

IEA INTERNATIONAL ENERGY AGENCY



Hybrid and Electric Vehicles

THE ELECTRIC DRIVE ADVANCES



MOVE ELECTRIC
MARCH 2010

International Energy Agency

Implementing Agreement for co-operation on
Hybrid and Electric Vehicle Technologies and Programmes

Hybrid and electric vehicles

The electric drive advances

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Move electric

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Cover Design:

The electric drive advances. Hybrid electric vehicles (HEVs) are now considered mainstream vehicles, while plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) are beginning sales to larger markets than ever before.

Pictured are the Protoscar Lampo BEV concept from 2009 (photo courtesy of Protoscar) and the 2011 Chevrolet Volt PHEV (photo courtesy of General Motors). These cars are set against a background image of a full hybrid engine.

(Night traffic photo credit Henk L. Cover designer: Kizita Awuakye.)

International Energy Agency

Implementing Agreement for co-operation on
Hybrid and Electric Vehicle Technologies and Programmes

Annual report of the Executive Committee and Annex I
over the year 2009

Hybrid and electric vehicles The electric drive advances

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Report structure

This report consists of five main parts. Part A “About IA-HEV” describes the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV), its activities, and its plans for the coming years. The Chairman’s message in chapter 1 includes a summary of IA-HEV activities in 2009, as well as the current structure of the IA-HEV today and its strategy for the 4th phase of the programme which is currently in its first year. Chapter 2 explains the relationship between IA-HEV and the International Energy Agency (IEA), as well as describing the IA-HEV history, results, and working programme. Chapter 3 presents the latest recipients of the IA-HEV clean vehicle awards.

Part B “IA-HEV task forces” presents the results of the work that is performed by the task forces working under this Agreement. The work of each task force is organized in the form of an Annex.

A general picture of hybrid and electric vehicles (H&EVs) around the globe is painted in part C, “H&EVs worldwide.” The first chapter (12) in this section gives worldwide H&EV statistical information and developments in 2009. This year the overview chapter includes a section on national goals for H&EVs on the road as a special topic. The following chapter addresses the impact of the global economic slowdown on overall automotive sales in various IA-HEV member countries and the strategies each pursued during 2008 and 2009 in order to sustain its domestic automotive industry and increase the fuel efficiency of its fleet. More detailed information on H&EV activities in each IA-HEV member country is presented in chapters 14 through 28. Chapter 28 highlights H&EV issues in selected IA-HEV non-member countries.

Part D is dedicated to an outlook for the future of hybrid and electric vehicles through offering up a summary of the factors that should influence the uptake of these vehicles by the market as named by the members of the IA-HEV Executive Committee.

Finally, Part E gives practical information related to hybrid and electric vehicles and the Agreement, including a list of IA-HEV publications, definitions of vehicle categories, conversion factors for H&EV related units, a glossary of terms, abbreviations, and contact information of the IA-HEV participants.



Chairman's Message

THE FUTURE WILL BE ELECTRIC AND RENEWABLE

The strong interest in hybrid and electric vehicles among politicians and the public creates the danger of confusion and too-high expectations. As a result, accurate information and international collaboration are more important than ever. Communicating balanced information to governmental decision makers is one of the goals of the International Energy Agency (IEA) Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) in its 4th phase, extending from December 2009 through 2014.

1.1

Introduction

Hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs) have been enjoying a heightened profile among politicians and members of the public over the past couple of years. The public's higher level of awareness has arisen from the imminent announcement of new PHEVs and BEVs to the consumer market as well as from the increasing number of governments incorporating these vehicles as part of their transportation and energy policies.

As a result, the International Energy Agency (IEA) and its program the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) consider fostering policy discussions and the exchange of information on HEVs, PHEVs, and EVs to be more important than ever. In 2009, collaboration and communication within these organizations has borne fruit as the IEA created a roadmap for EVs and PHEVs, and IA-HEV worked with other IEA Implementing Agreements on several joint efforts. Also, last year the IA-HEV moved ahead in its own efforts and welcomed new member countries. Finally, the IA-HEV concluded its 3rd phase in November 2009 and has now entered its 4th phase, which lays out a new set of goals through 2014 towards informing decision makers about the benefits and challenges related to hybrid and electric vehicles.

1.2

The IEA and IA-HEV collaborate on hybrid and electric vehicles in 2009

1.2.1

The IEA roadmap for electric and plug-in hybrid vehicles shows the way

The International Energy Agency (IEA) has identified 20 important technologies to lower CO₂ emissions towards 2050. One of these is the technology for EVs and PHEVs. In 2009, the IEA began to publish roadmaps that describe how these technologies can contribute to the whole picture. In one of the first five roadmaps, electric and hybrid vehicles are described as part of the solution. The IEA's roadmap for PHEVs and EVs over the next few decades is described in the next chapter of this report.

The roadmap is an important milestone for the IA-HEV because it brings together different energy-saving technologies and renewable energy sources into a single integrated picture. Equally important is the fact that the roadmap provides a good example for strong collaboration between the researchers in the IEA headquarters and our Implementing Agreement. Sometimes the IEA forecasts have been criticized by experts from member countries as too conservative. Therefore it is important to have a tighter feedback process between experts in the member countries and at the IEA headquarters. The EV and PHEV roadmap is a good example of putting this into action. Our IA-HEV chair Urs Muntwyler and our secretary Martijn van Walwijk made special efforts to maintain good contact with the IEA headquarters throughout this process.

1.2.2

Stronger collaboration with the other Implementing Agreements

The coordination within the transport-related Implementing Agreements is better than ever through the Transport Contact Group (TCG) led by the End Use Working Party (EUWP) deputy chair for transport Mr. Nils-Olof Nylund. This collaboration is important because many IEA Implementing Agreements still target transport issues by applying a single technology or fuel. The TCG now enables these groups to approach transport problems collectively with an appropriate mix of all relevant technologies. Because the Transport Contact Group does not currently have an overall view on mobility, this gives the TCG further room for discussions.

We have a fruitful collaboration with the Implementing Agreement for Renewable Energy Technology Deployment (RETD). The RETD Implementing Agreement is working on a study on renewable energy in the transport sector. This cost-shared activity is mainly an international study covering the most interesting mature technologies as biofuels, fuel cells, and hybrid and electric vehicles. The IA-HEV has contributed to the study and worked on the advisory committee. The results of the study will be ready in 2010 and will cover areas of renewable energy important to the IA-HEV.

The RETD Implementing Agreement likewise shares interest in our “Clean city vehicles” Annex IX initiative, which we closed in 2009. Nevertheless, this collaboration may yet produce results in this area in 2010. Also, though our members are not generally engaged in the topic of clean vehicles in developing countries, still the IA-HEV had success in outreach in this area. One specific accomplishment was that the IA-HEV helped in enlisting the Swiss REPIC fund to support an electric bus demonstration project launched by the NGO Clean Air Island (CAI) in Mumbai, India.

In an interconnected world it is crucial that multiple stakeholders work together to meet all the challenges posed by the threat of climate change, including restructuring the automotive industry and restraining the use of fossil fuels and other resources. Thus, through the efforts of Switzerland and the United States of America we entered the IEA multiple IA Annex on fuel and technology alternatives for buses through our new Annex XVI. This joint effort is supported by three Implementing Agreements: Advanced Motor Fuels, Bioenergy, and IA-HEV.

1.3

Summary of IA-HEV activities in 2009

The year 2009 saw the IA-HEV make progress within its own programs as well as the collaborations noted above. The program’s Annexes (or task forces) convened and shared a great deal of information, and new member countries joined the IA-HEV. Finally, the program completed the 3rd phase of the IA-HEV and launched the 4th phase in late 2009.

1.3.1

IA-HEV member countries

The “customers” of an Implementing Agreement are the member countries and possible sponsors from industry. As of 2010, the 15 countries listed in Box 1.1 are active:

BOX 1.1 IA-HEV MEMBER COUNTRIES - 2010		
Austria	France	Sweden
Belgium	Ireland*	Switzerland
Canada	Italy	Turkey
Denmark	The Netherlands	United Kingdom
Finland	Spain	United States
*Final approvals under way.		

Additionally, sponsors and observers from three more countries typically join the meetings. Ten countries and organizations have expressed their interest in IA-HEV, and we expect to grow to more than 20 member countries within the fourth phase.

The main achievement of IA-HEV is that it allows member countries to coordinate their research and pilot demonstration efforts in the field of hybrid and electric vehicles. They get easier access to reliable information which can help lower the transaction costs. The IA-HEV is open to all countries which strive for co-ordination and improvement of their research and promotion activities in the field of hybrid, fuel cell, and electric vehicles. Of specific value are discussions on actual “special topics.” For example, at the last meeting of 2009, the countries presented governmental strategies to fight the economic crisis, its effects on the automotive industry, and how this related to our work.

We welcome two new member countries, Spain and the United Kingdom

Through the rising interest in electric and hybrid vehicles, we have been able to attract new member countries to our working group. New member Spain has a very interesting mix in renewable electricity and a well-known car industry. We also welcome back our former member, the United Kingdom. We expect to learn a lot for the further deployment of electric vehicles in big cities from observing the results of ongoing electrification efforts to address the traffic situation in its capital, London. Finally, the next new member country will be Ireland, which we expect will become official during 2010.

We will see further growth in 2010 and beyond

We feel that membership and collaboration in our Implementing Agreement provides access to a valuable forum for all countries interested in electric and hybrid vehicles. IA-HEV membership is also a sign of how serious a country is about putting together a well-informed strategy to tackle the field of hybrid and electric vehicles. We expect several new member countries within the next few years to result in growth to over 20 countries and organizations.

1.3.2

Strong interest in new and running Annexes

Currently IA-HEV is running eight Annexes and preparing four new Annexes. Although it takes a lot of time to start a new Annex, we can see rising interest in existing Annexes, as for example in the case of Annex XIV covering lessons learned from previous deployments of hybrid and electric vehicles in the commercial marketplace.

The Annexes with no participation fee are particularly popular: Annex I (Information exchange), Annex X (Electrochemical systems), and Annex XV (Plug-in hybrid electric vehicles). I think the high interest in these Annexes is not only because of the missing member fee but also is more likely due to the fact that the sponsor countries (the USA supports Annexes I and X, and Canada runs Annex XV) put significant effort into managing the Annexes. I very much appreciate the special effort of these two member countries and their respective staffs.

Please check out the work, results, and the future plans of the Annexes in this report and find how you can contribute to these efforts.

IA-HEV existing working groups (Annexes)

The active work of an Implementing Agreement happens in working groups - the "Annexes" in the IEA language. To start a working group, at least two or more countries have to find an agreement about a work plan. The work can be shared by cost (cost-shared) or tasks (task-shared). Within IA-HEV, the latter arrangement of task-sharing is more common. The work is co-ordinated by the Operating Agent (OA) who reports to the Executive Committee (ExCo) of the Implementing Agreement. The following Annexes were running in 2009:

INFORMATION EXCHANGE (ANNEX I)

This working group plays a key role in the programme. It establishes a regular information exchange on hybrid, electric, and fuel cell vehicle developments and promotion measures in the IA-HEV member countries, as well as in the most interesting non-member countries. The working group also works as a central hub by publishing the figures and basic information on the Agreement's website. The informal information that is the specific benefit of participation is only available for the member countries. The Operating Agent of this Annex is Kristin Abkemeier on behalf of the U.S. Department of Energy.

ELECTROCHEMICAL SYSTEMS (ANNEX X)

This working group is a continuation of the working group on batteries of the first Phase of this Agreement (1993–1999). It focuses on special technical details that are not discussed within the battery community or at special battery conferences, like experiences with specific test protocols or abuse testing. The group has held topic-oriented workshops on themes including aging tests for high-energy batteries (Hawaii, January 2010) and the world supply of lithium (December 2008). Further topics under consideration for discussion are:

- › Batteries under extreme conditions
- › Testing PHEV batteries
- › First responder issues
- › Recycling and reclamation of battery materials
- › Government incentives for production of batteries
- › Improved collaboration among battery researchers

The operating agent is James Barnes from the department Energy Storage for Vehicles of the U.S. Department of Energy (DOE).

ELECTRIC CYCLES (ANNEX XI)

In several countries, electric two-wheeled vehicles have become a huge market segment in the transport field, especially in China. In several European countries electric bicycles are used for commuter trips and have become a successful market niche. Because of different quality standards, the vehicles do not necessarily match for both markets, and there are still many open questions concerning standards, licensing, and market deployment. This group has started work addressing electric scooters, and an extension of the scope to electric three wheelers (trishaws) has been discussed. This year a specific focus on the booming Chinese e-bike market in conjunction with the 25th World Battery, Hybrid, and Fuel Cell Electric Vehicle Symposium and Exposition (EVS-25) can be expected. The operating Agent is AVERE, the European Association for Battery, Hybrid, and Fuel Cell Electric Vehicles.

HEAVY-DUTY HYBRID VEHICLES (ANNEX XII)

This working group aims at structuring the information about heavy-duty hybrid vehicle components and configurations. An important aspect of this task is to gain insight in existing and possible applications of hybrid vehicle technologies. Besides the obvious vehicle types like buses and trucks, other applications of conventional heavy-duty vehicle technology like off-road vehicles may be candidates for hybridization. In addition to identifying the application area of hybrid technologies, this Annex also studies the current situation of existing hybrid prototypes and standard vehicles. Information collection focuses on the applied technology, its costs, and its merits. This will broaden the insights in these applications and provides essential information for future hybrid vehicle deployment projects. The lessons learned will not only focus on the technical barriers to overcome, but also on the required framework (training, support, etc.) for successful implementation projects. Besides these specific subtasks, a more general task of information gathering and dissemination is co-ordinated by the Operating Agent VITO, a dedicated research institute in Belgium.

FUEL CELLS FOR VEHICLES (ANNEX XIII)

Fuel cells as electrochemical systems are not limited by the thermodynamic restrictions of combustion processes. Therefore they offer unique advantages concerning energy efficiency, the reduction of noise, and exhaust emissions. Considered by many scientists as an optimal long-term solution for clean and efficient energy conversion for mobile and stationary applications, the transport industry, energy utilities, and producers of portable consumer products are investing strongly in the development of this technology. Nevertheless, limited lifetime as well as high production costs due to noble metal catalysts have impeded the broad market introduction of fuel cells beyond specialized niches like space applications. In recent years cheaper and more stable materials for separators and electrodes have achieved major improvements for fuel cell technologies. Rising costs for after-treatment of internal combustion engine emissions due to tightening emissions standards are bringing fuel cell vehicles closer to competitiveness with today's vehicles.

This IA-HEV task force concentrates its activities on tuning the properties of fuel cells as well as using their high potential for successful application in vehicles. The main focus is on road vehicles, but other means of transport will be considered as well if their specific needs could play an interesting intermediate step for the market introduction of fuel cell road vehicles. In this respect boats, airplanes, and mining equipment could be niches for early adoption of fuel cells for transport. The Annex XIII Operating Agent is the Austrian Agency for Alternative Propulsion Systems (A3PS).

MARKET DEPLOYMENT OF ELECTRIC VEHICLES: LESSONS LEARNED (ANNEX XIV)

IA-HEV Annex XIV analyzes the reasons for success and failure at introducing electric and hybrid vehicles on the market. Previously, the now-concluded Annex VIII on deployment strategies for hybrid, electric and alternative fuel vehicles investigated 95 promotion measures run by governments and various other organizations to enable the market deployment of clean vehicle technologies. However, this earlier effort did not include gathering stories about the success or failure of each of these measures. Understanding what did and did not work in earlier programs is becoming more important as car manufacturers and users have several options when choosing a clean propulsion technology (including alternative fuels like natural gas and ethanol, fuel cell vehicles, etc.). The last 20 years have seen new electric vehicle models and EV manufacturers come and go. The individual stories behind this evolution follow identifiable patterns which can educate manufacturers, policy makers, and others to avoid the repetition of mistakes.

Annex XIV has prolonged its working programme through the middle of 2010. Some of the interim results are:

- 90% of EV charging takes place at home.
- Introducing fast charging points in Tokyo resulted in more extensive use of EVs (in terms of vehicle miles travelled), although the fast charging points were not used much.
- The lack of a standard, defined interface between vehicle and grid has been a problem for both utilities and EV manufacturers.
- Past efforts underestimated the importance of establishing a network of sales points with trained staff that also showed competence in maintenance and service for EVs.

More details have been discussed in workshops in which representatives of EV and component manufacturers, utilities and project leaders of demonstration programmes shared their experiences. The release of the final results of this Annex's investigations will be restricted to the member countries of this Annex (Austria, Sweden, Switzerland, UK, and USA). The interest in the results of this group is high and shows the need to investigate the market introduction process. This group is lead by Tom Turrentine of the Institute of Transportation Studies at the University of California, Davis.

PLUG-IN HYBRID ELECTRIC VEHICLES (PHEVS) (ANNEX XV)

This Annex is a group of specialists from Canada, USA, and Europe that works on new vehicle concepts for the plug-in hybrid vehicle (PHEV). A PHEV is a hybrid vehicle which can be charged from the grid and can travel longer distances in electric mode. The GM Chevrolet Volt is such a concept. PHEVs have the potential of further reducing oil use and CO₂ emissions over HEVs, with increased fuelling flexibility (through the electricity grid or with liquid fuels). They also offer the exciting option of distributed power generation and storage (vehicle-to-grid or V2G). This new Annex therefore has the objective to provide essential information for member countries to better understand the current situation of PHEVs and their related prospects. It will concentrate on advanced battery technologies, other PHEV-specific components, policy issues and marketability, and especially on utilities and the grid. The results of this Annex will be published in 2010. Natural Resources Canada is the Operating Agent.

FUEL AND TECHNOLOGY ALTERNATIVES FOR BUSES (ANNEX XIV)

This joint Annex run together with the Implementing Agreements for Advanced Motor Fuels (AMF) and Bioenergy will assess the overall efficiency, emissions, and costs (direct and indirect) for various drivetrains for buses. Switzerland and USA joined this Annex 2009 via IA-HEV and made it possible to establish the biggest collaboration of Implementing Agreements in IEA history.

WORKING GROUPS IN PLANNING

Currently we are preparing new working groups (Annexes). Most likely we will start work in the following topics within the next one or two years:

- Electrification of road transport
- Life cycle analysis and e-waste
- Battery electric vehicle system integration
- EV readiness forum

A list of potential additional topics is regularly under discussion, including:

- Future energies for H&EV
- Drive cycles
- Lightweight design
- Test procedures
- E-motors, controllers, and chargers

This list will be regularly expanded and rated. If you want to be part of this preparation, please ask your country delegate in the IA-HEV Executive Committee (ExCo).

1.3.3

Dissemination activities

The main target public for the work of the IA-HEV are governments and public institutions of the member countries. Confidential reports and the results of the many working groups are the most important “products” of this Implementing Agreement. Furthermore, a wide range of information and dissemination activities is available for interested experts even in non-member countries:

- ▶ **Annual report:** The annual report summarizes all the activities relating to HEVs, PHEVs, and EVs in the member countries as well as some non-member countries. It also covers the Annexes, and thus gives a good overview of the latest news in the most important markets of hybrid and electric vehicles. The report is available via the secretariat (free for member countries) as well as through your country’s IA-HEV delegate.
- ▶ **IA-HEV clean vehicle awards:** Since 2005, this has been a medium to point out the necessity of a large clean vehicle share in transportation and the commitment of the automotive industry to clean vehicle production. There is not only the pressure of air quality standards or energy efficiency issues, but there is also the appeal of a prospective market. The example of Toyota (first IA-HEV award winner in 2005) shows that a commitment to producing quality clean vehicles can capture a share of the market and increase the value of the brand. Three awards are granted annually:
 - ▶ For more than 25,000, 50,000, 100,000, and 250,000 vehicles sold.
 - ▶ For the best application of HEV and fuel cell vehicles.
 - ▶ For a uniquely committed person in the field of HEV and fuel cell vehicles.
- ▶ **Website:** The IA-HEV website at www.ieahev.org presents interesting results of our work and news flashes from the EV and HEV market.
- ▶ **Electronic newsletter:** The IA-HEV electronic newsletter informs about our work and IEA-related activities in our field. A PDF version can be downloaded from the IA-HEV website at www.ieahev.org.
- ▶ **Insight newsletter:** This monthly electronic newsletter informs about the work of our Implementing Agreement, for members only!
- ▶ The Executive Committee increases the value of the Implementing Agreement by elaborating an “Outlook” chapter in the annual report (since 2006). This Outlook shows trends in vehicle technologies and market shares in the most relevant countries. Here you learn what a board of specialists expects of future clean vehicle developments and markets.
- ▶ Presentations at conferences like the Electric Vehicle Symposium (EVS), the International Advanced Mobility Forum (IAMF), and others.

1.4

Strategy for the 4th Phase of the IA-HEV, 2009 – 2014

Since 1994, the IA-HEV has been working on the field of electric, hybrid electric, and plug-in hybrid vehicles and their infrastructure. Every five years the work is reviewed by the IEA, and for its work to continue IA-HEV must propose a new strategy and work plan to be accepted by the IEA.

The 4th Phase runs from December 2009 through to late 2014. The main strategic topics mirror the most pressing issues in today's discussion on sustainable transportation:

- Energy consumption
- Efficient technologies, with a focus on EVs and PHEVs
- Energy storage
- Market deployment
- Outlook on future sustainable transportation (individual and mass transport)

The IA-HEV has identified the following important factors influencing the future share of electric, hybrid, and plug-in hybrid vehicles:

- Regulatory and other governmental measures to overcome the barriers for large deployment of EVs, HEVs, and PHEVs
- Advances in battery technology
- Application of HEV technology in high-volume vehicle models
- The difference in purchase price between EVs, HEVs, and PHEVs and standard vehicles
- The availability of components for EV/HEV/PHEV drivetrains
- The quantities of EVs, HEVs, and PHEVs that manufacturers will be able to supply

The first point will remain a main target of Annex I “Information exchange,” while the second point is covered by the Annex X “Electrochemical systems.” The Executive Committee of this Implementing Agreement also agrees that at least one Annex has to deal with market issues. A continuation of Annex XIV may focus on various problems that occur as a result of the discrepancy between producers' intentions and consumers' actual use patterns. The application of EV/HEV/PHEV technology in high-volume vehicle models must be focused on by a technically-oriented Annex.

Additional Annexes are suggested that will investigate electronics and system integration, materials, and questions of the interface between vehicle and grid. This includes answering the question, “Where will the electricity come from?” as this affects not only the sustainability of future transportation but also the efficiency and stability of the grid.

1.5

Acknowledgments and final remarks

Words of thanks to the management team of our Implementing Agreement

In 2009 we finalized the 3rd phase of the IA-HEV and started the new 4th phase. This gave all of us, and especially the chair and the secretary Martijn van Walwijk, much extra work. We wrote the end-of-term report and produced the new strategy which we had been preparing since 2008. Finally, we had to present the results and the new strategy to the End Use Working Party (EUWP) and the Committee on Energy Research and Technology (CERT) of the IEA. The collaboration with all the different levels of the IEA organizations were efficient and effective. I thank especially Carrie Pottinger, Lew Fulton, and Pierre Paolo Cazzola from the IEA headquarters in Paris. We also had a good collaboration with the deputy chair for transport of the EUWP, Mr. Nils-Olof Nylund; the chair of the EUWP, Mr. Hermann Halozan; and the chair of CERT, Mr. Peter Cunz. In 2009 we were appointed a new desk officer for our Implementing Agreement from the IEA, Mr. François Cuenot.

In 2009 we had two Executive Committee (ExCo) meetings in Stavanger (Norway) and Golden (USA) and many workshops of the various Annexes all over the world. The two deputy chairs, Arie Brouwer and Dave Howell, supported me in this work. So I have to thank the secretary and the members of the Executive Committee for their contributions and efforts.

Most important in our work are the collaborations occurring within the Annexes and the preparation of new Annexes, and this focus will continue in the 4th phase. One change is that we have a new operating agent for Annex I (Information exchange). Chris Saricks who has done a great job over the last few years is stepping down, and we welcome Kristin Abkemeier to take on this role.

Final remarks: clear vision – steady course

When we look ahead the next five to ten years at the world of electric and hybrid vehicles, we see some challenges. The shift from traditional powertrains to more electric powertrains is a great challenge for the industry. You could say it's like climbing a steep mountain. We have to tackle the ascent with a well-trained and motivated team, professional guides (in this case, IA-HEV), and strong awareness of the likelihood for unplanned events. Then we need well-planned rests, where we can recharge our batteries for the next step. The car industry says that we need patience and must understand that they need to have a profitable business case for selling electric vehicles. But even as we accommodate

1 CHAIRMAN'S MESSAGE

some of our slower fellow travelers, I expect that we will lose some of them on our journey. Finally, we have to carefully explain to consumers how the shift away from the internal combustion engine and towards hybrid and electric vehicles will occur. For example, even if 5% of the cars sold annually from 2010 on were EVs, the growth in the EV share of the market for new vehicles will still be slow enough that even in 2020 95% of all vehicles on the road will still not be electric. The challenge of politicians and the media will be communicating this fact that to the consumer, and we members of IA-HEV will have to moderate this change process.

February 2010
Urs Muntwyler
IA-HEV chairman



The IEA and its Implementing Agreement on Hybrid and Electric Vehicles

This chapter introduces the International Energy Agency (IEA) and its Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV).

2.1 The International Energy Agency

2.1.1

Introduction

The IEA acts as energy policy advisor for the governments of its 28 member countries (see box 2.1) and beyond to promote reliable, affordable and clean energy for the world's consumers. It was founded during the oil crisis of 1973-74 with a mandate to co-ordinate measures in times of oil supply emergencies. This is still a core mission of the agency. In 2005, when devastation to oil production and refining infrastructure in the Gulf of Mexico by hurricane Katrina became known, in 24 hours the IEA made 60 million barrels of emergency oil available to the market. The IEA stood ready to take further measures as the Gulf Coast was pounded a second time (hurricane Rita). This was the fourth time in its history that the IEA has been called upon to be able to respond to international energy market crises.

Australia	France	Republic of Korea	Slovak Republic
Austria	Germany	Luxembourg	Spain
Belgium	Greece	The Netherlands	Sweden
Canada	Hungary	New Zealand	Switzerland
Czech Republic	Ireland	Norway	Turkey
Denmark	Italy	Poland	United Kingdom
Finland	Japan	Portugal	United States

With the evolution of the energy markets, the IEA mandate has broadened. It now focuses well beyond oil crisis management. Energy efficiency, climate protection, energy technology collaboration, and sharing its accumulated energy policy experience with the rest of the world have become core agency objectives. In July 2005, the G8 leaders at the Gleneagles summit asked the IEA to

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provide advice on strategies for a clean, secure, and sustainable energy future.

The shared goals of the IEA form the basis of balanced energy policy making:

- **Energy security:** Promote diversity, efficiency, and flexibility within the energy sectors of the IEA member countries. Remain prepared to respond collectively to energy emergencies. Expand international co-operation with all global players in the energy markets.
- **Environmental protection:** Enhance awareness of options for addressing the climate change challenge. Promote greenhouse gas emission abatement, through enhanced energy efficiency and the use of cleaner fossil fuels. Develop more environmentally acceptable energy options.
- **Economic growth:** Ensure the stable supply of energy to IEA member countries and promote free markets in order to foster economic growth.

2.1.2

Structure of the IEA

The IEA meets its evolving mandate through the activities of its offices and focused international collaboration. Fostering energy technology innovation is a central part of the IEA's work. Development and deployment of safer, cleaner, and more efficient technologies is imperative for energy security, environmental protection, and economic growth. IEA experience has shown that international collaboration on these activities avoids duplication of effort, cuts costs, and speeds progress.

The IEA Committee on Energy Research and Technology (CERT) co-ordinates and promotes the development, demonstration, and deployment of technologies to meet challenges in the energy sector. The CERT has established four expert bodies: the Working Party on Fossil Fuels; the Working Party on Renewable Energy Technologies; the Working Party Energy on End-Use Technologies and the Fusion Power Co-ordinating Committee. In addition, expert groups have been established to advise on electric power technologies, R&D priority setting and evaluation, and on oil and gas (figure 2.1).

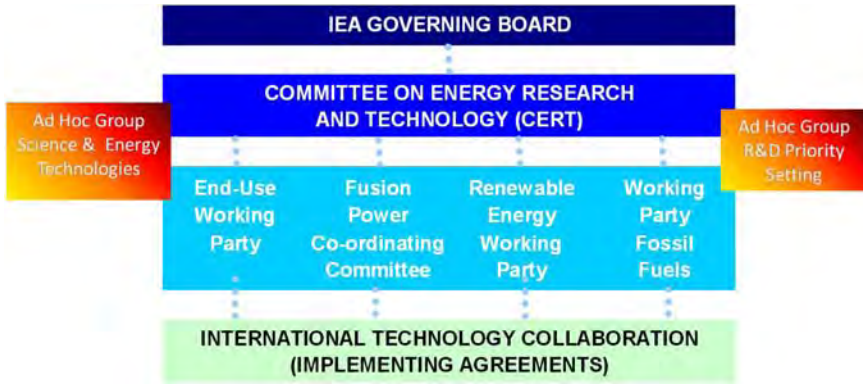


Fig. 2.1 The IEA energy technology network.

The IEA also provides a legal framework for international collaborative energy technology RD&D (research, development, and deployment) groups, known as Implementing Agreements (IAs). There are currently 42 Implementing Agreements covering fossil fuels, renewable energy, efficient energy use (in buildings, energy, and transport), fusion power, electric power technologies, and technology assessment methodologies. The Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) is one of them. It reports to the End-Use Working Party (EUWP). A full list of current Implementing Agreements is available on the IEA website at www.iea.org/te-chagr. For more information, see also section 2.1.3. below.

Under guidance from the CERT, the IEA Secretariat provides authoritative information and analysis on how energy technology can make a difference. It plays a strong role in IEA work under the 2005 Gleneagles summit mandate from G8 leaders to “advise on alternative energy scenarios and strategies aimed at a clean, clever, and competitive energy future.”

2.1.3

IEA Implementing Agreements

Since its creation in 1974, the International Energy Agency (IEA) has provided a structure for international co-operation in energy technology research, development, and deployment. Its purpose is to bring together experts in specific technologies who wish to address common challenges jointly and share the fruits of their efforts. Within this structure, there are currently 42 active programmes, known as the IEA Implementing Agreements. Over three decades of experience have shown that these Agreements contribute significantly to achiev-

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ing faster technological progress and innovation at lower cost. Such international co-operation helps to eliminate technological risks and duplication of effort, while facilitating processes like harmonization of standards. Special provisions are applied to protect intellectual property rights.

IEA Implementing Agreements are at the core of the IEA's international energy technology co-operation programme. This programme embraces numerous other activities that enable policy makers and experts from IEA-member and non-member countries to share views and experience on energy technology issues. Through published studies and workshops, these activities are designed to enhance policy approaches, improve the effectiveness of research programmes, and reduce costs.

The "IEA framework for international energy technology co-operation" sets out the minimum set of rights and obligations of participants in IEA Implementing Agreements. Participants are welcomed from OECD member and OECD non-member countries, from the private sector, and from international organizations.

Participants in Implementing Agreements fall into two categories: Contracting Parties and sponsors.

- Contracting Parties can be governments of OECD member countries and OECD non-member countries (or entities nominated by them). They can also be international organizations in which governments of OECD member and/or OECD non-member countries participate, such as the European Communities. Contracting Parties from OECD non-member countries or international organizations are not entitled to more rights or benefits than Contracting Parties from OECD member countries.
- Sponsors, notably from the private sector, are entities of either OECD member or OECD non-member countries that have not been designated by their governments. The rights or benefits of a sponsor cannot exceed those of Contracting Parties designated by governments of OECD non-member countries, and a sponsor may not become a chair or vice-chair of an Implementing Agreement.

Participation by Contracting Parties from OECD non-member countries or international organizations or by sponsors must be approved by the IEA CERT.

The Implementing Agreement mechanism is flexible and accommodates various forms of energy technology co-operation among participants. It can be applied at every stage in the energy technology cycle, from research, development, and demonstration through to validation of technical, environmental, and economic performance, and on to final market deployment. Some Implementing Agree-

ments focus solely on information exchange and dissemination. The benefits of international co-operation on energy technologies in Implementing Agreements are shown in box 2.2.

BOX 2.2 BENEFITS OF INTERNATIONAL ENERGY TECHNOLOGY CO-OPERATION THROUGH IEA IMPLEMENTING AGREEMENTS
<ul style="list-style-type: none">• Shared costs and pooled technical resources• Avoided duplication of effort and repetition of errors• Harmonized technical standards• A network of researchers• Stronger national R&D capabilities• Accelerated technology development and deployment• Better dissemination of information• Easier technical consensus• Boosted trade and exports

Financing arrangements for international co-operation through Implementing Agreements (IAs) is the responsibility of each IA. Types of financing fall into three broad categories:

- Cost sharing, in which participants contribute to a common fund to finance the work.
- Task sharing, in which participants assign specific resources and personnel to carrying out their share of the work.
- Combinations of cost and task sharing (such as in the IA-HEV).

Effective dissemination of results and findings is an essential part of the mandate of each Implementing Agreement. Wide-ranging products and results are communicated by various means to those who can use them in their daily work. For its part, the IEA Secretariat circulates the online OPEN Energy Technology Bulletin, which reports on activities of the Implementing Agreements. IA-HEV activities are regularly highlighted in the OPEN Bulletin. The IEA also bi-annually issues a publication, “Energy technologies at the cutting edge,” that presents updates on the Implementing Agreements’ major achievements. These reports can be downloaded free of charge from the internet website: www.iea.org/Textbase/publications/free_all.asp.

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In March 2008, the vice chairman for transport of the End-Use Working Party started a new initiative by organizing a Transport Contact Group (TCG) workshop for the transport-related Implementing Agreements, with the objective of strengthening their collaboration. IA-HEV actively participates in the Transport Contact Group.

2.1.4

IEA technology roadmap – electric and plug-in hybrid electric vehicles

The IEA has started to develop roadmaps for more than 20 major technologies which may counteract climate change. This was done at the request of the Hokkaido G8 summit that took place in July 2008. These technologies include electric vehicles and plug-in hybrid electric vehicles. This EV and PHEV roadmap addresses technology targets, vehicle deployment infrastructure, and the required investments. The final report has been ready since October 2009 for the attention of international energy transport policy makers. The report may be found at the IEA website: http://www.iea.org/papers/2009/EV_PHEV_Roadmap.pdf. A brief summary of the report's main points is included here.

GLOBAL CO₂ CUT BY 2050: WHERE THE REDUCTIONS COME FROM

The roadmap study is based on two scenarios: the baseline with CO₂ emissions continuing to grow along current trends, and the more ambitious BLUE Map scenario. According to this latter scenario, introduced in the IEA publication *Energy Technology Perspectives 2008*, global CO₂ emissions could be reduced by 50% from 2005 levels by 2050. The chart (figure 2.2) shows the respective shares of the reduction from four different energy users: power production, industry, buildings, and transport.

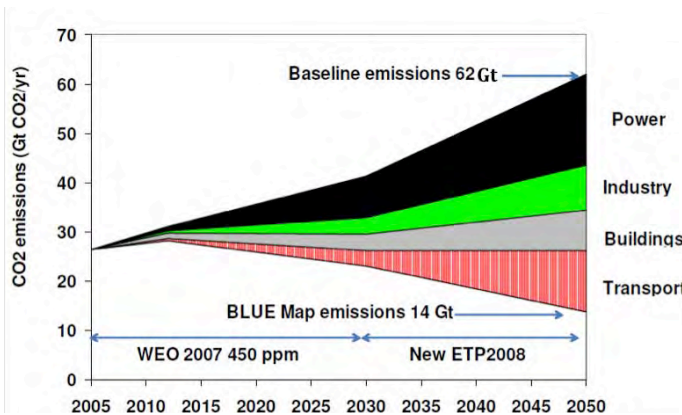


Fig. 2.2 Cutting carbon emissions from baseline growth to the BLUE Map scenario. (Source: *Energy Technology Perspectives 2008*, IEA.)

TRANSPORT ENERGY USE BY SCENARIO

In the BLUE Map scenario, transport energy consumption decreases almost to the level of 2005, including a more than 50% share of low-CO₂ fuels (see figure 2.3). The baseline scenario (IEA *World Energy Outlook* reference case) shows an 80% increase of fuel usage for transportation by 2050. This depends mainly on car sales and freight, which is sensitive to economic growth. Besides increasing fuel economy, improvement to vehicle electrification seems to be key to achieving the necessary reduction in fuel consumption, with the following factors in its favor:

- › Costs for batteries and fuel cells are dropping.
- › EVs may reach commercial production very soon.
- › PHEVs appear to be a promising transition strategy.
- › Additional reductions may come from changes in the nature of travel.

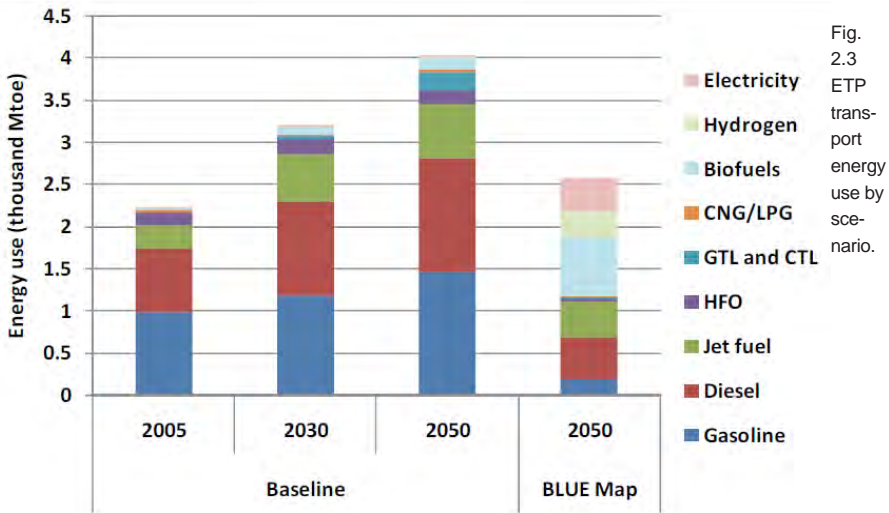


Fig. 2.3 ETP transport energy use by scenario.

(Source: *Energy Technology Perspectives 2008*, IEA.)

BLUE MAP SCENARIO: ADVANCED TECHNOLOGIES MUST PLAY A MAJOR ROLE

The market penetration of new technologies is needed to support the transition to decreased carbon emissions. The BLUE Map scenario for passenger light-duty vehicles is shown in figure 2.4. Part of this scenario is a strong growth of passenger vehicle sales per year, which almost triple by 2050 compared to 2005. This growth happens in the developing countries such as China, India, Brazil, and Indonesia and could create shortages in raw materials. The key point is that the IEA roadmap sees rapid light-duty vehicle technology evolution over time.

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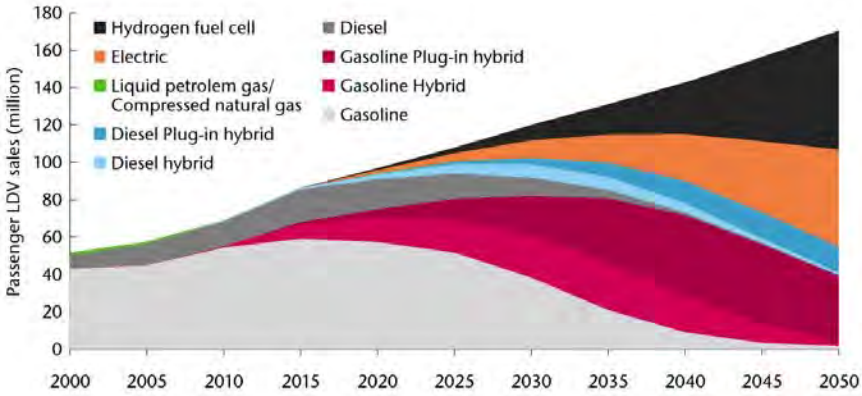


Fig. 2.4 Annual light-duty vehicle sales by technology type, BLUE Map scenario. (Source: *Technology Roadmap: Electric and plug-in hybrid electric vehicles*, IEA, 2009.)

BLUE MAP SCENARIO: EV AND PHEV SALES TRAJECTORY TO 2050

To reach the goals of the BLUE Map scenario, the sales of the two propulsion technologies of the future—EVs and PHEVs—must increase to 100 million units per year in 2050, as depicted in figure 2.5. This is a very ambitious goal, requiring that EV and PHEV sales reach a significant level by 2015 and rise rapidly thereafter. The magnitude of this challenge is easy to imagine if you compare with today’s situation, where EVs and PHEVs have yet to break out of niche markets into the mainstream.

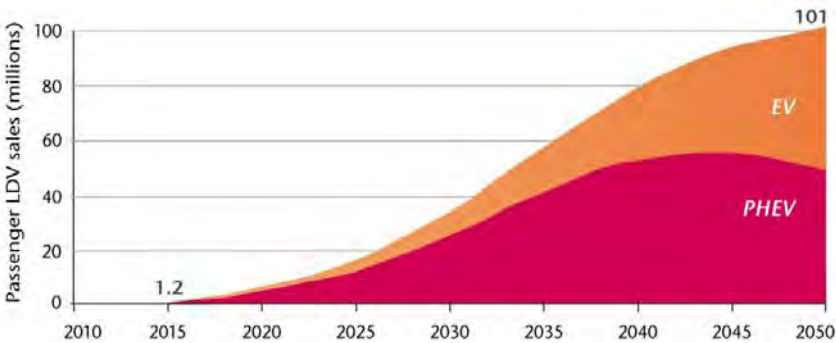


Fig. 2.5 Annual global EV and PHEV sales in BLUE Map scenario (Source: *Technology Roadmap: Electric and plug-in hybrid electric vehicles*, IEA, 2009.)

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In order to achieve these deployment targets, many EV and HEV production plants are needed. The bottlenecks are the production capacities for the key components like motors, power electronics, and especially high-energy batteries. A key element will be the battery price, which must fall to US\$300 per kWh if total EV vehicle costs are to be competitive with those of today's internal combustion engine cars and trucks.

The roadmap also offers a feasible growth scenario for reaching appreciable sales of EVs and PHEVs by 2020, which could evolve as shown in table 2.1. This scenario shows that sales per model must rise rapidly to reach the economic scale. At the same time, the number of producers and models must also rise rapidly.

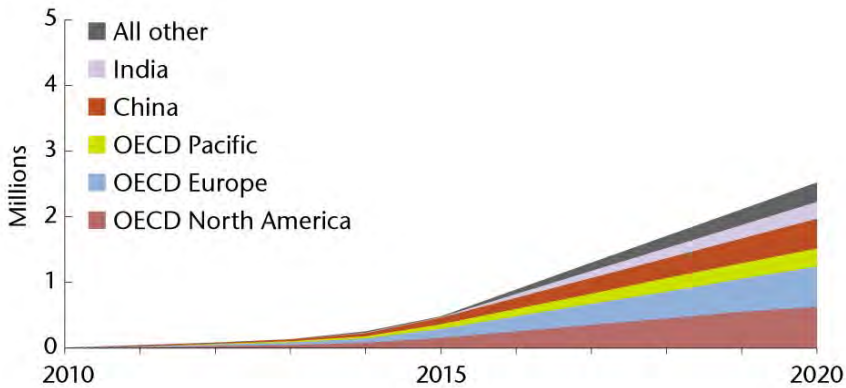
Table 2.1 A scenario for ramping up sales of EVs and PHEVs between 2010 and 2020. (Source: *Technology Roadmap: Electric and plug-in hybrid electric vehicles*, IEA, 2009.)

NUMBER OF MODELS AND ANNUAL SALES FOR EVS AND PHEVS	Year			
	2010	2012	2015	2020
EV – number of models	2	4	8	20
Annual EV sales per model	2,000	10,000	50,000	120,000
Total annual EV sales	4,000	40,000	400,000	2,400,000
PHEV – number of models	2	4	16	40
Annual PHEV sales per model	2,000	10,000	50,000	120,000
Total annual PHEV sales	4,000	40,000	800,000	4,800,000

EV AND PHEV ROADMAP VISION OF SALES PER REGION

The roadmap lists 16 countries with EV and PHEV sales targets cited from different sources. Many governments have announced ambitious figures for the EV and PHEV sales in their respective countries. As shown in figure 2.6, in the starting phase the OECD countries will be dominant. After 2020 sales in the non OECD-countries like China and India will gain importance.

EV Sales



PHEV Sales

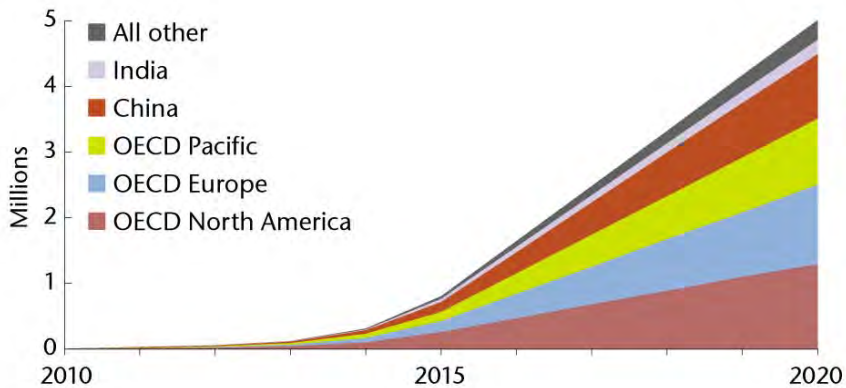


Fig. 2.6 EV and PHEV total sales by region through 2020: Sales figures for EVs (top) and PHEVs (bottom). (Source: *Technology Roadmap: Electric and plug-in hybrid electric vehicles*, IEA, 2009.)

NEAR-TERM ACTIONS FOR EV AND PHEV EXPANSION

To reach these ambitious sales figures, the automotive industry, governments, electric power companies, and other stakeholders must work together. The key actions are:

- › Setting targets for electric vehicle sales.
- › Developing coordinated strategies to support the market introduction of electric vehicles, including policy support and incentives which make the vehicles cost-competitive.

- ▶ Exploring new approaches such as battery leasing, which a fleet test in Mendrisio, Switzerland, showed to be a very helpful measure to bring the vehicle purchase price to a competitive level.
- ▶ Improving understanding of consumer needs and behavior: Governments and industry must identify and target “early adopters” by using successful business models for vehicles with different driving ranges, performances, and price levels.
- ▶ Developing performance metrics for characterizing vehicles and to track progress in areas including driving range and battery performance.
- ▶ Expanding RD&D initiatives to reduce battery costs and address resource issues, because costs must come down from the current range of US\$500–800 per kWh to US\$300–400 per kWh by 2020.
- ▶ Developing and implementing recharging infrastructure. In the first market introduction phase, the infrastructure for EVs and PHEVs is not critical. It is important that electricity comes from clean and mainly new renewable sources. Availability of public infrastructure supports the market introduction of these vehicles. In the meantime, smart grid issues must be developed and introduced to provide the background for further market growth.

2.2

The Implementing Agreement on Hybrid and Electric Vehicles

Very few IEA countries do not have problems with urban air quality, and a few others are self-sufficient in oil, but all IEA countries have problems with greenhouse gas emissions from automobiles. There is a range of technologies available to address these problems, including hybrid and electric vehicles. This means that there is a sound basis for an IEA Implementing Agreement (IA) working on these vehicles. The IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) was created to collaborate on pre-competitive research and to produce and disseminate information. IA-HEV is now in its fourth five-year term of operation that runs from December 2009 until November 2014. The fourteen active Contracting Parties (member countries) per January 2010 are Austria, Belgium, Canada, Denmark, Finland, France, Italy, the Netherlands, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the USA.

Compared to the automotive industry and some research institutes, IA-HEV is a relatively small player in the field. By focusing on a target group of central and local governments and government-supported research organizations, and by providing a forum for different countries to co-operate in joint research and

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information exchange activities, IA-HEV can play a role. More countries are invited to join the Agreement and to benefit from this international co-operation on hybrid and electric vehicles.

The work of IA-HEV is controlled by the Executive Committee (ExCo), which consists of one member designated by each Contracting Party. Contracting Parties are either governments of IEA countries or parties designated by their respective governments. The IA-HEV ExCo meets twice a year to discuss and plan the working programme. The actual work on hybrid and electric vehicles is being done by different task forces that work on specific topics. Each topic is addressed in an Annex, which is managed by an Operating Agent (OA). The work plan of a new Annex is prepared by an interim Operating Agent (either on its own initiative or on request of the ExCo) before it is submitted for approval to the IA-HEV Executive Committee. The Annexes that are currently active are described in part B (chapters 4 through 11) of this report. The activities regarding hybrid and electric vehicles in IA-HEV member countries can be found in part C.

The next two subsections (2.2.1 and 2.2.2) briefly report on IA-HEV activities and results in its second and third terms of operation (phase 2 and phase 3), respectively. In 2008 the IA-HEV began to build the strategy for the current term of operation, phase 4 (2009–2014), and its details are reported in subsection 2.2.3.

2.2.1

Description and achievements of IA-HEV phase 2, 1999–2004

The second phase of IA-HEV started in November 1999 at a time when the first hybrid vehicle, the Prius, had just been introduced to the market, and battery electric vehicles were considered suitable for some market niches such as neighborhood electric vehicles, small trucks for local deliveries, or two- or three-wheel vehicles. Although good progress had been made in battery technology, low-cost, high-performance traction batteries were not yet commercially available. Progress with fuel cell technology led to optimism about a “hydrogen economy,” and car manufacturers switched their attention to fuel cells and away from battery electric vehicles.

Against this background, the most important objective of IA-HEV for phase 2 was the production and dissemination of objective information on hybrid and electric vehicles, and their effects on energy efficiency and the environment. The principal way in which information was produced was by collecting it from participating countries and organizations and bringing it together into one

report or database. The main ways in which information was disseminated was through technical reports, the annual report, articles in technical journals, newsletters, the internet, and through verbal presentations at meetings.

The added value of the work in IA-HEV came from:

- Bringing together information from many different countries and thereby presenting a global overview on hybrid and electric vehicle technologies.
- Collecting the most recent developments and the latest news, often months before it was officially published.
- Sharing information at meetings on successes and failures of government programmes and personal opinions on prospects of certain technologies that would never appear in print.

The task forces (Annexes) in phase 2 and their main achievements are listed below:

- **Structured information exchange and collection of statistics (Annex I):** The format of the today's Annex I was established, with a website divided into both public and members-only portions. The ExCo also decided that all participating countries in the IA-HEV should automatically be participants in Annex I and established the financial arrangements to support this.
- **Hybrid vehicles (Annex VII):** This task force published reports on questions pertaining to hybrid vehicles. Issues included their current costs and estimated future cost reductions; the environmental performance, fuel efficiency, and advantages and disadvantages of the various types of hybrid vehicles; how hybrid vehicles could be most effectively introduced to the market; and questions on testing, licensing, and taxation. One of Annex VII's most interesting findings was that the decision of a customer to purchase a hybrid is based more on reduced fuel costs and projecting an environmentally responsible image rather than on the cost of the vehicle.
- **Deployment strategies for hybrid, electric and alternative fuel vehicles (Annex VIII):** This Annex considered 95 government programmes in 18 countries that were aimed at introducing clean vehicles and fuels. The scope of the work included both vehicles and fuels, and for this reason the task force was a joint effort between two IEA Implementing Agreements, IA-HEV and the Implementing Agreement on Advanced Motor Fuels (IA-AMF). The objectives of the task force were to analyze how governments can accelerate the deployment of advanced automotive technologies in the market place and to make recommendations that will enhance the ef-

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fectiveness of policies, regulations, and programmes. The final report made practical recommendations for future deployments, including how to apply lessons learned in previous deployments and among various countries to avoid repeating mistakes.

- ▶ **Clean city vehicles (Annex IX):** This Annex arose because cities in many developing countries were growing very rapidly and were experiencing the same or worse air quality and traffic problems as cities in IEA countries. At the same time, innovative solutions and technologies had been worked out in some developing countries, and there was a lot that IEA countries could learn from them. Planning was initiated for a task force (Annex IX) to study the application of clean vehicle and fuel technologies in developing countries. In 2002, a joint workshop with IEA headquarters in Paris included representatives from Bangladesh, China, Colombia, Costa Rica, India, Indonesia, Kenya, Mexico, Nepal, Peru, and Thailand. As a direct result of the workshop, representatives from Bangladesh subsequently travelled to Bogotá to learn about the bus rapid transit system there, and they constructed a similar system in Dacca. This result was directly due to the workshop.
- ▶ **Electrochemical systems (Annex X):** During phase 2, this task force concentrated on the sharing of test methods for supercapacitors and batteries. Test procedures play a key role in moving new technologies from the laboratory to the market, and developing them involves a large amount of technical work and can easily cost more than a million dollars. Consequently, the sharing of test procedures can result in large savings. The Annex also played a valuable role in co-ordinating the work of the fuel cell Implementing Agreement, the hybrid vehicle Annex, and itself in the field of electrochemical technologies.

The publications chapter in part E of this report lists the most important publications of phase 2. Many of them are available on the IA-HEV website: www.ieahev.org.

2.2.2

Description and achievements of IA-HEV phase 3, 2004–2009

The emphasis during the third phase of the Agreement, from 2004 until 2009, was on collecting objective general information on hybrid, electric, and fuel cell vehicles. Governmental objectives of improving air quality and energy efficiency—and of reducing greenhouse gas emissions and dependence on petroleum fuel—ensured that the need continued for the IA-HEV’s mission.

The IA-HEV Executive Committee approved the following formal objectives for the third phase:

1. To provide governments, local authorities, large users and industries with objective information on electric and hybrid vehicles and their effects on energy efficiency and the environment, by means of general studies, assessments, demonstrations, comparative evaluation of various options of application, market studies, technology evaluations, industrial opportunities, and so forth.
2. To disseminate the information produced to groups and organizations that have an interest.
3. To collaborate on pre-competitive research projects and related topics and to investigate the need for further research in promising areas.
4. To collaborate with other Implementing Agreements that have transportation aspects in their activities (Annexes, tasks, or joint Annexes) and to collaborate with specific groups or committees with an interest in transportation, vehicles, and fuels.

The third phase of the Agreement focused on collecting objective general information on hybrid, electric, and fuel cell vehicles, with the same value-added aspects as described in the previous section for phase 2. Topics addressed during the third phase are shown in box 2.3.

Annex I and Annex X are the only Annexes remaining from phase 2, with the rest having concluded operation during phase 3 or before. Phase 3 also saw the introduction of new Annexes on electric cycles (Annex XI), heavy-duty hybrid vehicles (Annex XII), fuel cells for vehicles (Annex XIII), lessons learned from market deployment of hybrid and electric vehicles (Annex XIV), and plug-in hybrid electric vehicles (Annex XV). Many of the Annexes active in phase 3 have continued into the current phase 4. Therefore, specific details on each of these ongoing Annexes and their respective histories are collected in chapters 4 through 10 of this report, in addition to their descriptions in the chairman's message in Chapter 1.

Chapter 1 also describes many of the IA-HEV's other achievements during 2009, the final year of phase 3. These include contributing to the IEA's roadmap for electric and hybrid vehicles. In addition to that effort, it is worth emphasizing how IA-HEV began to interact more closely with different Implementing Agreements (IAs) of the International Energy Agency, especially between the seven IAs with transportation as an item in their work programme. The IEA End-Use Working Party (EUWP) vice chairman for transport organized a first Transport Contact Group (TCG) meeting in March 2008, to further foster the

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collaboration between these seven IAs. IA-HEV actively participated in this TCG meeting and gained insights provided by experts from other IAs. This will also continue in the new multiple-IA Annex on fuel and technology initiatives for buses (Annex XVI), which will be sharing information between IA-HEV and the Implementing Agreements on Advanced Motor Fuels and Bioenergy. This Annex is described in additional detail in Chapter 11.

BOX 2.3

TOPICS ADDRESSED IN THE THIRD PHASE OF IA-HEV (2004–2009)

- Information exchange (Annex I). The work includes: country reports, census data, technical data, behavioural data, information on non-IEA countries
- Electrochemical systems for EVs & HEVs (Annex X)
- Electric bicycles, scooters, and light weight vehicles (Annex XI)
- HEVs & EVs in mass transport, and heavy-duty vehicles (Annex XII)
- Market aspects of fuel cell electric vehicles (Annex XIII)
- User acceptance of HEVs; barriers for implementation (Annex XIV)
- HEVs & EVs for power correction or decentralized power production (Annex XV)

2.2.3

Strategy for a fourth phase of IA-HEV, 2009–2014

Interest in HEVs, PHEVs, and EVs as a means to reduce energy consumption and emissions from road transport is strongly increasing worldwide. At the same time, many questions are still open regarding issues such as potential efficiency improvements, safety, durability, vehicle range, production potential, and raw material availability for batteries, impact on electricity grid management, standardization, the potential to introduce renewable energy in road transport, and market introduction strategies. There is a strong need for objective and complete information about these issues, to enable balanced policy making regarding energy security, economic development and environmental protection, and the role that hybrid and electric vehicles can play.

All of these reasons provided a sound basis for the continuation of the Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) after phase 3 concluded in November 2009. Therefore, during 2008 the IA-HEV Executive Committee (ExCo) prepared a Strategic Plan for a new phase of the Agreement, running from December 2009 until November 2014. In 2009, the Strategic Plan was presented to the IEA End-Use Working Party and to the IEA Committee on Energy Research and Technology and from both entities it received approval to enter into this new phase of operation.

The IA-HEV ExCo has formulated the following strategic objectives for its fourth phase (2009–2014):

1. To produce objective information for policy and decision makers on hybrid and electric vehicle technology, projects and programmes, and their effects on energy efficiency and the environment. This is done by means of general studies, assessments, demonstrations, comparative evaluation of various options of application, market studies, technology evaluations, highlighting industrial opportunities, and so forth.
2. To disseminate the information produced to the IEA community, national governments, industries, and—as long as the information is not confidential—to other organizations that have an interest.
3. To collaborate on pre-competitive research projects and related topics and to investigate the need for further research in promising areas.
4. To collaborate with other transportation-related IEA Implementing Agreements (in Annexes, tasks or joint Annexes), and to collaborate with specific groups or committees with an interest in transportation, vehicles, and fuels.
5. To be a platform for reliable information on hybrid and electric vehicles.

Besides defining its strategy for phase 4, the IA-HEV ExCo has also identified topics to address in this new phase. All Annexes that were active at the end of phase 3 are continuing in phase 4. The IA-HEV ExCo has also identified a number of potential topics for new Annexes, and these are shown in box 2.4. The list of topics reflects the issues that today are expected to be important in the time period until 2014. However, new topics may emerge during phase 4. The IA-HEV ExCo will continuously monitor developments (in all fields, ranging from vehicle technologies to policy making and market introduction) that are relevant for hybrid and electric vehicles, and the ExCo may start new Annexes on topics that are not yet mentioned in box 2.4. The actual number of new Annexes in phase 4 will depend on the level of interest inside and outside the Agreement. Outsiders who are interested in developing a new Annex are invited to contact the IA-HEV chairman, secretary or one of the country delegates to discuss the possibilities.

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BOX 2.4 POTENTIAL NEW TOPICS TO BE ADDRESSED IN IA-HEV PHASE 4 (2009–2014)

- Vehicle to electricity grid issues, smart grids
- Electric motors, controllers, and chargers
- Battery electric vehicles
- Drive cycles
- Test procedures
- Future energies for HEVs & EVs
- Re-use and recycling of HEVs & EVs at the end of their operational life
- Lightweight constructions
- HEVs & EVs in mass transportation
- Market aspects of fuel cell electric vehicles
- HEVs & EVs for special applications
- HEVs & EVs in developing countries
- Testing standards and new vehicle concepts
- Impacts of HEVs & EVs on industry and the economy
- Driver response to advanced instrumentation inside the vehicle
- Universal battery cell design across electric drive systems
- Safety of first responders and rescue workers
- Life cycle analysis (LCA) of batteries
- Trolley buses
- Mobile machinery such as fork lift trucks, earth moving equipment and forestry machinery
- Non-road electric “vehicles” like boats, (light) rail and airplanes
- Standardization issues
- Deployment strategies for hybrid and electric vehicles
- Special electric vehicles (like wheelchairs, one-person mobility, etc.)
- Electricity grid capacity issues
- Integration of vehicle components for battery electric vehicles
- Accelerated testing procedures for lithium battery life



IA-HEV Clean Vehicle Awards

3.1

Introduction and background

To put a new technology on the market and create a market breakthrough are very ambitious goals. Yet this quickly changing society expects market breakthroughs within a very short time. When a complex technology like cars is introduced, such breakthroughs do not often occur; the attention of public and mass media turns quickly into disappointment, and they look for the next promising technology.

Continuous progress, however, does occur. It is driven by committed persons, teams and manufacturers. This is the reason why the IEA Implementing Agreement for Co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) launched its award program for those who dedicate their work to the dream of a clean and energy-efficient vehicle technology. The awards cover three categories:

- ▶ Clean Vehicle Award—This is granted to manufacturers with outstanding sales figures. There are four categories based on the number of vehicles sold: bronze for 25,000, silver for 50,000, gold for 100,000, and platinum for more than 250,000.
- ▶ Best Practice Award – This is granted to the organizers of an outstanding promotion project.
- ▶ Personal Award – This is granted to a person who has dedicated her or his work to the development or promotion of clean vehicles in an outstanding way.

3.2

The procedure

Each specialist in the field of hybrid, electric, or fuel cell vehicles worldwide is invited to nominate one or more candidates in the three award categories. It is preferred that nominees for the Best Practice and Personal Award be candidates from the region in which the World Electric Vehicle Association (WEVA) Electric Vehicle Symposium is held. The WEVA section of the applicable region is contacted to co-operate in the nomination process. In years when there is no WEVA Electric Vehicle Symposium, no regional restriction is made. An IA-HEV committee ranks the nominations.

3.3

Winners of 2009 awards

The 2009 award ceremony took place at the EVS-24 opening ceremony in Stavanger. The Clean Vehicle Award was given to Honda Motor Co. Ltd. for achieving cumulative sales exceeding 250,000 units for its Civic hybrid vehicle. The Best Practice Award was given to the Energy Saving Trust for its extensive and influential work in developing programmes that have led to increased numbers of hybrid vehicles on roads in the United Kingdom as well as ongoing development of low-carbon technologies for road transportation. Finally, the Personal Award went to Steen V. Jensen of Denmark for his pioneering work in developing a production electric vehicle in the late 1980s that is still manufactured and sold today.

3.3.1

Clean Vehicle Award for Honda Motor Co. Ltd (Japan)

Honda has a long tradition in the development of clean vehicle technologies. As a precondition for a successful series production of hybrid vehicles, Honda developed the “Integrated Motor Assist (IMA)” system which applies a brushless 10 kW electric motor with a nickel-metal hydride battery to assist propulsion and acceleration from a 52 kW 1-L engine. The electric motor acts as a generator: up to 100 A can be generated from the batteries, and much of the energy of braking may thus be recaptured for recharging the propulsion batteries (so-called “regenerative braking”). The IMA system was first offered in the Insight introduced into the market in 1999. Although boasting very great efficiency, this model enjoyed only around 18,000 unit sales, the main reason being the fact that it was a 2-seater. In 2002, the 4-seater Civic hybrid followed, again using the IMA system. From both models based on the seventh and eighth generation of the gasoline version Civic, this hybrid has achieved more than 250,000 in unit sales worldwide between 2003 and February 2009. Adding in sales of the “mild” hybrid Accord, Honda has sold more than 300,000 hybrid vehicles worldwide.

Honda continues to market clean vehicle technologies. A new generation Insight with improved design became available in 2009, and sales figures of 200,000 units per year worldwide are expected for this model. Other hybrid models are in development, Honda is planning to put a new hybrid electric vehicle on the market in 2010 and 2011 as well.

3.3.2

Best Practice Award for the Energy Saving Trust (U.K.)

The Energy Saving Trust was founded in 1993 following the 1992 Earth Summit in Rio de Janeiro as a public-private partnership with the goal of elaborating and spreading independent information on energy efficiency, renewable energies, transport, water, and waste. Its sphere of interest encompasses home improvement, home power generation, and technical guidance for energy-efficient and low-carbon construction and transportation. For this purpose, beginning in 1996, the Trust set up a network of local advice centres across the United Kingdom. In addition, the Trust acts as consultant for the UK Government and Parliament, the European Commission, and other decision groups.

Within the transportation division, the implementation of the subsidy programme Power Shift constituted the most important step toward increasing the number of clean vehicles on the road. As a result, the Trust has been nominated as the organization to define the car technologies that are to be exempted from the London Congestion Charging Scheme. The PowerShift register listing these cars now provides essential information to Londoners wishing to avoid this congestion charge which can reach £1,300 annually, thus contributing to the increased sales of hybrid cars.

Today's Trust activities emphasize achieving the objectives of the Powering Future Vehicles Strategy of the Government published in 2002. The target of this strategy is the development of small cars that emit less than 100 g/km CO₂ in a well-to-wheel calculation – a rather ambitious goal. To push such clean vehicle technologies, the UK Department for Transport funded a promotion programme that subsidizes the development of low-carbon vehicle technologies, covering on the one hand industrial research and on the other vehicle projects in a pre-competitive development stage. The Energy Saving Trust is in charge of carrying out this programme. This is a shift from supporting existing technologies in the PowerShift programme to enabling the development of advanced technologies. Current projects cover the system integration of a lithium iron phosphate battery into a Modec or Zytec car (project “Develop & Scarlet” by Axion); the development of a parallel hybrid diesel vehicle with integrated starter-alternator and a li-ion battery (project CV-ISA by Zytec); developing electronic management devices for a hybrid vehicle (project ADDZEV by Cranfield University); and the development of a fuel cell hybrid vehicle (project “Red Lion” by Ricardo and QinetiQ).

In addition, the Energy Saving Trust runs information campaigns for energy-efficient fleets, smart driving, and cleaner taxis.

Last but not least, the Energy Saving Trust has spawned many subsequent initiatives that have arisen to work for a reduction of CO₂ emissions in transportation, e.g., the Sustainable Transport Solutions Network (founded 2004) and the Low Carbon Vehicle Partnership, each of which fosters close partnership with the industry.

3.3.3

Personal Award for Steen V. Jensen (Denmark)

Mr. Steen V. Jensen is the developer of the most successful series production electric vehicle model to appear in the late 1980's and early 1990's, the CityEl (shown in figure 3.1). The story of the CityEl began after the first oil crisis in 1973 when Steen V. Jensen started to think about mobility. Starting in 1982, when he worked as a product development manager with the company Dronningborg Maskinfabrik which produced machines for farming, he transformed his mobility ideas into an actual vehicle. Mobility in Denmark meant an average distance to work of 11 km; and 92% of these commuters sat alone in their cars. Consequently Jensen developed a small lightweight electric vehicle with one seat. The vehicle first appeared in 1985 in a magazine under its project name U36, but shortly thereafter it acquired the name "Ellert", a combination of "electric" and the Danish word for moped, "knallert." As Dronningborg Maskinfabrik had no interest in producing this vehicle, Jensen collected money from 3,000 private investors, and in 1987 he started the series production of the vehicle in Randers.



Fig. 3.1 Steen V. Jensen standing with a version of his CityEl. (Photo courtesy of Steen Jensen.)

However, the Ellert had several early setbacks, such as incorrectly fixed electrical relays and melting fuses that in one case overheated the waste gas hose of the batteries causing a hydrogen-off-gas flameout. An expensive recall campaign led the press to publish several negative reports. Although the electronic devices and cabling were then improved and the motor was replaced by a more powerful one, the now so-called “MiniEI” suffered from the bad reputation of its predecessor, and the repair costs for first-generation Ellerts were high. Jensen had to sell the production to German investors in 1991, and since 1996 the CityEI (as the “MiniEI” was renamed) has been produced in Aub, Germany.

None of this detracts from Jensen’s achievements. His concept of designing a vehicle by starting with an analysis of specific mobility needs was fundamentally new at that time. He understood that the electric drive demanded maximum efficiency of the overall system and light materials for the body. As a pioneer, he had to deal with technical imperfection, problems of series production, and market demands at the same time. Moreover, this was at a time when components for electric propulsion systems had to be developed in parallel with complete vehicles. His lifetime achievement, the CityEI, is still on the road. Together with his firm conviction that his signal contributions were the appropriate answer to the problems caused by individual mobility needs, and his will to realize his idea, Steen V. Jensen and his pioneering electric vehicle remain a shining example for emerging developers of clean vehicles.

3 CLEAN VEHICLE AWARDS

3.4 Gallery of award winners

BOX 3.1 IA-HEV AWARD WINNERS SINCE 2005	
2005	
Clean Vehicle	Platinum: Toyota, Japan. More than 250,000 Prius models sold
Best Practice	Reggio Emilia, Italy. Application of EVs
Personal	René Jeanneret, Switzerland
2006	
Clean Vehicle	Silver: Honda, Japan. More than 50,000 hybrid models sold Silver: Toyota, Japan. More than 50,000 hybrid Lexus models sold Bronze: Ford, USA. More than 30,000 hybrid models sold
Best Practice	China. Electric bicycle and scooter fleet
Personal	Hans Tholstrup, Australia
2007	
Clean Vehicle	Silver: Ford, USA. More than 50,000 hybrid Escape models sold
Best Practice	The Plug-In Partners National Campaign, USA
Personal	Paul MacCready, USA
2008	
Clean Vehicle	None
Best Practice	Electricité de France
Personal	Karl Kordesch, Austria/USA
2009	
Clean Vehicle	Platinum: Honda, Japan. More than 250,000 Civic hybrids sold
Best Practice	The Energy Saving Trust
Personal	Steen V. Jensen, Denmark



Information exchange (Annex I)

4.1

Introduction

The Implementing Agreement (IA-HEV) maintains a forum and facilitating platform for the exchange of information among member countries about their activities in the advancement of technology and markets for two- to four-wheel hybrid and electric vehicles. Fifteen years ago this function was assigned the first designation (Annex I) as an official task group of the Agreement. Any member country of the Implementing Agreement automatically becomes eligible for membership in Annex I. A country becomes a participating member of the Annex by designating an agency or non-government organization to represent it, and from that point forward it is entitled to voting representation at each meeting by a designated country expert.

The responsibility for the affairs of the Annex is coordinated by an Operating Agent, with input and material contribution from the member country experts. The specific objectives, responsibilities, and working methods of Annex I are discussed below.

4.2

Objectives

The function and objective of the Information Exchange task group (Annex I) is to collect, analyze and disseminate information from both member and non-member countries regarding research, concept development, commercialization, marketing, sales, and fleet penetration of two- to four-wheel electric (EV) and hybrid electric vehicles (HEVs) and their components. Vehicles in this context are generally classified as electric and electric-assist bicycles, electric scooters, three- and four-wheel light-duty electric vehicles (including small trucks and delivery vans), hybrid gasoline-electric automobiles and light trucks, and hybrid diesel-electric heavier trucks and buses (which could also include mobile off-road equipment). With the creation of an annex dedicated to the subject, plug-in hybrid (PHEV) forms of each of these (but especially of the light-duty subset) are also now covered under the agreement. PHEVs are able to obtain at least 20% of their operation range from purely electric power. To qualify as a hybrid, a vehicle's electric motor must be able to contribute to propulsion through the drivetrain, not merely to provide engine-off and restart capability in idle.

4.3

Working method

The work of collecting and analyzing EV, HEV, and PHEV information within respective nations is carried out by the country experts, who then make it available to other members at experts' meetings, held twice annually in conjunction with meetings of the IA-HEV Executive Committee. The IA-HEV web site (www.ieahev.org) also offers additional information, and the Annex also hosts a website that serves as a repository for documents accessible by IA-HEV members only. The Operating Agent (OA) is responsible for coordinating these activities, maintaining the IA-HEV web site, and editing and supervising the production of the Executive Committee (ExCo) annual report. The OA also acts as liaison to the OAs for other Annexes and, through the Executive Committee Secretary, to the ExCo chair and cognizant IEA Desk Officer.

A significant component of the information exchange for the Annex occurs at the experts' meetings, in which participants who have spent time compiling the relevant reports, facts, and statistics from their home countries brief the other attendees. These presentations generally cover developments since the previous meeting in the statistical and market situations for EVs and HEVs (national sales and fleet penetration, by vehicle type); the progress of international, national, or local programmes and incentives in the field; and new initiatives in vehicle and component development arising from both the private sector and public-private partnerships.

An ongoing role of this Annex is the collection of less technical data and news to inform the preparation and dissemination of as many as three newsletters per year. Timely information updates, comments, and new ideas may also be obtained for web posting from country experts and Operating Agents of other annexes, a benefit much more difficult to offer without direct access to such a well-informed international network as that of the IA-HEV.

Participation in Annex I experts' meetings is not limited to members, and these meetings have frequently included experts on local activities invited to discuss these programmes and sit in as observers. For example, guests from New Zealand, Portugal, and Spain presented informative updates on activities related to electric mobility in their respective countries at the autumn 2009 meeting.

4.4

Results

Twenty-eight experts' meetings have been conducted since the inception of the IA-HEV. As many as twelve nations have participated in Annex I and sent experts to these meetings during the first three phases of the Implementing Agreement. Through 2004, the Annex published an annual report separate from that of the Executive Committee; this report was primarily a digest of EV and HEV statistics for the preceding year and a compendium of country presentations from that year's experts' meetings. Beginning in 2005, the Annex I and ExCo annual reports were combined. This joint annual report was issued throughout Phase 3 and will continue into Phase IV in an approach that has eliminated much prior redundancy of statistical and topical coverage between the two reports. Similarly, the consolidation of the Annex I and Executive Committee (IA-HEV) Internet sites under the administration of the Annex I OA has eliminated considerable duplication between the two predecessor sites whilst facilitating the presentation of HEV information to a broader audience that spans the various annexes, the Executive Committee, and interested persons within the International Energy Agency.

4.5

Further work

The objective of assuring that the information and data posted on the IA-HEV/Annex I combined Internet site are as timely and accurate as possible continued throughout 2009 to pave the way for a new Operating Agent and site server going forward into Phase IV of the Agreement. Access to proprietary data and other "late-breaking" information will continue to be limited to participating members as an inducement to non-member countries to join. Items from both member and non-member nations may be posted. The Annex I OA will continue to employ the wide spectrum of international contacts to which it has access to facilitate incorporation into website content the views and insights of experts from non-member countries in Asia and North America. Because the world has entered an unprecedented period of growth in the fleet of HEVs worldwide, it will be important to ensure that key developments in technologies, vehicle configurations, and markets stay highlighted and up to date.

4.6

Contact details of the Operating Agent

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Electrochemical systems (Annex X)

5.1

Introduction

This Annex addresses issues related to the chemistry and performance of electrochemical energy storage devices (batteries and ultracapacitors) of interest to the hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV) and electric vehicle (EV) communities. Topics covered by the Annex include basic electrochemical couples, battery materials, cell and battery design, and evaluation of the performance of these systems under normal and abusive conditions. The Annex's focus does not extend to the interface between batteries and the vehicle or circumstances of vehicular use. These areas are covered by other Annexes.

5.2

Objectives

This Annex exists to advance the state-of-the-art of battery and capacitor science and technology for use in vehicles. It covers all aspects of batteries and capacitors that might be used in vehicles, from basic electrochemistry to the testing of full systems.

The goal of Annex X is to facilitate the exchange of relevant information among technical experts from the field of electrochemical power sources. In contrast with many governmental agencies, this Annex will not try to fund or control research and development projects.

5.3

Working method

The Operating Agent for Annex X is supported by the U.S. Department of Energy. Any country that is a member of the Implementing Agreement may be a member of this Annex at no additional cost. Participants in the Annex are expected to cover their own incidental costs such as their time and travel.

The Annex addresses selected topics in the form of focused working groups. Each working group meets one or two times to discuss a specific topic. Products from the working groups vary depending upon the nature of the discussions and might include items such as publications in the open literature or restricted meeting notes. Once a country has joined the Annex, the decision to participate

in a working group may be based upon the level of interest in the particular subject matter. Therefore each working group will have its own unique members, and a country or organization may participate in one working group without making a multiyear commitment to every meeting of the Annex.

IA-HEV Annex X held no meetings during 2009, but it did hold a working group on accelerated aging of batteries in Hawaii in January 2010 in conjunction with the meeting of the International Battery Association and the Pacific Power Sources Symposium.

5.4 Results

The workshop on the world's supply of lithium was jointly sponsored by the battery subtask of Annex XV on plug-in hybrid electric vehicles (PHEVs). The goals of the workshop were to collect data on the world's lithium supply, allow for interested parties to discuss the issue, and to encourage follow-on analysis and publications on the subject.

In order to allow for effective discussions, attendance at the workshop was limited. Invitations were sent to companies supplying lithium, battery companies, vehicle manufacturers, the recycling industry, and representatives of governments and universities. Over 25 people attended the two-day meeting. Attendees represented the following groups and companies:

- ▶ Governments and national laboratories: Canada, UK (guest), USA.
- ▶ Universities: Sweden.
- ▶ Large lithium suppliers: Chemetall/Foote (USA), FMC Lithium (USA), SQM (Argentina, guest).
- ▶ Smaller lithium suppliers: Simbol Mining (USA), Avalon Ventures (Canada).
- ▶ Battery manufacturers: A123Systems (USA), EnerDel (USA), Johnson Control/Saft (USA/France), EaglePicher (USA), Saft (USA/France), Max-Power (USA).
- ▶ Vehicle manufacturers: GM (USA/global).

Battery recycling industry: RSR Technologies (USA/global).

- ▶ Topics that were discussed included:
- ▶ Current supply of lithium.
- ▶ Potential sources of lithium, not being exploited today.
- ▶ Current uses of lithium.
- ▶ Impact of HEVs, PHEVs and EVs on the lithium market.
- ▶ Impact of recycling on lithium supply.

A brief summary of the conclusions of the working group meeting includes the following:

- ▶ The world's current production capacity for lithium exceeds current demand.
- ▶ Current production capacity can be increased significantly, but increasing capacity at a given site can require several years.
- ▶ Lithium reserves exist around the world in Europe, North America, South America and Asia.
- ▶ The technology for exploiting these reserves exists. These technologies may be marginally more expensive than the brine-based technologies that are used today.
- ▶ As lithium-ion batteries are used in more and more vehicles, recycling of lithium metal and lithium compounds could become a significant part of the supply stream. For comparison, today about 85% of the lead in lead acid batteries is recycled.
- ▶ The world's supply of lithium is sufficient to allow for the use of lithium-ion batteries in all appropriate HEVs, PHEVs and EVs likely to be produced in the next several decades.
- ▶ It was noted that some HEVs will not use lithium-ion batteries and that micro hybrids (vehicles with engine stop-start systems) will probably use lead acid batteries.
- ▶ A scenario that projects ALL light, passenger vehicles in the world being EVs using lithium-ion batteries was mentioned. This situation would require significant increases in lithium production and might require turning to new ores and other sources than those being used today.
- ▶ In discussion, it was mentioned that other materials (metals) critical to electric-drive vehicles were likely to be in short supply before lithium and its compounds.

Since the working group meeting, several groups and individuals have completed more detailed analyses of the situation based on the data and discussions from the meeting. Among these studies is one done by Dr. Linda Gaines of Argonne National Laboratory. She may be contacted at lgaines@anl.gov.

5.5 Further work

New working group meetings will be held on topics that emerge as being highly relevant to advance battery and capacitor technology. Developments in hybrid and electric vehicle technology and markets will have an impact on the selection of topics for future working groups.

Recent interest in plug-in hybrid electric vehicles reveals a need for advanced battery technology dedicated to this kind of vehicles. Therefore Annex X expects to continue to co-operate and co-ordinate with the battery subtask of Annex XV. Future meetings are expected to follow the focused workshop format. Anyone who might be interested in participating in such meetings is invited to contact the Operating Agent of Annex X.

5.6

Contact details of the Operating Agent

Individuals interested in helping organise a future working group meeting on a focus of interest to them are urged to send the Operating Agent a message indicating their interest. The Operating Agent of Annex X is:

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Electric cycles (Annex XI)

6.1

Introduction

City governments see it as an important part of their responsibilities to improve mobility in their urban areas. Their constraints are more than just reducing emissions or fuel consumption. The limited space that is available per vehicle, traffic safety, and noise reduction make urban mobility a key issue. City governments have to take a wide range of measures, including the improvement of public transport, facilitation of non-motorized transport like walking or cycling, and improvement of roads and parking facilities for vehicles. Many solutions have to be implemented, and the interface among these solutions has to be convenient and smooth so that inhabitants can still enjoy a good quality of life.

Within this context, electric two-wheelers are an important component of an overall programme to improve mobility. They require very little space and do not cause pollution or make noise. They are therefore perfectly suited to replace specific short vehicle trips.

Regarding the energy issue, electric two-wheelers are an optimal solution in two ways. First, they reduce energy consumption compared to other transport modes, and second they can also run on renewable energy sources. So why are they not seen on the roads more often? One of the main reasons is that some important actors are not sufficiently committed. The three major actors—users, industry, and governments—do not interact in a satisfying way. First, potential customers misjudge the benefits of these vehicles, and importers and dealers are not prepared to engage in active marketing efforts. Second, authorities at national and local levels may recognize the benefits but cannot take leadership in market introduction of electric two-wheelers. Last but not least are the manufacturers—the supposed leaders in market introduction—that seem to have insufficient insight into the market systems, likely because these vary strongly from country to country.

In summary, there seems to be an attractive opportunity to integrate electric two-wheelers as clean vehicles into existing transportation systems, but the different actors and their various activities should be better co-ordinated. In this context, IA-HEV has decided to set up an Annex that deals with electric cycles and to foster the market to adopt these vehicles.

6.2

Objectives

The objectives of this Annex are to identify barriers that so far have hindered the market penetration of electric cycles, and to develop and test ways to overcome these barriers. This should help to establish electric two-wheelers as a sustainable means of transport in many countries. In this co-ordinated action, a wide range of synergies can be achieved.

The following key issues are addressed in the subtasks under this Annex:

- ▶ Assessing the role that two-wheeled electric vehicles can play in improving urban mobility and their interaction with other transport modes.
- ▶ Identifying e-bikes' energy-saving potential to justify governmental support.
- ▶ Recommending market introduction strategies directed at manufacturers, importers and dealers, as well as authorities at all levels.
- ▶ Identifying technology improvements that are required.
- ▶ Identifying infrastructure requirements.
- ▶ Sharing experiences and information obtained from ongoing and completed projects (extended dissemination).

6.3

Working method

The work of this Annex is performed in five well-integrated subtasks:

SUBTASK 1: ENERGY-SAVING AND MARKET POTENTIALS

- ▶ Inventory of vehicles that are offered on the market, and also prototypes.
- ▶ Successful fields of application.
- ▶ Benefits of electric cycles for users and the public.
- ▶ Success factors regarding market introduction.
- ▶ Justification of governmental support.

SUBTASK 2: MARKET INTRODUCTION

- ▶ Analysis of the role of market actors in different countries.
- ▶ Recommendations for national and local governments as well as for manufacturers, importers, and dealers regarding collaboration in market introduction.
- ▶ Promising networks for the market introduction of electric cycles.

SUBTASK 3: TECHNOLOGY IMPROVEMENTS

- State of the art of vehicle technology.
- Requirements for electric and hybrid drive systems for electric two-wheelers in different market segments.

SUBTASK 4: INFRASTRUCTURE

- Public charging infrastructure for electric scooters.
- Safe parking places and preferred parking facilities for electric cycles.

SUBTASK 5: SHARING EXPERIENCES

- Implementation and co-ordination of sharing experiences.
- Technical visits.

In parallel to the daily work, the task force meets regularly. So far the following meetings have taken place:

- Kick-off meeting. Taiwan, March 10-11, 2006, in conjunction with the LEV conference.
- 1st progress meeting. Paris, France, June 13, 2006, in conjunction with the Challenge Bibendum.
- 2nd progress meeting. Tokyo, Japan, October 24, 2006, in conjunction with EVS-22.
- 3rd progress meeting. Hsinchu, Taiwan, March 24, 2007, again in conjunction with the LEV conference.
- 4th progress meeting. Chiasso, Switzerland, November 7, 2007, in conjunction with the EICMA exhibition.
- 5th progress meeting. Anaheim, USA, December 5, 2007, in conjunction with EVS-23.
- Workshop. Geneva, Switzerland, March 11, 2008, in conjunction with the IAMF/EET-2008 conference.

The first term of this Annex has come to an end. Plans for a second phase of the Annex are being developed in order to continue work to further integrate electric two-wheelers into existing transportation systems.

6.4

Results

During the first phase of this Annex, particular attention was paid to the market potential of electric cycles, and the task force identified the following as critical issues to address:

6 ELECTRIC CYCLES (ANNEX XI)

- › The need for clear explanations why governments should support both electric bicycles and scooters,
- › Safety aspects in manufacturing batteries, and in particular the social responsibility.
- › “Adaptation sets” to convert conventional bicycles into electric ones.
- › The issue of poor quality products which can lead to negative publicity.
- › Homologation or labelling to ensure that existing regulations are respected.
- › Charging facilities, which could remain a crucial issue for electric scooters. In areas with low requirements on e-scooter performance (range, speed, driver’s weight), an approach with removable batteries could be successful. However, for most of today’s applications batteries are too heavy to be removed and charged at any outlet, which is common practice for most of the e-bikes.

A lot of information was gathered in phase 1, so that the task force now has a broad vision on the electric cycle market and its actors, as well as on the market situation and governmental support measures. Regarding technology, an extensive investigation of product characteristics was made, as well as the most important requirements for market introduction. In order to optimize investments by manufacturers, particular attention was paid to identify the elements of highest leverage, i.e., those which would give the largest increase in customer satisfaction for the lowest investment, while also highlighting the main technological constraints.

Phase I has now come to an end and a report is in preparation to present the findings of this two year period. The report will focus on the following topics:

- › E-bike product overview.
- › Manufacturer’s profiles.
- › Battery price and safety.
- › Product affordability (price, quality, design, etc.).
- › Views on policies and context.
- › Key recommendations for governments to support electric two-wheelers.
- › Life cycle analysis (LCA).
- › Hints to remove barriers for development and foster the market to take off, including:
 - › harmonization of connectors for charging,
 - › leasing systems of the batteries,
 - › battery swap systems,
 - › safety issues,
 - › developing countries,

- creating a need for electric cycles,
- and minimal requirements for product quality and after sales.
- Standardization and the link with relevant bodies at local, European, and ISO levels.
- Role of the dealers and, in particular, helping them to make the link between R&D efforts and market requirements.
- Education of consumers, dealers, and authorities.
- Study tours.
- Identification of highest leverage between manufacturer's investments and consumer requirements.

6.5

Further work

Urban transport is increasingly seen as one of the main challenges for the coming decade. In all related conferences, electric cycles are systematically pointed out as part of the global solution. Not a single expert denies that today's challenges can only be solved by the development of vehicles adapted to cities, and therefore electric bicycles and scooters will have a critical role to play in the future.

The electric cycle is clearly crucial for better and sustainable urban mobility. Actions have to be taken to offer alternatives to traditional scooters, and this IEA IA-HEV Annex XI is clearly an opportunity. The task force of this Annex is therefore welcomes reinforcement by additional partners, to become a permanent exchange platform for as broad a base as possible.

Therefore, the main objectives for the second phase of Annex XI will be to:

- Structure the related information and to become the premier reference source for electric cycles.
- Organize dedicated workshops that focus on topics like batteries, safety, efficiency, drivetrains, and standards.
- Work on the popularization of electric cycles.
- Educate consumers, dealers, industry, and authorities.
- Organize educational meetings with dealers and other interested parties.

6.6

Contact details of the Operating Agent

For further information regarding this Annex, please contact the Operating Agent:

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Heavy-duty hybrid vehicles (Annex XII)

7.1

Introduction

Heavy-duty vehicles encompass a wide diversity of applications and have specific technical requirements and economic boundary conditions compared to the passenger car market. Therefore, some members of the IA-HEV felt the need for setting up a specific Annex on this topic. Annex XII focusing on heavy-duty hybrid vehicles was initiated and approved at the IA-HEV Executive Committee meeting in October 2006. The work of Annex XII formally started on January 1st, 2007 and is scheduled to end on November 30th, 2010.

Belgium, Canada, the Netherlands, and the United States have been participating in Annex XII since 2007. Finland joined Annex XII in 2008. Austria and Switzerland began the process of joining Annex XII at the end of 2009.

7.2

Objectives

Annex XII aims to report on the current status of the heavy-duty hybrid vehicles “playing field.” The status report will focus on the available and emerging hybrid vehicle technologies and on the current and expected state of the market.

A classification of heavy-duty hybrid vehicles according to purpose or operational application is agreed upon to pose fewer difficulties in combining the vehicles of Europe and the USA. These are listed in table 7.1.

To collect and organize the required information, three subtasks have been defined.

The first technology-oriented subtask aims at structuring the information on heavy-duty hybrid vehicle components, systems and configurations. This subtask identifies and illustrates the technical requirements, especially highlighting where they are different from light-duty requirements, the available technologies and their characteristics, and the system integration requirements. Additionally, there is a focus on powertrain configurations (topologies) and powertrain strategies for high efficiency and low emissions.

7 HEAVY-DUTY HYBRID VEHICLES (ANNEX XII)

Table 7.1 Classification of heavy-duty hybrid vehicles for Annex XII purposes.

MAIN CATEGORIES	SUB CATEGORIES
Bus	<ul style="list-style-type: none"> ▸ City ▸ Regional ▸ Long distance
Truck	<ul style="list-style-type: none"> ▸ City distribution/delivery truck ▸ Regional distribution ▸ Inter- and national transport
Mobile work machines	<ul style="list-style-type: none"> ▸ Construction, mining, and earth moving: loaders, excavators, dumpers, bulldozers, etc. ▸ Agriculture and forestry: tractors and their accessories, harvesters, forwarders, etc. ▸ Transportation of goods and material handling: forklifts, straddle carriers, RTGs, terminal tractors, etc. ▸ Municipal or janitorial machines: gardening, cleaning, etc.

The second market-oriented subtask targets collecting market information on heavy-duty hybrid vehicles. The current market of existing hybrid prototypes and standard vehicles needs to be investigated. The information gathering will focus on the applied technology, as well as the costs and its merits in meeting customer expectations. In this way it complements the first subtask. This subtask will increase the insights into the applications where heavy-duty hybrids have been an effective solution and can thus provide essential information for future hybrid vehicle deployment projects. The lessons learned will not only focus on the technical barriers to overcome but also on the required framework (training of mechanics, support, etc.) for successful project implementations. To address the potential of heavy-duty hybrid vehicles it is useful to identify niche applications that may benefit to a great extent from hybridization.

The third dissemination-oriented subtask involves collecting and disseminating general information and promoting the Annex XII objectives and results to a broad range of stakeholders. This can be done by setting up a dedicated website, preparing papers, giving presentations at relevant conferences, and keeping up contact with relevant platforms by sharing information on heavy-duty hybrid developments.

7.3

Working method

The Operating Agent organizes two expert meetings per year, predominantly in participating countries. Each meeting tries to include a technical visit to the participant's facilities and/or other interesting projects or events. This allows

the local participant to illustrate its capabilities and infrastructure in the field of heavy-duty hybrid vehicle technology. The Operating Agent chairs the meetings, prepares agendas and minutes, and reports to the Executive Committee of the Implementing Agreement. The Operating Agent provides project management and co-ordination, to ensure that activities are implemented and objectives are achieved.

A subtask leader is designated for each of the three main objectives. The Operating Agent is best placed for leading the topic of information exchange in the third subtask. The subtask leaders for the other two topics have been assigned. They co-ordinate the progress of their subtasks and complete the respective reports. All other participants in the Annex take part in the information exchange based on their specific interest and expertise and will support the subtask leaders in reaching their objectives.

The subtask reports as well as other documents are accessible for the members through the members' part of the Annex XII website (<http://ieahev.vito.be>). A document management system facilitates the exchange of working documents, final reports and other information. Papers and presentations become public matter once they are published in proceedings and presented at conferences. From that moment on, the document management system can make them publicly available. The reports have a more proprietary nature and therefore are initially only made available to countries that participate in this Annex. A timing as well an approval system to make these reports publicly available will be established.

7.4 Results

Six expert meetings have been organized and successfully executed so far, as indicated in box 7.1.

The first expert meeting in 2007 in San Diego was combined with a heavy-duty hybrid vehicle workshop with some key speakers from the USA. One of the other expert meetings in 2008 was held in South Bend, Indiana, USA, in conjunction with the Hybrid Truck User Forum 2008. HTUF is a multi-year, user-driven program to accelerate the commercialization of medium- and heavy-duty hybrid technologies in the USA. It is operated by CALSTART in partnership with the U.S. Army's National Automotive Center (NAC) (more information about this programme can be found on the internet at www.htuf.org). The expert meeting in 2009 took place at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, USA, affording a look at their ongoing research projects into developing renewable energy solutions.

7 HEAVY-DUTY HYBRID VEHICLES (ANNEX XII)

BOX 7.1 EXPERT MEETINGS OF IA-HEV ANNEX XII			
#	Date	Place	Country
1	February 9, 2007	San Diego	USA
2	May 10, 2007	Mol	Belgium
3	September 19, 2007	Istanbul	Turkey
4	February 6-7, 2008	Vancouver	Canada
5	October 16, 2008	South Bend	USA
6	October 30, 2009	Golden	USA

Combining the expert meetings with a local workshop, conference or company visit has brought a lot of added value and information to Annex XII. But besides that, all participants have excellent contacts with stakeholders in their own countries to collect further information on heavy-duty hybrid vehicles. This information will be complemented with literature and desk research. As of 2010 Annex XII is going into its final year, all collected information will be organized in reports for the different subtasks.

The market of heavy-duty hybrid vehicles is growing slowly from prototype phase to a more demonstration/commercial phase. Market activities in 2009 indicate increasing developments in all categories of heavy-duty hybrid vehicles: trucks, buses and mobile work machines. Some examples of events can be found at following links:

For Trucks:

- › Hybrid Truck Users Forum - National Conference 2009 in Atlanta (USA)
- › <http://www.calstart.org/projects/hybrid-truck-users-forum.aspx>

For Buses:

- › Busworld 2009 in Kortrijk (Belgium): <http://www.busworld.org/exhibitors>
- › Workshop on Bus Ecology And Alternative Fuels Conference
- › Exhibitors showed a lot of new developments in hybrid buses

For Mobile Work Machines:

- › Bauma 2010, München (Germany)
- › Engine Expo 2010 - Electric & Hybrid Pavilion, Stuttgart (Germany)
- › FinnMetko 2010, Jämsä (Finland)

7.5 Further work

Two expert meetings to finalize the work of Annex XII are scheduled for 2010. Expert Meeting 7 was held on June 25 in London, UK and the second one will be in September or October.

The final reports are scheduled to be presented to the IA-HEV Executive Committee at its 33rd meeting which will be held in conjunction with EVS-25 in Shenzhen, China in the first week of November. If necessary, final adjustments can be made during the second half of November 2010.

7.6

Contact details of the Operating Agent

Organizations that are interested in the work on heavy-duty hybrid vehicles are invited to contact the Operating Agent to discuss their possible role in this Annex.

The research institute VITO is the Operating Agent of this Annex. For more information about Annex XII or in case of comments or questions please contact the Operating Agent:

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Fuel cells for vehicles (Annex XIII)

8.1

Introduction

The success of hybrid vehicles in recent years has strongly boosted the interest in electric vehicles in industry as well as in the research community. Electric drivetrains offer unique advantages in torque, power output, and starting behavior.

Fuel cells offer a number of interesting options for vehicle design, including unique advantages concerning energy efficiency, possible driving distance in relation to pure battery electric vehicles (BEVs), and the reduction of noise and exhaust emissions. Many scientists see them as an optimal long-term solution for clean and efficient energy conversion for both mobile and stationary applications. The transport industry, energy utilities, and producers of portable consumer products have been investing strongly in the development of this technology.

Nevertheless, limited lifetime as well as high production costs due to noble metal catalysts have until now impeded the broad market introduction of fuel cells beyond specialized niches such as space applications. In recent years the use of cheaper and more stable materials for separators and electrodes has achieved major improvements for fuel cell technologies. An external driver that could also improve the cost-competitiveness of fuel cell vehicles is more restrictive emission standards since it would raise the costs for aftertreatment of internal combustion engine emissions.

Fuel cells are a highly relevant technology for an Implementing Agreement dedicated to hybrid and electric vehicles, as they complement batteries and other energy storage devices by offering silent, clean, and efficient energy conversion technology with the capability to substitute for the internal combustion engine. The energy recuperation and peak power capacity of batteries and supercapacitors provides an optimal combination with the efficient baseload capability of fuel cells. One such example, the Mercedes-Benz B-Class, is depicted in figure 8.1.



Fig. 8.1 Mercedes Benz B-Class (2009). Motor output (continuous/peak): 70 kW/100 kW. 80 kW PEM fuel cell system and lithium-ion battery with an output of 24 kW/30 kW (continuous/peak) and a capacity of 1.4 kWh to boost power and recover braking energy. Fuel: hydrogen at 700 bars. (Source: www.mercedes-benz.de.)

8.2 Objectives

IA-HEV Annex XIII focuses its activities on tuning fuel cell properties as well as using their high potential for successful application in vehicles. The emphasis is on road vehicles, but other means of transport are considered as well if their specific needs could be an interesting intermediate step towards market introduction of fuel cell road vehicles. Niche markets, especially material handling and the market for scooters in Asia, seem promising as early markets for fuel cell technology in the transport sector.

The specific demands for power, cost, lifetime, and range of vehicles powered by fuel cells, batteries, and all kinds of hybrid solutions are the main reasons to run this Annex on fuel cells for vehicles. Nevertheless, IA-HEV aims for strong ties and co-operation with the IEA Implementing Agreement on Advanced Fuel Cells (IA-AFC).

The different types of fuel cells currently under development display an extreme variety of technical properties. Therefore, a thorough analysis of all kinds of fuel cells regarding their potential to fulfil the propulsion requirements of different vehicles is the first task in this Annex. The strong expertise on electric

drivetrains and battery technology available in the HEV Implementing Agreement enables its participants to investigate new and innovative combinations of energy storage and energy conversion technologies. The Annex can provide a much broader view for the optimization of the electric drivetrain than the isolated development of pure fuel cell vehicles pursued in many R&D institutions.

The Annex is focused on polymer electrolyte membrane (PEM) fuel cells as the dominating technology for vehicles today, but the potential of other fuel cell types is analyzed as well. Since many scientists consider that auxiliary power units (APUs) might be the first economically viable niche for the market introduction of fuel cells in vehicles, the Annex studies the potential of fuel cells for this market segment, after the preliminary investigation of all fuel cells mentioned above.

Another important issue of specific importance for the transport sector is the quick cold start capability. On the other hand, overheating can also threaten the performance of fuel cells and batteries. Therefore thermal management also plays an important role in this Annex.

The choice of the most suitable fuel and how to store it on board is probably the most crucial question for fuel cell vehicles. Therefore different storage technologies for hydrogen are investigated, taking the specific limitations of a mobile application in vehicles into account.

A special added value of the Annex is the analysis of technological solutions that are outside the mainstream of fuel cell development. The costs for these technology foresight and assessment activities are moderate and allow with limited financial resources the consideration of technical solutions beyond mainstream R&D. This may open up interesting niches and the chance for a unique selling position for Annex participants. To minimize development risks, the Annex also addresses components that offer multiple benefits for other areas of technology, such as efficient electric motors.

8.3

Working method

The activities in this Annex predominantly consist of foresight studies and technology assessments. The cost for these activities are strongly reduced compared to independent investigations by each country, due to shared costs and broader data records. Also, this international co-operation reduces each country's risk of overlooking regional technological trends or results in the global development

process.

This shared activity allows different partners to combine their respective strengths in a coordinated R&D process. The vast task of changing the transport system requires the allocation of resources that surpasses the capabilities of any individual country or company. Therefore dividing the labor among the Annex members not only saves participants money, but it also saves time by enabling parallel tasks and by assigning responsibilities to partners with the greatest expertise related to a specific problem. IA-HEV and its Annexes have direct access to national, industrial, and scientific representatives. The results of the Annex will therefore guide their R&D activities and initiate coverage of missing research areas. Internal information available for participants will facilitate their decisions on how to organize their fuel cell research most efficiently and how to embed it in international research co-operation.

Close co-operation with the Implementing Agreement on Advanced Fuel Cells (AFC) has already been established. On the one hand, this ensures that information and knowledge from fuel cell experts is integrated into this Annex, and on the other hand it avoids duplication of topics that are relevant for both Implementing Agreements.

In parallel to this annex, some IA-HEV member states strongly support fuel cell research in their national R&D programs and participate in regional multilateral activities such as the Fuel Cells and Hydrogen Joint Technology Initiative of the European Union launched in late 2008. Ongoing international trends in regional activities are also monitored within the work of this Annex.

8.4 Results

In November 2006, the IA-HEV Executive Committee formally started Annex XIII. The Annex launched its operative work at the kick-off meeting in Graz (Austria) in September 2007. Experts from six countries presented their work at this meeting. A detailed work plan was discussed intensively. Because the resources of each partner in this Annex are limited, a focused work plan with a limited number of topics was created. These topics are:

- › The fuel cell vehicle system
- › Hybridization
- › System integration and behavior
- › Cross-cutting issues

Two Annex XIII expert meetings were held during 2008. The first expert meeting and a separate workshop on cold start behaviour of fuel cell vehicles were organized in parallel to the Geneva International Motor Show 2008 and the International Advanced Mobility Forum (IAMF) 2008 conference. The background of the participants was a well-balanced mixture of research and industry institutions.

The main conclusions of this workshop were:

- ▶ Considerable work on degradation mechanisms of components due to freezing has already been done, and the degradation models are suitable for special applications.
- ▶ Further basic research in the area of membranes, catalysts, stack design, and degradation mechanisms is still needed.
- ▶ From an industry point of view, the problem can be solved with available technology, for reasonable costs and moderate energy consumption.
- ▶ Additional information is still necessary for a proper understanding of the complex “fuel cell vehicle system” (e.g., energy demand of storage systems and behaviour at subzero temperatures, better understanding of degradation of MEAs (Membrane Electrode Assemblies) in different applications, etc.).

The structure of the final report was discussed at the second expert meeting in November 2009 at NREL (Golden, CO, USA). The objective of the final report is to provide updates and assessment reviews on the technical and commercial status of fuel cells for vehicle applications. In order to guarantee a broad coverage of relevant issues, it will be important to address vehicle components such as the fuel cell as well as the whole system.

In June 2009, a second workshop with the title “Fuel cells: Perspectives for the vehicle industry, research institutions and public authorities” was organized. It covered the current status of fuel cell vehicle technology and worldwide funding, demonstration, and deployment activities, with the participation of representatives from automotive OEMs, research and funding institutions. This workshop was held at the Paul Scherrer Institute in Villigen, Switzerland.

The main discussion points on the status of fuel cell vehicle technology were as follows:

- ▶ All present OEMs reported that significant progress in the development of fuel cell vehicles and hydrogen storage devices has been achieved in the last years. The latest generation of fuel cell vehicles shows a remarkable improvement in terms of reliability, driving range, power density, durability and cold start capability.
- ▶ The investment by industry and various governments into this technology within the last 10 years is in the range of billions of euros.
- ▶ The proof of concept phase has been reached, but costs are still very high (approximately US \$100,000 per car), among other reasons due to economies of scale (production of a few units).

The main topics of the discussion on current trends in fuel cell (vehicle) funding programs worldwide were:

- ▶ In Europe, the Fuel Cell and Hydrogen Joint Technology Initiative (FCH-JTI) of the European Commission is creating a stable and long-term (10 years) oriented funding scheme for fuel cell technology.
- ▶ Germany's National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP) also has a long-term-oriented strategy with a total project budget of €1.4 billion over a period of ten years.
- ▶ The budget proposal for the U.S. Department of Energy's hydrogen program discussed in 2009 planned a significant reduction of funding from US\$ 200 million to US\$ 70 million. The influence of this decision on other countries was discussed.

A final important task foreseen for the Annex is information dissemination. In 2009 two papers were presented at international conferences, "Comparison of different R&D approaches on fuel cell vehicles around the world" at the International Mobility Forum in March, and "Worldwide promotion and deployment of fuel cell vehicles" at the Electric Vehicle Symposium in May 2009.

8.5

Further work

Annex XIII plans to publish a final report by the end of 2010. This report is structured in two sections. The first section will feature an update on fuel cell vehicle technology including components (e.g. electric motors and power electronics), hydrogen storage, and its corresponding interface with an offboard fuelling system. This section will also include an overview of experiences of this

technology in operation and the resulting data regarding fuel economy, component durability, and fleet and customer feedback. The second section will cover current RD&D programs in this field, the market situation, and trends as well as the potential for this technology.

8.6

Contact details of the OA

The Operating Agent of this annex is Ms. Gabriela Telias. If you have any questions concerning this annex please feel free to contact her:

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Market deployment of electric vehicles: Lessons learned (Annex XIV)

9.1

Introduction

In the wake of high oil prices and growing concern over greenhouse gas emissions, electric vehicles (EVs) made a comeback in 2008. Neither the retreat of oil prices later in the year nor the world recession, which continued to affect the auto companies well into 2009, seemed to dampen this new wave of EV policy and manufacturing efforts. In fact, several car-making nations have embraced electrification as a means to invigorate their car industries, pumping research and support funds towards industry to accelerate development and commercialization of plug-in hybrids (PHEVs) and EVs. Also, several automakers have continued to feature electric drive vehicles in car shows, experimental programs, and announced market rollouts.

In policy developments, China became the world's largest car market in 2009, and itself began an electrification program to place up to 10,000 EVs in 10 Chinese cities in an effort to kick-start the EV industry in China. The new United States president made electrification of vehicles a theme of his efforts to save the US auto industry as well as a point of collaboration with China. The US government set aside more than \$2 billion towards electrification efforts, with \$7,500 credits to car buyers, loan guarantee programs to manufacturers of batteries, and vehicle demonstration programs in several cities. European countries matched and surpassed these steps, with comprehensive deployment efforts in several major cities and significant credits to EV buyers—as much as €5000 to individual consumers. Several European governments also set aggressive market goals and loan guarantees to battery makers.

Among carmakers, Nissan-Renault continued with a commitment to mass production and deployment in 2011, arranging early market deals with cities and some governments around the world. BMW deployed 550 converted MINI E cars in Germany, the United Kingdom, and the US. Tesla Motors sold over 100 of its high-priced Roadsters. General Motors, now owned by the US government, redoubled its focus on the Volt program, an EV-like PHEV to arrive in the US market in late 2010. Daimler began deployment of an electric version of its Smart Car. The biggest car companies—Toyota, Ford, and Volkswagen (VW)—are perhaps less enthusiastic about pure EVs. Nevertheless, all of these have announced efforts to deploy new designs, aware of the significant incentives

9 MARKET DEPLOYMENT OF ELECTRIC VEHICLES: LESSONS LEARNED (ANNEX XIV)

for buyers, and the increasing possibility of regulation in cities that could make EVs a viable option for a growing number of consumers.

Finally, a number of new deployments worldwide have come to reality. BMW, with a converted Mini Cooper, deployed 500 vehicles in Los Angeles, New York and Berlin. Renault-Nissan has been developing deployments worldwide, with manufacturing plans on all three continents. Cities like London, Paris, Madrid, Berlin, Rotterdam, Stockholm, New York, San Diego, San Francisco, Tokyo, Beijing, and many others have announced new plans for deployment, with infrastructure development and incentives. OEMs including Daimler, VW, Toyota, BYD, Mitsubishi, Subaru, Ford, GM, and Chrysler have all announced intentions to deploy in these locations.

In response to this burst of activity, Annex XIV shifted its focus to study new EV deployment efforts and explore whether these are including lessons from the past. For example, a past lesson was that much of the public infrastructure put in place during previous deployments was poorly used and difficult to maintain. However, many cities, OEMs, and infrastructure developers are proceeding to install public charging, and it is unclear whether these new plans apply the knowledge from the old. As a result, during 2009, the “Lessons Learned” Annex held workshops in London and Boston to discuss past and new deployments.

9.2 Objectives

As efforts to manufacture and market EVs reformulate, this Annex is designed to capture and report important lessons learned in past and new deployments of electric vehicles. The goal is to develop practical advice for utilities, local governments, OEMs, small firms, regulators, and other parties involved in future deployments.

9.3 Working method

The work of this Annex will rely upon at least three research components:

- Workshops in former deployment areas (United States, Switzerland, Sweden, Japan, United Kingdom, France, and Germany) that bring together experts who have experience pertaining to the deployment of electric and hybrid vehicles. These experts can offer a range of experiences and perspectives on the lessons they have learned in these deployments in the areas of manufacturing, distribution, sales, charging infrastructure, and market support from the utilities and governments. This approach will yield a

useful comparative project across these regions.

- › Additional interviews with important experts who cannot attend workshops.
- › Review of literature and historical material from each deployment region, including other sources of interest. For example, surveys among EV and HEV users in fleet tests will be evaluated.

During 2009 the main researchers from IA-HEV member countries in Annex XIV were:

- › Björn Budde, Systems Research, Austria.
- › Sigrid Muntwyler, Muntwyler Energietechnik AG, Switzerland.
- › Robin Haycock, Office of Low Emission Vehicles, United Kingdom.
- › Danilo Santini, Argonne National Laboratory, USA.
- › Kanehira Maruo, ETC Battery & FuelCells Sweden AB, Sweden.
- › Tom Turrentine, Annex XIV Operating Agent, University of California at Davis, USA.

Nine workshops have been held between October 2007 and October 2009 in Japan, Sweden, Switzerland, UK, and USA. Box 9.1 presents an overview of the nine workshops that have been organized to date, and box 9.2 lists the participants in these workshops.

BOX 9.1		
OVERVIEW OF IA-HEV ANNEX XIV WORKSHOPS		
No.	Location	Date
1	Santa Cruz, California, USA.	October 3-4, 2007
2	Anaheim, California, USA.	December 5, 2007
3	Geneva, Switzerland.	March 10, 2008
4	Tokyo, Japan.	May 23, 2008
5	Tokyo, Japan.	May 26, 2008
6	Göteborg, Sweden.	September 19, 2008
7	Stockholm, Sweden.	September 22, 2008
8	London, United Kingdom.	September 2009
9	Boston, Massachusetts, USA.	October 2009

9 MARKET DEPLOYMENT OF ELECTRIC VEHICLES: LESSONS LEARNED (ANNEX XIV)

BOX 9.2	
PARTICIPANTS IN IA-HEV ANNEX XIV WORKSHOPS	
	Workshop no.
Takafumi Anegawa, Tokyo Electric Power Company.	5
Mr. Asakura, Toyota.	4
Ms. Baba, Keio University.	4
Tom Balon, MJ Bradley & Associates.	9
James Barnes, US Department of Energy.	1 2 3
John Batterbee, ETI.	8
Jon Bentley, IBM.	8
Joseph Berreta, PSA Peugeot-Citroën.	3
Annalisa Bevins, CARB, presided over ZEV process in the 1990s.	1
Cyriacus Bleijs, Electricité de France.	3
Per Brannstrom, Grontmij AB.	7
Björn Budde, Systems Research.	4 5 6 7 8 9
Andrew Burke, University of California, Davis.	4
Dave Buttery, Office for Low Emission Vehicles, UK.	8
Tom Cackette, CARB, presided over ZEV process in the 1990s.	1
Stefan Camenzind, ESORO.	3
Craig Childers, veteran of the California ZEV regulatory process.	2
John Dabels, former head of marketing for the GM EV1 program.	1
Tien Duong, US Department of Energy.	2 3
Bernhard Egger, A3PS.	3
Robert Eriksson, Volvo Car Corporation.	6
Sture Eriksson, Royal Institute of Technology, Stockholm.	6
Ricardo Espinosa, Azure Dynamics.	9
Robert Evans, Cenex.	8
Mark Evers, TFL.	8
Hans Folkesson, the Swedish Hybrid Vehicle Center.	6
Yuichi Fujii, former president of Panasonic EV Energy.	5
Masato Fukino, Nissan.	4
Harold Garabedian, Vermont (formerly VT DEC).	9
Bernt Gustafsson, Swedish Energy Agency.	7
Robin Haycock, Office of Low Emission Vehicles, UK.	8 9
Rusty Heffner, Booz Allen Hamilton.	9
Roger Hey, E-ON.	8
Torben Holm, DONG Energy, Denmark.	8
Joergen Horstmann, consultant, Denmark.	8
Tomohiko Ikeya, CRIEPI.	4
Professor Ishitani, Keio University.	4
Bengt Jacobson, Volvo Car Corporation.	6

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BOX 9.2 (CONTINUED)									
PARTICIPANTS IN IA-HEV ANNEX XIV WORKSHOPS									
	Workshop no.								
Maytom Jon, AMI.									8
Marie-Loise Karlsson, Embassy of Sweden.		4	5						
Magnus Karlstrom, Hydrogen Sweden.						6			
Peter Kasche, Swedish Energy Agency.								7	
Kerry-Jane King, NYPA.									9
Edward Kjaer, EV deployment veteran, Southern California Edison.	2								
Sigrid Kleindienst, Muntwyler Energietechnik AG, Annex XIV.	1	2	3	4	5	6	7	8	9
Urban Kristiansson, Volvo Car Corporation.						6			
Ken Kurani, market research projects for the State of California.	1								
Greger Ledung, Swedish Energy Agency.								7	
Anders Lewald, Swedish Energy Agency.								6	
Stefan Liljemark, Vattenfall Power Consulting AB.								7	
Kanehira Maruo, ETC Battery & FuelCells Sweden AB, Annex XIV.	1	2	3	4	5	6	7	8	9
Akiteru Maruta, TECHNOVA.					5				
Arno Mathoy, Brusa Electronics.			3						
John Miles, Arup.									8
Paul Miller, NESCAUM.									9
Takeshi Miyamoto, Nissan.				4					
Urs Muntwyler, IA-HEV chairman.	1	2	3						
Ranbir Nota, Office for Low Emission Vehicles, UK.									8
Mr. Ono, President & CEO Tokyo R&D.					4	5			
Marco Piffaretti, Managing Director, Protoscar.			3						
Hans Pohl, Vinnova.						6	7		
Ichiro Sakai, Honda.									9
Danilo Santini, Argonne National Laboratory.	1	2	3	4	5	6	7		9
Chelsea Sexton, a front lines EV1 sales person for GM.	1	2							
Joachim Skoogberg, Fortum Markets AB.								7	
Rosie Snashall, Department for Transport, UK.									8
Matt Solomon, NESCAUM.									9
Eva Sunnerstedts, Environment and Health Admin., Stockholm.								7	
Fujio Takimoto, Consultant & Representative Fuji Tech. Info Service.						5			
Dean Taylor, EV deployment veteran, Southern California Edison.	2								
Masahiko Teramoto, Nissan.					4				
Jonan Tollin, Vattenfall AB.								7	
Tom Turrentine, Operating Agent IA-HEV Annex XIV.	1	2	3	4	5	6	7	8	9
Jun Watanabe, Nissan Motor Manufacturing.									8
James Worden, former owner of Solectria.									9
Dr. Yaegashi, Toyota.					4				
Sigvard Zetterstrom, Royal Institute of Technology, Stockholm.								6	

9.4

Results: Lessons learned

The workshops have resulted in the compilation of practical lessons for future deployments in the areas of how regulators can work best with OEMs, how local governments and utilities can best develop infrastructure and incentives for future EV deployments, and how state and OEM marketing can best introduce EVs to the public. In particular, these small workshops have resulted in candid and in-depth discussions.

The study contains many lessons and detailed discussions of past deployment efforts in several countries, which we are synthesizing into a report. We offer here examples of the types of lessons collected in the workshops held during 2009:

- Lessons about cold-weather deployment of EVs.
- Lessons on how to plan infrastructure that meets user needs over large regions.
- Lessons about regulating and encouraging EV deployment in large urban regions.
- Lessons on integrating charging systems with renewable energy systems across grid regions.

9.5

Further work

During 2010, the final year of Annex XIV, we will continue to collect lessons learned, including at least three more workshops in the spring of 2010, in Paris, Berlin, and Madrid. Specific interviews with experts who have been unable to attend the workshops are also planned. The workshops and interviews here will be synthesized into a final report in 2010.

9.6

Contact details of the Operating Agent

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The plug-in hybrid electric vehicle concept (an example is shown in figure 10.1) is increasingly seen as the best powertrain concept to significantly reduce air pollutants, GHG emissions, and fossil fuel consumption. This being said, there remains a need to further investigate certain aspects of technologies that are required for a successful introduction of these vehicles in the marketplace.

The principal reason why the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) has initiated this Annex is to encourage the development and commercialization of PHEVs. More specifically, the reasons can be enumerated as follows:

- ▶ A renaissance of electric transportation applications
- ▶ Recent interest in PHEV technologies
- ▶ The increasing popularity of hybrid electric vehicles
- ▶ An increase in the volatility of world petroleum prices
- ▶ Shortfalls in refining capacity

10.2 Objectives

The main goals and objectives of the first three-year phase of this Annex group are to focus on issues identified by the final report of IA-HEV Annex VII on hybrid electric vehicles, and those related items identified on renewable energies.

The Annex VII final report addressed issues such as modelling, simulation, life cycle analysis, fuel consumption and energy savings estimation, potential reduction of greenhouse gas emissions and fossil fuel dependency, battery cost, and lastly infrastructure.

Items related to renewable energies for electricity production will also be important, such as the investigation of merits and costs from using PHEVs as energy storage, source devices for renewable and other low-carbon electric energy sources, and determining the benefits of using PHEVs for grid power management.

Along with the identified issues and background information, this Annex group will endeavour to identify new areas to be included in future iterations of this group. It will classify these subjects in one of its 5 identified subtasks, which are:

1. Advanced battery technologies
2. PHEV components
3. Policy issues and marketability
4. Utilities and the grid
5. Group administration and communication

10.3

Working method

The Canadian Federal Government through the Department of Natural Resources (NRCan) acts as Operating Agent (OA) of this Annex which involves organizing biannual expert meetings in participating countries, and making the practical arrangements in co-operation with the host organization. Each meeting may include a technical visit to the participant's facilities and/or other interesting projects or events. This allows the local participant to illustrate its capabilities and infrastructure in the field of plug-in hybrid electric vehicles and related technologies.

The OA chairs the meetings, prepares agendas and minutes, and reports to the Executive Committee of the Implementing Agreement. He provides project management and co-ordination to ensure that activities are implemented and objectives are achieved.

Subtask leaders have been designated for each of the areas. Their initial tasks are to prepare a working plan for each topic and report to the OA on their findings. This will allow distribution of efforts to all participants. The subtask leaders co-ordinate the progress for his/her subtask and completes the report.

All participants in the Annex take part in information exchange. Participation and contribution concerning the other objectives and subject areas, is on a voluntary basis. The amount of quality work will rely on the expertise of participating organizations/members, their time, and available resources. For the entire task force the participating organizations are expected to set aside appropriate time and resources.

10.4

Results

With the completion of the second year of operation, Annex XV is still a relatively new group. Nonetheless, having established a group of members with backgrounds and knowledge in modelling, economics, automotive and battery research and development (R&D), as well as experts from the electricity generation and distribution sector, is an accomplishment in itself. The numerous points of view arising from this diverse group of experts working together ensures a better understanding of the issues related to PHEV technology.

Due to the expertise of this group, Annex XV is progressing smoothly to meet its objective and to identify and address the R&D needs, including issues related to the manufacturing, introduction and use of PHEVs as they relate to the identified subtasks of this group. To date, three major activities have been concluded, the findings of which are very important as we progress forward with our work: a meeting on the lithium supply, a session on the cold-temperature performance of PHEVs, and a workshop evaluating grid-connected vehicles in various systems around the world.

WORLD'S SUPPLY OF LITHIUM

In December 2008, a meeting on the "World's Supply of Lithium," co-sponsored by this Implementing Agreement's Annex X and Annex XV was conducted in Charlotte, NC, USA. A more detailed report of the conclusions of this workshop will soon be available from Annex X experts; however, general conclusions indicate that lithium (Li) availability will not be an issue.

Lithium industry participants were confident that their production can match demand for the foreseeable future, and all estimates indicate the total resource available to be adequate to supply even extremely optimistic EV growth scenarios out to at least 2050. As lithium demand rises, exploration is expected to reveal additional resources. Furthermore, recycling could serve to moderate demand for virgin materials.

There could, however, be legitimate concern about reliance on other materials. Examples include cobalt and rare earths (neodymium and dysprosium for magnets and motors). Rare earths may require an order of magnitude increase in mine production in the next 10 to 12 years.

COLD TEMPERATURE PERFORMANCE OF ELECTRIC DRIVE VEHICLES

In September 2009, during the PHEV Conference in Montreal, Canada, a special session on cold temperature performance of electric drive vehicles was hosted by Annex XV's Battery Subtask Leader.

With important contributions from North American researchers and scientists, it was said that extreme conditions, such as cold winters and hot-humid summers found in the interior of several major industrialized nations of the Northern Hemisphere, pose unusual challenges on the performance of batteries. Compared to islands and coastal locations, interior locations generally experience more dramatic extremes in temperature, both seasonally and diurnally. This session included five presentations that addressed the nature of climatic challenges.

Two presentations illustrated that for personal PHEVs using a combination of nickel metal hydride and lithium-ion packs, average fuel and electricity consumption rose as temperature dropped. One of these presentations demonstrated that when compared to a conventional internal combustion engine (ICE) vehicle and a HEV, the fuel consumption penalties with such a PHEV were found to be the greatest. Efficiency of the battery dropped as temperature decreased, and time required to charge increased. A presentation for HEV urban buses using a nickel metal hydride pack showed no temperature penalties on average. The bus was driven many hours per day, making the cold start portion of the day small relative to the PHEV tests. This suggests that pre-heating when plugged in could be very effective in reducing the effects of cold starts for personal PHEVs. One of the two PHEV presentations demonstrated that very high temperature areas in the USA also cause losses of PHEV operating efficiency, and incomplete battery charging. However, for the range of ambient temperatures evaluated, the operating efficiency effects of extreme cold were considerably more dramatic than for extreme heat. However, an issue not addressed in the presentations is the effect of extreme temperatures on calendar life of battery packs.

One presentation that examined experiences with pure electric vehicles in eastern Canada illustrated significant deterioration of range in cold and snowy conditions. It was also observed that an otherwise watertight battery pack had nevertheless been contaminated with salt intrusion. The fifth presentation, on designing for fast Li-ion battery pack warm-up for jet fighters, also noted that “salt fog” was a design issue for such batteries. These two separate observations on salt intrusion suggest the possibility that even though temperature extremes and road salt may not be issues in seaside areas, battery packs used there may nevertheless need to be designed to deal with salt related problems.

GRID-CONNECTED VEHICLES AND RENEWABLE ENERGY

Finally, in November 2009, an international workshop entitled “Grid-Connected Vehicles and Renewable Energy Workshop – Exploring Synergies” was conducted in Frederica, Denmark.

The focus of this workshop was to better understand how different electricity systems from different regions and jurisdictions around the world will provide/acquire power to/from grid-connected vehicles and to learn from different approaches to better take advantage of the opportunities these vehicles present. The final report from this workshop is still being developed, though many important lessons and facts were brought forward by the participants.

It was found that the integration of renewable energies in existing grids varies greatly from region to region. Those countries that have an above-average renewable energy capacity were considered more ready than others to supply “green” electricity to these vehicles; however, the implementation of “smart grid” systems was seen as essential to effectively manage these loads, particularly if these vehicles are to make up a significant portion of their total vehicle fleet.

Other discussions focused on how grid-connected vehicles can promote the use of renewables, and vice-versa. Several strategies were discussed to help both vehicles and renewables, including regulatory requirements, financial incentives, and infrastructure build-up schemes.

10.5 Further work

Having such a wide scope to work from, most subtask leaders of Annex XV will be conducting focused workshops in different locations around the world. This will allow them to fully explore a given subject area and pull information from a pool of experts directly linked to the chosen topic. Other subtask leaders will focus their efforts, expertise and resources on completing ongoing country specific analysis and then widen their scope to include other participants and member countries. Both approaches will provide a truly international perspective and should yield some worthwhile findings.

After the success of the lithium supply workshop held December 2008, Subtask 1 on advanced battery technologies is continuing to work with Annex X and conducted their second Workshop in early 2010 on “Accelerated Life Testing of Batteries.” Plans for additional workshops are already underway. Additional workshops are also being planned for Subtask 2 on PHEV components and Subtask 4 on Utilities and the grid.

Of particular interest to Annex XV is the work coming from Subtask 3 on policy issues and marketability. Next year, members will begin incorporating international input and expand on a study from the USA addressing the marketability of several fundamentally different electric drive passenger vehicle designs, including:

- Short-to-medium range PHEVs derived from existing HEVs;
- Clean sheet designs of extended-range EVs (E-REVs) designed for all-electric operation when charge-depleting over distances as high as 64 km; and
- City electric vehicles capable of 160 km of range in mild temperatures with gentle driving.

This study has also been carefully evaluating battery pack cost at various production volumes, and for the various requirements of the vehicles above. Since subsidy policies for PHEVs and EVs have already been implemented internationally, this study can only retrospectively examine the likely effectiveness of the subsidies.

10.6

Contact details of the Operating Agent

A new Operating Agent has not been appointed yet. In the interim, please contact:

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Fuel and technology alternatives for buses (Annex XVI, joint Annex with Advanced Motor Fuels (AMF) and Bioenergy)

11.1

Introduction

Bus­es are the backbone of many public transport systems around the world.

Until now the baseline bus in most parts of the world has been a diesel-powered 12-meter or 40-foot-long bus. Now the spectrum of technology options for buses is increasing, both regarding vehicle technology (advanced diesel technology, hybridization, lightweight designs, etc.) and fuels (sulphur-free diesel, biofuels, synthetic fuels, gaseous fuels, etc.). Some manufacturers are already offering hybrid buses, and some are just in the phase of launching hybrids. The procurement or delivery of bus services is often handled by municipalities or the state in a centralized manner. As the service life of buses is as long as 20 years, solid data on the performance of new technology is needed.

11.2

Objectives

The objective of the project is to bring together the expertise of IEA's transport-related implementing agreements to produce information on the overall energy efficiency, emissions, and costs of various technology options for buses. Here technology options cover variations in engine technology, powertrain technology (including hybridization), and fuels.

The various Implementing Agreements have expertise and knowledge in the following areas:

- › Advanced Fuel Cells (AFC): automotive fuel cells
- › Advanced Motor Fuels (AMF): alternative fuels in general and fuel end-use
- › Advanced Materials for Transport (AMT): lightweight materials
- › Bioenergy (specifically Task 39): production of biofuels
- › Combustion: new combustion systems
- › Hybrid and Electric Vehicles (HEV): hybrid and electric powertrains
- › Hydrogen: the use of hydrogen as an energy carrier

The outcome of the task will be the production of unbiased and solid IEA-sanctioned data for policy- and decision-makers responsible for public transport using buses.

11 FUEL AND TECHNOLOGY ALTERNATIVES FOR BUSES (ANNEX XVI)

Three of the Implementing Agreements –Advanced Motor Fuels, Bioenergy and Hybrid and Electric Vehicles – contribute with actual funding to the project. All transport-related Implementing Agreements are expected to contribute with condensed technology outlooks for their respective technologies.

11.3

Working method

The project encompasses a combination of desk studies and actual measurements on new types of buses. The financing model is a combination of task and cost sharing. The overall budget of the project is €1.2 million.

The project is divided into two main parts, WTT (well-to-tank) fuel pathway analysis and TTW (tank-to-wheel) vehicle performance. For the well-to-tank studies, experts at institutes like Argonne National Laboratory (ANL), Natural Resources Canada (NRCan), and VTT Technical Research Centre of Finland are co-operating to evaluate and filter data for the chosen fuel alternatives. Well-to-tank energy efficiency and GHG emissions are expected to show a range of values depending on feedstock and process technology for the various fuel alternatives.

Environment Canada (EC) and VTT are carrying out chassis dynamometer emission testing on buses to establish tank-to-wheel performance (see figure 11.1). EC will cover North American vehicle technology and VTT will test European vehicle technology. In addition, Swedish powertrain developer and consultant AVL is conducting on-board emission measurements on buses in conjunction with VTT's chassis dynamometer emissions tests. This will enable a comparison of chassis dynamometer and on-board measurements, with the expectation that the comparison will show the influence of ambient conditions and real traffic situations on tank-to-wheel performance. Alternatively, on-board measurements may also be used on vehicles which are not available for chassis dynamometer measurements. The first set of on-board emission measurements took place in November 2009.



Fig. 11.1 A prototype hybrid bus being tested in VTT's chassis dynamometer facility. (Photo supplied by VTT.)

11.4 Results

Actual city bus tests (tank-to-wheel) are currently running in vehicle laboratories at both EC and VTT.

In 2009, EC performed preliminary tests with several fuels on a model year 2008 40-foot bus powered with an 8.9-liter Cummins ISM (with EGR, or exhaust gas recirculation) engine and hybrid transmission. Next in line, a 2008 6.7-liter Cummins ISB (with EGR) engine with hybrid transmission is being tested.

VTT started its bus measurements with a comprehensive fuel matrix in vehicles with conventional drivelines. Two older buses representing Euro II and Euro III emission certification have been measured for reference. Three new buses with EEV certification (enhanced environmentally friendly vehicle) have also been measured: one diesel vehicle representing SCR technology (selective catalytic reduction), one diesel vehicle representing EGR technology (exhaust gas recirculation), and one natural gas bus with a stoichiometric engine. The diesel buses were tested with several types of fuels.

11 FUEL AND TECHNOLOGY ALTERNATIVES FOR BUSES (ANNEX XVI)

The well-to-tank analysis has also commenced at Argonne National Laboratory, Natural Resources Canada, and VTT. A review of 25 LCA (Life Cycle Assessment) studies for biofuels has been done. The results of the various LCA studies vary remarkably and are currently being analyzed and documented.

Different calculation models (US GREET, Canadian GHGenious, EU Directive (2009/28/EC) are under evaluation and a number of fuels have been selected as references for comparison. Biofuels analyzed so far are: FAME (fatty acid methyl ester) from rapeseed, FAME from soybeans, FAME from palm oil, HVO (hydrotreated vegetable oil) from palm oil, HVO from rapeseed, HVO from soybeans, HVO from jatropha, HVO from animal fats, BTL (biomass to liquid) from wood residues, BTL from energy crops, ethanol from grain, ethanol from sugarcane, ethanol from cellulosic feedstock, and ethanol from waste.

11.5

Further work

In 2010, EC plans to test a hybrid urban bus meeting U.S. 2010 emissions standards with a combination of fuels, including second-generation biodiesel fuels, and various drive cycles. Other buses, representing conventional and advanced bus technologies, will be tested as well.

VTT is discussing testing of European hybrid buses with vehicle manufacturers. Two different parallel hybrids are already scheduled for measurements, and further discussions on serial and hydraulic hybrids are under way.

On request from the European Commission, DME (dimethyl ether) has been added to the fuel matrix. This means that VTT will conduct both WTT evaluations and actual vehicle TTW tests in 2010 using a prototype DME truck to simulate bus operation.

11.6

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The contact person and Operating Agent within IA-HEV has not been appointed yet.

Overview of hybrid and electric vehicles in 2009

This chapter presents data and developments for hybrid and electric vehicle (EV) fleets around the world in the first section. This year, the other part of the chapter focuses on national goals for putting vehicles with electric drives onto the roads of IA-HEV member countries. Many of these countries have stated target numbers of hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs) that they aim to put onto their roads by 2020 or earlier. This report gathers the current best estimates, official or unofficial, of these goals.

12.1

Statistical information and fleets

The downturn in vehicle sales that began in 2008 continued as an overall trend in 2009. However, in several IA-HEV member countries, sales of vehicles were sustained with the help of government programs to renew the vehicle fleet on the road. Many of these programs provided financial incentives to encourage consumer purchases of “green” vehicles, which in some places helped boost the proportion of hybrid vehicle sales. The details of these programs are described in further detail in chapter 13, “Strategies out of the automotive crisis.”

Table 12.1 gathers the data on the recent trends for EV and HEV fleets in IA-HEV member countries. All-electric vehicles continued to see the most growth in the two-wheeler niche. However, Denmark saw a surge in sales of other types of EVs in 2009 due to participation in its EV promotion program for fleets. The cause of EVs was advanced in other ways as several countries began to install the charging infrastructure to support the introduction of four-wheeled PHEVs and EVs, including Belgium, Spain, Switzerland (in addition to existing charging infrastructure dating to the 1990s), the United Kingdom, and the US. Plans for charging networks have also been announced in several countries, including Canada, Denmark, and France. Finally, other members have charging network research projects, including Austria and Finland.

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Table 12.1 Actual or estimated (*estimates in italic*) electric vehicle (EV) and hybrid electric vehicle (HEV) populations of IA-HEV member countries, per December 31st of each year that is shown.

YEAR	2006		2007		2008		2009	
Vehicle type	EV ¹	HEV	EV ¹	HEV	EV ¹	HEV	EV ¹	HEV
Austria	565	481	691	1,264	1,200	2,592	n.a.	n.a.
Belgium²	990	<i>1,560</i>	1,030	<i>2,900</i>	1,109	<i>4,800</i>	1,229	n.a.
Canada	18	13,253	21	25,783	29	45,703	n.a.	n.a.
Denmark	<i>650</i>	<i>50</i>	<i>650</i>	<i>76</i>	<i>10,600</i>	<i>300</i>	<i>15,600</i>	<i>380</i>
Finland	n.a.	n.a.	<i>404</i>	<i>303</i>	<i>470</i>	<i>1,142</i>	<i>820</i>	<i>1,876</i>
France	<i>11,000</i>	<i>> 7,000</i>	n.a.	<i>>13,000</i>	n.a.	<i>>22,000</i>	n.a.	<i>>31,000</i>
Italy	153,695	4,285	206,300	8,786	217,200	11,254	n.a.	n.a.
Netherlands	20,450	5,003	30,450	6,005	60,452	20,005	<i>90,060</i>	<i>27,005</i>
Spain	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	10,698	14,000
Sweden	<i>> 335</i>	6,100	3,320	9,400	3,370	13,500	3,368	16,102
Switzerland³	17,590	4,722	23,400	7,762	39,000	11,140	n.a.	<i>13,000</i>
Turkey	n.a.	n.a.	n.a.	n.a.	n.a.	264	n.a.	n.a.
UK	n.a.	n.a.	n.a.	n.a.	1,405	47,035	n.a.	n.a.
USA	53,526	655,000	55,654	1,006,000	57,782	1,322,000	59,800	1,586,000
Total IA-HEV	259,000	698,000	322,000	1,081,000	430,000	1,500,000	490,000	1,800,000

n.a.= not available

(1) Includes e-bikes and e-scooters.

(2) EV data for Belgium are per August 1st of each year.

(3) Swiss EV data does not include industrial and agricultural vehicles. The 2009 HEV figure is for September 2009.

Despite the overall drop in new vehicle registrations from the previous year seen in many locations, hybrids achieved a greater proportion of new vehicle sales in the Netherlands and US in 2009. Switzerland has the highest number of hybrids per capita in Europe, with 16 HEVs for every 10,000 people in 2009. The Netherlands has the next highest hybrid rate at 15 HEVs, and both Germany and the UK are at the level of 2.4 HEVs, all per 10,000 people. Hybrids have penetrated the USA's market at three times the Swiss rate, with 48 HEVs per 10,000 people, and Japan has 44 HEVs for the same number of people. In contrast, Spain reported that sales of HEVs remain constrained by limited supply.

12.2

National goals for vehicles with electric drives

There is increasing consensus that vehicles with electric propulsion systems should play a role in reducing energy consumption and emissions from road transport, because an electric drive is more energy-efficient than a conventional drive based on the internal combustion engine. Electric vehicle propulsion also enables the use of clean and renewable energy in road transport.

The most important options for vehicles with an electric drive are hybrid electric vehicles (HEVs), battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles. In a hybrid electric vehicle the internal combustion engine (ICE) is combined with an electric motor to reduce the vehicle's fuel consumption, but the ICE remains the most important power source to propel the vehicle. In battery electric vehicles there is no ICE, while a plug-in hybrid electric vehicle can be seen as a BEV with an (relatively small) ICE as range extender. In fuel cell vehicles, there is no ICE and the fuel cell is the energy source for the electric drive.

When vehicle batteries are charged from the electricity grid, the emissions from electricity production must be allocated to the vehicle kilometres travelled. In the case where the electricity is produced with fossil energy such as coal and natural gas, the well-to-wheel CO₂ emissions of an electric vehicle may not differ much from those of a conventional vehicle. However, when clean and renewable electricity is used, road vehicles with electric propulsion systems are a major step towards sustainable transport. This is the reason why national governments have started to define goals for the number of vehicles with electric drives up to the year 2020 (see Table 12.2). Fuel cell vehicles are not expected to be able to gain a substantial market share before 2020 and therefore they are not included in the national goals.

Car manufacturers are developing electric vehicles (EVs) and have announced that the first models will be put on the market in 2010. However, both the continuing development of these vehicles and building the production capacity for EVs will take time, so for the coming years the EV market share will remain very small. The speed at which EV production capacity will be built depends on expected demand. Governmental policies and objectives will play an important role here. In a scenario with a stable set of regulations that stimulate EV deployment, the car industry will be more eager to quickly expand EV production than in a scenario without such regulations. So governmental targets and regulations will influence the vehicle numbers targeted in the production plans of industry,

but the numbers will be capped by what is physically feasible. By publishing an overview of current goals for electric vehicle numbers, IA-HEV aims to support policy and decision makers in governmental bodies as well as in industry in their activities towards sustainable road transport, and to stimulate the dialogue among all parties involved.

Table 12.2 National goals for numbers of vehicles with electric drive, in selected IA-HEV countries, Germany and Ireland. Background information on the numbers is given below this table, in alphabetic order of the countries.

	2014			2020			Ref.
	HEV	PHEV	BEV	HEV	PHEV	BEV	
Austria	-	-	-	-	-	-	[12.7]
Belgium	-	-	-	-	-	-	[12.2]
Canada	-	-	-	-	500,000		[12.14]
Denmark	-	-	-	-	400,000		[12.1,12.3]
Finland	-	-	-	-	84,000	56,000	[12.6]
France	-	-	-	-	2,000,000		[12.9]
Germany	-	-	-	-	1,000,000		[12.1]
Ireland	-	-	-	-	230,000		[12.5]
Netherlands	-	-	-	-	200,000		[12.1,12.4]
Spain		1,000,000		-	-	-	[12.1]
Sweden	-	-	-	-	40,000		[12.13]
Switzerland	-	-	-	-	-	-	[12.11]
Turkey	-	-	-	-	-	-	[12.15]
USA	-	-	-	-	-	-	[12.16]

BEV= Battery electric vehicle
 HEV= Hybrid electric vehicle
 PHEV= Plug-in hybrid electric vehicle

Austria

No specific national goals have been set for Austria [12.7].

Belgium

Belgium has not yet defined national goals [12.2].

Canada

The number of vehicles shown for Canada is not an official target. This number is taken from the “Electric vehicle technology roadmap for Canada” vision statement, which was developed by Canadian industry and reads as follows: “By 2018, there will be at least 500,000 highway-capable plug-in electric-drive vehicles on Canadian roads, as well as what may be a larger number of hybrid-electric vehicles” [12.14].

Denmark

The vehicle number that is shown for Denmark is not a governmental goal. The organization Better Place is aiming for 400,000 PHEVs in Denmark by 2020, which would form 20% of the estimated Danish vehicle fleet in that year. Mr. Horstmann, who is working at the Department of Electrical Engineering of the Technical University of Denmark, considers this estimate highly ambitious; he himself has lower expectations [12.3].

Finland

During a Committee review by the Ministry of Employment and the Economy on August 6, 2009, Finland set a target that in the year 2020, 25% of the new cars can be recharged from the electricity grid. Of that 25% that are rechargeable vehicles, 40% should be full electric vehicles (BEV) [12.6, 12.8].

Mr. Suomela, Research Scientist at the Department of Automation and Systems Technology of the Helsinki University of Technology, estimates the following. If it is assumed that the number of new passenger cars sold in 2020 will be similar to that in 2008 (about 140,000 units), then it follows for new electric car sales in 2020 that:

- 14,000 should be battery electric vehicles
(25% of 140,000 cars should be electric, of which 40% should be BEV, yielding $140,000 \times 0.25 \times 0.4 = 14,000$),
- 21,000 should be plug-in hybrid electric vehicles
(the remaining 60%, gives $140,000 \times 0.25 \times 0.60 = 21,000$).

Now assuming that the market introduction of BEVs and PHEVs will have started before 2020, and that the life expectancy of electric cars is similar to conventional cars, the total number on Finland’s roads should be about four times the 2020 sales. This leads to the estimates of 56,000 BEVs and 84,000 PHEVs in the Finnish vehicle fleet in 2020 [12.6].

France

The French energy minister Jean-Louis Borloo announced on October 1st 2009 that the French government is aiming for 2 million electric cars (including both BEVs and PHEVs) on the road by 2020. To recharge the batteries of these vehicles, the government aims to have 4.4 million charging points installed by 2020 [12.9,12.10].

Ireland

In September 2009, the best estimate of Ireland's 10% EV target by 2020 was 230,000 vehicles [12.5].

Netherlands

The goal of the Dutch government is to have 200,000 electric vehicles (comprising both BEVs and PHEVs) on the roads in 2020. This number does not include hybrid electric vehicles [12.4].

Spain

The Spanish government aims to have 1,000,000 hybrid and electric vehicles (including BEVs, PHEVs and HEVs) on the roads in 2014. This vehicle number objective in the "Activation plan for energy efficiency 2008 – 2011" was approved by the board of ministers on August 1st 2008.

The Spanish government is currently working on a plan to spur electric vehicle deployment in Spain. This plan will define and co-ordinate strategic actions in three different fields (infrastructure and utilities, car industry, and promotion and management of EV demand) to reach the 2014 objective [12.12].

Sweden

The 40,000 EVs number that is shown for Sweden is not a governmental goal but rather a long-term prognosis from the Swedish Energy Agency. The Swedish power companies are working together in a joint initiative promoting EVs and PHEVs with the goal to bring 600,000 of these vehicles to the market by 2020 [12.13].

Switzerland

No specific national goals have been set for Switzerland [12.11].

Turkey

No specific national goals have been set for Turkey [12.15].

United States

No specific national goal has been set for the United States, although the Obama Administration is currently targeting enough advanced battery manufacturing capacity to support 500,000 PHEVs a year by 2015 [12.16].

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Strategies out of the automotive crisis

13.1

Introduction

The worldwide economic crisis that started in 2008, combined with a peak in crude oil price in the same year, is also affecting the automotive industry. In 2008, vehicle sales started to decline in most countries (figure 13.1), and the automotive industry had to deal with the consequences of an over-capacity in production. The light-duty (cars) sector as well as the heavy-duty (trucks and buses) sector continued to be affected throughout 2009. The crisis led to financial difficulties for many vehicle producers and their suppliers all over the world, and these difficulties persist into 2010. Employment in the automotive industry is threatened and last year many governments decided to take measures to dampen the impact of the crisis.

This chapter presents strategies out of the automotive crisis pursued by the member countries of the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV), and the impact of these strategies on the automotive industry and on vehicle sales. It aims to inform policy and decision makers working on automotive issues about possible strategies and their effectiveness. This chapter is a synthesis of the information that IA-HEV country delegates presented during their Executive Committee (ExCo) meeting October 28–29, 2009, completed with updates through February 1st, 2010.

13.2

Measures

With the exception of Denmark, all IA-HEV member countries host research organizations and suppliers to the automotive industry. France, Italy, and the USA are countries with large native car manufacturers. In the other member countries, the original equipment manufacturers (OEMs) are often assembly plants, such as Magna Steyr in Austria, GM and Chrysler in Canada, and as one example, many European and Asian OEMs have assembly plants in Turkey. Sometimes the OEMs are part of a larger group: DAF Trucks in the Netherlands is a Paccar company, Seat in Spain is member of the Volkswagen group, Mini in the UK is owned by the BMW group, and Volvo in Sweden was part of the Ford organization until Chinese automaker Geely Automobile acquired it in early 2010. Furthermore, there are small native OEMs such as the bus manufacturers Van Hool in Belgium and Kabus in Finland, and e-bike manufacturers in Swit-

zerland. All these manufacturers have to deal with the consequences of reduced vehicle sales and are taking measures to survive. Only the clean vehicle manufacturers in Switzerland have not seemed to suffer from the crisis.

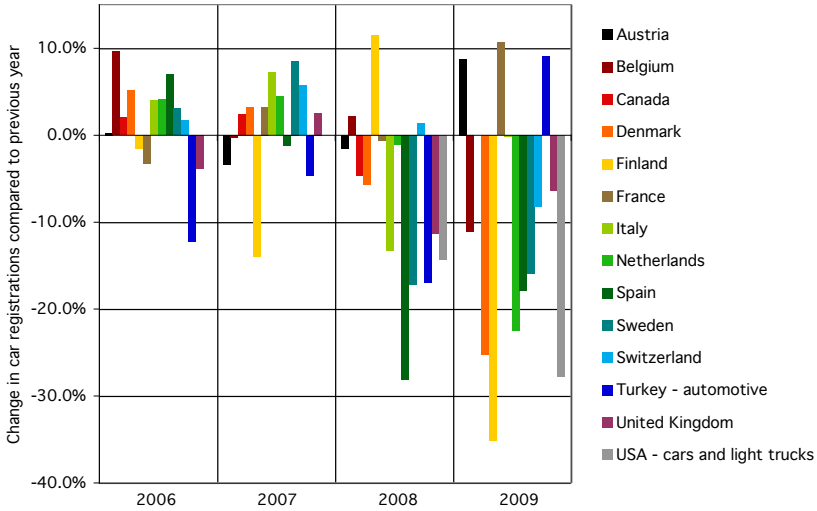


Fig. 13.1 Trends in car registrations in IA-HEV countries. A positive value means that more cars were registered than in the previous year, and a negative value means that fewer cars were registered than in the previous year. The 2009 values for Turkey and the USA are estimates. (Data sources [13.1, 13.2, 13.12].)

The way industry responds to the sales crisis is predominantly driven by economic considerations, and many companies have taken similar measures to cut costs. Many manufacturers also opted not to renew temporary employee contracts and in different cases laid off employees. When a number of OEMs reduced their numbers of employees, many governments decided to establish measures and incentives to support companies and to avoid or at least dampen the effects of unemployment. The measures enacted depend on the type of industry that is present in a country. For example, the options for an assembly plant of a foreign company are very different from the options for a native vehicle manufacturer. Two types of governmental responses to the crisis can be distinguished: specific short-term crisis measures (addressed in section 13.2.1), and reinforcing clean vehicle programmes for the longer term (section 13.2.2).

13.2.1

Specific crisis measures

Depending on the automotive activities in their country, governments of IA-HEV member countries have responded differently to the crisis in the automotive sector. Table 13.1 presents an overview of the measures that have been put in place and that are meant to directly counteract the crisis' impact. Other measures are addressed in section 13.2.2.

Most of the measures are meant to improve the economic situation of the automotive industry, to deal with unemployment, or to increase vehicle sales. The diversity of approaches is large and the actual impact has in most cases not been quantified yet. However, table 13.1 shows one common theme in that many countries have introduced vehicle fleet renewal programmes. These programmes offer financial incentives for trading in and scrapping an old vehicle when purchasing a new one. Besides stimulating vehicle sales, these programs also aim to reduce energy consumption and emissions of pollutants and CO₂ by the national vehicle fleet. Table 13.2 gives an overview of the programmes, vehicle criteria and incentives in IA-HEV member countries.

Most countries have set a maximum budget that can be spent on fleet renewal incentives. In countries like Austria, Italy, and the USA the success of the programmes exhausted the available budgets before their originally announced formal end date. Table 13.3 gives an overview of the available budgets in IA-HEV countries with fleet renewal programmes.

The aim of the fleet renewal programmes is to stimulate new vehicle sales (in countries like the Netherlands and Spain, the vehicles may be up to a few years old) and trading in old "dirty" vehicles. The impact of these programmes can be measured by counting the number of vehicles that are turned in for scrapping. The fleet renewal programmes are a success and vehicle numbers are becoming available (table 13.4).

The impact of measures other than vehicle fleet renewal programmes is much more difficult to quantify, and because the measures have only been introduced recently, their impact may not be fully clear yet. Nevertheless, the IA-HEV delegates were able to present qualitative statements about the impact of the crisis measures in their country. Table 13.5 gives an overview.

13 STRATEGIES OUT OF THE AUTOMOTIVE CRISIS

Table 13.1 Specific governmental measures against the crisis in the automotive sector in IA-HEV member countries [13.1, 13.5, 13.8, 13.9].

COUNTRY	SPECIFIC GOVERNMENTAL MEASURES AGAINST THE CRISIS IN THE AUTOMOTIVE SECTOR
Austria	Increase R&D budget. Elaborate automotive strategy. Implement vehicle scrappage programme.
Belgium	Provide loan guarantees to OEMs.
Canada	Provide loans to OEMs. Obtain shares in OEMs. Put warranty programme in place. Expand suppliers' accounts receivable insurance. Launch secured credit facility for consumers to purchase new vehicles. Implement vehicle scrappage programme.
Denmark	None.
Finland	None.
France	Provide loans for the automotive industry. Introduce short-term unemployment facilities. Implement vehicle scrappage programme.
Italy	Introduce a purchase subsidy for ecological cars. Promote 2-wheelers. Implement vehicle scrappage/park renewal programme.
Netherlands	Introduce specific support measures for workforce when temporary laid off. Develop a special support programme to encourage investments in EVs. Implement vehicle scrappage programme.
Spain	Increase incentives for R&D. Increase support for workforce that is laid off. Provide loans for industry. Implement vehicle scrappage programme.
Sweden	Provide loans to OEMs and subcontractors. Increase incentives for vehicle R&D, particularly for electric cars.
Switzerland	None.
Turkey	Introduce tax reductions.
United Kingdom	Provide loan guarantees to OEMs. Implement vehicle scrappage programme.
USA	Provide loans to OEMs. Obtain shares in OEMs. Introduce recovery and reinvestment act – vehicle electrification. Introduce recovery and reinvestment act – tax incentives for manufacturing. Implement vehicle scrappage programme.

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Table 13.2 Fleet renewal incentives for scrapping old vehicles in IA-HEV member countries [13.1, 13.3, 13.6, 13.7, 13.8, 13.11].

COUNTRY	PROGRAMME RUNNING TIME	CRITERIA VEHICLE TO SCRAP	CRITERIA NEW VEHICLE	INCENTIVE PER VEHICLE
Austria	Scrap incentive April – December 2009 ⁽¹⁾	Car at least 13 years old	Car meets Euro-4 emissions	€ 1.500
Belgium	None	—	—	—
Canada	Retire Your Ride Started January 2009	- Model year 1995 or earlier - In running condition - Registered and insured for the last 6 (12 in BC) months	—	- Federal \$300, or other that vary by province. - OEMs: \$ 500-3.000 - BC offers \$ 750-1.250
Denmark	None	—	—	—
Finland	None	—	—	—
France	Prime à la casse Until end of 2009	Over 10 years old	Maximum CO ₂ emissions 160 g/km	€ 1.000
	Prime à la casse (provisional) January - June 2010	Over 10 years old	Maximum CO ₂ emissions 160 g/km	€ 700
	Prime à la casse (provisional) July- December 2010	Over 10 years old	Maximum CO ₂ emissions 160 g/km	€ 500
	Motorbikes and scooters park renewal Enacted in February 2009	Euro-0 or -1 emissions.	- Euro-3 emissions - Maximum engine size 400 cm ³	€ 500
Italy	Passenger car park renewal	Registered before December 1999	New, with Euro-4 or -5 emissions - Diesel: CO ₂ less than 130 g/km - Gasoline: CO ₂ less than 140 g/km	€ 1.500
	Commercial van park renewal	- Euro-0, -1 or -2 emissions - Registered before December 1999	New	€ 2.500
Netherlands	Temporary scrap regulation for cars and vans May 2009 - December 2010	- Cars and vans - Gasoline, LPG: registered before 1996 - Diesel: registered before 2000	- Gasoline, LPG: built after 2000 - Diesel: Euro-4, -5 or EEV ⁽³⁾	€ 750-1.750 ⁽²⁾

13 STRATEGIES OUT OF THE AUTOMOTIVE CRISIS

Table 13.2 *Continued*

COUNTRY	PROGRAMME RUNNING TIME	CRITERIA VEHICLE TO SCRAP	CRITERIA NEW VEHICLE	INCENTIVE PER VEHICLE
Sweden	None	—	—	—
Switzerland	None	—	—	—
Turkey	None	—	—	—
United Kingdom	Scrappage Scheme April 1, 2009 - February 28, 2010	Over 10 years old	—	£ 2.000
	Car Allowance Rebate System (CARS) ⁽⁵⁾ July 27 - August 24, 2009	—	Fuel economy new vehicle 4-10 mpg ⁽⁶⁾ greater than traded-in vehicle	US\$ 3.500
USA	Car Allowance Rebate System (CARS) ⁽⁵⁾ July 27 - August 24, 2009	—	Fuel economy new vehicle more than 10 mpg ⁽⁶⁾ greater than traded-in vehicle	US\$ 4.500
	Truck allowance rebate system July 27 - August 24, 2009	—	Similar to cars	Lower than for cars

(1) *The available budget was already consumed in July 2009.*

(2) *The financial incentive depends, among others, on vehicle fuel, weight and age.*

(3) *EEV = Enhanced Environmental friendly Vehicle.*

(4) *Alternative technology is hybrid, electric, natural gas or hydrogen.*

(5) *Also known as "Cash for clunkers."*

(6) *mpg = miles per gallon.*

Table 13.3 National budgets for fleet renewal incentives in IA-HEV countries [13.1, 13.7, 13.8, 13.10, 13.11].

COUNTRY	PROGRAMME	AVAILABLE BUDGET
Austria	Scrap incentive (Verschrottungsprämie)	€ 22.5 million
Canada	Retire Your Ride	Can\$ 92 million
Italy	Park renewal	Subsidy for power assist bikes was consumed in 4 days
Netherlands	Temporary scrap regulation for cars and vans	€ 80 million
Spain	VIVE cars and vans renewal 2009	€ 700 million
	VIVE bus renewal 2009–2010	€ 236 million
	Plan 2000 E 2009	€ 140 million
	Plan 2000 E 2010	€ 100 million
United Kingdom	Scrappage Scheme	£ 400 million
USA	Car Allowance Rebate System (CARS), including trucks	US\$ 3 billion

Table 13.4 Number of vehicles turned in for scrapping under fleet renewal programmes in IA-HEV countries [13.1, 13.3, 13.4, 13.7, 13.8, 13.13].

COUNTRY	PROGRAMME	END OF NOVEMBER 2009	END OF DECEMBER 2009
Austria ⁽¹⁾	Scrap incentive (Verschrottungsprämie)	30,000	30,000
Canada	Retire Your Ride	26,000	–
France	Prime à la casse	–	575,000
Netherlands	Temporary scrap regulation for cars and vans	49,500	53,000
Spain	Plan 2000 E	–	260,000
	VIVE	–	70,000
United Kingdom	Scrappage Scheme	213,000	246,000
USA ⁽²⁾	Car Allowance Rebate System (CARS)	109,380	109,380
	Truck allowance rebate system	575,821	575,821

(1) The available budget was consumed in July 2009.

(2) Programmes ended in August 2009.

13.2.2

Reinforcing clean vehicle programmes

Besides the crisis in the automotive sector, other concerns in society currently affect road transport as well. The transport sector predominantly uses fossil fuels, and continued growth in transport causes it to emit increasing amounts of CO₂, while other sectors are stabilizing or reducing their CO₂ emissions. As a result, the share of transportation in climate change-related emissions is increasing, and the sector gets more and more attention from policy makers who are aiming to reduce CO₂ emissions.

Fossil fuel reserves are not endless, and annual crude oil production may be expected to reach its peak in the coming years before starting to decline. On top of that, the oil reserves are located in a limited number of areas. This fact raises concerns about security of supply and it increases the need for alternative energy sources. For these reasons, interest in alternatives for internal combustion engine vehicles running on conventional gasoline and diesel fuels is increasing. Alternative fuels such as biofuels are under consideration, and electrification of the powertrain enjoys massive attention today. Electric vehicles fuelled by clean and renewable energies are often seen as a good option for the long term.

13 STRATEGIES OUT OF THE AUTOMOTIVE CRISIS

Table 13.5 Impact of governmental measures against the crisis in the automotive sector, in IA-HEV member countries [13.1, 13.5, 13.7, 13.8].

COUNTRY	IMPACT OF GOVERNMENTAL CRISIS MEASURES
Austria	Available budget for vehicle scrappage programme already ran out after three months.
Belgium	No specific crisis measures were taken.
Canada	OEMs have been saved and restructured. National and provincial governments have become part-owners of some OEMs. By the end of November 2009, about 26,000 vehicles had been scrapped.
Denmark	No specific crisis measures were taken.
Finland	No specific crisis measures were taken.
France	Vehicle scrappage / park renewal programme is a success, with 2009 car sales up 10% over 2008 and the highest number since 1990.
Italy	Incentives have worked to stabilize the market. Various measures have increased public awareness.
Netherlands	Workforce from industry is temporarily employed in research organizations.
Spain	Avoided a very negative year for the sector, by improving car registration and production. Car purchase incentives in other European countries also contributed to this improvement (more than 83% of Spain's car production is exported to EU countries).
Sweden	Subcontractors to the vehicle industry have been saved and restructured.
Switzerland	No specific crisis measures were taken.
Turkey	Tax reductions resulted in temporary recovery of vehicle sales.
United Kingdom	Scrappage scheme has been a success and as a coincidence average CO ₂ emissions per car have declined.
USA	OEMs have been saved and restructured. National government has become a part-owner of some OEMs. Vehicle scrappage/park renewal programme is a success; average vehicle fuel economy has improved.

Therefore, many governments have put programmes in place to develop electric vehicle and battery technology and to develop a recharging infrastructure, often simultaneously aiming to reinforce the strengths of their domestic industry. Utilities (electricity suppliers) will play an important role in the development and deployment of electric mobility, and they are working on smart grids to in-

tegrate large amounts of vehicle battery recharging. Developing plug-in hybrid electric vehicles and later the battery electric vehicle can be seen as long-term activities to help the automotive industry out of the current crisis, so governments have recently reinforced and/or expanded their support programmes for electric mobility. Programmes focusing on other options such as biofuels or modal shift, are outside the scope of this chapter. Table 13.6 presents an overview of important governmental programmes to stimulate development and deployment of clean vehicles in IA-HEV member countries, with emphasis on electric mobility. It should be noted that these programmes do not address the current overcapacity in the automotive industry, and the impact of these programmes will only become visible in the long term.

13.3 Conclusions

National governments have been able to save car manufacturers from disappearing amid severe financial losses beginning in late 2008. The policies they created also managed to reduce the impact of the unemployment resulting from the crisis in the automotive sector by making large amounts of money available as loans to industry and to incentivize car purchases by consumers. Short-term measures such as tax reductions and fleet renewal (e.g., “cash for clunkers”) programmes have worked to stabilize vehicle markets. However, there are concerns that this short-term sales boost may depress future vehicle sales as some consumers used the financial incentives to move up a car purchase that they had been planning to make even before the incentives were announced.

Long-term strategies are also necessary to get out of the crisis in the automotive industry. Here the crisis offers opportunities. Governments are reinforcing existing programmes to support the transition to sustainable transportation. For example, developing electric mobility that is based on clean and renewable energy fights the crisis by providing work to the automotive and other industries. Simultaneously, it contributes to moving towards improved security of the energy supply and less greenhouse gas emissions.

13 STRATEGIES OUT OF THE AUTOMOTIVE CRISIS

Table 13.6 Important governmental programmes to stimulate development and deployment of clean vehicles in IA-HEV member countries, with an emphasis on electric mobility [13.1, 13.3, 13.5, 13.7, 13.8, 13.9].

COUNTRY	GOVERNMENTAL PROGRAMMES
Austria	<ul style="list-style-type: none"> • Launch of "Lighthouse initiative" programme for large-scale electromobility demonstration projects. • Launch of "Electric vehicle model regions" programme. • Add new area to the "New energy 2020" programme: energy-efficient vehicle components and systems (focused on conventional technologies). • Increase annual RD&D budget from €40 to €60 million for the automotive sector.
Belgium	<ul style="list-style-type: none"> • Tax advantages for low-CO₂ emission vehicles. • Tax advantages and subsidies for electric vehicles and recharging infrastructure. • Support the automotive sector in the transformation to 'green and clean' via studies and financial support of R&D projects.
Canada	<ul style="list-style-type: none"> • Establish the Automotive Innovation Fund to support R&D to build innovative, greener, and more fuel-efficient vehicles. • Government of Ontario: financial incentives for the purchase of PHEVs and BEVs.
Denmark	<ul style="list-style-type: none"> • Promotion of hybrid and electric vehicles has not changed in response to the economic crisis.
Finland	<ul style="list-style-type: none"> • Tax support and preferential treatment in city traffic and parking for electric vehicles.
France	<ul style="list-style-type: none"> • 14 actions have been launched to speed up EV development and deployment. • New budgets in the R&D program for low-CO₂ vehicles, which is managed by ADEME. • Co-ordinated joint purchase of electric vehicles by public organisations.
Italy	<ul style="list-style-type: none"> • Maintain "Industria 2015", an industrial research support programme that was already in place before the crisis. • Purchase subsidy of ecological cars can be combined with fleet renewal subsidy.
Netherlands	<ul style="list-style-type: none"> • Programme for BEV and PHEV pilot projects. • Tax measures and subsidies for EV purchase, production, and recharging infrastructure.

13.4 References

COUNTRY	GOVERNMENTAL PROGRAMMES
Spain	<ul style="list-style-type: none"> • “Competitiveness plan for the automotive sector” supports R&D and manufacturing programmes for EVs. • “Guarantee plan” offers financial support for automotive programmes, mainly oriented to hybrid and electric vehicles. • Tax incentives for low-CO₂ emission vehicles. • The frame of the Spanish Strategy for Energy Efficiency and Savings (E4) includes the following programmes to promote deployment of hybrid and electric vehicles: • MOVELE Plan: a project to demonstrate the electric vehicle’s viability, which will put 2.000 electric vehicles and 546 public charging networks into service. • Collaboration programmes between IDAE and regional administrations to support acquisition of alternative vehicles and to establish charging networks. • “Strategic support line of IDAE” to channel relevant acquisition of alternative vehicles (through renting and leasing companies and through large enterprises).
Sweden	<ul style="list-style-type: none"> • Launch a new vehicle R&D programme for traffic safety and energy. • Start a government-owned holding company called FourierTransform to support new vehicle technology.
Switzerland	<ul style="list-style-type: none"> • Maintain research programmes on efficient energy use in transport and on energy storage/accumulators. • Indirect incentives such as “green taxation” are in place.
Turkey	<ul style="list-style-type: none"> • Investments to keep competitive advantage with technology and R&D capacity.
United Kingdom	<ul style="list-style-type: none"> • Incentives to put electric infrastructure in place. • Incentives to purchase EVs and PHEVs. • Programme to encourage public sector to purchase electric vans.
USA	<ul style="list-style-type: none"> • Recovery and reinvestment act on vehicle electrification. Budgets for battery and component manufacturing, for developing electric drive components, for transportation electrification demonstration projects, and for electric drive vehicle education. • Tax incentives for BEVs and PHEVs. • PHEV demonstration programme, and utility network and charging options study.

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14.1 Introduction

The automotive sector is a key element of the Austrian economy; employing approximately 175,000 people in more than 700 enterprises (mostly suppliers), this sector is one of the top five in Austria in terms of number of employees and turnover.

In Austria, 2009 was an eventful year for electromobility. Many initiatives were launched; activities included the preparation of the National Introduction Plan for Electromobility, the start-up of a strategic platform (AMP: Austrian Mobile Power), and the introduction of new research funding programmes in this area. These comprise the electromobility model regions funded by the Climate and Energy Fund for large-scale demonstration of technologies in this field, as well as the Lighthouse Projects Initiative for vehicles with electric drivetrain as main propulsion system and corresponding charging infrastructure (Leuchtturminitiative, and abbreviated LTPI). These initiatives will be described in more detail in the following sections. In addition, the total public funding assigned to the automotive sector for research, development, and demonstration (RD&D) of all relevant technologies increased from €40 to 60 million between the years 2009 and 2010.

14.2 Policies and legislation

The process leading up to the preparation of the National Introduction Plan for Electromobility started in 2009 at the Ministry for Transport, Innovation, and Technology (BMVIT). In a later phase it will include other relevant stakeholders (other ministries, the automotive industry, transport companies, local governments, consumer associations, utilities, and infrastructure providers/operators among others). The goal is to prepare a group of measures that involve the following components:

- Specific application: taxi fleets, commuting traffic, holiday traffic, urban distribution, long-distance freight transport, communal fleets.
- Type of vehicles: 2-wheelers, passenger vehicles, light commercial vehicles, buses, trucks.
- Specific location: urban, rural, transport corridor.
- Potential or demand for intermodal linking.
- Business models: car sharing, battery leasing, mobility service packages.

- For the previously mentioned categories the best-suited technology should be considered: hybrid (micro to full), plug-in, battery electric, or fuel cell vehicles.
- Appropriate instruments: research, development, and demonstration; funding; development of public transport; development of required infrastructure; legal adaptations such as tax regulations; public procurement.
- Time plan.
- Involvement of corresponding stakeholders.

The measures are classified in the following categories:

- Financial support of consumers/users through public funding.
- Regulative measures (emissions limits for greenhouse gases and pollutants, as well as noise limits for individual vehicles or for the fleet average).
- Financial compensation through differentiation of different taxes, where cleaner vehicles are favored over less-sustainable technologies.
- Non-financial measures such as access to restricted zones or the use of reserved parking places.

The first phase for the preparation of this plan was expected to be complete by February 2010.

Another relevant initiative is “E-connected,” launched in 2009 by BMVIT, the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW), and the Climate and Energy Fund. The outcome of this initiative, in which a network of relevant stakeholders was organized in different expert groups, was the discussion of research, development, and demonstration needs in the area of electromobility, the exchange of experiences in the field, the facilitation of joint projects, and information dissemination.

A final initiative started in 2009 is the development of the Austrian Energy Strategy, which aims to achieve the ambitious climate and energy policy goals of the European Union (EU). As Austria is already now above the EU-wide goal of obtaining 20% of its energy from renewable resources, due to its hydropower resources, the EU has set a more ambitious target of 34% renewable energy by 2020. To achieve this goal, electric vehicles have received a strongly increased amount of attention by policy makers.

14.3 Research

Research and development (R&D) and technological innovation provide the basis for economic growth, competitiveness, employment, and, ultimately, the prosperity of a country and its citizens. In Austria, BMVIT promotes research at all levels, from applied basic research to the industrial application of research results.

Fostering innovation for an efficient and sustainable transport system, BMVIT's Mobility and Transport Technologies Unit has been supporting research, development, and demonstration (RD&D) projects for many years. The A3 (Austrian Advanced Automotive) technology promotion programme was launched in 2002, and since 2007 it has continued as the A3plus programme; its aims are to secure the competitiveness of the Austrian supply industry and to address the environmental impact of transportation through the promotion of clean and innovative vehicle technologies.

In this section we describe the A3plus programme and a few other research programmes on other technologies relevant for the automotive sector that also pertain to hybrid and electric vehicles. We also explain the strategic platforms set up in recent years that facilitate interaction among public and private entities with an interest in electromobility.

14.3.1

Governmental programmes

Mobility plays a key role within a modern society. Therefore, BMVIT conducted the IV2S (Intelligent Transport Systems and Services) research programme from 2002 to 2006, followed by the IV2Splus programme in 2007. Highly relevant for the development of electromobility in Austria are the A3plus programme (within the IV2Splus programme), the LTPI initiative (Lighthouse projects initiative or Leuchtturminitiative) launched in 2009, and the electromobility model regions (launched in 2008).

IV2Splus programme

IV2Splus focuses on expanding RD&D excellence through stronger international integration into value-added production activities and the supply chains of successfully established Austrian RD&D competencies.

The structure of the IV2Splus strategy programme is shown in figure 14.1; it covers projects from problem-oriented basic research to demonstration and pilot

projects with differences in core areas depending on the particular programme line.






		Strategy Programme Intelligent Vehicular Transport Systems and Services plus 2007-2012			
					
Alternative Propulsion Systems and Fuels	Intermodality and Interoperability of Transport Systems	Technologies for Evolving Mobility Needs	Basic Research for Innovations in Transport		
European Research Area Network					
ERA-NET TRANSPORT					

Fig. 14.1 Overview of Intelligent Vehicular Transport Systems and Services plus (IV2Splus) strategy programme. (Logos © BMVIT.)

A3plus programme line

BACKGROUND

In 2007, BMVIT continued its funding of the original A3 programme in A3plus. This programme strives to make transportation of the future significantly more energy-efficient and environmentally friendly by promoting RD&D in innovative propulsion technologies and alternative fuels in order to achieve reductions in the energy consumed by surface transport vehicles and to reduce emissions from this sector. The programme also aims to develop such systems for rail and inland waterway transportation.

In the first A3plus call for proposals in 2007, a total of €5 million in funding was awarded to 18 co-operative RD&D projects involving 42 partners, including foreign entities. Within ERA-NET TRANSPORT (ENT, a network of national transport research programmes in Europe), the A3plus call was tuned for funding activities in Germany and Switzerland in order to match technology promotion programmes in these countries and provide funding for foreign partners in A3plus projects.

GOALS

The A3plus programme line is intended to support co-operative proposals involving industrial, university, and non-university research across the entire RD&D cycle. These partnerships should strengthen the innovativeness and competitiveness of the Austrian drive train technology industry. Beyond this, the promotion of technological innovation should help increase the social and ecological sustainability of surface transport. The transfer of technology and knowledge across the different modes of transport should strengthen the development of interdisciplinary know-how in alternative propulsion technologies in Austria. Complementary to the European research programmes and in line with the European Commission's transport and energy policy, the A3plus programme line supports system solutions and technology advances in the Austrian engine and automotive supplier industries. This work will also help in meeting the Austrian government's targets for the future use of alternative fuels and propulsion systems in the transportation sector.

Calls for proposals for research projects are scheduled annually over the time frame of the IV2Splus programme.

A3PLUS CORE AREAS

The core areas for the 2009 call of this programme were defined as follows:

- 1. Alternative propulsion systems for road, rail, and waterways**
 - › Scope: drive systems and drive trains for road transport, rail transport, and inland waterway transport, including electric drive for surface transport.
 - › Examples: highly specialised mono-fuel or highly flexible multi-fuel combustion engines, new combustion processes, innovative hybrid concepts, range extender concepts, electric drive, and fuel cells.
 - › Objectives: increased motor efficiency and overall energy efficiency (including energy recuperation), reduction of emissions.

- 2. Automotive electronics for energy-efficient control and management of system operation** (new area introduced for the 2009 call)
 - › Scope: power electronics, energy management, energy efficiency optimization of subsystems, monitoring and sensor systems, bidirectional energy conversion.
 - › Examples: efficient converters, V2G interfaces (vehicle side), battery management and balancing.
 - › Objectives: increased driving range; adaptation of control and operation of automotive components to the requirements of electromobility; weight and

volume reduction of components; reduction of costs; increased efficiency, safety, and durability of components through permanent monitoring of operation.

3. Innovative storage concepts

- › Scope: tanks for liquids and gases, electrochemical and electrostatic storage, storage of kinetic energy.
- › Examples: high-pressure storage tanks (hydrogen, natural gas), cryotanks, metal hydrides, flywheels, batteries, and high-performance condensers.
- › Objectives: high specific storage density, low storage and conversion losses, capacity for rapid energy uptake and supply, and safety.

4. Alternative fuels

- › Scope: liquid and gaseous (bio-)fuels or fuel combinations.
- › Examples: hydrogen, methane, methanol/ethanol, DME (dimethyl ether), and synthetic fuels.
- › Objectives: high energy density, sustainability, and energy efficiency in production; security of supply; low environmental impact; and compatibility with existing distribution infrastructures.

5. Development of required infrastructure (recharging/filling stations) for alternative propulsion systems

- › Examples: hydrogen/gas filling stations, charging stations for batteries; distribution networks; on-site synthesis.
- › Objectives: possibility to use existing distribution networks, ensure flexible use for various alternative energy carriers relative cost reduction for homogeneous area coverage.

2009 CALL FOR PROPOSALS FOR THE A3PLUS PROGRAMME LINE

Funding for the A3plus call for proposals in 2009 was set at €5 million. A total of 15 RD&D projects were selected out of 32 proposals, eight of which are relevant for hybrid and electric vehicles. These eight projects cover a wide range of areas: freight and passenger transport; zero-emission vehicles for local public transport; electrical-mechanical power distribution transmissions; battery and fuel cell development; use of renewable energy sources; and charging infrastructure.

More information about funded projects is available at www.verkehrstechnologien.at.

OTHER GOVERNMENTAL FUNDING PLANS

Also relevant for electromobility research activities in Austria are the funding programmes of the Klima- und Energiefonds (Climate and Energy Fund). This is a governmental funding programme with a total budget of 500 M€ for the period 2007–2010 supporting projects in the following areas: R&D in sustainable energy technologies, market penetration of climate-related energy technologies and transport. Within the framework of “Research and Technology Development,” the “Neue Energien 2020” programme with a total budget of 44.0 M€ for two calls in 2009 covers the following areas: energy efficiency, renewable energy carriers, and intelligent energy systems. The focus of Neue Energien 2020 for 2009 was set on the transportation sector: energy from biological sources including biofuels (budget set at 4 M€), energy storage technologies (budget set at 5 M€), energy efficiency of surface transport (budget set at 7 M€), and electromobility (budget set at 7 M€). Also within the framework of Research and Technology Development is the programme “Infrastructure for the simulation of electric grids,” with a budget of 4 M€. This programme covers projects related to the decentralized generation of electric power and smart grids.

A second relevant funding framework is “Electromobility,” covering the Lighthouse Initiative (LTPI) with a total budget of 11 M€, launched in 2009, and the Electromobility Model Regions, launched in 2008 with a total budget of 2.5 M€. These are funding plans for the demonstration of new technologies in the area of electromobility. As mentioned before, it covers the demonstration and implementation of large-scale proposals including the required infrastructure facilities and involves developers, producers, downstream operators, and future users.

The Electromobility Model Regions anticipates the implementation of an integrative mobility concept which should include the installation of the necessary charging infrastructure based on renewable energy, the procurement and integration of electric vehicles in the regional transport system (public and commercial passenger transport, transport of goods and bicycles), and the analysis of the data obtained from the operation within the model region.

The Lighthouse Initiative funds demonstration projects in the field of electromobility for technologies which are still not market-ready, whereas the model regions programme provides a framework for market-ready technologies to be tested within new business models and to increase public awareness. Despite their differences, synergies will take place between these two programmes; it is recommended, for example, that a group of partners applying

for funding within the model regions programme include stakeholders who also applied for funding within the Lighthouse Initiative.

The first project to be funded through the Model Regions programme is VLOTTE in Vorarlberg (start-up in 2009). In this “model region” with more than 250,000 inhabitants, electric mobility is being demonstrated and further developed as an integrated mobility concept. Within this project, a total of 100 electric vehicles are being operated by private and public companies as well as individual consumers. The required electric power to supply these vehicles is provided by photovoltaic plants; the vehicles available for this project cover a wide range of applications: two-wheelers, light commercial vehicles, and small buses. The access to the use of these vehicles is provided through “mobility cards” at a cost of €500 per month (considering a residual purchase value of 25% after 4 years). Besides the operation of the electric vehicles and their maintenance, this also includes battery recharging free of cost and the possibility to use the local public transportation network. Based on the data collected through the first year and assuming the market availability of higher numbers of electric vehicles, there are plans to extend this project significantly by leasing the vehicles in 2010.

I2V PROGRAMME LINE

I2V is the Austrian programme to promote cooperative RD&D projects in the area of intermodality and interoperability of transportation systems. The goal is to increase the efficiency of the overall transportation system by improving the smooth interoperation of different modes of transportation, increasing integration of environmentally sustainable modes of transportation, and making more efficient use of the existing infrastructure. New technologies and system solutions for transporting both goods and passengers are to be developed and tested.

WAYS2GO ACTION LINE

The Austrian ways2go action line aims to develop sustainable mobility solutions in the context of challenges posed by future demographic and social changes. The programme’s goal is to develop and raise awareness of innovative new technologies, systems, and organizational structures designed to meet these significant challenges.

14.3.2

Strategic platforms

There are also several strategic platforms, which are partnerships of stakeholders usually from different sectors who cooperate in the coordination of thematic sectoral activities. Several are listed below.

A3PS - AUSTRIAN AGENCY FOR ALTERNATIVE PROPULSION SYSTEMS

Besides the financial instruments to support the development of new technologies, in 2006 the BMVIT established the Austrian Agency for Alternative Propulsion Systems (A3PS) as a strategic public-private partnership for close cooperation among industry, research institutions, and the ministry. The common goal for this partnership is the development and deployment of alternative propulsion systems and fuels. Independently from the RD&D funding programmes of the BMVIT, the A3PS offers its 26 members the following portfolio of additional support services.

- ▶ Collaboration between complementary partners and developing interdisciplinary research cooperation and cross-sector pilot and demonstration projects.
- ▶ Support for procuring, compiling, and analyzing information (e.g., technology predictions and assessments; comparative evaluations of studies; analyses of international RD&D trends and strategies; organization of lectures and seminars; publication of reports after participation in conferences; provision of information about EU, national, and other RD&D funding alternatives).
- ▶ Framework conditions that promote innovation in order to overcome barriers to market entry (e.g., regulatory and fiscal policies, fuel taxation, funding endowments for RD&D programmes, technical and safety standards, values for emission limits, ordinances regulating access to garages, differentiated access restrictions for sensitive areas).
- ▶ Opportunities for international networking and for marketing their technological, engineering, and production know-how through publications and presentations at conferences; supporting Austrian research institutions in their participation in EU projects, programmes, and technology platforms; and representing their interests in the EU or the International Energy Agency committees and in the preparation of the EU Research Framework Programmes.

The A3PS promotes the development and deployment of all alternative propulsion systems and fuels by supporting Austrian research institutions in their technological development projects as an agency and platform for their national and international activities.

A3PS is also the Austrian representative in the Annex XIII (Fuel Cell Vehicles) of the Implementing Agreement HEV. In that capacity, it acts as an agent for the interests of Austrian enterprises, universities, and research institutions.

AMP (AUSTRIAN MOBILE POWER)

This strategic platform which started in 2009 integrates key Austrian companies from the energy sector (utilities), research institutions, and industry. Its goal is to introduce at least 100,000 electric vehicles that are fuelled with renewable energy before 2020; the investment to achieve this goal was set at €50 million. The partners of this platform (including Siemens Austria, Infineon, Verbund, KTM, Magna Steyr, AVL, and AIT) are working on an integrative concept that takes into account the complete system (power plant—grid—charging station—vehicle). The pilot phase is planned for 2010 with a test fleet of 100 vehicles in an urban “mobile power region.” The necessary infrastructure will be implemented stepwise, including smart grids, charging stations, and suitable billing systems. The rollout phase for this initiative is planned for 2013; the goal for this phase is to reach 10,000 electric vehicles in operation within the model regions.

Finally, much research on EVs, batteries, and fuel cells takes place at universities and research centres: Vienna University of Technology, Graz University of Technology, University of Leoben, Joanneum Research Forschungsgesellschaft mbH, AIT (Austrian Institute of Technology), HyCentA Research GmbH, and the Virtual Vehicle Competence Centre, among others. These research centres work co-operatively with automotive industry companies, such as Plansee, AVL-List, BMW, and Magna Steyr.

Principal research topics include solid oxide fuel cells (SOFCs) in auxiliary power units (APUs), propulsion systems for PEM (proton exchange membrane) fuel cell vehicles, simulation of drive trains and vehicle systems, fuel cell catalysts, power electronics, onboard storage systems, tank isolation, control systems for hybrid vehicles, and lithium-ion batteries.

14.4 Industry

The strategic platforms described in the previous section engage a number of companies in Austria's automotive industry, demonstrating that the private sector is becoming as active as the public sector in working towards the goal of electromobility.

Austria has more than 700 automotive and automotive component companies. Magna Steyr is deeply involved in developing a lithium-ion battery system for automotive applications, especially for a hybrid sports utility vehicle (HySUV) (figure 14.2).



Fig. 14.2 Under the hood of the lithium-ion battery equipped HySUV from Magna Steyr. (Photo: M. van Walwijk.)

AVL is a key player in the development of diagnostic tools and real-time hardware-in-the-loop testing equipment and software. Figure 14.3 shows the AVL battery testing solution based on the real-time hardware-in-the-loop system with real-time models in cruise mode. That approach is part of the TÜV (Technischer Überwachungs-Verein or Technical Inspection Association) -certified safety concept for testing lithium-ion batteries.

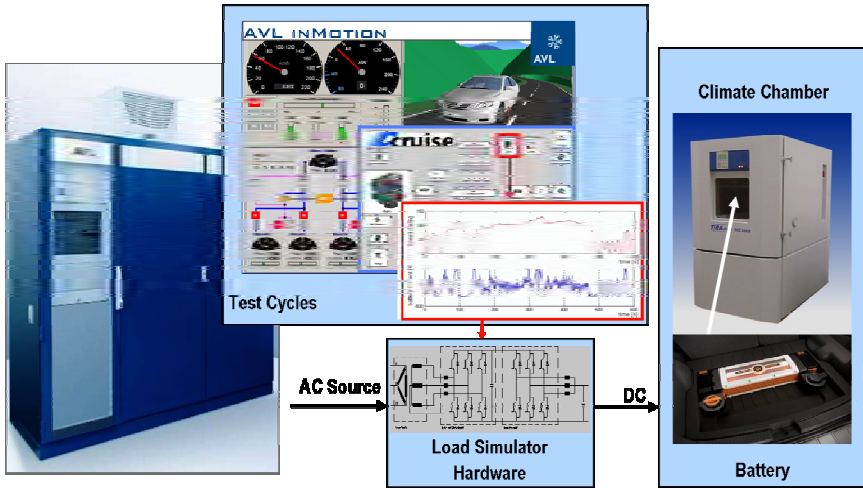


Fig. 14.3 Battery test bed with real-time hardware-in-the-loop simulation and safety concept. (Picture © AVL.)

14.5 On the road

Statistics show that the total number of hybrid electric vehicles in Austria has been increasing in recent years (figures 14.4 and 14.5). The number of EVs has increased slightly after a relatively steep decline between 2003 and 2004. Motor-assisted bicycles, which can be operated without a driver's license, are the largest share of the Austrian EV fleet; the number of vehicles more than doubled between 2007 and 2008. The number of HEVs (bivalent gasoline/electric cars) is also increasing significantly. Table 14.1 gives an overview on the HEV fleet in Austria; nine HEV models are available on the market. As of December 31, 2009, the Toyota Prius had an HEV fleet share of 61%, followed by the Honda Insight with 23% and the Lexus RX 450h with 9%.

IA-HEV ANNUAL REPORT

Table 14.1 Distribution of the Austrian hybrid and electric vehicle fleet as of December 31, 2007 and 2008.

Vehicle type	DECEMBER 31, 2007			DECEMBER 31, 2008		
	EV fleet	HEV fleet	Total fleet	EV fleet	HEV fleet	Total fleet
Motorised bicycle (Cat. L1e)	264	n.a. / 0	294,719	668	n.a. / 0	301,399
Motorbike (Cat. L3e)	4	n.a. / 0	205,457	50	n.a. / 0	211,830
Passenger vehicle (Cat. M1)	131	1,264	4,245,583	146	2,592	4,284,919
Bus (Cat. M2/M3)	101	n.a. / 0	9,299	101	n.a. / 0	9,368
Truck (Cat. N)	29	n.a. / 0	353,744	32	n.a. / 0	362,990
Total	691	1,264	5,796,973	1,200	2,592	5,873,281

n.a. = not available.

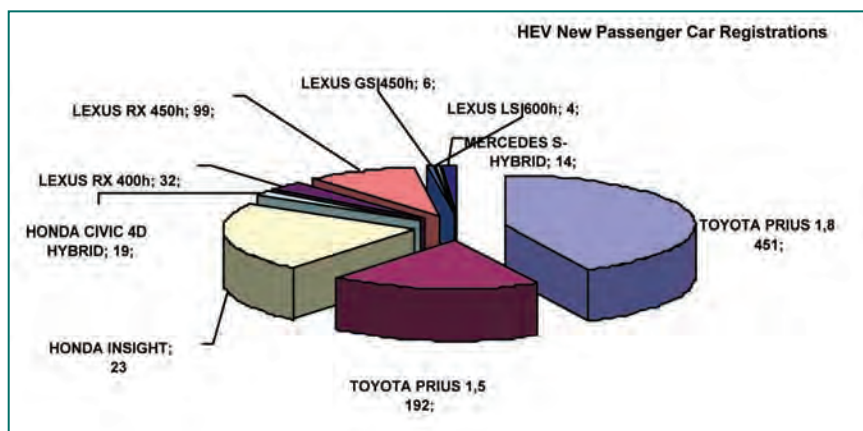


Fig. 14.4 New registrations and market share of hybrid vehicles (passenger vehicles) in Austria, 2009 (Source: Statistics Austria).

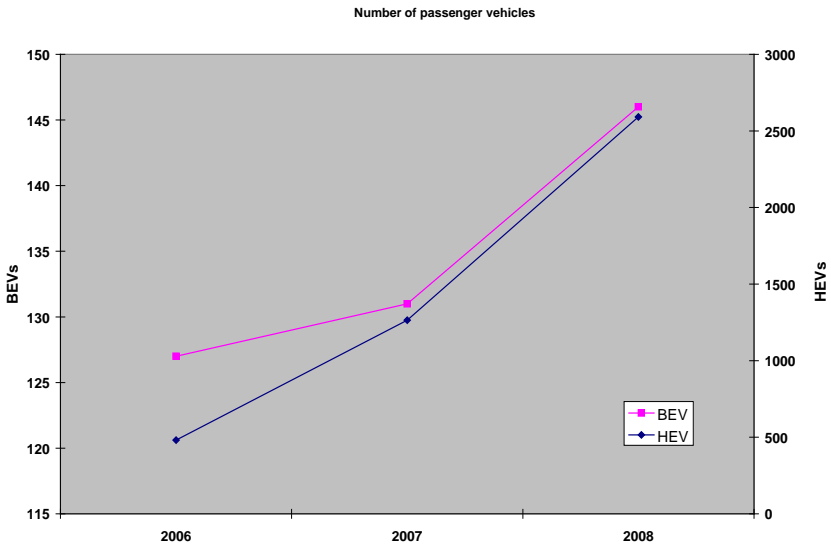


Fig. 14.5 Hybrid and electric passenger vehicles in Austria 2006–2008.

14.6 Outlook

The importance of the role that EVs and HEVs could play in addressing worldwide issues, such as global warming, energy security, energy costs, and sustainability, has been increasing. Austrian industrial and research facilities are also active in EV, HEV, and fuel cell vehicle development. The Austrian government actively supports these research areas with funding and cross-linking activities. As high gasoline prices and advertising campaigns raise the public awareness of alternatives to conventional propulsion systems based on petroleum, the market for these vehicles should certainly continue to grow in Austria.

In addition to addressing important research topics, the Austrian government is strongly interested in the deployment and market introduction of EVs in the country. Further EV model regions are planned to start, together with demonstration projects for electromobility supported by the Lighthouse Initiative.

14.7

Benefits of participation

The benefits for Austria from its participation in the IA-HEV include the exchange of information about EV and HEV technology and drivetrain developments with other countries. Other benefits include the transfer of this knowledge to local industry and participation in a network of well-known automotive laboratories, research organizations, and governmental agency representatives in order to prepare joint studies and reports.

14.8

Further information

More information on Austrian activities related to HEVs and EVs can be found on the following websites.

- ▶ The Austrian Institute of Technology (AIT, former Austrian Research Centres), one of Austria's main research institutions: www.ait.ac.at (information available in English and German); its departments of energy and mobility are involved in the following relevant areas: electric energy systems, electric drive technologies, and transportation and infrastructure solutions, among others.
- ▶ Activities in engineering and vehicle assembly: www.magnasteyr.com (information available in English, German, and Japanese).
- ▶ Core competences in solar electronics, welding, and battery charging systems: www.fronius.com (information available in English and German). Ongoing development of forklifts powered by fuel cells.
- ▶ Development of a zero-emission enduro motorcycle presented in 2008 and ongoing development of three- and four-wheeled electric vehicles: www.ktm.at (information available in English).
- ▶ AVL-List GmbH: www.avl.com (information available in English); the world's largest privately owned and independent company for the development of powertrain systems, as well as instrumentation and test systems.
- ▶ Manufacture of traction battery systems (lead acid): www.banner.at (information available in English and German).
- ▶ The Austrian Agency for Alternative Propulsion Systems (A3PS): www.a3ps.at (information available in English and German).
- ▶ Austrian Advanced Automotive Technology Programme of BMVIT: www.bmvit.gv.at/innovation/verkehrstechnologie/iv2s/a3plus/index.html (information available in German).
- ▶ Austrian Energy Agency: www.energyagency.at (information in English and German).

- ▶ Platform for innovative technologies in the area of energy efficiency and renewables: www.energytech.at (information available in English and German).
- ▶ Information about funded projects from different programme lines of the BMVIT: www.verkehrstechnologien.at (information available in German).
- ▶ Klima und Energiefonds: <http://www.klimafonds.gv.at>.
- ▶ E-connected initiative: www.e-connected.at (information available in German).
- ▶ Österreichische Forschungsförderungsgesellschaft mbH (FFG), Austrian Research Promotion Agency: <http://www.ffg.at/content.php> (information in German and English).
- ▶ Austrian Mobile Power: <http://www.austrian-mobile-power.at/en/index.htm> (information available in German and English).
- ▶ Electric vehicle model region Voralberg (information available in German): www.vlotte.at.



15.1 Introduction

The automotive sector has always been one of the most important industrial sectors in Belgium. In 2008 the turnover of the automotive sector was €15.9 billion and 81,661 people were employed at the nation's assembly plants and suppliers. But as in many other West European countries, the local automotive sector is under severe pressure. Compared to 2007, turnover dropped 7.7% and employment has decreased by 2.9%, according to the industry association Agoria Automotive. The local automotive industry needs a fundamental transformation to be able to tackle future challenges of a potential rise in oil prices and European requirements to reduce CO₂ emissions, and hybrid and electric vehicles can play an important role. But immediate actions are needed from all stakeholders: government, industry, the research community, and the education sector.

15.2 Policies and legislation

Federal and regional governments took actions in 2009 to support the further introduction of hybrid and electric vehicles in Belgium. Special tax rules have been set up to stimulate the business and residential markets to choose more environmentally friendly vehicles.

BUSINESS MARKET

The company car tax is based on CO₂ emissions, with the deductibility of expenses related to car usage having most recently been changed to range between 50% and 120% of the purchase cost. The 120% deductibility is meant to stimulate the use of pure electric vehicles, and the company is also allowed to write off the investment over a period of two years. Also, the extra legal advantages for the user of the company car will now be based on the level of CO₂ emissions of the car.

RESIDENTIAL MARKET

Tax incentives are granted to private persons purchasing a car based on CO₂ emissions per kilometer. The incentives consist of a reduction on the invoice price by the following amounts:

- Cars emitting less than 105 g CO₂/km: 15% of the purchase price, with a maximum of €4,540
- Cars emitting between 105 and 115 g CO₂/km: 3% of the purchase price, with a maximum of €850

- For diesel vehicles (< 130 g CO₂/km) and with a diesel particulate filter (< 5 mg CO₂/km): a bonus of €210

Extra incentives have been worked out to stimulate the introduction of pure electric vehicles. A distinction has been made among motorcycles, quadricycles, and passenger cars. Without going into too much detail, these are the general rules:

- Incentive not directly on the invoice, but via taxes
- For two- & three-wheelers: 15% of the purchase price, with a maximum of €2,770
- For quadricycles: 15% of the purchase price, with a maximum of €4,540
- For passenger cars: 30% of the purchase price, with a maximum of €9,000

OTHER

Several systems exist to define the environmental friendliness of vehicles, including fuel type, CO₂ emission level, or homologation legislation (e.g., EURO-4). However, these approaches are not sufficient to describe the complete impact on the environment. For this reason, VITO and other partners, including the Vrije Universiteit Brussel, have developed the Ecoscore methodology. With this methodology, climate change counts for 50% of the final score, health effects for 20%, impact on ecosystems for 20%, and noise for 10%. The pollutants considered are CO₂, CH₄, N₂O, CO, NMVOS, PM₁₀, NO_x, and SO₂. The environmental evaluation permits the combination of different effects in one indicator. The methodology is based on a well-to-wheel analysis. The Belgian government is evaluating how this methodology could be incorporated in the regulations, but at this point it is being used as an objective information source to compare the environmental friendliness of different vehicles.

More information on how car models rate according to this system can be found at www.ecoscore.be, which may be read in English by choosing “EN” in the upper left-hand corner.

15.3 Research

The following key organizations (including research institutes, universities, private companies, and other platforms) are involved in Belgian research on hybrid and electric vehicles: VITO, Katholieke Universiteit Leuven (K.U.Leuven), Vrije Universiteit Brussel (VUB), Flanders’ DRIVE, Green Propulsion, the Limburg Catholic University College (LCUC, or in Flemish KHLim), and the electric vehicle not-for-profit organization AVERE, together with its Belgian arm, ASBE.

VITO

VITO (Flemish institute for technological research) is a leading independent European research and consulting centre developing sustainable technologies in energy, environment, materials, and remote sensing. VITO's 600 highly qualified employees co-operate with sector federations, universities, European research institutes, and business communities. The budget of 2009 was €88 million, of which more than half was from contract research.

The energy unit has a strong link with sustainable transport, such as hybrid and electric vehicles, and combines two units with very complementary knowledge bases: the Energy Technology Unit and the Transition Energy and Environment Unit. The Transition Energy and Environment Unit's connection to hybrid and electric vehicles is less direct in that it does research simulating different scenarios of energy consumption and the environmental impact of vehicles and traffic flows with models. However, VITO's Energy Technology Unit is conducting research that engages hybrid and electric vehicles.

The topics studied in the Energy Technology unit includes both vehicles and the electrical infrastructure that they will connect to. Energy production has to be matched continuously with the energy demand in the electricity grid. Integrating more distributed and renewable energy sources in the grid, will lead to more unpredictable energy production. Therefore energy demand flexibility, through intelligent control systems, and local energy storage will play a crucial role in "smart grids." Within the programme "Smart energy systems for smart grids," VITO focuses on all these aspects and also on the inverters (DC/DC and DC/AC) for grid connection. Apart from the innovative simulation models and monitoring instruments, VITO has an extensive smart grid test infrastructure at its disposal which combines a thermal-technical and electrical lab with battery test infrastructure and a test bench for hybrid vehicles.

Hybrid and electric vehicles can play a crucial role in the transition to a more sustainable transport sector in the near future. VITO performs research on different areas in this field, from improving the energy efficiency of the vehicles itself (e.g., via brake energy recuperation) up to the integration aspects of plug-in and electric vehicles in the electricity network of today and tomorrow. This is depicted in figure 15.1.

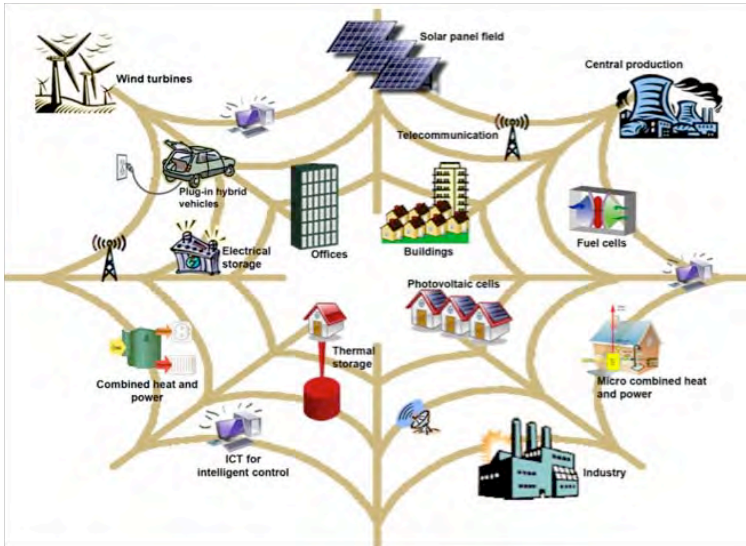


Fig. 15.1 Plug-in hybrid and electric vehicles and smart grids: A perfect match.

Smart grids offer a solution for electric vehicles: hybrid and electric vehicles can easily charge their batteries with (ideally) green electricity via the grid at moments that are advantageous for the network as well as the user, in an approach known as intelligent charging. A smart grid relies on the integration of power electronics, intelligent communication structures, and control algorithms, which are some of the research areas of VITO.



Fig. 15.2 VITO's first plug-in hybrid vehicle (Photo courtesy of VITO).

Besides research, VITO also has a more social role of promoting sustainable technologies, for example, by stimulating the use of hybrid and electric vehicles in Belgium. This is possible by informing stakeholders about the potential social and ecological benefits. Therefore VITO has converted one of its Toyota Prius fleet cars into a plug-in vehicle (see figure 15.2). This fits quite well with the scope of the internal research projects, but gives also extra visibility of new technologies to a broader audience.



Fig. 15.3 Brake-energy recovery on hybrid buses using ultracapacitors (inset). (Photo courtesy of Van Hool).

VITO is also working on the energy efficiency of the vehicle itself. VITO has developed an energy storage system for use in hybrid diesel-electric city buses, shown in figure 15.3. The energy storage system is used to store the regenerated braking energy, which later gets used when the bus starts to accelerate or when the bus needs some additional energy under certain driving conditions. By using ultracapacitors as the basic storage cell, this process of storing and releasing energy can be repeated very frequently for a long time. A control system manages the complete storage system and communicates the status of the system to the drivetrain controller. Hybrid buses equipped with this storage system consume up to 25% less fuel than similar diesel buses and are less noisy. VITO has transferred this technology to a spin-off company, Bluways, for the further commercialization of energy storage systems in different types of heavy-duty hybrid vehicles.

Other research projects at VITO related to hybrid and electric vehicles include ESTO and Trans2House. The ESTO project seeks breakthroughs in energy storage technologies such as lithium-ion battery cells and packs and battery management systems. Partners in this effort are Flanders' DRIVE, Emrol, PEC, PsiControl, Punch Powertrain, Triphase, Umicore, VDL Jonckheere, VITO, and VUB. Trans2House, short for "Transition pathways to efficient (electrified) transport for households," is a study into how to develop driving forces and shift the social, cultural, technological, economic and political barriers to household energy consumption reduction, with transport a major portion of this.

More information can be found at www.vito.be.

K.U.Leuven

The K.U.Leuven (Katholieke Universiteit Leuven), in particular the research group ESAT-ELECTA dealing with electrical energy-related research and teaching as a member of the K.U.Leuven Energy Institute, performs research on the production, transmission, distribution, and rational use of electrical energy. In this domain they conduct work related to electric and hybrid vehicles in the field of power electronics, electrical drivetrains, and grid integration of plug-in vehicles.

In power electronics, this group conducts fundamental work in the field of converter circuits suited for automotive applications. The focus is on the use of wide-band gap semiconductors such as GaN, having the advantage that high-temperature and ultra-compact converters can be built. In drivetrains the static and dynamic energy efficiency of the motor drivetrains (induction and permanent magnet motor) is modelled and related measurement methods are developed. Contributions are made to the standardization (IEC) in this field.

Special attention goes to the interaction of plugged-in electric vehicles with the electricity grid. In the intelligent "Smart Grid" that is being established, those vehicles will form a substantial but flexible electricity demand. Both grid-to-vehicle (G2V) and vehicle-to-grid (V2G) are studied and the bottlenecks in the electricity grid are identified and resolved. Smart charging methods are developed and tested.

More information can be found at www.kuleuven.be.

Vrije Universiteit Brussel

VUB (Vrije Universiteit Brussel) is a full (Dutch-language) university located in the Brussels capital region. It was created in 1969 as a partition of the (French-language) Université Libre de Bruxelles. It counts more than 9000 students and 2000 personnel.

In the Department of Electrical Engineering and Energy Technology (ETEC) of the VUB Faculty of Engineering Sciences, Professor G. Maggetto has led a long tradition (since 1974) of R&D on electric, hybrid and fuel cell vehicles. The research in these domains is now led by Professor Joeri Van Mierlo. The VUB has 35 years of experience in this field, making it the premier electric vehicle research facility in Belgium. ETEC's work mainly emphasizes the characterization, testing and demonstration of electric, hybrid and fuel cell vehicles and their components, such as electric drives and batteries.

ETEC is working together with a multitude of external partners, both from the industrial and the academic world, as well as with local authorities. Companies like Van Hool and Dana-Spicer make use of ETEC's expertise for the development and optimization of their new hybrid products. Currently ETEC is involved in the ESTO project that assembles the major players in the Flemish automotive industry around the application of Li-ion batteries in future EVs and HEVs.

ETEC has also participated in several past European projects in the field of electric, hybrid, and fuel cell vehicles. Currently ETEC is participating in the European SAFEDRIVE project, in which an open platform power management system using a scalable, low cost drive motor topology is being developed.

ETEC works closely together with the MOSI-t team at the VUB, which focuses on the application of socio-economic evaluation methods in the field of transport and logistics, and is led by Professor Cathy Macharis. Both teams work together under the umbrella of the MOBI research group, led by Professor Joeri Van Mierlo. The multidisciplinary nature of the group results in scientific expertise in which technical, social, and economical aspects of development and deployment of electrified vehicles are taken into account.

More information can be found at www.vub.be.

Flanders' DRIVE

Flanders' DRIVE is the competence center established in 2001 to support the Flemish automotive industry in their research activities. Targeted markets are passenger cars, trucks, buses, trailers and off-road vehicles, as well as services and suppliers. Activities focus on product and process innovation on different technological domains like manufacturing, lightweight materials, clean powertrains, and active safety. Flanders' DRIVE has about 170 active members and is setting up collaborative research projects with them in the domains mentioned above.

More information can be found at www.flandersdrive.be.

Green Propulsion

Green Propulsion was founded in 2001 as a spinoff of the University of Liege. It has since become an independent specialist in ever cleaner motorizations, including:

- Expertise for decision-makers based on practical experience with alternative fuels, battery electrics, hybrids, fuel cells, and an overall “Well to Wheel” vision
- Simulations and optimization of virtual vehicles for cost-effectiveness before development
- Evaluation of state-of-the-art technologies on its test benches
- Full development of prototype vehicles by a multidisciplinary team

Thanks to the 15 years of experience of its founders and the more than 15 unique prototypes it has built, Green Propulsion now works closely—not just as a subcontractor—with several European manufacturers, primarily in the fields of urban transport and motor sports.

In the field of plug-in hybrids, in particular, Green Propulsion is without a doubt one of the leading independent R&D centres in Europe, with no fewer than seven topologies and innovative management strategies to its credit.

In 2009, Green Propulsion mainly concentrated on the development of three prototype hybrid vehicles:

- A plug-in hybrid, 12-m urban bus equipped with the Automixte® combined series-parallel technology, which is now at the road test phase.
- A plug-in hybrid estate car combining electric predominance and CNG, which is now in the final assembly phase.

- ▶ The plug-in hybrid Imperia GP roadster, whose PowerHybrid® motorization has been following road tests for over 3 years under an Escort 1970 skin, and whose tubular chassis n°1 is now assembled.

More information can be found at www.greenpropulsion.be.

LCUC (KHLim)

The Limburg Catholic University college (LCUC, or in Flemish KHLim) has an important role in research and development. As a member of the University Association Catholic University Leuven, the KHLim focuses on applied research, bringing research results to companies and organizations on a national and international level.



Fig. 15.4 “Green” Charging Station for electric scooters. (Photo courtesy of KHLim.)

LCUC has built a “green” charging station powered by photovoltaic panels of 10 kWp, shown in Fig. 15.4. The charging station contains five charging points, namely Elektrobay and ChargePoint from Coulomb Technologies. ThePlugInCompany and 365 Energy are the respective distributors. The Elektrobay, for example, will supply 240 volts AC at 13 amps and is suitable for all electric vehicles and plug-in hybrid electric vehicles that are compatible with this voltage supply.

The research group ECO-2 develops sustainable, modular and situational charging infrastructure for electrical vehicles. For testing purposes 22 electric scooters were bought in China from the company Haoren. These e-scooters will be leased by the students of the KHLim campus. The e-scooters are equipped with a tracking system to analyze the use of the scooters. The impact of the driver’s weight on the range and the impact of the loading behaviour on the aging of the batteries are being investigated. At the moment, identification by RFID and the

potential of the back office systems for innovative billing concepts and other services (e.g., to localize free charge points) are being examined.

The charging station is integrated in a MicroGrid of 200 kVA. Future research projects will explore the impact of charging on the utility grid in grid-to-vehicle (G2V) and vehicle-to-grid (V2G) concepts.

Besides the technical aspects of charging infrastructure, ECO-2 also pays attention to design and the visual aspects of integrating charging stations into the landscape. ECO-2 is already collaborating with the cities Hasselt and Leuven to build specially designed and adapted charging stations.

More information can be found at www.khlim.be.

AVERE and ASBE

AVERE and ASBE, the Belgian chapter of AVERE, are non-profit associations, founded in 1978 under the aegis of the European Community, as a European network of industrial manufacturers and suppliers for electric vehicles. The Association's goal is to promote the use of battery, hybrid, and fuel cell electric vehicles, and to rationalize the efforts of its member companies in the scientific and technological developments.

It is composed of National Associations, 12 up to now, which indirectly represent over 500 companies active in the field. With EDTA covering the Americas and EVAAP covering the Asia Pacific region, AVERE and these other organizations form the World Electric Vehicle Association, or WEVA. AVERE is associated with CITELEC, the Association of European Cities interested in Electric Vehicles, and EURELECTRIC, the Association of the Electricity Industry in Europe.

With more than 500 members, AVERE represents the whole European electric vehicle industry and is an important force for the promotion of electric vehicles. With 400 members, industry is the most heavily represented in the organization, but AVERE is nevertheless linked with the other economic agents, such as end users and public organizations.

AVERE organizes conferences, meetings and workshops so that everyone involved in electric vehicle production can keep abreast of changing technology and evolving markets. In particular EET, the European ELE-DRIVE Transportation Conference, and EVS, the Worldwide International Battery, Hybrid and

Fuel Cell Electric Vehicle Symposium & Exhibition are worth mentioning. This latter event is jointly organized by AVERE and its two sister associations EDTA and EVAAP and is attended by more than 1,500 people involved in the world electric vehicle market.

The ASBE was restarted beginning in 2009 and brings together a mix of new EV entrepreneurs together with scientists and industry. ASBE, together with Febiac and Federauto (members of the ASBE) jointly published some guidelines for speeding up deployment of an EV-favorable climate in Belgium. The ASBE was chosen as the primary communication channel for all hybrid, plug-in hybrid and battery electric vehicle, infrastructure, regulation, education and press-related matters.

More information can be found at www.asbe.be.

15.4 Industry

Belgium still hosts several car assembly plants: Ford Genk, Audi Brussels, Opel Antwerp, and Volvo Cars Gent. Toyota Motor Europe also has a lot of activity in Belgium, including its European headquarters, logistics centres, and its technical R&D center for Europe. But besides the car OEMs, Belgium also hosts manufacturers of other types of vehicles, like bus and coach makers Van Hool and VDL Jonckheere and a truck assembly plant from Volvo. An important part of the activities can also be found in the local supplier base of about 300 companies at companies like Punch Powertrain.

Here we provide a description of some of these companies' activities in Belgium with a particular focus on those related to hybrid and electric vehicles.

Toyota Motor Europe

Toyota Motor Europe is active at different locations in Belgium and employs more than 3,000 people in the country. Locations include Toyota's European headquarters in Evere, the technical center and training center in Zaventum where cars are developed for the European market, logistics centers in Zeebrugge and Diest, and Toyota Belgium in Braine-l'Alleud. More than 386,900 Toyota cars pass through Zeebrugge each year to points across Europe. In 2008, the sales of Toyota cars in Belgium amounted to 28,363 units, which represents a market share of 4.3%.

Toyota is well-established in the area of hybrid vehicles with its Prius, and in

2007 it also announced that it had a project to develop a plug-in hybrid version of this car. Toyota Motor Europe is involved in the European road trials with the plug-in hybrid vehicle (or PHV, in Toyota's abbreviation). The automaker partnered with the French electricity group EDF to experiment with PHVs in France and in the UK. The cars have been provided to EDF employees, who have used them intensively in real-life situations: day-to-day commute from home to work, weekend trips, etc. One aspect of this pilot has been the development of an innovative charging and invoicing system.

In 2009, as a critical next step towards broader commercialization, Toyota announced that it was expanding its road trials to fine-tune the technology, study the market, understand consumer expectations, and prepare for a future launch. The company planned to produce about 600 Prius PHVs at the end of 2009, with about 200 to be delivered to selected partners and customers in Europe. France will again be at the heart of the project: in collaboration with EDF, Toyota will lease about 100 PHVs to selected fleet customers and public bodies in Strasbourg, supported by charging points in users' homes, the offices of business partners, in public parking lots and on public roads. The other vehicles will go to about 10 other European countries, including the UK, Portugal, Germany, Belgium, and the Netherlands. The plug-in hybrids will be leased to public authorities and organizations as well as private companies for 3 years.

More information can be found at www.toyota.eu.

Volvo Cars

"DRIVE Towards Zero" is Volvo Cars' vision for developing cars entirely free from harmful exhaust emissions and environment-impacting carbon dioxide. Volvo Cars is therefore working on optimizing the efficiency of traditional combustion engines, alternative fuels, and hybrid and pure electric cars.

Volvo feels that the most effective way to cut its product range's total carbon dioxide emissions in the short term is to reduce the fuel consumption of its diesel and petrol engines and to switch to renewable fuels. This is because cutting the emissions of cars sold in large volumes will make a bigger impact than making huge cuts in a small number of cars.

However, in the somewhat longer time perspective, the biggest potential for achieving significant reductions in environmental impact is with plug-in hybrid and electric cars. In early 2009, Volvo Cars introduced microhybrid technology, a start/stop function that switches off the combustion engine whenever the car

comes to a standstill. In 2012, Volvo expects to sell plug-in hybrids that can be recharged via a regular household electric socket. For shorter distances in and around cities, it is likely that dedicated battery-powered cars may be in demand. In 2010, Volvo will be carrying out comprehensive field tests with Volvo C30s equipped for dedicated battery power. At the end of the field tests, the results will be evaluated and a decision will be taken on possible market introduction. In this case, the Volvo Cars Ghent plant is a candidate to build these cars.

More information can be found at www.volvocarsghent.be.

Ford

Ford has different activities in Belgium, including a major assembly factory in Genk and a proving ground in Lommel. Since 1965, all vehicles developed by Ford of Europe have been tested and validated at Ford Lommel Proving Ground (LPG). The main purpose of a proving ground is to move the vehicle testing from the public roads to a controlled and safe testing environment. In that respect the proving ground needs to simulate a wide range of road types and events, all correlated with the customers' usage of the vehicle.

More information can be found at www.fordlpg.eu.

Imperia Automobiles

Imperia Automobiles was founded in 2009 as a spin-off from Green Propulsion. It will produce and sell the Imperia GP (figure 15.5) developed by Green Propulsion as well as its PowerHybrid® motorization.



Fig. 15.5 Imperia GP. (Photo courtesy of Imperia.)

The assembly hall is now under construction. Production of the Imperia GP, starting in 2011, is expected to reach 200 units per year.

More information can be found at www.imperia-auto.be.

Van Hool

Van Hool manufactures approximately 1,600 buses and coaches, and as many as 4,000 commercial vehicles annually of which 80% are exported worldwide. With a workforce of over 4,100 employees, Van Hool is a major bus manufacturer in Europe, offering a complete range of buses for public transport for international markets, ranging from a 9-m midi bus to a 25-m double articulated low floor bus, as shown in figure 15.6. Many public transportation companies are investing in environment-friendly vehicles at the moment.



Fig. 15.6 Range of Hybrid Buses. (Photo courtesy of Van Hool.)

AN OVERVIEW FROM SOME DEVELOPMENTS IN 2009:

- › Flemish public transportation company De Lijn put the first three of 79 Van Hool hybrid buses on order onto its routes. The first articulated hybrid diesel bus went into service in Ghent on March 10, 2009. On March 20, a standard hybrid bus was introduced in Louvain, and from April 27 onward, a midibus version was put into service in Bruges. After evaluating these three prototypes, Van Hool will start manufacturing the remaining buses from July 2010. De Lijn decided on a first investment of €15 million for

35 hybrid buses: 5 city buses, 5 ordinary buses, and 25 articulated buses. Twenty of these buses will ride in Ghent, 10 in Louvain, and 5 in Bruges. In June, De Lijn ordered another 44 hybrid buses (12-m long) for service in Louvain, Antwerp, and Hasselt. All the hybrid buses have to be delivered by the end of 2010.

- ▶ Dutch public transportation company Connexxion also has ordered 24 hybrid buses. On behalf of the Province Zuid-Holland, its transportation company Connexxion ordered 4 standard hybrid buses (A300 type). The vehicles were delivered and put into service in September 2009. Connexxion ordered another 20 hybrid diesel-electric buses of the same type for further expansion of its environment-friendly network.



Fig. 15.7 New-generation fuel cell hybrid electric bus. (Photo courtesy of Van Hool.)

- ▶ After the well-received introduction of the first fuel cell buses by Van Hool in California and Connecticut, a new order for 16 hybrid fuel cell buses has been placed (figure 15.7). The première of the first vehicle of the new series was on the Van Hool stand at Busworld 2009.

More information can be found at www.vanhool.be.

Punch Powertrain

Punch Powertrain was originally a part of VCST, designer and supplier of engine and driveline components, and pioneered with push belt continuously variable transmissions (CVT). Through the years the company remained a niche player in the transmission industry with a small customer base and fairly low production numbers. Finally in 2006, Punch International took over the company and renamed it Punch Powertrain. Under the new management, several

contracts for application projects were signed and production forecasts for the next years predict yearly volumes of 200,000-plus transmissions for customers in North-America and South-East Asia.

Following the takeover, Punch Powertrain initiated the development of a hybrid powertrain for passenger cars based on the VT2 CVT. Its efforts to develop a solution that would reduce fuel consumption while being cost-competitive and easily integrated into a vehicle has yielded a hybrid transmission based on many existing parts that are already produced in large volumes at low cost. A photo and exploded drawing depicting the new parts developed especially for this new transmission are included in figure 15.8, and another view is given in figure 15.9.

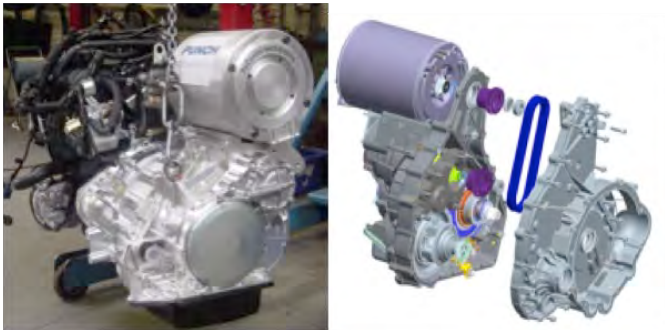


Fig. 15.8 Transmission with motor: Actual prototype and exploded view of new components. (Photo courtesy of Punch Powertrain.)

For the other hybrid powertrain subsystems, Punch Powertrain also made less obvious choices. The selected motor technology is a fairly new one known as Switched Reluctance (SR). SR motors allow a very dynamic operation like what occurs in a hybrid. Moreover, they combine the advantages of induction motors (low cost) and permanent magnet motors (high efficiency) without their usual disadvantages of torque ripple and noise.

For the battery system, Punch Powertrain is contacting suppliers of battery packs with LiFePO_4 cells. Their choice for this chemistry is based on its intrinsic safety and longer lifetime compared to other lithium-based chemistries.



Fig. 15.9 Powertrain being integrated into a demonstrator vehicle. (Photo courtesy of Punch Powertrain.)

In the spring of 2009 Punch demonstrated its new hybrid powertrain for the first time with a Smart ForFour as carrier, showing that the powertrain fits into a small, compact car (figure 15.10). The car was driven as an electric vehicle in initial tests. Although intended as an HEV motor, its EV performance is excellent. The vehicle is agile, motor noise is more than acceptable, and its torque is ripple-free. Then the powertrain control was modified for hybrid operation. Currently the vehicle is being fine-tuned and calibrated.



Fig. 15.10 The Smart ForFour HEV Demonstrator. (Photo courtesy of Punch Powertrain.)

The excellent performance of the electric motor inspired Punch Powertrain to convert another Smart ForFour to an EV. A large 15-kWh battery pack was sourced to provide an EV range of 80 to 100 km depending on the vehicle use. The vehicle has been in use for battery tests as well as electric motor assessment since November 2009. Its performance is excellent for city traffic and good enough for rural and motorway traffic. In 2010 Punch Powertrain will validate the hybrid powertrain strategy and establish the fuel-saving capabilities of its powertrain. It will also prepare the hybrid transmission and electric motor design for mass production. Punch Powertrain is also considering developing a transmission for EVs if market interest solidifies.

More information can be found at www.punchpowertrain.com.

Electric Drive bvba

Electric Drive bvba started to host the commercial activities of Joeri de Ridder, a technical expert responsible for electric car company Reva Benelux and chairman of AVERE Belgium. Electric Drive is the Belgian agent for the Dutch company Electrocar bv, who are the Benelux distributors of Melex and Goupil Electrotrucks. Melex has been building high-quality electrocars since 1971, and Goupil is the number one French manufacturer of commercial electric vehicles for use in parks, old city centers, cemeteries, and closed industrial plants. This very narrow truck of Goupil has impressive specs including 700 kg load capacity, 3.5m³ volume, 120km autonomy and 1.5 tons towing capacity.

More information can be found at www.electrocar.eu.

15.5

On the road

At this moment, the passenger car market in Belgium is still dominated by diesel vehicles. Belgium has one of the highest market shares of diesel passenger cars in Europe. Though we can see the growth of smaller and more environmentally friendly vehicles on the market, the share of hybrid and electric vehicles is still limited, as shown in tables 15.1 and 15.2.

Table 15.1 Number of new passenger cars sold in Belgium and average fuel consumption, 2002 through 2008. (Data © VITO.)

		2002	2003	2004	2005	2006	2007	2008	2008
Number of vehicles (x 1,000)	Gasoline	154	135	143	128	133	94	114	21%
	Diesel	288	303	342	351	392	430	425	79%
	Total	442	438	485	479	525	524	539	100%
Average fuel consumption (liters/100 km)	Gasoline	7.10	7.00	6.90	6.70	6.60	6.60	6.40	
	Diesel	5.80	5.80	5.70	5.60	5.60	5.60	5.50	
	Total	6.25	6.17	6.05	5.89	5.85	5.78	5.69	

Table 15.2 Hybrid car sales in Belgium. (Data © VITO).

MAKE	MODEL	2004	2005	2006	2007	2008
Honda	Civic	5	3	86	149	132
Lexus	GS 450h	0	0	47	101	73
Lexus	RX 400h	0	106	283	264	246
Lexus	LS600h & LS600hL	0	0	0	0	47
Toyota	Prius	126	362	486	778	1399
	<i>Total</i>	<i>131</i>	<i>471</i>	<i>902</i>	<i>1292</i>	<i>1897</i>
Total car market		484757	480088	526141	526141	539485
Share of Hybrids		0.03%	0.10%	0.17%	0.25%	0.35%

Motorized vehicle fleet data for Belgium is presented in table 15.3. Comparable separate data for hybrid electric vehicles was not available at the time of writing.

Table 15.3 Characteristics and population of the Belgian motorized vehicle fleet per August 1, 2005–2009. (Source: FOD Economie - Algemene Directie Statistiek en FOD Mobiliteit en Vervoer.)

Vehicle type	2005	2006	2007	2008	AUGUST 1, 2009	
	EV fleet	EV fleet	EV fleet	EV fleet	EV fleet	Total fleet
Motorized bicycle (no driver licence)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Motorbike	5	8	10	20	39	403,940
Passenger vehicle	22	13	8	10	10	5,192,566
Multipurpose pass. vehicle	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bus	n.a.	21	19	19	19	16,061
Truck	66	62	51	56	62	724,062
Industrial vehicle	965	886	942	1,004	1,099	238,160
Total	1,058	990	1,030	1,109	1,229	6,574,789

n.a.= not available

The definitions of the different vehicle categories can be found in section E of this report chapter "Vehicle categories."

Besides hybrid passenger cars, the first pure electric passenger cars are appearing on Belgian roads again, as can be seen in table 15.3. As to specific EV models that are on the roads, based on some market information we can state that we have about two Tesla Roadsters and 16 Revas driving in Belgium, most of them with lead-acid batteries, but also some with lithium-ion batteries (source: Electric Drive bvba). New market players are also starting to import and sell electric vehicles, including Ineltra Systems with the Italian Tazzari Zero (figure 15.11). The first five vehicles were sold after its debut at the Brussels European Motor Show.



Fig. 15.11 Tazzari Zero at European Motor Show Brussels. (Photo courtesy of Ineltra Systems.)

Besides hybrid and electric passenger cars, we can also see more and more commercial light-duty vehicles like Goupil (see figure 15.12). Center Parcs has chosen Goupil as sole supplier for service vehicles in all their European resorts after two years of extensive testing. These vehicles are also being used in cities including Antwerp, Brussels, and Kessel-Lo, and at industrial companies like Umicore, Electrabel-Suez, and VF-Europe. In Belgium this adds up to a total of 56 vehicles (source: Electric Drive bvba).



Fig. 15.12 Goupil G3-S at City of Antwerp. (Photo courtesy of Electric Drive bvba.)

Finally, we can also see some movement in heavy-duty hybrid vehicles like trucks and buses. Public transport in particular has increased its fleet of hybrid buses since 2009. In Brussels, the first full-electric bus has been put in service and in other cities (Brugge, Gent, Leuven, etc.) De Lijn has been rolling out an initial fleet of 79 hybrid buses.

15.6 Outlook

Like in most other countries worldwide, the interest in hybrid and especially plug-in hybrid and electric vehicles has grown enormously in Belgium. Electric mobility (e-mobility) has become a top priority on the agenda of national and regional governments, research institutes, and industry. Potential customers are anxious to get more information on the rollout scenarios and are curious about the expected benefits of those vehicles (cost, environmental, etc.). Expectations from all stakeholders are very high and the market looks very promising on economic and ecological scale. However, there are still huge technical challenges in the way of widespread e-mobility: for example, battery technology needs further development in terms of cost reduction, energy density, safety, and durability, and charging systems need standardization. Also, non-technical issues involving regulatory or social aspects of driving electric vehicles will play a crucial role, with uptake of electric vehicles partly dictated by user acceptance of new technology or required behavior changes.

It is clear that a wide range of stakeholders are involved in e-mobility, and all of them need to take action. A good example is the rollout of the charging infrastructure needed to support the introduction of electrified transport. Market introduction of plug-in hybrid and electric vehicles will be hampered without the rollout of a matching charging infrastructure. This means that the electricity and automotive sector need to work closely together, as we can see in some big demonstration projects in France (EDF-Toyota). In 2009 different new companies began to undertake the necessary actions to start the rollout of charging infrastructure in Belgium. For example, ThePluginCompany has been very active in installing the first charging stations (Electrobay) in Belgium, and at the moment there are about 50 “public” charging stations at clients like Brico, LeasePlan, McDonalds, VinciPark, Eandis, K.U.Leuven, KHLim, Toyota Motors Europe, and other sites. At this moment most charging infrastructure initiatives are coming from private companies. It is interesting to see that commercial charging station suppliers are also aware of the benefits from linking the charging station to renewable energy sources and talk about “green from well to wheel” solutions.

Because investments in the electricity grid are long-term investments, important choices have to be made to make sure the electricity grid is flexible enough to handle a massive introduction of electric vehicles in the future. This flexibility in the electricity grid is also needed to handle all future distributed renewable energy sources (for example, solar and wind) connected to the grid. We will need a “smart grid” with bi-directional energy and communication flows, but this will give opportunities for new services to the end customers.

On the European level and in most European countries, large initiatives have been taken to support new R&D and demonstration projects on smart grids, charging infrastructure, and ecological vehicles. In Belgium some studies have been initiated by local governments to perform SWOT analysis on the position of the local industry (one by Flanders’ DRIVE and one by BBL) and to investigate the set-up of a test bed for introducing electric vehicles into the Flemish society (coordinated by Flanders Institute for Mobility with support from VUB). The project will facilitate a test environment where companies and governments can try out new technologies and mobility concepts in the Flemish society thus revealing the concept for a successful and quick introduction of electric vehicles. The project will look into the impact of electric vehicles on mobility and travel patterns and also investigate levers for increasing their deployment. In 2009, a group of stakeholders from the electricity grid sector joined forces in the Flemish Smart Grids Platform and a specific workgroup on grid-connected vehicles will keep a link with the other initiatives in Belgium.

All those initiatives fit quite well with the more global approach on sustainable energy technologies for the future as described in the European Strategic Energy Technology (SET) plan. One strategic pillar in this plan is “smart cities” where e-mobility will be combined with intelligent energy-efficient buildings to develop complete “smart cities” and “smart regions” with low impact on the environment and high comfort for the people living there. Keeping the global targets on climate change and oil independence in mind, the key element in the future will be to think broadly to find innovative breakthrough concepts on mobility and energy in general. We should not settle for sub-optimal solutions but instead go one step further. This means that different sectors and also different types of stakeholders need to work together. A good example is the European Institute of Innovation and Technology (EIT), which launched a call in 2009 to bring together the complete knowledge triangle (education, research and industry) to stimulate entrepreneurship in strategic areas like sustainable energy, climate change, and information communications technology (ICT). Within the area of sustainable energy, the InnoEnergy consortium was designated by the EIT governing board to become the Knowledge and Innovation Community

(KIC). Within this consortium, Flanders and the Netherlands have joined forces to become the innovation hotspot on “smart cities” in Europe. From the Flemish side, VITO, K.U.Leuven, and Eandis are formal partners. More information can be found at www.innoenergy-initiative.com.

15.7

Benefits of participation

Participation in the activities of the IEA IA-HEV has several advantages:

- The exchange of information between relevant public research and development programs in the transport sectors of various countries allows for better preparation of Belgian national programs and projects.
- The informal personal contacts with experts from different countries and various organizations is a source of new ideas, collaboration and enlarged co-operation in various scientific, technological, and regulatory/standardization fields.

15.8

Further information

More information about Belgian organizations not explained above that are active in the field of hybrid and electric vehicles can be obtained from the following internet websites:

- www.agoria.be
Agoria is Belgium’s largest employers’ organisation and trade association, representing and helping more than 1,600 companies in the technology industry
- www.vim.be
VIM is a membership organization that consists of companies, knowledge centres and government agencies working or interested in the field of sustainable mobility
- www.vswb.be
Flemish Cooperative on Hydrogen and Fuels Cells. The objectives are to promote and support the introduction of Fuel Cells and hydrogen technologies in different applications
- www.ineltra-mobile.be
Sales, installation and service of charging stations (Mennekes and Rittal) and electric vehicles (Tazzari and Piaggio)
- www.theplugincompany.be
ThePlugincompany, market leader in Belgium and Luxembourg, is a leading provider of sustainable and easy to use “plug-in” solutions for recharging and driving electric vehicles via Elektrobay® charging posts.

- www.becharged.eu
Distributor and developer of recharging systems for electric vehicles.
- bluways.com
Energy storage systems for hybrid vehicles



16.1 Introduction

Transportation accounts for over one-quarter of Canada's total greenhouse gas emissions. The Government of Canada is committed to reducing Canada's total greenhouse gas emissions by 17% from 2005 levels by 2020, and is also committed to:

- ▶ the goal of having 90 percent of Canada's electricity provided by non-emitting sources such as hydro, nuclear, clean coal or wind power by 2020; and,
- ▶ introducing tough new regulations to limit greenhouse gas emissions from the automotive sector.

Canada is already a world leader in the use of renewable energy. Canada's electricity supply mix is one of the cleanest and most renewable in the world. Hydroelectricity, the largest renewable energy source in Canada, accounts for approximately 60% of Canada's electricity generation, making Canada the world's second largest producer of hydro power. Along with energy sources such as nuclear, biomass, wind, and solar, clean energy contributes approximately 73% of Canada's total electricity mix. As a result, the opportunity to reduce greenhouse gas (GHG) emissions by electrifying the transportation system is significant.

16.2 Policies and legislation

Though Canada does not have many federal regulations that specifically apply to hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (EVs), national policy is moving towards increasingly stringent GHG emissions standards that could encourage growing use of such vehicles. However, in 2009 some provinces began to address PHEVs and EVs in their policies, as Québec, Ontario, and British Columbia announced a variety of goals and plans to support the introduction of these vehicles.

Federal

New vehicles sold in Canada are required to meet the safety standards laid out in Canada's Motor Vehicle Safety Act (MVSA; see www.tc.gc.ca/acts-regulations/acts/1993c16/menu.htm). This act, administered by Transport Canada, regulates the manufacture and import of motor vehicles and motor vehicle equipment in order to reduce the risk of death, injury, and damage to property and the environment. New vehicles sold in Canada are also required to meet

emissions standards. Canada's national emissions regulations are established under the authority of the Canadian Environmental Protection Act and administered by Environment Canada (www.ec.gc.ca/CEPARegistry/regulations). In Canada, electric passenger vehicles must meet the same MVSA safety standards as those that apply to all passenger cars. The electric low-speed vehicle (LSV), however, does not have the same legal status as a passenger car, and so it is not required to meet the same strict safety standards. The LSV class was created for low-speed (maximum speed of 32 to 40 km/h) environments. Because LSVs were designed for controlled and protected environments, they also do not have to meet any crash test requirements. However, to offer a minimum level of safety, they must meet Technical Standard No. 500 of the Canada Motor Vehicle Safety Standards (CMVSS) for low-speed vehicles (www.tc.gc.ca/roadsafety/safevehicles/mvstm_tsd/tsd/5000rev1_e.htm).

In 2001, Transport Canada amended the MVSA regulations to allow the introduction of power-assisted bicycles in Canada. These are electric bicycles propelled either by the cyclist and a motor or by the motor alone. The current regulation specifies components for power-assisted bicycles; for example, it specifies a maximum of three wheels, one or more electric motors that can assist the cyclist up to a speed of 32 km/h and that do not exceed a total output of 500 Watts, and an on/off switch or mechanism that prevents the motor from being engaged until the bicycle reaches a speed of 3 km/h.

Because of the rising concern about the impact of GHG emissions, vehicle fuel consumption has become an issue of importance for governments. Over the past 30 years, Canada has had a voluntary policy for improving the fuel consumption of cars and light trucks. Despite some improvements in fuel consumption and emission-control technology that have resulted from adherence to these voluntary policies, the total fuel consumed and GHG emissions have still risen substantially over the last two decades.

In response to this increase, in 2005 Canadian vehicle suppliers signed a memorandum of understanding (MOU) to reduce GHG emissions from cars and light trucks by 5.3 million metric tons in 2010. Canada is also establishing stringent regulated standards to progressively tighten limits for greenhouse gas emissions from new cars and light trucks over the 2011 to 2016 model years, following the termination of the MOU. The proposed GHG emission standards would align with U.S. national standards for improving fuel economy and reducing GHGs, through the authority of the Canadian Environmental Protection Act, 1999 (CEPA).

On December 7th, 2009, the Government of Canada released draft regulations on the CEPA Registry for consultation with provinces/territories and stakeholders. Following these consultations and after having taken into consideration the views of interested parties, the proposed regulations are expected to be published in the Canada Gazette Part I for a 60-day formal public comment period. It is expected that the final regulations will be in place in the summer of 2010.

The proposed standards would require substantial environmental improvements from new vehicles and would put Canadian GHG emission standards at par with U.S. national standards and, by 2016, at par with the California standards. Through the implementation of the proposed standards, it is anticipated that the average GHG emission performance of the 2016 Canadian fleet of new cars and light trucks would match the average level of 155 g CO₂/km (250 g CO₂/mile) that has been projected for the U.S. This would represent an approximate 20% reduction compared to the new vehicle fleet that was sold in Canada in 2007.

Because of Canada's geopolitical links with the United States, all the above-mentioned standards and regulations are being continually developed with the intent of achieving full harmonization, both to ease the burden on the automotive industry and to facilitate trade and product availability. Canada also participates in the United Nations Economic Commission for Europe (UNECE) world forum for the creation of global technical regulations.

Transport Canada implements programs and strategies to protect the natural environment and promote a more sustainable transportation system. The ecoTRANSPORT Strategy is part of the government of Canada's ambitious agenda to protect the environment and the health of Canadians and to further Canada's economic prosperity. Initiatives announced to date include ecoFREIGHT, ecoMOBILITY, and ecoTECHNOLOGY for Vehicles (www.tc.gc.ca/programs/environment/ecotransport):

- ecoFREIGHT. This program aims to reduce the environmental and health effects of freight transportation through the use of technology.
- ecoMOBILITY. This program aims to reduce urban passenger transportation emissions by helping municipalities increase transit ridership and use sustainable transportation options.
- ecoTECHNOLOGY for Vehicles. This program explores how advanced technologies can help reduce vehicle GHG emissions, pollutants, and fuel consumption. Goals are to promote a sustainable transportation system for Canadians and to help Canadians make informed decisions about purchasing vehicles that use clean technologies.

Natural Resources Canada administers two related initiatives: ecoENERGY for Fleets and ecoENERGY for Personal Vehicles:

- ecoENERGY for Fleets. This program is designed to benefit trucking companies and other commercial fleet operations by helping them cut fuel costs and reduce harmful emissions. The initiative emphasises information sharing, workshops, and training to help fleets increase their fuel efficiency.
- ecoENERGY for Personal Vehicles. This program provides Canadian motorists with helpful tips on buying, driving, and maintaining their vehicles to reduce fuel consumption and GHG emissions.

Provincial and territorial

QUÉBEC

Québec wants to make itself known as a place that is in favour of and that possesses all the necessary assets for the distribution of electric vehicles. As such, the Government of Québec's 2010–2015 Action Plan for electric vehicles, which will be unveiled at the start of 2010, will adopt concrete measures to implement the pre-requisites for introducing electric cars, including supporting the related industrial development and backing and stimulating the demand for these new vehicles.

The Government of Québec has already announced a purchase/lease incentive for recognized energy-efficient vehicles. This incentive is available for purchases or leases made between December 31, 2008, and January 1, 2016. The amount of the tax credit will be based on the environmental performance of the vehicle and will vary from \$2000 to \$8000.

Hydro-Québec has developed an Action Plan for transportation electrification. Their Action Plan consists of four thrusts:

1. Financial support for the development of electrical infrastructure for public transit
2. Development and marketing of advanced technologies
3. Test-driving and experimenting with integration into the power grid
4. Planning of support infrastructure for vehicle charging

As part of their Action Plan, Hydro-Québec is conducting projects to demonstrate the reliability and advantages of plug-in vehicles.

- ▶ Hydro-Québec has signed a three-year agreement with the Ford Motor Company and the Electric Power Research Institute (EPRI) under which Ford provided it with a prototype Escape Plug-In Hybrid in June 2009. The only electric utility in Canada to sign such an agreement, Hydro-Québec will field-test this vehicle in order to analyze different charging modes and their impact on the power grid.
- ▶ In January 2010, Hydro-Québec and Mitsubishi Motor Sales of Canada Inc. (MMSCAN) announced the signature of a memorandum of understanding that will lead to the launch of Canada's largest all-electric vehicle pilot project in fall 2010. In collaboration with the City of Boucherville, Hydro-Québec will test the performance of up to 50 all-electric Mitsubishi iMiEVs (see figure 16.1) on the road under a variety of circumstances, notably winter conditions. The project, which is evaluated at \$4.5 million, is the first of its kind to include the participation of a car manufacturer, a public utility, a municipality, and local businesses that will integrate the vehicles into their existing fleets. The trial is designed to study the vehicles' charging behaviour, the driving experience, and overall driver satisfaction.



Fig. 16.1 Mitsubishi iMiEV. (Photo courtesy of Hydro-Québec.)

In April 2009, the Québec Advanced Transportation Institute (ITAQ) launched a one-of-a-kind advanced transportation laboratory for the Canadian development of the automobiles of tomorrow. ITAQ focuses on energy efficiency, reduction of greenhouse gases and pollution emissions, and promotes renewable energy sources in the ground transportation sector. ITAQ is mainly involved in the following three areas of activity: hybrid and electric traction, biofuels, and energy efficiency.

ONTARIO

Ontario's target is to become a world leader in building and driving electric cars. In July 2009, the provincial government announced a goal to have one out of every 20 vehicles driven in Ontario to be electrically powered by 2020. In support of this aim, Ontario has announced several incentives.

Those who acquire plug-in hybrid and battery electric vehicles will receive:

- Purchase incentives for new plug-in hybrid and battery electric vehicles acquired after July 1, 2010.
- A green vehicle licence plate that would allow drivers to:
 - Use less-congested High Occupancy Vehicle (carpool) lanes, even if there is only one person in the vehicle.
 - Access public charging facilities and parking at Ontario government and GO Transit lots.

The Ontario government will lead the way in building consumer demand by purchasing electric vehicles for the Ontario Public Service fleet. Twenty per cent of eligible new Ontario Public Service passenger vehicle purchases will be electric vehicles by 2020.

Infrastructure for charging electric vehicles will be built through a combination of private sector companies and Ontario's existing electricity utilities. The government will take the lead in supplying this infrastructure by ensuring recharging capacity is integrated into parking facilities owned by the Ontario government and GO Transit parking facilities for the public to use. Ontario is also working with the private sector and electricity organizations to develop business models for recharging facilities that will work within Ontario's regulated electricity market.

The environmental benefits of electric vehicles will vary depending on the source of electricity generation used to power them. In 2009, Ontario enacted the Green Energy Act (GEA), which among other goals, will seek to make On-

tario a leader in Renewable Energy in North America. The GEA will expedite the growth of renewable sources of energy, like wind, solar, hydro, biomass and biogas; and build on Ontario's commitment to eliminate coal from its power supply.

BRITISH COLUMBIA

The Province of British Columbia (BC) is committed to reducing greenhouse gas emissions from the transportation sector by investing in new technology requiring renewable fuels, raising public awareness, and offering a range of energy options for British Columbians. By working with businesses, educational institutions, non-profit organizations and other governments, British Columbia is moving forward on new and exciting transportation technologies. The focus will be on research and development, marketing strategies and demonstration projects to further promote innovative technologies to the world.

The Ministry of Energy, Mines and Petroleum Resources is currently leading a Plug-In Vehicle Project in BC, further supporting the Province's commitment to sustainable transportation through the use of new technologies. The project has a Steering Committee that includes the Ministries of Energy, Mines and Petroleum Resources, Transportation and Infrastructure, Environment, Labour and Citizens' Services, as well as BC Hydro, the City of Vancouver, BCTC, Green Fleets BC and the University of Victoria's Institute for Integrated Energy Systems. The Steering Committee is acting in five key areas:

1. Plug-In Vehicle Technology Deployment
2. Plug-In Vehicle Infrastructure
3. Plug-In Transportation Policy
4. Plug-In Transportation Market Transformation
5. Plug-In Transportation Technical Studies

BC Hydro, an active member of the Steering Committee, has completed charging infrastructure guidelines for BC, an initiative commissioned by BC Hydro and sponsored by Natural Resources Canada, with the intent of facilitating consistent and safe deployment of charging infrastructure required for charging electric vehicles at homes, businesses and on public streets. These guidelines were created by the Electric Transportation Engineering Corporation and provide an excellent reference for utilities facing the challenges of creating a comprehensive plan for the emerging electrical vehicle market. The Centre for Energy Advancement through Technological Innovation (CEATI) International is leading efforts to create a national guideline for Canada and is accepting comments and feedback on the guidelines developed for BC. The BC guidelines can be found on CEATI's website at www.ceati.com/ev.

BC Hydro is also planning an infrastructure demonstration project with multiple partners, including BC's Ministry of Energy, Mines and Petroleum Resources and the City of Vancouver. The project represents the implementation of the charging infrastructure guidelines with the objective of developing "best practices" for infrastructure deployment. The best practices will address stakeholder needs such as:

- A streamlined process for permitting and installation;
- Smart infrastructure designs that minimise the need for upstream infrastructure upgrades; and
- Insights into infrastructure deployment challenges for informing policy development for government and the utility.

The findings of the demonstration project will also help verify the guidelines and refine it into a more robust reference document.

BC Hydro was the first utility in Canada to announce a deal with Mitsubishi Motors to take delivery and begin road testing the i-MiEV (a fully electric vehicle) by the end of 2009.

Finally, on October 6, 2009, BC Hydro, the Province of BC, the Renault–Nissan Alliance and the City of Vancouver announced a partnership that will see British Columbia become the initial launch point for Nissan's Canadian zero-emission transportation program. British Columbia is scheduled to be the first Canadian province to receive the Nissan LEAF, Nissan's first all-electric real-world car, in 2011, in advance of global distribution in 2012.

16.3 Research

Canada has well-established ongoing federal research programs supporting more energy-efficient transportation, including PHEVs and fuel cell vehicles. In 2009, three additional initiatives which each support research into vehicle electrification were launched, including the Clean Energy Fund, Automotive Partnership Canada, and a prototype electric-drive rover development program within the Canadian Space Agency. Each of these programs is explained in further detail below.

PROGRAM OF ENERGY RESEARCH AND DEVELOPMENT

The Program of Energy Research and Development (PERD) is a federal, inter-departmental program operated by Natural Resources Canada (NRCan). PERD funds research and development (R&D) designed to ensure a sustainable energy future for Canada in the best interests of both the economy and environment. It

directly supports energy R&D conducted in Canada by the federal government and is concerned with all aspects of energy supply and use. The Clean Transportation Systems Portfolio, under PERD, supports R&D in the five following program areas:

- › **Electric Mobility:** This program concentrates on plug-in hybrid electric vehicles (PHEVs) and focuses its efforts on four activity areas: energy storage systems; electric drive components; powertrain optimization; and development of regulations for emissions and fuel efficiency.
- › **Hydrogen and Fuel Cells:** This program focuses research development and demonstration activities in six areas, namely: hydrogen production; hydrogen storage; hydrogen utilization; safety; codes and standards; demonstrations; and outreach activities. Activities not only serve to progress the transportation sector, but also to advance stationary and portable applications of hydrogen and fuel cell technologies, such as backup power for buildings and hand-held personal devices such as portable telephones.
- › **Advanced Structural Materials for Next-Generation Vehicles:** The vision of this program is to develop conventional and new materials, structural components and vehicle subsystems that can be used on virtually all types of next-generation vehicles enabling them to reduce their weight, and to improve their crashworthiness and overall fuel efficiency.
- › **Advanced Fuels and Technologies for Emissions Reduction:** This program conducts R&D to support the design and use of conventional and new hydrocarbon fuels, alternative transportation fuels, novel combustion technologies and associated technologies to reduce vehicle emissions and fuel consumption. Activities focus mainly on: fuel blends; new alternative transportation fuels; advanced diesel engines; conceptually new engines; and associated environmental and health issues.
- › **Particles and Related Emissions:** This program provides knowledge and tools to support the development of technologies to control and reduce emissions of particulate matter and other related emissions from transportation sources. Activities focus mainly on: the study, measurement and control of emissions formed during internal combustion engine operation; the study of how emissions from transportation sources affect smog levels, air quality and climate change; and the study of the public health impacts and associated economic burden of transportation-related emissions.

THE CLEAN ENERGY FUND

The Clean Energy Fund (CEF), part of the Government of Canada's Economic Action Plan, provides \$795 million over five years for research and development and the demonstration of promising technologies, including large-scale

carbon capture and storage (CCS) projects and renewable energy and clean energy systems demonstrations.

In the spring of 2009, a request for proposals was issued for smaller-scale, demonstration projects of renewable and alternative energy technologies and systems. On January 11, 2010, the Minister of Natural Resources announced the selection of 19 successful project proposals. Of specific interest are the two following projects:

- **Utility-Scale Electricity Storage Demonstration Using New and Repurposed Lithium-ion Automotive Batteries:** This project will address electricity storage for renewable and high-density urban applications. The project will demonstrate utility-scale electricity storage systems using new and repurposed automotive batteries. This concept will reduce cost for electric vehicle batteries providing a future market to meet urban electricity demand using automotive batteries.
- **Interactive Smart Zone Demonstration in Québec:** This project will ensure the installation of an interactive network area in a neighborhood of Boucherville. This will demonstrate different technologies and concepts related to modernization of electrical networks, in particular the deployment of infrastructure for charging electric and hybrid rechargeable vehicles.

AUTOMOTIVE PARTNERSHIP CANADA

Announced in April 2009, Automotive Partnership Canada is a five-year, \$145 million initiative to support collaborative research and design to drive the Canadian automotive industry to greater levels of innovation. This initiative is a partnership between five federal research and granting agencies under the Industry Canada umbrella. Research projects approved to date will focus on reducing weight by using more plastic parts in engines, improving the efficiency of transmissions, and advancing the state-of-the-art in longer-range electric vehicles.

CANADIAN SPACE AGENCY

The Canadian Federal Stimulus Budget 2009 provided an additional \$110 million over three years for the Canadian Space Agency (CSA) to contribute to the development of terrestrial prototypes for space robotic vehicles, such as the Mars Lander and the Lunar Rover, and the further development of other technologies and space robotics. In the particular case of a prototype rover development (see figure 16.2), solar powered electric-drive platforms are imperative requirements given the absence of oxygen for combustion on the lunar surface or Mars.

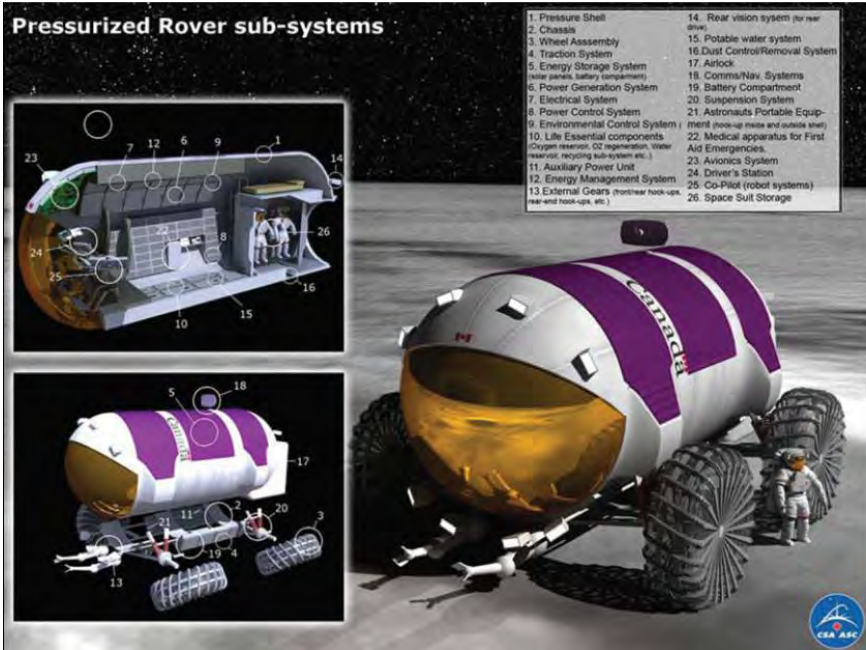


Fig. 16.2 Representation of a lunar rover prototype. (Photo courtesy of the CSA.)

The CSA strategy behind this R&D infrastructure contribution is to allow, de facto, parallel development of signature technologies that could be commercialized in terrestrial applications. The CSA will award contracts to a qualified set of industry-academia consortia towards the development of three types of prototype electric mobility systems in preparation for future space exploration missions towards the Moon or Mars. The strategic nature of these electric mobility infrastructure contributions is characterized by:

- Canada's legacy in the field of specialized transportation in rugged environments, such as the Canadian pioneer early work by Joseph Armand Bombardier.
- A natural developmental continuity with Canada's robotics heritage.
- The synergy potential with Terrestrial Commercial Applications.

The synergy potential with both the automotive industry and with other Federal Science and Technology Departments are deemed to be in:

- Significant advances in lightweight, compact and high energy density energy storage devices (batteries).
- Advanced wheel-drive systems.
- Improved electric mobility systems reliability, safety and operations at ex-

treme temperatures.

- Advances in lightweight materials applicable for terrestrial transport applications to improve vehicle energy efficiency.

16.4 Industry

The Canadian automotive industry produces light duty vehicles—cars, vans, pickup trucks; heavy duty vehicles—trucks, transit buses, school buses, military vehicles; and a wide range of parts, components, and systems used in vehicles of this nature. To complement its manufacturing activities, the industry boasts a well-developed vehicle dealer network, plus an aftermarket organization which has grown into a world-class distribution system and service provider.

The automotive industry is Canada's largest manufacturing sector, accounting for 12% of manufacturing gross domestic product (GDP) and 24% of manufacturing trade in 2008. The industry consists of 17 passenger/commercial vehicle assembly plants and more than 1000 auto parts plants. It directly employs about 137,500 people in automotive assembly and component manufacturing. Manufacturing is clustered in central Canada, while distribution is spread across the country.

Canada's industry is active in planning for electric vehicles. In September 2009, the electric mobility association of Canada (EMC – Electric Mobility Canada), released its Executive Summary of the Canadian Electric Vehicle Technology Roadmap (evTRM), to the government of Canada (see Fig. 16.3). The full report is scheduled to be released in March 2010. The development of the evTRM was an industry-led initiative with government participation. The recommendations and strategic initiatives identified in the Executive Summary, as well as the full report, are available on line at www.evtrm.gc.ca. The government of Canada is currently in the process of identifying how it can best help industry in the implementation of the recommendations included in the evTRM.

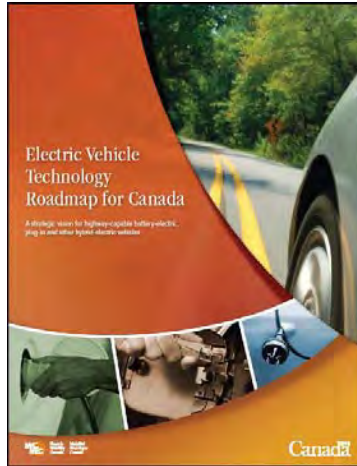


Fig. 16.3 Electric Vehicle Technology Roadmap for Canada.

Canada's industry continues to grow in electric vehicle-related directions as well. In October, 2009, the Bolloré Group announced an additional \$120 million investment in its Boucherville (Québec) battery plant for electric vehicles. The plant will initially produce 5,000 lithium-metal-polymer batteries a year. Bolloré plans to invest an additional \$100 million to increase the rate of production to 15,000 units within 18 months.

This plant is part of a larger plan from Bolloré to market electric vehicles. Bolloré is working with Pininfarina to produce its BlueCar, a fully battery electric vehicle that has already booked 6,500 orders and is to be available later in 2010.

In April 2003, the Government of Canada announced a \$9.9 million strategic investment as part of a \$33 million project being undertaken by Electrovaya Inc. The investment, funded through Technology Partnerships Canada, will support Electrovaya in developing smaller, more efficient, and high-power rechargeable batteries for portable wireless communications devices, electric vehicles and other mobile vehicles, such as forklifts and golf carts. In August 2009, the government of Ontario announced an investment of up to \$16.7 million to support battery research and pre-commercialization activities at Electrovaya. Electrovaya is a world leader in the design, development and manufacture of its proprietary Lithium Ion SuperPolymer® battery systems.

16.5

On the road

The only vehicle data currently available in Canada are based on provincial vehicle registrations and are for light-duty passenger vehicles and light-duty trucks. The registered population totals of EVs and HEVs from 2004 to 2008, as of July each year, are shown in table 16.1.

Table 16.1 Light-duty vehicle registrations in Canada, as of July each year. (Source: Desrosiers Automotive Consultants Inc.)

TYPE OF FLEET	2004	2005	2006	2007	2008
EV fleet ^(a)	14	11	18	21	29
HEV fleet	2,939	6,053	13,253	25,783	45,703
Total fleet ^(b)	18,709,017	18,882,567	19,365,344	20,242,775	21,202,441

(a) The EV fleet includes registered light-duty passenger vehicles, light-duty trucks, and low-speed EVs.

(b) The total fleet numbers include all propulsion systems and fuels (gasoline, diesel, liquefied petroleum gas [LPG], natural gas, biofuels, etc.).

16.6

Outlook

The outlook for EVs, HEVs, and PHEVs in Canada over the coming years will depend greatly on their availability in the Canadian market. The popularity of current-technology HEVs has increased steadily over the last 5 years and will continue to increase as more models become available. The Government of Canada and some Provincial Governments are currently developing, and in some cases implementing, strategies for clean energy technologies that could assist with the introduction of EVs and PHEVs in Canada. There are a number of barriers to address for the uptake of these vehicles to succeed. Cost, infrastructure, and public acceptance will be key issues that will require government attention. Creating an environment that will promote the market introduction of these vehicles, will greatly improve our chances of success.

16.7

Benefits of participation

Participation in the activities of the International Energy Agency's (IEA's) Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes is important to Canada because it:

- ▶ Encourages the development and commercialization of hybrid and electric vehicles.
- ▶ Allows Canada to exchange information on policies, R&D programs, demonstrations, and other supportive initiatives with member countries and to learn from their experiences.
- ▶ Offers the country opportunities to collaborate on R&D projects and joint studies in areas of mutual interest when possible, through the sharing of resources.
- ▶ Gives Canada a place to learn about technology developments by industries in member countries.

16.8

Further information

The following websites may be consulted for further information:

FEDERAL

- ▶ www.ec.gc.ca (in English and French)
Environment Canada
- ▶ www.nrc-cnrc.gc.ca (in English and French)
The National Research Council (NRC)
- ▶ www.nrc-cnrc.gc.ca/automotive (in English and French)
The National Research Council (NRC) – Automotive sector
- ▶ www.apc-pac.ca (in English and French)
Automotive Partnership Canada
- ▶ www.nserc-crsng.gc.ca
Natural Sciences and Engineering Research Council of Canada (NSERC)
- ▶ www.nrcan-rncan.gc.ca/com (in English and French)
Natural Resources Canada (NRCan)
- ▶ www.nrcan.gc.ca/eneene/science/index-eng.php (in English and French)
NRCan's Office of Energy Research and Development (OERD)
- ▶ www.nrcan.gc.ca/eneene/science/perdprde-eng.php (in English and French)
NRCan's Program of Energy Research and Development (PERD)
- ▶ www.tc.gc.ca (in English and French)
Transport Canada

- www.ic.gc.ca
Industry Canada

PROVINCIAL

- www.hydroquebec.com/transportation-electrification
Hydro Quebec's Action Plan for transportation electrification
- www.hydroquebec.com/technology
Hydro Quebec's Research Institute (IREQ)
- www.empr.gov.bc.ca/RET/TransportationPolicyPrograms
BC Ministry of Energy, Mines and Petroleum Resources
- www.bchydro.com/about/our_commitment/sustainability/plugin_vehicles.html
C Hydro, Plug-In Vehicles

OTHER

- www.ceati.com
Centre for Energy Advancement through Technological Innovation
- www.evtrm.gc.ca
Canada's Electric Vehicle Technology Roadmap
- www.emc-mec.ca
Electric Mobility Canada – Mobilité électrique Canada
- www.itaq.qc.ca
L'institut de transport avancée du Québec



17.1 Introduction

In January 2007, the Danish government announced a new energy strategy aiming for a higher share of renewable energy in the Danish energy system. The long-term vision is to obtain independence from fossil fuels such as coal, oil, and natural gas.

The government's goal is to double the current share of renewable energy of 15% to at least 30% by 2025. As of 2009, biomass accounts for almost half of the use of renewable energy, and wind turbines produce about 20% of the total electricity consumed. In 2025, 50% of the electricity consumed might be produced by wind turbines through expansion of the total capacity from 3,000 MW to about 6,000 MW.

This new energy strategy faces several challenges. A major one is to adapt the electricity system to manage a considerably higher share of intermittent electricity produced by wind turbines. Flexible electricity consumption will be an important factor, and in this context, battery, plug-in hybrid, and fuel cell electric vehicles (EVs) have now been assigned important roles.

17.2 Policies and legislation

Policies

The national energy strategy has included the transportation sector since January 2007. To reduce oil dependency and CO₂ emissions from the transportation sector, the main focus is to promote more energy-efficient vehicles and the use of biofuels. The Danish government has decided to give priority to development of second-generation biofuels produced mainly from agricultural waste products.

In August 2007, the Danish Energy Authority published a report on alternative fuels in the transportation sector. One of the report's conclusions is that in the long term, battery EVs have the potential for both the highest energy efficiency and important advantages for the local environment, such as no local emissions and a very low noise level. The electricity storage capability of the batteries has an interesting potential to optimize the integration of intermittent renewable energy such as wind power into the electricity system.

To support development and demonstration of new energy technologies to realize the energy goals, the government initiated the Energy Technology Development and Demonstration Programme (EUDP) in 2008. During 2008 and 2009, hybrid electric vehicles (HEVs) and EVs were increasingly identified and cited in political and public discussions as an optimal and realistic answer to the challenges of the transportation sector. The energy sector, especially, has shown a high interest in plug-in hybrid (PHEVs) and EVs as important means to meet the challenge to integrate 50% of wind power into the electricity system. The energy sector has advocated for demonstration programs for EVs with advanced engineering.

Additionally, last year saw the start of two major new programs to promote EVs, the EV promotion program and the new Centre for Green Transport, which will implement EV demonstration projects among its duties.

The Danish EV promotion program

In February 2008, almost all political parties in the Danish Parliament entered into a new Climate and Energy Agreement. As part of this agreement, the parties agreed to allocate 30 million DKK (€4 million) to the promotion of demonstration programs for battery EVs, beginning in December 2008.

The purpose of the EV promotion program is to obtain data about users' experiences with EVs. Monitoring experiences will help identify practical barriers for the deployment of EVs in Denmark. All knowledge gathered about technical, organizational, economic, and environmental factors associated with using, operating, and maintaining EVs will be made available to the public. Another purpose of the EV promotion program is to analyze the potential for EVs to store excess electricity production from wind turbines through intelligent recharging.

Organizations and enterprises with fleets of vehicles can receive subsidies for the acquisition of EVs and charging facilities when they participate in the program. Public authorities, as well as public and private enterprises and institutions, may apply.

All subsidized EVs are equipped with the same type of measuring instrument. This makes it possible to monitor usage of EVs in practice. Data are gathered about daily driving patterns, including number of trips, trip length, and the duration and time of day when the EV is charged. Users can also apply for additional subsidies if they participate in additional data-gathering activities on the use of their EVs. Finally, subsidies are also available for cross-sector projects, such as analyses of collected EV data and reports on communication of experiences.

The program is being administered by the Danish Energy Agency. In spring 2009, support was granted, totaling DKK 10 million for 17 projects with a total of 49 EVs, including cars, vans, minibuses, and trucks. In early 2010, about DKK 7 million will be allocated; DKK 5 million is expected to be allocated later in 2010 and in 2011 and 2012.

The new Centre for Green Transport

In the political agreement in December 2008 for “A green transport policy,” a total of DKK 284 million was allocated for initiatives to help reduce CO₂ emissions from the transportation sector. The Centre for Green Transport was established in April 2009 to create the framework for a Danish centre in the field of sustainable transport and to manage these initiatives. To create synergy between the specific initiatives and the most recent research and knowledge, the Centre collaborates with stakeholders in the private and the public sectors and conducts ongoing test and demonstration projects about energy-efficient transport solutions.

Projects conducted by the Centre include a transport certification program for municipalities and companies, an energy-efficient driving campaign, and energy labeling of light commercial vehicles. DKK 200 million has been allocated specifically for demonstration projects between 2010 and 2013 that promote environmentally aware and energy-efficient transport solutions, including test projects with alternative types of fuels, electric cars, electric buses, and electric trucks.

The Centre is a part of Denmark’s Road Safety and Transport Agency, which creates an optimal basis for influencing legislation both in Denmark and the EU.

Legislation

The Danish registration tax for passenger cars is very high (180%) and is based on the value of the car. In August 2007 the tax rules for light vehicles (passenger cars and vans) were changed to promote the sales of more energy-efficient vehicles. The new rules reduce the registration tax for gasoline cars that are more energy-efficient than 16 km/L (18 km/L for diesels) and a higher tax for less energy-efficient cars. The reduction is 4,000 DKK for each km/L higher than 16 km/L, and the extra tax is 1,000 DKK for each km/L less than 16 km/L. These changes have already had a considerable effect on the sales of passenger cars in Denmark. The share of small energy-efficient cars—especially diesel cars—has increased considerably.

The annual tax for the past several years has also been based on energy consumption and CO₂ emissions to promote the sales of energy-efficient and environmentally friendly cars.

There are no special incentives to purchase hybrid cars. Of course, the Prius benefits from the recent changes in registration tax and a low annual tax, but the price for the passenger version is still considered too high. A new possibility from January 2008 is to register the Prius as a van, with front seats only, qualifying this model for the lower tax rate on vans and thus reducing the price considerably. In 2008 and 2009, sales of the Prius increased significantly, but the absolute figures are still small.

Battery EVs and fuel cell vehicles are exempted from registration tax and annual tax until the end of 2012.

There are no special tax rules for PHEVs. As part of the new Climate and Energy Agreement, it is stated that tax rules with the necessary incentives to allow the introduction and deployment of plug-in hybrid vehicles should be decided. A government tax committee is now overhauling the taxation system for cars and is expected to present proposals for a revised tax system, including the future taxation of EVs and PHEVs, in the autumn of 2010.

17.3 Research

Denmark has no conventional automobile industry, but it houses many component suppliers. The main focus of Danish research in transportation technologies has been on biofuels and hydrogen and fuel cells.

Denmark has two world-leading companies—Novozymes and Danisco—that develop enzymes to produce biofuels. In 2007, construction of a full-scale demonstration plant for second-generation bioethanol using agricultural waste products began with support from the EUDP. Inbicon, a subsidiary of DONG Energy, opened the new plant in November 2009. It is one of the largest full-scale production plants for second-generation bioethanol in the world. The enzymes for the production are delivered by Novozymes and Danisco, and the production of bioethanol is distributed to the market by Statoil. Statoil is the first company in Denmark to sell gasoline blended with bioethanol.

The Danish Energy Authority has conducted a Hydrogen and Fuel Cell Programme for several years, focusing on research and development of solid oxide fuel cells (SOFCs) and polymer electrolyte membrane (PEM) fuel cells. SOFCs are demonstrated and tested as micro-CHP (combined heat and power) units running on natural gas. PEM fuel cells are demonstrated and tested as micro-CHP units running on hydrogen produced from off-peak wind power.

H2 Logic is developing fuel cell systems and hydrogen refueling stations for transportation use. One of the company's latest projects is the integration of a fuel cell system as range extender in a THINK City battery EV. Six of these vehicles are now in operation in Copenhagen and a hydrogen station has opened (figure 17.1).

Transportation efforts in Denmark related to hydrogen are coordinated by the Hydrogen Link Denmark network. Hydrogen Link together with similar networks in Norway and Sweden form the Scandinavian Hydrogen Highway Partnership, which aims to establish an early hydrogen refueling infrastructure. Seven hydrogen stations are now in operation and three more stations are under construction.



Fig. 17.1 THINK City EV with a fuel cell system as range extender at the opening of the first hydrogen station in Copenhagen in 2009. (Photo courtesy of H2 Logic)

Several activities and research projects were initiated in 2008 and 2009 to analyze the potential of intelligent charging systems and vehicle-to-grid (V2G) services for PHEVs and battery EVs. These activities are expected to expand considerably in the coming years.

In March 2009 the EDISON project began. The EDISON project is an international research venture partly publicly funded through the research program FORSKEL, administered by the Danish transmission system operator Energinet.dk. The total budget is approximately 49 million DKK (€6.5 million), 33 million DKK of which come from FORSKEL. The consortium behind the project consists of IBM, Siemens, DTU/Risø, DONG Energy, Eurisco, Østkraft, and Dansk Energi.

The aim of the project is to develop system solutions and technologies for EVs and PHEVs that:

- ▶ Enable a sustainable, economic, and reliable energy system with substantial fluctuating renewable energy.
- ▶ Provide a technical platform for Danish demonstrations of EVs with emphasis on power system integration.
- ▶ Are applicable globally and export Danish expertise in distributed energy resources and operation of energy systems with high wind power penetration.

The EDISON project connects research institutions and major industry enterprises to cover all stages, from research through concept and technology development to demonstration. The main emphasis is on the two first stages: research, and concept and technology development. The project also includes proof-of-concept where the developed technologies will be tested by using EVs and charging stations installed in the grid on the island Bornholm. Bornholm is chosen for the pilot test because it offers an opportunity to show the interaction between wind turbines and EVs in an isolated system. After a successful proof-of-concept test, the consortium expects to be ready for a large-scale demonstration by the end of 2011.

17.4 Industry

Denmark has no conventional car industry, but it houses many component suppliers. Denmark was one of the first countries to produce and market electric vehicles. Production of the small Ellert—which became the best-selling EV in the world—began in 1987, and in 1991 production of the KEWET El-Jet commenced. To facilitate sales of these vehicles in Denmark, EVs were exempted from registration tax and the annual car tax based on weight. However, both manufacturers have ceased production in Denmark, and improved versions of the vehicles are currently produced in Germany and Norway.

In 2008 and 2009, the new interest in electric drive vehicles in Denmark has to a large extent focused on the potential for using electricity from renewable sources in transportation, and on the role of the vehicles in adapting the electrical system to manage a higher share of intermittent electricity produced from wind turbines. As a result, a new trade association and three companies have recently launched in Denmark with the EV as their focus. The Danish Electric Vehicle Alliance, Better Place Denmark, ChoosEV, and CleanCharge Solutions are each described in further detail below.

THE DANISH ELECTRIC VEHICLE ALLIANCE

The Danish Electric Vehicle Alliance was established as a trade association under the Danish Energy Association in November 2009. The main objective of the Alliance is to represent the interests of member companies in matters regarding authorities, politicians, and organizations, both nationally and internationally.

The Danish Electric Vehicle Alliance represents 42 companies with a direct commercial interest in the introduction of EVs in Denmark, including energy companies, suppliers of components for the charging infrastructure, charging operators, and suppliers of EVs.

BETTER PLACE DENMARK

In January 2009 Better Place Denmark and DONG Energy closed a joint agreement investing €103 million in a nationwide Danish infrastructure for EVs, paving the way for Denmark to adopt EVs on a larger scale.

Better Place Denmark is developing and deploying EV services, systems, and infrastructure. The company works with all sectors of the transportation ecosystem, including automakers, battery suppliers, energy companies, and the public, to create a competitive solution scalable for global rollout.

To make the purchase of an EV feasible for the consumer, Better Place Denmark owns the expensive batteries and offers them as part of a subscription, thus eliminating a high extra cost for the car owner and making the EV's price competitive with the conventional car. Subscribers and guests get access to a network of charging spots (figure 17.2), battery switch stations, and systems—offering the mobility of the conventional car combined with an optimized driving experience and minimized environmental impact and costs.



Fig. 17.2 Prototype of the Better Place Denmark charging spot, thousands of which will be deployed in Denmark by 2010. (Photo courtesy of Better Place Denmark.)

Recharging the battery usually takes place at a charging spot because most car rides in Denmark do not exceed 100 km. For trips exceeding the current range limit for a fully charged battery (160 km), Better Place Denmark subscribers can switch the depleted battery for a fresh one in less than three minutes at a battery switch station. Better Place Denmark revealed and demonstrated a prototype of its battery switch station in May 2009.



Fig. 17.3 The Renault Fluence Z.E. is the world's first EV with a switchable battery. It will be launched in Denmark in the second half of 2011. (Photo courtesy of Better Place Denmark.)

Simultaneously with the charging infrastructure, the Renault Fluence (Figure 17.3) will launch in the Danish market in 2011. The Fluence is the first EV with a switchable battery. Better Place Denmark is working internationally to create partnerships with more car component manufacturers to develop EVs with switchable batteries. The Better Place Denmark infrastructure will be compatible with and open to all EVs, with or without the battery switch technology.

In 2009, Better Place Denmark entered an agreement with DSB, the state-owned Danish railway company, to provide door-to-door sustainable transportation by combining trains and EVs once the infrastructure is established. Together, the companies will deliver a shared EV service, which will be available at a number of major Danish train stations, starting with a pilot project at the Høje-Taastrup and Skanderborg stations in 2010. The two companies are also evaluating the possibility of establishing charging spots for EVs at other major commuter stations in 2012.

The first charging spots are already established in Copenhagen, and more will follow as a result of the agreements between Better Place Denmark and Danish municipalities and companies. Better Place Denmark has signed agreements with eight Danish municipalities and more agreements are under way. Better Place Denmark also enters into agreements with companies that wish to prepare for the introduction of EVs.

The first Danish battery switch station will be deployed during 2010, along with many charging spots. Before the full commercial launch in 2011, Better Place Denmark is planning to install enough battery switch stations to enable Danish EV drivers to drive from one end of the country to the other without the need to charge along the way.

The Better Place Denmark solution is focused on utilizing the high availability of wind energy in Denmark, making it possible to use wind energy more efficiently. An intelligent software solution, AutOS, will take into account wind forecasts, driving patterns, fluctuating energy prices, and various other factors when planning charging patterns for EVs. The software will be a key element in storing the vast amounts of excess wind energy produced in periods with low electricity demand by directing it to the batteries of the Danish EV fleet.

CHOOSEV

ChoosEV was established in November 2009, with the two utilities Syd Energi and SEAS-NVE and the car rental company Sixt as owners. The purpose of ChoosEV is to lease and maintain EVs (including PHEVs) and to establish an infrastructure of charging facilities throughout the country.

In summary, ChoosEV:

- ▶ Leases all types of EVs available for sale on the market.
- ▶ Provides and maintains charging facilities. The initial version of the charging facility will be capable of controlling the charging period to optimize the use of renewable energy in the grid.
- ▶ Offers tools to analyze driving patterns in an existing fleet to determine which vehicles could be replaced by EVs.



Fig. 17.4 Converted Citroën C1 EV. (Photo courtesy of ChoosEV.)

Because very few EVs are on the market, ChoosEV has decided to start with the sales and leasing of the converted Citroën C1 (Figure 17.4). The car will be converted by a company in Denmark. Five hundred EVs are expected to be on the road in 2010. The range of the vehicle is expected to be about 100 km. Users who need a longer range have the option of renting a gasoline or diesel car at a favorable rate.

CLEANCHARGE SOLUTIONS

CleanCharge Solutions is a small Danish company developing intelligent public and private charging facilities for EVs. Its main purpose is to optimize the possibility for the EV to charge according to the availability of renewable energy in the grid (figure 17.5). This is done by offering three main charging products:

- The public charging station—part of a Europe-wide network of public charging stations with the same technology (figure 17.6).
- The parking and workplace charger.
- The dedicated home charging socket.



Fig. 17.5 CleanCharge equipment displaying the actual rate of electricity from wind power in the grid. (Photo courtesy of CleanCharge.)



Fig. 17.6 Public charging station developed as part of European network. (Photo courtesy of CleanCharge.)

The basic electronics to optimize charging with renewable energy is the same in the three products. The main differences are the physical appearance and the payment systems. The solutions are based on open standards of communication and can accommodate other charging technologies and payment systems.

17.5 On the road

The total number of passenger cars in Denmark has just passed 2.1 million and is slightly increasing. However, the number of EVs has been slightly decreasing and was estimated at 200 at the end of 2008. The cars were mainly the French Citroën Saxo, Berlingo Électrique, and the Danish Kewet El-Jet. For several years, there were no sales of new EVs, and some EVs were taken out of service as a result of technical issues, such as problems with batteries or electrical equipment. Many EVs that were originally bought and owned by companies and public authorities have since been sold for private use or have been exported.

In 2009, however, sales of EVs were resurrected, to a large extent as a result of the Danish EV promotion program. In 2009, 111 new EVs were sold, and the total EV fleet by the end of the year was 292, as shown in table 17.1. About 350 City-El vehicles and a few electric scooters and e-bikes are also in use. With 5 million unmotorized bicycles in use, the Danish average more than one bicycle per person. However, electric bikes are still not selling in large numbers, even though their quality improved in 2008 and 2009. Many e-bikes are now equipped with lithium-ion batteries.

Until April 2009, only Toyota was marketing hybrid vehicles in Denmark. The Prius hybrid has been on the Danish market since May 2004, but only a limited number have been sold: as of the end of 2007, only 25 were registered in Denmark. However, as a result of the recent changes in registration taxation, sales in 2008 reached about 210 vehicles, and at the end of 2009, about 290 were registered. The most important barrier is still the high price of the Prius; also, there are no special incentives to buy one, such as a reduced registration tax.

Sales of the Lexus RX 400H hybrid sports wagon began in September 2005. Because of the Danish registration taxation rules, this car—configured as a van with only front seats—can be sold at a lower price than the Toyota Prius passenger car. By the end of 2009, about 60 vehicles were registered and on the road.

Table 17.1 Characteristics and population of the Danish motorized vehicle fleet per December 31, 2008 and 2009. Estimates are in italics.

Vehicle type	DECEMBER 31, 2008			DECEMBER 31, 2009		
	EV fleet	HEV fleet	Total fleet	EV fleet	HEV fleet	Total fleet
Motorized bicycle (no driver licence)	<i>10,000</i>	0	n.a.	<i>15,000</i>	0	n.a.
Motorbike ^(a)	350	0	200,000	350	0	200,000
Passenger vehicle	250	250	2,000,000	292	325	2,100,000
Multipurpose pass. vehicle	0	50	25,000	0	55	25,000 ^(b)
Bus	n.a.	0	15,000	n.a.	0	15,000
Truck	n.a.	0	50,000	10	0	50,000
Industrial vehicle	n.a.	0	n.a.	n.a.	0	n.a.
Total	10,600	300	2,290,000	15,600	380	2,390,000

n.a. not available

- a) Motorbikes include City-el.
- b) Not including vans. Many MPV's and SUV's are registered as vans in Denmark.

In 2006, the sale of the new Lexus GS 450h started in Denmark. The price is more than US\$200,000, but this car segment seems to be less sensitive to higher costs related to new advanced technology. At the end of 2009, about 10 GS 450h cars were on the road.

The Lexus LS 600h was introduced in the Danish market in 2007. Sales in this market segment are very limited in Denmark. As of the end of 2009, seven LS 600h had been sold.

The new Honda Insight hybrid was introduced to the Danish market in April 2009 (figure 17.7). By the end of the year, 18 vehicles had been sold.



Fig. 17.7 The new Honda Insight hybrid. (Photo courtesy of Honda.)

DANISH EXPERIENCES WITH BATTERY ELECTRIC VEHICLES

In 2005 the Danish Environmental Protection Agency (Ministry of Environment) published the report “Experience with electric cars in Denmark.” The report collated and assessed the practical experience of electric cars in Denmark from 1998 through 2001, and it also includes user experience from later years. The emphasis was on user experience with the new generation of Citroën and Think electric cars, which were marketed in Denmark from 1997 to 2004. These experiences might offer valuable lessons to apply to the introduction of next-generation EVs.

About 150 Citroën and about 20 Think electric cars were sold in Denmark, mostly between 1998 and 2002. Three-quarters, or 75%, of these vehicles were bought by municipalities and electricity companies, 5% by government agencies, 15% by private enterprises and 5% by private individuals. After 2002 more private individuals purchased second-hand electric cars.

Almost all users of electric cars in the study stated that they were very pleased with the performance of the cars, especially in city traffic. Many of them said that driving an electric car in congested urban areas with traffic jams and frequent stops was far less stressful than with a conventional car. The users reported that the electric cars accelerated well and could keep up with the traffic. They also considered the low noise level inside the car to be a great advantage.

All groups of users felt that the electric cars showed that they are well-suited to carry out the functions for which they were acquired. Private users have driven significantly more kilometers in their electric cars than public users, primarily because private owners used their electric cars in daily commuting to and from work.

Most users also experienced that the electric cars were reliable and had fewer breakdowns and visits to the repair shop than conventional cars. However, when problems have arisen, many were dissatisfied with the service from the repair shop. An important reason for the unsatisfactory service has been that it is difficult to establish a satisfactory service organization for a very limited number of electric cars operating throughout Denmark.

In this study, the experiences of the private owners in particular are very interesting as a background for an assessment of the potential of new improved technologies. These experiences could be an indication of the potential of the possible share of the electrically driven mileage of plug-in hybrid vehicles with a similar electric range of 70–100 km.

17.6 Outlook

From 2001 to 2006, EVs were not considered a realistic possibility for future road transportation in Denmark. However, the market success of hybrid vehicles and the new concept of plug-in hybrid vehicles have changed public opinion. In light of the new Danish target stating that 50% of the electricity consumption in 2025 should come from wind power, the combination of PHEVs and renewable energy from wind is seen as a very strong solution to some of the future challenges in the electricity and transportation sectors.

Demonstration projects with PHEVs and development of V2G technologies will be in focus in the coming years. Better Place Denmark's full-scale introduction of battery EVs and the activities of ChoosEV will also be in focus.

17.7 Benefits of participation

Participation in IA-HEV activities offers opportunities to:

- Exchange information on the latest developments in hybrid and electric vehicles and technologies.
- Make personal contacts with experts from different countries and organizations who are a source of new ideas that go beyond the information available through written communication.
- Make informal contacts with experts from other countries to discuss and evaluate new findings related to hybrids, PHEVs, and EVs, as well as new issues that come up in the member country.

17.8

Further information

More information about EVs in Denmark may be obtained from the following websites:

- ▶ www.danskelbilkomite.dk (in Danish) – Danish EV Committee.
- ▶ www.mst.dk/udgiv/publikationer/2005/87-7614-619-7/html (in Danish; a summary in English is also provided on this website) – A report on EVs in Denmark.
- ▶ www.danskeenergi.dk – Danish Energy Association.
- ▶ www.hydrogennet.dk – Danish hydrogen and fuel cell working group.
- ▶ www.scandinavianhydrogen.org – Scandinavian Hydrogen Highway Partnership.
- ▶ www.choosev.com – ChoosEV.
- ▶ www.betterplace.com – Better Place.
- ▶ www.cleancharge.nu – CleanCharge Solutions.
- ▶ www.ens.dk – Danish Energy Authority.
- ▶ www.edison-net.dk – The Edison Project.
- ▶ www.danskelbilalliance.dk – The Danish Electric Vehicle Alliance.



18.1 Introduction

The main topic of 2009 was the economic recession, as the crisis also hit Finland, whose economy is highly export-dependent. The total CO₂ emissions of the country were rapidly reduced, as was the sale of new cars: only 90,568 new cars were registered during 2009, as compared to 2008's amount of 139,535 (a 35% decrease).

Despite the recession, activities in the area of hybrid and electric vehicles developed well. In August, the Ministry of Employment and the Economy published a task force memorandum entitled "Electric Vehicles in Finland," which projects that the Finnish electric vehicle component and system industry will make remarkable gains in the future, and thus research and education in this field should be promoted. The memorandum also published a target number of electric cars to have on Finnish roads by 2020. The report's focus, however, is on creating business through an electric vehicles economy and not on electric vehicles as part of a climate policy. More detailed studies are to follow in 2010, with greater emphasis paid to the off-road heavy-duty vehicle industry, which is remarkably strong in Finland, unlike the car industry.

In the industrial sector, the most notable issues were the start of electric car production and the roof-wetting party at a lithium-ion (Li-ion) battery plant. Valmet Automotive, the only (passenger) car manufacturer in Finland, started the serial production of both the luxury golf car, Garia (figure 18.1), and small electric car, Think City (figure 18.2). Both vehicles are battery electric vehicles (BEVs). European Batteries, a Finnish Li-ion battery and battery management system (BMS) manufacturer, will start serial production during 2010 in Varkaus. In addition, Keliber Resources, Ltd., plans to open a lithium mine near the city of Kaustinen. It will be the first lithium mine in the EU.

The first fair held in Finland and targeted only to electric vehicles took place in November 2009. Industry professionals, researchers, enthusiasts, and the public met at the Electric Motor Show 2009 in the Helsinki Fair Centre. This event will be held again this year September 10–12, 2010.



Fig. 18.1 The Garia is tested on the assembly line (Source: Valmet Automotive).



Fig. 18.2 The first Think City cars were finished in December 2009. The target for 2010 is to increase production to several thousands of vehicles produced (Source: Valmet Automotive).

18.2 Policies and legislation

At the start of 2008, the purchase tax on new cars was changed so that it is based on CO₂ emissions. The effect of this tax change was visible in 2009. Figure 18.3 presents the average CO₂ emissions of registered cars by year. The change occurring between 2007 and 2008 is clear.

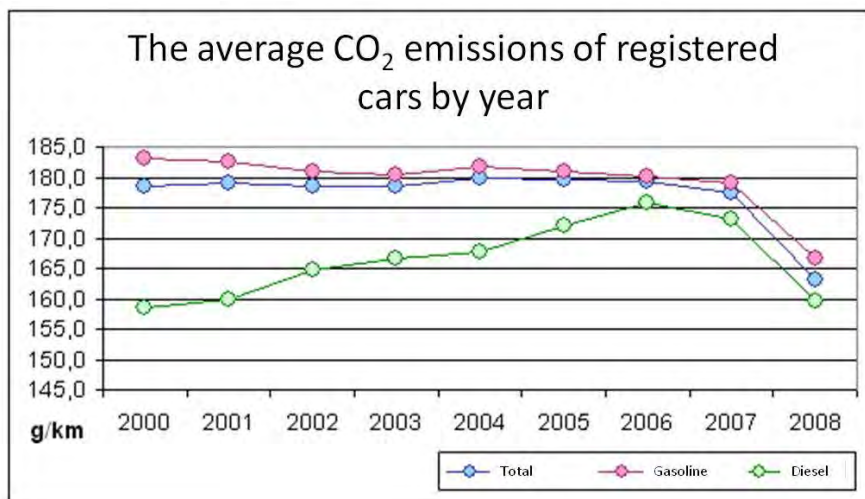


Fig. 18.3 The average CO₂ emissions of registered cars by year (Note: blue = total vehicles, red = gasoline vehicles, green = diesel vehicles).

During 2009, the main political happening in this area was the task force memorandum highlighted in the introduction. The memorandum pointed out that, because of the strength of Finland's electrical equipment and electronics manufacturing industry, the electric vehicle component industry should also become remarkably strong in the future. Therefore, more resources will be allocated to education and R&D in this area.

Also mentioned the first time was the 2020 target for electric vehicles: "In Finland the target is that in the year 2020, 25% of the new cars can be charged from the network and 40% of those are full electric." These targets are generally regarded as being rather optimistic.

In addition, the annual car tax will become dependent on CO₂ emissions. The new tax will be introduced gradually in 2010. The existing constant tax (127.75 euros/year) will then vary from between 20 euros (66 g/km or less) and 605.90 euros (400 g/km or more).

18.3 Research

Hybrid electric vehicle (HEV) research in Finland is mainly focused on off-road heavy-duty vehicles because of their industrial and economic relevance. Typically, research projects are financed by the Finnish Funding Agency for Technology and Innovation (TEKES) and national industry. HEV development is now under TEKES's Fuel Cell programme 2007–2013. The total budget of the programme is 144 M€. At the end of 2008, the programme board made a decision to move its focus from fuel cells and toward HEVs. TEKES will undertake a study concerning the business potential of the HEV industry in Finland during 2010. New financing policies in the HEV area will be based on the study.

Most of the research work is carried by the technical universities in Helsinki, Tampere, and Lappeenranta and by the VTT Technical Research Centre of Finland. Active projects focus on control and modelling of hybrid machines with different hybrid architectures and electric energy regeneration from hydraulic actuators.

The only active research partners in the car technology area are Metropolia University of Applied Sciences and VTT. Metropolia has developed an innovative city-car demonstrator based on the Toyota Prius and a full electric racing car, the "Electric RaceAbout."

VTT started a new research programme for energy efficiency and renewable energy in transport. The TransEco programme includes performance evaluation and also studies low-temperature performance of various hybrids and BEVs.

The energy company Fortum and Espoo City are testing electric cars (BEVs) for use by city employees. A total of five charging stations have been set up for the test. Fortum has also conducted a similar test with plug-in HEVs (PHEVs) in Stockholm, Sweden.

18.4 Industry

As mentioned in the introduction, in 2009 Valmet Automotive, the only (passenger) car manufacturer in Finland, started producing two BEVs. European Batteries will start serial production of its Li-ion batteries and battery management system (BMS) during 2010 in Varkaus. Finally, Keliber Resources, Ltd., plans to open a lithium mine near the city of Kaustinen.

Listed below are the principal players (and their specialties) in Finland's automotive and components manufacturing sector.

- ▶ **Akkuser Oy**, recycling of batteries: www.akkuser.fi
- ▶ **Axco Motors**, special motors and generators: www.axcomotors.com
- ▶ **European batteries**, manufacturer of Lithium-ion batteries and balancing systems: www.europeanbatteries.com
- ▶ **Hybria**, HEV system integration and software development: www.hybria.fi
- ▶ **Hydrocell**, manufacturer of fuel cells and hydrogen storage systems: www.hydrocell.fi/en/
- ▶ **Kabus**, bus operator and manufacturer; introduced a parallel hybrid city bus prototype at the end of 2007: www.kabus.fi/etusivu/96-etusivu/2151-briefly-in-english
- ▶ **Kalmar Industries** (part of Cargotec Corporation), manufacturer of terminal machines, including several EVs; introduced its prototype of a serial hybrid straddle carrier in June 2008: kalmarind.com
- ▶ **Keliber**, Lithium mining: www.keliber.fi
- ▶ **Konecranes**, manufacturer of industrial cranes and terminal machines, including several EVs: www.konecranes.com
- ▶ **MSc electronics**, power electronics, energy storage converters: www.mscelectronics.fi/sivut/
- ▶ **Rocla**, forklifts and AGVs: www.rocla.com/default.asp?lang=eng
- ▶ **Sandvik Mining and Construction**, mining machines, including several electric models: www.miningandconstruction.sandvik.com/
- ▶ **Valmet Automotive**, service provider for automotive industry; manufacturing of the Fisker Karma PHEV; first deliveries at the end of 2009: www.valmet-automotive.com
- ▶ **Vacon**, inverters and converters: www.vacon.fi

18.5

On the road

Tables 18.1 and 18.2 show fleet data by vehicle transport category for 2008 and 2009, respectively.

Table 18.1 Fleet data presentation categories for 2008. (Source: Finnish Vehicle Administration (AKE)).

VEHICLE TYPE	AS OF DECEMBER 31, 2008		
	EV FLEET	HEV FLEET	TOTAL FLEET (INCL. EVS AND HEVS)
Bicycles (no driver licence)	250 ^a	0	3,050,000 ^b
Mopeds	120*	0	215,165
Motorbikes	0	0	203,698
Passenger vehicle	100	1,141	2,682,831
Multipurpose passenger vehicle	0	0	13,030
Bus	0	1	12,230
Truck	0	0	105,106
Industrial vehicle	NA	NA	43,932 ^c
Tractor	0	0	360,795
Total	470	1,141	6,686,787

^a Estimate.

^b An estimate based on 370 000 new bicycles sold in 2007.

^c Registered machines.

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Table 18.2 Fleet data presentation categories for 2009: (Source: Finnish Vehicle Administration (AKE)).

VEHICLE TYPE	AS OF DECEMBER 31, 2009		
	EV FLEET	HEV FLEET	TOTAL FLEET (INCL. EVS AND HEVS)
Bicycles (no driver licence)	500 ^a	0	3,050,000 ^b
Mopeds	200*	0	238,174
Motorbikes	0	0	215,157
Passenger vehicle	120	1,876	2,758,291
Multipurpose passenger vehicle	0	0	12,821
Bus	0	1	12,974
Truck	0	0	110,638
Industrial vehicle	NA	NA	45,792 ^c
Tractor (agricultural)	0	0	366,995
Snowmobiles			117,051
Total	820	1,876	6,927,893

^a Estimate.

^b An estimate based on 370,000 new bicycles sold in 2007.

^c Registered machines.

18.6 Outlook

Year 2009 was dominated by the global economical crisis. Car sales and industrial activities decreased dramatically. However, one interesting development was seeing that the car purchase tax renewal in 2008 clearly reduced the average emissions of new cars, and the same trend continued in 2009. It seems that both government and the public are taking CO₂ emissions seriously. A large car is no longer considered a status symbol and people are increasingly inquiring why there are no electric cars available on the market.

A positive issue included activities in the HEV-related industry. A new lithium-ion battery factory and the planned opening of a lithium mine create the basis for future growth in business. The start of electric vehicle production—even in a small series—shows that HEVs can generate new business opportunities, even for the very small Finnish automotive industry. Charging stations and intelligent charging infrastructure can also be an opportunity for Finnish industry. The

existing, unique 1.5-million electric outlet network in car parks, today used for motor and cabin heating during winter time, combined with a robust power distribution network and a broad electronics and software industry provide a good basis to develop applications and solutions for intelligent charging.

It can be seen that the “early adopters” are already active in spite of the obstacles of a non-existent supply and very high prices for electric cars. Groups of individuals with various professional backgrounds are making electric cars by converting normal Toyota Corollas that are two to four years old into pure BEVs. This eCorolla society has an “open source” approach; that is, all engineering is published, and individuals as well as small car service companies are encouraged to make the conversions. This activity is considered a positive sign of adoption of EV use, although this activity is more of a hobby among enthusiasts than an industrial activity.

18.7

Benefits of participation

The numerous benefits of Finland’s participation in Annexes of the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) include:

- Remaining informed about technology developments and policies in other countries.
- The informal personal contacts with experts from different countries and various organizations is a source of new ideas, collaboration, and enlarged cooperation in various scientific, technological, and regulatory/standardization fields.
- Parties working in Finland can receive practical information based on experiences in other countries.

18.8

Further information

More information on Finnish activities regarding hybrid and electric vehicles can be found on the internet at the websites that are mentioned in section 18.4 “Industry.”



19.1 Introduction

Electric vehicles (EVs) have garnered increased attention recently in France. While there remains little doubt that this technology will have a significant impact on the French industry moving forward, several factors will determine just how quickly and deeply EVs will penetrate the European market and whether or not it will become a sustainable market segment. For these reasons, in 2009, the French government announced strong investment measures to assist the French automotive industry in anticipating its “electrification.” Those unprecedented governmental investments encouraged the French automotive industry to orient its research and development (R&D) and technology deployment roadmap from hybrid EVs (HEVs) to battery EVs (BEVs) and plug-in HEVs (PHEVs).

The drivers influencing France’s engagement with BEVs and PHEVs include secular and economic trends aligning to create opportunities for a new business model, and an increased focus on sustainability in developing the nation’s future ecosystem.

The automotive sector is undergoing a deep transformation

EV penetration requires that an entire ecosystem be in place, including cars, batteries, charging capabilities, and the interface to utilities. While it would be tempting to overlay the current industry structure onto EVs, that is not the way that disruptive technologies typically work. Separating the battery purchase from the car purchase is a more likely scenario, as Better Place’s pay-by-the-mile model aims to do. In addition, France is anticipating that the car industry will undergo a deep transformation for several reasons:

- In France, market demand has evolved, and a segment of consumers is turning to higher-quality and more fuel-efficient vehicles. Individuals within the younger segment of the market are also now looking at convenient mobility solutions rather than their next car acquisition.
- Consumers are acting as fleet operators, looking at the total cost of ownership. These consumers are more informed and more selective. In some cases, they question the value of or are not interested in owning a car.
- Finally, the bottom line is reducing fuel consumption, which has become a major concern to automakers because of customers’ priorities and the constraints of stringent European regulations.

This combination of the evolution of customers' preferences and emissions regulations is seen as a threat to automakers still using a business model based only on maximizing profit margins instead of reducing performance to the minimal needs actually required by the customers. However, prime movers — such as EV and PHEV pioneers and new entrants using a different cultural model such as being service providers — are attempting to catch this opportunity.

In contrast to those prime movers in EVs and PHEVs, the French automotive industry so far has preferred to invest in continuous improvement of existing technologies. France has developed significant competitive advantages with its small diesel cars and has been reluctant to make any changes that could jeopardize this comfortable position. However, those comparative advantages are not sustainable anymore, particularly when attempting to stay in front of the Asian automotive industry (figure 19.1).

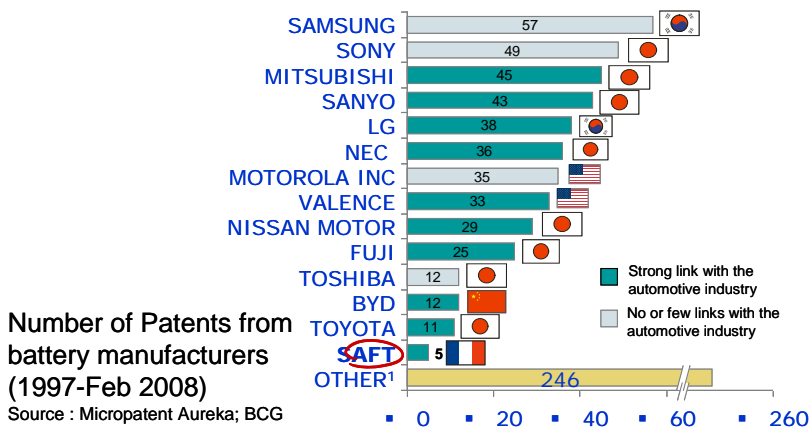


Fig. 19.1 Number of patents from battery manufacturers from 1997 through February 2008.

In this very dynamic environment, the French automotive industry needs to react to survive. Automakers need to adapt their economic models in order to market to the evolution in demand. In France, the EV is seen as the lever to implement those new consumer demand models, and it has become a necessity for the automakers to develop electric vehicle offerings.

Environmental sustainability has become a priority

The “Grenelle de l’Environnement” summit that occurred in 2007 identified new strategies to counter climate change and set other environmental goals that would be targeted by a national sustainable development program. Vehicle electrification is also viewed as part of the solution for achieving sustainability in France.

It is now believed that development along a model in which the transport of passengers and goods is accomplished primarily on roads now risks reaching its operational limits, as a result of its general implementation around the world and its impact on global warming. The threats to society are seen in:

- A very strong resistance to controlling, let alone cutting back, CO₂ emissions from transport vehicles in developed countries;
- Sharply rising CO₂ emissions in this sector, most notably on a global scale, with the growth of vehicle fleets (passenger cars in particular) in emerging-economy countries; and
- A nearly total dependence on fossil fuels, especially petroleum.

While the French government is engaged in combating the greenhouse effect, it is facing difficult challenges that require solutions to widely varying problems:

- Environmental issues (e.g., forthcoming regulation of pollutants and CO₂, modal transfer policies, mobility management policies);
- Economic issues (e.g., the large proportion of automobile industry jobs in industrial employment, economic models for alternative solutions [funding of public transport, urban planning, etc.]);
- Regulatory issues tied to our car-aligned transport system (where outlying urban areas are deprived of public transport, security requirements, etc.); and
- The place occupied by cars in our cultural imagery, in which cars are linked to the acquisition of independence, freedom, power, etc.

19.2

Policies and legislation

The French government is dedicated to steering the industry towards vehicle electrification by operating several levers. On March 26, 2009, Luc Chatel, Secretary of State in charge of industry, stated: “We can’t imagine that France won’t have electric solutions to offer in the coming years.” On October 1, 2009, The French energy minister, Jean-Louis Borloo, announced that the French government is aiming to have 2 million electric cars (the sum of BEVs and PHEVs) on the road by 2020. To recharge the batteries of these vehicles, the government aims to install 4.4 million charging points by 2020. In order to reach those ambitious economic and environmental goals, the French government:

1. Provided support to industry to get out of the automotive crisis and to anticipate the automotive industry transformation.
2. Developed a 14-point program aiming at tackling the barriers to EV deployment.

European emissions regulations context

The first approach consists of imposing emissions regulations. However, current regulations favor the continuous innovation of conventional vehicles. European emissions regulations aim to move emissions limits from 160 g CO₂/km as of 2006 to 130 g CO₂/km by 2015 (see figure 19.2). Though these limits are more stringent than those in the United States, Japan, or China, that 130 g CO₂/km level can still be reached by improving small diesel engine technology; therefore, specific policies are still needed to drive adoption of the electrification of the vehicles.

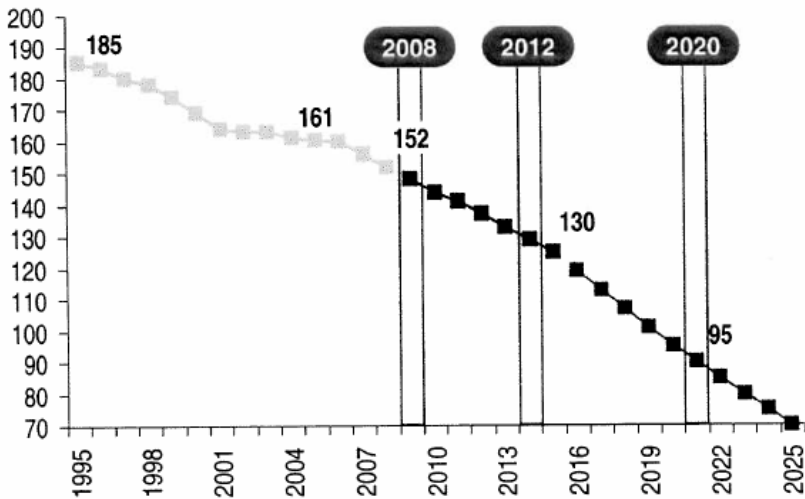


Fig. 19.2 European CO₂ emissions targets in g/km. (Source: ACEA.)

Support to industry

First of all, a set of specific measures has been set up to cushion the shock of the crisis in the automotive sector:

- **“Cash for clunkers” program:** On September 2nd 2009, the French minister of Economic Affairs, Christine Lagarde, announced that the country’s current cash-for-clunkers scheme, called *prime à la casse*, will be extended for two additional years. The initial plan was to end the program by the end of 2009, but the government believes that the car market would likely crash if the stimulus euros were withdrawn now. In order to apply for the €1,000 grant from the government, French car buyers need to replace an old car with one that has CO₂ emissions under 160 g/km.
- **€7.5 billion loans at 6% for 5 years:** French auto makers Renault SA and PSA Peugeot-Citroën received a government rescue package which includes €7.5 billion in low-interest industry loans by promising not to lay anyone off in 2009 or close factories. The government offered Peugeot-Citroën and Renault a five-year direct loan of €3 billion each at an interest rate of 6%, well below market rates, to help finance investment in producing low-polluting vehicles. An additional €500 million has been lent to Renault Trucks under the same conditions. The government has also allocated €1 billion in loans for the financing arms of Renault and Peugeot-Citroën, doubling an existing facility. The loans by the Societe de Financement de l’Economie Francaise, set up by the government to help banks overcome the financial crisis, aimed at helping auto makers give people credit to buy their cars.
- **A specific measure for low-CO₂ vehicles (bonus-malus system):** In 2008, the French government introduced a bonus-malus system based on CO₂ emissions. This plan included bonuses ranging from €200 to €5,000 for cars with emissions below 130 g CO₂/km, a penalty or “malus” levied for emissions from €200 to €2,600 if a car’s emissions are 161 g CO₂/km or above, and no reward or penalty for cars emitting at levels between these two boundaries. Also, initially the government planned to lower the CO₂ emissions limits at a regular pace of 5 g CO₂/km every two years for the automaker to adapt their production accordingly.
- However, in 2009, France decided to adopt a simpler system and to introduce a more stringent measure for the most polluting vehicles, namely, an annual tax of €160 for the vehicles emitting more than 250 g CO₂/km, as outlined in table 19.1.

Table 19.1 France's 2009 bonus-malus system.

	BONUS	NULL	MALUS	
CO ₂ emissions [g/km]	<120	121 to 160	161 to 250	>250
Bonus or malus [Euros]	From -200 To - 5,000	0	From +200 To +1600	+2,600 + annual tax of €160

A 14-point program aiming at tackling the barriers to EV deployment

The second type of policy directly concerns actions to speed up adoption of electric vehicles. On October 1st, Jean-Louis Borloo, France's Minister for Ecology, Energy, Sustainable Development and the Sea, presented a national 14-point plan designed to accelerate the development and subsequent commercialization of electric vehicles and plug-in hybrids in France.

Among the financial highlights of the plan are a public investment of €1.5 billion to establish a network of 1 million charging points by 2015 and the building of a €625 million lithium-ion battery plant at a plant owned by Renault with a public contribution of €125 million toward the total.

The 14 elements of the plan are:

1. ADEME (the French Environment and Energy Management Agency) will launch in early 2010 a new call for projects on infrastructure costs, to support plug-in demonstrators and trials combining infrastructure, applications and target territories, and to validate the functioning of the ecosystem of rechargeable vehicles. Budget: €70 million.
2. ADEME will establish early in 2010 a roadmap for specific new mobility solutions, dealing with developments in transportation of people or goods, based both on technology (new vehicles, dissemination of renewable energy, electric traction, etc.) and service (Vélib, Carsharing, Carpool, etc.) ADEME will then launch a new call for projects, with a budget of €25 million.
3. Renault will establish a lithium-ion battery factory in Flins, in partnership with CEA (France's Atomic Energy Commission), at an investment of €625 million. This site may produce more than 100,000 batteries per year. Bolloré, Dassault, and Saft are also conducting parallel projects.
4. A group of large companies and associations of local and state officials are committing to purchase electric vehicles with a range of at least 150 km.

The public tenders and private joint purchasing will target a market fleet of 100,000 vehicles by 2015. The first 50,000 are already identified. Led by La Poste, the group includes EPA, Air France, Areva, Bouygues, Darty, EDF, Eiffage, France Telecom, GDF SUEZ, SNCF, SPIE, UGAP, Veolia, Vinci, associations and communities represented by Association of Urban Communities of France and the Association of Regions of France.

5. A €5,000 grant for the purchase of vehicles with CO₂ emissions less than or equal to 60 g/km until 2012. Hybrids with CO₂ emissions that are less than or equal to 135 g/km may receive a bonus of €2,000, as will LPG or natural gas vehicles.
6. Availability of a standard outlet to charge the cars outside of the home.
7. The construction of buildings (offices and homes) by 2012 with compulsory integration of charging systems.
8. Supporting the installation of charging systems in condominiums.
9. Compulsory charge points in parking for office buildings by 2015.
10. Agreement on common European charging standards.
11. Municipalities to receive support to deploy the public recharging infrastructure.
12. Organize the operational deployment of the network. €1.5 billion for public infrastructure.
13. Maximize the use of low-carbon or renewable electricity for recharging vehicles.
14. Giving batteries and battery materials a second life after their vehicular applications, either through reuse (in grid storage, for example), or recycling.

Though much work remains to establish the specific details of applying these policies, these show France's intentions for vehicle electrification.

19.3 Research

Priority research demonstration projects for new energy technologies have been identified in the French national energy research strategy and in the work of the operational committee for research under the "Grenelle de l'Environnement" summit that occurred in 2007.

The first priority is to check the growth of forced urban mobility due to urban sprawl and develop alternative modes of transport to road vehicles, such as rail and waterway transport. Moreover, action is needed not only on vehicles themselves but also on their entire infrastructure or "ecosystem," including vehicles, their components, and how they are refuelled or recharged. In response to these

priorities, specific R&D measures have been taken to place individual passenger transport on a trajectory to reach ambitious goals such as “Factor 4,” which is an objective for France to reduce greenhouse gas emissions by a factor of four by 2050.

In this context, vehicle technologies that rely on electric power offer paths that are both promising and difficult to explore. At the Grenelle environmental summit, the French government decided on a special plan to move these technologies forward via a series of demonstration projects covering all aspects of the required ecosystem. This French R&D program for low-CO₂ vehicles consists in funding several research demonstrators with a budget of €400 million over 4 years.

In 2009, the French environment agency ADEME awarded €57 million via its technology demonstrator to 11 low-carbon vehicle projects selected through an initial call for proposals. The projects include light- and heavy-duty applications, and hybrid or electric powertrains. A second call for proposals for research projects on vehicle decarbonization ended 26 June 2009. Projects selected will be announced in mid-2010 and receive awards totalling €50 million. The projects selected for the first round of funding are:

- VELROUE project, developed by Michelin, Renault, and IFP, is a research demonstrator to demonstrate the feasibility of a vehicle equipped with dual, non-hybrid combustion engine-electric motor system. A rear-wheel motor and battery pack will provide electric mobility in urban areas
- FOREWHEEL, presented by Michelin, Heuliez, and CEA, will develop weight-optimized EVs featuring in-wheel electric motors with full braking and suspension functionality.
- HYDOLE, proposed by PSA, Freescale, and EDF, is working on a plug-in hybrid electric vehicle with an all-electric range of 50–70 km (31–43 miles).
- MHYGALE, proposed by Valeo, PSA, and Freescale, is developing an affordable mild hybrid solution that will offer stop-start, regenerative braking, and torque assist functions.
- VEGA/THOP, is led by Valeo and Renault and aims to improve the range of electric and hybrid vehicles, particularly in extreme temperatures, by offering innovative thermal systems which drastically reduce the amount of energy used to heat and cool the passenger compartment. Two Renault Mégane-type demonstration electric vehicles will be developed by 2011.
- DHRT2 (Démonstrateur Hybride Rechargeable Toyota II): Toyota, EDF, Ecoles des Mines, and the INES are fielding a test fleet of plug-in hybrid electric vehicles with innovative recharging infrastructure in urban areas.
- VELECTA: Aixam, the ECA, and INRETS are demonstrating light electric

vehicles. The consortium wants to integrate new technologies for rechargeable lithium batteries and electronic control of battery performance.

- ▶ QUAT'ODE: Véléance and CAR&D will construct a light quadricycle electric vehicle for urban deliveries.
- ▶ WATT, developed by the PSI, is developing demonstrator buses using supercapacitors for energy storage.
- ▶ Melody, proposed by Renault Trucks, PVI, and the IFP will build three heavy-duty hybrid demonstrators in various configurations (for urban delivery vehicles, refrigerated vehicles, and refuse collection vehicles).
- ▶ EILiSup is a project of Irisbus-Iveco, Michelin, EDF, CEA, ERCTEEL, RECUPYL, RATP, INRETS, and the IFP. This project aims to test two types of demonstrators: a hybrid bus and an all-electric bus that will achieve an operating cost close to that of diesel.

19.4 Industry

The automotive industry crisis

The automotive industry crisis is part of a global financial downturn, which is affecting the European, Asian, and American industries. The automotive industry was also weakened by substantial increases in the prices of automotive fuels in 2008, which discourages purchases of high-profit-margin vehicles. As a consequence, France has suffered less than other countries as a result of a large offering of fuel-efficient models.

Automotive industry trends

To date, French automakers' projects to design, develop, and produce specifically urban vehicles have never reached the commercial stage. Many actors are rushing to get into this potentially large market, particularly in areas with significant space constraints. Different options are being explored not only for new motive power units but also for the very nature of passenger cars, as indicated by automakers' initiatives such as the Renault Twizy pictured in figure 19.1 below.



Fig. 19.1 Renault Twizy. (Photo supplied by Renault.)

Another driver for this comes from the fact that the rapidly growing urban markets are marked by space constraints and the limited purchasing power of middle-class consumers.

These trends could lead to unconventional and specifically urban models, such as three- or four-wheeled vehicles inspired by two-wheeled motorbikes. Examples include the Ion and Tulip projects designed by PSA (1994–1995) and the recent concept cars, Zo and Zoom, pursued by Renault (see figures 19.2 and 19.3).



Fig. 19.2 Renault Zo concept car. (Photo supplied by Renault.)



Fig. 19.3 Renault Zoom concept car. (Photo supplied by Renault.)

The French industry is anticipating a shift toward mobility services, combining these technical options with system management tools. Most of these software tools are already widely available on the market and could be adapted readily, such as positioning software (for tracking trucks in real time) and fleet management software (for maritime shipping containers, self-service bicycles, etc.).

The OEMs' position

In this context, French vehicle manufacturers are developing their supply chain to meet the demands of their current and future vehicle programs. In the area of PHEVs and EVs, the main relationships are between OEMs and battery companies. PSA Peugeot Citroën is supplied by Batscap, the joint venture Johnson Controls-Saft, and Lithium Energy Japan. Renault has batteries supplied by AESC and Enerdel. Here we describe the current HEV-, PHEV-, and EV-related activities of the French auto manufacturers PSA and Renault-Nissan, along with suppliers Johnson Controls-Saft, BatScap, and Valeo.

PSA Peugeot Citroën

PSA Peugeot Citroën has already sold more than 10,000 electric vehicles. The Group is building on this expertise to develop hybrid vehicles. Studies are focused on two types of hybridization.

In the city, vehicles are at a standstill position with the engine running around 30% of the time. On the basis of this observation, PSA Peugeot Citroën introduced a first level of hybridization, the Stop & Start system (STT), on vehicles such as the Citroën C2 and C3 (figure 19.4). This technology cuts the engine and restarts it again in a split second, reducing fuel consumption in the city by

up to 15%. This technology will be rolled out on a large-scale basis in the Peugeot and Citroën model ranges from 2010.



Fig. 19.4 Logo for the C2 Stop & Start. (Photo supplied by PSA Peugeot Citroën.)

The Group will go further in 2011 with HYbrid4 technology. This new diesel hybrid architecture, presented on the Peugeot Prologue and Citroën Hynos at the 2008 Paris Motor Show, is the continuation of the HDi hybrid research program presented on two demonstration vehicles, the 307 and C4 Hybrid HDi in early 2006. HYbrid4 optimizes the diesel hybrid powertrain and also boasts an all-new four-wheel drive mode, bringing more value for the additional cost of the hybrid. This technology can be applied to different range levels. But given its extra cost, it will be available initially on the Group's distinctive and premium mid- and upper-range models.

HYbrid4 technology combines a 2-litre HDi diesel engine fitted with a particulate filter (DPFS) and a high-voltage Stop & Start system, together with an electric motor on the rear axle, a power inverter, high-voltage batteries, and a dedicated electronic control unit. Transmission is via an automated manual gearbox.

Average fuel consumption for a mid-sized crossover vehicle equipped with HYbrid4, like the Peugeot Prologue, will be roughly 4.1 L/100 km (diesel), with CO₂ emissions at a low 109 g/km, equivalent to those of a Peugeot 107. This figure is remarkable for a vehicle of this size, 25% lower than that of a similar vehicle equipped with a petrol hybrid powertrain. PSA Peugeot Citroën will market its HYbrid4 technology from 2011 on Peugeot and Citroën vehicles.

PSA will also sell a PSA-badged Miev in Europe, continuing its partnership with Mitsubishi. This vehicle will use batteries from the Mitsubishi-GS Yuasa joint venture.

Renault-Nissan

Renault aims to become the first full-line manufacturer to market zero-emission vehicles that are accessible to the greatest number of people by 2011. The Renault-Nissan Alliance is developing a complete range of 100% electric powertrains with power ratings of between 50 kW (70 hp) and 100 kW (140 hp).

For Renault, the electric vehicle is the real long-term solution to today's environmental and noise pollution issues. Technological innovations now make it possible to mass-market an electric vehicle at reasonable cost. In addition, changes in vehicle use make electric cars ideal for the majority of trips, with 80% of Europeans currently driving less than 60 km a day.

Renault will bring its customers a complete range of electric vehicles by as early as 2011. Their design will be largely inspired by the concept cars revealed at the 2009 Frankfurt Motor Show:

- The Kangoo Z.E. Concept announces a light commercial vehicle, especially designed for professionals, that will be available during the first semester of 2011;
- The Fluence Z.E. Concept prefigures an electric version of a family car that will be launched first in Israel (first semester of 2011) and then in other countries;
- By mid 2012, a full-electric city car (close to the Zoe Z.E. Concept) is expected to arrive that will measure less than four meters in length and will have five seats — an ideal vehicle for commuting;
- Also in the second half of 2012, a new type of urban vehicle arrives that will be close to the Twizy Z.E. Concept (in which a passenger can sit behind the driver); and
- Beyond 2012, Renault will continue to extend its electric car range to cover all segments.

Renault will also bring customers access to innovative services to make electric vehicle use easier and to advanced battery technology currently under development by the Renault-Nissan Alliance.

Renault is currently working on a number of fronts in preparation for the launch of its range of zero-emission vehicles:

- In R&D, €200 million is invested every year on electric cars as part of the Renault-Nissan Alliance;
- Cooperation with governments on infrastructure development and purchase incentives; and
- Partnerships are being formed with mobility operators worldwide.

Johnson Controls-Saft

Saft has leveraged its technological expertise to set up a joint venture with the U.S. firm Johnson Controls, Inc., a Tier-1 automotive supplier, to address the fast-growing EV and HEV market, particularly capitalizing on its lithium-ion (Li-ion) battery expertise.

Johnson Controls-Saft Advanced Power Solutions (JC-S), which was launched in January 2006, has already made considerable progress in bringing together R&D and sales and marketing teams. JC-S presently has several announced production and development contracts for vehicles using hybrid technologies, including the Mercedes-Benz S-Class hybrid for which JC-S began production of its Li-ion battery in the summer of 2009.

BatScap

In December 2007, BatScap announced the creation of a 50/50 joint venture with Pininfarina to build a fully electric vehicle. The vehicle will be a four-seater powered by a lithium-metal-polymer (LMP) battery developed by Bolloré, and it will have a range of 250 km (155 miles) in an urban environment. LMP batteries and supercapacitors were developed at the research centre of the Bolloré Group's production site at Ergué-Gabéric near Quimper in Brittany, France (figure 19.5).



Fig. 19.5 Bolloré Group's Production Site at Ergué-Gabéric, Brittany, France. (Photo supplied by Bolloré.)

Valeo

With more than 10,000 vehicles equipped between 1995 and 2005, Valeo is the world's largest supplier of electric powertrains. Vehicles driven by electric powertrains developed by Valeo and Leroy Somer — including the Citroën AX, Saxo and Berlingo, Peugeot 106 and Partner, and Renault Kangoo — have already covered more than 1 billion kilometers.

Valeo, with its partners Leroy Somer and GKN, is developing a line of second-generation powertrains at affordable prices. Its goal is that the cost of the electric motor as a whole, including the inverter, charger, voltage converter, and reduction gear, will eventually be equivalent to that of the gasoline-driven powertrain (engine, gearbox, and differential), which it aims to replace. The overall cost represents a major factor if second-generation rechargeable electric and hybrid cars are to be available for mass distribution at economically viable prices and without providing governmental subsidies for buyers.

To become a leading global player in the electric powertrain market, Valeo has signed development agreements with major industrial partners. In addition to Valeo, this consortium also includes some of the leading equipment suppliers in their fields, such as Leroy-Somer, JC-S, GKN, Michelin, and Leoni.

19.5

On the road

Neither BEVs nor PHEVs are available in France, and few plug-in hybrid vehicles have been officially announced. Toyota is currently testing different plug-in configurations of the Prius, especially in terms of range (battery type and capacity). The vehicles use Toyota's hybrid technology, but with the added benefit that their batteries can be recharged by using a standard electrical plug. The utility Electricité de France (EDF) and Toyota have also developed an innovative charging and invoicing system, equipped in each of the test vehicles. This system is compatible with a new generation of public charging stations, which aims to make electric power more accessible on public roads and car parks while reducing the cost to the customer.

Hybrid Car Sales

The hybrids currently available in France include the Honda Civic, Honda Insight, Lexus GS 450h, Lexus LS 600h, Lexus RX 450h, Mercedes S400 Blue Hybrid, and the Toyota Prius III. Hybrid car sales in France for the different models on the market in 2009 are shown in figure 19.6.

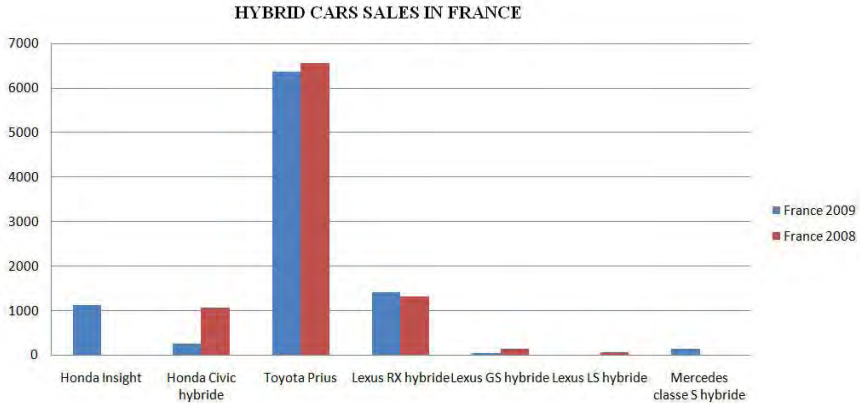


Fig. 19.6 Hybrid car sales in France in 2008 and 2009. (Source: www.avem.fr.)

19.6 Outlook

Forecasts for the EV market range from the highly optimistic to the deeply pessimistic. One of the most optimistic surveys claims that 25% of vehicles sold in France in 2020 will be electric, and 50% in 2050. On the other hand, other studies show that the European market for electric vehicles will represent a mere 250,000 cars in 2015. These divergent views result because of the difficulty in making reliable predictions in view of complex relations among the multitude of parameters involved.

The French auto industry is following three different trends or directions:

- The emergence of a new market segment, with production of city and urban-area vehicles and the appropriate automobile and four-wheeled cycle regulations, in France. The size, design, and engines of these vehicles would be entirely revamped to correspond to the mobility needs of consumers in cities and urban areas (i.e., range) and to environmental criteria (e.g., local pollution, noise, occupation of space).
- Vehicles that could be specifically adapted for service options (e.g., autolib rentals modeled after Vélib).
- Reduced energy needs, thanks to much lighter vehicles (average vehicle weight could drop by 50% by 2050). These will be obtained by the development and use of new materials and the rethinking of vehicle design rules that make it possible to incorporate these materials, as well as by reduced vehicle drag (aerodynamic architecture, rolling contact). The growing use of electric powertrains in hybrid and electric vehicles means that design concepts can be entirely revised, leading to improvements in these areas.

19.7

Benefits of participation

Keeping up to date with the latest developments in HEV technology and demonstration projects is an important benefit of participation in IA-HEV. Participation also enables the exchange of experiences in the French automotive industry and achievements related to demonstration projects with representatives from other countries that are active in the same field. Parties working on HEVs in France also receive practical information based on experiences in other countries. The personal contacts enable an exchange of experiences that goes beyond the information that is available through simple written communication.

19.8

Further information

Additional information about hybrid and electric vehicles in France may be found on the following Web sites:

- ▶ www.ademe.fr (in French): French Environment and Energy Management Agency – ADEME Roadmap for Low-Carbon Vehicles.
- ▶ www.avem.fr (in French): Avenir du Véhicule Electrique Méditerranéen⁷ (AVEM) is an association based in the South of France that promotes usage of EVs. Its content includes local information, EV events, and EV links.
- ▶ www.batscap.com (in English and French): BatScap is developing and producing energy storage components that are intended for applications related to electric or hybrid transportation and the backup power supply.
- ▶ www.clean-auto.com (in French): Site of the clean@uto magazine. Very rich site provides information about clean solutions for transportation (EVs, HEVs, fuel cell EVs, etc.).
- ▶ <http://transports.edf.fr> (in French): EV pages of the French utility Electricité de France (EDF). Its content covers all activities of EDF in the EV domain, as well as some technical and economical information.
- ▶ www.predit.prd.fr (in French, with summaries in English and German): PREDIT is a program of research, experimentation, and innovation in land transport.
- ▶ www.psa-peugeot-citroen.com (in English, French, and Spanish): The site of the French carmaker PSA Peugeot Citroën, with many documents on clean vehicles, EVs, and HEVs.
- ▶ www.renault.com (in English and French): The site of the French carmaker Renault, with a section on eco-technologies.

- www.venturi.fr (in English and French):
The site of the carmaker Venturi contains all technical specifications of the Eclectic and Fétish models, as well as a vision of future clean vehicles.
- www.valeo.fr (in English and French):
Valeo — Zero Emission Vehicle report.



20.1 Introduction

The weak international economy has continued to strongly impact the political, industrial, and social decisions that influence the Italian energy sector and automotive market. In 2009, overall energy consumption was reduced by 4.9% from the previous year, with the share of fossil fuels — mostly imported — still greater than 90%. Conversely, the renewable energy contribution increased by 8.5%, with an excellent improvement of 13% in the electricity production share. Furthermore, the transport sector remained the major contributor to overall energy consumption, at about 30%, and was the largest emitter of carbon dioxide (CO₂), at about 29% of total emissions in 2009.

As agreed upon at the European Union level, the Italian government aims to reach the national targets for energy and climate control by achieving a 13% reduction in greenhouse gas emissions by 2020, compared to 2005 levels, with 17% of the overall energy sources consisting of renewable energy sources. In addition, the national policy which previously did not support nuclear energy has changed because of a new commitment to introduce nuclear energy at several power stations.

At the onset of 2009, the central government did not have a specific policy and strategy, with defined introductory goals, to encourage the popularization of electric vehicles (EVs), hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs). However, it did begin to fund projects aimed at promoting the research, purchase, and demonstration of cleaner cars, including electrically-driven vehicles. Moreover, local authorities at the regional and municipal levels defined various actions to promote the diffusion of these vehicles by reaching agreements with various suppliers (i.e., car makers and electric utilities), by expanding charging infrastructure, and by enacting non-technical measures to promote sustainable mobility in restricted-circulation areas (i.e., free parking areas, access to restricted-circulation areas, no city entry toll, and so forth). These initiatives, together with larger media coverage through magazines, broadcasting, and national symposia, augmented the perception and awareness of cleaner cars and their potential applicability in the general public, with the focus mostly on new batteries and the availability and applications of EVs.

Finally, new legislative initiatives included the preparation of specific laws that favor the expanded use of EVs, such as proposals for larger popularization incentives and dedicated charging infrastructures. The more favorable conditions and the significant financial effort to subsidize the park renewal with cleaner cars have resulted in more than doubling the market share of these vehicles in 2009 with respect to 2008: natural gas vehicles (NGVs) and liquefied petroleum gas vehicles (LPGVs) increased from 7.09% to 21.62%, while the percentage of hybrid cars rose to 0.35% from 0.16%.

20.2

Policies and legislation

During 2009, the Italian government became more proactive in identifying measures to support the transport market in the short-term and, jointly, in preparing initiatives for a long-term strategy to reach the national objectives agreed upon as European Union targets in the fields of energy and climate control (to be reached by 2020). Different ministries (Economic Development, Environment, Research, and Transport) were involved in the process, with various funding schemes designed to promote the supply side through specific programmes for research and industrial innovation (i.e., Project INDUSTRY 2015 and the Action Plan for Energy Efficiency), as well as a more significant initiative to promote the demand side by supporting the vehicle industry during the economic crisis. Moreover, a new National Energy Plan has been prepared and should be in place by the beginning of 2010. Some regulatory activities for dedicated standards for HEVs and related components (e.g., rechargeable lithium battery applications and supercapacitors) also have been initiated by the national standard-setting bodies (the Italian Electrotechnical Commission (CEI) and CUNA) as part of an international effort promoted by the International Organization for Standardization (ISO) and the International Electrochemical Commission (IEC).

Governmental programs

In 2009, the Italian government established a set of subsidy initiatives in a major effort to support the transport sector:

1. In February 2009, a large “scrappage – park renewal” subsidy programme was launched, with a total estimated budget in excess of €1.0 billion, to both clean the national car fleet by removing polluting cars older than 10 years and support the automotive sector by subsidizing the purchase of new vehicles. All vehicles entitled to receive funding had to be ordered in February 2009 and registered by March 2010. The incentives ranged from €1500 up to €6000, depending on the CO₂ emissions and vehicle size.

2. A similar programme has been proposed to promote the park renewal and assist the related market of motorbikes, mopeds, and bikes (including power-assisted bikes). The allowed financial incentive could not exceed a total of 30% of the retail price.

Legislation

During 2009, some legislative initiatives were implemented to create more favorable conditions for electrically driven vehicles. In particular, a law proposal was presented in October to establish a charging infrastructure and other local regulatory measures (i.e., dedicated parking, free-of-charge refuelling, no property tax, and so forth). Because of the problem of uncontrolled pollution in urban areas, various municipal and local authorities have reached agreements with car makers and defined specific rules for improving and extending the use of cleaner vehicles.

20.3 Research

As a result of national and European programs that were ongoing or launched during 2009, Italy remains a major participant in research endeavors for EVs, HEVs, and fuel cell vehicles (FCVs). Italian research groups include research organizations, universities, and industry, which often work together as required by most of the publicly funded programs. Research and demonstration activities primarily address major technical and practical barriers, such as improved energy efficiency for the stricter emission standards, and the cost and availability of fuel. The research topics continue to concentrate on a spectrum of enabling technologies. Compared to previous years, research now has a reduced focus on hydrogen and fuel cells, with projects limited to fuel cell cost reduction and life improvements, and hydrogen storage studies.

However, research and innovation for HEVs and EVs have intensified with the announcements of new prototype vehicles, storage systems, production alliances, and research centres or consortia. Currently there are several projects involving research on electric drivetrains for HEVs, PHEVs, and EVs to help vehicles reach the European Union CO₂ emissions and energy consumption targets. Also, another area of ongoing research focuses on better integration and more dedicated designs for EVs and HEVs to reduce the cost gap between these and conventional internal combustion engine (ICE) vehicles.

The major entities in Italy conducting research into electric-drive and fuel cell vehicles are ENEA, CIRPS, the National Council of Research (CNR), and the Fiat Research Centre. The relevant activities of each of these are described below.

ENEA

The Italian National Agency for New Technologies, Energy, and Sustainable Economic Development (ENEA) has continued with activities associated with several national and European-funded projects aimed at the research, development, and application of various novel technologies in electric drive vehicles. The Ionic Liquid-based Hybrid Power Supercapacitors (ILHYPOS) project, with contributions from research organizations and industry from France, Germany, and Italy, was completed with the realization of advanced asymmetric supercapacitors based on a “green” electrolyte that uses ionic liquid. Figure 20.1 shows the final assembly of different configurations of ILHYPOS supercapacitors.



Fig. 20.1 ILHYPOS asymmetric and hybrid prototype cells with ionic liquid in the electrolyte. (Photo supplied by ENEA.)

ENEA has also proposed to use supercapacitors in various real applications. Two compact car prototypes were presented in 2008 and completed in 2009, coinciding with the start of the experimental campaigns and participation in dedicated races. Figure 20.2 shows one of the ENEA electric prototypes, the City-car GINKO, during the race held at the ENEA Research Centre in October 2009. This light EV, developed with Rome Universities and Semikron, uses lead-acid batteries and supercapacitors to propel a 4.8-kW electric motor for a range of about 130 km at full discharge in defined driving patterns.



Fig. 20.2 Light electric City-car prototype with supercapacitors, developed by ENEA. (Photo supplied by ENEA)

The “ZeroFiloBus” project began in 2009, in cooperation with the bus manufacturer, Breda Menarini. This new project involves an innovative concept for public buses, in which the key technological idea is to store energy in supercapacitors during stops at intermediate stations to reduce or eliminate the need for overhead electrical charging line infrastructure.

CIRPS

CIRPS is an academic consortium of the University of Rome. With the financial support of the Lazio Region, CIRPS has continued research activities on hydrogen technologies, through the consortium “Lazio Region Hydrogen Centre.” Among other activities, a small fuel cell bus (shown in figure 20.3) is being tested at this research centre.



Fig. 20.3 Technobus Gulliver fuel-cell minibús. (Photo supplied by ENEA.)

National Council of Research (CNR)

Through its research institute, the “Nicola Giordano” Institute for Advanced Energy Technologies (CNR-ITAE), the CNR has extensive experience in the field of basic and applied research on fuel cells, hydrogen storage, and their applications. In 2009, the institute showcased the BHYKE, a power-assisted bike that uses a fuel cell. The BHYKE, which is ready for market introduction, has a claimed range of 150 km and a hydrogen refuelling cost of €18 (about 12 euro-cent/km). Figure 20.4 shows the BHYKE prototype.

The CNR-ITAE is an academic consortium of the University of Rome. With the financial support of the Lazio Region, the CNR-ITAE has continued research activities on hydrogen technologies, through the consortium “Lazio Region Hydrogen Centre.” Among other activities, a small fuel cell bus (shown in Figure 20.3) is being tested at this research centre.



Fig. 20.4 CNR BHYKE prototype. (Photo supplied by ENEA.)

Fiat Research Centre

The Fiat Research Centre (CRF) continues targeted research activities on EVs and HEVs, most of which are included in European projects, such as HYSYS (FCV components development) and HI-CEPS (novel hybrid drivelines development). The main focus of the short-term activities relate to the cleaning of conventional engines by introducing cleaner fuels, such as natural gas. The types of commercial vehicles fuelled by natural gas include almost all the major models. In 2009, two main activities were related to hydrogen or electric-drive vehicles: (1) the beginning of a demonstration program with a new Panda (Hyper Panda) that uses hydrogen-natural gas blends as a fuel, and (2) the completion of the demonstration Fuel Cell Panda in the European project, “Zero Regio.”



Fig. 20.5 Fiat Hyper Panda that uses hydrogen-natural gas blends. (Photo supplied by ENEA.)

The Lombardia Region has received 20 Hyper Panda vehicles (shown in figure 20.5) to be tested in Milan. This version of the Panda is expected to be more efficient than all the current Panda vehicles that use conventional fossil fuels or pure natural gas. Figure 20.6 compares the CO₂ emissions of different evolutions of the Panda with different fuels.

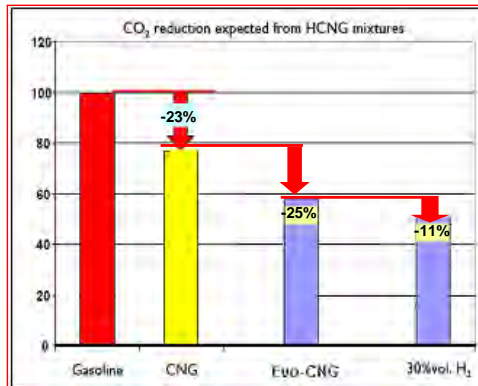


Fig. 20.6 CRF comparison of FIAT Panda emissions with different fuels and hydrogen-natural gas blends. (Photo supplied by CRF.)

Interesting results are now available from the European demonstration FCV project, “Zero Regio.” At the end of the demonstration, the 3 Panda FC Hydrogen exceeded 24,500 km, with a total hydrogen consumption of 265 kg (an average of about 100 km per hydrogen kg).

20.4 Industry

In 2009, the Italian electric-drive vehicle industry suffered the worldwide car crisis and took advantage of the support measures put in place by the government and local authorities. The number of active companies, as surveyed by the Italian Electric Road Vehicle Association (CIVES), totalled approximately 50 producers, assemblers, and importers. A few large vehicle manufacturers (Breda Menarini, Piaggio, Cacciamali, and IVECO) continued to work with new projects or established products. The larger share of manufacturers consisted of small and medium-size enterprises. The availability of EVs and HEVs remained substantial and covered all categories of vehicles, including power-assisted bikes, scooters (with two, three, or four wheels), light- and heavy-duty pure electric and hybrid buses, and electric boats. The types of available EVs and HEVs exceeded 100 versions. The commercial versions provide a basic layout with a variety of configurations, thereby accommodating the various needs of passengers and goods transport. Retail prices range from a few hundred euros for power-assisted bikes to hundreds of thousands of euros for hybrid buses.

A component industry also is still present in Italy, with various announcements for new enterprises or industrial consortia. This industry works mainly on power electronics, complete electric and hybrid drivetrains, electric motors, conventional and new batteries, and battery recharging systems.

Italian companies that introduced new models of EVs and HEVs during 2009 include Micro-Vett, Pininfarina, Piaggio, and Aspes.

Micro-Vett

This small enterprise is the largest producer of EV and HEV commercial vans. In 2009, the production was significantly renewed with new models, which all use lithium-ion batteries from various manufacturers. Figure 20.7 presents the latest version of the FIAT Fiorino, electrified by Micro-Vett. This vehicle has a range that varies from 70 km to 140 km, depending on the type of lithium-ion battery. This EV is part of a supply of 50 EVs for the Tuscany Region, mostly based on the electric Porter, to be used by health agencies in the region.



Fig. 20.7 The electric Fiat Fiorino, fully electrified by Micro-Vett with lithium batteries. (Photo supplied by ENEA.)

Pininfarina

At the Geneva Motor Show in 2009, Pininfarina presented the final version of the electric car developed with the French group, Bolloré. The name of this car is Bluecar (shown in figure 20.8), and commercialization is planned for 2011. The car is a fully electric, four-seat vehicle with a photovoltaic panel on the top, a targeted range of 250 km, and a limited top speed of 130 km per hour. The Bluecar is powered by lithium metal batteries with supercapacitors, produced by Bolloré in France and Canada, and it has an expected life of 200,000 km. About 6,000 orders already have been collected through a website enquiry. The commercial plan is to lease the Bluecar at 330 €/month.



Fig. 20.8 Pininfarina-Bolloré Bluecar. (Photo supplied by ENEA.)

Piaggio

Piaggio, one of the largest producers of scooters and motorbikes in the world, officially launched a hybrid scooter in July 2009. The new motorbike, named the MP3 Hybrid (see figure 20.9), is a 3-wheel vehicle with a hybrid powertrain (a thermal engine integrated with an electric motor and electronically driven “ride by wire”). It uses gasoline and lithium-ion batteries and can reach an energy economy of 60 km/L of gasoline. The MP3 Hybrid has a plug-in version capable of battery recharging from the grid, with a retail price of about €9,000.



Fig. 20.9 Piaggio MP3 Hybrid. (Photo supplied by ENEA.)

In addition, Piaggio has also produced a limited edition of an old 3-wheel taxi that has been used in tourist areas for more than 40 years. The APE Calessino Electric Lithium is available in 100 samples (figure 20.10). It uses lithium-ion batteries and has a driving range per charge of 75 km.



Fig. 20.10 Piaggio APE Calessino Electric Lithium. (Photo supplied by ENEA.)

Aspes

In May 2009, another small company, Aspes, also launched a small hybrid (dual-mode) scooter. The scooter, named Sirio, is shown in figure 20.11.



Fig. 20.11 Aspes Sirio hybrid scooter. (Photo supplied by ENEA.)

20.5

On the road

The total fleet of clean vehicles substantially increased in 2009, thanks to the financial incentives from the government. The overall market remained almost unchanged with respect to 2008. The most significant increase in sales was related to NGVs and LPGVs (and even for HEVs), which almost tripled the market share, from about 7.25% (0.16% for HEVs) sold in 2008 to about 21% at the end of 2009. The stability of the market and the significant increase of market shares for cleaner cars was a direct result of the park renewal policy (with car scrapping), as well as the strong financial support to the car demand sector, with particular focus on the purchase of more efficient and less polluting vehicles. The statistics at the end of 2009 were consistent with these evaluations: more than 1,000,000 passenger cars (about 50% of the total sold) were purchased with public financial incentives, and more than 95% of purchases were related to a car scrapping. Table 20.1 provides statistical data on the vehicle fleets in Italy.

Table 20.1 Characteristics and population of the Italian motorised vehicle fleet, per December 31, 2007 and 2008.

Vehicle type	DECEMBER 31, 2007			DECEMBER 31, 2008		
	EV fleet	HEV fleet	Total fleet	EV fleet	HEV fleet	Total fleet
Motorized bicycle ^a (no drivers licence)	160,000	0	3,850,000	170,000	0	3,973,138
Motorbike	36,200	0	5,590,259	37,000	0	5,859,094
Passenger vehicle	2,600	8,532	35,680,097	2,700	11,000	36,105,183
Multipurpose passenger vehicle	6,760	0	594,643	6,760	0	619,706
Bus	740	254	96,419	740	254	97,597
Truck	0	0	3,842,995	0	0	3,914,998
Industrial vehicle	0	0	1,173,022	0	0	1,182,962
Total	206,300	8,786	50,827,435	217,200	11,254	51,752,678

^a The motorized bicycle category includes mopeds and scooters with an engine cylinder volume up to 50 cm³.

The definitions of the different vehicle categories can be found in Section E of this report, in the chapter on Vehicle Categories.

The CIVES estimations at the end of 2008 showed a slight increase in the total number of EVs and HEVs on Italian roads compared with the 2007 figure (217,000 versus 206,000 vehicles). The market share of HEV passenger cars remained negligible in Italy compared with other countries, but it reached a market share of passenger cars of about 0.35% in 2009 — more than doubling the share in 2008. Large EVs and HEVs were purchased mostly by fleet users, such as public service utilities.

For the 2-wheel vehicle categories, the situation was significantly worse, with a strong reduction in mopeds/scooters sales (-18%), which are generally to private users. Sales of motorbikes remained stable. Despite public financial support from public authorities and a prompt and enthusiastic reaction from the general public (more than 55,000 2-wheel vehicles of many types were ordered in a four-day period), the 2-wheel vehicle market was unable to fully recover from the instability related to the economical crisis.

Furthermore, mandatory initiatives were taken by different municipal authorities to mitigate air pollution in urban areas. These initiatives have enlarged the offer of non-technical or financial measures to favor the introduction of EVs and HEVs by increasing the number of charging stations, dedicated parking lots, and the exemption to limited circulation in restricted areas.

20.6 Outlook

Near the end of 2009, the policy and strategy of the government and local authorities are going to be changed, with specific attention to electrically propelled vehicles, even in virtue of European Union initiatives to reduce CO₂ emissions from the transport. The worldwide economic situation is greatly affecting the national position in some key sectors related to EV and HEV applications. The market crisis in the automotive industry has required dedicated interventions and assistance to stabilize the market. At the same time, the industry must maintain international commitments in terms of greenhouse gas emissions and vehicle standards.

As a large importer of fossil fuels, the Italian economy is very sensitive to decisions regarding power generation and the related energy economy. This strong dependence has subsequent environmental consequences. The decisions and strategy of the new government which entered office in April 2008 seem to substantially support the clean vehicle market. Examples include financial incentives and dedicated innovation programs to reduce energy consumption and

emissions by introducing new technologies and reformulated or cleaner fuels. (Occasionally, the present financial incentive for cleaner vehicle purchases includes hydrogen-powered vehicles.)

These first measures will have some impact on research for new vehicles and fuels. The INDUSTRY2015 project will fund industrial innovations with €180 million and also include activities focused on any type of HEV and EV. The market growth for EVs and HEVs is estimated to slightly increase in the first 2 to 3 years, with a more significant increase when more vehicles and new batteries become available after 2010–2012. The steep increase can be motivated by concurring reasons:

- The financial support of local and central governments;
- The introduction of more severe emission standards (as of September 2009, Euro-6 will be mandatory), as well as new directives and laws for renewing car fleets, which will require improved vehicle drivetrains and fuels;
- The plans of various carmakers (already announced) to produce and introduce new vehicles with pure electric or hybrid configurations; and
- The establishment of a set of non-technical and non-financial measures by local authorities to limit private car use in urban areas, including restricted circulation areas for polluting vehicles, free parking for clean cars, no access tolls for clean cars, free recharging stations, and enlarged recharging infrastructures.

According to present car manufacturers, the current uncertainties in the car market make it very difficult to draw any numerical estimation of the possible market growth for cleaner vehicles. As such, the creation of specific charging infrastructures for the new energy carriers (i.e., electricity and hydrogen) will be vital for the perspectives of the related market for EVs, fuel cell hybrid vehicles, and plug-in hybrids. In Italy, the present plans offer an opportunity for EVs, HEVs, and, to a much lower degree, plug-in hybrids to become more widely adopted, due to the effect of the combined support on the demand side (financial incentives and enlarged infrastructure) and on the supply side for new vehicles (financial incentives and funding for research, development and innovation).

The focus on EV technologies has increased with different initiatives from the industry and preliminary indications from the government, which are all working to accelerate the development and introduction of these technologies.

20.7

Benefits of participation

The benefits derived from participation in the International Energy Agency (IEA) Implementing Agreement for Co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) have been recognized by the Ministry of Economical Development, which is financially supporting this international activity. Also, various other Italian organizations are potentially interested in the activities of IA-HEV, since they may benefit from the feedback from participation in the Agreement. These organizations include:

- ▶ Governments and ministries involved in defining policy, supporting measures for cleaner transport technologies and related research and deployment programs, and appraising the level of knowledge and initiatives in place in other countries;
- ▶ Industries interested in collaborating on aspects that facilitate the development and commercialization of their products (e.g., common standards, common lower cost components, easy access to a variety of suppliers, and identification of market opportunities);
- ▶ Research organizations interested in collaborating at an international level on basic and applied research (e.g., components, infrastructure, impact evaluation, usability constraints, and safety); and
- ▶ Local authorities and end users focused on learning more about the status of the technology and its possible applications.

20.8

Further information

Additional information about EVs and HEVs in Italy may be found on the websites listed below. The websites of the major producers of EVs and HEVs that are mentioned in this chapter also may be consulted for additional information.

- ▶ www.ceiweb.it/cives/home.htm (in Italian)
This is the official website of the Italian Electric Road Vehicle Association (CIVES), an internal committee of the Italian Electrotechnical Commission (CEI) and the national section of the European Association for Battery, Hybrid, and Fuel Cell Electric Vehicles (AVERE). The website offers extensive information about the vehicles available in the market, the status of laws, and the major initiatives at national and local levels. It also provides the addresses of all members of CIVES, major Italian manufacturers, importers.
- ▶ www.crt.unige.it (in English and Italian)
This is the website of an academic research centre on transport, located at the University of Genova. The website addresses public transport in general.

- ▶ www.enea.it (in English and Italian)
The ENEA website presents programs, projects, and activities in general terms, as well as a special report about energy and the environment.
- ▶ www.h2roma.org (in English and Italian)
This sustainable mobility website was initiated by the university group that organises the yearly H2 Roma event.
- ▶ www.minambiente.it (in Italian)
This Ministry of the Environment and Territory Safeguard website contains up-to-date information about environmental legislation and initiatives. A specific area is dedicated to sustainable mobility, renewable energy, and the environment.
- ▶ www.regione.lombardia.it (in Italian)
The Lombardia Region website contains information about the use of main initiatives for a sustainable mobility, including funding initiatives.
- ▶ www.sph2.org (in English and Italian)
This is the website of “Sistema Piemonte Idrogeno,” an initiative of the Piemonte Region to create a network of stakeholders to work on hydrogen-related issues.
- ▶ www.pomos.it
This is the website of the “Sustainable Mobility Centre” of the Lazio Region, where various projects and activities are described.

21.1 Introduction

Hybrid cars have been commercially available in the Netherlands since 2004, when the Toyota Prius II — now a major sales success — was introduced. Lexus and Honda are also on the market with hybrid models. In 2009, sales of these cars increased substantially, largely as a result of the decrease in the incremental income tax rate (from 25% to 14% of the car sales price) for employees who use company cars.

In contrast, sales of electric vehicles (EVs) have virtually ceased. They are commercially available only for special applications in which a vehicle registration plate is not required. These applications include utility vehicles in cities and local grocery delivery vans in urban areas. Electric bicycles, however, are best sellers in the Netherlands, and the sales of electric mopeds are taking off. This market is helped by the fact that charging points for bicycle batteries are available at restaurants in tourist areas.

As is the case worldwide, interest in electric drive vehicles, such as battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), is on the rise. This trend is due to increased political attention, as well as innovative developments in the automotive field.

The Dutch Government has ongoing policies and legislation for reducing carbon dioxide (CO₂) and nitrogen oxide (NO_x) emissions and improving air quality. The objectives are (1) to encourage consumers and research institutes to devote more attention to improving the efficiency of transportation systems and practices and (2) to facilitate the hybridization of vehicles. The relevant automotive research and development (R&D) organizations are concentrated in the south-east part of the country. These organizations benefit from good relationships and collaborations with their automotive counterparts in Germany and Belgium.

21.2

Policies and legislation

Policies

Government-supported programmes focus most strongly on the principal environmental policy objectives of reducing CO₂ and NO_x emissions and improving air quality. One programme supports the production of biofuels for transportation. Another programme encourages investment in refuelling stations for alternative fuels, such as compressed natural gas (CNG) used as a motor fuel.

Dedicated communication programmes sponsored by the Dutch Government promote the concept of “eco-driving” for drivers of all vehicle types. The principles that underlie this fuel-efficient driving behavior are incorporated in the training course required to earn a car operator’s license. More information on eco-driving is available on the website, at www.ecodrive.org/What-is-ecodriving.228.0.html.

Legislation

Special tax rules are in place for EVs and hybrid vehicles. The EVs are exempt from the yearly road tax. Since mid-2006, hybrid vehicles have qualified for a substantial bonus/registration tax reduction to encourage their sales. The bonus is dependent on the energy efficiency label of the car, which reflects the fuel economy of the car (i.e., for the highest fuel-economy label A: €5,000; label B: €2,500). Conventional cars that are very energy efficient also earn a registration tax reduction, depending on their CO₂ emissions in grams per km.

The effort to improve air quality in cities has led to the introduction of “environmental zones,” which have specific entry rules, in urban areas. Some of the largest cities in the Netherlands have already designated environmental zones with more stringent entry rules for vehicles on the basis of their emission characteristics. Greater restrictions are imposed on vehicles not classified as “environment friendly.”

21.3

Research

The Netherlands has several automotive research institutes, such as:

- › TNO Industry and Technology — Automotive
- › Technical University Eindhoven
- › Technical College, Automotive Division, Arnhem

- Automotive Technology Centre (ATC)
- Drive Train Innovations (DTI)

Most research institutes are located near Eindhoven, in the southeast, which has good connections to the areas associated with the automotive industry near Aachen, Germany, and the institutes in Belgium. Substantial co-operative efforts involving Dutch, Belgian, and German research institute partners and car and truck manufacturers are under way.

The majority of car manufacturers are changing their strategies for developing components and subsystems, with the number of co-operative manufacturing ventures (i.e., co-makerships) increasing. Joint R&D ventures involving universities and several small consultant firms address transportation, not only at the component and vehicle system levels, but also at the system (macro) level.

Among the demonstration projects related to the production and use of biogas for transportation is an effort that involves converting waste biomass to biogas and then upgrading it to natural gas of near-pipeline quality. The product is then used to fuel vehicles with CNG spark-ignition engines.

High Tech Automotive Systems (HTAS) Programme

The HTAS is a market-driven programme set up and directed by the Dutch automotive industry. Its goal is to focus automotive innovation on areas that match the strengths and ambitions of the Dutch automotive sector and on future opportunities and challenges in the international automotive industry. Key focus areas are vehicle efficiency and vehicle guidance. The HTAS Programme was established in 2007 to run for 5 years. At the end of 2009, a research plan for Electric Vehicle Technology was added. More information is available on the website, at www.htas.nl.

21.4 Industry

The Dutch automotive industry consists of:

- A truck manufacturer, DAF Trucks N.V. (a subsidiary of PACCAR, Inc.)
- A truck assembly plant in the Netherlands, owned by Scania
- A manufacturer of public transport buses and touring cars, Van de Leegte Bus B.V.
- A car assembly factory, owned by Mitsubishi
- Various manufacturers of semi-trailers, trailers, and truck bodies
- Various manufacturers of automotive component

Since DAF Trucks is fully integrated into the U.S.-based PACCAR, Inc., it is a worldwide player in the truck industry. The market share of DAF Trucks in Europe has grown steadily over the last decade. In fact, co-development and comakership among all the entities have intensified during the last decade. Research institutes and the automotive components industry will have ample opportunity to be part of the European vehicle manufacturing arena.

21.5 On the road

The vehicle park (in-use population) in the Netherlands is shown in Table 21.1. Car density is one car per 2.3 inhabitants.

Table 21.1 Characteristics and population of the Dutch motorized vehicle fleet, per December 31, 2008 and 2009 (estimates are shown in italics).

Vehicle Type	DECEMBER 31, 2008			DECEMBER 31, 2009		
	EV Fleet	HEV Fleet	Total Fleet	EV Fleet	HEV Fleet	Total Fleet
Motorized bicycle (no drivers licence)	60,000	0	530,000	<i>90,000</i>	<i>0</i>	<i>550,000</i>
Motorbike	0	0	605,000			<i>600,000</i>
Passenger vehicle	50	24,000	7,500,000	<i>50</i>	<i>27,000</i>	<i>7,500,000</i>
Multipurpose passenger vehicle	0	0	0	<i>0</i>	<i>0</i>	<i>0</i>
Bus	0	5	11,300	<i>0</i>	<i>5</i>	<i>11,300</i>
Truck ^(a)	2	0	1,090,000	<i>10</i>	<i>0</i>	<i>1,100,000</i>
Industrial vehicle	400	n.a.	n.a.		<i>n.a.</i>	<i>n.a.</i>
Total	60,452	20,005	9,544,000	90,060	27,005	9,761,300

n.a.= not available

^(a) The numbers include vans and minibuses. Minibuses are vehicles that carry up to nine people, with a gross vehicle weight up to 3.5 tons. In Dutch statistics, this category cannot be separated from vans up to 3.5 tons. Their estimated number as of December 31, 2009, is 875,000.

The definitions of the different vehicle categories can be found in Section E of this report, in the chapter on Vehicle Categories.

The in-use population at the end of 2009 was at approximately the same level as it was at the beginning of the year. As a result of the financial crisis in 2009, sales of new vehicles declined substantially (i.e., about 22% compared with 2008), and sales of smaller vehicles tended to increase.

About 450 BEVs remain in service — mainly cars and utility vehicles (i.e., EVs that require a license plate to be used on public roads). Barriers to greater sales and use of electric cars include their purchase price and driving range, as well as the limited availability of service support.

The Netherlands is a bike-friendly country, with about 20 million bicycles — more than the number of inhabitants! Various makes and models of electric bicycles are available, primarily the power-assist type (i.e., electric assistance is supplied only when the rider is pedalling). They are allowed to travel at a maximum speed of 25 km/h. Their share of the total bicycle market is about 4%.

Only a few models of hybrid cars are available for sale in the Netherlands: Toyota Prius III, Honda Civic Hybrid, and Lexus RX 400h and GS 450h. The Prius is the most often sold hybrid in the country, with sales of about 8,300 vehicles in 2009. The sales volume for the Honda Civic Hybrid reached about 6,000 units. The Honda Insight is also a bestseller, with 1,800 registrations in 2009.

Hybrid buses and goods vehicles are not commercially available in the Netherlands. As such, their numbers are negligible in the current truck and bus stock. DAF Trucks produced a prototype hybrid distribution truck but is not yet offering it for sale. However, two electric distribution vehicles, especially made in the United Kingdom, are in service. These vehicles are operated by TNT for parcel delivery services.

21.6 Outlook

Current trends

Although most car manufacturers throughout the world are pursuing intensive product development work on hybrid vehicles, the supply of those vehicles to the Netherlands is very limited. Only Toyota, Lexus, and Honda offer hybrid car models to the Dutch market. However, by 2015, quite a variety of hybrid car makes and models will be available. Hybrid goods vehicles (i.e., delivery vans and trucks) are still in the prototype stage, while hybrid buses are generally in the very early development phase, with some demonstration projects under way.

Compatibility of HEVs and EVs with the country's objectives

Every day, 2.5 million cars with an average occupancy rate of 1.15 persons per car (i.e., nearly single-person occupancy) commute over Dutch roads. At the end of 2007, the Dutch Government issued a white paper that articulates policies that would promote a clean environment and energy efficiency within all sectors of the society. For the transportation sector, these policies address (1) the need for consistent regulations within the European Union, (2) the need to encourage demand for clean and fuel-efficient vehicles, and (3) the need to promote innovation in demonstration projects. During 2008, the policy paper was developed into a work plan for specific government support programmes. These programmes were established in 2009. The use of hybrid and electric vehicles, both cars and goods vehicles (i.e., light-duty goods delivery vans and heavy-duty distribution trucks and buses), is very compatible with these policies.

Public opinion

Society in general is moving toward “green” behavior and consumption patterns. This trend also applies to how people move. The use of public transport is increasing. Sales of smaller cars are also increasing — and this trend is not solely the result of governmental fiscal measures. The trend affects the average curb weight of cars, which decreased from 1,125 kg in 2006 to about 1,025 kg in 2008. These developments will have a positive effect on the future prospects for HEVs and EVs.

Present plans

As mentioned, the market for hybrid and electric vehicles in the Netherlands depends mainly on the supply of these vehicles from manufacturers outside the country. However, this market can be influenced by specific policies of the Dutch Government, such as fiscal measures and entry rules for urban areas (i.e., environmental zones in cities). Research, development, and demonstration plans have triggered research projects, and project plans for the 2009–2015 period are in place.

A governmental programme was established to support demonstration projects that focus on BEVs and PHEVs in specific transportation applications during 2010. These projects will provide information to determine and evaluate how these vehicles operate in practice.

Core technologies

The Netherlands does not have a national car manufacturer. DAF Trucks (a U.S.-based PACCAR company) is the only truck manufacturer with the capacity to develop products, produce components, and assemble vehicles. The country does have universities and a few research institutes with R&D capabilities. These resources are used by vehicle manufacturers throughout the world. In an institutional sense, the HTAS Programme will play a major role in the future development of core technologies.

Market developments

For the 5-year period from 2004 through 2008, the average annual sales volume of cars in the Netherlands was about 500,000 units. In 2009, the sales dropped substantially, by 22%, to about 390,000 units. In 2009, the sales share of hybrids was about 4% — an increase over the previous year that resulted from the decrease in net taxes for company cars. By 2015, this hybrid segment will increase, but the share will remain in the single digits and depend substantially on a supply of vehicles from manufacturers outside the country.

PHEVs

During 2009, the technical possibility of increased use of the electrical grid for plug-in charging of HEV batteries came closer to feasible commercial production. Some issues must still be resolved. These issues relate to the dependency of the battery capacity to provide a greater all-electric range (AER), the removal of technical and infrastructure barriers, the safety of connections, and the impacts of PHEV use on electricity production and utilities. Because the mean commuting distance in the Netherlands is less than 20 km one way, the PHEV represents a good fit to meet Dutch transportation needs. Thus, a PHEV(40) (i.e., a PHEV with an AER of 40 km) would be an acceptable vehicle for commuting and short city trips.

Energy and environmental impacts

Even though fuel prices have risen quickly over the last 3 years, the average annual number of kilometres travelled by a vehicle has also continued to increase slightly (for a private car powered by gasoline, to about 10,500 km; for the average of all private cars powered by all fuels, to 13,800 km). Since the penetration of hybrid cars into the total market will be slow during the coming 5 years, the salutary impact that these vehicles have on energy and the environment will be limited. Nevertheless, HEVs and PHEVs will have a substantial positive impact on local air quality in urban areas. The hybridization of goods vehicles (i.e., dis-

tribution vans and distribution trucks) and public transport buses will also have a positive effect on air quality in cities. However, for these vehicles to dominate the market, substantial development of both the products themselves and the production machinery will have to occur.

21.7

Benefits of participation

From the perspective of the Netherlands, the benefits of participating in the International Energy Agency (IEA) Implementing Agreement for Co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) include the following:

- Obtaining available information on advanced transportation and automotive technologies from around the world.
- Partnering to produce joint studies and take advantage of opportunities to involve national research bodies in the work.
- Using results from the programmes of other countries and cultures as guidance in the preparation of national programmes.
- Participating in a worldwide network of transportation experts, research institutes, and government officials responsible for transportation. This dimension of having access to an international perspective is important.

21.8

Further information

Further information can be obtained from the following websites:

- www.atcentre.nl (in Dutch and English), Automotive Technology Centre
- www.hn.nl/kc/automotive_eng (in English), HAN University of Applied Sciences, Automotive Expertise Centre
- www.htas.nl (in English) (HTAS is the innovation programme of the Dutch automotive industry, in which industry, knowledge institutes, and government participate.)
- www.agentschapnl.nl (in Dutch and English), Dutch Agency for Innovation and Sustainability
- www.tno.nl (in Dutch and English), website of the Netherlands Organisation for Applied Scientific Research TNO, including automotive activities

22.1 Introduction

Spain is pursuing many ambitious objectives in advanced transport technologies, and since late 2008 it has set the goal of putting one million hybrid and electric vehicles on the nation’s roads by 2014. One major reason for this effort is that the country relies on external sources for 80% of its energy, with oil consumption accounting for almost half of its total energy use as of 2008 (figure 22.1).

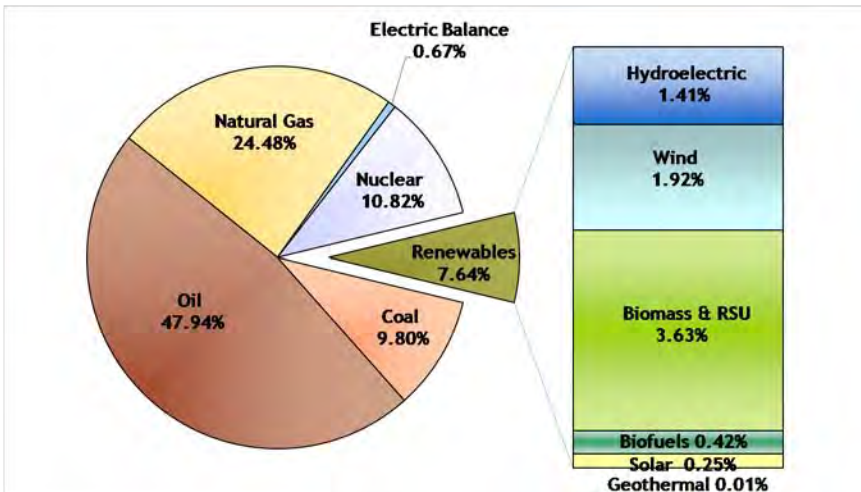


Fig. 22.1 Primary energy consumption in Spain, 2008. (Source: IDAE.)

Total energy consumption in Spain grew 135% from 1973 to 2004, while the transportation sector’s energy usage grew 240% in the same period. Alternatively, over the time span from 1990 until 2008, energy usage for transportation grew by 77.2%. As of 2008 the transportation sector uses 37.9% of total energy consumed, which is more energy than any other sector, as seen in figure 22.2. Over the same period, Spain has also experienced the greatest percentage increase by far in highway miles and cars per inhabitant in Western Europe, with road transport accounting for 25.4% of national CO₂ emissions today.

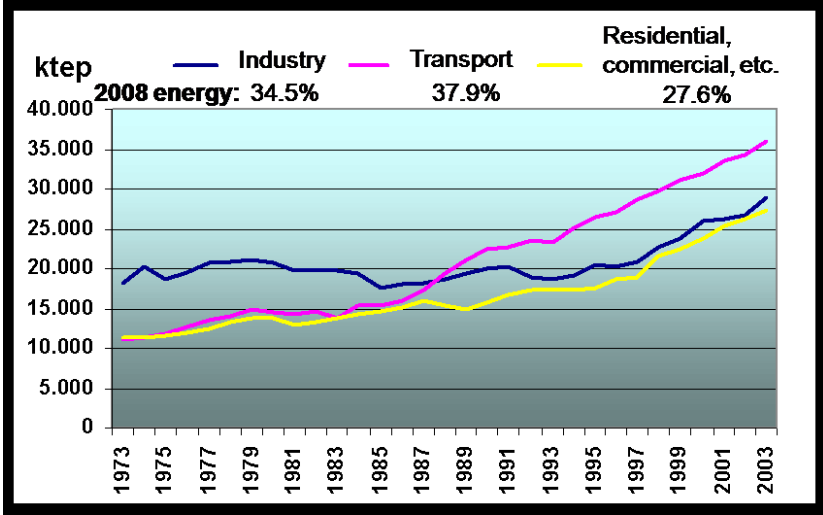


Fig. 22.2 Final energy consumption in Spain. (Source: IDAE.)

Within Spain’s growing transportation sector, road transport currently accounts for more than 80% of energy consumption, and its share of this sector has increased from 69.1% in 1980 (figure 22.3). Oil fuels more than 98.2% of the total energy consumed by transport, and around 65% of the oil imported into Spain each year is used in the transportation sector. This strong reliance upon road transport consequently has a negative impact on Spanish energy independence and efficiency, environmental emissions, and the national infrastructure.

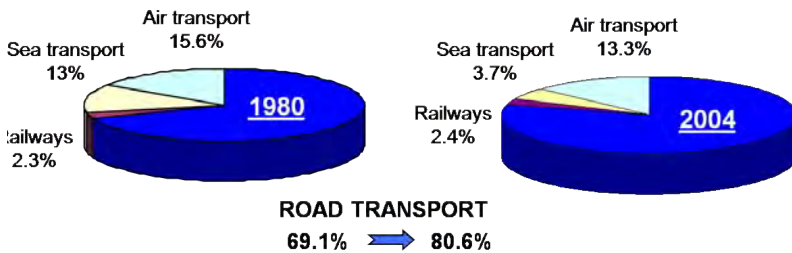


Fig. 22.3 Percentages of different transport modes in transportation energy consumption in 1980 and in 2004. (Source: IDAE.)

The Spanish government expects that introducing EVs to the nation’s roads could reduce the country’s dependence on imported energy sources by more than 20 percentage points overall. It calculates that it could halve the amount of oil that it would need to import, reducing the nation’s current trade deficit by

25%. Moreover, Spain would achieve savings of 81 Mt CO₂/year, which translates to 1,000 M€/year in CO₂ emissions rights.

22.2

Policies and legislation

Spain's policies regarding HEVs, PHEVs, and EVs have arisen within the context of its national commitments to meet international environmental goals. Spain's Kyoto Commitment allows CO₂ emissions in the period from 2008 to 2012 to rise 15% above 1990 levels. However, by 2004 CO₂ emissions had risen by 42% instead. To address the reality of Spain's energy consumption and to match the energy efficiency objectives in the Kyoto Commitment and in the European Union 2020 Strategy ("triple 20"), the government established the Spanish Strategy for Energy Savings and Efficiency 2004–2012 (known as E4). Under E4, Spain has implemented two action plans (from 2005–2007 and from 2008–2012) which define relevant measures, actors, and budgets to improve the energy efficiency of different sectors. The E4 also covers a large percentage of the objectives for CO₂ reductions in the National Plan for GHG Emissions. Finally, the E4 is complemented by the Activation Plan on Energy Efficiency and Savings 2008–2011 which intensifies the E4 objectives through initiatives on new regulations, including towards the goal of one million HEVs, PHEVs and EVs in Spain by 2014. All of Spain's major energy efficiency efforts are diagrammed in figure 22.4, and so far the programs have managed to reduce Spain's CO₂ emissions to only a 32% increase over 1990 levels as of 2009. Reduction of the remaining 17% to meet the Kyoto Commitment are expected to come from emissions market operations (15%) and establishing CO₂ drains including reforestation and investment in renewable energies in underdeveloped countries (2%).



Fig. 22.4 Spain's energy efficiency efforts to meet its Kyoto Commitment objectives.

For the transportation sector, up to 9,087 ktoe (kilotonnes oil equivalent) of energy consumption could be reduced by adopting the most stringent measures in these plans compared to the business as usual scenario.

The E4 framework defines the steps towards a policy that can balance the goals of a secure energy supply with a basic level of self-sufficiency, reducing energy consumption in accordance with international environmental agreements, and maintaining a competitive economy. Transport is one of the seven sectors addressed by E4, and there are three main supporting lines to promote the introduction and mass uptake of electric vehicles:

- ▶ **Agreements with regional administrations:** Signed between IDAE (Institute for Diversification and Saving of Energy) and the governments of the different regional administrations, to support the acquisition of electric vehicles and the setting up of electric charging stations for fleets as well as public charging networks.
- ▶ **Strategic support plan:** A national support plan managed by IDAE aiming to support the acquisition of alternative vehicles on a large scale (generally channeled through leasing and renting companies).
- ▶ **MOVELE project:** Demonstration project with an objective of creating relevant charging networks in big cities (Madrid, Barcelona and Sevilla) and to support the acquisition (up to 20% of their market prices) of electric vehicles.

In addition to the three lines above, Spain also has policies to address the European regulations and also introduced measures to support the country's automotive industry in 2009. Finally, there are some additional initiatives to support EVs that are under consideration.

Agreements with regional administrations

The first strategic effort in E4 which supports electric mobility is the current set of agreements signed by IDAE with Spanish regional administrations to support actions in various sectors in order to improve energy efficiency. These programmes started in 2005 and are renewed each year with an assigned budget and planned actions to carry out in each region. In collaboration with IDAE, regional governments are responsible for the realization of these measures.

In the transportation sector, two key measures focus on fleet renewal (for cars and industrial vehicles). These support the acquisition of alternative vehicles (natural gas, LPG, hybrid, electric, hydrogen and fuel cell). Vehicle types include quadricycles, motorbikes, cars, buses, and trucks, and the incentives are offered to a wide range of beneficiaries including transport fleets, companies, and individual citizens. The incentives can also be used with various financial arrangements including leasing and renting. The establishment of electric vehicle charging stations is part of these measures as well. The financial support provided by IDAE and the regional governments varies by type of vehicle used, with the amounts listed in the table in table 22.1. The budget for these actions is supported by IDAE (77%) and the regional governments (23%).

Table 22.1 HEV and EV incentives provided by IDAE and regional governments.

SPAIN: AGREEMENTS WITH REGIONAL ADMINISTRATIONS (E4)	HEV AND EV INCENTIVES (APPLICABLE TO BOTH PUBLIC AND PRIVATE SECTORS)
Car fleet renewal (private cars)	
Motorbikes	Maximum of 750€ for motorbikes above 4 kW
Passenger vehicles (M1), commercial vehicles (N1), and quadricycles (L7e)	Up to 15% of their market prices, with a maximum of €7,000
Full hybrid	Support up to a maximum of €2,300 , for HEVs with pure electric traction and CO ₂ emissions below 130 g CO ₂ /km in 2009, and decreasing by 10 g CO ₂ /km each year after
Mild hybrid	Support up to a maximum of €2,000 , for HEVs without voluntary pure electric traction and CO ₂ emissions below 130 g CO ₂ /km in 2009, and decreasing by 10 g CO ₂ /km each year after
PHEV and BEV	Support up to a maximum of €7,000 , with a minimum electric range of 20 km (12 miles) for PHEVs.
Charging points	Up to 30% of the inversion costs, with a maximum of €60,000
Industrial vehicle fleet renewal	
Buses and trucks	up to 15% of their market prices, with a maximum of €50,000
Charging points	up to 30% of the inversion costs, with a maximum of €60,000

The results of this programme through 2008 are tabulated in table 22.2 and show how HEVs and EVs have begun to penetrate fleets at increasing rates.

Table 22.2 Results of E4 fleet renewal programme, 2006–2009.

RESULTS OF E4 FLEET RENEWAL PROGRAMME, 2006 THROUGH 2009		
Year	Types of vehicles	Totals
2006	Total cars renewed (GLP, Natural Gas, HEV, EV, Fuel Cell)	142
	Total vehicles renewed	142
	Hybrid vehicles	137
2007	Total cars and motorcycles renewed	917
	Total industrial vehicles	154
	Total vehicles renewed	1,070
	Total hybrid and electric vehicles (estimated)	963
2008	Total vehicles (cars, motorcycles, and industrial) renewed	3,151
	Hybrid vehicles confirmed	1,794
	Electric vehicles confirmed	43
	Total hybrid and electric vehicles (estimated)	2,062
2009	Total vehicles (cars, motorcycles, and industrial) renewed (estimated)	3,065
	Electric charging points	41
	Total hybrid and electric vehicles (estimated)	2,957
	Total vehicles renewed	7,428
	Total hybrid and electric vehicles for 2006 – 2009 (estimated)	6,119

Strategic projects: fleet renewal for leasing companies and buses

The second plan of action in the framework of the E4 pertaining to HEVs and BEVs includes the strategic projects. These projects involve more than three regions or have duration of longer than one year. Proposals are solicited from all E4 sectors (Industry, Transport, Building, Public Services, Residential and office computer system, Agriculture, Energy Transformation), with €60 million available in 2008, and €120 million available in 2009.

These strategic projects also include support for the acquisition of HEVs, PHEVs, and EVs at the same financial levels as the fleet renewal initiatives at the regional scale, with the difference being that these are aimed at large operations with high numbers of car renewal, mostly channelled by leasing and renting companies. The results of this plan are shown in table 22.3.

It is also worth noting here the Electrobus project, which supports the acquisition of hybrid buses and the transformation of conventional buses into hybrid buses (done by Siemens and Nage). This project is focused in the transport consortiums of the major cities of Madrid, Barcelona, and Valencia.

Table 22.3 Results of strategic projects/fleet renewal programs, 2008–2009.

RESULTS OF STRATEGIC PROJECTS FLEET RENEWAL PROGRAMS, 2008 THROUGH 2009		
Year	Types of vehicles	Totals
2008	Total cars renewed (GLP, Natural Gas, HEV, EV, Fuel Cell) – mostly hybrids 7 renting/leasing companies Total investment committed: 36 M€ IDAE support: 4.2 M€	1900
2009	Total cars renewed (HEV, EV, Fuel Cell) – mostly hybrids 7 renting/leasing companies Total investment committed: 22 M€ IDAE support: 2.6 M€	1382
2009	Electrobus project (urban buses in Madrid, Barcelona, and Valencia): Hybrid transformations (Siemens + Nage) €110,000 per bus IDAE support: €51,000 per bus Hybrid buses (Mercedes, Scania, Volvo) €345,000 per bus IDAE support: €230,000 per bus Fuel cell buses (Mercedes, Scania, Volvo) €1,200,000 per bus IDAE support: €180,000 per bus (max. 15%) Total investment committed: 44.6 M€ IDAE support: 15 M€	192 121 63 8

MOVELE project: EVs and infrastructure

On 1st October 2008, the Spanish Council of Ministers approved an Activation Plan on Energy Efficiency whose objectives were to strengthen and activate the measures developed in the framework of the E4 Action Plan 2008–2012 and consider 31 additional measures that would cost 245 M€ and achieve energy savings of 6 Mtoe. One of these measures is to carry out a demonstration project towards the ultimate goal of having one million EVs and HEVs operating in Spain by 2014.

Named MOVELE (MOVilidad ELEctrica), this pilot project aims to introduce 2,000 electric cars to the market by the end of 2010, preferably in fleets, in urban and peri-urban environments. Through MOVELE, a charging station network is being installed in three major cities, with 280 stations in Madrid, 191 in Barcelona, and 75 in Seville, for a total of 546 charging stations. An example of a charging station is shown with Spain's Minister of Industry and the mayors of Barcelona, Madrid, and Seville in figure 22.5. This project will enable the analysis of energy results under real-use conditions, and it is expected that the data gathered may eventually lead to amendments to current regulations that may enable wider development of these mobility alternatives. As of January 2010, a total of 263 vehicles have been rolled out as part of the MOVELE demonstration.



Fig. 22.5 Spanish Minister of Industry (Miguel Sebastián) with the mayors of Barcelona, Madrid, and Seville at the MOVELE presentation in September 2009.

Other cities in Spain also intend to make electric charging networks for public use similar to the MOVELE systems. Therefore, a measure was defined in the framework of the collaboration agreements with the regional administrations to provide support for establishing charging networks of 40% of eligible costs up to a maximum of €200,000. These networks must have at least ten charging points, with a ratio of one charging point per 10,000 inhabitants.

All of the networks planned as of early 2010 are shown in the electric network map of Spain in figure 22.6.

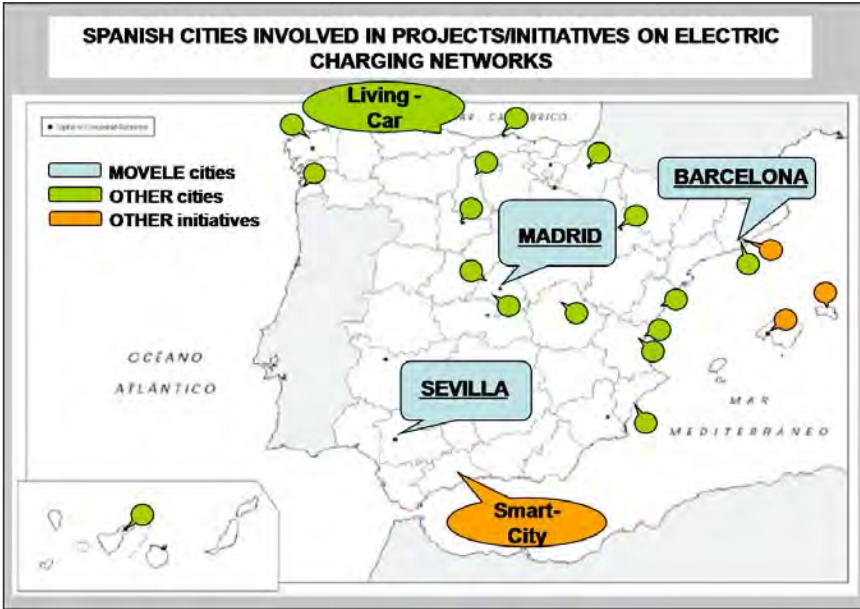


Fig. 22.6 Spanish cities involved in projects or initiatives on electric charging networks.

Including the numbers of HEVs, PHEVs, and EVs introduced to Spain through both the regional administration programs and the strategic projects above, the 2,000 vehicles introduced through MOVELE will bring the total to 11,403 such vehicles. Also, an estimated additional 15 projects planned with 10 charging points each will add 150 charging points to the 546 charging points in the MOVELE network, leading to a total of 696 charging points throughout Spain by the end of 2011.

POLICIES TO ADDRESS EUROPEAN REGULATIONS

It is assumed by the Spanish Government, town councils, car manufacturers, auxiliary industry, utilities and information and communications technology companies that hybrid and electric vehicles are necessary to match the new regulations for CO₂ reductions in cars (Regulation CE/443, adopted by the European Union in April 2009), improve the air quality in cities and the energy efficiency, and reduce the nation's energy dependence on other countries. For this reason, all these stakeholders signed a Memorandum in November 2009 in which are collected the respective commitments for each party involved.

At the national Electric Vehicle Summit in November 2009 a working group was formed to include representatives of all the stakeholders mentioned in the previous paragraph in order to develop an Integral Plan (led by the Ministry of Industry) for promoting mass production and demand for electric vehicles. This Integral Plan will be presented in the first four months of 2010, during the Spanish Presidency of the EU, which has the promotion of electric mobility as one of the key plans of action. Within the framework of this working group, the commitments reached by the different actors are as follows:

- ▶ **Government:**
 - ▶ To define a plan to stimulate demand for electric vehicles, define norms and administrative procedures, and maintain the supporting lines in the framework of the E4 to promote the acquisition of electric vehicles and the installation of charging stations.
 - ▶ To create a framework of incentives for investments in industry and to support research, development, and innovation (R&D&I) related to these vehicles.
 - ▶ To create financing solutions for energy and technology companies to set up systems related to the use of electric vehicles.
 - ▶ To facilitate a regulatory framework to promote the charging of batteries during off-peak consumption hours for the electricity grid, in order to promote better energy efficiency and the use of renewable energies, and to adapt the energy infrastructure to these requirements.
- ▶ **Town councils, represented by FEMP (Spanish Federation of Town Councils):** To promote actions to prioritize electric vehicles in cities, to set up electric charging stations, to introduce electric vehicles into town fleets, and to facilitate administrative procedures.
- ▶ **Car manufacturers and auxiliary industry:** To promote agreements and market alliances regarding the industrialization of electric vehicles, and the standardization of systems and charging communication protocols.
- ▶ **Energy sector:** To sign collaboration agreements with the car industry and design specific offers regarding electric charging stations and services.
- ▶ **Technology companies:** To collaborate in projects related to electric vehicles and spur the standardization of systems and protocols.

A second initiative to promote electric vehicles is the creation of FOREVE (Foro Español del Vehículo Eléctrico), a national platform created by entities in Spain related to electric mobility with the objective of developing studies, holding strategic meetings within the sector, issuing elaborate publications, and other tasks. The technical office is managed by FITSA (a foundation on car technologies and policies supported by different Spanish Ministries).

A third EV-related initiative is the participation of IDAE in the European Grid for

Vehicles (G4V) project that officially launched in January 2010. Over 18 months, participants in G4V will conduct analysis of the impact and possibilities of a mass introduction of electric and plug-in vehicles on the electricity networks in Europe. This initiative was presented to the EU's Seventh Framework Programme (FP7) by a consortium of companies led by RWE Energy AG (Deloitte in the technical office). In this project, Spain is going to participate in a Scientific Advisory Board (SAB) with the objective of ensuring that requirements of different stakeholders are taken into account and also for gathering data input and feedback. The final outcome will be a recommendation to the EU on R&D on grid infrastructure, investment tax credit (ITC) protocols, and policies for the mass introduction of EVs and HEVs.

SPANISH AUTO INDUSTRY SUPPORT MEASURES

Spain is implementing additional policies, programs, and research projects that also aim to address the crisis in its automotive sector resulting from the global economic downturn that began in 2008. Though these efforts are specifically directed at encouraging the adoption of HEVs, PHEVs, and EVs, these incentives may lead some consumers to opt for such vehicles.

In February 2009 Spain's Council of Ministries approved the Integral Plan for the Car Industry in response to the global slump in automotive sales that began in 2008. The plan dedicated €4 billion (0.28% of the GDP) to create incentives to stimulate demand (€2,000 per car) and to support R&D, and measures aimed to improve logistics and industry.

The framework of the Integral Plan for the Car Industry includes the VIVE Plan (Vehículo Innovador, Vehículo Ecológico), a plan oriented toward increasing vehicle demand. VIVE supports the acquisition of new cars and vans weighing up to 3,500 kg and used ones less than 5 years old with emissions under 140g CO₂/km and a price below €30,000. This plan involves scrapping the old car, which must be more than 10 years old for acquisition of new cars and more than 15 years old for acquisition of used cars, or have more than 250,000 km on the odometer. The support is channeled through financing discounts (80% of all car purchases in Spain are made through finance companies), in collaboration with the Spanish Institute for Official Credit (ICO). The VIVE plan budget was assigned 700 M€ in 2009 for a total renewal of 70,000 vehicles.

A second VIVE plan was also approved by Spain's Council of Ministries to increase the vehicle demand for buses. This plan supports acquisition of new buses of at least Euro IV standard for emissions or powered by alternative technolo-

gies (hybrid, electric, natural gas, hydrogen), and scrapping buses more than 10 years old. It also improves the credit conditions in collaboration with ICO, enabling financing for 100% of the total market price of the vehicle (the first €130,000 at 0% interest rate over 5 years). A total of 236 M€ was approved for the VIVE buses programme for the purchase of 2,100 vehicles.

A third plan created for promoting vehicle demand is the 2000-E Plan, through which a combination of national and regional administrations offer direct financial support up to €2,000 toward the purchase of a new vehicle. This plan is compatible with the support offered in the collaboration programmes with the regional administrations for the acquisition of alternative vehicles, but not with VIVE plan. The Plan 2000-E helped to support the sales of 200,000 cars from 18th May to October 2009 and recently has been extended to 2010 for 200,000 more vehicles.

INITIATIVES UNDER CONSIDERATION TO SUPPORT EVS

The Spanish government is currently considering a package of tax incentive measures for promoting electric mobility. This would include modifications of the taxes on the purchase and use of PHEVs and EVs, VAT, and other taxes linked in a direct way to electric vehicles.

Finally in the area of regulations and legislation, it is worth mentioning here the modification of the Law 19/2009 (23rd November 2009) related to promoting and the energy efficiency of buildings. This modification is aimed at home charging and allows a person living in a residential community to set up an electric charging point in his parking place only by communicating his intention to do so. Previously, installing a charging point required a person to ask for permission from the community, which would generally require a majority vote in a referendum by the neighbors.

22.3

Research

The development of technologies for HEVs, PHEVs, and EVs in Spain occurs as part of European initiatives, at the national and regional level via the support of the government and other closely related entities, in the private sector, and at universities.

As a member of the EU, Spain participates in the European Green Car Initiative (EGCI). Part of the European economic recovery plan, the EGCI aims to allocate €5 billion (US\$6.7 billion) through a public-private partnership (PPP)

to bolster innovation in the automotive sector and sustain its focus on environmental progress.

A working group is currently summarizing Spanish contributions, interests, and needs for the EGCI. The group is emphasizing three major avenues of research: heavy-duty vehicles, electrification of urban and road transport, and logistics and co-modality (the use of different modes of transportation on their own and in combination with the aim of obtaining an optimal and sustainable utilization of resources).

On the Spanish national level, one of the most active entities in the R&D arena is the Centre for Industrial Technological Development (CDTI), a public company founded in 1977 and supervised by the Ministry of Science and Innovation. CDTI supports the development of new products, services, and standards in many areas, including mobility. The working group representing Spain for the EGCI is from the CDTI. The Ministry of Science and Innovation also supports Spanish technology platforms in many areas including that of transport. Finally, IDAE is implementing the MOVELE Project, the EV pilot project described in the Policies and Legislation section of this chapter.

Vehicle development efforts are also underway in the private sector. Spanish automaker SEAT is developing a Leon Twin-Drive prototype PHEV in its Technical Centre in Barcelona. SEAT presented the concept for the new car to the Ministry of Industry in January 2009, with initial results expected by the end of 2009, and the goal of introducing a car in 2014.

Bus manufacturer Hispano Carrocera is developing hybrid products, including:

- A hybrid bus product line, to be developed from 2009 to 2011, that will include a modular, ergonomic, lightweight, and efficient electricity-powered bus
- ACE EV and hydrogen light transport vehicle to satisfy the needs of neighborhood transportation, to be developed over the 2009 – 2010 period
- An electric minibus to be launched in 2010 in an electrically-powered version

Currently EMT, the bus operator in Madrid, has been using Hispano's electric minibus model in two bus lines in city centers since early 2008, where it is found to be suitable to the narrow streets and environmental restrictions for such sites.

Finally, Spain's universities are also involved in R&D programmes related to EVs, including collaborations with technology centers and companies. Examples include INSIA-UPM (Polytechnic University of Madrid), Polytechnic University of Catalonia (UPC), and Polytechnic University of Valencia (UPV).

22.4 Industry

Spain is the 8th largest vehicle producer in the world, the 3rd largest European manufacturer of cars and the largest manufacturer of light commercial vehicles in Europe. In 2008, 2.5 million vehicles were produced in Spain, 83% of which were exported. Turnover totalled 51.768 M€ in 2007 (4.5% of GDP). The main component manufacturers in Spain hold the 6th position in the world in turnover (29.97 M€ in 2008). Exports of vehicles, parts, and pieces accounted for 22% of total Spanish exports in that year.

Spain's automotive industry experienced the consequences of the global economic downturn that began in 2008. In the first nine months of 2009, registrations were down 28.6% when compared to the same period in 2008. Moreover, the declines in 2009 had come on top of the fact that car sales had plunged 28% in Spain in 2008 over the previous year. However, after 16 consecutive months of decline, in September 2009 new car sales in Spain were at last up 18% over the same period the previous year, according to Spanish car manufacturers' association ANFAC.

Because the automotive sector represents such a significant portion of the country's economy, Spain unveiled measures in February 2009 to aid its automakers to weather the storm.

A competitiveness plan for the automotive sector implemented by the Ministry of Industry included the following efforts. In 2009, the Ministry gave 56 M€ towards electric vehicle manufacturing in Spain, along with automakers Seat, Renault, Nissan and Peugeot investing 88 M€ in Spain's EV industry. The Ministry will give another 250M€ to strategic projects in the automotive sector in 2010. A new guarantee plan for the automotive sector also includes €1 billion (presented in the 2010 budget assigned to the Ministry of Industry to support projects and actions principally oriented to HEVs and EVs.

The manufacturer Renault has announced that it will introduce Spain's first "mass-produced" BEVs in Valladolid. Production will begin in 2011, and it is expected that in 2013 that 20,000 BEVs will be produced at this plant out

of 100,000 vehicles total. This will entail investment of 500 M€ in the next 4 years, with 70 M€ focused on the EV, and also rests on an agreement reached with trade unions that will secure the continuity of 5,000 direct and 30,000 indirect employees for at least 4 to 10 years.

22.5 On the road

Spain currently has about 14,000 HEVs and almost 11,000 EVs out of a total fleet size approaching 45 million vehicles. At the end of November 2009, cumulative sales of specific models of HEVs included 8,121 Toyota Priuses, 1,694 Honda Civic Hybrids, 4,141 Lexus HEVs, and 9 Mercedes-Benz S400h cars. Most electric vehicles in Spain are bicycles, with small quantities distributed in other vehicle categories, as shown in table 22.4.

Table 22.4 Hybrid and electric vehicle fleet numbers at the end of 2009.

Vehicle type	PER 31 DECEMBER 2009		
	EV fleet	HEV fleet	Total fleet (incl. EVs and HEVs)
Bicycles (no driver license)	<10,000	0	15,000,000 aprox.
Motorbikes	250	0	2,500,819
Passenger vehicles	240	14,000	22,145,364
Multipurpose passenger vehicles	170	0	2,364,471
Buses	20	0	62,196
Trucks	18	0	2,290,942
Industrial vehicles	0	0	213,366
Total	10,698	14,000	44,577,158

The most common hybrid car on Spain's roads, the Toyota Prius, has shown the following sustained growth in sales since its introduction, as shown in Table 22.5.

As described in previous sections, the continuous growth of hybrid acquisitions is sustained by public grants, fiscal incentives, and also by a change in consumer behavior, which is becoming more sensitive to fuel efficiency and environmental matters.

Table 22.5 Sales of Prius hybrids in Spain.

SALES OF PRIUS HYBRIDS IN SPAIN					
Year	2000	2004	2008	2009	2010 (estimated)
Units sold	120	400	1,000	3,000	4,000

The delivery time for the Prius has decreased from 7 months in 2009 to between one and 4 months today. In this way, both Toyota and Honda demonstrate that there is a problem of a lack of capacity because these OEMs' current production is limited (concentrated in Japan and USA). In many countries like Spain, importers are having problems meeting the increasing demand for these vehicles.

22.6 Outlook

Spain has established the goal of achieving one million HEVs, PHEVs, and EVs on the road by 2014. The MOVELE project is a key demonstration programme aimed to prove the viability of PHEVs and EVs. The framework of this project supports the acquisition of PHEVs and EVs by public and private entities as well as citizens; it also supports the installation of basic charging infrastructure to support a shift to electric mobility. Within the framework of the E4 and in collaboration with IDAE, other local governments are extending the EV charging infrastructure beyond the initial MOVELE programme in order to promote the use of electric vehicles by their citizens.

Regarding the goal of a million hybrid and electric vehicles on Spain's roads by 2014, around 250,000 of these are estimated to be cars and vans that are EVs and PHEVs. The national plans described earlier in this chapter are focused on reaching that figure. The remaining 750,000 vehicles would include other electric vehicles (motorbikes and heavy duty vehicles) and conventional hybrid vehicles.

It is considered that the 250,000 electric cars and vans is a sensible objective, and national and regional governments are working to achieve this goal. Most of the other 750,000 vehicles are expected to be hybrid vehicles. The acquisition of hybrid cars in Spain is currently supported by different measures and programmes through grants and tax incentives, but achieving the targeted goals will also depend on an increase of the production capacity of hybrid vehicles within the OEMs as well as the spread of this technology to other OEMs.

The different measures that Spain has implemented as part of its strategy out of the automotive crisis are making progress to recover the demand for vehicles. The nation believes that PHEV and EV vehicles represent a great opportunity for private fleets to improve their economic competitiveness in the future by attending to energy efficiency. Also, administrative fleets are including EVs and PHEVs as part of their environmental policies to reduce urban emissions and improve air quality.

22.7

Benefits of participation

As shown in the previous sections, key stakeholders are committed to encouraging the adoption of electric mobility in Spain and are working seriously on this effort. However, Spain has joined the IA-HEV because it seems necessary to be involved in a collaboration framework at the international level with the main objective of sharing relevant information at the national level about plans and procedures to adopt electric vehicles. It also would be valuable to exchange information about technologies and systems, commercialization markets, planned initiatives, and other matters related to the implementation of electric vehicles.

We also consider very important the personal contacts with experts in the different fields related to electric mobility and the potential collaboration of Spanish entities which work in this matter with them.

Finally, Spain wants to show, at the international level, its firm commitment, strategies, and plans to promote and implement electric mobility.

22.8

Further information

More information about Spain's initiatives in hybrid and electric vehicles may be found at the following resources:

- ▶ www.idae.es
IDAE (Institute for Diversification and Saving of Energy), which is managing the MOVELE project, which is detailed further within this website
- ▶ *Spanish Capabilities in the Eco-Electro Road Mobility Sector and the FP7 Green Cars Initiative*, a publication edited by Aragon regional technology incubator Tecnoebro, CDTI, and SERNAUTO (the Spanish Association of Manufacturers of



Equipment and Parts for the Automobile Industry). Published in 2009, this report collects and summarizes the most recent activities and the scientific and technological capabilities of the Spanish sector in electro road mobility. It also includes information about EGCI and key Spanish stakeholders in this sector. This publication is available as a free download on the Tecnoebro website: http://www.tecnoebro.com/htm/noticias/noticias_ing.php?id=54



23.1 Introduction

In Sweden, eco cars (cars eligible for governmental subsidy, including hybrid and electric vehicles) continued to make inroads into the market during 2009, while the country's automotive industry overall suffered from the drop in demand also witnessed by many other countries. The Swedish market for personal cars decreased by 16% and that for heavy vehicles fell by 28%. Over the year there was also much uncertainty about the survival of famed Swedish brands Volvo Car and Saab Automobile and who their new owners would be.

Still, eco ("green") vehicles made great progress in Sweden despite bad times for the whole vehicle industry. The sales share of private cars that are eco vehicles increased from 33% to 38%. One reason could be the great interest in climate change, but economic reasons, like high oil prices and government legislation that financially promoted eco vehicles, also played a part. Ethanol vehicles (E85) still had the largest share of the eco vehicle market, but more efficient conventional vehicles with maximum emissions of 120 g CO₂/km also increased. Table 23.1 shows 2007, 2008, and 2009 eco vehicle sales shares by vehicle type.

Table 23.1 Relative sales shares (in %) for "green" vehicles in Sweden.

CATEGORY	2007	2008	2009
E85 (ethanol)	65	68	49
Max 120 g CO ₂ /km, gasoline	14	13	16
Max 120 g CO ₂ /km, diesel	12	13	24
Hybrids	6	4	3
Gas	3	2	8
Total	100	100	100
Eco share of total private car sales	18	33	38

Over the past decade, Sweden has put into place policies that reduce certain taxes and fees on eco cars including hybrids (HEVs), plug-in hybrids (PHEVs), and electric vehicles (EVs). Currently, the national government is considering additional measures to further encourage the uptake of these vehicles. In May 2009, the Swedish Energy Agency delivered to the Swedish Government an overall knowledge base report regarding the market for electric vehicles and re-

chargeable hybrids. The report suggests a four-year period for economic support of demonstration projects in order to increase the number of electrical vehicles and rechargeable hybrids on the market. This is due to the fact that the increased cost compared to ICE cars for PHEVs and EVs over the next few years is considerable and also uncertain; therefore the expansion of the electric charging infrastructure requires considerable development and standardization. Also, the report states that the government needs to encourage the participation of the Swedish automotive industry in the development of PHEVs and EVs.

A major new programme co-ordinating Swedish Government and private-sector research efforts in vehicle research started on 1 January 2009. Called the Vehicle Strategic Research and Innovation programme (FFI), it focuses on traffic safety, energy efficiency, and the environment with a pronounced emphasis on electrification. In 2009 the Swedish Energy Agency supported two projects where a total of 150 battery electric vehicles will be demonstrated. One project will test the Volvo C30 EV in 2011 (Fig 23.1). The other concerns 100 Saab 9-3 EVs during 2010 and 2011.



Fig. 23.1 Volvo Cars C30 Battery Electric Car (50 cars will be demonstrated in 2011)

The Swedish consumers' interest in electric vehicles remains very high. The major Swedish power companies began working together in 2008 in a joint initiative promoting EVs and PHEVs. The goal is to bring 600,000 vehicles to the market by 2020. One ongoing subproject involves converting ten Toyota Priuses to PHEVs and field-testing them.

Other privately-funded research efforts include an ongoing project in which Volvo Cars, ETC Battery and Fuel Cells AB, and electric power producer Vattenfall are demonstrating three Volvo PHEVs in practical use. In the spring of 2009, Scania began field-testing its serial hybrid buses in the Stockholm city public transportation system. Volvo also started serial production of its hybrid buses during 2009.

23.2 Policies and legislation

Taxation

In December 2001, the Swedish Government reduced the notional taxation burden of certain eco vehicles in order to encourage their sales. The present rules were set in the Government's December 2003 Budget Bill. Under these rules, the notional taxation burden of hybrid or electric cars owned by a company is reduced by 40% relative to the closest comparable gasoline model, subject to a maximum reduction of US\$ 2,500 per year. This reduction can be compared with the 20% reduction given for company cars running on E85, natural gas, or biogas; such vehicles are subject to a maximum reduction of US\$ 1,250 per year. Table 23.2 presents some examples.

Table 23.2 Notional benefit reductions for some common eco vehicles in Sweden.

VEHICLE	APPROXIMATE NOTIONAL TAXATION BENEFIT [US\$ PER YEAR]
Toyota Prius hybrid electric car	2,500
Volvo bi-fuel models	1,250 less than corresponding gasoline models
Mercedes E200 NGT	1,250 less than corresponding gasoline model
Volkswagen Golf Bi-fuel	1,250 less than corresponding gasoline model
Ford Focus Flexifuel	950 less than corresponding gasoline model
Opel CNG models	950 less than corresponding gasoline models

Rules for public purchasing of vehicles

The current requirement governing the public purchase and leasing of vehicles for public authority fleets is that at least 85% of the total number of cars purchased or leased by a public authority during a calendar year should be eco vehicles. The "Ordinance concerning public purchasing and leasing of eco vehicles" has been in force since 1 January 2005. In 2006, the National Road Administration published a definition of the types of vehicles that qualify as eco vehicles in accordance with the requirements of the ordinance. This is described in the following subsection.

Grants for eco vehicles

Any private individual who bought a new eco car between 1 April 2007 and 30 June 2009 received an “eco car subsidy” of SEK 10,000 = US\$ 1,100. After 30 June 2009, the subsidy was replaced by an exemption from vehicle tax at approximately the same level. The criteria for an eco car tax exemption are:

- The fuel consumption of an alternative fuel vehicle (flexible fuel, bi-fuel, and/or electric) must be below the energy equivalent of 9.2 L of gasoline, 9.7 m³ of natural gas (CNG), or 37 kWh of electric energy per 100 km.
- An alternative fuel vehicle must run predominantly on alternative fuels as opposed to fossil fuels.
- A vehicle run on fossil fuels can be called an eco car if the carbon dioxide emissions are below 120 g/km. In order to meet this requirement, the fuel consumption per 100 km must be below 4.5 L for diesel or 5.0 L for gasoline. (Note that this consumption restriction is due to the carbon dioxide requirement).
- In addition, for vehicles with diesel engines, emissions of particulate matter must be below 5 mg/km. In practice, this means that vehicles that run on diesel must be equipped with a particulate filter to be classified as eco cars.

Other incentives can reward drivers of hybrid, electric, and other eco vehicles. Some local authorities have reduced parking charges for eco vehicles; the rules vary from one local authority to another.

A congestion-charging scheme (i.e., tax charged during times of traffic congestion) has been in effect in central Stockholm since the summer of 2007. The congestion tax is imposed on Swedish-registered vehicles driving into and out of the Stockholm inner city zone on weekdays (Monday through Friday) between 6.30 a.m. and 6.29 p.m. Each passage into or out of the inner city zone costs SEK 10, 15, or 20 (about US\$ 1 to 2), depending on the time of day. This policy benefits PHEVs and EVs as there is no taxation on vehicles equipped with the technology to run either completely or partially on (1) electricity or a gas other than LPG or (2) a fuel blend that consists predominantly of alcohol.

23.3 Research

There were five national research programmes dealing with issues related to electric, hybrid, or fuel cell vehicles active during 2009. The programmes are closely linked in order to benefit from common tasks and overall synergies among them. They also share in monitoring and analyzing business intelligence. In brief, these are:

- ▶ **The Vehicle Strategic Research and Innovation programme (FFI)** started on 1 January 2009, as soon as a previous three-year effort of advanced research into HEVs, EVs, and FCVs named the Green Vehicle Programme and other vehicle research programs ended on 31 December 2008. The programme is a cooperative effort between the Government and the Swedish automotive industry. The programme will finance common research efforts, innovation, and development activities primarily aimed at the overall theme areas Climate and Environment and Safety, respectively. The project will be managed by Vinnova (Swedish Agency for Innovation Systems), the Swedish Energy Agency, and the National Road Administration. It comprises five sub programmes: Sustainable production technology, Vehicle development, Transport efficiency, Vehicle and traffic safety, and Energy and Environment. The venture includes R&D operations valued at approximately SEK 1 billion per year (approximately US\$ 140 million per year), of which public funds amount to SEK 450 million per year (approximately US\$ 65 million).
- ▶ **Energy Systems in Road Vehicles**, administered by the Swedish Energy Agency, involves several research projects dealing with batteries, fuel cells, and other vehicle components that use electricity as a means of improving energy efficiency. The programme entered its third phase in 2007 and will run until the end of 2010 with an additional budget of about US\$ 12 million. US\$ 7 million of these are devoted to hybrid vehicles and fuel cells. Under the programme to date, several PhD students have been trained in the field of hybrid vehicles and fuel cells, and a number of patents for new types of hybrid drive lines have been granted. This programme now concentrates on hybrid vehicles, especially their drive systems, battery technology, diesel reformers for fuel cells, and the architecture of hybrid systems.
- ▶ The aim of the **Swedish Hybrid Vehicle Centre (SHC)** is to establish an internationally competitive centre of excellence for HEV technology by facilitating education and research to meet industrial and societal needs in this area and by forming a natural framework for co-operation between industry and academia. Participating in the centre are AB Volvo, Scania CV AB, Saab Automobile AB/GM Powertrain AB, Volvo Car Corporation AB, BAE Systems Hägglunds AB, Chalmers University of Technology, Lund University, and the Royal Institute of Technology. The Centre started in July 2006, and the budget for the first period, 2007 to 2010, is about US\$ 11 million.
- ▶ The **Environmental Vehicle Development Programme** started in June 2007 and will run through 2010. Its total budget from the Swedish Government is about US\$ 29 million, and it is administered by the Swedish Energy Agency. The programme covers hybrids, engines for alternate fuels,

and lightweight and fuel-efficient engines. It includes co-operative projects between the United States (U.S. Department of Energy, Mack Trucks) and Sweden (Swedish Energy Agency, AB Volvo).

- Additionally, **Fuel Cells in a Sustainable Society** was the third part of a joint programme between universities and the fuel cell industry that ran from 1997 through 2009. The administrator was the Foundation for Strategic Environmental Research (MISTRA). The total budget of the programme was about US\$ 14 million, which funded research projects on fuel cell system components, materials, and systems.

23.4 Industry

Sweden's economy is very dependent on its automotive industry. The sector employs about 125,000 people, which includes 1,000 or so automotive subcontractors. During 2009, the industry laid off 15,000 people; this followed 12,000 layoffs during the previous year, leaving total employment at about 82% of the level it stood at the beginning of 2008. The decline in vehicle sales that led to these layoffs also led to uncertainty as the fates of the unprofitable Volvo and Saab brands were unclear throughout 2009. As of this writing in early 2010, the Chinese automotive group Zhejiang Geely Holding Group is close to finalizing the purchase of Volvo from U.S. automaker Ford Motor Co., and Dutch company Spyker Cars had just completed its \$74 million purchase of Saab from American owner General Motors.

The major manufacturers Volvo AB, Volvo Cars, Saab Automobile, and Scania, all have presented electric and/or hybrid concept vehicles. As the hybrid vehicle portion of the automotive sector has become more commercial, data on R&D activities have become proprietary and impossible to obtain from the companies.

Examples of subcontractors and small companies that are engaged in the fields of electric vehicles, fuel cells, and/or hybrid vehicle development are listed in box 23.1.

BOX 23.1 SUBCONTRACTORS AND SMALL COMPANIES IN THE FIELDS OF ELECTRIC VEHICLES, FUEL CELLS AND/OR HYBRID VEHICLES DEVELOPMENT	
Company	Activity
ETC, Battery and Fuel Cells AB	Development and sale of batteries for hybrid vehicles: primarily nickel metal hydride, and various activities in the fuel cell sector.
Alelion Batteries AB	High-performance batteries and power electronics.
Morphic Technology AB	Development of production technology for PEM fuel cells.
Cellkraft AB	Development of systems for PEM fuel cells.
Opcon Autorotor AB	Air supply systems for PEM fuel cells.
Woxna Graphite AB	Graphite for fuel cells.
Outocumpo Stainless AB	Stainless steels for fuel cells.
Actia Nordic AB	Power electronics for electric and hybrid vehicles.
LiFeSiZE AB	Up-scaled production and sale of low-cost Fe-based cathode materials for EV/HEV Li-ion batteries, especially $\text{Li}_2\text{FeSiO}_4$.
Transic	Development of silicon carbide power electronics.
Effpower	Development and sale of bipolar lead acid batteries for hybrid vehicles.
Powercell	Development and commercialization of fuel cell auxiliary power unit (APU) for heavy-duty truck applications.
Bevi	Electric machines.
Danaher	Hybrid electric drivetrains.
Vehiconomics	Development of small commuter and city vehicles.
Calix	Development of charging technology for electric vehicles.
ABB	Total systems provider of electric machines and components.
Electroengine in Sweden AB	After-market conversion to electric drive.
Cell Impact AB	Development and sale of bipolar plates for PEM fuel cells.

23.5

On the road

In total, there were more than 4.8 million private cars and heavy vehicles on the road in Sweden at the end of 2009 (see also table 23.3). About 41% of newly registered private cars had diesel engines. In January 2010, there were 279,000 eco cars in Sweden, an increase from 198,570 eco cars at the start of 2009. The market share of eco cars increased from 13% in 2006, to 18% in 2007, 33% in 2008, and to 38% in 2009.

Table 23.3 Characteristics and population of the Swedish motorized vehicle fleet per December 31, 2008 and 2009. Estimates are in *italics*.

Vehicle type	DECEMBER 31, 2008			DECEMBER 31, 2009		
	EV fleet	HEV fleet	Total fleet	EV fleet	HEV fleet	Total fleet
Motorized bicycle (no driver licence)	3,000	0	250,000	<i>n.a.</i>	0	270,000
Motorbike	0	0	450,000	0	0	465,000
Passenger vehicle	310	13,500	4,300,000	310	16,100	4,300,000
Multipurpose pass. vehicle	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>
Bus	10	0	13,000	8	2	13,400
Truck	50	0	505,000	50	0	510,000
Industrial vehicle	<i>n.a.</i>	0	500,000	<i>n.a.</i>	0	500,000
Total	3,370	13,500	6,018,000	3,368	16,102	6,058,400

n.a.= not available

The definitions of the different vehicle categories can be found in section E of this report, chapter "Vehicle categories."

Development

All through 2009, interest in electric and hybrid vehicles has been high. Industry has taken the role as the main driving force behind the continuing discussions on several R&D programmes and is showing great interest in building upon these efforts, for example, in the case of FFI and SHC as well as the demonstration projects for EVs. Previously the state had led these initiatives.

23.6 Outlook

In Sweden, opinions are divided about the definition of eco cars and associated legislation. The market share of eco private cars increased to 38%, with the major portion of that share being still ethanol cars (49%, or almost 19% of all cars sold in 2009). There was recently much public debate on whether using ethanol fuel is a good way to reduce carbon dioxide emissions from the transport sector. Questions were raised on the fuel production methods used for ethanol and their effects, especially the effects on food prices and CO₂-emissions. Use of more efficient vehicle technologies (e.g., diesel, hybrid, electric, and fuel cell cars) could also reduce carbon dioxide emissions. These technologies could be combined with fuels that do not emit much carbon dioxide.

With all these options to consider, choosing the technology for energy-efficient cars is becoming even more interesting than before. The new EU directive (Regulation CE/443, adopted by the European Union in April 2009), with its tougher rules on carbon dioxide emissions for vehicle producers, promotes this effort further. The Swedish vehicle industry is therefore now very focused on technologies that increase fuel efficiency in order to comply with the new emission rules as well as satisfying the increasing customer demand for more fuel-efficient vehicles. In the future, plug-in hybrids, pure electric vehicles, and perhaps fuel cell vehicles will be seen as viable alternatives.

23.7

Benefits of participation

The benefits of participating in the IEA's Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) can be summarized as follows:

- The informal exchange of information and establishment of international contacts offered by the Agreement can be used to find out, in a cost-efficient manner, what other countries are doing (or not doing) and how they are doing it. At the same time, the network provides a way of benchmarking national efforts against those of other countries in order to improve the cost benefits of Sweden's work.
- The Agreement spreads out the costs of major worldwide work. Many investigations that have been carried out within the framework of the Agreement would have been impossible for any one country to perform on its own at a reasonable cost. Also, it is important that work be done by the best scientists in the field, and when R&D is being done by a group composed of representatives from several countries, each one with his or her own network, it is a lot easier to find out who these experts are.
- Giving national scientists the opportunity to participate in international groups that tackle points that may be of interest to more than one nation creates an exchange of information that strengthens everyone in the entire international network. Also, those involved can bring home new thoughts and ideas that can be developed into new R&D projects and business opportunities.

23.8

Further information

The following websites publish several reports covering “clean vehicle” issues:

- ▶ www.energimyndigheten.se (in English and Swedish).
The Swedish Energy Agency publishes reports, although mainly in Swedish. The primary cleaner vehicle focus is on energy efficiency in the transportation sector and the production of alternative fuels.
- ▶ www.vinnova.se (in English and Swedish).
The Swedish Governmental Agency for Innovation Systems (VINNOVA) provides a wide range of reports regarding cleaner transportation.
- ▶ www.vv.se (in English and Swedish).
The Swedish Road Administration publishes several reports covering emissions and safety issues, mainly in Swedish.

A few organizations that provide regional or national information on certain cleaner vehicle aspects are listed below.

- ▶ www.chalmers.se/shc (in English and Swedish).
Website of the Swedish Hybrid Vehicle Centre (SHC).
- ▶ <http://fuelcell.s2.chalmers.se> (in English).
This addresses fuel cells in a sustainable society.
- ▶ www.miljofordon.org (in English and Swedish).
This website shows a collaboration between the three largest cities in Sweden: Stockholm, Göteborg and Malmö. It is a website for cleaner vehicles that provides considerable information on vehicles, infrastructure and costs.
- ▶ www.sveva.org (in Swedish).
The Swedish Electric and Hybrid Vehicle Association’s website.



24.1 Introduction

The Swiss Constitution binds the Government to aim at sustainable development. In the last two decades, energy supply and climate change have emerged as fields that call for political interference, and in both transportation plays a deciding role. The need to reduce carbon dioxide (CO₂) emissions and fuel consumption and a shift in how many Swiss perceive and use cars are among the current drivers that may encourage the uptake of hybrid and electric vehicles in Switzerland.

Among European nations, Switzerland is especially affected by the prospect of global warming because its settlement and infrastructure reach alpine regions where glacial melting, thawing of subsoil permafrost, and extreme weather conditions have all been on the increase and are perceived as a real threat.

TRANSPORTATION, CO₂ EMISSIONS, AND ENERGY CONSUMPTION

Switzerland's power generation is completely CO₂- and pollutant-emission free, with a mix of 60% hydropower and 40% nuclear power. The share of CO₂ emitted by transportation is therefore continuously increasing and reached a share of 40% in the year 2009 (other sources of emissions were industry, domestic heating, and agriculture). The Kyoto target to reduce CO₂ emissions by 8% by 2010 compared to the reference year 1990 has been missed by far: Switzerland's CO₂ emissions have increased by 10% instead.

Switzerland has no car production. The government therefore cannot directly influence the production of cars, but it can have an impact on the car market. Since the mid-1990s, it has negotiated two voluntary agreements with the Swiss car importers with a goal of reducing the average fuel consumption of the new car fleet (during 1996–2000 and 2002–2008). Neither agreement achieved its goals, with the result that average fuel consumption was reduced by only about half of the targeted reduction, as shown in figure 24.1.

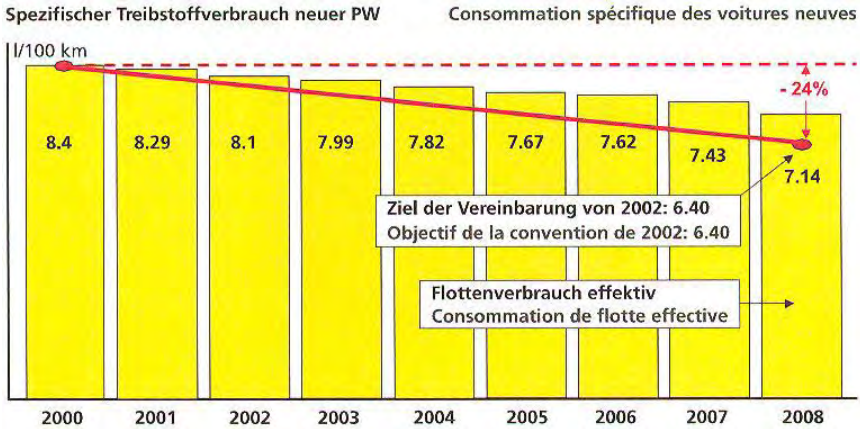


Fig. 24.1 Target (red line) and effective result (yellow columns) of the voluntary agreement 2002 to reduce the average fleet consumption of new cars (source: Touring Club Schweiz TCS).

The Swiss trend towards driving large and heavy cars contributed to this failure, as can be seen in table 24.1. Only in the second half of 2008 did this trend begin to reverse, and the share of small cars of less weight and therefore lower fuel consumption is now increasing in the new car fleet. However, the continued increase in total vehicle miles travelled is reducing the effect of the enhanced vehicle efficiency.

Table 24.1 Development of the Swiss car market in terms of consumption, CO₂ emissions, and weight.

	2003	2004	2005	2006	2007	2008
New cars sold	265,696	266,606	257,886	265,482	284,674	286,341
Average consumption L/100 km	7.99	7.82	7.67	7.62	7.43	7.14
Average emission CO₂/km	195	192	189	187	183 EU: 158.3	175 EU: 153.5
Average weight in kg	1440	1462	1478	1491	1516	1470
Consumption: target 6.4L/100 km by 2008 has not been achieved CO ₂ : target: 130 g/km by 2015						

A SHIFT IN THE PERCEPTION AND USAGE OF CARS

Although cars have symbolized mobility to youth for decades, today young people identify mobility in a similar way as the virtual mobility provided by Google, GPS, and other virtual channels. Mobility is increasingly seen as a challenge of logistics and is less associated with emotion such as the need to own a particular brand of car. As a result, the car is losing its role as a status symbol and is being replaced by the handheld mobile devices such as the Blackberry or iPod. Even the Swiss car importers have noticed that the purchase of cars has become a “more rational” decision, and brand loyalty is beginning to fade.

Urbanity also facilitates this trend away from cars. The emergence of de-industrialized cities and the aging of the population tend toward vicinity, short distances, walking and the use of public transport, as well as car sharing or mobility on demand. Clearly noticeable in Switzerland, this socio-technological change may encourage the development of small urban cars and new clean propulsion technologies.

The emotional aspect of mobility might instead be shifting to the “unplanned” recreational traffic which covers 45% of all trips by car in Switzerland. This is combined with shopping trips, which constitute 11% of all car trips, the most important “mobility producer.” Only 23% of travel is for commutes to work, 4% is for commutes to education facilities, and 9% is for commercial transport. In addition, leisure trips are also by far the longest, averaging 16.7 km.

WHAT ARE THE DRIVERS FOR ELECTRIC MOBILITY?

The key question for the market deployment of electric vehicles is still why car drivers should shift to electric vehicles. The experience of Swiss car importers demonstrates that the issues of energy consumption and CO₂ emissions do not significantly influence the purchase decision even though they are on top of the political agenda. An urban society like in Switzerland is instead more focused on the quality-of-life and health-related issues of noise and particulate matter. Clean cars must still show additional benefits for consumers to buy them. These may include practical issues such as comfort, low-noise and maintenance-free construction, free parking, special express lanes, and tax incentives. On the emotional level, HEVs and EVs must still offer qualities that consumers have come to expect in today’s cars, including driving pleasure (such as rapid acceleration, no gear change, and a smooth ride), prestige, and a desired image (“trendy” and innovative, in the case of HEVs and EVs).

The Swiss population is already sensitized to electric mobility by former experiences with EVs, having hosted the Tour de Sol from 1985 to 1993 and the VEL1 and VEL2 EV test projects in Mendrisio between 1994 and 2005. Along with being enthusiastic riders of public transportation, the Swiss people have the potential to become “early adopters” of electric mobility as soon as affordable electric-drive vehicles enter the Swiss market. In addition, the move to electric vehicles could be accelerated as local promoters emerge, in particular municipalities and local utilities that can exploit their action radius for local clean vehicle incentives.

24.2

Policies and legislation

The Federal Government focuses on framework conditions that help to improve energy efficiency and to reduce CO₂ emissions. The main instruments are the CO₂ regulations currently in force that will be amended in line with the policy of the European Union (Regulation CE/443, adopted by the European Union in April 2009), and the energy labelling of all energy-consuming products. The energy label for cars showing the fuel consumption in weight classes will be transformed into an “eco-label” that also shows the damaging effects on the environment of using this car model.

Though its focus extends beyond hybrid and electric vehicles, the nationwide “EnergieSchweiz” programme (a ten-year programme that will be terminated in 2010) acts as a platform for an “intelligent” energy policy through promoting energy efficiency and the use of renewable energy sources. Activities under the umbrella of this programme include providing information on greenhouse gas (GHG) emissions and other environmental impacts and also establishing voluntary agreements with industry. Although the programme has been successful in reducing overall energy consumption, the mobility sector will clearly miss the targets set for 2010. These goals included reduction of average CO₂ emissions to 140 g/km, and putting 30,000 natural gas (NG) vehicles and 20,000 hybrid cars on the road by 2010. As of the end of 2009, only around 9,000 NG vehicles had been licensed, 120 NG stations were available, and about 13,000 hybrid cars have been sold.

Table 24.2 below summarizes the current set of laws and regulations aimed at clean transport at various levels of Swiss government.

Table 24.2 Overview of the most relevant policy instruments for clean vehicle deployment in Switzerland.

NAME (YEAR OF [PLANNED] IMPLEMENTATION)	DESCRIPTION	EFFECT ON THE CLEAN VEHICLE POPULATION
Legislation at the federal level		
Lex CO ₂ (2000) regulation on CO ₂ taxes on fuels (2008)	Fuels for transportation exempted from CO ₂ taxes. Instead, a "climate rappen" (a duty of about 0.01 €/l on petroleum fuels, imposed in 2005) is used to fund projects that reduce CO ₂ emissions. However, most of these projects are run in the construction sector rather than transportation.	None
Amended Lex CO ₂ to be adopted [2011]	To be adopted by Parliament in 2010. The draft for the transportation sector includes the implementation of the EU new-car emissions target of 130 g CO ₂ /km by 2015 and a list of penalties the importers have to pay if this target is not achieved. In addition, it provides the legal basis for a CO ₂ taxation of fuels for transportation, and it forces car and fuel importers to compensate for at least ¼ of the emissions caused by transportation through CO ₂ -reducing measures.	Great impact expected
EnergieEtikette (Energy Label) (2002)	Mandatory labelling of all automobiles indicates energy consumption in 7 categories A – G in weight classes	Unknown effect, rising attention by car buyers
UmweltEtikette (Environment Label) to be adopted [August 2010]	Mandatory labelling of automobiles indicates consumption, CO ₂ emissions and a scoring for ecological damage in 7 categories A – G (weight classes still planned)	Unknown, some impact expected
Federal vehicle taxation		
Vehicle import taxes change of the taxation scheme in discussion	Governmental proposal that the federal car import taxes switch over to a bonus-malus-system based on the CO ₂ emissions of the relevant car model. The tax will rise for cars in the label categories C to G; cars of the lightest weight category A will get a bonus of CHF 2,000 (€ 1350), and cars of category B will get CHF 1,000 CHF (€ 675). Approval by Parliament is still pending.	Unknown, but a simulation shows the potential for CO ₂ reduction of between 3.1 and 3.9%
Cantonal vehicle taxation		
Annual vehicle taxes (implemented by the first Cantons already in the early 1990ies)	Several cantons provide a vehicle tax reduction for "clean" vehicles: 25 of 26 cantons exempt electric vehicles from the vehicle taxes or grant reductions, and 15 cantons reduce the taxes for hybrid vehicles. A few cantons have already changed the taxation criterion for motor vehicles from unit mass to CO ₂ emissions.	Unknown, mar- ginal
Voluntary agreements		
Reduction of the aver- age consumption of the new car fleet (2002)	Agreement with the Swiss car importers to reduce the average fuel consumption of new cars by 3% annually between 2002 and 2008	Goal was not achieved, so no effect

24.3

Research

Efficiency is identified as the leverage for advanced vehicles. Transportation uses more than 1/3 of the primary energy but only releases 1/8 of useful energy. The Mobility Research Programme of the Federal Office of Energy therefore has defined energy efficiency as the keynote of its funding principles.

Consequently, the Swiss Federal Office of Energy provides support for projects focusing on

- lightweight design.
- propulsion systems of highest efficiency.
- small transport systems, e.g., electric bicycles and scooters.

In the long term, an average consumption of an equivalent of 2.5 L per 100 km is defined as the goal for future private cars. In detail, the agenda of the Office of Energy until 2011 mentions developments in hybrid propulsion technologies (using natural gas engines, regulation strategies), fuel cell technologies (development of a city car with FC drive), lightweight design with the target of a 30% reduction in vehicle mass, and electric two-wheelers like advanced e-scooters and pedelecs.

GOVERNMENT-SUPPORTED RESEARCH

Several projects in the Office of Energy research programme into transport improve the performance of internal combustion engine systems (e.g., motor downsizing with “pneumatic” booster) or drive systems using advanced fuels. The results of these projects can also be used for enhancing the efficiency of hybrid drivetrains. The same strategy is pursued by a simulation project at the Federal Institute of Technology Zürich to optimize the motor and engine operation in parallel hybrid configuration.

The research in transport-related projects is centred at the Swiss Federal Institute of Technology (ETH Zürich) and its research institutes: the Paul Scherrer Institut (PSI) and the Federal Laboratories for Material Testing and Research (EMPA), or Universities of Applied Sciences with the focus on lightweight design (HTA Rapperswil).

The second exploratory focus lies on storage systems and is centred at the Universities of Applied Sciences Bern and Luzern. The Government-funded research in this field concentrates on lithium-ion cells with capacities over 100Ah and their application, battery management systems, and integration require-

ments, as well as mathematical lifetime models for sodium-nickel chloride (Na-NiCl) and lithium-ion batteries.

In the project HY_Change, the Paul Scherrer Institute PSI carried out test-bed measuring to assess the environmental impacts of hydrogen fuel cell vehicles.

RESEARCH AND DEVELOPMENT IN INDUSTRY

Because the official position of the Swiss Federal Office of Energy is that research must lead toward marketable products, it also supports research undertaken by private companies with an emphasis on battery research or lightweight structure. Good examples include the simulation of chassis and body parts in fibre-reinforced plastics and bionics using nanostructures by Georg Fischer at Alcan and the fuel cell vehicle project “HyCarPRO” of ESORO which is based on its HyCar developed in 2002 (figure 24.2). In the HyCarPRO a NedStack fuel cell has been built in and a control and monitoring system plus the necessary sub-systems (cooling, air, humidification, hydrogen) has been developed around this fuel cell. In a second step the efficiency of the sub-systems has been improved by reducing the pressure and minimizing the loss of pressure. A cooling system allows the recovery of the water for the humidification. The project has been completed 2008.

Additional research projects under way at other Swiss companies are listed in the “Industry” section.



Fig. 24.2 HyCar by ESORO. (Photo supplied by ESORO AG.)

24.4 Industry

The electric vehicle industry in Switzerland continues to expand, not only with growth in sales of the electric cycles and light EVs that Swiss companies have developed, but also through the development of services related to the charging infrastructure that vehicle electrification requires.

24.4.1

Products in the market

Electric cycles (“pedelecs”) are already a mass product. In Switzerland the sales figures rise annually; between January and September 2009 more than 17,000 e-cycles were sold, a nearly three-fold increase since 2007 when a little more than 6,000 cycles sold for the year. In 2009, the company BikeTec, manufacturer of the high-speed electric Flyer cycle, moved into a large production plant to keep up with the increasing demand and has already announced an extension to its factory. BikeTec is continuously expanding the range of pedelec models; the newest one, the X-series (figure 24.3), is currently waiting for its certification. The Swiss Federal Office of Energy acknowledged this contribution to clean commuting by the Watt d’Or 2009 award in the category Energy Efficient Mobility. Products originally developed in Switzerland but now manufactured by licensees in Germany include the “TWIKE” three-wheeler and “SwizzBee Dolphin” e-bike.



Fig. 24.3 Flyer X-series. (Photo supplied by BikeTec.)

In the area of electric vehicles, a small Swiss company has been selling versions of the Renault Twingo Quickshift and FIAT Panda that have been converted to run on electricity since 2008. These converted EVs use an assembly set made by Swiss automotive supplier MES DEA, which began offering these conversions in 2004.

The Swiss prototype electric three-wheeler SAM (figure 24.4) got a second chance after developer Cree Ltd had closed its doors in 2003 due to lack of funding and subsequently underwent restructuring. Since December 2009, the technically improved version with a 7-kWh lithium polymer battery is produced in Po-

land and sold by four Swiss companies with expertise in EV technology. The low vehicle weight of 500 kg (inclusive of the battery) allows a range of 90 km.



Fig. 24.4 The prototype electric three-wheeler SAM. (Photo supplied by SAM Group.)

Other developments concentrate on niche applications, as described in the following paragraphs.

HYBRID BUS

The company Hess, which specializes in bodywork for buses, has developed a hybrid bus called Swiss lighTram (figure 24.5; also offered in a trolley version) together with the German propulsion specialist Vossloh Kiepe. The drivetrain shows two electric asynchronous motors of 160 kW on axles two and three each, a biodiesel engine 250 kW in the rear, and supercapacitors as the electric storage system. In January 2008, this project was awarded the Watt d'Or 2008 award by the Swiss Federal Office for Energy in the category Energy Efficient Mobility.



Fig. 24.5 Swiss lightTram. (Photo supplied by Hess.)

MOTOR BIKES

Another promising niche product is the Quantya EV01 motor bike, originally designed for off-road use, with lithium polymer batteries (figure 24.6).



Fig. 24.6 Quantya EV01 Strada. (Photo supplied by Quantya.)

COMMUNAL VEHICLES

This promising niche is gaining traction with small manufacturers. Two projects in particular are aiming at market introduction in the near-term: an electric street cleaner by the company AB Metal Impianti, and the prototype “hy.muve” (hydrogen driven municipal vehicle, figure 24.7). The hy.muve was developed by a collaboration including EMPA (Swiss Federal Laboratories for Materials Testing and Research) and the Paul Scherrer Institute (PSI), which contributed the lithium polymer batteries; municipal vehicle manufacturer Bucher Schörling and electric drive manufacturer Brusa Electronics, which developed the motor and electronics; and hydrogen fuelling station manufacturer and hydrogen supplier Messer.



Fig. 24.7 hy-muve. (Photo supplied by EMPA.)

24.4.2

Prototypes

In the area of prototyping, Swiss automotive designers are still influenced in their approach to propulsion research by lessons learned during the first solar mobile races of the Tour de Sol (1985–1993), where winning designs were equipped with highly efficient components and lightweight construction. Today’s global trend to improve the efficiency of cars plays well to Swiss industrial strengths, and small vehicle design companies like Protoscar, Rinspeed, and Mindset represent these capabilities.

Protoscar designed a sportscar for the Autosalon Geneva 2009 to showcase the potential of lightweight design (figure 24.8), and a new model has been announced for the Autosalon 2010. Rinspeed has shifted from a sportscar to a small commuter vehicle for its entry in the Autosalon Geneva 2010. The electric vehicle model UC?—the letters standing for “Commuter Vehicle” as well as “you see?”—is designed with a range of 120 km as a short-trip vehicle. The vehicle itself is designed as part of a mobility philosophy in which the UC? is loaded on wagons and transported on railways for long trips.

Mindset, a company founded in 2007, has introduced its prototype car, the Mindset. The vehicle closely resembles the Swiss-developed TWIKE vehicle—not astonishing, as the main investor was involved in marketing the TWIKE during the 1990s. The vehicle is built on an aluminium space frame with a composite body. The details of the drive concept are not yet known, but it is a plug-in-hybrid configuration with a range extender. Mindset has already invested 5

million Swiss Francs in this car. The company has announced that the vehicle will be available at €70,000 during 2010, though the current economic crisis has already delayed its introduction from the mid-2009 date initially announced.



Fig. 24.8 Protoscar Lambo. (Photo supplied by Protoscar.)

24.4.3

Components and materials

Development and manufacturing of components for hybrid and electric vehicles are concentrated within the Swiss companies MES DEA (ZEBRA NaNiCl batteries and PEM fuel cells in the range of 500 W to 3 kW), Horlacher and ESORO (composite parts), and Brusa Electronics (control systems). Brusa Electronics worked out a label, together with Protoscar, called eQmotion (standing for electric-quotient-motion) to advertise the philosophy of 100% electric propulsion in their vehicle projects. All of these companies are also active in research projects. Research on the improvement of ZEBRA batteries concentrates on lowering the operational temperature. Suitable solvents have been tested, and the feasibility of lowering the temperature has been confirmed in laboratory testing. Nevertheless, near-term availability of a low-temperature ZEBRA remains unlikely. The high-temperature ZEBRA battery is already used in various electric and hybrid vehicles, especially in buses (e.g., Irisbus, Gruaut Microbus).

Several Swiss companies including Horlacher have developed a great amount of experience in processing lightweight materials. In 2002 ESORO developed a process for glass fiber-reinforced polypropylene for the volume production of lightweight body parts. This E-LFT process (endless fiber-reinforced long fiber thermoplastic) can be adopted to other materials like PET or PA. The lightweight tailgate of the Smart car is produced by this processing method.

24.4.4

Fuel cells

Regarding fuel cell propulsion, Swiss industry is interested in the development of components, such as electronics, control systems, and system management. Fuel cell systems are not only developed and tested by research institutes, but also by private companies. For example, ESORO is one of the renowned specialists in lightweight materials and processing. The lightweight rear door of the new “smart” car is produced by a method developed by ESORO. As long ago as 2002, ESORO demonstrated a fuel cell vehicle in hybrid configuration, and the prototype is still used as a company car. On the basis of this model, named HyCar, ESORO developed a control and monitoring system (with algorithms that also include the subsystems for cooling, air, humidification, and hydrogen) by integrating actuators and sensors. This project, called HyCarPRO, includes the development of the interface between the fuel cell stack and the electronics. In other fuel cell work, MES-DEA has developed a PEM fuel cell and has research groups investigating the aging and degradation problems of PEMFC. This project is supported by the Swiss Innovation Promotion Agency KTI. In 2007, scientists of the Paul Scherrer Institute founded the company Belenos to develop fuel cell and subsystem technologies which it intends to license out. The founders were able to convince celebrities like Nicolas Hayek, Josef Ackermann, and George Clooney to be partner in this company.

24.4.5

Electric utilities and infrastructure

Electric vehicles are also motivating action by Swiss utilities which have been confronted with the deregulation of the electricity industry, and which are now looking for additional market opportunities. These utilities are starting to deploy their own charging stations in addition to the existing network of the Swiss Park & Charge infrastructure that was installed beginning in the early 1990s. For example, the utility of the Canton of Zurich EKZ offers an annual flat rate of around 65 € for the use of their EKZ charging facilities (figure 24.9) and a starter kit which includes a socket for home-charging. The utility of the City of Zürich has ordered two Mindset EVs for promotion purposes. In addition, both utilities support a pilot project of the Smart brand in Switzerland and the Swiss car sharing organization Mobility, in which 50 Smart “ed” (an acronym for “electric drive”) EVs with lithium-ion batteries will be leased to businesses including insurance companies or breakdown services.

Some of the Swiss utilities are using the theme of electric mobility to extend their portfolios and to sharpen their business profiles. Bernische Kraftwerke

(BKW) support a pilot programme in a suburb of the City of Bern called “Inergie” planned for 2010 and 2011. The fleet manager of the Swiss Postal Service, Mobility Solution, will manage the vehicle allocation to local users, while BKW will install 13 charging stations with smart meters and evaluates the data.



Fig. 24.9 EKZ Charging station in Zurich. (Photo supplied by EKZ.)

The company Texx, founded in 2009 to provide “regenerative energy for mobility,” has opened the first 400-V 3-phase fast-charging stations at freeway service areas along the most important transit route in Switzerland. The partners of Texx include the founder of ASMO who designs electric carts. Another private company for electric and solar installations, Brunner+Imboden, has developed a solar charging station and is looking for partners to promote the combination of electric vehicles and new renewable energies.

The Swiss energy supplier KWO which operates one of the largest pumped storage power stations has initiated a project called “Electric Vehicles in the Alps.” In this project, tourists will experience the alpine region around the Gotthard by using various electric vehicles. KWO has already put two TH!NK EVs into operation to evaluate the modalities for such a touristic EV-rental project.

24.5 On the road

Vehicle density is rather high in Switzerland. By September 2008, more than 4.4 million light duty vehicles had been licensed, translating to a density of 586 cars per 1,000 inhabitants. The Swiss electric vehicle market is small and dominated by small lightweight vehicles, such as e-bikes, e-scooters, and three-wheeled vehicles (such as TWIKE and City-el, which are licensed as motor bikes). Table 24.3 reports the data on the Swiss car park as of December 2008.

Table 24.3 Hybrid and electric vehicle fleet numbers at the end of 2008.

Vehicle type	PER DECEMBER 31, 2008			Remarks
	EV fleet	HEV fleet	Total fleet (incl. EVs and HEVs)	
Bicycles (no driver licence)	>35,000		4,000,000 (about 50,000 mopeds included)	Swiss high-speed electric cycles are licensed as small motorbikes (mopeds) with a speed limit of 40 kmh, and drivers must have a license
Motorbikes	2,000		ca 700,000	Lightweight three-wheeled vehicles (TWIKE, City-el) are licensed as motorbikes
Passenger vehicle	ca. 900	11,120	ca. 4,400,000	
Multipurpose passenger vehicle	ca. 350			Special vehicles in the car-free resorts with a speed limit of 20 kmh
Bus	30	20	} ca. 375,000	
Truck				
Industrial vehicles (off-road)	4,000		246,656	(Data from Sept. 2006, no longer counted statistically)

Because very few commercially-produced EV models have been available in the Swiss market until 2009, the population of four- and three-wheeled EVs has been decreasing over the last five years. Most of the EV population in use is now more than 15 years old. However, the lack of new EV offerings has resulted in great interest in used electric vehicles, and the market for electric two-wheelers is growing fast. From January to September 2009, 17,000 electric cycles were sold. After a promotional campaign by Newride, the Swiss information platform for electric two-wheelers, sales figures of electric scooters have also increased remarkably. In 2008, the Swiss postal service decided to exchange mopeds for postal delivery with Oxygen Cargo Scooters, with 500 units on the road or on order, and another 500 units under negotiation.

The hybrid vehicle market continues to develop satisfactorily for importers. By September 2009, about 13,000 hybrid cars have been licensed (Toyota Prius I and II, HONDA Civic IMA, and all hybrid Lexus models). Switzerland has the highest number of hybrids per capita in Europe, with 16 HEVs for every 10,000 people in 2009. The Netherlands has the next highest hybrid rate at 15 HEVs, and both Germany and the UK are at the level of 2.4 HEVs, all per 10,000 people. (By means of comparison, hybrids have penetrated the USA's market at three times the Swiss rate, with 48 HEVs per 10,000 people, and Japan has 44 HEVs for the same number of people.) The importers expect a steadily growing market for the next several years, especially for the Prius III.

Several insurance companies currently grant a bonus for vehicles with low CO₂ emissions and low fuel consumption. The reductions can amount to as much as 32% of the standard annual coverage rates. For example, the driver of a Prius (at 104 g CO₂/km emissions) can save about US\$ 300 annually.

Finally, the prospect of new electric vehicle models is bringing new actors into the equation. In addition to the utilities that see synergies between power production and electric mobility, carsharing companies and fleet users are evaluating the use of electric cars and the need for recharging infrastructure. In 2009 the independent organization "Open Platform Infrastructure 2020" has been launched to study the needs for the recharging infrastructure, especially in view of new user segments like fleet operators and the standardization efforts on the European level. The Swiss postal service with its subsidiary Mobility Solutions AG is thinking about offering a service package for fleet users in which it would act as the fleets' agent to interact with financial institutions, car dealers, insurance companies, regulators, and breakdown service for the electric cars. These new players in a future EV market see the chance to test new mobility concepts in which the electric vehicle is part of a system depending on lifestyle and aspects of sustainability. Several analysts believe that the commitment of these new stakeholders will have the effect that fleet users will be the first group to buy electric vehicles in greater numbers. In this scenario the private customers will wait for lower prices for battery electric vehicles and will continue to buy hybrid vehicles.

24.6

Outlook

The Swiss approach to sustainable transportation policy is integral: individual trips should be done by using public transport, “slow transportation” like walking and cycling is supported, and goods should be transported on rail. This approach demands a close co-operation between federal, cantonal, and city administrations. It already works on the local level, especially in city agglomerations like Zurich, Basel and Bern. Commuting by car from outside of the cities is a result of overdevelopment, but efforts to impose restrictive environmental planning are hindered by the many divisions of authority on the cantonal or municipal levels.

The well-to-do inhabitants of small villages in the countryside tend to drive the heavy, relatively inefficient four-wheel-drive car. Yet this trend is diminishing at the moment due to the continued difficult economic situation and the fact that young people prefer to live in cities. In general, the acceptance of large inefficient cars is declining. In 2010, the Swiss population will vote on an initiative that will institute a ban the off-road use of four-wheel-drive vehicles. However, the growth in leisure trips will likely continue to counter any measures targeted at reducing fuel consumption. Recognition of this problem in part prompted the decision to award the Watt d’Or prize to BikeTec, an e-cycle producer that initiated several e-bike rental schemes in tourist areas (e.g., the “Rent me and Smile” program, available in Gstaad, the St. Moritz area, the Lago Maggiore area, and other locales) to enable tourists to experience the landscape without polluting it.

In recent years, transportation policy in both Switzerland and the European Union (EU) has shifted to the implementation of more stringent emission standards and the taxation of CO₂ emissions. In this context, the amendment of the Swiss CO₂ legislation and the proposed new taxation scheme on imported vehicles is in line with European efforts. The bonus-malus system of the vehicle import taxation scheme has the potential to reduce the CO₂ emissions by 3.1% to 3.9%, according to a simulation carried out by the Federal Institute of Technology (ETH Zurich).

However, the prospect of new electric vehicle models entering the market in the near future is not being met with any Governmental initiative towards a sustainable transport policy. Governmental efforts remain focused at the research and development level, while the promotion of the Swiss manufacture of HEVs and EVs and their market introduction is the responsibility of the private sector. In

view of the collective knowledge of HEVs and EVs within the Swiss automotive supply industry and the small specialized vehicle enterprises, some feel that the national government could be missing an opportunity to establish an early Swiss advantage in the emerging electric vehicle industry.

Finally, players new to the automotive arena—the utilities and mobility system providers—are seizing the opportunity they see in EVs. They see synergies with their businesses and are forming coalitions with the new EV suppliers and local or regional administrations. These new networks could get the ball rolling in building infrastructure and packaging services to ease the transition to electric mobility, and promising early results could convince other players to join their efforts.

24.7

Benefits of participation

Switzerland has participated in the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) since its inception in 1993. In the ensuing years, it has been one of the most active member countries in the promotion of EVs. Since most EV manufacturers have ceased production of new EVs, resulting in decreased EV activities in Switzerland, the information exchange with experts from other countries has become more important by providing insight to many key issues, including:

- The development of new batteries (e.g., those based on lithium-ion technology) and components could precipitate a resurgence of all-electric vehicles, at least for specific market niches. As such, the ability of the government to identify the right moment to consider active support will be enhanced.
- The realization that hybrid vehicles can succeed in the market without government subsidies.
- The recognition of political realities (e.g., CO₂ emissions and oil prices) that will demand a shift to clean vehicle technologies in the relatively short term. The activities of other member countries—as well as information provided by the International Energy Agency itself provide insight into possible measures to mitigate CO₂ emissions and real market opportunities for clean vehicle technologies.

24.8

Further information

- › Programme “EnergieSchweiz” of the Federal Office of Energy: www.energie-schweiz.ch (German, French, Italian, English)
- › EnergieSchweiz Mobility Agency EcoCar: www.ecocar.ch (German, French, Italian)
- › EnergieSchweiz EV Agency: www.e-mobile.ch (German, French, English)
- › Agency NewRide (electric cycles): www.newride.ch (German, French)
- › Fuel cell-prototype ESORO HyCar: www.hycar.ch (English)
- › Belenos: Fuel cell prototype HYLIGHT : www.psi.ch/medien/Medienmitteilungen/mm_hy_light (German)
- › Horlacher Lightweight Construction: www.horlacher.ch (German, English)
- › Twingo Quickshift Elettrica/ Fiat Panda elettra: www.kamoo.ch
- › ZEBRA batteries, PEM FC: www.cebi.com
- › Electric cycle “Flyer”: www.biketec.ch (German)
- › Electric cycle “Dolphin”: www.velocity.ch (German)
- › Rinspeed prototypes: www.rinspeed.com (German)
- › Prototype “Mindset”: www.mindset.ch (German)
- › Project Open Platform Infrastructure 2020: www.opi2020.com
- › NG-vehicles: www.erdgasfahren.ch (German)

Reports:

- › Project Lightweight Electric Vehicles in Mendrisio: Synthesebericht, full report on cd-rom: order at: EDMZ CH-3003 Bern
- › Martin Pulfer: Konzept 2008 Technologiebereich Verkehr & Technologiebereich Akkumulatoren. Bundesamt für Energie 2008. download: http://www.bfe.admin.ch/forschungsverkehr/02341/02347/index.html?lang=de&dossier_id=03671



25.1 Introduction

The hybrid vehicle market in Turkey is in its beginning phase. The Honda Civic hybrid is the first commercial hybrid being offered for sale in the Turkish automotive market, and Toyota has started selling hybrids in Turkey. During the last year, Turkish bus manufacturers Temsa and Otokar have announced that they have added the hybrid bus to their portfolios.

In addition, some companies have been introducing their hybrids and electric vehicles (EVs) on their web sites, and they are considering sales activity in the coming years. Electric two-wheelers have also begun to be sold in the last few years, but they have not yet achieved significant market penetration. In the year 2008 20.2% of the total energy consumption of Turkey was attributable to transportation and 83.9% of that was from road transportation. Statistics for 2008 show that Turkey's electricity was generated 49.7% from natural gas, 29.1% from coal, 16.7% from hydro sources, and 0.4% from wind.

Since 2002, strong and stable economic growth together with rising social wealth has led to a substantial increase in energy consumption. During the last six years primary energy consumption has increased by 36% and electricity consumption has increased by 49%. However, since the last quarter of 2008, when the global economic crisis started to profoundly affect the Turkish economy, a deceleration in economic activities combined with an increase in energy prices caused the demand for energy to decrease. After the 2001 crisis, the second and largest drop in electricity demand in the last 30 years was observed in 2009.

An awareness of environmental issues and clean vehicles is increasing in Turkish industries, research and development (R&D) organizations, and society as a whole. Turkish policies and legislation are encouraging reductions in greenhouse gas emissions and improved air quality.

25.2 Policies and legislation

In the last decade, the Turkish Government has significantly increased the amount of financial resources allocated for R&D. Because the automotive industry is an important industrial sector, automotive-related research is part of the vision of its R&D program. Turkey has several instruments that support the "greening" of transportation, which could help encourage the use of hybrids and EVs when they become more common in the country.

Turkey aims to fully cohere with European Union legislation. For this purpose, several new items of legislation were published, and many studies are underway to help prepare new regulations and legislation designed to reduce greenhouse gas emissions and improve air quality. Turkish emission standards for gasoline and light- and heavy-duty diesel vehicles and their implementation dates (according to emission legislation 70/220/AT and 88/77/AT-2005/55/AT) are summarized in table 25.1.

Table 25.1 Turkish emission standards and implementation dates.

Vehicle type	Approval	EARLIER LEGISLATION		NEW LEGISLATION	
		Standard	Date	Standard	Date
Gasoline	New type	Euro III	01.01.2001	Euro IV	01.01.2008
	All types	Euro III	30.09.2001	Euro IV	01.01.2009
Light-duty diesel	New type	Before Euro I	01.01.2001	Euro IV	01.01.2008
	All types	Before Euro I	31.12.2002	Euro IV	01.01.2009
Heavy-duty diesel	New type	Euro I	01.01.2001	Euro IV	01.01.2008
	All types	Euro I	31.12.2002	Euro IV	01.01.2009

In January 2009, a regulation that addresses informing consumers about the fuel economy and CO₂ emissions of new passenger vehicles was implemented with new additions. To help consumers choose vehicles with low fuel consumption, the government requires dealers of new passenger cars to give potential buyers useful information on the vehicles' fuel consumption and CO₂ emissions. This information must be displayed on the car's label, on posters and other promotional material, and in specific guides. The vehicle's official specific CO₂ emission class, as specified in table 25.2, must also be given.

Table 25.2 Official specific CO₂ emission classes for vehicles. The CO₂ emission values are given in grams emitted per km of travel.

Official specific CO ₂ emission class	Official specific CO ₂ emission
A	< 100 gCO ₂ /km
B	101 - 125 gCO ₂ /km
C	126 - 150 gCO ₂ /km
D	151 - 175 gCO ₂ /km
E	176 - 200 gCO ₂ /km
F	201 - 225 gCO ₂ /km
G	> 225 gCO ₂ /km

The recent taxation measures imposed on vehicles in Turkey are of two types. The first one is a tax on an initial new vehicle sale; it is about 62% of the actual cost for a passenger vehicle and 24% of the cost for light- and heavy-duty commercial vehicles. The second type is an annual vehicle tax; it is paid yearly and based on the engine cylinder volume and the age of the vehicle. The tax is lower for smaller engines and older vehicles. For buses, the tax is independent of the engine type or size; it depends instead on the vehicle's seating capacity and age. Table 25.3 shows the annual vehicle tax classification categories. Studies are underway to help the Turkish Government prepare new tax regulations that will be based on vehicle emission rates.

Table 25.3 Annual vehicle tax classification categories in Turkey.

PASSENGER VEHICLE		MOTORBIKE		MINIBUS	BUS		TRUCK	
Vehicle age (yr)	Engine cylinder volume (cm ³)	Vehicle age (yr)	Engine cylinder volume (cm ³)	Vehicle age (yr)	Vehicle age (yr)	Seating capacity	Vehicle age (yr)	Maximum total weight (kg)
1-3	<1,300	1-3	100-250	1-6	1-6	<25	1-6	<1,500
4-6	1,301-1,600	4-6	251-650	7-15	7-15	26-35	7-15	1,501-3,500
7-11	1,601-1,800	7-11	651-1,200	>16	>16	36-45	>16	3,501-5,000
12-15	1,801-2,000	12-15	>1,201			>46		5,001-10,000
>16	2,001-2,500	>16						10,001-20,000
	2,501-3,000							>20,001
	3,001-3,500							
	3,501-4,000							
	>4,001							

Also, in response to its current dependence on imported natural gas, Turkey is reassessing its energy portfolio. The Ministry of Energy and Natural Sources has announced a draft strategic document in 2009 regarding energy efficiency in order to collect feedback about its content. The topics below are mentioned in the Energy Efficiency in Transportation section.

Specific fuel consumption of domestically produced vehicles will be reduced. Vehicle efficiency standards will be upgraded, public transport systems will be expanded, and advanced traffic signalization systems will be installed. Urban transportation routes will be planned primarily according to energy efficiency. Legislation arrangements for the following measures will be included:

- The motor vehicle tax for higher engine cylinder volumes will increase;
- Vehicle energy efficiency labels will be applied, and efficient vehicles will be allowed to traverse bridges and highways free of charge;

- ▶ The number of days of free public transport will increase;
- ▶ Energy efficiency courses will be given in driver training;
- ▶ Rail and sea transport will be encouraged;
- ▶ Urban transport routes will be planned according to fuel consumption values;
- ▶ Bicycle routes will be arranged where local topography is suitable;
- ▶ The use of vehicles with small engine volumes, hybrid vehicles, cellulosic ethanol, and synthetic fuel that can be produced from a domestic biomass resources will be encouraged with tax incentives; and
- ▶ Vehicles that have been used at public institutions for 15 years or more will be removed.

25.3

Research

Research topics relevant to hybrid electric vehicle (HEV) technology are naturally a part of automotive R&D. With the growth of the HEV market, it was inevitable that scientific and industrial interest would become synergistic and joint projects would develop. Some of the major R&D players in the hybrid and electric vehicle area are the TÜBITAK MRC Energy Institute, OTAM, and MEKAR.

TÜBITAK MRC Energy Institute

The Scientific and Technological Research Council of Turkey (TÜBITAK) was founded in Ankara in 1963. Its aim is to develop, promote, plan, and coordinate R&D activities in fields consistent with the priorities for Turkey's development. The scientific and technological R&D activities of TÜBITAK are conducted through its research institutes. Of these, the Marmara Research Center (MRC) in Gebze, founded 1972, is the oldest and largest. The MRC Energy Institute's vehicle technology research emphasizes the following areas.

- ▶ Advanced energy technologies: fuel cell technologies (e.g., proton exchange membrane [PEM] fuel cells and direct sodium borohydride fuel cells [DSBHFCs]); hydrogen production and storage; and combustion, gasification, and gas cleaning systems.
- ▶ Fuel technologies: analyses of solid fuels (e.g., lignite, coke, and petro-coke); analyses of liquid fuels (especially gasoline, diesel, biodiesel, and fuel oil) according to international standards; and production of biodiesel.
- ▶ Vehicle technologies: system integration of HEV powertrains; modelling and simulation of EV and HEV technologies and HEV control systems; and rapid prototyping of control systems, electrical energy storage systems and battery technologies, and electric machines and drives for traction applications.

- Power electronics technologies: circuit designs; programming, control, and signal processing; power system simulation and analysis; and network analysis.

TÜBİTAK MRC Energy Institute has several completed and ongoing projects that address EVs and HEVs and their subcomponents. Examples are (a) ELIT-1 series HEV design and development, (b) Ford Otosan light-duty commercial HEV (FOHEV) development, (c) electric motor driver design and development, (d) HEV battery development, and (e) emission reduction in transportation projects.

At the MRC Energy Institute, a Hybrid & Electric Vehicle Excellence Center is being planned for testing HEVs, EVs, and their components. This project is supported by the Turkish State Planning Organization (DPT) and should be ready to serve the automotive industry at the end of 2010. The test equipment for the center will be chosen to meet the needs of automotive manufacturers (including companies from Turkey) that have developed HEVs that produce fewer emissions and offer fuel economy, some of which have added HEVs to their product profiles. Equipment might include a two-axle chassis dynamometer, an electric motor dynamometer, battery test systems, an engine dynamometer, and an emission measurement system. The center will also include various laboratories: labs for electronic control units and other subcomponents, an electric motor design lab, a hardware-in-the-loop lab, an automotive electronic control lab, an advanced vehicle simulation techniques lab, and a mechanical design lab.

OTAM - Automotive Technology Research and Development Center

OTAM was established in 2004 in partnership with the Automotive Manufacturers Organization (OSD), TÜBİTAK, and Istanbul Technical University (ITU). OTAM's overall goals are to carry out R&D on pre- and post-production efforts being done by the automotive industry and to act as a bridge between academia and local automotive companies in order to improve resource usage and technology exchange. OTAM was incorporated in 2006 when the Association of Automotive Parts and Components Manufacturers (TAYSAD) joined Uludag Automotive Exporting Union (UIB). This union provided the robust support and funding needed to establish a new platform for advanced projects.

OTAM operates and maintains the state-of-the-art laboratories in the ITU Department of Mechanical Engineering's Automotive Division. These labs were revived and improved in recent projects supported by DPT and the European Union. Experts in various areas of automotive research and qualified engineers

trained in ITU's undergraduate and graduate programs work together here under the same umbrella.

Recent R&D projects with the local automotive industry in Turkey took advantage of ITU facilities, including the automotive acoustics laboratory (with silent chassis and engine dynamometers), vehicle durability and performance laboratory (with a four-poster shaker), vehicle emissions laboratory (for passenger cars and commercial vehicles), and engine emissions laboratory (for testing against current exhaust emission regulations).

MEKAR

MEKAR is the acronym for the mechatronics research laboratories in the ITU Department of Mechanical Engineering. The MEKAR group consists of several faculty members, post-doctoral researchers, and graduate students. MEKAR's research projects were funded through governmental agencies (DPT, TÜBİTAK), the European Union Framework Programme 6, the Leonardo Programme, and automotive companies. Research efforts concentrate on automotive control and mechatronics, active safety control systems, HEV modelling and internal combustion engine control, and the development of hardware-in-the-loop simulator test benches and autonomous vehicles.

25.4 Industry

When the Turkish automotive industry was established before the 1960s, its objective was mainly to produce vehicles that would substitute for those the country was importing. The industry began to grow with the establishment of Tofas A.S. and Oyak Renault A.S. in 1970. In connection with the establishment of the main automotive industry, the supply industry also began to develop. Since the 1990s, it has qualified as an export-oriented, competitive industry. OSD, the Automotive Manufacturers Association, represents the 15 manufacturers (Anadolu Isuzu, B.M.C., Ford Otosan, Hattat, Honda Türkiye, Hyundai Assan, Karsan, M.A.N. Türkiye, M. Benz Türk, Otokar, Oyak Renault, Temsa Global, Tofas, Toyota, Türk Traktör) in Turkey. According to OSD's annual report, in 2008 the automotive industry had the largest share of exports, at 19.4%, and was the top sector in Turkey.

TAYSAD, established in 1978, represents the Turkish automotive supplier industry. With 262 members, TAYSAD represents 65% of the output of the automotive supplier industry and 70% of the industry's exports. Of TAYSAD's members, 85% operate in the Marmara region, 10% in the Aegean region,

and 5% in other regions of Turkey. The TAYSAD members employ a total of 72,000 people; when the suppliers of TAYSAD members are included, the total number of employees reaches about 127,000.

The Turkish automotive industry's awareness and interest have been increasing, and companies are in the prototype development phase. Research projects on system components are being carried out by several companies and research institutions. Industry interest has concentrated on battery, electric motor, and fuel cell technologies and on emissions and vehicle system integration.



Fig 25.1 TEMSEA Avenue Hybrid bus. (Photo courtesy of TEMSEA.)

In 2009, the Turkish bus manufacturing company TEMSEA introduced its hybrid bus, the Avenue Hybrid (figure 25.1). The 12-m bus has a series hybrid powertrain with two asynchronous electric motors on one axle, a permanent magnet generator, and an ultracapacitor as electric energy storage system.



Fig. 25.2 Otokar Doruk Hibra hybrid bus. (Photo courtesy of Otokar.)

Otokar recently announced a concept hybrid urban bus, Doruk 160LE Hibra (figure 25.2), based on Otokar's Doruk LE Series in the heavy-duty segment. When compared to conventional fossil fuel-powered buses, Doruk presents better emission and fuel consumption figures.

25.5 On the road

The number of vehicles on the road in Turkey is increasing. Although the total fleet of vehicles on the road is about 13 million, only a few HEVs are among them. (The Honda Civic hybrid fleet consisted of 264 in 2008.) The number of road vehicles presented in Table 25.4 is based on figures published by the Turkish Statistical Institute.

Table 25.4 Number of vehicles on the road in Turkey from 2004 through 2009. (Source: Turkish Statistical Institute.)

	2004	2005	2006	2007	2008	2009*
Passenger vehicle	5,400,440	5,772,745	6,140,992	6,472,156	6,796,629	7,056,945
Minibus	318,954	338,539	357,523	372,601	383,548	384,348
Bus	152,712	163,390	175,949	189,128	199,934	201,292
Light-duty truck	1,259,867	1,475,057	1,695,624	1,890,459	2,066,007	2,190,750
Truck	647,420	676,929	709,535	729,202	744,217	734,327
Motorbike	1,218,677	1,441,066	1,822,831	2,003,492	2,181,383	2,295,489
Tractor	1,210,283	1,247,767	1,290,679	1,327,334	1,358,577	1,364,199
Others	28,004	30,333	34,260	38,573	35,100	33,629
Total	10,236,357	11,145,826	12,227,393	13,022,945	13,765,395	14,260,979

* 2009 November – December numbers were not available at the time of preparation of this report.

Passenger vehicle: Vehicle with a designated maximum seating capacity of 8.

Minibus: Vehicle with a designated seating capacity of 9 to 15.

Bus: Vehicle with a designated seating capacity of 16 or more.

Light-duty truck: Vehicle designated for the transportation of equipment with a maximum gross vehicle mass of 3,500 kg.

Truck: Vehicle designated for the transportation of equipment with a gross vehicle mass of more than 3,500 kg.

Motorbike: Vehicle designated to travel with no more than three wheels contacting the ground.

Tractor: Agricultural vehicle not used for commercial transportation.

Others: Vehicles designated for the transportation of passengers or equipment, such as an ambulance, fire fighting vehicle, towing truck, and hearse.

Most passenger cars in Turkey were previously fuelled by gasoline; now, the proportions of diesel and liquefied petroleum gas (LPG) passenger vehicles are increasing. The population of road vehicles by fuel type based on Turkish Statistical Institute data is presented in table 25.5. Sales of electric two-wheelers have recently begun, but these sales have not yet led to a significant number of these vehicles being on the road. Table 25.6 profiles the makeup of the Turkish in-use fleet as of the end of 2008.

Table 25.5 Types of fuel used by motor vehicles in Turkey from 2004 through 2008. (Source: Turkish Statistical Institute.)

	2004	2005	2006	2007	2008
Gasoline vehicle	5,569,192	5,606,321	5,935,725	5,980,516	5,952,746
Diesel vehicle	3,346,355	3,836,399	4,372,042	4,850,837	5,323,478
LPG vehicle	819,007	1,298,830	1,569,951	1,880,023	2,276,283
Unknown	501,803	404,276	349,675	311,569	212,888
Total	10,236,357	11,145,826	12,227,393	13,022,945	13,765,395

Table 25.6 Characteristics and population of the Turkish motorized vehicle fleet as of December 31, 2008.

Vehicle type	DECEMBER 31, 2008		
	EV fleet	HEV fleet	Total fleet
Motorized bicycle (no driver licence)	n.a.	n.a.	n.a.
Motorbike	n.a.	n.a.	2,181,383
Passenger vehicle	n.a.	264	6,796,629
Multipurpose pass. vehicle	n.a.	n.a.	n.a.
Bus ^(a)	n.a.	n.a.	583,482
Truck	n.a.	n.a.	2,810,224
Industrial vehicle	n.a.	n.a.	1,393,677
Total	n.a.	264	13,765,395

n.a.: not available

(a) Includes minibuses.

The definitions of the different vehicle categories can be found in section E of this report, "Vehicle categories."

In the Prince Islands (or more commonly *Adalar* as they are officially named—a chain of nine islands off the coast of Istanbul, Turkey, in the sea of Marmara)

motorized vehicles—except a few municipality service vehicles—are forbidden (Fig. 25.3). The only vehicular transportation possibilities are bicycles and phaetons (horse and cart). In the last few years electric-assisted bicycles and other electric two-wheelers have become popular in the islands.



Fig. 25.3 Car-free zone in the Prince Islands of Istanbul.

25.6 Outlook

As mentioned previously, the hybrid vehicle market in Turkey is just starting. The Honda Civic hybrid is being offered for sale, and Toyota has started selling hybrids. Other companies are introducing hybrids on their web sites. Electric two-wheelers have also been sold in the last few years.

The National Automotive Technology Platform is a new program in which industry, trade organizations, universities, research institutions, and the public sector will jointly determine a vision for the Turkish automotive industry and identify strategic research areas (SRAs) to be addressed to realise this vision. Precompetitive R&D projects based on these SRAs will be awarded at both the national and European scale. Activities will be chosen to create an awareness of Turkey's vision and goals across all European technology platforms. The vision and the SRAs will be reviewed and possibly realigned on an annual basis.

Turkey aims to fully cohere with European Union legislation. It has published several items of legislation and is conducting many studies to prepare new regulations and legislation that will reduce greenhouse gas emissions and improve air quality.

Turkey's current situation and short-term policies indicate that the number of R&D projects related to electric vehicles, hybrid vehicles, fuel cells, energy storage, and alternative fuels will continue to increase. Also, because of greater

awareness about clean vehicles and the environment, more hybrids will no doubt be seen in the market and on the roads.

23.7

Benefits of participation

The advantages to Turkey from participating in IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) activities are as follows.

- ▶ The exchange of information among Turkish and worldwide experts gives Turkey international-level insight to better plan its national R&D programs.
- ▶ Turkey's ability to evaluate member countries' governmental implementation plans is important in helping it check and organise its own HEV technology standards and regulations.
- ▶ Turkish researchers have access to information on the latest developments in member countries and are able to share their experiences and the results from ongoing and completed programs with them.
- ▶ Turkish scientists and engineers are able to make informal personal contacts with other researchers with whom they could potentially collaborate on joint projects.
- ▶ The country can build networks with scientific experts around the world to share new ideas and projects.

23.8

Further information

Further information regarding the above topics can be obtained from the following websites, all of which are in both English and Turkish:

- ▶ www.dpt.gov.tr
Turkish Republic Prime Ministry State Planning Organization.
- ▶ www.ubak.gov.tr
Republic of Turkey, Ministry of Transport.
- ▶ www.enerji.gov.tr
Republic of Turkey, Ministry of Energy and Natural Sources.
- ▶ www.mam.gov.tr/english/EE/index.html
TÜBITAK Marmara Research Center Energy Institute.
- ▶ <http://mekar.itu.edu.tr>
Mechatronics research group at Istanbul Technical University.
- ▶ www.osd.org.tr
Automotive Manufacturers Association.
- ▶ www.otam.itu.edu.tr

Automotive Technologies Research and Development Center.

- www.taysad.org.tr

Association of Automotive Parts and Components Manufacturers.

- www.turkstat.gov.tr

Turkish Statistical Institute.

26.1 Introduction

The UK has committed to transition to a low carbon world and take charge of the steps that would transform its economy. Lord Nicholas Stern's landmark Review on the Economics of Climate Change in 2006 set out the economic case for UK Government action on climate change and for investment in a low carbon economy. Reducing the environmental impact of transport is a key part of this effort, as today 19% of CO₂ emissions within the UK come from road vehicles.

The strategy for making the shift to ultralow carbon vehicles in the UK was announced by the UK Secretaries of State for Transport and Business in April 2009 and is based on five goals. These recognize the vital way in which supply and demand for ultra low carbon vehicles will have to interact in the next few critical years.

The UK Government will actively encourage consumer uptake of ultra low carbon solutions, their development, and their manufacture in the UK by:

- Supporting the automotive industry through the downturn for a successful transition to a low carbon future.
- Securing the future competitiveness of the UK industry by enhancing its reputation as a leading location for research, development, and demonstration of ultra low carbon vehicle technology.
- Creating a viable environment to support the adoption of ultra low carbon vehicles in lead cities and regions, including investment in the skills base.
- Making ultra low carbon vehicle solutions more attractive for consumers by helping to reduce the upfront costs of these vehicles.
- Clear and strategic leadership by Government and a smarter coordination of public sector activity.

The Office for Low Emission Vehicles (OLEV) is the new cross-UK Government team which brings together existing policy and funding streams to drive policy delivery. Formed in November 2009, OLEV incorporates policies, people, and funding from the Departments for Transport, Business, and Energy and Climate Change.

OLEV's priorities are delivering the £260 million package of consumer incentives, through the Plug-In Car Grant and infrastructure, and through the

Plugged-In Places framework programme to support an early market for electric and plug-in hybrid cars. OLEV is also charged with the delivery of government support for ultra low carbon vehicle research and development and demonstration work. OLEV is the lead contact for major policies and funding streams supporting ultra low emissions vehicles.

26.2 Policies and legislation

EUROPEAN

The EU's New Car CO₂ Regulation (Regulation (EC) No 443/2009, adopted in April 2009), which the UK Government strongly supported, establishes a clear, long-term framework for action by industry to develop more fuel-efficient vehicles. The Regulation will ensure compliance through a financial penalty system, backed up by a rigorous monitoring process. The main flexibilities are an "eco-innovations" provision allowing crediting of off-test cycle emissions savings and "super-credits" for cars emitting less than 50g/km CO₂.

NATIONAL

The groundbreaking Climate Change Act 2008 introduces a binding long-term framework to reduce greenhouse gas emissions towards a target of at least an 80% reduction below 1990 levels by 2050. A system of "carbon budgets," which limit UK emissions over successive five-year periods, will set the trajectory towards 2050. At least three carbon budgets must be set ahead at any time to allow businesses to plan and invest with certainty about the future direction of travel. Carbon budgets are a world first and will drive the UK's transition to a low carbon economy by committing the nation to a series of legally binding emission caps between now and 2050.

In addition, the UK also has a range of fiscal measure and public programmes that support the development of the national EV and PHEV market. These are outlined below.

FISCAL MEASURES SUPPORTING EVS AND PHEVS

- EVs are zero rated for Vehicle Excise Duty (the UK's circulation tax).
- EVs are zero rated for Company Car Tax.
- There are Enhanced Capital Allowances for companies purchasing electric cars or vans. For example, electric cars and those with very low CO₂ emissions of 110 grams or less per kilometer (g/km) driven qualify for a 100% capital allowance until 31 March 2013. Also, in December 2009, the

Chancellor announced that, subject to State aid approval, there will be a 100% first-year allowance for business expenditure on new and unused (not secondhand) electric vans.

- ▶ There is a lower rate of value added tax (VAT) for domestic electricity. The domestic electricity VAT rate of 5% is well below the VAT rate of 17.5% for fuelling internal combustion engine (ICE) vehicles, which translates into lower vehicle operation costs.

PROGRAMME MEASURES

- ▶ The Low Carbon Vehicles Innovation Platform provides £140 million for research, development, and demonstration projects. The Technology Strategy Board manages this major programme, which it launched in September 2007. Programme funds include £25 million for ultra-low carbon car demonstration projects, which launched in late 2009 and will see more than 340 electric-drive vehicles trialled in several UK regions until the end of 2010. EVs and some PHEVs in a range of car models including taxis and people-carriers are being tested on the road by a variety of real-life users.
- ▶ The £20 million Low Carbon Vehicle Public Procurement Programme, which is managed by Cenex, aims to help public sector bodies to trial and demonstrate new low carbon vehicle options within their car and van fleets. Announced in 2007, this programme is supporting the demonstration of over 150 low carbon and all-electric vans in public sector locations across the UK. The initial trials were planned to begin by January 2010 and to last a minimum of three years.
- ▶ The £230 million Plug-In Car Grant programme will support the early adoption of electric and plug-in hybrid cars. The Plug-In Car Grant will support eligible vehicles delivered to customers from January 2011 and will run until 31 March 2014, or until the available funding for financial year 2013/14 has been distributed, whichever is earlier. The incentive has been timed to start when it is anticipated that a range of vehicles will be available in the UK. Eligible cars will receive a grant of 25% of the list price up to a maximum of £5,000. Manufacturers are now applying for their cars to be included once the scheme starts in January 2011. OLEV will have oversight of the programme, which will be managed by a yet to be appointed organization. Details on the application process are at <http://www.dft.gov.uk/pgt/sustainable/olev/grant/>.
- ▶ The UK Government's £30M Plugged-In Places scheme will provide the critical mass of charging infrastructure in from 3 to 6 key cities or regions to support this early market for electric vehicles. The first three Plugged-In Places were announced in February 2010 with over £8 million allocated

to London, Milton Keynes, and the North East in 2010/11 for schemes that will eventually see over 11,000 charge points installed over the next 3 years. Figure 26.1 depicts the Plugged-In Places plans. These schemes will also provide valuable lessons to inform any future national rollout of charging infrastructure to support a mass market in EVs.



Fig. 26.1 Map of Plugged-In Places electric vehicle infrastructure scheme.

The three schemes are led by consortia of the public and private sectors, including local authorities, regional development agencies, supermarkets, retailers, car park operators, car manufacturers, utility companies, car clubs, and car rental firms. They will provide valuable lessons in how

the public and private sectors need to work together to deliver charging infrastructure in the future, as well as how charging will work in different environments—urban, suburban and regional. The schemes are also trialling innovative technologies such as rapid charging, inductive charging, and battery swap to help determine the charging technologies of the future. Further details on the scheme can be found at <http://www.dft.gov.uk/pgpr/sustainable/olev/infrastructure/>.

- ▶ Smaller projects will be eligible for support through Department for Transport's Alternative Fuels Infrastructure Grant Programme (AFIGP), which supports electric, hydrogen, and natural gas vehicle infrastructure projects. Information gathered from Plugged-In Places and AFIGP will support any future nationwide electric vehicle infrastructure rollout.
- ▶ Finally, the Automotive Assistance Programme (AAP) includes a low carbon goal that would support EVs and PHEVs at the R&D stage. The AAP is meant to sustain investment in innovation in the UK through the recent economic downturn, but it encourages of low carbon technologies as one of several objectives. The AAP aims to unlock up to £2.3 billion in loan guarantees specifically for companies in UK's automotive manufacturing and supply chain businesses. Managed by the Department of Business Innovation and Skills, the programme launched on 27 February 2009 and extends through December 2010.

LOCAL

Local authorities have a number of policy levers they can use to stimulate the nascent EV and PHEV market. For example, they can provide parking discounts, access to priority lanes, and exemptions from congestion charging or other traffic measures. It is up to the individual authorities to decide which mix of policies best suits their needs and aspirations.

Some local authorities are also developing comprehensive EV strategies. For example, in May 2009 London published "An Electric Vehicle Delivery Plan for London," which sets out three key targets: putting 100,000 electric vehicles on the capital's streets as soon as possible; installing 25,000 charging spaces within London by 2015; and adding at least 1,000 electric vehicles to the Greater London Authority fleet by 2015. One North East, the regional development agency covering North East England, has ambitious joint venture plans with several private sector companies to install 750 charging points throughout the region during 2010 and 2011. This programme was announced in June 2009, not long after the North East region was named as one of the UK Government's Ultra Low Carbon Vehicle Demonstrator areas where 35 new electric passenger vehicles

will be trialled, some of which are already being tested.

The overall aim is to ensure the development of a network of electric vehicle infrastructure across the UK that will lead to the linking of cities and regions. Central government will take an overall lead in the development of this programme, drawing on the work of the Energy Technologies Institute and pioneering local authorities, like the City of Westminster, in this area. Although government has a role in helping support the minimum infrastructure to make the transition to ultra-low carbon vehicles viable, the UK Government expects that the private sector, either in the form of electricity suppliers and distributors or other third parties, will ultimately take the lead in infrastructure provision.

26.3 Research

In the UK, the EV and PHEV research strategy is part of the Integrated Delivery Programme (IDP), which is a £140 million investment programme jointly funded by Government and business. Its aim is to speed up the introduction of new low carbon vehicles onto Britain's roads. The Programme coordinates the UK's low carbon vehicle activity from initial strategic research through collaborative research and development, leading to the production of demonstration vehicles. The Department for Transport, the Engineering and Physical Sciences Research Council (EPSRC), and the regional development agencies Advantage West Midlands and One North East have agreed to invest in the programme. The programme will seek further support from other regional development agencies and the devolved administrations.

The Integrated Delivery Programme features:

- A strategic programme of university-based research targeted towards future technologies for which there are good prospects of commercialization in the long term.
- An industry-led advisory panel that will help shape the technological direction and priorities for the programme. It will be composed of representatives of leading elements of the UK automotive industry and low carbon vehicle technology developers, as well as relevant academic experts.
- Flexible rolling opportunities for industry to seek support for high quality collaborative research and development proposals which take technology through to system or vehicle concept readiness.
- Funding to support trialling and demonstration of particularly innovative lower carbon vehicle options.

This five-year programme is managed by a Funder's Panel with an industry-focused Advisory Panel providing input into the areas of strategic research needed. There will be several separate competitions throughout the five years, with the subjects of these competitions based on strategic research and development needs as advised by the Advisory Panel.

26.4 Industry

The automotive industry is a pivotal part of the UK manufacturing sector. Automotive businesses are leaders in many areas of manufacturing, purchasing, product development, and logistics. Major inward investors have brought with them best practices, and the skills and knowledge of the industry provide a key source for improvement across the UK manufacturing sector as a whole.

The automotive sector has two distinct parts: the manufacture of vehicles and components, and the motor trade (including retail, distribution and aftermarket services). In the case of manufacturing, Britain has a diverse and productive vehicle manufacturing base and is a global centre of excellence for engine development and production. More than 40 companies manufacture vehicles in the UK, ranging from global volume car makers and van, truck, and bus builders, to specialist niche players. The industry is supported by a dynamic supply chain including many of the world's major component manufacturers, technology providers, and design and engineering consultancies; and it benefits from a world-renowned knowledge base.

The sector was boosted recently with the announcement that Nissan would be manufacturing the Leaf electric car at their Sunderland plant from 2013 with planned production of 50,000 cars.

The automotive industry in the UK is characterized by significant foreign direct investment and high exports, equivalent to 13% of the UK's exports of goods. Overall, automotive manufacturing provides 180,000 jobs and contributes some £10.2 billion value-added to the UK economy (6.4% of the total for the whole UK manufacturing sector). The UK accounts for some 2.4% of worldwide vehicle output and 8.7% of European assembly, ranking it fourth in Europe and twelfth globally. The companies based in the UK operate in Europe's third biggest automotive market with UK customers in 2008 accounting for the purchase of more than 2.1 million new cars, equivalent to 14% of European vehicle registrations.

Moreover, the UK offers a highly sophisticated automotive retail, service, and maintenance sector, which last year generated some £24 billion value added to the UK economy. It comprises some 67,000 businesses employing 552,000 people.

There are also around 2,600 component manufacturers in the UK, ranging from the global players to small and medium-sized businesses. Together they contribute £4.7 billion added value and employ around 106,000 people. The components sector exports over £5 billion worth of goods annually, 75% destined for Europe. The UK is also an increasing force in powertrain design and production (the components making up the power transmission system of a motor vehicle from engine to final drive), with a particular strength in engines.

There is a long-established, independent, design engineering sector offering the full spectrum of services from concept design through to limited-series vehicle production. The sector is recognized internationally for its flexibility and responsiveness and for the innovative qualities of its engineers. It continues to evolve, and the last five years have witnessed a succession of acquisitions, closures and re-emergences in response to the changing demands of its global market.

The UK is a centre for design engineering where around 7,500 people are employed, generating a turnover of some £650 million, with around 65% exported. The UK is home to the dedicated facilities of vehicle manufacturers, such as those at Ford's engineering centres at Dunton, Gaydon and Whitley, and Nissan's R&D centre at Cranfield. In addition, renowned names such as Lotus Engineering, MAHLE, MEL, Millbrook, MIRA, mi Technology, Perkins, Pi Technology, Prodrive, Ricardo, RLE, Roush, TRW Conekt, TWI, and Zytec are also active in the UK. Many of these have other overseas operations, located everywhere from mainland Europe to the US, Japan, and China.

This strong combination of heritage, diversity and agility places the automotive industry in the UK in excellent shape to face the unremitting pressures for change in the 21st Century. The principal challenge is for the UK's automotive manufacturing industry to align its technology, product, and business performance to deliver customer value in a global industry subject to relentless cost-cutting pressures. Regulation poses further challenges. Environmental protection and safety legislation are set to strongly influence the number and type of vehicles that will be manufactured, marketed and used. The focus within Europe will be on securing these environmental benefits while generating competitive advantage.

26.5

On the road

As of the end of 2008 the UK currently has about 47,035 HEVs and 1,405 EVs, as shown in table 26.1.

Table 26.1: Hybrid and electric vehicle fleet numbers at the end of 2008.

Vehicle type	PER 31 DECEMBER 2008		
	EV fleet	HEV fleet	Total fleet (incl. EVs and HEVs)
Bicycles (no driver license)	n/a	n/a	n/a
Motorbikes	898	0	898
Passenger vehicles	1,405	47,035	48,440
Multipurpose passenger vehicles	13	34	47
Buses	70	0	70
Trucks	5,310	34	5,344
Industrial vehicles	3,320	9	3,329
Invalid Vehicles	25,773	5	25,778
Unknown	74	1	75
Total	36,863	47,118	83,981

26.6

Outlook

The UK believes that there is a collective will among stakeholders for the market in EVs and PHEVs to develop among early adopters. However, the pace of this uptake is uncertain, not least because in the UK decisions on the price of vehicles, the value of the Government support for each vehicle, and the public's perception of infrastructure provision are still in the process of being answered.

26.7

Benefits of participation

As the UK only rejoined the IA-HEV in 2009, it has not been possible to properly assess the benefits of participation. However, early indications are that the UK's ambitious EV and PHEV plans will greatly benefit from membership of the IA-HEV and from the opportunity to share knowledge and experience, for example of ongoing trials of new vehicles and infrastructure.

26.8

Further information

More information about UK initiatives in low emission vehicles may be found at the following resources:

- ▶ Office for Low Emission Vehicles website
www.dft.gov.uk/olev
- ▶ *Ultra-Low Carbon Vehicles in the UK* report
<http://www.dft.gov.uk/adobepdf/187604/ultralowcarbonvehicle.pdf>
- ▶ *An Independent Report on the Future of the Automotive Industry in the UK*, by the New Automotive Innovation and Growth Team (NAIGT)
<http://www.berr.gov.uk/files/file51139.pdf>
- ▶ *Government Response to the New Automotive Innovation & Growth Team Report*, by the Department for Business Innovation and Skills, November 2009
<http://www.berr.gov.uk/files/file53570.pdf>
- ▶ Climate Change Act 2008
http://www.opsi.gov.uk/acts/acts2008/ukpga_20080027_en_1

27.1 Introduction

The United States, through the U.S. Department of Energy (DOE), has been actively supporting research and development (R&D) on innovative vehicle technologies. DOE supports R&D on more energy-efficient and environmentally friendly highway transportation technologies at the National Labs and also works through industry partnerships to develop and deploy advanced transportation technologies. Government-industry partnerships for the advancement of high-efficiency vehicles envision affordable full-function cars and trucks, reduced import of oil, and less emission of greenhouse gases and other pollution. For example, DOE's Clean Cities Program supports public-private partnerships that would deploy alternative fuel vehicles (AFVs) and build supporting infrastructure.

27.2 Policies and legislation

27.2.1

Federal

The Federal government policies and legislation designed to directly or indirectly promote the U.S. market for hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and electric vehicles (EVs) include both long-term programs on the development of Federal standards for improved fuel economy (and air quality) as well as some short-term (“one-time only”) steps under the recent economic stimulus plan.

Long-term programs

The following Federal activities, ongoing for several years, are intended to provide long-term solutions to replace less energy-efficient transportation technologies with more efficient counterparts like HEVs and EVs.

- **Improved fuel economy standards:** The provisions of the Energy Policy Act of 1992 (EPACT) included a requirement that state and Federal government fleets and providers of alternative fuels (including electric utilities, natural gas utilities, and other producers/suppliers) convert an increasing percentage of their vehicle fleets to AFVs over time. A 2005 amendment to EPACT included changes to the Corporate Average Fuel Economy (CAFE) program by extending the existing manufacturing incentives program for

AFVs and by authorizing appropriations for fiscal years 2006–2010 to implement and enforce the CAFE standards. A limited Federal tax credit was available for light-duty HEVs placed in service between December 31, 2005 and January 1, 2011. Certain tax credits for medium- and heavy-duty vehicles were also made available for a time. Subsequently, Sections 1141–1143 of the American Recovery and Reinvestment Act of 2009 (ARRA) provided tax credits for purchasing plug-in electric drive vehicles (\$2,500 – \$7,500 per vehicle, depending on battery capacity), low-speed electric vehicles (\$2,500 per vehicle, maximum), or conversion kits (\$4,000 per vehicle, maximum).

The Energy Independence and Security Act (EISA) mandated that the model year (MY) 2011–2020 CAFE standards be set sufficiently high to ensure that the industry-wide average of all new passenger cars and light trucks combined is not less than 35 miles per gallon by MY 2020. This is a minimum requirement, as the U.S. National Highway Traffic Safety Administration (NHTSA) must set standards at the maximum feasible level in each model year. The NHTSA is to determine, based on all of the relevant circumstances, whether the additional requirement calls for establishing standards that reach the 35 mpg goal prior to MY 2020. NHTSA published a proposal in May 2008 to begin implementing EISA by establishing CAFE standards for MYs 2011–2015. A draft final rule for those model years was completed, but not issued during the change in administration. Instead, the new President issued a memorandum requesting NHTSA to divide its rule-making into two parts. The agency was asked to issue a final rule adopting CAFE standards for MY 2011 only while the issue of post-MY 2011 standards could be revisited (including the underlying methodologies, economic and technological inputs, and decision-making criteria). Accordingly, the NHTSA issued a Final Rule on March 30, 2009 raising the industry-wide combined average to 27.3 mpg for MY 2011 only.

- ▶ **Setting safety standards for new transportation technologies:** The NHTSA has set special safety standards for Neighborhood Electric Vehicles (NEVs), defined as electricpowered motor vehicles with three or more wheels in contact with the ground, a fully enclosed passenger compartment, a vehicle curb weight of less than 2,000 pounds, and a top operating speed of 40 miles per hour or less. A Federal Motor Vehicle Safety Standard, number 500, requires such vehicles to incorporate specific safety devices (e.g., three-point restraints, safety glass, 3-mph bumpers, rearview mirrors, horns, parking brakes and lighting and reflector equipment). Some state laws allow certain types of NEVs on city streets.

- ▶ **Favorable emission standards:** The U.S. Environmental Protection Agency (EPA) proposed a Finding that greenhouse gases from new vehicles and industrial plants pose a danger to the public, initiating a process that could result in tighter regulation of carbon dioxide emissions.

Short-term programs

The following recent Federal activities were designed to provide an immediate boost to the U.S. economy, especially to its auto industry. These were funded on a one-time only basis (although some of the programs initiated through them may last several years).

- ▶ **The “Cash for Clunkers” program:** Under a law entitled the Car Allowance Rebate System (CARS), nicknamed “Cash for Clunkers”, owners of inefficient vehicles were offered cash vouchers of up to \$4,500 to replace those vehicles with new, fuel-efficient cars and trucks. The program, which was allocated \$3 billion in total, appeared to create a sales momentum for dealers. Also, while a third of the “clunker” buyers bought a new car, many individuals whose vehicles did not qualify for the program still ended up buying another car upon visiting dealerships. However, after the program ended, the sales appeared to go down substantially.
- ▶ **Economic stimulus for the auto industry:** The U.S. announced \$2.4 billion in grants to GM, Ford, Chrysler, and other companies to speed the development of EVs and automotive batteries in the United States. The grants, funded under the stimulus package enacted in February, included the largest U.S. investments ever for advanced battery technology for HEVs, PHEVs, and EVs. A total of \$1.5 billion would be given to U.S. manufacturers to make batteries and their components as well as toward battery recycling. GM, Chrysler, and Ford will receive a total of more than \$400 million to manufacture advanced hybrid and electric vehicles, batteries, and electric drive components; and for conducting transportation electrification demonstration projects. Grants of up to \$400 million would help battery companies build plants to make cells and packs for PHEVs and EVs in the U.S. For example, Compact Power Inc. plans to shift battery cell production to Michigan from the factories of parent company LG Chem in South Korea. The company’s suburban Detroit plant will design and assemble up to 10,000 lithium-ion battery packs a year by the end of 2010. It will supply the first battery packs for the Chevrolet Volt extended-range electric vehicle (EREV).

- ▶ **Advanced Technology Vehicle Manufacturing Loan Program (ATVMLP):** Created under Section 136 of the Energy Independence and Security Act of 2007, the ATVMLP provides loans to automobile and automobile part manufacturers for the cost of re-equipping, expanding, or establishing manufacturing facilities in the United States to produce advanced technology vehicles or qualified components, and for associated engineering integration costs. The FY 2009 Continuing Resolution appropriated \$7.5 billion to support a maximum of \$25 billion in loans under the ATVMLP. As of the end of 2009, more than one-third of the available funds had been awarded to four applicants, including Ford, Nissan, Tesla Motors, and Fisker Automotive. For example, DOE is loaning the California-based Fisker \$529 million to complete the development of the Karma, a mid-sized PHEV, and the Nina, a new line of smaller and less expensive HEVs.

27.2.2

State

As shown in table 27.1, at least 38 U.S. states (and the District of Columbia) maintain regulations promoting HEV usage, including high occupancy vehicle (HOV) privileges, waived emissions inspection, tax credits/rebates, or preferential purchase directives. The overwhelming majority (31 out of 38) provide tax benefits or rebates of one kind or other. In addition, thirteen other states—Connecticut, Florida, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington; and the District of Columbia—have attempted to adopt California-like clean air standards, which would require automakers to reduce greenhouse-gas emissions for their vehicles by 30% before 2016. Several others are actively pursuing or considering adoption of similar standards, including Colorado, Florida, Illinois, Iowa, Minnesota, Montana, North Carolina, and Utah.

IA-HEV ANNUAL REPORT 2009

Table 27.1 2009 Status of U.S. state-level incentives for hybrid electric vehicles.

STATE	HOV/ PARKING PRIVILEGES	EMISSIONS BENEFITS	TAX/ REBATES	PURCHASE DIRECTIVE
Arizona	X		X	
Arkansas			X	
California	X	X	X	
Colorado		X	X	
Connecticut	X			
Delaware				X
District of Columbia	X		X	
Florida	X			
Georgia	X	X	X	
Hawaii			X	
Illinois	X		X	
Indiana			X	
Iowa			X	
Louisiana			X	
Maryland		X	X	
Michigan		X	X	
Missouri		X	X	
Montana			X	
Nebraska			X	
Nevada		X	X	
New Hampshire		X		
New Jersey	X		X	
New Mexico			X	
New York	X		X	
North Carolina			X	
Ohio		X		
Oklahoma			X	
Oregon		X	X	
Pennsylvania			X	
Rhode Island			X	
South Carolina			X	
Tennessee	X			
Texas		X		
Utah	X		X	
Vermont			X	
Virginia	X		X	
Washington		X	X	
West Virginia			X	
Wisconsin			X	

Source: http://www.afdc.energy.gov/afdc/fuels/electricity_laws.html

27.3 Research

27.3.1

Barriers

To be a realistic solution, a high fuel-economy vehicle will need to meet the design targets while remaining acceptable to the market. Thus, any new HEV, PHEV, or EV faces significant barriers of cost, emission standards, and fuel infrastructure.

COST

High cost is a serious barrier in almost every research area for advanced vehicle technologies. The current costs of most advanced vehicle technology components exceed cost-effective targets. For example:

- Lightweight body construction, compression ignition direct injection (CIDI) engines, batteries, and electronic control systems all increase the vehicle cost.
- Emission control systems for high efficiency direct injection gasoline and diesel engines, when developed, would be more expensive than current systems.
- Many concept cars in their present form do not represent an affordable alternative compared to conventional vehicles with similar mission, although the prices could reduce for large scale manufacturing.

EMISSIONS STANDARDS

The U.S. EPA Tier 2 NO_x and particulate matter standards are significantly more stringent than prior standards and may delay an early introduction and widespread use in the U.S. of certain advanced engine technologies for passenger cars.

FUEL ISSUES

Successful introduction of CIDI engines, spark ignition direct injection (SIDI) engines, or fuel cells will be critically dependent on widespread availability of suitable fuels. The large capital expenditures and long lead times required to manufacture and distribute a significantly modified fuel requires that the petroleum industry must be fully aware of the needs well in advance of the production of the first automobile which will use such a fuel. Furthermore, the change must be cost-effective for the petroleum companies (or mandated by regulation). A 2001 U.S. EPA regulation that required refiners to produce high-way diesel fuel with a maximum sulfur content of 15 parts per million (ppm)

by June 1, 2006, represented a significant progress. However, the development of cost-competitive combustion and emission control systems to perform and endure at Tier 2 levels (even with 15 ppm sulfur fuel) remains a challenge. For automotive fuel cell power plants, the most efficient and lowest-emission system involves direct hydrogen storage on the vehicle, which will require major infrastructure changes.

27.3.2

Enabling technologies

The U.S. supports research efforts to promote technologies for AFVs. Funding is provided for relevant research by the National Laboratories and by private industry through government-industry partnerships. The enabling technologies include hydrogen and fuel cells, advanced energy storage technologies, vehicle systems research, advanced combustion engines R&D, lightweight materials, and advanced power electronics – individually described below.

ADVANCED ENERGY STORAGE TECHNOLOGIES

An important step for the electrification of the nation's personal transportation is the development of more cost-effective, long-lasting, and abuse-tolerant lithium-ion batteries. For successful commercialization of EVs, HEVs, PHEVs, and extended-range electric vehicles (EREVs), their respective battery systems must meet several requirements simultaneously. For EVs, batteries must have high energy density; for HEVs, they must have high power density; and PHEVs and EREVs need batteries to have both high energy and high power densities. Moreover, battery systems for all of these vehicle types must also offer rechargeability, long life, safety, and low cost.

To reach the required goals, DOE funds three primary battery research areas. First is the developer program which assesses, benchmarks, and develops advanced batteries for vehicles, and is performed in close collaboration with the industry through the United States Advanced Battery Consortium (USABC). The second area is the applied battery research program, which provides near-term assistance to high-power battery developers to overcome the barriers associated with lithium-ion batteries for light and heavy-duty vehicles; these barriers include problems with calendar life, abuse tolerance, low-temperature performance, and cost. Finally, the DOE's focused fundamental research program conducts research into the next generation of battery technologies for vehicle applications. Recent significant accomplishments of DOE-funded energy storage research included:

- ▶ Johnson Controls-Saft (JCS) announced that it will provide lithium-ion bat-

teries for production versions of BMW's 7 Series ActiveHybrid car. JCS will use new high-power cells, developed under several programs sponsored by the DOE and US entry is scheduled in spring 2010.

- ▶ In support of the FreedomCAR Technical Team, the National Renewable Energy Laboratory (NREL) performed analysis to show that power-assist hybrid electric vehicles (PA-HEV) can still achieve significant fuel savings with a lower-energy, higher-power energy storage system (ESS). Existing USABC targets for ESS in PA-HEVs call for 300 Wh of "available" energy, which is believed to make the ESS expensive. Based on this analysis, a new set of technical requirements were created for lower energy ESS for PA-HEVs that could be less expensive.
- ▶ Argonne National Laboratory (ANL) made progress in improving the rate capability of a composite structure cathode material technology to 225 mAh/g at the C/2 discharge rate. Partially as a result of this, BASF, the world's largest chemical company, plans to mass produce and market the material. In addition, ANL, in collaboration with Envia Systems, was chosen as an R&D 100 Award winner for Envia Systems' lithium-ion battery which uses ANL's composite structure cathode material technology.
- ▶ Researchers at NREL completed the fabrication and calibration of a large, advanced calorimeter for measuring heat from automotive batteries.
- ▶ Researchers in the Batteries for Advanced Transportation Technologies (BATT) Activity at LBNL found a way to substantially reduce performance problems associated with the low-cost, high voltage lithium manganese phosphate (LiMnPO_4) cathode material for Li-ion batteries.

ADVANCED POWER ELECTRONICS AND ELECTRICAL MACHINES

This activity develops new technologies for power electronics and electric machinery, including motors, inverters/converters, sensors, control systems, and other interface electronics. It is divided into power electronics, electric motors/generators, and thermal control and integration sub-activities. A primary research focus is the thermal control of inverters and motors with advanced cooling technologies.

VEHICLE SYSTEMS RESEARCH

This activity provides support and guidance for many cutting-edge automotive and commercial vehicle technologies under development. Research is focused on understanding and improving the way the various new components and systems of future automobiles and commercial vehicles will function in a vehicle to improve fuel efficiency. It also supports development of advanced automotive accessories and the reduction of parasitic losses (e.g., aerodynamic drag, thermal management, friction

and wear, and rolling resistance). Recent research findings include:

- ▶ The Advanced Vehicle Testing Activity (AVTA) added another five PHEVs to the National PHEV Demonstration Fleet, bringing to a total of 124 the number of PHEVs in active operation in that fleet.
- ▶ In June 2009, ANL entered into a memorandum of understanding (MOU) with the Korea Automotive Technology Institute (KATECH). The goal of this agreement is to accelerate the development and commercialization of a variety of green car technologies. The MOU will focus on three key areas of research, including electric-drive vehicle benchmarking and battery systems testing.
- ▶ ANL engineers developed a robot driver to aid testing of electric vehicles at its Advanced Powertrain Research Facility (APRF). The robot driver will investigate the sensitivity of vehicles to small variations in the drive cycle and produce more repeatable results without concern for driver fatigue.

LIGHTWEIGHT MATERIALS

The reduction of vehicle mass through the use of improved design, lightweight materials, and new manufacturing techniques, is key to meeting fuel economy targets for commercially viable EVs, HEVs, and PHEVs. The DOE Lightweight Materials technology area focuses on the development and validation of advanced lightweight material technologies to significantly reduce automotive vehicle body and chassis weight without compromising other attributes. It pursues research in the areas of cost reduction, manufacturability, design data and test methodologies, joining, and recycling and repair. Priority lightweight materials include aluminum, magnesium, titanium, and carbon fiber composites. In 2009, the following efforts were carried out:

- ▶ The Magnesium Powertrain Cast Components Project was completed and demonstrated that there are no technical show-stoppers to prevent production implementation of magnesium power-train components, and that using magnesium can lead to a 29% mass reduction for those components.
- ▶ The Low-Cost Titanium for Feedstock project demonstrated that a novel low-cost titanium powder could be processed to a bar stock with an unprecedented combination of cost, strength, and ductility that can be used for suspension applications. Titanium's low density and elastic properties make it ideal for springs and can reduce the mass of suspension applications by more than 50% in solid bar and 72% in hollow bar.
- ▶ Preliminary costing of the Lightweight Composite Seat comprising bonded composite shells of 40% glass-reinforced polypropylene indicates an incremental cost of about \$1 per pound saved, which lies within the competitive range for weight-saving ideas.

ADVANCED COMBUSTION ENGINES R&D

The Advanced Combustion Engine R&D subprogram focuses on removing critical technical barriers to commercialization of higher efficiency, advanced internal combustion engines in passenger and commercial vehicles. These engines operate in combustion regimes that increase efficiency beyond current advanced diesel engines, reduce engine-out emissions of nitrogen oxides (NO_x) and particulate matter (PM) to near-zero levels, and use clean, hydrocarbon (petroleum- and non-petroleum-based fuels), and hydrogen. Work is done in collaboration with industry, national laboratories, and universities.

FUEL CELLS

The DOE Office of Energy Efficiency and Renewable Energy's Fuel Cell Technologies Program (FCT) (formerly the Hydrogen, Fuel Cells, and Infrastructure Technologies Program) leads efforts to enable the widespread commercialization of fuel cells across several application areas. In order to strengthen our nation's energy security and improve our stewardship of the environment, the Program engages in research, development, and demonstration of critical improvements in the technologies, as well as activities to overcome commercialization obstacles. The Program addresses the full range of barriers facing the development and deployment of fuel cell technologies by integrating basic and applied research, technology development and demonstration, and other supporting activities. The FCT Program also works closely with other U.S. government agencies to identify and facilitate deployment opportunities for fuel cells in their organizations. Congress appropriated \$195.865 million in fiscal year (FY) 2009 and \$174 million in FY 2010. Additional information on the Program appears in the 2009 Annual Progress Report (http://www.hydrogen.energy.gov/annual_progress09.html). The following are highlights in progress made by the FCT program in FY 2009 and since:

- During 2009, 11 new patents were issued for discoveries or technologies developed in FCT projects. An additional 21 applications were filed or being awarded.
- Twelve projects were initiated to support the deployment of nearly 1,000 fuel cell systems for emergency backup power and material handling applications (e.g., forklifts), and the demonstration of fuel cells for residential combined heat and power, auxiliary power units, and portable applications. These projects were funded under the American Recovery and Reinvestment Act of 2009 (\$41.9M over two years; \$114.3M with cost share), with significant near-term impact, creating jobs in various fuel cell-related sectors.
- The FY 2009 cost assessment projected the high-volume fuel cell system cost at \$61/kW for transportation applications, primarily as a result of reducing platinum loading and improving power density, representing a 16%

reduction from the prior FY value of \$73/kW.

- ▶ Los Alamos National Laboratory (LANL) developed two paths toward high-performance fuel cell cathodes that use no platinum or platinum group metals. Results showed a five-fold and an eleven-fold improvement over the best performing non-noble catalyst of the past year.
- ▶ 3M continued to play a significant role in fuel cell system cost reduction, demonstrating a new baseline membrane electrode assembly (MEA) with a 40% decrease in platinum loading from 2008. The 3M MEA exceeded by more than 30% DOE's lifetime targets for minimal surface area and performance loss under open circuit voltage hold tests.
- ▶ Giner Electrochemical Systems, which is working on combining the good conductivity properties of high acid content perfluorosulfonic acid (PFSA) membranes and improving their mechanical properties by using composite materials, demonstrated a PFSA membrane with conductivities exceeding the values set by DOE as 2009 milestones.

27.4 Industry

During the 1990s, a number of battery electric vehicles became available to US consumers. Chrysler, Ford, GM, Honda, Nissan, and Toyota produced limited numbers of EVs on lease to customers in response to the California Air Resources Board's 1990 zero-emissions vehicle mandate (which was later successfully challenged in court). However, no new EVs were manufactured for consumers. Over the past few years, interest in EVs among the U.S. auto industry and consumers has surged, with manufacturers planning to introduce new generations of EVs. HEVs reached a cumulative one million sales in 2007, and have consistently remained in the vicinity of 2.5% of all vehicle sales over the last couple of years. In addition, based on information announced by individual manufacturers, the list of HEVs, PHEVs, and EVs expected to enter the US commercial market over the next few years is shown in table 27.2.

27 UNITED STATES

Table 27.2 An overview of planned HEVs, EVs, and PHEVs.

TYPE OF VEHICLE	YEAR	MAKE AND MODEL(S) ¹
Hybrid Electric Vehicle (HEV)	2010	Lexus HS 250h Mercedes E Class Hybrid Porsche Cayenne S Hybrid Toyota Camry Hybrid Toyota Prius Hybrid (redesigned) Toyota Prius PHEV (limited leasing only) ² Audi A8 Hybrid (likely introduction) BMW 5-Series ActiveHybrid
	2011	Honda CR-Z sport hybrid coupe Lexus CT 200h Hybrid Hatchback Suzuki Kizashi Hybrid Audi Q5 Crossover Hybrid Hyundai Sonata Hybrid Infiniti M35 Hybrid
	2012	New Toyota HEV (spin-off of Toyota Yaris) ² Hyundai PHEV ²
	2014	Ferrari Hybrid
Battery Electric Vehicle (EV)	2010	Coda Automotive Sedan Chrysler EV ² Nissan LEAF Ford Battery Electric Van Tesla Roadster Sport EV
	2011	Renault Kangoo Z.E. Renault Fluence Z.E. Tesla Model S BYD e6 Electric Vehicle Ford Battery Electric Small Car
	2012	Audi e-tron Nissan Infinity EV ² Mitsubishi iMiEV EV
	2016	Tesla EV
Extended Range BEV	2010	Chevy Volt Extended Range BEV Toyota Plug-in Hybrid
	2011	BYD F3DM Plug-in Hybrid
	2012	Bright Automotive IDEA Plug-in Hybrid Ford Plug-in Hybrid
	(unspecified)	Fisker Karma S Plug-in Hybrid
Fuel Cell Electric Vehicle	2012	Hyundai Tuscon ix35 Fuel Cell
	(unspecified)	Honda FCX Clarity GM Hydro-GEN3 Chevy Equinox Fuel Cell Ford Fuel Cell EV

¹ Based on information provided on www.electricdrive.org, unless otherwise noted.

² Based on news accounts published in auto industry trade journals.

The following summarizes 2009 industry highlights related to EVs, HEVs, and PHEVs:

TOYOTA

- ▶ The redesigned 2010 Toyota Prius became available for sale. The new model is larger, with a more fuel-efficient hybrid power-train, and an improved nickel-metal hydride battery. It is equipped with a new 1.8-liter four-cylinder engine (134 hp including the electric motor). Its system weight was 20 percent less. Toyota will also lease 150 Prius PHEVs in the U.S. in 2010 and plans retail sales afterwards.
- ▶ Toyota announced plans for a new small hybrid car (possibly a spinoff of the Toyota Yaris) to compete with the Honda Insight Hybrid. Toyota also announced plans to sell a new EV in 2012, for which the platform and model are yet to be decided.
- ▶ Lexus unveiled the HS 250h, its first model offered only as a hybrid and said to have a fuel economy exceeding 35 mpg.

NISSAN

- ▶ Nissan announced in 2009 that it will start EV fleet sales to utilities and commercial users in 2010, followed by retail sales to consumers through dealer networks two years later. In 2010, the company will market its Leaf EV, which would have a 100-mile range on full charge. The lithium-ion batteries will be produced initially in Japan as joint venture with NEC Corporation but will be later made in Smyrna, TN (in 2012 and later). Nissan may also lease out the Leaf's rechargeable battery pack separately from the sale/lease of the rest of the vehicle.
- ▶ Nissan and Renault have been creating partnerships with government and utility groups to lay the groundwork for vehicle recharging. The partnering local authorities pledge to begin moving forward on EV recharging networks, new power-grid plans, residential electrical permit policies, etc. In 2009, Nissan set up eight such partnerships with local governments and/or utilities, including those in San Diego, Phoenix, and Raleigh, N.C.

HONDA

- ▶ Honda's second-generation five-door, five-seat 2009 Insight became available for sale. It is powered by a 1.3-liter four-cylinder engine and a nickel-metal hydride battery system that offers 30 percent more power output per module than that offered by the 2006 Civic Hybrid. The battery weight is reduced 28% and the number of battery modules was reduced from 11 to 7.
- ▶ Honda plans to develop an EV which can meet more stringent U.S. fuel economy and emissions rules down the road, to bring to the U.S. market by 2015.

GM

- ▶ GM unveiled three fuel-efficient vehicles the Chevrolet Spark mini-car, the Chevrolet Orlando small crossover, and a Cadillac concept PHEV to be called the Cadillac Converj. (Plans for the third vehicle were later scrapped.)
- ▶ In its viability plan provided to the Treasury Department, GM pledged to boost the number of gasoline-electric hybrids in GM's lineup to 26 models by 2014 (from the current 8 models).
- ▶ GM said it will limit Chevrolet Malibu Hybrid sales to fleets while completing the development of the two-mode hybrid systems, expected next year and similar to the systems used by the Ford Fusions and Toyota Camry hybrids.
- ▶ GM plans to build about 10,000 Chevy Volts in 2010 and between 50,000 and 60,000 units in 2011. It is building a battery-pack assembly plant south of Detroit for those vehicles. The \$43 million plant will assemble individual cells from South Korea's LG Chem Ltd. into 70,000 packs a year at full production for the Volt and other EREVs/PHEVs. Each pack will have 220 cells and is estimated to cost \$8,000.



Fig. 27.1 The 2011 Chevrolet Volt Extended Range EV. (Photo supplied by General Motors.)

FORD

- ▶ Ford is preparing to sell its Focus EV developed by Magna International inside a Ford Focus body for demonstration purposes. Magna's agreement with Ford is not exclusive and it plans to sell the system to other carmakers besides Ford. The Focus EV will go on sale in early 2011.

CHRYSLER

- ▶ A123Systems, of Watertown, Mass., will supply the next-generation lithium-ion batteries for a range of Chrysler EVs, which was announced to debut in 2010. Chrysler plans a plant in Michigan to manufacture battery cells, modules and packs.
- ▶ Chrysler showcased five electric-drive concept vehicles at the Detroit Auto Show. The Chrysler 200C, built on a rear-drive platform, is a concept version of a next-generation mid-sized sedan. The Dodge Circuit EV is an all-electric sports car. The Chrysler Town & Country EV is coupled with a small gasoline engine to extend its range to 400 miles. The Jeep Wrangler Unlimited EV is a rear-wheel-drive-only version of Wrangler Unlimited with the same electric power-train as the Chrysler 200C and Town & Country EVs. The Jeep Patriot EV compact crossover has front-wheel drive powered by a 150-kW (200-hp) electric motor.

OTHERS

- ▶ Several automakers (including Toyota, Ford, Chrysler, Nissan, Mitsubishi, BMW, and Hyundai) declared plans to produce a PHEV or EV. However, some automakers were considering quick recharging or battery swapping options instead of the standard charging time required (e.g., Nissan's linkage with Better Place, in Palo Alto, CA, which aims to create a network of battery-swapping stations in several places around the world.)
- ▶ China's BYD Co., a major producer of lithium-ion batteries for cell phones, indicated it plans to sell its F3DM PHEV in the USA, possibly as early as 2011.
- ▶ At the January 2009 Detroit Auto Show, Mercedes-Benz showcased three powertrains of concept vehicles, collectively called Concept BlueZero – representing an EV, a PHEV and a FCV. The BlueZero E-Cell uses a 35 kWh lithium-ion battery pack to provide a 120-mile range, the E-Cell Plus adds a 67-hp three-cylinder engine, while the BlueZero F-Cell variant gets a 90 kW hydrogen fuel cell for a 240-mile range.
- ▶ Mitsubishi said it will sell a small electric car (the i-MiEV) in the U.S. sometime after 2012, a Japan-built ultra-compact with a 330-volt lithium-ion battery.
- ▶ Hyundai plans to have a PHEV for sale in the U.S. by late 2012. The new hybrid-only vehicle will be based on its Blue-Will concept. The lithium-ion batteries will be supplied by LG Chem, of South Korea.

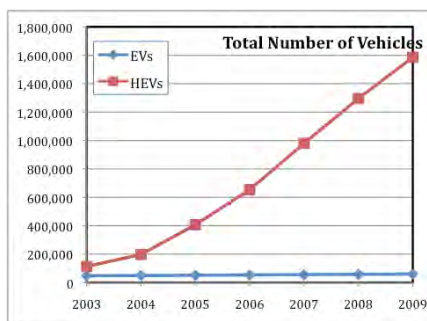
27.5

On the road

Compared to its total inventory of over 240 million light vehicles, the U.S. has a relatively small but growing number of HEVs. Table 27.3 lists the number of EVs and HEVs present in the U.S. over the past few years. HEV sales for 2005-2009 appear in table 27.4. At this time, the U.S. population of EVs appears to remain stable due to the lack of new personal mobility EVs. The electric vehicle population is likely to grow as new technologies are introduced, starting with the 2010 Chevy Volt extended range EV and other EVs.

Table 27.3 Number of EVs and HEVs present in the U.S. (mostly passenger cars)

YEAR	EVs ¹	HEVs ³
1995	2,860	NA
1996	3,280	NA
1997	4,453	NA
1998	5,243	NA
1999	6,964	17
2000	11,834	9,367
2001	17,847	29,649
2002	33,047	65,691
2003	47,485	113,257
2004	49,536	197,490
2005	51,398	407,201
2006	53,526	653,843
2007	55,654 ²	979,981
2008	57,782 ²	1,295,669
2009	59,800 ²	1,585,906



¹Energy Information Administration (EIA) (<http://www.eia.doe.gov/emeu/aer/txt/stb1004.xls>). Additional resource: Department of Energy (DOE) (<http://www.eere.energy.gov/afdc/data/vehicles.html>)

²Estimate (EV data for 2007 and thereafter are extrapolated)

³Electric Drive Transportation Association web site (<http://www.electricdrive.org>) and other sources as listed. Cumulative numbers calculated from annual sales.

IA-HEV ANNUAL REPORT 2009

Table 27.4 Number of EVs and HEVs present in the U.S. (mostly passenger cars)

MAKE	MODEL(S)	SALES (BY YEAR)				
		2005	2006	2007	2008	2009
Ford	Ford Fusion hybrid, Ford Escape hybrid, Mercury Milan hybrid, Mercury Mariner hybrid	19,795	22,603	11,444 ^c	19,522	33,502
Honda	Civic hybrid, Accord hybrid, and Insight hybrid	43,356	37,573	35,983	31,495	35,691
Lexus	RX400h, 600h, 250h, and GS	20,674 ^d	20,674 ^h	17,832 ^d	16,858 ^b	21,890
Nissan	Altima hybrid	--	--	7,209	8,827	9,357
Toyota	Camry hybrid, Highlander hybrid, and Prius	125,886 ⁱ	165,792 ^g	248,823 ^f	224,547	173,655
GM	Cadillac Escalade, Chevy Tahoe, Chevy Malibu, Chevy Silverado, GMC Yukon, GMC Sierra, Saturn Aura, Saturn VUE	--	--	4,837 ^e	14,439 ^a	16,142
Total U.S. HEV Sales		209,711	246,642 ^{g,h}	326,138	315,688	290,237
Total U.S. Light Duty Vehicle Sales		16,946,611	16,518,686	16,114,815	13,212,467	10,440,180
Total U.S. HEV Sales Percent		1.2%	1.5%	2.0%	2.4%	2.8%

^a Chevy Tahoe/GMC Yukon, Chevy Malibu Hybrid, Saturn Aura Hybrid, Saturn Vue Hybrid (June–August, October, December only); Cadillac Escalade 2-Mode Hybrid (August, October, December only)

^b Lexus 600h (through March only)

^c Ford Escape (through June 2007); Mercury Mariner (May and June 2007 sales only)

^d Lexus LS 600h (September–November Sales Only)

^e Saturn VUE (through May 2007 only)

^f Toyota Camry (through November 2007); Toyota Highlander (January–July 2007, November 2007 only)

^g Toyota Camry Hybrid (excludes December 2006 sales; on sale April 2006)

^h Lexus GS 450h 513 (excludes October–December 2006 sales; on sale April 2006)

ⁱ Toyota Highlander (on the market in June 2005)

^j Lexus 400h 20,674 (on the market in April 2005)

Sales data summarized from figures published at the Electric Drive Transportation Association website (www.electricdrive.org), then aggregated by manufacturers.

Although HEV sales have grown during the last five years, HEVs are not immune to the recent new car market declines (which continued during 2008 and 2009). In 2009, although the number of HEVs sold in the USA dropped about 8% when compared to 2008 levels (dropping from 315,688 in 2008 to 290,237 in 2009), the reduction is reflective of the overall decline in the domestic light vehicle sales (which reduced by over 20%, declining from 13,212,467 to 10,440,180) rather than a loss of consumer interest in HEVs themselves. In fact, the HEV percentage of light-duty vehicles sold rose from 2.4% in 2008 to 2.8% in 2009. Therefore, the market share of HEVs continued to rise in 2009, although at a slightly reduced rate than the prior two years.

Another observation is that a number of the HEVs entering the market in 2009 were in the higher price range. The average price of an HEV has increased during the past five years, mostly due to the introduction of more luxury hybrids. However, the average incremental price—the price differential between the HEV and its non-hybrid counterpart—has not been rising. According to the DOE 2008 Vehicle Technologies Market Report (DOE/GO-102009-2860), this differential actually declined from \$7,755 to \$5,814 from 2006 to 2008.

27.6 Outlook

There are varying projections on the future market shares of HEVs and EVs in the US and on how quickly those shares would be reached. A 2008 survey by the Ann Arbor-based Center for Automotive Research found that automotive executives and suppliers expect hybrid vehicles would compose 10 percent of overall market share by 2016.

During a conference organized by the Ann Arbor-based Center for Automotive Research in October 2009, the participants made note of a shift in consumer attitudes, acknowledging that consumers are starting to embrace the idea of a car without a typical internal combustion engine. However, the industry must drive down the cost of lithium-ion batteries to ensure widespread adoption of EVs. During this conference, results from a University of Michigan (UM) survey were also discussed that indicated that 46 percent of consumers would consider paying a \$2,500 PHEV premium.

Other analysts have made more optimistic projections about the future market penetration of HEVs and EVs. Boulder-based Pike Research issued a report recently that projects 4 million fleet hybrids on streets worldwide by 2015. The report entitled “Hybrid Electric Vehicles for Fleet Markets” reviews market trends

that could contribute to a 16% growth in fleet hybrid ownership in the next six years. It projected hybrid fleet sales of 830,000 in 2015, citing the need for businesses, universities, and government agencies to reduce fuel costs and emissions for this potential hybrid vehicle explosion. North America would be the most likely site for growth, experiencing annual increases of 8% from 2009 to 2015. Pike Research attributes some of this growth to a projected 10% growth in hybrid bus sales and comparable sales of hybrid trucks and commercial vehicles. The US could become the largest market for fleet hybrids by 2015.

In a separate research paper, Pike Research made the following EV-related industry predictions for 2010: (1) the cost of owning/driving an EV on a per mile basis is not likely to be cheaper than using gasoline; (2) PHEVs down the road (in 2020) may be significantly different from current PHEVs; (3) lithium-ion batteries from the first EVs may have a negligible resale value, since the current costs are likely to be high and batteries produced in future would have come down in price; and (4) the overall grid would accommodate EV charging and its effect could generally benefit the grid, with isolated exceptions.

The U.S. Energy Information Administration (EIA) released its Annual Energy Outlook 2010 which examines light-duty alternative fuel vehicle (AFV) sales over the years 2000–2035. It predicts that AFVs could reach a nearly 50% market share by 2035 (see Figure 27.2) and flex-fuel, at 20%, will continue to dominate the AFV market, but the US will see an increase in mild hybrid electric vehicles and full HEVs. In total, the predicted 2035 market share for all hybrid models is 22%.

Source: Annual Energy Outlook 2010 (<http://tonto.eia.doe.gov/oog/info/twip/twiparch/100303/twipprint.html>).

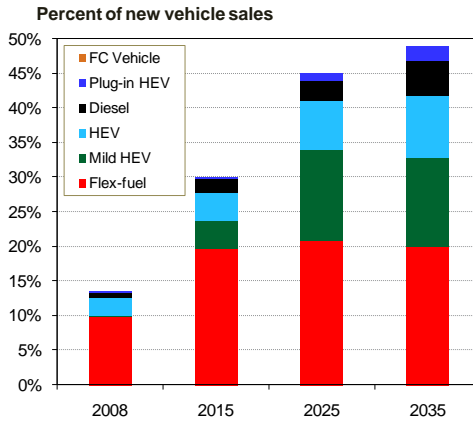


Fig. 27.2 Alternative light-duty vehicle sales projections for the U.S.

27.7

Benefits of participation

The numerous benefits of U.S. participation in various IEA Annexes include:

- Obtaining information on advanced transportation technologies not available from other sources as well as being a source for such information;
- Producing joint studies and reports for mutual benefits;
- Remaining informed about technology developments in other countries; and
- Participating in a network of well-known automotive research entities and government officials responsible for advanced transportation issues, while providing information regarding work at U.S. national laboratories.

27.8

Further information

- www.eere.energy.gov/vehiclesandfuels
DOE Vehicle Technologies Programs
- www.electricdrive.org
Electric Drive Transportation Association
- www.eia.doe.gov
Energy Information Administration

As hybrid vehicles set new records for sales and electric vehicles began to enter the market in 2009, the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) has continued to attract countries outside of the agreement to attend meetings. In 2009, IA-HEV welcomed Ireland, New Zealand, Portugal, and South Africa as observers at its ExCo meetings.

Several of the year's exciting developments in hybrid and electric vehicles occurred in countries which are not yet IA-HEV members. Most notably, the third-generation Toyota Prius HEV became Japan's best-selling car, the first mass-produced PHEV racked up a few sales in China, and Portugal broke ground on an ambitious nationwide EV recharging infrastructure pilot project. The Republic of Korea and Germany also saw significant technical and commercial developments. Finally, although it is still early days in India for most hybrid and electric vehicles, the potential of this vast market has attracted several automakers to announce their intentions for bringing HEVs and EVs to that country. Therefore, in alphabetical order, we will look more closely at developments in China, Germany, India, Japan, Portugal, and the Republic of Korea.

28.1 China

China became the world's largest automotive market in 2009 as government incentives helped national vehicle sales to jump more than 46% over the previous year to reach 13.6 million units, eclipsing the 10.4 million units sold in the recession-impacted United States. While 2010 is unlikely to see the same rate of growth, in March 2009 China's State Council released the Automotive Re-adjustment and Revitalization Plan, which has a goal of 10% annual growth in domestic auto sales over each of the three years from 2009 to 2011 as part of its development blueprint for the auto industry in China.

Among its goals for the period from 2009 to 2011, the Plan aims to build capacity to manufacture 500,000 "new energy" vehicles such as EVs and PHEVs, which are intended to make up 5% of all vehicle sales in the country, includ-

ing trucks and buses. The Chinese government has committed to supporting these vehicles both through financial incentives and pilot projects for building recharging infrastructure, while Chinese auto manufacturers also introduced PHEVs and EVs to the commercial market beginning in late 2008 and throughout 2009 (these vehicles will be described further below). Prior to these events, about 600 new energy vehicles, including 55 supercapacitor lithium-ion battery electric buses and 410 electric cars, were used in the Beijing Olympic Games in 2008.

In contrast to the new energy vehicles, HEVs have already been available in the Chinese market for a few years, with Toyota building the Prius in China since 2005 and Dongfeng Honda offering the Civic Hybrid since 2007, and some Chinese manufacturers also offering HEVs. However, hybrids have not sold well since their introduction, with only 2,100 hybrids sold nationwide in 2008, and HEV sales in 2009 continued to remain low, with Toyota selling about 50 Priuses a month and Honda closing a sale on precisely one hybrid-powered vehicle in the first four months of the year. Observers have cited the large price differential between entry-level domestic ICE cars and the Japanese hybrids—which cost more than twice as much as the ICE vehicles—as the reason for the low HEV sales rate.

China has some incentives that reward fuel efficiency, though these are not specific to hybrid and electric vehicles. In September 2008, China's government doubled the sales tax on sports cars and SUVs with engines above four liters to 40%, while smaller-engine vehicles were taxed at 10%. In January 2009, China then halved the sales tax on cars with engines of 1.6 liters and below to 5% and also offered 5 billion yuan (US\$732 million) in cash incentives to replace old vehicles, insulating the country from slumping global demand and leading to record sales levels. In December the government announced that the new vehicle sales tax would increase to 7.5% for 2010.

China's fuel economy standards could also facilitate the growth of the national market for HEVs, PHEVs, and EVs. Today an average new car in China achieves almost 36 miles per gallon (mpg), which American CAFE standards do not require for U.S. cars until 2015. By then, China will require cars to reach over 42 mpg, which besides further downsizing of internal combustion engines could be a driver to spur additional adoption of HEVs, PHEVs, and EVs. (It should be noted that Europe remains ahead of China in terms of gas mileage, with at least 120 vehicle models currently on the market that already achieve at least 5 L/100km, or 47 mpg.)

In terms of government policies that explicitly address HEVs, PHEVs, and EVs, in March 2009, China's Ministry of Science and Technology, Ministry of Finance, and National Development and Reform Commission designated thirteen model cities to promote energy saving and new energy vehicles. Taxi and public services companies in these cities are requested to add alternative fuel vehicles their fleets, and the government also offers purchase subsidies of 50,000 yuan per hybrid and 60,000 yuan (US\$8,800) per fully-electric model produced by domestic car manufacturers. The subsidies were extended to consumers as well in early 2009.

Besides these incentives, China has also committed to building the charging infrastructure to support PHEVs and EVs in the thirteen model cities. Beginning with Shanghai, Tianjin, and Xi'an, these cities are being outfitted with electric car charging stations to support a growing number of PHEVs and EVs. As an illustrative example, in December 2009, the city of Shenzhen saw the opening of two charging stations, one of which is currently the largest such station in China with a capacity for 12 cars at six express charging posts and built with an investment of over 10 million yuan. The city's infrastructure also includes 134 charging pillars distributed throughout the city districts as of the end of 2009. Shenzhen has a target of 24,000 new energy vehicles by 2012 and 100,000 such vehicles by 2015—or around six percent of all vehicles in Shenzhen. Also, French automaker Renault and Japanese automaker Nissan have established a partnership with the Chinese government to work with China's Ministry of Industry and Information Technology and the Wuhan municipal government to build a pilot electric-car program in that city.

On the supply side, Chinese automakers have begun to mass-produce the EVs and PHEVs that will benefit from the subsidies and charging infrastructure, although initial sales of these constitute only an infinitesimal fraction of the market to date. Most notably, on December 15, 2008, Chinese automaker BYD Auto launched domestic fleet sales of its F3DM sedan, which is the world's first mass-produced PHEV. (BYD notably attracted a significant investment from Berkshire Hathaway, run by American investor Warren Buffett, in September 2008.) During 2009, the F3DM PHEV sold several hundred cars, falling short of BYD's original target of 3,000 to 4,000 PHEV sales. In contrast, the company's internal combustion engine-driven F3 sedan was the best-selling car in China for the first eleven months of the year, enabling the company to reach its 2009 target of 400,000 vehicles sold by November. BYD has also announced its first battery electric car, the e6, the world's first 5-seater EV that can run 400 kilometers on a full charge.

In addition to BYD, all the rest of China's major state-owned and joint-venture automotive companies have announced plans to launch electric vehicle models. Most prominently, SAIC Motor Corp will release a Roewe 750 sedan HEV in 2010 and a Roewe 550 PHEV and a fully-electric car in 2012. Automaker Chery expects to offer its S18 electric vehicle for initial sales in June 2010. Finally, Geely Automobile, China's largest privately owned car firm, announced that it would release its EK-1 electric vehicle at the end of 2009, though this schedule appears to have slipped.

28.2

Germany

Small lightweight electric vehicles have been popular in some niches in Germany for many years, but 2009 saw EVs make further strides toward becoming mainstream in both policy and the commercial arena. In August, the German Federal Government finalized and adopted the *National Development Plan for Electromobility*. The Plan lays out a vision with milestones for the future of mobility in Germany and identifies the specific goal of deploying one million electric vehicles by the year 2020. According to data from manufacturer Audi, fewer than 1500 EVs are registered in Germany as of 2009, or 0.035% of all registered vehicles. The country aims to increase annual electric vehicle production from less than 2,000 units currently to one million units by 2020 and 5 million units by 2030. To reach this goal, Germany will spend €500 million through 2012 to fund transportation research that will focus on improving battery technology and to build a network of charging stations across the country.

As of this writing, Germany has not decided whether it will offer subsidies to electric vehicle consumers. The government estimates, however, that subsidizing as much as one-third of the cost of a vehicle's battery should allow for competitiveness with gasoline-powered vehicle counterparts. How the subsidy would be financed remains to be decided, but likely sources include general tax revenue or the country's relatively high gasoline tax.

German automakers advanced new hybrid and electric technologies during 2009. In the summer, the mild hybrid sedan Mercedes-Benz S400 Hybrid entered into production, becoming the first hybrid in the world to use lithium-ion batteries rather than the nickel-metal hydride (NiMH) used in other widespread hybrid models. Later in the year, Mercedes-Benz also announced the full hybrid 2010 Mercedes ML 450 Hybrid, which has a liquid-cooled NiMH battery pack and a hybrid powertrain which uses a pair of electrical motors and several gears to drive completely electrically at low speeds and to provide electrical assist

to the gasoline engine at highway speeds (a two-mode hybrid). The automaker's Smart Fortwo electric drive vehicle has been in production since November 2009—a follow-up to the smart EVs that have avoided congestion charges in London since 2007—and it has also announced that it would introduce an EV, the Mercedes-Benz A-Class E-CELL, in October 2010.

In May 2009, Daimler AG, parent company of Mercedes-Benz, spent tens of millions of dollars to purchase a 10% stake in U.S.-based EV manufacturer Tesla Motors. Tesla has agreed to supply battery packs and electric powertrain for the Smart EV, and Daimler will offer auto manufacturing and design expertise in the arrangement. Competing German automaker BMW announced in March 2009 that it was working on an eco-friendly machine called the Megacity Vehicle. This is second specific car to come out of BMW's "i project" after the all-electric MINI E that is currently being tested by 500 customers in California, New Jersey, and New York in the U.S. Finally, Volkswagen VW expected to make only 20 Golf twinDRIVE plug-in hybrids during 2009, and in July CEO Martin Winterkorn stated that his company would not introduce its first electric vehicle until 2013.

28.3 India

With its vast and growing middle class, India presents an attractive market for all types of vehicles. Electric vehicles are not new to India, with the REVA Electric Car Company putting an evolving series of EVs into production since 2001. However, the major obstacles to hybrid and electric vehicles gaining traction in India are the cost of both types of vehicles and the lack of a charging infrastructure for EVs. A battery-powered vehicle can cost double the sticker price of a standard vehicle, and the electrical system is not reliable in many parts of the country, beyond the fact that charging stations are few and far between. Currently there are no announced plans to build this necessary infrastructure either at the national or local level.

Subsidies are available, with the high cost of EVs mitigated slightly through the national government exempting them from excise taxes. Also, the Delhi local government offers a subsidy of 15% on EVs as well as an exemption from road tax and value-added tax of 12.5%.

In order to bring down the cost of buying its car, REVA has unbundled the car and the battery so that a buyer purchases only the car and leases the battery from the company. This saves the buyer 60,000 rupees, while REVA books the

depreciation on the battery. REVA has realized sales of its EVs evenly split between 1,700 in India and 1,700 cars sold in 23 foreign countries since 2001. This total includes the original lead-acid battery-powered REVA-i introduced in January 2008 and the lithium-ion battery-powered REVA L-ion model launched in January 2009.

Despite the lack of charging infrastructure and any strategy to build it, during 2009 additional automakers announced plans to bring new competition for EVs and to introduce hybrid drive vehicles to the Indian market. General Motors (GM) has partnered with REVA to create what it intends to be an “affordable” electric version of GM’s popular Spark hatchback, which in India costs a quarter of a million rupees (£3,000). Hyundai will bring its EV, the i10 Electric, to the country in 2010, though the company anticipates low sales due to the lack of recharging infrastructure.

In comparison to EVs, hybrid drive vehicles are subject to an excise duty of 14%. Despite this, Toyota has said that it plans to begin sales of its Prius HEV during 2010. Also, in December 2009 India’s Tata Group announced plans to produce a hybrid version of its cheapest vehicle, the Nano, in its home market. The company has also announced that it will be bringing out a few hybrid buses in March 2010 for demonstration purposes, delayed from a rollout originally planned for 2009.

As noted in last year’s IA-HEV report, electric two-wheelers have been on the Indian market for a few years. However, after a 44% increase from 2007 to 2008, sales of these vehicles by the two manufacturers Electrotherm India Ltd. and TVS Motor Co. dropped significantly from 22,000 in 2008 to 12,000 electric two-wheelers sold in 2009. Reasons cited by automotive consultants included concerns about cost and battery replacement.

28.4 Japan

The biggest news on the Japanese auto market for 2009 was that new-generation HEVs achieved unprecedented popularity. Automakers also announced the imminent commercial production of PHEVs. Finally, though Japan has not announced specific plans for installing charging infrastructure at a large scale, the country which currently manufactures about half of the world’s lithium-ion battery supply remains committed to research and development of advanced automotive batteries.

Policy measures introduced as a stimulus to help tide Japan's automakers over through the global economic slump have led to a surge in HEV sales. In April 2009, Japan introduced an incentive program that included vouchers worth up to US\$4,500 for trading in old cars for more fuel-efficient vehicles and made HEVs immune from the tax of about US\$1,500 normally levied on new car purchases. The tax-free hybrid policy move occurred only two months after Honda released a second-generation version of its Insight hybrid. The tax break helped the Insight to rack up April 2009 sales of 10,481 units to rank as the best-selling car in Japan for that month, marking the first time that a hybrid vehicle has even appeared on a best-sellers list anywhere, let alone ranking as number one for the month. However, Toyota released its third-generation (Gen 3) Prius hybrid on May 18th, and though the HEV was on the market for less than half of the month, the Prius then posted sales of 10,915 units to become the best-selling car in Japan for May 2009—and it would hold the top spot for the rest of the year. In fact, HEVs accounted for 9.7% of new-auto sales in unit terms in Japan in November 2009, up seven percentage points on the year.

Japanese automakers also announced plans to introduce EVs and PHEVs to the commercial market over the next two years. In late July, Nissan Motor announced the Leaf, which it claims will become the first affordable, mass-market electric vehicle, with retail sales expected to begin in fall 2010 (figure 28.1). At the Tokyo Motor Show in October, Toyota displayed the Prius Plug-In Hybrid, a PHEV based on the Gen 3 Prius with Li-ion batteries substituting for the NiMH batteries used in the HEV. The company announced that it would lease 500 of the PHEVs to fleets in Japan, the U.S., and Europe beginning in late December 2009, and it is targeting retail sales to begin in late 2011.



Fig. 28.1 The Nissan Leaf, open and on display. (Photo: M. van Walwijk.)

Though no large-scale plan to build charging infrastructure exists, in August 2009 the Japanese government awarded funding for a pilot project for the world's first electric taxis with switchable batteries to the Israeli-U.S. company Better Place partnering with Tokyo's largest taxi company Nihon Kotsu. Japanese taxis represent a mere two percent of all passenger vehicles on the road in Japan, yet they emit approximately 20 percent of all carbon dioxide (CO₂) from vehicles due to their average annual mileage.

Finally, as reported last year, Japan has dedicated research funds towards improving the performance of lithium-ion battery technology for PHEVs and EVs as one of the priorities of the Ministry of Economy, Trade, and Industry's Cool Earth 50 Program announced in May 2007. In addition, the New Energy and Industrial Development Organization (NEDO) continues its Li-ion and Excellent Advanced Batteries Development (Li-EAD) project, which runs through 2011 and which has targets of achieving high energy density of 100 to 200 Wh/kg and high power density of 2,000 to 2,500 W/kg. In the 2009 fiscal year, NEDO launched a new project, the R&D Initiative for Scientific Innovation on New Generation Batteries (RISING), which is funded at ¥3 billion/year (approximately US\$33 million/year) through 2015 and has an even more ambitious target of 500 Wh/kg energy density.

28.5 Portugal

Portugal is pursuing an integrated strategy to make EVs a viable transportation option in the country's major cities by the end of 2011. Portugal's plan arises from the fact that it has been forced to import most of its energy because it has no domestic coal, natural gas, or oil resources. However, as of 2009 Portugal has come to produce over a third of its energy from renewable sources such as hydro and wind power, and as a result the nation is interested in converting its transportation system entirely to electricity. Portugal currently has about 2,500 HEVs on the road, but the focus of national policy has switched to EVs.

Portugal's electric mobility program is known as MOBI.E (Mobilidade Eléctrica). The initial phase of MOBI.E includes both building a nationwide recharging infrastructure and growing the domestic market for EVs, which will begin sales in Portugal in 2011. Though the initial phase is publicly funded, a goal of this program is that private business development based on renewable energy sources will grow the network further.

To launch the infrastructure component, Prime Minister Jose Socrates unveiled plans in June 2009 for a nationwide pilot network of 1,350 recharging stations for EVs spread across 21 cities. The first station in the MOBI.E network opened in Lisbon on July 23, with about 100 more slated to be added by the end of 2009. The MOBI.E network is planned to reach a total of 320 charging stations in 2010 and ultimately 1,350 stations in 2011. Customers are expected to be offered charging options that would include a cheaper six- to eight-hour recharge, as well as an express recharge lasting less than 30 minutes.

Beyond establishing the charging station network, Portugal is also planning to generate consumer demand for EVs through several means. To encourage sales, it is offering purchasers of the first 5,000 EVs to be sold in the country both a €5,000 direct subsidy on the purchase of an EV as well as an additional €1,500 subsidy from a scrappage program for older vehicles. Purchasers of EVs will also be exempt from purchase and road taxes, with EV priority lanes and parking spaces as additional incentives. The Portuguese government itself will commit to choosing EVs as 20% of its annual fleet renewal purchases as well as buying 20 EVs for marketing purposes.

Finally, electric vehicles will become available to supply this market from 2011 through the result of a public-private partnership between Portugal and automaker Renault-Nissan Alliance announced in 2008. In July 2009, Renault-Nissan built upon its commitment to Portugal by announcing that it would build a new €250 million (US\$355 million) plant in the city of Aveiro to produce 60,000 lithium-ion batteries a year for electric cars.

The government estimates that Portugal could have 180,000 EVs on the roads by 2020, with 25,000 recharging stations in its network. Portugal's major electricity operator and business group EDP (Energias de Portugal) estimates that the recharging market could be worth up to €2 billion (US\$2.8 billion) in 2020.

28.6

Republic of Korea

During 2009, Korea saw the commercial release of its first domestically manufactured hybrids. In October, the Ministry of Knowledge Economy (MKE) then announced Korea's intentions to build EVs as well, driven by environmental and global competitive pressures. The national government intends for Korea to capture 10% of the global electric vehicle market by 2015 and replace more than 10% of small vehicles (up to 1.6-L engine capacity) with electric cars by 2020. As a result, the government also announced initial steps towards build-

ing charging infrastructure to support EVs expected to enter the Korean market by the end of 2011. Additionally, researchers at the Korea Advanced Institute of Science and Technology (KAIST) demonstrated a novel electrical mobility scheme that would enable cars to pick up electricity from a cable embedded underneath the road.

Automakers Hyundai and its affiliate Kia both began mass-production of HEVs that they had announced back in 2007. Hyundai introduced the Elantra LPI (Liquid Petroleum Injection) hybrid to the Korean market (where the car is known as the Avante LPI hybrid) in July 2009 at the Seoul Motor Show. This car is the world's first liquefied petroleum injection engine-hybrid and the first car to use a lithium-ion polymer battery for propulsion. Hyundai's mild hybrid design incorporating a 1.6-liter engine and 15kW electric motor, incorporated with an Atkinson cycle and 12:1 (15% increased) compression ratio, delivers a better than 40% fuel economy improvement over the conventional 1.6-liter Elantra.

Hyundai-affiliated automaker Kia also introduced the Forte LPI Hybrid to the South Korean market in as that company's first foray into commercial HEVs. With many features of full parallel hybrids now on the market, including continuously variable transmission (CVT), idle-off, regenerative braking, and "Eco-Drive" optimization with driver instruction, the Forte will boast impressive composite fuel efficiency of 5.6 L/100km (42 mpg) on the Japanese cycle, as well as SULEV (Super Low-Emitting Vehicle) classification by U.S. EPA's metric. Though Kia announced in 2007 that it would test a hybrid version of its compact Rio sedan, that car has not reached the market.

In October 2009, MKE officials unveiled a list of steps to help Korea enter the EV market through building charging infrastructure, supporting research in the source technologies involved in EVs, and offering purchase incentives for fleets and individual customers. First, the government plans to install 50 charging stations in an as yet unspecified city where the electric car project will be tested from 2011 to 2013. In 2014, 150 charging stations will be built in the area, for a total of 300 facilities in areas designated for EV tests.

On the commercial side, Hyundai and the Korea Electric Power Corporation (KEPCO) signed a memorandum of understanding on developing electric vehicles and recharging mechanisms in late October 2009. The two companies will collaborate in developing electric vehicles and the charging mechanisms, as well as developing and standardizing recharging interfaces, while also commercializing the electric vehicles. KEPCO unveiled its new charging station in January 2010.

Hyundai-Kia Automotive Group's electric car plans aim to supply electric vehicles in limited volumes in August 2010 and to begin commercial production of such vehicles the following year.

Finally, on the research side, the Korean government already announced plans to invest about 400 billion won (US\$349 million) by 2014 to develop high-performance batteries and other related technology. Korean researchers have also demonstrated an intriguing electric transport concept that could help alleviate the range anxiety associated with electric vehicles. In May 2009, researchers at the Korea Advanced Institute of Science and Technology (KAIST) demonstrated a transport system in which electric vehicles are charged inductively from electrical cables installed underneath the surface of the road. According to KAIST, this On Line Electric Vehicle (OLEV) system transfers power from the road to receiving units on the cars at 60 percent efficiency through 12 cm of air. Test vehicles followed the track in a convoy formation to minimize air resistance and therefore improve efficiency, and in July a bus was also demonstrated using the OLEV system. KAIST has set up a company to prepare OLEV for commercial production and entry into the market.



Outlook for hybrid and electric vehicles – 2010

Hybrid and electric vehicles are in the spotlight today. They are prominently presented at car shows, they receive a lot of media attention, they are at the focus of many governmental programmes, and the general public is increasingly interested in these kinds of vehicles. Are hybrid and electric vehicles on the verge of a breakthrough in the market? This chapter presents the views of hybrid and electric vehicle experts (IA-HEV, see box 29.1) collaborating under the framework of the International Energy Agency (IEA).

In early 2010 there is still a lot of uncertainty about the economic situation in the world. There are signs of recovery from the crisis, but on the other hand in many countries unemployment is still increasing. This situation also affects the automotive industry. As shown in figure 13.1 in Chapter 13, “Strategies out of the automotive crisis,” vehicle registrations have fallen in many of the IA-HEV member countries during 2008 and 2009. This decline in registrations reflects a drop in sales, and recovery of the market is still fragile in many areas.

The increasing interest in electric propulsion for road vehicles suggests that plug-in hybrids and electric vehicles may provide an opportunity for the automotive industry to get out of the crisis. However, because the market for electric vehicles is in its infancy and budgets for auto makers to develop such vehicles are limited, there is much uncertainty about how this market will develop. Predictions vary widely for future electric vehicle sales, because the growth of total vehicle sales remains unclear, as the economies of some countries will take longer to recover from the 2008 financial crisis than others. Moreover, what share of these future sales will come from plug-in hybrid (PHEV) and electric vehicles (EVs) is also uncertain.

Many factors influence the uptake of hybrid and electric vehicles in the market. Because of all these uncertainties, this year the IA-HEV outlook for hybrid and electric vehicles does not give numerical estimates for market shares or vehicle numbers, but instead it presents the factors that are important and how they influence the market.

Box 29.1 - IA-HEV

IEA IMPLEMENTING AGREEMENT FOR CO-OPERATION ON HYBRID AND ELECTRIC VEHICLE TECHNOLOGIES AND PROGRAMMES

The current fourteen IA-HEV member countries are Austria, Belgium, Canada, Denmark, Finland, France, Italy, the Netherlands, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. The Executive Committee of the Agreement consists of people working for governmental bodies and research institutes, who are appointed by the governments of the IA-HEV member countries. This outlook is a synthesis of inputs from the IA-HEV Executive Committee members.

IA-HEV functions within a framework created by the International Energy Agency (IEA). Views, findings and publications of IA-HEV do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

Different countries present a broad range of circumstances and factors that may influence vehicle choice. The factors having an impact on hybrid and electric vehicle sales that are most often mentioned by IA-HEV member country delegates are presented below.

Important governmental measures with an impact on hybrid and electric vehicle development and deployment are:

▸ **Strategies for clean energy technologies.**

In the cases where a national government has a strategy for clean energy technologies in place, usually PHEVs and EVs fit into this strategy. Vehicles running in electric mode have no tailpipe emissions, and when electricity is produced using solar, hydro, or wind power, the “well-to-wheels” vehicle emissions are very low.

▸ **Funding of research and innovation in industry and research organizations.**

Supporting research and innovation helps the development of new technologies such as hybrid and electric vehicles for the market. It also contributes to national goals regarding energy efficiency, the environment, and the economy.

▸ **Regulations and legislation.**

The characteristics of products that are put on the market are strongly influenced by regulations and legislation. Hybrid and electric vehicles usually fit the rules for energy-efficient road transport with low CO₂ emissions. Harmonization of regulations between different countries and also standardization enables economies of scale and thus lowers the hurdles for market introduction of hybrid and electric vehicles.

- ▶ **Financial incentives.**

Cost is a very important factor in making purchase decisions. Therefore appropriate financial incentives such as subsidies and tax reductions can be very effective in helping a new and initially more costly technology take off in the market.

- ▶ **Deployment and demonstration projects.**

By supporting deployment and demonstration projects, governments contribute to the development of new vehicle technologies for the market.

Besides testing the technology in practical applications, such projects also help to raise awareness among the general public because people actually see new, clean vehicles on the road.

Besides governmental measures, many other factors have an impact on hybrid and electric vehicle deployment. The ones that are most often mentioned by the IA-HEV members are listed below. These factors are also important in other countries. These include:

- ▶ **Public awareness creating demand.**

When people are convinced of the advantages of a new technology, they will create a market pull. When demand for electric cars is large enough, industry will start producing such vehicles. Early adopters are ready to accept some limitations in terms of performance or price, but they can also demonstrate the possibilities of a new technology. By talking about their experiences, they have an impact on the general opinion and may contribute to increase the popularity of unconventional products such as electric vehicles.

- ▶ **Industry activity and the availability of vehicles.**

If no hybrid and electric vehicles are available, neither governmental rules and incentives nor market demand can result in the deployment of such vehicles. In IA-HEV member countries such as Canada, the Netherlands, and Spain, the availability of hybrid and electric vehicles is expected to be below demand for the coming years, therefore limiting the deployment of these kinds of vehicles in these markets.

- ▶ **Infrastructure.**

For the deployment of battery electric vehicles and plug-in hybrid electric vehicles, the presence of a public recharging infrastructure plays a role in encouraging consumers to purchase such vehicles. Even though overnight battery charging from a standard outlet would be sufficient for the initial group of electric vehicle owners and for most of their trips, the visibility of public charging points significantly reduces the range anxiety of other potential electric vehicle drivers.

- Additionally, collaboration between the different stakeholders involved could lower the hurdles for deployment of electric vehicles. And of course the overall economic situation in a country impacts the market for hybrid and electric vehicles.

The opportunity for new, clean vehicles continues to ripen. Many governmental programmes aim at improving energy efficiency and reducing CO₂ emissions from road transport. Industry currently plans to start producing plug-in and pure battery electric vehicles. Finally, interest in these types of vehicles is increasing within society. Given these conditions, the IA-HEV Executive Committee is convinced that sales of hybrid and electric vehicles will grow and that they will form a substantial share of the worldwide road vehicle fleet in the future. However, the pace at which this will happen is uncertain. Due to the limited availability of these vehicles, their market share will remain low for the next few years. What will happen after that depends on the factors that are mentioned in this chapter.

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Vehicle categories

In the “On the road” sections of the country chapters on Austria, Denmark, Finland, Italy, the Netherlands, Spain, Sweden, Switzerland, Turkey, and the UK, fleet numbers of motorized road vehicles are presented in a standardized table as much as possible. The definitions of the vehicle categories that are used in these tables are given below.

VEHICLE	DESCRIPTION
Motorized bicycle (no driver licence)	Two-wheeled motorized (internal combustion engine or electric motor) vehicle with an appearance similar to a conventional bicycle or moped.
Motorbike	Vehicle designated to travel with not more than three wheels contacting with the ground.
Passenger vehicle	Vehicle with a designated seating capacity of 10 or less, except Multipurpose passenger vehicle.
Multipurpose passenger vehicle	Vehicle with a designated seating capacity of 10 or less that is constructed either on a truck chassis or with special features for occasional off-road operation.
Bus	Vehicle with a designated seating capacity greater than 10.
Truck	Vehicle designed primarily for the transportation of property or equipment.
Industrial vehicle	Garbage truck, concrete mixer, etc., including mobile machinery like forklift trucks, wheel loaders and agricultural equipment.



Conversion factors

This chapter presents conversion factors for quantities that are relevant for hybrid and electric road vehicles, such as kilometers per hour and miles per hour for vehicle speed, and miles per gallon and litres per 100 km for fuel consumption. The International System of Units (SI - *Système International*) gives the base units for these quantities, and therefore the relevant SI units are presented first. The actual conversion factors can be found in the second section of this chapter.

BASE UNITS

Table 1 Selection of SI base units.

QUANTITY	UNIT	SYMBOL
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A

Table 2 Selection of SI prefixes.

PREFIX	SYMBOL	VALUE
Kilo	k	1 000 Thousand
Mega	M	1 000 000 Million
Giga	G	1 000 000 000 Billion

Table 3 Selection of derived units.

QUANTITY	UNIT	SYMBOL	
Energy	Joule	J	$1 \text{ J} = \text{N}\cdot\text{m}$
Force	Newton	N	$1 \text{ N} = 1 \text{ kg}\cdot\text{m}/\text{s}^2$
Power	Watt	W	$1 \text{ W} = 1 \text{ J}/\text{s}$
Pressure	bar	bar	$1 \text{ bar} = 10^5 \text{ N}/\text{m}^2$
Time	hour	h	$1 \text{ hour} = 3600 \text{ s}$
Volume	litre	L	$1 \text{ litre} = 0.001 \text{ m}^3$

SELECTED CONVERSION FACTORS

Table 4 Mass, dimensions, and speed.

QUANTITY	UNIT	SYMBOL	CONVERSION	REVERSE CONVERSION
Mass	pound (US)	lb	1 lb = 0.45359 kg	1 kg = 2.2046 lb
Length	inch	in	1 inch = 0.0254 m	1 m = 39.3701 inch
Length	foot	ft	1 ft = 0.3048 m	1 m = 3.2808 ft
Length	mile	mile	1 mile = 1.60934 km	1 km = 0.62137 mile
Volume	barrel (petroleum)	bbl	1 bbl = 159 l	--
Volume	gallon	gal (UK)	1 gal (UK) = 4.54609 L	1 L = 0.21997 gal (UK)
Volume	gallon	gal (US)	1 gal (US) = 3.78541 L	1 L = 0.26417 gal (US)
Speed	miles per hour	mph	1 mph = 1.609 km/h	1 km/h = 0.621 mph

Table 5 Energy and power.

QUANTITY	UNIT	SYMBOL	CONVERSION	REVERSE CONVERSION
Energy	British thermal unit	Btu	1 Btu = 1055.06 J	1 J = 0.0009478 Btu
Energy	kilowatt-hour	kWh	1 kWh = $3.6 \cdot 10^6$ J	1 J = $277.8 \cdot 10^{-6}$ kWh
Power	horse power	hp	1 hp = 745.70 W	1 W = 0.001341 hp
Pressure	pound-force per square inch	psi	1 psi = 0.0689 bar	1 bar = 14.5037 psi
Torque	pound-foot	lb-ft	1 lb-ft = 1.35582 Nm	1 Nm = 0.73756 lb-ft

Table 6 Fuel consumption.

x mile/gal (UK)	\Leftrightarrow	$282.48/x$ l/100 km
x l/100 km	\Leftrightarrow	$282.48/x$ mile/gal (UK)
x mile/gal (US)	\Leftrightarrow	$235.21/x$ l/100 km
x l/100 km	\Leftrightarrow	$235.21/x$ mile/gal (US)

Table 7 Comparison of energy carriers.

ENERGY CARRIER	UNIT	ENERGY CONTENT
Battery	Stored energy, expressed in kWh	1 kWh = 3.6 MJ
Diesel fuel	Calorific value, based on volume	34.9 - 36.1 MJ/l
Gasoline (petrol)	Calorific value, based on volume	30.7 - 33.7 MJ/l

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This glossary of terms related to hybrid and electric vehicles also includes information on the “competition” to the electric drive, because plug-in hybrid electric vehicles illustrate the many ways that electric and conventional drives may be combined, including multiple fuel possibilities for the conventional drive.

Advanced Technology Partial Zero Emission Vehicle (AT-PZEV)

As defined by the California Air Resources Board in a regulatory incentive system, a vehicle that uses electric drive components that should ultimately help industry introduce ZEVs such as EVs or FCVs.

All-electric range (AER)

This is a term used by CARB which has legal meaning related to a requirement that a PHEV be able to operate electrically until a specified set of conditions is no longer met. Within CARB regulations as of 2007, a credit system within their LEV regulations existed for PHEVs with 10 (16) or more miles (km) of AER.

Ampere

The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} Newton per meter of length. The ampere unit is symbolized by “A”.

Ampere-hour capacity

The quantity of electric charge measured in ampere-hours (Ah) that may be delivered by a cell or battery under specified conditions. One ampere-hour is the electric charge transferred by a steady current of one ampere for one hour. In EV applications, typical conditions involve a specific ambient temperature and a discharge time of 1 or 3 hours: in these cases the capacity is expressed as C_1 or C_3 (see also “Rated capacity”, “Installed capacity”, “Energy capacity”).

Ampere-hour efficiency

The ratio of the output of a secondary cell or battery, measured in ampere-hours, to the input required to restore the initial state of charge, under specified conditions (also coulombic efficiency). It is not dependent on the change of voltage during charge and discharge.

Battery cell

A primary cell delivers electric current as the result of an electrochemical reaction that is not efficiently reversible, so the cell cannot be recharged efficiently. A secondary cell is an electrolytic cell for generating electric energy, in which the cell, after being discharged, may be restored to a charged condition by sending a current through it in the direction opposite to that of the discharging current.

Battery module

A group of interconnected electrochemical cells in a series and/or parallel arrangement, physically contained in an enclosure as a single unit, constituting a direct-current voltage source used to store electrical energy as chemical energy (charge) and to later convert chemical energy directly into electric energy (discharge). Electrochemical cells are electrically interconnected in an appro-

appropriate series/parallel arrangement to provide the module's required operating voltage and current levels. In common usage, the term "battery" is often also applied to a single cell. However, use of "battery cell" is recommended when discussing a single cell.

Battery pack

A completely functional system that includes battery modules, battery support systems, and battery-specific controls. It may also be a combination of one or more battery modules, possibly with an added cooling system, and very likely with an added control system. A battery pack is the final assembly used to store and discharge electrical energy in a HEV, PHEV, or EV.

Battery round-trip efficiency

The ratio of the electrical output of a secondary cell, battery module, or battery pack on discharge to the electrical input required to restore it to the initial state of charge under specified conditions.

Battery State Of Charge (SOC)

The available capacity in a battery expressed as a percentage of rated nominal capacity.

C rate

Discharge or charge current, in amperes, expressed in multiples of the rated capacity. For example, the $C_5/20$ discharge current for a battery rated at the 5-h discharge rate is derived as follows: C_5 (in Ah) divided by 20 gives the current (in A). As a cell's capacity is not the same at all discharge rates and usually increases with decreasing rate, a cell which discharges at the $C_5/20$ rate will run longer than 20 h.

Capacitance

The ratio of the charge on one of the conductors of a capacitor (there being an equal and opposite charge on the other conductor) to the potential difference between the conductors. Capacitance is symbolized by "C".

Capacitor

A device which consists essentially of two conductors (such as parallel metal plates) insulated from each other by a dielectric (an insulator that may be polarized by an applied electric field). As part of an electric circuit, a capacitor introduces the capability of storing electrical energy, blocks the flow of direct current, and permits the flow of alternating current to a degree dependent on the capacitor's capacitance and the current frequency.

Certification fuel economy or fuel consumption

An estimate of fuel economy (or the inverse, consumption) developed for official purposes by means of specified test procedures including particular driving cycles. These estimates usually result in fuel economy values that exceed what consumers actually realize in everyday use. Fuel economy and fuel consumption may for example be expressed in l/100km (liters per 100 km), km/l, or mpg (miles per gallon).

Charge / charging

The conversion of electrical energy, provided in the form of current from an external source, into chemical energy within a cell or battery. The (electrical) charge is also a basic property of elementary particles of matter.

Charge / charging factor

The factor by which the amount of electricity delivered during discharge is multiplied to determine the minimum amount required by the battery to recover its fully charged state. Normally, it is higher than 1.0 for most batteries in order to account for the losses in discharging and charging processes.

Charge rate

The current at which a battery is charged (see C rate).

Charger

An energy converter for the electrical charging of a battery consisting of galvanic secondary elements.

Charge depletion (CD)

When a rechargeable electric energy storage system (RESS) on a PHEV, EV or extended-range EV is discharged.

Charge depletion in blended mode (CDB)

When a rechargeable electric energy storage system (RESS) on a PHEV or extended-range EV is discharged, but it is not the only power source moving the vehicle forward (blended mode). A separate fuel and energy conversion system works in tandem with the RESS to provide power and energy to move the vehicle as charge of the RESS is depleted. This mode of operation allows use of a much less powerful RESS than does CDE operation.

Charge depletion all electrically (CDE)

When a rechargeable electric energy storage system (RESS) on a PHEV, EV or extended-range EV is discharged, and continuously provides the only means of moving the vehicle forward (all-electric operation).

Charging equalizer

Device that equalizes the battery state of charge of all the modules in an EV during charging. Employing this measure ensures that the voltage of all the batteries will rise equally and that the battery with the smallest capacity is not overcharged.

Coal-to-liquids (CTL)

Conversion of coal to a diesel-like fuel low in sulfur suitable for use in compression-ignition direct-injection (CIDI) ICEs. The process used for conversion is called Fischer-Tropsch chemistry.

Compression ignition (CI)

Ignition of a mixture of air and fuel in a cylinder of an ICE via heating by compression of the mixture. A name consistently used for ICEs that use this method of ignition is “diesel”.

Controller

An element that restricts the flow of electric power to or from an electric motor or battery pack (module, cell). One purpose is for controlling torque and/or power output. Another may be maintenance of battery life, and/or temperature control.

Controller, Three-phase

An electronic circuit for controlling the output frequency and power from a 3-phase inverter.

Conventional mechanical drivetrain

A mechanical system between the vehicle energy source and the road including engine, transmission, driveshaft, differential, axle shafts, final gearing and wheels. The engine is operated by internal combustion (ICE).

Conventional vehicle

A vehicle powered by a conventional mechanical drivetrain.

Current

The rate of transfer of electricity, meaning the amount of electric charge passing a point per unit time. The unit of measure is the ampere, which represents around 6.241×10^{18} electrons passing a given point each second.

Cut-off voltage

The cell or battery voltage at which the discharge is terminated. The cut-off voltage is specified by the cell manufacturer and is generally intended to limit the discharge rate.

Cycle

A sequence of a discharge followed by a charge, or alternatively a charge followed by a discharge, of a battery under specified conditions.

Cycle life

The number of cycles under specified conditions that are available from a secondary battery before it fails to meet specified criteria regarding performance.

Diesel fuel – conventional and low-sulfur

Diesel fuel is a refined petroleum product suitable for use in compression-ignition direct-injection (CIDI) engines. In recent years there has been a worldwide movement to reduce sulfur content of diesel fuel in order to improve the reliability of required emissions aftertreatment for vehicles using CIDI engines. The sulfur reduction also reduces emissions of SO_x , which in turn reduces sulfate particle matter in the atmosphere. Costs of diesel fuel have been driven up by the need to remove sulfur from a mix of crude oil that is increasing in average percent of sulfur.

Depth of Discharge (DOD)

The percentage of electricity (usually in ampere-hours) that has been discharged from a secondary cell or battery relative to its rated nominal fully charged capacity (see also “Ampere-hour efficiency”, “Voltage efficiency”, and “Watt-hour efficiency”).

Direct current motor / DC motor

An electric motor that is energized by direct current to provide torque. There are several classes of direct current motors.

Discharge

The direct conversion of the chemical energy of a cell or battery into electrical energy and withdrawal of the electrical energy into a load.

Discharge rate

The rate, usually expressed in amperes, at which electrical current is taken from a battery cell, module, or pack (see “C rate”).

Driving range

See “Range”.

E-bike / electric bicycle

With an E-bike, riding a bicycle is possible without pedaling. The motor output of an E-bike is activated and controlled by using a throttle or button. Human power and the electric motor are independent systems. This means that the throttle and pedals can be used at the same time or separately. This contrasts with a Pedelec, which requires that the throttle and pedals always be used at the same time. As a result, an E-bike is more or less used in the same way as a scooter or motorcycle rather than a bicycle. Swiss and Italian regulations define the maximum power that can be used for an E-bike. More power makes it an electric scooter.

Electric assist bike

See “E-bike”.

Electric bike

See “E-bike”.

Electric drive system

The electric equipment that serves to drive the vehicle. This includes (a) driving motor(s), final control element(s), and controllers and software (control strategy).

Electric drivetrain (including electric drive system)

The electromechanical system between the vehicle energy source and the road. It includes controllers, motors, transmission, driveshaft, differential, axle shafts, final gearing, and wheels.

Electric motorcycle

An electric vehicle usually with two wheels, designed to operate all-electrically, and capable of high speed, including ability to travel on high speed limited access highways and motorways. It is usually capable of carrying up to two passengers. Such vehicles have a relatively high power to weight ratio. In addition to greater capability on highways, these vehicles are also more capable of travel off-road on undulating terrain with steep slopes, than are electric scooters.

Electric scooter

See “E-scooter”.

Electric Vehicle (EV)

An EV is defined as “any autonomous road vehicle exclusively with an electric drive, and without any on-board electric generation capability” in this Agreement.

Electrochemical cell

The basic unit able to convert chemical energy directly into electric energy.

Energy capacity

The total number of watt-hours that can be withdrawn from a new cell or battery. The energy capacity of a given cell varies with temperature, rate, age, and cut-off voltage. This term is more common to system engineers than the battery industry, where the ampere-hour is the preferred unit and terminology.

Energy consumption

See “Fuel consumption”.

Energy density

The ratio of energy available from a cell or battery to its volume in liters (Wh/L). The mass energy density in battery and EV industry is normally called specific energy (see “Specific energy”).

Equalizing charge

An extended charge to ensure complete charging of all the cells in a battery.

Equivalent All Electric Range (EAER)

A legal term defined by CARB, in which a formula is used to translate the blended-mode charge-depleting (CDB) operations distance of a PHEV into an equivalent all-electric range.

E-scooter

Small electric sit-down or stand-up vehicles ranging from motorized kick boards to electric mini motorcycles. Differences between the two types of small electric scooters are as follows. With stand-up scooters, instead of pushing the scooter forward with one leg, the rider simply turns the throttle on the handlebar and rides electrically. A typical stand-up scooter is a little more than one meter long and weighs between 12 and 25 kg. In contrast, sit-down scooters are small electric vehicles with a seat and are used much the same way as gasoline-powered scooters. A throttle on the handlebar regulates the acceleration. Sit-down e-scooters are usually bigger and heavier than the stand-up types. The appearance and accessories vary from trendy and stylish products to more utilitarian models with large seats and a big shopping basket.

Ethanol (EtOH)

A chemical that may be used as a motor fuel, either “neat” (pure) or blended into refined petroleum products such as gasoline. When used as a fuel, it requires multiple revisions of engine controls and of materials used in the engine and emissions aftertreatment system. Generally, the higher the percentage of ethanol blended into gasoline, the more changes have to be made to the engine and exhaust system. It is possible to design a vehicle to use varying blends of gasoline and ethanol. Such vehicles are called “flexible-fuel vehicles” (FFVs). Brazil, the United States, and Sweden produce significant quantities of FFVs. The leading producers of ethanol in the world are the US, which produces this fuel from corn, and Brazil, which produces it from sugar cane. In the future, the US intends to expand production of ethanol by use of biomass other than corn. Production of vehicles capable of using ethanol costs hundreds of dollars per vehicle, in contrast to PHEVs and EVs, where the costs of conversion to electric drive are in the thousands.

Extended-range electric vehicle

Also known as a series PHEV, an extended-range electric vehicle is an “autonomous road vehicle” primarily using electric drive provided by a rechargeable electric energy storage system (RESS), but with an auxiliary on-board electrical energy generation unit and fuel supply used to extend the range of the vehicle once RESS electrical charge has been depleted.

E85, E20

Ethanol blended into gasoline is generally labelled according to the volume percentage of ethanol in the mixed fuel. Thus, E85 contains 85% ethanol by volume, while E20 contains 20% ethanol, and so forth. Generally the lowest percentage of gasoline in gasoline-ethanol blends is 15% (i.e., as found in E85). In E85 the gasoline-like hydrocarbons contribute to improved vehicle cold

starting, flame luminosity to help fire-fighters if the fuel catches fire, and also acts as a denaturant (prevents human consumption of the ethanol).

Federal test procedure (FTP)

The US Environmental Protection Agency's (EPA) federal test procedure used to measure emissions, from which an estimate of city fuel economy is also constructed. The FTP involves running a complete urban dynamometer driving schedule (UDDS), starting with a cold start, turning the engine off for ten minutes, restarting warm and running the first 505 seconds of the UDDS again. The running time for the UDDS is 1372 seconds. The running time for the FTP is 1877 seconds (ignoring the ten minutes with engine off). The average weighted speed of the FTP is 34 km/h, while the average speed for the UDDS is 31 km/h. This test is conducted at ~ 24 degrees Celsius. For purposes of developing estimates of "on-road" fuel economy, accounting for starting in cold temperatures, the US EPA has recently developed the "Cold FTP", which is conducted at approximately -6.7 degrees Celsius.

Fuel cell

An electrochemical cell that converts chemical energy directly into electric energy, as the result of an electrochemical reaction between reactants continuously supplied, while the reaction products are continuously removed. The most common reactants are hydrogen (fuel) and oxygen (also from the air).

Fuel cell vehicle (FCV)

A vehicle with an electric powertrain that uses the fuel cell as a source of the electricity to provide electric drive. FCVs may also include an electric storage system (ESS) and be HEVs or PHEVs. However, an ESS is not technically necessary in a FCV.

Fuel consumption

The energy consumed by a vehicle per unit distance (in km) and, sometimes, also per unit weight (in tons). It may be expressed as kWh/km and also kWh/(ton-km). For EVs and PHEVs the electrical energy counted, expressed in AC kWh, is from the plug (charger input). Usually developed from tests of vehicles when driven over a "driving cycle" (a speed versus time requirement), with a specified passenger and/or luggage load. Standardized methods of estimating fuel consumption of PHEVs have not yet been developed.

Fuel economy

Also referred to as fuel efficiency. For an EV it is the distance (in km) travelled per unit energy from the plug, in kWh. For an internal combustion engine vehicle it represents the distance travelled per liter of fuel. It is the reciprocal of the energy per unit distance (the reciprocal of fuel consumption). Usually developed from tests of vehicles when driven over a "driving cycle" (a speed versus time requirement), with a specified passenger and/or luggage load. Standardized methods of estimating fuel economy of PHEVs have not yet been developed.

Full HEV

A full HEV has the ability to operate all-electrically, generally at low average speeds. At high steady speeds such a HEV uses only the engine and mechanical drivetrain, with no electric assist. At intermediate average speeds with intermittent loads, both electric and mechanical drives frequently operate together. A PHEV can be developed based on a full HEV powertrain.

Gasoline – reformulated (RFG) and conventional

Gasoline is a refined petroleum product burned in spark ignition (SI) internal combustion engines. It comes in many types and grades, with formulations varying for purposes of octane rating and to influence evaporative and tailpipe emissions. In the US two very broad categories are “reformulated”, which is a minority grade used in areas that need low emissions to improve air quality. The majority of gasoline in the US is “conventional”.

Gas-to-hydrogen (GH₂)

Conversion of (natural) gas to a synthesis gas (or syngas) containing hydrogen (H₂) and carbon monoxide (CO), followed by clean-up of the gas to produce pure H₂. The common process used is steam reforming.

Hourly battery rate

The discharge rate of a cell or battery expressed in terms of the length of time during which a fully charged cell or battery can be discharged at a specific current before reaching a specified cut-off voltage. The hour-rate = C/i , where C is the rated capacity and i is the specified discharge current. For EVs, a 3-hour or a 1-hour discharge is preferred.

Hybrid road vehicle

A hybrid road vehicle is one in which propulsion energy during specified operational missions is available from two or more kinds or types of energy stores, sources, or converters. At least one store or converter must be on-board.

Hybrid electric vehicle (HEV)

The 1990s definition of IA-HEV Annex I was “a hybrid electric vehicle (HEV) is a hybrid road vehicle in which at least one of the energy stores, sources or converters delivers electric energy”. The International Society of Automotive Engineers (SAE) defines a hybrid as “a vehicle with two or more energy storage systems, both of which provide propulsion power, either together or independently”. Normally, the energy converters in a HEV are a battery pack, an electric machine or machines, and internal combustion engine. However, fuel cells may be used instead of an internal combustion engine. In a hybrid, only one fuel ultimately provides motive power. One final definition is from the UN, which defines an HEV as “a vehicle that, for the purpose of mechanical propulsion, draws energy from both of the following on-vehicle sources of stored energy/power: a consumable fuel, and an electrical energy/power storage device (e.g.: battery, capacitor, flywheel/generator, etc.).”

Hybrid electric vehicle (HEV) – Parallel configuration

A parallel hybrid is a HEV in which both an electric machine and engine can provide final propulsion power together or independently.

Hybrid electric vehicle (HEV) – Series configuration

A series hybrid is a HEV in which only the electric machine can provide final propulsion power.

Hybrid vehicle

UN definition: A vehicle with at least two different energy converters and two different energy storage systems (on vehicle) for the purpose of vehicle propulsion.

Induction motor

An alternating-current motor in which the primary winding on one member (usually the stator)

is connected to the power source, and the secondary winding on the other member (usually the rotor), carries only current induced by the magnetic field of the primary. The magnetic fields react against each other to produce a torque. One of the simplest, reliable, and cheapest motors made.

Inductive charging

The use of magnetic coupling devices instead of standard plugs in charging stations. This technology was actively pursued for EVs in the 1990s in the US.

Infrastructure

Every part of the system except the vehicle itself that is necessary for its use. For PHEVs or EVs the infrastructure includes available fuel (electricity), power plants, transmission lines, distribution lines, access to parts, maintenance and service facilities, and an acceptable trade-in and resale market.

Installed capacity

The total number of ampere-hours that can be withdrawn from a new battery cell, module, or pack when discharged to the system-specified cut-off voltage at the HEV, PHEV, or EV design rate and temperature (i.e., discharge at the specified maximum DOD).

Internal combustion engine (ICE)

The historically most common means of converting fuel energy to mechanical power in conventional road vehicles. Air and fuel are compressed in cylinders and ignited intermittently. The resulting expansion of hot gases in the cylinders creates a reciprocal motion that is transferred to wheels via a driveshaft or shafts.

Kilowatt-hour (kWh)

One thousand (1000) watt-hours of energy, which also equals 1.341 horsepower-hours (or 1.35962 CVh).

Lithium ion (Li-ion)

The term “lithium-ion” refers to a family of battery chemistries. Li-ion chemistries commonly used today have come down significantly in cost and have increased gravimetric and volumetric energy density over the last 15 years, with progress accelerating in the last few years. Li-ion has nearly completely supplanted nickel-metal hydride (NiMH) batteries in consumer electronics. NiMH remains the chemistry of choice in HEVs, but is anticipated that it will be replaced by emerging Li-ion chemistries. Because it has already attained significantly higher gravimetric and volumetric energy densities than NiMH in consumer cells and is improving further with new chemistries, Li-ion is seen as the coming enabling technology for PHEVs, in addition to being a solid competitor to replace NiMH in HEVs.

Low emissions vehicle (LEV)

A vehicle with tailpipe emissions below a specified level, as determined by regulations and test procedures specified by CARB.

Maintenance-free battery

A secondary battery, which during its service needs no maintenance, provided specified operating conditions are fulfilled.

Mild HEV

A HEV that has a less powerful electric machine and battery pack than a full hybrid. According to the Netherlands Organisation for Applied Scientific Research (TNO), a mild HEV cannot operate all-electrically. Electric assist always works together with the internal combustion engine.

Motor, electric machine, generator

A motor is a label for an electric machine that most frequently converts electric energy into mechanical energy by utilising forces produced by magnetic fields on current-carrying conductors. Most electric machines can operate either as a motor or generator. When operating as a generator, the electric machine converts mechanical energy into electrical energy. In HEVs, PHEVs, and EVs, electric machines operate both in motoring and generating modes.

Neighborhood Electric Vehicle (NEV)

A vehicle defined in US Federal Regulations. NEVs are low-speed electric vehicles that have a maximum speed of 25 mph and can only be driven on roads with a maximum speed of 35 mph. Such vehicles have a much less stringent set of safety requirements than do other US light-duty vehicles.

Nickel cadmium (NiCd)

Nickel cadmium was a common battery chemistry used in many EVs of the 1990s as well as in consumer electronics. It is no longer in common use because of restrictions put on hazardous substances, which include cadmium.

Nickel-metal hydride (NiMH)

Nickel metal hydride was a common commercial battery chemistry in the 1990s for consumer electronics. In the late 1990s it became the battery of choice for HEVs. It has higher gravimetric and volumetric energy density than nickel cadmium (NiCd), but lower than those for lithium-ion chemistries.

Nitrogen oxides (NO_x)

NO₂ and/or NO – “criteria pollutants” whose emissions from the tailpipe and concentration in the air is regulated. NO_x reacts in sunlight and high temperatures with reactive organic gases (ROG) to form ozone, a regulated pollutant of general concern. NO_x also reacts with ammonia to form the particulate matter (PM) ammonium nitrate. Total PM, by mass per unit volume of air, is also regulated.

Nominal capacity

The total number of ampere-hours that can be withdrawn from a new cell or battery for a specified set of operating conditions including discharge rate (for EV, usually C₁ or C₃), temperature, initial state of charge, age, and cut-off voltage.

Nominal voltage

The characteristic operating voltage or rated voltage of a cell, battery, or connecting device.

Normal charging

Also called slow or standard charge. The most common type and location for charging of a PHEV or EV battery pack necessary to attain the state of maximum charge of electric energy.

On-road (or “in use”) fuel economy (or consumption)

Official certification test fuel economy (consumption) values typically exceed (underestimate) actual values experienced by vehicle drivers. To varying degrees, nations that have been involved with the IA have conducted research to determine actual “on-road” fuel economy (consumption). The US has adopted a method to estimate, and publish for consumers, estimates of on-road fuel consumption that use five different driving cycles. The official US certification fuel economy rating system uses only two different driving cycles. Europe has conducted studies on this topic, but has not yet developed an “on-road” rating system for consumers.

Opportunity charging

The use of a charger during periods of EV or PHEV inactivity to increase the charge of a partially discharged battery pack.

Overcharge

The forcing of current through a cell after all the active material has been converted to the charged state. In other words, charging is continued after 100% state of charge (SOC) is achieved.

Parallel battery pack

Term used to describe the interconnection of battery cells and/or modules in which all the like terminals are connected together.

Parallel HEV

A HEV in which the engine can provide mechanical power and the battery electrical power simultaneously to drive the wheels.

Partial zero emission vehicle (PZEV)

A category defined in the regulatory structure of the California Air Resources Board (CARB). From CARB’s perspective, the vehicle has some of the desirable emissions characteristics of a ZEV, but not all.

Particulate matter (PM)

A mix of chemicals in particulate form, emerging from the tailpipe of a vehicle or within air. Both tailpipe PM and PM concentrations in ambient air are regulated in most advanced nations. PM emissions historically have consistently been far higher from diesel (compression ignition) engines than from petrol (spark ignition) engines.

Peak power (in kW)

Peak power attainable from a battery, electric machine, engine, or other part in the drive system used to accelerate a vehicle. For a battery this is based on short current pulse (per 10 seconds or less) at no less than a specified voltage at a given depth of discharge (DOD). For an electric machine, the limiting factor is heating of insulation of copper windings. Peak power of an engine is generally related to mechanical capabilities of metal parts at peak allowable revolutions per minute, also affected by heat. Generally, continuous power ratings are well below peak power ratings.

Pedelec

Pedelec stands for “pedal electric cycle”. While pedaling the rider gets additional power from the electric drive system. The control of the motor output of a pedelec is linked to the rider’s pedaling contribution by means of a movement or power sensor. In other words, the electric motor is activated as soon as the rider starts to pedal, and it is deactivated as soon as the rider stops pedaling.

Plug-in hybrid electric vehicle (PHEV)

A HEV with a battery pack with a relatively large amount of kWh of storage capability, with an ability to charge the battery by plugging a vehicle cable into the electricity grid. This allows more than two fuels to be used to provide the propulsion energy.

PHEVxk

A plug-in hybrid electric vehicle with “x” miles or kilometers of estimated charge depletion all electrically (CDE) range (also known as all-electric range, or AER). In this glossary, we suggest adding a small letter “k” to denote when the “x” values are in kilometres, or an “m” to denote when those values are in miles.

Power

The rate at which energy is released. For an EV, it determines acceleration capability. Power is generally measured in kilowatts.

Power density (volumetric)

The ratio of the power available from a battery to its volume in liters (W/L). The mass power density in battery and EV industry is normally called specific power (see “Specific power”) or gravimetric power density.

Range

The maximum distance travelled by a vehicle, under specified conditions, before the “fuel tanks” need to be recharged. For a pure EV, it is the maximum distance travelled by a vehicle under specified conditions before the batteries need to be recharged. For a PHEV it will be the maximum distance achievable after emptying both the battery pack and fuel tank. For a conventional vehicle or HEV it will be the maximum distance achievable after emptying the fuel tank.

Rated capacity

The battery cell manufacturer’s estimate of the total number of ampere-hours that can be withdrawn from a new cell for a specified discharge rate (for EV cells usually C_1 or C_3), temperature, and cut-off voltage.

Reactive organic gases (ROG)

These are emissions from the tailpipe as well as evaporation of fuel from vehicles. Consistent with the name, they are problematic because they react in air with other gases (NO_x in particular) to form ambient air pollution, primarily ozone. Generally, both the emissions of ROG from vehicles and ozone in the air are regulated.

Rechargeable electric energy storage system (RESS)

Battery packs, flywheels, and ultracapacitors are examples of systems that could be repeatedly charged from the grid, with the charge later discharged in order to power an electric machine to move a vehicle.

Regenerative braking

A means of recharging the battery by using energy produced by braking the EV. With normal friction brakes, a certain amount of energy is lost in the form of heat created by friction from braking. With regenerative braking, the electric machines act as generators. They reduce the braking energy lost by returning it to the battery, resulting in improved range.

Self-discharge

The loss of useful electricity previously stored in a battery cell due to internal chemical action (local action).

Series HEV

A series hybrid is a HEV in which only the electric machine can provide final propulsion power.

Smart charging

The use of computerized charging devices that constantly monitor the battery so that charging is at the optimum rate and the battery life is prolonged.

Spark ignition (SI)

Ignition of a mixture of air and fuel in the cylinders of an internal combustion engine via an electric spark.

Specific energy, or gravimetric energy density (of a battery)

The energy density of a battery expressed in watt-hours per kilogram.

Specific power, or gravimetric power density (of a battery)

The rate at which a battery can dispense power measured in watts per kilogram.

Start-stop

The lowest level of electrification of a powertrain, involving a slightly larger (higher kW) electric machine and battery than for starting alone, providing an ability to stop the engine when the vehicle is stopped and save fuel that would have been consumed at engine idle.

Start-stop + regeneration (and electric launch)

This technology package can also be called “minimal” or “soft” hybridization. According to the International Society of Automotive Engineers (SAE), a hybrid must provide propulsion power. If a start-stop system includes regeneration and electric launch, it is a hybrid, according to the SAE definition. If it does not, it is not a hybrid.

State of charge (SOC)

See “Battery state of charge”.

Sulfur oxides (SO_x)

Sulfur oxides are a “criteria pollutant” whose concentration in the air is regulated. Sulfur content of fuel is usually regulated, both in order to reduce conversion of fuel sulfur to SO_x from the tailpipe, and also to increase the reliability and functionality of vehicle emissions control systems. SO_x mass per unit volume concentrations are regulated. SO_x also reacts with ammonia to form the particulate matter (PM) ammonium sulfate. Total PM, by mass per unit volume of air, is also regulated.

Super ultra low emissions vehicle (SULEV)

For a given type of vehicle, the lowest “non zero” emissions rating under the CARB LEV emissions regulations.

Type 0 (as defined by CARB)

Utility EV with less than a 50 mile range.

Type I (as defined by CARB)

City EV with a range of 50 miles to 75 miles.

Type I.5 (as defined by CARB)

City EV with a range of 75 miles to less than 100 miles.

Type II (as defined by CARB)

Full function EV with a range of 100 or more miles.

Type III (as defined by CARB)

ZEV with a range of 100 or more miles, plus fast refuelling.

Type IV (as defined by CARB)

ZEV with a range of 200 or more miles, plus fast refuelling.

ULEV II

Ultra Low Emissions Vehicle after 1998 CARB regulation revisions.

Useable capacity

The number of ampere-hours (or kilowatt-hours) that can be withdrawn from a battery pack installed in a PHEV, taking into account decisions on control strategy designed to extend battery pack life or achieve vehicle performance goals (refers to a minimum power level). Useable capacity is a smaller number than nominal capacity.

Volt

A unit of potential difference or electromotive force in the International System units, equal to the potential difference between two points for which one Coulomb of electricity will do 1 Joule of work in going from one point to the other. The volt unit is symbolised by “V”.

Voltage efficiency

The ratio of the average voltage during discharge to the average voltage during recharge under specified conditions of charge and discharge.

Watt-hour efficiency

The ratio of the watt-hours delivered on discharge of a battery to the watt-hours needed to restore it to its original state under specified conditions of charge and discharge.

Watt-hours per kilometer

Energy consumption per kilometer at a particular speed and condition of driving. It is a convenient overall measure of a vehicle's energy efficiency. Watt-hour efficiency = Ampere-hour efficiency x voltage efficiency.

Zero emission vehicle (ZEV)

A vehicle that has no regulated emissions from the tailpipe. Under California Air Resources Board (CARB) regulations, either an EV or a FCV is also a ZEV.

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A	Ampere
AC	Alternating Current
ACEA	European Automobile Manufacturers Association
ACT	Accelerated Technology (IEA)
ADEME	Agency for Environment and Energy Management (France)
AEI	Advanced Energy Initiative (USA)
AER	All-Electric Range
AFV	Alternative Fuel Vehicle
AGV	Automatic Guided Vehicle
Ah	Ampere-hour
AHFI	Austrian Hydrogen and Fuel cell Initiative
AIM	Asynchronous Induction Machine
AIST	National Institute of Advanced Industrial Science and Technology (Japan)
ALABC	Advanced Lead-Acid Battery Consortium
ALM	Automotive Lightweight Materials
ANL	Argonne National Laboratory (USA)
ANR	Agence Nationale de la Recherche (France)
ANVAR	Agence Nationale de Valorisation de la Recherche (France)
APRF	Advanced Powertrain Research Facility (at ANL)
APSC	Austrian Alternative Propulsion Systems Council
APU	Auxiliary Power Unit
ASBE	Belgian Electric Vehicles Association
AT-PZEV	Advanced Technology Partial Zero Emission Vehicle
AVEM	Avenir du Véhicule Electrique Méditerranéen (France)
EVERE	European Association for Battery, Hybrid and Fuel Cell Electric Vehicles
A3	Austrian Advanced Automotive technology R&D programme
A3PS	Austrian Agency for Alternative Propulsion Systems
BES	Basic Energy Sciences
BEV	Battery Electric Vehicle
BMVIT	Federal Ministry for Transport, Innovation and Technology (Austria)
BTL	Biomass-to-liquid (fuel)
CAC	Criteria Air Contaminants
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
cc	cubic centimetre
CCFA	Comité des Constructeurs Français d'Automobiles
CCS	CO ₂ Capture and Storage
CD	Charge Depletion
CDB	Charge Depletion - Blended mode
CDE	Charge Depletion - all Electric operation
CEI	Italian Electrotechnical Commission
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CERT	Committee on Energy Research and Technology (IEA)
CHF	Swiss Franc
CHP	Combined Heat and Power (generation)

PRACTICAL INFORMATION

CH ₄	Methane
CIDI	Compression Ignition Direct Injection
CITELEC	Association of European Cities interested in Electric Vehicles
CIVES	Italian Electric Road Vehicle Association
CMVSS	Canada Motor Vehicle Safety Standards
CNG	Compressed Natural Gas
CNR	National Research Council (Italy)
CO	Carbon monoxide
Co.	Company
Corp.	Corporation
CO ₂	Carbon dioxide
CRF	Fiat Research Center (Italy)
CRIEPI	Central Research Institute of Electric Power Industry (Japan)
CTL	Coal-to-liquid (fuel)
CUTE	Clean Urban Transport for Europe
CVT	Continuous Variable Transmission
DC	Direct Current
DKK	Danish Crown
DME	Dimethyl ether
DOD	Depth Of Discharge
DOE	Department of Energy (USA)
DOT	Department of Transportation (USA)
DPF	Diesel Particulate Filter
DPT	State Planning Organization (Turkey)
DSBHFC	Direct Sodium Borohydride Fuel Cell
EAER	Equivalent All-Electric Range
EC	European Commission
ECN	Energy research Centre of the Netherlands
ECU	Electronic Control Unit
EDF	Electricité de France
EDTA	Electric Drive Transportation Association
EET	European Ele-Drive Transportation Conference
EEV	Enhanced Environmentally friendly Vehicle (Europe)
EIA	Energy Information Administration (USA)
EM	Electric Motor
EM	Expert Meeting
EMPA	Institute for Material Sciences and Technology Development (Switzerland)
EMU	Electrified Motive Unit
ENEA	Italian National Agency for New Technologies, Energy and the Environment
EPA	Environmental Protection Agency
EPACT	Energy Policy Act (USA)
EPE	European Power Electronics and Drives Association
EPRI	Electric Power Research Institute (USA)
EREV	Extended-Range Electric Vehicle
ESS	Electric Storage System
ESS	Energy Storage System
ETEC	Department of Electrical Engineering and Energy Technology (VUB)
ETH	Eidgenössische Technische Hochschule Zürich (Swiss Federal Institute of Technology Zürich)

ABBREVIATIONS

ETO	Office of Energy Technology and R&D (IEA)
EtOH	Ethanol
EU	European Union
EUDP	Energy Technology Development and Demonstration Programme (Denmark)
EURO-x	European emission standard, level x
EUWP	End-Use Working Party (IEA)
EV	Electric Vehicle
E.V.A.	Austrian Energy Agency
EVS	Electric Vehicle Symposium
EVT	Electrical Variable Transmission
evTRM	EV Technology Roadmap (Canada)
ExCo	Executive Committee
E85	Fuel blend of 85 vol-% ethanol and 15 vol-% gasoline
F	Farad
FC	Fuel Cell
FCEV	Fuel Cell Electric Vehicle
FCV	Fuel Cell Vehicle
FFI	Strategic Vehicle Research and Innovation Initiative (Sweden)
FFV	Flexibly Fuelled Vehicle or Fuel Flexible Vehicle
FH	Fachhochschule (University of applied sciences - Germany, Switzerland)
FISR	Special Integrative Fund for Research (Italy)
FMVSS	Federal Motor Vehicle Safety Standard (USA)
FP	European Framework Programme for research and technological development
FT	Fischer-Tropsch
FTP	Federal Test Procedure (USA)
FY	Fiscal Year
g CO ₂ /km	Grams of CO ₂ per kilometre (emissions)
GDP	Gross Domestic Product
GEM	Global Electric Motorcars
gge	gallon gasoline equivalent
GHG	Greenhouse Gas
GM	General Motors
GMC	General Motors Corporation
Gt	Giga ton (10 ⁹ tons)
GTL	Gas-to-liquid (fuel)
GVW	Gross Vehicle Weight
G2V	Grid-to-Vehicle
h	hour
HCCI	Homogeneous Charge Compression Ignition
HECU	HEV Electronic Control Unit
HEV	Hybrid Electric Vehicle
HFCIT	Hydrogen, Fuel Cells and Infrastructure Technologies
HIL	Hardware-in-the-loop
HMI	Human Machine Interaction
HOV	High Occupancy Vehicle
hp	horsepower
HTAS	High Tech Automotive Systems (The Netherlands)
HTUF	Hybrid Truck User Forum (USA)

PRACTICAL INFORMATION

H ₂	Hydrogen
H&EV	Hybrid and Electric Vehicle
IA	Implementing Agreement (of the IEA)
IA-AFC	Implementing Agreement on Advanced Fuel Cells
IA-AMF	Implementing Agreement on Advanced Motor Fuels
IA-HEV	Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes
IAEA	International Atomic Energy Agency
IAMF	International Advanced Mobility Forum
ICE	Internal Combustion Engine
ICT	Information- and Communication Technology
IDAE	Institute for the Diversification and Saving of Energy (Spain)
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IGBT	Insulated Gate Bipolar Transistor
IMA	Integrated Motor Assist™ (by Honda)
Inc.	Incorporated
INL	Idaho National Laboratory
INRETS	Institut National de Recherche sur les Transports et leur Sécurité (France)
IPCC	Intergovernmental Panel on Climate Change
IPHE	International Partnership for a Hydrogen Economy
IPT	Inductive Power Transfer
IRS	Internal Revenue Service (USA)
ISO	International Organization for Standardization
ITRI	Industrial Technology Research Institute (Taiwan)
ITS	Intelligent Transport System
ITU	Istanbul Technical University (Turkey)
IV2S	Intelligent Vehicular Transport Systems and Services research programme (Austria)
JARI	Japan Automobile Research Institute
JCS	Johnson Controls, Inc. and Saft joint venture
kWh	Kilowatt-hour
L	Liter
LCA	Life Cycle Analysis
LDV	Light-duty Vehicle
LEV	Light Electric Vehicle
LEV	Low Emissions Vehicle
Li	Lithium
LiP	Lithium Phosphate
LiP	Lithium Polymer
LLNL	Lawrence Livermore National Laboratory
LMP	Lithium Metal Polymer
LNG	Liquefied Natural Gas
LNT	Lean NO _x Trap
LPG	Liquefied Petroleum Gas
LRT	Light Rail Transit
LSV	Low-speed Vehicle

ABBREVIATIONS

MATT	Mobile Advanced Technology Testbed
MCFC	Molten Carbonate Fuel Cell
MEA	Membrane Electrode Assembly
Mg	Magnesium
MH	Metal Hydride
min	minute(s)
MOU	Memorandum of Understanding
mpg	miles per gallon
mph	miles per hour
MPV	Multi Purpose Vehicle
MRC	Marmara Research Center (TÜBİTAK, Turkey)
MVSA	Motor Vehicle Safety Act (Canada)
NAC	National Automotive Center (USA)
NEDO	New Energy and Industrial Technology Development Organization
NEET	Networks of Expertise in Energy Technology (an IEA initiative)
NEV	Neighbourhood Electric Vehicle
NGO	Non Governmental Organization
NGV	Natural Gas Vehicle
NHTSA	National Highway Traffic Safety Administration (USA)
NiCd	Nickel Cadmium
NiMH	Nickel-Metal Hydride
NL	The Netherlands
NMVOS	Non-Methane Volatile Organic Substances
NOx	Nitrogen Oxides
NRC	National Research Council of Canada
NRCan	Natural Resources Canada
NREL	National Renewable Energy Laboratory (USA)
NZES	New Zealand Energy Strategy
N2O	Nitrous Oxide (not considered a NOx compound)
OA	Operating Agent
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OERD	Office of Energy Research and Development (NRCan)
ORNL	Oak Ridge National Laboratory (USA)
OSD	Automotive Manufacturers Association (Turkey)
OTAM	Automotive Technology Research and Development Center (Turkey)
P.A.	Power-Assisted
PCA	Peugeot Citroën Automobiles (France)
PCCI	Premixed Charge Compression Ignition
PEFC	Polymer Electrolyte Fuel Cell
PEFC	Proton Exchange Fuel Cell
PEM	Polymer Electrolyte Membrane
PEM	Proton Exchange Membrane
PERD	Program of Energy Research and Development (NRCan)
PHEV	Plug-in Hybrid Electric Vehicle
PHEVx	Plug-in Hybrid Electric Vehicle that has the ability to travel x miles on electric-only mode
PM	Particulate Matter

PMSM	Permanent Magnet Synchronous Motor
PM10	Particulate Matter, size < 10 µm (10 ⁻⁶ m)
ppm	parts per million
PR	Public Relations
PRC	People's Republic of China
PSAT	Powertrain Systems Analysis Toolkit (ANL)
psi	pound-force per square inch
PSI	Paul Scherrer Institut (Switzerland)
PTO	Power Take Off
PV	Photovoltaic
PZEV	Partial Zero Emission Vehicle
RD&D	Research, Development and Demonstration
RD&D	Research, Development and Deployment
RESS	Rechargeable (electric) Energy Storage System
RFG	Reformulated Gasoline
ROG	Reactive Organic Gases
RT	Real-time
R&D	Research and Development
SAE	Society of Automotive Engineers
SAM	Super Accumulator Module
SC	Sub-Committee
SCE	Southern California Edison
SCR	Selective Catalytic Reduction
SEK	Swedish Crown
SHC	Swedish Hybrid Vehicle Centre
SHHP	Scandinavian Hydrogen Highway Partnership
SI	Spark Ignition
SI	Système International (International System of Units)
SIDI	Spark Ignition Direct Injection
SMEs	Small and Medium Enterprises
SOC	State Of Charge (battery)
SOFC	Solid Oxide Fuel Cell
SOH	State Of Health (battery)
SOx	Sulfur Oxides
SO ₂	Sulfur dioxide
SQAIM	Squirrel cage rotor Asynchronous Induction Machine
SRA	Strategic Research Area
SULEV	Super Ultra Low Emissions Vehicle
SUV	Sport Utility Vehicle
S.V.E.	Société des Véhicules Electriques (France)
SWEVA	Swedish Electric & Hybrid Vehicle Association
t	Ton(s) (1 t = 1,000 kg)
TC	Technical Committee
TCG	Transport Contact Group (IEA EUWP)
TEKES	Finnish Funding Agency for Technology and Innovation
TLVT	Technology Life Verification Test
TNO	The Netherlands Organisation for Applied Scientific Research TNO

ABBREVIATIONS

UC	University of California
UDDS	Urban Dynamometer Driving Schedule (USA)
UK	United Kingdom
ULEV	Ultra Low Emissions Vehicle
UN	United Nations
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
U.S.	United States (of America)
USA	United States of America
USABC	United States Advanced Battery Consortium
USCAR	United States Council for Automotive Research
US\$	U.S. dollar
V	Volt
VAT	Value-Added Tax
VITO	Flemish Institute for Technological Research (Belgium)
vol-%	Percentage based on volume
VRLA	Valve Regulated Lead Acid (battery)
VSP	Vehicle Simulation Programme (ETEC, VUB)
VSWB	Flemish Cooperative on Hydrogen and Fuels Cells (Belgium)
VTI	Programme Véhicules pour les Transports Terrestres (ANR, France)
VUB	Vrije Universiteit Brussel (Belgium)
VW	Volkswagen
V2G	Vehicle-to-Grid
WEVA	World Electric Vehicle Association
Wh	Watt-hour
WSC	World Solar Challenge (race for solar powered vehicles)
wt-%	Percentage based on weight
ZEV	Zero Emission Vehicle



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The website of the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) can be found at www.ieahev.org.

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Annex XV – Plug-in hybrid electric vehicles

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Annex X – Electrochemical systems

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Annex XII – Heavy-duty hybrids

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Annex XVI – Fuel and technology alternatives for buses

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