25
Gesamt	151

Fig. 9.13 EV vehicles per origin countries [1]

Figure 9.13 provides an overview of the different types of electric vehicles and shows the identified number of car types in the different countries. Reflecting the manufacturer's distribution, 53.6 % of the electric vehicles are developed in Europe. Asia comes in second (27.2 %), followed by North America with a share of 18.5 %. Most EV concepts in Europe are being developed in Germany and France. Especially Renault, Citroen and Venturi in France, and BMW, Mercedes and VW in Germany show high activities. The activity in the Asian region is growing very fast with large contributions from China, Japan, and India. In the future manufacturers from those countries want to compete with the European ones.

9.4.5 EV Moving into Public Awareness, Preparing Roll-out

Companies develop strategies to bring electric vehicles to market. Depending of the brands, they highlight specific characteristics as Fig. 9.14 shows.

Worldwide activities have begun and the car industry has been presenting its concepts. They have developed prototypes and delivered test fleets for field tests. Around 2010 in all important exhibitions car manufacturers presented their studies, prototypes or electric vehicles, already prepared for market entrance.

Below in Figs. 9.15, 9.16, 9.17, 9.18, 9.19, 9.20, 9.21, 9.22, and 9.23, some impressions from the Frankfurt Motor Show 2009 are presented. As a series hybrid car, the Opel Ampera with a range extender has potential for wide acceptance and to substitute conventional cars.

Beside the purely electric vehicles, it should be mentioned, that the Toyota Prius is available now in the third generation of its hybrid drive system. It has an innovative power steering system branching electric drives with combustion engine. Especially in cities with stop and go operation, it could benefit from the electric drive and save fossil fuels (Fig. 9.24).

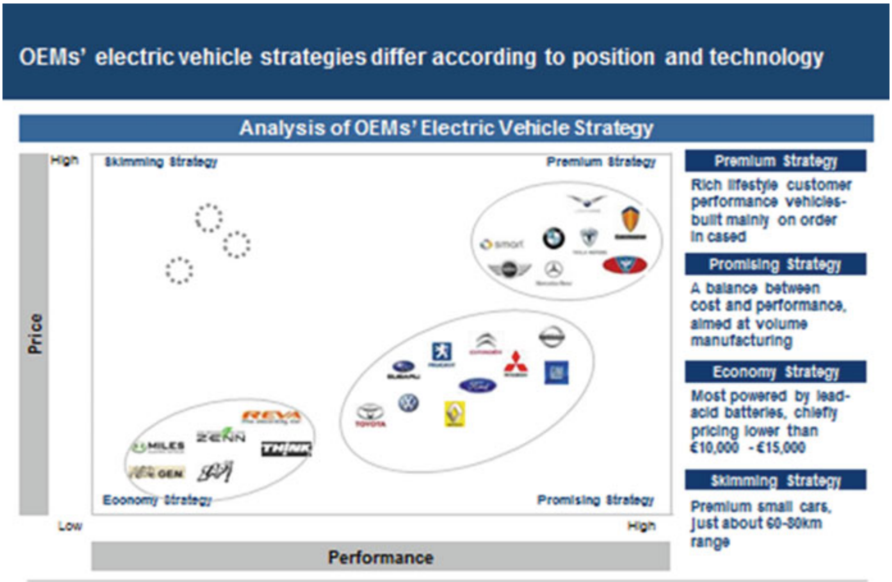


Fig. 9.14 OEM electronic vehicles strategies (*Source*: Results of a study made by Frost and Sullivan 2010)

Fig. 9.15 Audi e-tron

As already mentioned, the battery is the key element for the performance of an electric vehicle. As slight improvements were made to conventional lead-acid batteries, a new battery type has in recent years captured the market, lithium-based batteries. Lithium systems offer high specific energy and power. Conversely, lithium is highly reactive and poses a fire danger. Significant help came from the

Fig. 9.16 BMW concept car

Fig. 9.17 Ford Focus BEV

information and communication technology side. Mobile phones and notebooks achieved high market shares; powering these devices brought Li-battery development into the mass market, replacing the former Ni-Cd and Ni-MH battery systems. Also other key factors such as improved drive systems, the ability of new batteries to charge quickly, and the development of new electric vehicles brought a breakthrough.

Fig. 9.18 Open Ampera

Fig. 9.19 Renault Fluence Z.E.

9.5 Overview of Electric Vehicle Activities

The car industry is improving existing technologies step-by-step, optimizing the combustion engine to lower specific consumption and emissions. It starts from a wide variety beginning with mild hybrid systems, full hybrid and plug-in hybrid cars, electrical vehicles with range extenders and fuel cell vehicles; all that technical solutions are important steps to lower emissions. In the following an overview of certain projects, which are currently underway, is given with a focus on the

Fig. 9.20 Renault Zoe Z.E. concept

Fig. 9.21 Renault Twizy Z.E. concept

development and demonstration programs for purely electric vehicles. The market introduction of EV needs international cooperation, with the topic of standardization showing the difficulty and efforts of several stakeholder associations. R&D activities and demonstration projects are discussed. For some countries, in an exemplary way, an overview of research activities for electric vehicles, national associations for EV, and a description of research projects are given and country-specific characteristics defined.

Fig. 9.22 Electric smart

Fig. 9.23 VW up

9.5.1 International Energy Agency

At the International Energy Agency (IEA) the topic is addressed in two different working groups, the renewable energy working group and the hybrid & electric vehicle group. The working groups investigated the two topics renewables and EV in a combined way within the IEA RETD, RETRANS studies. Low- and zero-emission vehicles are a topic of worldwide interest; cooperation between key players can accelerate the common effort to reduce emissions, increase energy efficiency, and optimize integration of renewable energies. It can be seen, that both,

Fig. 9.24 HEV: Toyota Prius

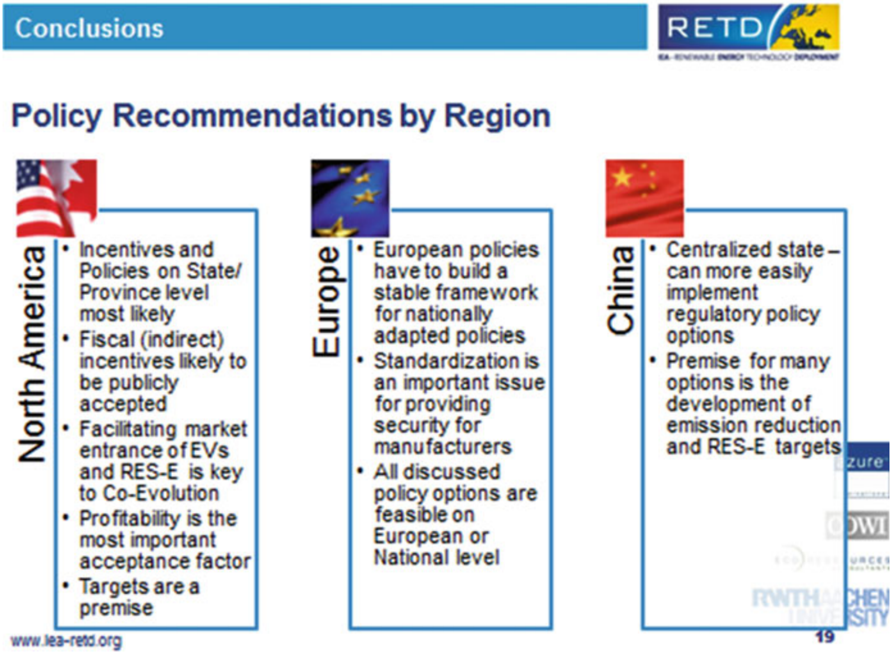


Fig. 9.25 Policy recommendations (*Source*: IEA)

renewables and EV contribute to emission reduction, and their co-evolution will cross-fertilize both technologies [2]. EV can be seen as a chance for economy. This is a global topic; Fig. 9.25 reflects the motivations and parallelism of different regions and summarizes policy recommendations.

9.5.1.1 IEA Implementing Agreement Hybrid Electric Vehicles (IA-HEV)

The IEA promotes execution of research by cooperating States on related topics through implementing agreements (IAs). Countries contribute information and benefit by sharing information and resources. In the HEV several topics are delineated into several tasks; in general, the first task is usually for information exchange concerning topics such as research and technology development, commercialization, marketing and sales, regulation, standards and policies. Specific tasks focus on batteries, market deployment of EV, plug-in hybrids, system integration, sustainability aspects and quick charging (see [3]).

9.5.2 Deriving Results from EV Tests

Evaluation criteria: In the last few years many pilot schemes in various regions tested electrical vehicles of the latest generation evaluating them in routine daily use. The scientific evaluation of pilot projects has no standardized methodology. To identify the most promising pilot projects, certain criteria should be defined which will lead to an evaluation model that is able to compare these different projects [1].

To be able to evaluate these projects some criteria should be considered. To help in benchmarking these criteria additional sub-criteria were defined and weighted differently, which is given by the following percentages:

- Innovation, pioneer position (5 %): Depends on project start, the earlier, the greater the pioneer position given.
- Business model (20 %): Assesses the availability of a master plan (in comparison to an isolated approach) and values cross-border concepts.
- Payment concept (20 %): This criterion evaluates the existence of an accounting system, the possibility of price determination by market prices, simplicity for the customer, package and product definition for the customer, and a guarantee of 100 % renewable energy for EV charging.
- Charging infrastructure (15 %): evaluates the density of charging posts, and availability of cooperation partners, for example in shopping centers or car parks.
- Car adoption (15 %): This criteria judges if the cars were used by many different users, private consumers/companies/public authorities and accounts for the density of EV and the number of different types of vehicles.
- Economic feasibility (25 %): For the pilot regions funding is considered in terms of economic operation in future times.

With such a systematic approach it is easier to compare different pilot regions as shown in Fig. 9.26.

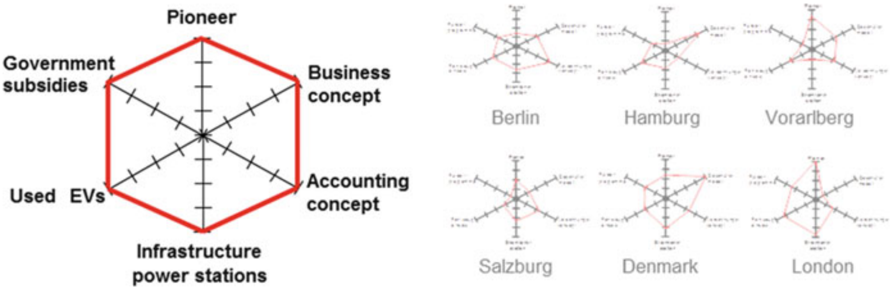


Fig. 9.26 Evaluation criteria and comparison of different pilot projects in Europe [1]

9.5.3 World Electric Vehicle Association

The World Electric Vehicle Association (WEVA), launched in 1990, is an international organization to promote research, development, and dissemination of electric vehicles. WEVA consists of three regional associations representing Europe, America, and the Asia-Pacific area and organizes the Electric Vehicle Symposium (EVS).

9.5.3.1 European Activities

Within the European research program, there is an effort to improve mobility and transport regarding efficiency, emissions, and use of renewable energies. With the *Green Cars Initiative* financial support is provided for research activities into green technologies. It comprises R&D support for cars, trucks, and buses in a variety of areas such as greener combustion engines for trucks, biofuels, electric and hybrid cars. Hydrogen technology and fuel cell research is bundled in *The Fuels Cells and Hydrogen Joint Technology Initiative*. Some actual EU-funded research projects will be mentioned in the following. Standardization is a key topic because without agreement between countries investing in the wrong plug design would lead to stranded investments or lead others to postpone investment until binding decisions are made. Eurelectric has made an effort to accelerate that process, but harmonization between different stakeholders is time consuming.

CARS21: In January 2005 the Competitive Automotive Regulatory System for the twenty-first century (CARS21) initiative was launched. It is a high-level expert group chaired by the vice president of the European Commission. Members of ministries, the European Commission and Parliament, representatives of the car industry and car manufacturers have joined this group. The task is the preparation of suggestions for the European Commission to increase the competitiveness of the EU car industry, which is a key technology in Europe for 2.1 Mio involved employees.

Fig. 9.27 Overview of demonstration regions in the Green eMotion project. *Source*: http://www.greenemotion-project.eu

9.5.3.2 EU Research Activities

Green e-Motion

Research and development for electric vehicles and erection of the charging infrastructure cannot be carried out by single countries or companies. Of course, there is high specific Know-how in different states available, but the implementation of e-mobility needs R&D cooperation on a European, or better worldwide, scale. One of the intentions of this large Green eMotion project with 43 partners involved is to bring all necessary stakeholders together, to investigate best practice, and collect the distributed knowledge in European countries to create a common system. The project budget is 42 Mio € with 24 Mio € funded by the European Commission.

The project consortium consists of partners from major industry (Alstom, Better Place, Bosch, IBM, and Siemens), utilities (Danish Energy Association, EDF, Endesa, Enel, Electricity Supply Board [ESB], Eurelectric, Iberdrola, RWE, and PPC), electric vehicle manufacturers (BMW, Daimler, Micro-Vett, Nissan, and Renault), municipalities (Barcelona, Berlin, Bornholm, Copenhagen, Cork, Dublin (represented by the energy agency Codema), Malaga, Malmo, and Rome), universities and research institutions (Cartif, Cidaut, CTL, DTU, ECN, Imperial, IREC, RSE, TCD, and Tecnalia), and EV technology institutions (DTI, fka, and TÜV NORD) and covers a great variety of issues, such as building electric vehicles, preparing charging infrastructure, deals with charging strategies and grid issues and is aiming to overcome international billing problems. User aspects are well addressed and experience can be collected by the involved demonstration regions (Fig. 9.27).

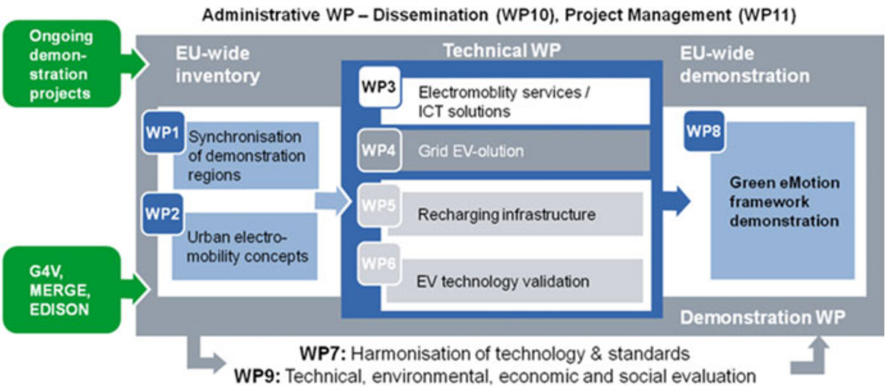


Fig. 9.28 Structure of work packages in the Green eMotion project. *Source*: http://www.greenemotion-project.eu/workpackages/index.php

The comprehensive research and development tasks have been assigned to 11 work packages (WP), as shown in Fig. 9.28. In the following, the key work is described. Within the 12 demonstration regions there is a great variety of different cars, fleets, concepts and implementing mechanisms, incentives, and charging infrastructures. In WP1 they evaluate all the experience of the different demonstration regions and aim to synchronize those activities. It is the task of WP2 to assess the different concepts of municipality planning, policy measures and regulations. It should be clarified, which key features are necessary for a successful mass roll-out of EV in Europe. In WP3 the electromobility services and ICT solutions are addressed. As ICT is penetrating daily life to a greater and greater extent, it could advance EV technology by providing roaming solutions for easy charging and fleet management services. WP4 investigates solutions for the future requirements of the grid, as high penetration of EV charging has a strong impact on the stability of the grid. The influence of EV is investigated from the grid operator's viewpoint to plan charging infrastructure in the best way. Users need a simple and reliable system to accept e-mobility; within WP5 the interoperability and DC fast charging, battery swapping and inductive charging is demonstrated and smart network management systems developed. WP6 evaluates the EV technology in daily life, different climatic zones for user performance, durability and costs. In WP7 the harmonization of technology and standards is addressed on the vehicle, infrastructure and communication side for mass roll-out of plug-in hybrid and electric vehicles. WP8 will demonstrate the enhanced interoperable and upgradable e-mobility solutions of the Green-eMotion framework. In WP9 technical, economic, environmental, and social aspects of the mass roll-out are investigated. WP10 aims at dissemination of information gained and offers an external stakeholder board to exchange information in a bi-directional way to companies and stakeholders outside of the partners of the consortium. Execution of the project is carried out through effective project management (WP10).

Grid for Vehicles (G4V)

It should be mentioned, that the results of the "Grid for Vehicles" project, finished at the end of June 2011, have been published. Within the 1½ years of the project, an analytical framework to plan the required technological developments in the grid infrastructure was developed and defined the related ICT and policy requirements to cope with mass roll-out of EVs [4].

Mobile Energy Resources in Grids of Electricity (MERGE)

This project aims to prepare Europe's grid for electric vehicles. Grid planning and operation is already changing by increasing the number of decentralized generators such as PV or wind power. Mass penetration of EV has a serious impact on the grid, EV can be seen as a simple load, a controllable dynamic load, or as storage in the future. Studies were carried out by 16 partners based on certain power systems in various countries and showed interesting results.

An adequate EV integration into the system could mean an increase in the use of renewable resources. EV charging in hours where there is a surplus of renewable power in the system decreases demand of wind power spillage. A high penetration of EV increases slightly system-specific costs and CO_2 emissions. Simulations for the transmission grids have shown that major complications will arise for the transmission grid. However, it is recommended smart charging strategies be implemented. A steady state analysis has been performed in order to assess the impact to the medium-voltage (MV) distribution grid and showed that only with smart charging are more EVs allowed to be connected as it takes into account the power produced from renewable energies. Transformers/lines tend to be more quickly overloaded in cities, while in rural networks low voltage problems are expected. For low-voltage (LV) networks, large-scale EV integration may affect quality of service and cause technical problems (increased losses, power quality and imbalances) [5].

9.5.4 Standardization

For E-mobility, there is a strong requirement for harmonized plugs for the charging infrastructure. Working documents have been prepared within CEN/CENELEC, but until 2012 there is no union European agreement for a specific type of plug.

The Union of the Electricity Industry, Eurelectric, is supporting the harmonization process and published already on 27 October 2009 a declaration on "Standardisation of Electric Vehicle Charging Infrastructure" [6], signed by 49 CEOs of European electricity companies.

In September 2010 Eurelectric completed a concept paper "Market Models for the Roll-Out of Electric Vehicle Public Charging," (Fig. 9.29) with a description of

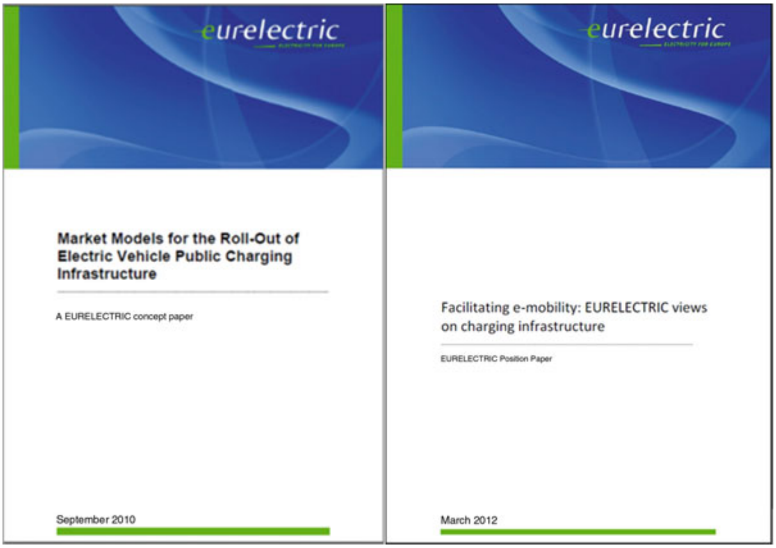


Fig. 9.29 Eurelectric concept paper to market models and position paper related to charging infrastructure. *Source*: www2.eurelectric.org

four market models. These models represent the value chain from "electricity distribution," "charging station ownership and/or operation" to "retail of electricity." Within this value chain the four market models are described:

1. The integrated infrastructure market model.
2. The separated infrastructure model.
3. The independent e-mobility model.
4. The spot operator owned charging station model.

These identified market models give an overview and allow the development of different business models, which depend on different national market conditions given by specific national laws, government decisions, incentives and economy of scale or different technical solutions. This paper shows the different options with various regulatory degrees; for example nonregulation, self-regulation, framework regulation, full regulation, and regulation through public provision. The possible locations and their specific characteristics are explained, for example Charging on public area on public property (typical public parking lots), public area on private property (shopping mall, multioffice-building garages), and private area on private property.

At least Eurelectric addressed in March 2012 with its position paper "Facilitating e-mobility: EURELECTRIC views on charging infrastructure" the need for a harmonized European charging solution. It is now necessary to undertake appropriate actions and decisions to enable an EU-wide e-mobility market. Different stakeholders and countries have different suggestions and safety requirements; in general there are different types of plugs under consideration. Controlled charging of EV is seen as part of the smart grid of the future. Actual uncertainties have led to a situation where some countries are waiting for a common solution while others are installing the Type 2 connector (with/without shutters) or the Type 3.

9.5.5 Activities in European Countries

In the following examples of some countries are given (in alphabetic order) to obtain an impression of ongoing EV activities.

9.5.5.1 Austria

In the following Austrian activities are described, including the best practice example of establishing an interdisciplinary platform Austrian Mobile Power (AMP) with all relevant stakeholders to push the topic, the lighthouse project EMPORA to stimulate development, a cross-border project and other demonstration projects to enable easy charging.

AMP Platform: The introduction of electric vehicles needs an interdisciplinary approach. Stakeholders of different areas have to make an effort to design and integrate the new system, although to prepare a possible market penetration by suggestion of specific measures (incentives, regulatory framework) at the starting phase.

The "Austrian Mobile Power" (AMP)-platform as association at the good example of best practice. Big steps need key players which guarantee continuity and a stable financial background for the development of such an intention. In 2009 Verbund (utility) began together with five key players including three from the car industry (AVL, KTM, and MAGNA), an electricity company (SIEMENS) and a research institute (AIT Austrian Institute of Technology) to write a position paper for R&D demand and established the "Austrian Mobile Power" (AMP)-platform as association at the end of 2009. They committed to bringing Austria into a leadership position in e-mobility, to implement an overall system in pilot regions with more than 10,000 EV, to establish energy, infrastructure and a uniform accounting system and to trigger around five billion € investments by 50 million € investments in R&D. The AMP open platform creates solutions that fit Austria and develops an open system for e-mobility for all market players, based on EU-standards.

Two years later, in 2012 AMP has reached more than 30 members that are involved in lighthouse projects related to e-mobility, strategy development, and participates and represents specific topics in working groups to provide input to Austrian ministries. AMP communicates its activities by initiating high-level events and organized for example an EV-day during the world exhibition 2010 in Shanghai, China. AMP's members strive to make e-mobility a reality.

E-Mobile Power Austria (*EMPORA*): EMPORA, initiated and coordinated by Verbund is the largest Austrian R&D lighthouse project for e-mobility with a total

Fig. 9.30 EVs of the cross-border VIBRATe test fleet

project volume of 26 Mio €; it involves 21 core companies from car and system development, infrastructure and research. It is organized into two supplementary research projects Empora1 and Empora2 (Jan 2010 to March 2014), which are funded with 12 Mio € by the "Klima- und Energiefonds" (energy and climate fund) of the federal government. The main focus is the benefit for the customer; barriers for implementation are identified and solutions elaborated.

Specific tasks are formulated in 28 work packages; project coordination and management is led by VERBUND, system architecture and data analysis is coordinated by SIEMENS with support from AIT. Car technology development addresses Li-Ion battery packs, cooling, steering, the E-drivetrain, regenerative braking, high-voltage systems including DC/DC converters and charger vehicle control units and low voltage systems, and is coordinated by MAGNA with AVL and Infineon. The infrastructure topic comprises renewable energy generation, day ahead forecast and planning of e-car charging, data aggregation and intelligent charging control for the charging points and is organized by SIEMENS with VERBUND, WIEN Energie and A1. User aspects are handled by AIT with the support of A1, VERBUND, AVL DiTest, and finally the demonstration of EV, which starts in 2012 is organized by Raiffeisen Leasing in cooperation with AIT and VERBUND.

Within the project the whole value chain is covered. Connection with other European projects is managed for active information exchange.

VIenna BRATislava e-mobility (*VIBRATe*): Complementary to this, some other interesting activities should be mentioned. VIBRATe (*VI*enna *BRAT*islava *e*-mobility) is a cross-border e-mobility pilot project between Austrian and Slovakian companies. Within the project on public and semi-public areas normal power and five high-power charging stations will be erected to enable barrier-free cross-border e-mobility. Electric vehicles are supported to provide sustainable mobility [7] (Fig. 9.30).

The first EV demonstration test "VLOTTE" started in 2008 in Vorarlberg. After a countrywide call for proposals they could offer an integrated mobility card including electric vehicle, charging infrastructure, maintenance, Austrian Automobile Association and mobility card for public transport. The intention was to bring cars to the streets and test them. Different types of EV, such as Th!nk, City, Fiat500, Mitsubishi i-MIEV, Citroen C-Zero, Peugeot Ioin and a few cars of other types, in total a planned 357 until the end of 2012, were to be applied. Energy for the EVs is generated by small hydro power plants and PV.

An interesting approach started in March 2012 in Salzburg in the form of a car-sharing project using EVs. The local utility Salzburg AG and the department store chain Rewe jointly funded a company called *EMIL* and gave the city an impulse to test and supplement the public transport system with EVs. They started with five renting stations; the customers can book the EV car over the internet. One study suggests that one shared car could replace up to eight conventional cars.

Two of the leading technology companies, SIEMENS and VERBUND announced in April 2012 that they were going to erect infrastructure for electric vehicles in the next years and offer a mobility package for private persons and companies. The official start of the company is in summer 2012. By 2020 this e-mobility provider plans to erect 4,500 (semi-) public charging stations for normal power and high power for fast charging (especially needed on highways), thus will trigger an investment of around 300 Mio €. To achieve break-even point in the next 8 years 80,000–240,000 EV should be on the road.

9.5.5.2 Denmark

To explain the high interest in electric vehicles one needs some information on the electricity system. Energy companies will change from generation based on fossil fuels to a system that is dominated by renewable energies. There is significant experience in wind power and decentralized biomass generation available. Wind power has already reached 3 GW in total, which leads to a situation where power from wind can be higher than energy demand for certain hours, reflected in a negative electricity price for that time. Denmark plans to double wind energy capacity to 6 GW. The situation would be critical for dispatcher (oversupply by wind energy) without additional measures (smart charging of EV), the and an intelligent charging strategy is seen as a solution to integrate more wind power.

EDISON project: The Danish transmission system operator funded the "Electric vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks" (Edison) project to develop optimal system solutions for the integration of electric vehicles. The Danish government sees the EV as a potential storage device for fluctuations in wind energy. Emissions of CO_2 can be reduced and vehicles are energized by wind power. The project budget is 49 Mio DKK, within seven work packages the seven project partners analyze EV technology, design system architecture for EV including vehicle to grid (V2G), develop solutions for distributed integration technology development, develop fast charging and battery swapping station design, and work out solutions for power and information/communication management [8] (Fig. 9.31).

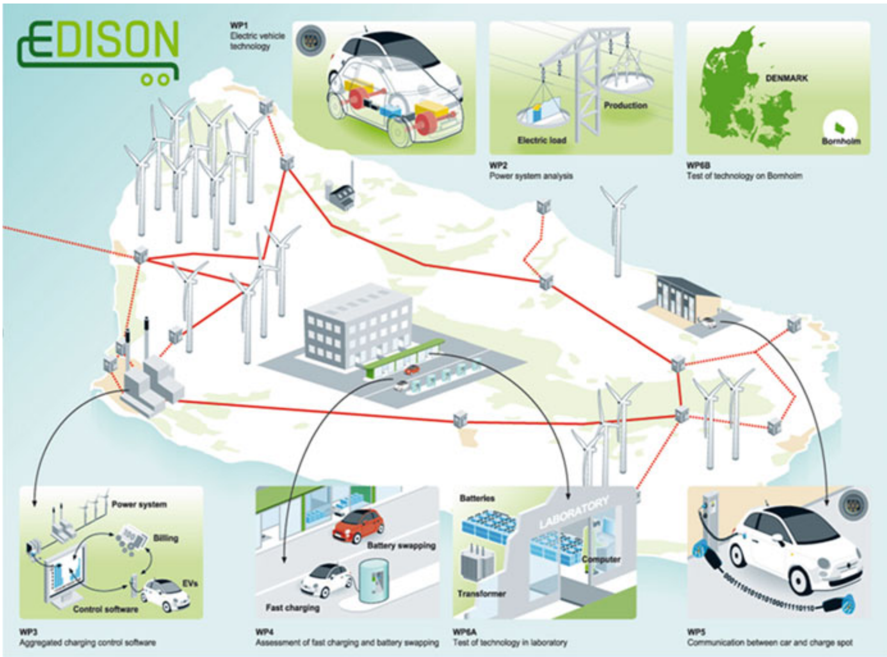


Fig. 9.31 EDISON project overview [8]

In July 2011 Better Place unveiled the first battery swap station in Europe. The process of battery exchange is automated. The driver drives into the station, after identification the battery changing procedure starts, it needs less than 1 min and is faster than conventional refueling of a car, and the disadvantage is the high investment cost for such a station (Fig. 9.32).

9.5.5.3 Finland

In December 2011 a private-public partnership of public authorities, private corporations, entrepreneurs, and researchers developed a business model for electric vehicles. The "Electrictraffic.fi project" is part of the 100-Mio € Electric Vehicle Systems Program EVE, administered by the Finnish Funding Agency for Technology and Innovation. The program addresses three relevant topics, i.e., electric vehicles, smart grids, and intelligent traffic.

Several companies committed to the project and it is still possible to join later. The test fleet of 500 EVs is the source for gathering basic information within the research part of the project, carried out within 15 work packages; the planned project time is 4 years.

Fig. 9.32 Demonstration model of battery swapping

9.5.5.4 France

EV test center: France is addressing customers to obtain information on personal experiences with electric vehicles. The EV manufacturer Renault opened a test center for zero-emission (Z.E.) electric vehicles in Boulogne-Billancourt (at Paris) in December 2011. This center is the first of its kind in Europe; the zero-emission test center also includes a reception and exhibition area. It is open to the public and potential users and customers are informed about EV technology, receiving information about different cars, batteries, and charging infrastructure. Test drives are offered at the 1.8-km-long test route to experience silent e-drives in the Kangoo Z. E., Fluence Z.E., and the four-wheeler Twizy.

brilleCarsharing: Autolib has offered car charging for the 46 communes of greater Paris. Infrastructure will be erected to achieve around 1,100 charging stations by the end of 2012 for the planned fleet of 1,740 electric vehicles. Driving license holders may choose between two subscription models consisting of a fixed fee and time-dependent rate.

9.5.5.5 Germany

Germany has put much effort into promoting electric vehicles, and a 10-year national strategy plan foresees the implementation of 1 Mio EV by 2020. This needs close cooperation between all relevant ministries such as those for economy and technology, traffic, construction and city planning, research and environmental protection, and reactor safety. First, the market and technology will be prepared, followed by commercialization and market growth and as a fourth step large-scale production is planned.

Electric vehicles will change requirements for the automotive supply industry dramatically; there is a need for investment to establish a commercially competitive product and market, requiring subsidies only during the starting phase. Effort is focused on the development of the battery system, drive motor, power electronics and control. Over a long transition phase of about 20 years, fossil and biogenic fuels will dominate the mix of automobile energy source.

Pilot regions: Within a support program eight pilot regions (Oldenburg-Bremen, Hamburg, Berlin-Potsdam, Leipzig-Dresden, Rhein-Main, Rhein-Rhur, Stuttgart, and Munich) were funded (source: BMVBS Modellregionen Elektromobilität, 2009).

Car2go mobility concept: In autumn 2008 Daimler started the new mobility concept car2go in Ulm, Germany, which meets customer needs for mobility in a simple and flexible way. After application to car2go, the customer has access to the cars via a car2go member card. Then he is able to take the closest available car, searching for the nearest one on car2go.com by clicking the car finder, using a mobile phone (iPhone or Android), or by calling a service number. After placing the member card near a card reader behind the windshield, the car opens and can be put into operation with a 4-digit customer PIN code and the input of a form of payment. He can drive his individual route and use the navigation system if necessary. After reaching his destination, he is able to park the car at any allowed free parking area and end the car rental. He is able to make an intermediate stop whilst continuing the rental or end the rental. There is no need to return the EV to a particular location in the car2go city area. However, it is suggested the car be parked at one of the charging stations within the network. Further cities using the car2go fleets in Germany are Düsseldorf and Hamburg. Several car2go fleets have been introduced in European and North American cities with a total of 70,000 users (March 2012).

9.5.5.6 Ireland

In Ireland *ESB* is an international energy company and is one of the forerunners in the implementation of electric vehicles. They designed a concept for the introduction of e-mobility, working together with partners and involved government and car industry players to develop a sustainable transport system. They have foreseen home chargers for the vehicle owner and a public charging infrastructure of 1,500 charging posts and additionally about 60 DC-fast charging stations to enable inter-urban travel. The official launch of this project was in May 2011. To introduce electric vehicles, ESB is involved in several organizations; for example they support the development of products such as home charging boxes and mobile charging units and work with relevant car manufacturers. An electric taxi is included in this field test; when customers order a taxi, they check whether this is within the range of the EV to guarantee transport. To demonstrate the performance of the modern EV a promotional tour over 900 km within 3 days was organized; it could be shown that driving with an electric vehicle within Ireland is possible.

An internet-based platform for ESB ecars shows on a map the location of all the installed and planned AC charging and DC fast-charging stations. The map is available for download to a smart phone. Information regarding address, type of plug, and access time is delivered. After registration the EV car users can use charging points via a charge point access card. Until the IT infrastructure and payment system has been developed (in 2012), public charging is free. The driver will have the opportunity to select the energy supplier, will see the status of charging points for reservations, but various features are still under development.

9.5.5.7 Portugal

Portugal wants to enlarge the share of renewable energies by usage and intelligent charging of electrical vehicles. There was an early decision by the government to erect EV infrastructure and they supported that intention. To build a market-orientated approach, they launched the *Mobi.E* project with an open-access approach to enable investors to erect public charging posts. Simple access to the charging infrastructure operated by different providers is guaranteed by a universal smart card, which the customer can buy. A countrywide charging infrastructure of 1,300 charging stations and around 50 fast-charging stations had already been erected by the middle of June 2011. The Portuguese model can be seen in Fig. 9.33.

9.5.5.8 The Netherlands

In the Netherlands the Distribution System Operators (DSO) agreed to erect the infrastructure for EV charging and suggested their government a challenging proposal for EV-infrastructure erection.

e-laad: Within the e-laad project they erected from 2009 to 2012 around 10,000 charging stations and created a uniform technology and communication platform. They will benefit in the future because of the developed control appliances for optimum control of the charging algorithm. This is not only to shave peaks, other ancillary services include congestion management, power balancing, better integration of fluctuating production from renewable power, and disturbance management.

Treaty of Vaals—international roaming: National initiatives for enabling cross-country mobility announced in April 2012 a transnational roaming system via the use of RFID cards with partners in seven European countries (Ireland, the Netherlands, Belgium, Luxembourg, Germany, Austria, and Portugal). The three partners ladenetz.de, e-laad, and Blue Corner developed and founded the agreement on e-roaming, which bases on an Open Clearing House Protocol (OCHP). It is an

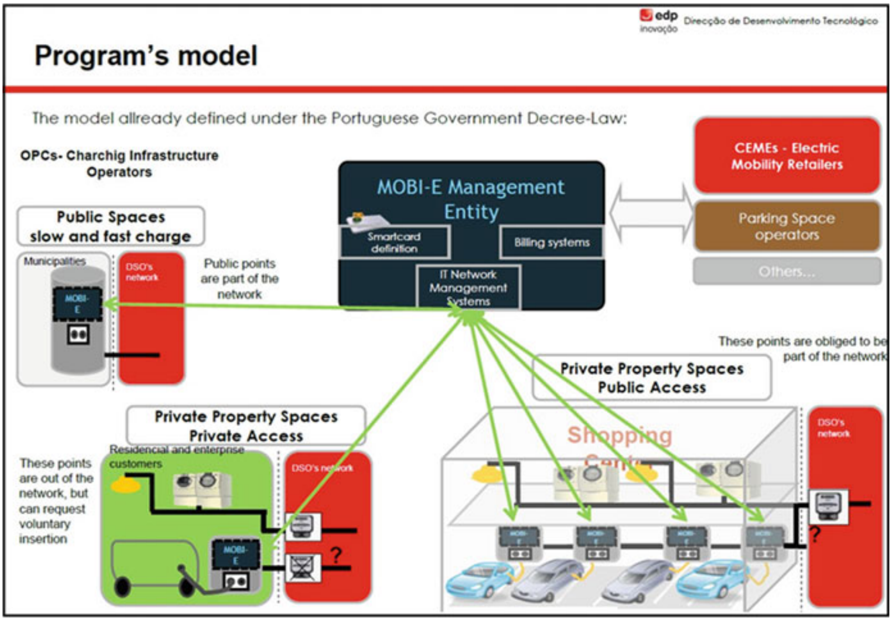


Fig. 9.33 Structure of the Mobi-e model in Portugal. *Source*: www.edp.pt

important step towards enabling international charging; automatic data exchange enables easy payment comparable to the use of a credit card.

We cannot provide a description of all activities across Europe for reasons of space and a few were picked out to give an impression. It is worthwhile to mention a few further activities. In the *Czech Republic*, the CEZ Group realized concepts for e-mobility within the FutureMotion strategies. They will begin testing electric vehicles and will implement a pilot fleet test in Prague and Ostrava for real long-term operation and erect a charging infrastructure. The long-term plan is to be with partners a provider for e-mobility. In *Italy* various cities are performing demonstration projects and ENEL, a utility, is introducing e-mobility and smart grid technologies. They have in 2012 around 460 low/high-power chargers in private and public areas (Rome, Pisa, Milan, and Bologna) but they are planning to erect 8,000 low/high-power charging stations. An easy way to find a free charging post is provided by the plug serving service, showing possible charging points on a map-based program.

9.5.6 Activities in the USA

There is a great deal of experience in the development of electric vehicles in the USA. Already in the 1960s and later in the 1980s the key driver was to reduce air pollution; the Clean Air Act was announced to reduce emissions. California was a forerunner, founding the California Air Resources Board (CARB) in 1967 as a regulatory agency.

Recovery Act: Under the Obama administration's comprehensive plan 1,800 electric vehicle charging stations were installed to save money and improve the nation's energy security. Since 2009 the Department of Energy (DOE) has invested more than $5 billion in grants and loans to spur the growth of the EV and battery industry to force competitiveness in their industry in the fast growing market. Within the Transport Electrification Initiative they will deploy 13,000 grid-connected EV and over 22,000 charging points in residential, commercial and public locations by December 2013 [9]. Under the *Coulomb* project the deployment of 2,000 GM Volt, 200 Ford Transit Connect, 100 Ford Focus EV, and 100 Smart EV vehicles, as well as establishing 4,600 EV charging locations nationwide is planned.

Recent activities include a partnership between the DOE and car industry players (USCAR, US Council for Automotive Research) and the project "FreedomCAR" was established to develop fuel cell technologies for the mass market. The DOE identified within the Energy Efficiency & Renewable Energy (EERE) offices research topics for hybrid and electric vehicles giving an overarching vehicle system perspective. All basic topics were addressed such as the hybrid and plug-in hybrid EV, modeling and simulation, integration and validation, benchmarking, propulsion system and power electronics, energy storage, fuels, advanced combustion engines, and material technologies. Partners from industry support the working team within the U.S. DRIVE partnership. Research work is carried out at several universities and in national laboratories. The Plug-in Hybrid Electric Vehicle Center (PHEV Research Center) is at the University of California, Davis, and helps to solve questions related to the topic of commercializing the PHEV and electric cars. The DOE hosts multidisciplinary transportation research centers in their laboratories and include relevant topics concerning fuel cell, hybrid and EV research.

9.5.6.1 National Research Centers

Idaho National Laboratory: Light-duty vehicle testing activities of the Advanced Vehicle Testing Activity (AVTA) are conducted by the Idaho National Laboratory. Within the vehicle testing activities, they provide benchmark data for technology modeling and validating of different technologies, for example PHEV, REX-EV, HEV, EV and hydraulic technologies, advanced electric drive technologies and engine technologies, advanced energy storage (i.e., batteries) technologies and chemistries, advanced climate control, power electronic, and other ancillary systems technologies and internal combustion engines burning advanced fuels (i.e., 100 % hydrogen and hydrogen/CNG-blended fuels) [10].

National Renewable Energy Laboratory (NREL): In the focus of NREL's Center for Transportation Technologies and Systems (CITS) is the reduction of dependency on fossil fuels and air pollution by means of innovative vehicles and fuel technologies. Within their advanced vehicle activities they conduct research projects in advanced power electronics, energy storage and thermal management of the vehicle and supports with modeling, analysis, development and demonstration activities. They have long experience in renewable energy generation and investigate fuels and lubricants. Fleet vehicles were assessed in real-world tests as well as in controlled laboratory experiments. NREL is joining with Google and other industries to provide consistent, up-to-date information about EV charging stations in communities nationwide. On the basis of Google Maps the coordinates of all U.S. charging stations (not only electric, also alternative fuels) are available online and easy to use in customer navigation systems.

Sandia National Laboratories: Within the Sandia national labs they have a wide spectrum of experience, especially in hydrogen and related topics such as influence of hydrogen on materials as a basis for hydrogen storage, safety, codes, and standards. Within their research programs they contribute to the development of batteries, supercapacitors, and thermoelectric heating and cooling as well as increasing overall performance of energy efficiency.

Argonne National Laboratory: They perform research into alternative fuels, batteries, hybrid electric vehicles, hydrogen and fuel cells, modeling, plug-in hybrid technologies, and also cover intelligent EV charging by the use of smart grids, for example by connection of a EV to the grid using a J1772 connector featuring power and communication pins [11].

Oak Ridge National Laboratory (ORNL): This laboratory covers research areas in fuel cell technologies to develop materials, components, and processes within the Hydrogen, Fuel Cells & Infrastructure Technologies Program (HFCIT). They carry out research on storage technologies, hydrogen generation, and the transition to a hydrogen economy. In the Power Electronics and Electrical Power Systems Research Center (PEEPSRC) they focus on drive systems consisting of advanced power electronics, machines and system control. An integrated approach covering advanced engine technologies, power electronics, vehicle testing and evaluation, modeling and simulation is enabled by the Advanced Vehicle Systems (AVS) Research Program.

Electric Vehicle Infrastructure Training Program (EVITP): The Electric Vehicle Infrastructure Training Program provides training and certification for people installing electric vehicle supply equipment (EVSE). As a voluntary collaboration of electrical industry organizations, EVITP supports the development of electric vehicle (EV) charging infrastructure for residential and commercial markets. In their courses they cover topics concerning different types of batteries, charging characteristics, utility interconnection requirements, fundamentals of charging stations and integration of EV to the grid, national standards, and support the roll-out phase of EV.

Fig. 9.34 Tesla S

9.5.6.2 Industry Activities and Field Tests

In the following we select and describe some examples of activities and experiences gained during a commercial trip to California to car manufacturers, utilities, battery manufacturers, component developers, partnership organizations, regulators, and others [12].

9.5.6.3 Car Manufacturer

The car manufacturer *Tesla motors* was founded in 2003 and demonstrated the Tesla Roadster, an electric vehicle with unique performance shedding a new light of power and efficiency on e-mobility. They produce cars in relatively small production runs (in comparison to the car industry). The basis is the Lotus Elise from Great Britain, and it will be completed at Pomona with the addition of an electric drive train and battery system. The next generation, Tesla S is a four-seat limousine and they predict a cost reduction as they can build on lessons learned with the roadster (Fig. 9.34).

Fisker Automotive with its headquarters in Anaheim, CA, was founded in 2007. They designed the electric hybrid sports car Karma. It combines a sustainable and efficient electric drive with a range extender and offers a luxury interior.

Phӧnix Motorcars has developed several EVs as zero-emission vehicles since 2002. They use the Altair-Nano Battery, a lithium titanate oxide battery based on nano-technology; the graphite electrode is substituted by one made from lithium titanate oxide. This enables fast battery charging and provides high battery lifetime.

Fig. 9.35 Race car at NASA Test Center

9.5.6.4 Battery Producer

Altair nano produces the lithium titanate oxide battery with a high energy and power density. This battery type can be charged with high power, operates over a wide temperature range from −50 to 150° F, has a good performance at low temperatures, and provides high cycle lifetime under deep discharge conditions.

Quallion is specialized in cell and battery development and optimize batteries depending on a combination of lithium, cobalt, Manganin, and nickel for different applications such as long life batteries for satellites, high density, high cycle lifetime, or safety. *A123* offers different cells (cylindrical, prismatic type), modules and systems for several applications. Nanophosphate technology of the LFP delivers high energy and power density, extended cycle life time and safety.

Imara Corporation is producing a high-power 18,650 lithium nickel manganese cobalt oxide cell (NMC) for the outdoor equipment and transportation market. The cycle life is very stable, and low cathode impedance enables high currents.

9.5.6.5 Component Development

NASA Ames Research Facility realized high-power drive trains that enable fast acceleration (to 130 km/h in 4 s) for race cars. A high efficiency (97 %) synchronous disc type motor is excited with a minimal required current to provide torque with minimum possible losses (Fig. 9.35).

AC Propulsion developed an integrated box which contains the motor controller and charger. Parts of the motor windings are used as inductivity for the charger. They deliver power electronics components for several car manufacturer such as

Fig. 9.36 AC propulsion vehicle

Tesla, BMW mini, Toyota, and Volvo. Power range is from 150 to 300 kW. They also offer vehicle-to-grid (V2G) features, for example the car was part of the European EDISON project and can be operated as an uninterrupted power supply unit (Fig. 9.36).

System design: Electric vehicles have to be integrated into the electrical grid and *OSIsoft* develops software for smart grid, smart home and smart city applications. *Better Place*, Palo Alto, CA, started with the goal of realizing sustainable transport without fossil fuels; e-mobility was the result of various scenarios. They deliver services, plan, erect and operate infrastructure and systems to enable confident adoption and use of EVs.

9.5.6.6 Hydrogen Technology

California Fuel Cell Partnership: In 1999 CARB and CEC (California Energy Commission) joined with partners from industry to form the California Fuel Cell Partnership to demonstrate and promote fuel cell vehicles and opened 1 year later the headquarters in West Sacramento. The building is equipped with models of the FC vehicle; they have a show room for fuel cells and their function and deliver all relevant information. As this technology has a chance for success on the market, further members from the car industry, fuel cell manufacturers, energy companies, and governmental agencies joined. Particularly impressive is the test fleet of cars to obtain real experience by driving cars which have the fuel cell as their core element; a compact model of the UTC power S300 is shown in Fig. 9.37. For refilling

Fig. 9.37 UTC power's S300 automotive fuel cell stack

hydrogen a station is available at the site, providing hydrogen at two pressure levels 3,600 and 5,000 psi and cryogenic liquid H_2.

9.5.6.7 Utilities

Southern California Edison is a utility and interested in new technologies. They operate a large test center for batteries and can simulate different situations for stationary and mobile use. As the electricity grid is already highly utilized, decentralized generation and electricity storage is of high interest; the EV is a part of this concept of the smart grid. Vehicle-to-grid (V2G) has the potential to contribute balancing power to the grid. Demonstration tests are running with real-time demand response (DR) meters, measuring 30 times per second data which are compressed before data transmission, thus helping to maintain stable grid operation. An interesting approach is the use of ice, which can be produced during electricity oversupply as a storage medium for air conditioning.

9.5.6.8 EV Demonstration Projects

The EV Project

"The EV project," managed by ECOtality and its subsidiary ECOtality North America, was launched in autumn 2009 and received a grant of 99.8 Mio $ from the DOE for deployment of EV and charge infrastructure. With the contribution of partners and an additional grant from the DOE a total volume of 230 Mio $ could be reached. Within the project data from the vehicles are collected and analyzed for lessons learned. The partners (ECOtality, ECOtality North America, Nissan, Chevrolet, Idaho Nat. Lab., Zero Emission) cooperate with more than 60 strategic partners (car manufacturers, states, cities, national laboratories, utilities, companies, and associations). In addition to data collection and analysis The EV Project is writing position and policy papers to support the transition.

Car2go

The *car2go* concept was launched on 18 Nov 2011 in San Diego; within 3 months about 6,000 new EV users registered with the car-sharing program and they used the cars for more than 25,000 trips. The 300 Smart two electric drive vehicles have the estimated potential to substitute about 2,000 individual cars. This makes San Diego one of the top cities in terms of EV users. It was announced that car2go would be introduced in Washington, DC and Portland in March 2012.

An analysis has shown that usually the average trip distance is between 5 and 10 miles and the rental time for the car2go is from 15 to 30 min. As can be seen in the rapidly increasing registrations, customers accepted and assimilated this additional mobility service well as a new life style option. They can simply take a car, drive, park at their individual destination, give it back within the car2go area by closing the car and checking out by placing the car2go member card close to the windshield reader. Thus, the next customer can take the car for another individual route.

The calculated price for using the car2go service bases on three rental modes: The car can be rented for a short period by the minute depending on the time the car was used. In San Diego the rate is $0.35 per minute and includes all services such as re-charging, parking, mileage, insurance, maintenance, cleaning, support service and hotline. For longer renting periods, costs decrease to an hourly rate of $12.99 and for daily use to $65.99 plus taxes.

9.5.7 Asian Activities

In comparison to other regions, there is high economic growth in the Asian region; large investments go into economy and infrastructure projects. Vehicles with alternative drive systems offer a chance to enable efficient and environmentally friendly transport systems.

9.5.7.1 China

Traffic in China is growing rapidly, causing environmental pollution and traffic jams. So they limit growth by reducing new licenses for cars; for example, permissions for new drivers are selected in Beijing by random generator, while Shanghai is auctioning them. China has a rapidly growing car industry and focuses on the EV to decrease dependency on oil with resulting increasing costs for fossil fuel imports.

Fig. 9.38 CRH high-speed train

Policy by central government is able to realize infrastructure projects such as new highways, but that is not seen as the only solution; significant investments go into the public transport system too. For example, Shanghai opened the first metro in 1999, and after rapid construction activity they have 11 lines with a metro grid of about 430 km today. The CRH high-speed trains (Fig. 9.38) enable a countrywide fast and high capacity transport system enabling travel between the large megacities within a few hours; this is more efficient and faster than connection by airplane. E-mobility is already a reality with two wheelers like scooters and motor bikes. The government introduced these electric drive systems and more than 120 Mio of them are now in operation.

National Strategy Plan

863 Program: The main activities concerning electric vehicles go back to the year 1986, when the state council initiated in March the so-called 863 program with policies for "New Energy Vehicles" (NEV). The ministry coordinates the technology and research projects, provinces subsidize NEV car purchases. The tenth Five-Year plan (2001–2006) funded research projects for fuel cell, hybrid and pure electric vehicles. Increased funding was given in the 11th Five-Year plan (2006–2011). On 23 March 2009 MII (Ministry of Information Industry) presented an additional "Plan on Adjusting and Revitalizing the Auto Industry" and set ambitious goals for 2011, 5 % should be NEV ones.

From 2012 to 2022 the Chinese government will invest more than 15 billion US$ in subsiding the country's industry for energy-saving technologies and announced as an official goal 500,000 plug-in hybrid and electric vehicles. That will be accompanied by a nationwide program to install charging stations. A key element of the 12th Five-Year plan (2012–2017) is development of automotive electronics, information, communication and software solutions according to the Ministry of Industry and Information Technology (MIIT) of the People's Republic of China [13].

Well-known Chinese research centers and universities are involved in the development of electric vehicles, for example in the development of power electronics, chargers, battery and battery management systems, drive systems, car components, and charging infrastructure.

25 Pilot Cities: In 2011 China reported about 25 new energy vehicle demonstration pilot cities, including for example Beijing, Shanghai, Dalian, Chongjing, Guangzhou, Shenzhen, and Hefei. China State grid will erect infrastructure; more than 6,000 charging posts and additional fast-charging stations are planned in the pilot regions over the short term. These cars are supported by parking fees and road access to force individual customers, companies, institutions and the government to buy this NEV.

In *Shenzhen* a *taxi fleet* trial was initiated; they tested the BYD e6, a relatively large and comfortable car, in daily use. BYD developed a reliable Li-FeP battery with a battery management system enabling a range up to 300 km. Operation for one shift of work was possible, but the theoretical range was reduced by consumption for the air conditioner. Large incentives were given for this pilot test such as investment funding and a taxi license exemption; in combination with saved fuel costs this resulted in cheaper total costs for the taxi operator. A hybrid car is offered by BYD too, enabling emission-free operation and large range by use of a range extender.

EXPO 2010: At the world exhibition, in Shanghai, May to Oct 2010, China demonstrated its competence in this sector. Several car manufacturers are located in the northwestern area of Shanghai. Transport within the exhibition area was enabled with electric vehicles, and many projects were presented, for example a joint venture project between AVL List and Tongji University in developing a fuel cell car was demonstrated as well as future concept cars.

9.5.7.2 India

In India, as the second highest populated country, the economy is growing second fastest and is fourth ranked in terms of oil consumption. India has a young population; 60 % of the people are aged below 30 years. Sixty-eight cities have more than 1 Mio inhabitants and will generate 70 % of the country's GDP. That fact causes rapid growth in the transport sector; private transport is predicted to double in the next 20 years.

Current traffic bases on bicycles, public transport, scooters, motorcycles, and cars. E-scooters seem to be a cheap means for individual transport; around 50 Mio

Fig. 9.39 Mahindra REVA NXG

two wheelers are on Indian roads. They are already in mass market production, increasing by around 9 Mio every year.

A small electric car designed for city commuters is the Mahindra REVA, produced from an Indian company based in Bangalore, India. The car was shown at the Frankfurt Motor Show and it can be equipped with lead-acid batteries or Li-Ion phosphate batteries. The NXR shown in Fig. 9.39, an M1 class model, is a four seat EV with a range of 200 km and a top speed of 130 km/h. The car offers dual charging ports for regular low-power (80 % SOC in 6.5 h) and if needed high-power (15 min increases range by 40 km, 1.5 h for 100 %) charging.

Remarkable is the monitoring system of the Lithium-Ion battery. If the battery discharges below a certain charge level, normally the car stops to prevent damage to the battery. The REVA offers telematics remote control of the battery; the support center is able to analyze and check the battery's state of health remotely and can individually allow a deeper discharge of the battery, thus enabling the customer to reach the next charging station. They called this system REVive (remote emergency charge over SMS).

9.5.7.3 Japan

Comparing the car industries of several regions, it could be said, that Japan has a pioneering position in developing hybrid and electric vehicles. In terms of the development of hybrid cars, the Toyota Prius has been for 10 years the most well-known one and is now available in the third generation of development; the company has been able to collect experience over many years for actual development.

Fig. 9.40 CHAdeMO charger at TEPCO, Yokohama

They brought the Mitsubishi i-MIEV (Mitsubishi Innovative Electric Vehicle) to the mass market. The car offers four seats, air conditioning, power-assisted steering, traction control, and safety features. The Lithium-Ion battery is produced in a joint venture company together with GS Yuasa. A 16-kWh energy package enables a nominal range of 150 km and the 49-kW permanently excited synchronous machines accelerate the car to a top speed of 130 km/h. As verified at the test bench and in daily use, these figures could be reduced considerably by use of the heating system in winter and air conditioning during hot summers. Charging is possible within 6–8 h at a conventional socket; DC high-power charging enables one to reach 80 % state of charge within 30 min.

In comparison to other vehicles, the Nissan LEAF was designed from the beginning as an electric vehicle. The batteries are integrated under the bottom of the car, thus offering enough space for five persons and luggage. An 80 kW drive enables a top speed of 145 km/h, the nominal range is 160 km. In addition to the production in Japan, manufacturing capacity is being built up in the US (2012) and France (2013) to reach a capacity of 250,000 cars per year.

CHAdeMO: For nearly unlimited mobility high-power charging (fast charging) is necessary, although most of the time low-power charging is the regular case. The utility TEPCO (The Tokyo Electric Power Company), together with the car companies Nissan, Mitsubishi, Fuji Heavy Industries and Toyota developed the "CHAdeMO" (Charge de Move) standard for DC high-power charging (Table 9.2). The power electronics is part of the fast-charging station and therefore causes no additional weight in the car. Charging current is controlled by the battery management system of the car; all necessary data for control are sent to the charging station. In the meantime around 300 companies have joined the CHAdeMO association (Fig. 9.40).

Table 9.2 Specifications of CHAdeMO quick charger

Type	Switching type, constant current power supply
Input power	3-Phase 200 V (200–430 V)
Output power	50 kW (10–100 kW)
Maximum DC output voltage	500 V
Output current	125 A (20–200 A)
Target charging time	5 min for 40-km driving range 10 min for 60-km driving range

As they were the first with a "de facto standard" for DC charging, many countries overseas have erected these DC high-power charging stations for their pilot and demonstration regions. From the point of view of the car, the CHAdeMO standard is compatible with the following EV: Subaru Plug-in Stella, Mitsubishi Motors i-MiEV, Nissan LEAF, Protoscar LAMPO2, Peugeot iON, Citroen C-ZERO, Toyota iQ based EV, THINK City, and Micro-Vett Fiorino.

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