



Hybrid and electric vehicles

The electric drive establishes a market foothold



February 2009

Progress towards sustainable transportation

International Energy Agency

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

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The IA-HEV, also known as the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes, 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.

Cover photo:

The electric drive establishes a market foothold.

More and more vehicles with an electric drive under the hood are on the road.

One example is shown here, the well-known hybrid electric Toyota Prius.

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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 2008

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The electric drive establishes a market foothold

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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 2008 (section 1.2). Chapter 2 explains the relationship between IA-HEV and the International Energy Agency (IEA) and it describes the IA-HEV history, results and working programme. This year it also includes essentials of the strategic plan for the fourth phase of the Agreement (2009-2014). Chapter 3 presents 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 organised 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 2008. This year the overview chapter includes a section on trolley buses, as a special topic. More detailed information on H&EV activities in each IA-HEV member country is presented in chapters 13 through 24. Chapter 25 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, as it is seen by the IA-HEV Executive Committee.

Part E gives practical information related to hybrid and electric vehicles and the Agreement: 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.

1***Chairman's message******The future will be electric and renewable***

The strong interest for hybrid and electric vehicles as one of the future mobility solutions had a great impact on the work of the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV). It inspired the planning of the 4th phase of the Implementing Agreement that will start in December 2009.

1.1***Hybrid and electric vehicles and the role of IA-HEV******The technical solution is known: it is electric and renewable!***

The best solution and therefore the future for transportation will be electric and renewable. Why is this so obvious? Basic physics and nature tell us why:

- The electric drive is at least 3 times more efficient than combustion processes.
- Many options for the clean and renewable production of the electricity already exist, ranging from hydro- and wind power, locally produced biomass power plants to decentralized solar power stations, photovoltaics, etc.

Within the framework of the 'Large scale test with lightweight electric vehicles' in Mendrisio (Switzerland), test bench measurements in the automotive department of the University of Applied Sciences Bern compared the energy consumption of the Volkswagen Golf and Peugeot 106 with electric-, diesel- and gasoline drivetrains (figure 1.1). Measurements in daily use have substantiated this result.

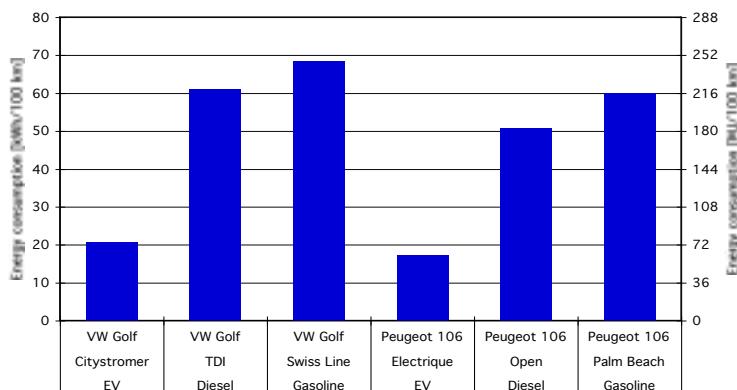


Fig. 1.1 Electric vehicles are at least 3 times more energy efficient than internal combustion engine vehicles. Shown are Volkswagen (VW) Golf and Peugeot 106 test bench measurements for the big fleet test in Mendrisio, Switzerland, 1994.

What is your sustainable mobility portfolio?

In our annual report of March 2008 we compared the ranges of vehicles using different kinds of biomass-based fuels produced on one hectare of land with a plug-in hybrid electric vehicle (PHEV) with electricity produced by one hectare of photovoltaics. This comparison shows the big advantage of the electric solution over renewable energies made from crops. You can repeat this exercise with electricity produced by wind, or by a hydropower plant. The IEA report 'Towards a sustainable energy future' mentions "there is no intrinsic ceiling to variable renewables" potential". The integration of renewable electricity into the transport sector can be supported by the use of the vehicle-to-grid (V2G) concept, which is under investigation by our specialists in the PHEV task force (IA-HEV Annex XV). Even 100% renewable energy is attainable.

Our position in the actual debate of the use of biofuels is important - also because hybrid and plug-in hybrid electric vehicles can and will use biofuels in addition to electricity. So the conclusion that alternative motor fuels are obsolete is being rash in judgement. For some transportation applications such as certain heavy-duty vehicles, large ships and especially commercial airplanes the electric solution is actually not competitive. Alternative motor fuels and later hydrogen produced by renewable energies can fill this gap. By using electric drivetrains we can limit the use of arable land for the production of alternative motor fuels as a worthy resource for special applications. It lowers the pressure for an excessive use of land in developing and industrialized countries and it avoids a destructive competition between food and the use in transportation.

Future transportation may show the following portfolio:

- Go by foot and use bicycles - for longer distances use electric assist bicycles.
- Use clean electricity for means of mass transportation (railways,) as much as possible.
- Replace passenger vehicles and buses as much as possible by trams and electric trolley buses in densely populated areas.
- Replace diesel buses, diesel trucks etc. by hybrid vehicles with alternative motor fuels (later perhaps hydrogen) as much as possible.
- Replace short distance trips with internal combustion engine vehicles as much as possible by electric vehicles, starting with electric 2-wheelers and small lightweight electric vehicles, and gradually introducing four-wheeled electric vehicles.
- Replace mid- and long distance trips by hybrid electric- and plug-in hybrid electric vehicles as much as possible.

- Start using alternative motor fuels for selected applications and perhaps start using hydrogen to fuel airplanes.

The development of such a ‘sustainable mobility portfolio’ is just at a starting point. Many R&D efforts, demonstration projects and applications are needed to give a detailed picture. The optimum picture may differ from country to country, from region to region and from town to town. But first pieces of the puzzle can already be used today with benefits for the users. As members of the various IEA Implementing Agreements in the transport sector, countries can share these results and learn from each other. This will speed up the development and it saves taxpayers’ money.

The way to electric mobility is a marathon

IA-HEV Annex XIV ‘Market deployment of hybrid and electric vehicles: Lessons Learned’ interviews many specialists committed to electric vehicle (EV) development and marketing in the 1990s: EV manufacturers, producers of components, organizers of demonstration projects, representatives of utilities, policy makers, etc. Besides a lot of lessons that can be learned from their analyses of this period, there is common agreement on one lesson: a technological change needs time, especially if the previous technology is so dominant. The culture of thinking in short or even mid-term payback periods in company boards clashes with the time needed for the developments of components and system integration. And even if all homework is done by the manufacturers, there is a market outside the factory building that asks which advantages consumers may have by driving an electric vehicle. The way to electric mobility is comparable to an expedition to a high mountain peak. You need good preparations, a trained team, good know-how and a roadmap. Then you still need good weather conditions or you have to wait and try again another time. If everything is right you have to go step by step from one milestone to the next. Quick success will not happen. This is a critical situation in a world where media and politics look for quick solutions.

The pathway to the electric and renewable mobility has many milestones.....

High oil prices and the current economical crisis lead to much attention for electric vehicle technologies in all the media. It is obvious that gas-guzzlers are outdated. But I am critical about today’s ‘EV hype’. Electric propulsion will be the dominant drivetrain of future vehicles, but this needs time.

The first milestone that has to be reached is ramping up production figures, starting with basic components like power electronic parts, batteries and their components, even power contacts, rare materials for motors, and DC- and AC-motors. This is only part of the whole chain that has to be built up.

IA-HEV Annex XIV on lessons learned clearly showed that even if the manufacturer was sure that he had done his homework, electric vehicles still failed on the market. Consumers are used to the current network of refuelling stations, service points and garages, and an infrastructure that is adapted to the use of vehicles with internal combustion engines. It is a huge challenge to build up such a network for vehicles with electric drives. In the 1990s, especially the lack of trained salespersons and service stations added to the failure of the EV market introduction. Building up this network needs huge investments from the private industry and it also needs time.

We assume that the time to market is a critical factor. To assess a realistic period of time for a substantial market penetration could be another task for our Implementing Agreement. This would allow decision makers to rate this new technology according to realities and not according to wishful thinking or even a new hype as we have seen in the past.

.....but there is a window of opportunity for vehicle developments

It is very well possible that new types of entrepreneurs enter this field with new products and offers. Mastering the technology of hybrid and electric vehicles provides perfect opportunities for new competitors. They could arise outside of today's industrialized part of the world, in regions like China and India, or in new industries like IT technologies. Actually we have an exciting time for new entries - and a frightening one for 'veteran' car producers, their employees and their hometowns.

IEA report 'Towards a sustainable energy future'

The G8+5 summit in Gleneagles asked the International Energy Agency to outline a pathway to a sustainable energy future. The group of specialists working on this report also used studies and comments of the various Implementing Agreements. The transportation segment has been identified as one of the most important, but also as one of the most difficult fields decisive for the sustainability of the future global energy supply. The most important facts are:

- Transport remains a challenge. 60% of all the oil is consumed by the transport sector.
- There is a need to de-carbonize transport energy.
- To lower CO₂ by 50%, new transport technologies e.g. EVs and PHEVs are needed.
- EVs and PHEVs are mentioned among the 17 key technologies in the 'Energy technology perspectives' report of the IEA.
- Research, development, demonstration and deployment of advanced vehicle technologies (like fuel cell vehicles and EVs) must be doubled if these are to play a major (and sustainable) role by 2030 and beyond.

- Funding should be increased in the next 5-10 years, to increase the probability of successful development.
- Electricity grid integrity: there is no intrinsic 'ceiling' to variable renewables' potential.

The automotive industry will change

This change is a very critical process for the existing car industry. It is not guaranteed that all companies will survive. From history we know that several big companies failed to make the switch from one technology to another. Just remember that the triumphal march of the gasoline car killed the industry of steam driven road vehicles. The actual world economy aggravates this problem of a shift in technology. One thing is clear: people enjoy to drive a car and to travel to unknown places. For society in the actual organizational structure vehicles are a necessity. The demand and the market still exist. The winners will be those companies that can align advanced clean vehicle technology and consumer demands.

International collaboration brings clarity in the process of change

Decision makers are highly dependent on the information they get before they decide. It is not only the independency, but also the completeness and the global view that is crucial but hard to attain. To put objective information on electric and hybrid vehicles and their effects on energy efficiency and the environment at the disposal of governments, local and city authorities, fleet users and industries is one of the, if not the most important, goals of our work. Many R&D efforts, demonstration projects and applications are needed to build a detailed picture. The optimum may differ from country to country, from region to region and from town to town. Nevertheless, first pieces of the puzzle can already be used today with benefits for the users. As members of various IEA Implementing Agreements (IAs) in the transportation sector, countries can share these results and learn from each other. This will speed up the development, will help to identify main streams in industry as well as in markets and, last but not least, it will save taxpayers' money.

An additional step towards international collaboration was the first meeting of the Transport Contact Group (TCG) in March 2008 at the IEA-headquarters in Paris. This initiative of the new vice chairman of the End-Use Working Party (EUWP), who is responsible for the transportation IAs, Mr. Nils-Olof Nylund, will enhance collaboration between transport related Implementing Agreements and will animate the discussions in our working group.

Working fields for the future

IA-HEV has identified the following factors that are important to influence the future market share of electric, hybrid and plug-in hybrid electric 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, PHEVs and conventional vehicles.
- The availability of components for EV, HEV and PHEV drivetrains.
- The quantity of EVs, HEVs and PHEVs that manufacturers will be able to supply.

The first point will still remain a main target of IA-HEV Annex I on information exchange, while the second point is covered by IA-HEV Annex X on electrochemical systems. The steering committee of this Implementing Agreement also agrees that at least one Annex has to deal with market issues. The application of EV, HEV and PHEV technologies in high-volume vehicle models must be addressed by a technically oriented Annex. A continuation of Annex XIV on deployment strategies may focus on various problems that occur as a result of the discrepancy between producers' intentions and consumers' actual use patterns.

Additional Annexes are suggested that will investigate electronics and system integration, materials, and questions of the interface between plug-in vehicles and the electricity grid. This includes answering the question: where will the electricity come from? For this does not only affect the sustainability of future transportation, but it also affects the efficiency and stability of the grid.

The better will win - join the group!

Consider you find a technical solution that is 3 times better than the traditional established one. You would shout "Eureka!", and you would have the opportunity to watch companies that convert this superior solution into practice coming up like mushrooms. Well, this solution exists: the electric vehicle *is* at least 3 times more energy efficient than all internal combustion engine technologies.

Unfortunately there is one difference with the mushroom example: not all framework conditions that are necessary for the electric vehicle are in place. Production facilities are not yet ready and there is a lack of specialists. The automotive industry has to learn how to produce this new product and how to bring it to the marketplace. The electric power industry and the utilities must realize how important this technology will be for their businesses. Governmental authorities must adapt their regulations. Car retailers have to learn how these new vehicles have to be marketed and how

maintenance and service have to be organized. And consumers have to learn how to use this new technology.

The variety in electric vehicle technologies is large. There are hybrid vehicles, plug-in hybrid electric vehicles and small electric solutions like e-bikes and e-scooters. The Implementing Agreement on Hybrid and Electric Vehicles is working on all these variants. Actually we are in the final discussions for the 4th five-years working programme that will start in December 2009. In all these discussions we miss important countries like Germany, Japan, South Korea and the United Kingdom, which already have been members in our Implementing Agreement in previous phases. Important countries like China, India and Russia must also be convinced to become new IA-HEV members. Actually we regularly welcome new countries that join an international working group that can proudly say: "This solution is at least 3 times better!".

1.2

Summary of IA-HEV activities in 2008

1.2.1

Introduction

The strong interest for hybrid and electric vehicles created a lot of chances and new challenges for the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) in 2008. Electric vehicles are now on everyone's lips as 'the' future drive technology. The Swiss Minister of Energy and Transport, Moritz Leuenberger, mentioned in an interview "that the gasoline based tax system has to be changed because future vehicles will use electricity".

The new trend towards electric vehicles created a high interest in our work. We welcomed specialists from Germany, Japan, New Zealand, Portugal, South Africa and Spain in our meetings and we had discussions with many other country delegates. To enhance communication with new member countries and potential participants in the Annexes, we have prepared an IA-HEV Annexes menu summarizing all important facts, including the financial contribution and the amount of work per country or participant (see table 1.1). We hope this will answer many questions and helps more countries and experts to join our work.

Among the highlights of 2008 we had the return of Finland as an IA-HEV member, completing the actual number of twelve members countries, and we had the successful start of the new Annex (XV) on plug-in hybrid electric vehicles. Annex XV addresses many new aspects, e.g. the integration of vehicles into the

grid (vehicle-to-grid V2G). Information exchange with other IEA Implementing Agreements and Annexes working on these topics is necessary. This will allow us to focus our work on the vehicle components, the vehicles, the infrastructure and the use of the various applications.

Table 1.1 IA-HEV Annexes menu.

Annex no.	Annex title	Running time	Financial contribution per participant, per year	In kind contribution per participant, per year
I	Information exchange	Continuous	None	Country presentation, country chapter for annual report, information for newsletter.
IX	Clean city vehicles	Currently not active	--	--
X	Electrochemical systems	Continuous	None	Varies. Enough (few days) to make meetings meaningful.
XI	Electric cycles	Phase 1: until spring 2009	--	--
XII	Heavy-duty hybrid vehicles	January 2007 - November 2009	6'000 Euros	At least one person month.
XIII	Fuel cells for vehicles	September 2007 - Mid 2010	6'700 Euros	At least one person month.
XIV	Lessons learned	October 2007 - January 2010	5'500 Euros	At least one person month.
XV	Plug-in hybrid electric vehicles	March 2008 - Spring 2011	None	At least one person month.

1.2.2

Efforts in 2008

2008 was another very active year for IA-HEV:

- We started the Annex on plug-in hybrid electric vehicles (PHEVs), with Natural Resources Canada as the Operating Agent.
- Our specialists worked in six other Annexes.
- At the Geneva International Motor Show and in Vienna we could present our 4th round of clean vehicle awards in two categories, to Electricité de France (EDF) and to Prof. Dr. Kordes (Austria/USA).
- We presented the work of the Implementing Agreement at different conferences and workshops in Austria, Finland, Russia, USA, etc.
- The second IA-HEV Outlook was produced.
- At the IA-HEV Executive Committee meeting parallel to the Geneva International Motor Show we started working on the strategic plan for the 4th phase of the Implementing Agreement.

- The collaboration with the IEA headquarters in Paris was deepened by workshops, meetings and the exchange of information.
- Contacts with other transport related Implementing Agreements were reinforced in March 2008 through the new IEA EUWP Transport Contact Group (TCG).
- Many countries interested to join our working group contacted us.
- The dissemination activities were enhanced. The number of printed copies of the annual report was doubled and is already sold out.
- The workloads of our secretary, the chairman and the deputy chairman were at a constant high level. Efforts to increase our resources are a continuing issue.

Hybrid and electric vehicles: waiting for the new models of 2009 and 2010

The producers of hybrid electric vehicles met with a strong demand for their models in the first months of 2008. Under the influence of the economic crisis and the low oil prices the sales of hybrid vehicles went down in the last months of the year.

Additionally, consumers are waiting for the new Toyota Prius III that is announced for 2009. As predicted one year ago, the most common hybrid model in the market, the Toyota Prius, passed the one million sales figure. No doubt that the Prius III will continue to be the flagship of this technology. 2009 will see the introduction of the new Honda Insight and new models from other producers, but the two Japanese carmakers Toyota and Honda will remain ahead. The product range of hybrid electric vehicles available on the market is still very small. Most of the car manufacturers are not ready yet. The situation is even worse concerning electric vehicles and plug-in hybrid electric vehicles (PHEVs). We expect more new battery EV models and the first PHEVs in 2010. Electric vehicles are in production today, but only in small numbers and/or for niche applications.

Electric two-wheelers like e-bikes are continuing their market success in Asia, Europe and some states of the USA. A huge production number of 25 million bikes per year is reported from China. In the IEA countries, e-bikes are a segment for selected consumers who accept the relatively high price level. More and more electric scooters and even cross-country motorbikes are introduced on the market, like the Quantya from Switzerland and the electric KTM cross bike. The new lithium batteries are perfect for these vehicles.

Co-ordinated research- and development activities speed up the work

Today's twelve IA-HEV member countries (Austria, Belgium, Canada, Denmark, Finland, France, Italy, the Netherlands, Sweden, Switzerland, Turkey and the United States of America) co-ordinate their research and pilot- and demonstrations efforts in the field of hybrid and electric vehicles. Additionally we have sponsors from industry such as Tokyo R&D, and AVERE, which collaborate in the Annex XI task force. They have a better access to reliable information and therefore lower transition costs. IA-HEV tries to expand these benefits to new member countries. We expect to have

up to 15 member countries at the start of the 4th phase of the Agreement in December 2009.

Collaboration within different transport related Implementing Agreements resulted in the foundation of the Transport Contact Group (TCG)

Four Implementing Agreements (IAs) of the International Energy Agency are working in the field of transportation. These are:

- Advanced Fuel Cells. The main focus of this IA is on ‘sustainable heating’, but transport issues may be included in the work.
- Advanced Materials for Transportation. The focus of this Agreement is ‘reduced friction saves energy’.
- Advanced Motor Fuels. This IA focuses on ‘new fuels and new emission results’.
- Hybrid and Electric Vehicles.

It is obvious that one Implementing Agreement only works on a small and specific part of the whole transportation segment. In March 2008, these four Implementing Agreements founded the Transport Contact Group (TCG) to co-ordinate their work.

Initiative for an exchange program for young researchers

New technologies need technical experts. This will be another bottleneck in our field. Therefore the idea emerged to promote an exchange program for young researchers among research institutes of our member countries. If you have to offer a place for a young researcher please contact our secretary. If a young researcher is interested, she or he may contact the IA-HEV ExCo member (see the ‘IA-HEV contact information’ section at the end of this report) in her/his country.

1.2.3

Our working menu of today: seven Annexes running and two in preparation

The reports of IA-HEV Annexes that so far have been concluded mirror the information needs of the first market introduction phase in the 1990s: environmental impacts of electric vehicles, infrastructure, batteries, hybrid vehicles and governmental market deployment strategies. This enabled government administrations of the participating countries to shape their policies and to profit from the experiences of other countries. In its second and third phase, IA-HEV has been one of the first experts groups informing about the potential of plug-in hybrid technologies (presentation at EVS-20 in Long Beach, public workshop at EVS-21 in Monaco in 2005), evaluating governmental support to identify successful market deployment strategies (2002) and investigating how learning processes in the automotive industry help to improve the second generation electric and plug-in hybrid electric vehicles (2008).

Active Annexes

The following Annexes were running in 2008.

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 'turntable' by publishing the figures and basic information on the Agreement's website. The informal information that is the specific benefit of the participants is only available for the member countries. The Operating Agent of this Annex is Argonne National Laboratory, 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 issues that are not discussed within the battery community or at special battery conferences, like experiences with specific test protocols or abuse testing. The availability of lithium for batteries was the topic of an Annex X workshop in December 2008. The Operating Agent is the U.S. Department of Energy.

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 became a small successful market niche. Because of different quality standards vehicles do not necessarily match for both markets, and there are still a lot of open questions concerning standards, licensing and market deployment. This group under the guidance of AVERE will conclude its first phase of work in 2009.

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, the costs and the 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, ...) 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 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 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 invest strongly in the development of this technology. Nevertheless, limited lifetime as well as high production costs due to noble metal catalysts have impeded until now the broad market introduction of fuel cells beyond specialized niches like space applications. But in the last 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 will bring fuel cell vehicles nearer to competitiveness. This IA-HEV task force does not concentrate its activities on the development of fuel cells, but on tuning their properties as well as using their high potential for their 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, aeroplanes and mining equipment could be interesting niches preparing the market introduction of fuel cell vehicles. Operating Agent is the Austrian Agency for Alternative Propulsion Systems (A3PS).

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

IA-HEV Annex VIII on deployment strategies for hybrid, electric and alternative fuel vehicles investigated 95 promotion measures -run by governments or other public and private organizations- to enable the market deployment of clean vehicle technologies. Following up on this work, Annex XIV analyses the reasons for success and failure at introducing electric and hybrid vehicles on the market. This is even more important as car manufacturers (and users) have several options when choosing a clean propulsion technology (alternative fuels like natural gas and ethanol, fuel cell vehicles, etc.). The preliminary results show that car manufacturers underestimated the difficulties in the development of electric propulsion systems and the time frame a market deployment needs. Additionally, the interface between vehicle and grid

has never been defined between utilities and car manufacturers, and the lack of standards aggravated the problem. The importance to establish a network of sales points with trained staff that also showed competence in maintenance and service has been underestimated as well. More details are discussed in workshops in which representatives of EV and component manufacturers, utilities and project leaders of demonstration programmes share their experiences. 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 follows up on Annex VII 'hybrid vehicles' that was concluded in 2007. Annex VII had already started to evaluate the options of plug-in hybrid electric vehicles (PHEVs). PHEVs have the potential of further reduction in oil use and CO₂, 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 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.

Working groups in planning

Preparatory steps for two additional working groups have already been taken.

Renewable energies for hybrid and electric vehicles (in preparation)

The energy mix of each country is decisive for the environmental benefits of vehicle technologies including electric motors. Especially the wide range of hybrid propulsion systems with the combination of various forms of energy (fuel, electricity) needs a closer investigation concerning the use of renewable energies. The planned new working group will focus on the electricity production for battery electric vehicles and plug-in hybrid electric vehicles, biofuels for hybrid electric vehicles and an updated overview of well-to-wheel analyses of energy efficiencies, greenhouse gas emissions and costs of different pathways. This working group may join the PHEV Annex as a topical sub-task.

Clean city vehicles (Annex IX - pending)

This is a proposal for energy efficient transportation in developing countries. This scope demands a close co-operation with development agencies and a raising of additional funds. After a first successful workshop in Paris in 2002, the benefit of

such a co-ordination was clear. Two bus projects in Asia were influenced by this first effort. But the financing of a task that connects developing countries with energy efficient transport technologies is challenging.

1.2.4

New participants are welcome

Annexes finance their work themselves by contributing to the Annex fund. But the benefit of participation is much higher than the costs. For research institutes and industry it is also possible to collaborate as a sponsor or as subtask leader. Please contact the Operating Agent of the applicable Annex or the IA-HEV secretary in case you are interested. It is possible to participate for free in a workshop, if an interest in a further participation is expressed.

1.2.5

Dissemination activities

More and more decision makers in governments, states, communities and industries are interested and want to get more information on hybrid and electric vehicles. We updated or started additional activities to meet this demand:

- Annual report.

The IA-HEV annual report is published in the first quarter of the year. We added new chapters on an outlook for hybrid, electric and fuel cell vehicles and the winners of the IA-HEV clean vehicle awards. The annual report presents all the Annexes and gives an insight in the activities in our member countries. Non-member countries with interesting activities in our field are covered by correspondents from Annex I on information exchange. The annual report can be ordered at the IA-HEV national delegates.

- Electronic newsletter.

The IA-HEV electronic newsletter informs about our work and IEA related activities in our field. It can be ordered at our secretariat.

- Website.

The IA-HEV website presents interesting results of our work and news flashes from the EV and HEV market. The webmaster is a specialist from Argonne National Laboratory.

- Insight newsletter.

This monthly electronic newsletter informs about the work of our Implementing Agreement, for members only!

- IA-HEV clean vehicle awards.

Since 2005, this is 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 it is also a prospective market. The example of

Toyota (first IA-HEV award winner in 2005) shows that commitment results in increased market shares and value of the brand. Three awards are annually granted:

- 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 dedicated person in the field of HEV and fuel cell vehicles.
- 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 European Ele-Drive Transportation (EET) conference, the International Advanced Mobility Forum (IAMF), and others.

Workshops

Annexes organize many workshops as the most important and efficient platform for information exchange. Workshops are held in the following Annexes:

- Annex I - Information exchange: one workshop per year.
 - Annex X - Electrochemical systems: about 2 workshops per year.
 - Annex XI - Electric cycles: about 2 workshops per year (for members).
 - Annex XII - Heavy-duty hybrid vehicles: about 2 workshops per year.
 - Annex XIII - Fuel cells for vehicles: about 2 workshops per year.
 - Annex XIV - Lessons Learned: 2-4 workshops per year.
 - Annex XV - Plug-in hybrid electric vehicles: about 2 workshops per year.
- In 2008 the Annexes of this Implementing Agreement have organized several workshops. All these workshops are open for participants from member countries. If you are interested to visit them as an observer, please ask our secretary or the Operating Agent of the Annex.

1.2.6

Participation in the Implementing Agreement on Hybrid and Electric Vehicles

How member countries profit from their membership

Additionally to the IA-HEV goal of providing governments, local authorities, large users and industries with objective information on electric and hybrid vehicles and their effects on energy efficiency and the environment, the goals in the 3rd phase are:

- To provide this information through general studies, assessments, demonstrations, comparative evaluation of various options of application, market studies, technology evaluations, industrial opportunities and so forth.
- To disseminate the information produced in working groups (Annexes) to specialists and organizations.
- To collaborate on pre-competitive research projects and related topics and to investigate the need for further research in promising areas.
- To collaborate with other Implementing Agreements with transportation aspects, such as the IA Advanced Motor Fuels (IA-AMF) and the Advanced Fuel Cell Implementing Agreement (IA-AFC) in their activities (Annexes, tasks or joint Annexes).
- To collaborate with specific groups or committees with an interest in transportation, vehicles and fuels.

In 2008 the IA-HEV members have established new objectives for the 4th working phase, which will start in December 2009.

New countries and partners are welcome

Currently, the largest part of the world population has no access to motorised individual vehicles. No doubt that this will change. As we have shown in a former study, the numbers of vehicles worldwide could raise from 850 million today to 2-3 billion in the future. Co-operation with countries such as Brazil, China, India and Indonesia will be beneficial for both sides. Task forces like Annex IX on clean city vehicles or Annex XI on electric cycles address especially those countries.

IA-HEV membership is interesting for all countries that are involved in projects in the field of hybrid, electric and fuel cell vehicles. In the 4th phase, we are striving for a membership of 15-20 countries.

Outlook: Can you imagine a future world without HEVs?

The breakthrough of hybrid vehicles, the success of small EVs in market niches and the renaissance of new EV-concepts will strongly affect the work of our Implementing Agreement. Furthermore, the higher proportion of renewable electricity needs 'demand side management' to balance the electricity grid. Electric vehicles and plug-in hybrids are perfectly suited for this purpose. This will boost the interest for these vehicles and we will see countries with weak grids and a high share of renewable energies looking for EVs and PHEVs.

Good opportunity to join our international working group

The work plan for the 4th phase (2009-2014) of our Implementing Agreement is in place. This is a good opportunity for interested countries to share their experience and to join the group. Our secretary Mr. Martijn van Walwijk and I are eager to inform and to help you.

Final remarks: words of thanks

In 2008 I have to say “thank you” to many of our shareholders. The members of the Executive Committee, the Operating Agents and subtask leaders have been very active. Especially the efforts of our new Operating Agents were impressive. It is always very challenging to bring a new working group together. I especially want to mention Mr. Tom Turrentine of the Institute of Transportation Studies at University of California Davis who enables the extremely informative workshops within the Annex ‘Market deployment of hybrid and electric vehicles: Lessons learned’ and Mr. Charles Thibodeau of Natural Resources Canada who leads one of the core Annexes ‘Plug-in hybrid electric vehicles’ and is planning very ambitious work. I am also happy that Finland has rejoined our Agreement and will give new impetus to Annex XII ‘Heavy-duty hybrid vehicles’.

The fruitful collaboration with other organizations like AVERE, EVVA, WEVA and e’mobile went further in 2008. But first to mention is the support of the International Energy Agency with whom the collaboration was closer than ever. The chairman of the IEA End-Use Working Party (EUWP) Peter Cunz participated in our ExCo meeting in Geneva, and his successor Mr. Hermann Halozan joined our ExCo meeting in Vienna and confirmed the support we have from the EUWP. Also I really appreciate the initiative of the new EUWP vice chairman, Mr. Nils-Olof Nylund, who initiated the Transport Contact Group. This co-ordination will broaden our viewpoint, and I expect many impacts for further discussion in our working group.

A special thank goes to the IA-HEV deputy chair Mr. Arie Brouwer who represented our Implementing Agreement in several meetings. I thank our former deputy chair Tien Duong for his support and welcome his successor David Howell. Special efforts were made by our secretary Martijn van Walwijk and the staff in my office. Martijn van Walwijk is not only an experienced secretary, but he also supports our work with his expertise in the field of transport. The work on the ‘Outlook’ relates strongly to him. The country representatives from Switzerland and Austria did a great job in organizing the two ExCo meetings with many side events, from the Geneva International Motor Show to the technical conference in Vienna. Finally I have to thank the member countries and their representatives in the Executive Committee. They support our Implementing Agreement with the needed funds and with their expertise.

January 2009
Urs Muntwyler
IA-HEV chairman

2

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 (not to be confused with the IAEA in Vienna) 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.

**Box 2.1
IEA member countries - 2008**

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 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 collectively to respond 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 intensified international collaboration. Fostering energy technology innovation is a central part of the IEA's work. Development and deployment of safer, cleaner, 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 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).

The IEA also provides a legal framework for international collaborative energy technology RD&D (Research, Development and Deployment) groups, known as



Fig. 2.1 The IEA energy technology network.

Implementing Agreements (IAs). There are currently more than 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/techagr. For more information, see also section 2.1.3. below.

Under guidance from the Committee on Energy Research and Technology (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 ‘advice on alternative energy scenarios and strategies aimed at a clean, clever and competitive energy future’. (Section 2.1.4 gives more information about the collaboration between the G8 and the IEA.)

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 fruit of their efforts. Within this structure, there are currently more than 42 active programmes, known as the IEA Implementing Agreements. Over three decades of experience have shown that these Agreements are contributing significantly to achieving 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.

In April 2003, the IEA's Governing Board approved the new 'IEA framework for international energy technology co-operation'. The framework 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 Committee on Energy Research and Technology (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 Agreements 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

- Shared costs and pooled technical resources
- Avoided duplication of effort and repetition of errors
- Harmonised 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 on-line 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 - International energy technology collaboration IEA Implementing Agreements’ 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.

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

2.1.4

IEA's G8 Programme

At their Gleneagles summit in July 2005, G8 leaders addressed the challenges of climate change and securing clean energy and sustainable development. Agreeing to act with resolve and urgency, they adopted a Plan of Action. A dialogue was launched, open to other significant energy consumers. The five G8 non-member countries Brazil, China, India, Mexico and South Africa were also represented at the Gleneagles summit. The G8 leaders asked the International Energy Agency (IEA) to be a partner in this dialogue and to play a major role in delivering the Plan of Action, which focuses on six broad areas:

- Alternative energy scenarios and strategies.
- Increased energy efficiency in buildings, appliances, transport and industry.
- Cleaner fossil fuels.
- Carbon capture and storage.
- Renewable energy.
- Enhanced international co-operation.

G8 leaders invited the IEA to help activate dynamic worldwide networks for energy technology research and development. Building on its existing Implementing Agreement programmes, the IEA is linking with the international business community, with policy makers, researchers and other stakeholders in many countries. It is working to enhance awareness of existing research, development and deployment networks and to facilitate broader participation. For this purpose the IEA has created the NEET initiative (Networks of Expertise in Energy Technology). As part of the dialogue, the NEET team is planning workshops and high-profile presence at major international events.

Detailed information about the Plan of Action, the role of the IEA, its progress and deliverables can be found at the website: www.iea.org/G8/index.asp.

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 third five-year term of operation that runs from December 2004 until November 2009. The twelve active Contracting Parties (member countries) per January 2009 are Austria, Belgium, Canada, Denmark, Finland, France, Italy, the Netherlands, Sweden, Switzerland, Turkey 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 & local governments and government supported research organizations, and by co-operating between different countries in joint research and information exchange activities, IA-HEV can play its 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 subsection (2.2.1) briefly reports on IA-HEV activities and results in its second term of operation (phase 2), and the strategy for the current term of operation (phase 3) can be found in subsection 2.2.2. Preparing the strategy for a fourth phase (2009-2014) of operation commenced in 2008, and first results are reported in subsection 2.2.3. Similar to last year's annual report, chapter 3 presents the IA-HEV clean vehicles awards.

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 hybrid vehicles had just been introduced on the market, and battery electric vehicles were

considered suitable for some market niches such as neighbourhood 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. The first hybrid car -the Toyota Prius- had just appeared on the market. 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. The value added resulted from collecting individual pieces of a puzzle and putting them together to provide the overall picture.
- Collecting the most recent developments and the latest news, often months before it was officially published. The value added resulted from the ‘freshness’ of the information.
- 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 value added resulted from the uniqueness of the information; it was not available from other sources or by other means.

In evaluating the results of phase 2, it may be stated that the objectives regarding production and dissemination of objective information were fully achieved to the level expected by members when they formulated them. The participating governments and organizations benefited most because they received all of the information and all of the value added, but the interested general public also had access -by means like the internet and annual reports- to a lot of the information that was produced.

The activities in phase 2 included the work in task forces (Annexes) that addressed:

- Structured information exchange and the collection of statistics (Annex I).
- Hybrid vehicles (Annex VII).

- Deployment strategies for hybrid, electric and alternative fuel vehicles (Annex VIII).
- Clean city vehicles (Annex IX).
- Electrochemical systems (Annex X).

The IA-HEV Executive Committee (ExCo) not only managed and co-ordinated the work of the Annexes, but was also actively involved in disseminating information and the ExCo produced the annual reports, newsletters, articles for technical journals and the website. The publications chapter in part E of this report presents the most important publications of phase 2. Many of them are available on the IA-HEV website: www.ieahhev.org.

The remainder of this subsection describes the achievements of each of the Annexes in phase 2.

Information exchange (Annex I)

The information exchange task force (Annex I) added value to information in the three ways described above, and in addition it structured and organised the exchange of information in order to make it more efficient and effective. The Annex had its own website, on which some information was available for the interested public, and the remainder was restricted to participants only. The Executive Committee (ExCo) decided that all participating countries in the Implementing Agreement should automatically be participants in Annex I, and the ExCo established financial arrangements to bring this about.

Hybrid vehicles (Annex VII)

During phase 2, the hybrid vehicle task force (Annex VII) studied both existing hybrid vehicles and the possibilities for the future. It published reports on the questions that are of greatest interest to central and local governments, including:

1. What are the current costs of hybrid vehicles, and what are the prospects for future reductions?
2. What are the advantages and disadvantages of the different types of hybrid vehicles?
3. What is the environmental performance of hybrid vehicles, and what is their fuel efficiency?
4. What are the market introduction issues for hybrid vehicles?
5. What adjustments do governments need to make in the testing, licensing, and taxing of hybrid vehicles?

These reports were initially restricted to participants in the task force, but after two years they were made available to the interested public by publishing them on the IA-HEV website.

Even to summarise the large amount of work done by the task force on many different topics would take many pages. Since the full information is available on the internet, only one of the most interesting findings will be reported here. The higher cost of hybrid vehicles is often cited as the principal market barrier, and Annex VII studied this subject. It found that absolute cost in itself is rarely the deciding factor for car buyers, after all the lowest cost cars represent only a small segment of the total market. In the medium and higher price brackets, the customer is willing to pay a higher price, and makes choices about what the extra money is for. Is it an attractively shaped car body, a prestige brand name, leather seats, a stereo, air conditioning or an innovative drivetrain? Convincing the customer to buy a hybrid drivetrain is more a marketing issue than it is an affordability issue. Evidently the reduced fuel costs and projecting the image of an environmentally responsible person are the main motivations. Marketing strategies and campaigns can build on these motivations to increase the market share of hybrid vehicles. At the same time, the higher costs of hybrid drivetrains can be expected to decrease in the future due to increased production volumes and improving battery technology, and so the importance of this barrier will gradually diminish.

Annex VII was at the forefront of hybrid vehicle technology and produced valuable reports for the participating automotive research organizations and their governments. It shared test results on hybrid vehicles that were introduced on the market, and explored some of the issues that governments will have to address in their automotive and environmental regulations. It also created and sustained a network of highly reputable automotive research laboratories throughout the world, and encouraged the sharing of information both within the scope of the task force and on other subjects.

Deployment strategies (Annex VIII)

The task force on ‘Deployment strategies for hybrid, electric and alternative fuel vehicles’ 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 effectiveness of policies, regulations and programmes.

Report of the deployment strategies task force

The report ‘Deployment strategies for hybrid, electric and alternative fuel vehicles’ provides to central and local governments a ‘menu’ of recommendations on the

market introduction of clean vehicles and fuels. The choices that are available and the advantages and disadvantages of each of the options are set out. The key ones concern taking a realistic approach to the market and the extent to which the government can influence it. It is also important to evaluate programmes during their implementation and upon completion, because lessons learned in one programme can save large amounts of money and effort if they are used in planning of future measures. The study pointed out that there is a serious problem with corporate learning in government programmes. Frequently, lessons from previous projects are not retained and used in planning of future projects, so that similar mistakes or weaknesses are repeated over and over again. There is relatively little sharing of experience among countries, so that one country repeats the mistakes made by another one some years earlier. These observations were followed by positive recommendations on how this can be improved.

Benefits to participants

The government officials and research organizations that participated in the task force obtained the benefit of working on this subject over a two year period, and fully absorbing the information collected, its analysis, and the conclusions that could be drawn. Those who were personally involved obtained a far greater depth of understanding than could be had from reading the final report. The meetings of the task force were opportunities for ‘corporate learning’, which had been identified as a key weakness in previous programmes. The team of experts developed excellent working relations and a strong network, which had been identified as an important ingredient in success. From an organizational perspective, this joint task force involving two Agreements demonstrated that co-ordination among IEA Implementing Agreements can be successful if there are common interests and objectives.

Clean city vehicles (Annex IX)

Cities in many developing countries are growing very rapidly and are experiencing the same or worse air quality and traffic problems as cities in IEA countries. At the same time, innovative solutions and technologies have been worked out in some developing countries, and there is a lot that IEA countries could learn from them. For example, the urban transit systems in Curitiba, Brazil, and Bogotá, Columbia, -so-called ‘Bus rapid transit’ systems- are efficient and relatively low cost. Another example is the ethanol fuel industry of Brazil, which is a world leader in this technology and which is now producing ethanol from sugar cane at a lower cost at the pump than gasoline, without government subsidy. The IA-HEV believes that both IEA countries and developing countries could benefit from an improved transfer of clean vehicle technologies in both directions, and also developing countries could benefit from information transfer among each other. Some development organizations

-such as the World Bank, the Asian Development Bank, and bilateral donors- are already working on this subject and have implemented a number of successful projects.

During phase 2, planning was initiated for a task force to study the application of clean vehicle and fuel technologies in developing countries (Annex IX). As part of the planning process, a highly successful workshop was organised in September 2002 in Paris, jointly with the IEA headquarters. The Swedish International Development Agency (Sida) generously contributed travel and accommodation funds to enable representatives from developing countries to participate. The countries represented included: Bangladesh, China, Colombia, Costa Rica, India, Indonesia, Kenya, Mexico, Nepal, Peru and Thailand. Representatives from Bangladesh subsequently travelled to Bogotá to learn about the ‘Bus rapid transit’ system there (the TransMilenio project), and they constructed a similar system in Dacca. This result was directly due to the workshop. The workshop concluded that some technologies that could benefit developing countries are:

- Ethanol derived from sugar cane, as is done in Brazil and Colombia. (It created more than 1 million jobs in Brazil).
- Bus rapid transit systems similar to the ones in Curitiba (Brazil) and Bogotá (Colombia).
- Electric bicycles (over 1 million units had been sold in China).
- Three-wheel electrically driven taxis (variously called rickshaws, tuk-tuks, tempo's) as used in Nepal.
- Improved infrastructure for non-motorised transport (pedestrians and bicycles).

The potential benefits of work in this area are substantive, but some barriers must still be overcome in order to make the task force operational. The main ones are that the scope of the technologies that are suitable for developing countries is much wider than the scope of the IA-HEV, and that the Ministries of Energy that participate in the IEA do not have a mandate for development assistance. Consequently, obtaining financial support for this work is complex. Efforts to overcome these barriers continue in phase 3.

Electrochemical systems (Annex X)

The electrochemical systems task force (Annex X) dealt with devices that can store electrical energy (batteries), provide extra power to vehicles (supercapacitors), and cleanly convert the energy in hydrogen to electricity (fuel cells). These are key enabling technologies for sustainable transportation.

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 participants in Annex X benefited mainly from the sharing of testing methods, as described above. 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.

2.2.2

Strategy for the third phase of operation, 2004-2009

There is consensus among IEA member governments on the four main energy and environmental goals for the transportation sector. These goals are:

- Improve urban air quality by reducing noxious vehicle emissions.
- Reduce the greenhouse gas emissions due to the transportation sector.
- Reduce dependence on fossil fuels.
- Increase the overall energy efficiency of the transportation sector.

Urban air pollution is still a source of public concern during the 21st century and continues to be important in many cities and countries. Climate change and greenhouse gas emissions have a high priority at present and are the focus of attention around the world.

The governmental objectives of improving air quality and energy efficiency -and of reducing greenhouse gas emissions and dependence on petroleum fuel- are as valid or even more valid today than they were years ago when IA-HEV started. Governmental programmes aiming at developing technologies to achieve these objectives have been remarkably successful during the past decade and have now brought us to a point where advanced vehicles are starting to enter the market. During the coming decade, the growth of hybrid electric vehicle sales, the introduction of electric vehicles and in a later stage the introduction of fuel cell vehicles will cause unprecedented changes to the automobile market, and this will have major economic, environmental, and energy implications for all IEA member countries.

The countries that are participating in the HEV Implementing Agreement have a combined vehicle fleet that represents a large share of the global vehicle fleet. Because of its links to the IEA and its member governments, the Agreement is in a unique position to collect, analyze, and distribute information from governments and other sources, and to add value to this information by assembling a global overview.

The IA-HEV Executive Committee has approved the formal objectives for the third phase, concerning the years 2004-2009:

- a) 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.
- b) To disseminate the information produced to groups and organizations that have an interest.
- c) To collaborate on pre-competitive research projects and related topics and to investigate the need for further research in promising areas.
- d) 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 emphasis during the third phase of the Agreement is on collecting objective general information on hybrid, electric and fuel cell vehicles. More specific information is collected in the subject area of each Annex. Priorities for topics to be addressed during the third phase are shown in box 2.3.

Box 2.3 Topics to be addressed in the third phase of IA-HEV (2004-2009)
<ul style="list-style-type: none"> • 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) • Renewable energies for HEVs & EVs • HEVs & EVs in mass transportation, and heavy-duty vehicles (Annex XII) • Electric bicycles, scooters and light weight vehicles (Annex XI) • HEVs & EVs for power correction or decentralised power production • Market aspects of fuel cell electric vehicles (Annex XIII) • HEVs & EVs for special applications • HEVs & EVs in developing countries • Recycling HEVs & EVs at the end of their operational life • Testing standards and new vehicle concepts • User acceptance of HEVs; barriers for implementation • Impacts of HEVs & EVs on industry and the economy

Participating countries, organizations and other target groups enjoy many benefits resulting from the third phase. According to its members, the added value of the IA-HEV contains a number of aspects that can be summarised as follows:

- **Bringing information from all over the world**

The members of this Agreement are countries from all parts of the world. Value is added by collecting information from all these countries and publishing it in one or more convenient and authoritative reports.

- **Knowledge transfer by networking meetings**

All IA-HEV Annexes organise expert meetings to exchange information. Again, value is added by bringing together information from several areas of expertise and exchanging it in a meeting or in written reports. There is also an interaction between 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 organised a first Transport Contact Group (TCG) meeting in March 2008, to further foster the collaboration between these seven IAs. IA-HEV actively participated in this TCG meeting and gained insights provided by experts from other IAs.

- **Use of the best public sector laboratories in the world**

Automotive research is done by vehicle manufacturers as proprietary research, and by laboratories and research organizations that are often partially government supported. The work of the Implementing Agreement is done by the most reputable and best known public sector institutes and laboratories in the member countries. These institutes usually have research contracts with industry as well as with the government. Their research services related to EV, HEV and fuel cell technologies are at the forefront of developments. By collaborating in international research studies, national governments can avoid national research of a smaller scope, and can have a cost reduction through pooling of resources. The added value of this working method lies both in the high quality of research studies, and in the lower costs for member countries (research by cost and/or task sharing).

- **Knowledge transfer among experts from member countries**

By bringing experts from member countries together at expert meetings, knowledge is transferred among them and working relations are created or strengthened. By co-operating in joint studies, a high powered and effective network is formed among the (national) experts. This enables them to follow the evolution of technology and market developments for the purpose of assessing the market maturity and possibilities for implementation of EVs and HEVs. Possibilities are available for exchange of personnel amongst laboratories, sharing of testing methods and protocols, and also improved access to e.g. testing equipment.

- **Knowledge transfer among governmental officials responsible for automotive research**

The delegates of the IA-HEV member countries are (national) experts in the field of EVs and HEVs, or specialist on specific areas of automotive technologies.

By meeting regularly and making joint decisions on the priorities and activities of the IA, they also exchange knowledge and form a network. This enables them to provide their governments with advice based on in-depth knowledge of international developments and on the state-of-the-art of the technology.

- **A well-informed overview of the future of automotive technology**

The technical literature and the internet provide only a small part of the overall picture of research and development in the automotive sector. Many industry and government activities are simply not written down or published. Through the organization of workshops with stakeholders and other meetings, participants obtain valuable information from presentations and from informal discussions. Such workshops are organised for knowledge export and knowledge import.

Liaison with industry, officials and the research community allows for the exchange of current data and information, and forms a vital part of the overall picture of the direction of the technology and of the activities of government and industry.

2.2.3

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

The third phase of operation will end in November 2009. Currently, worldwide the interest in hybrid-, electric- and plug-in hybrid electric vehicles to reduce energy consumption and emissions from road transport is strongly increasing. 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. This means that there is a sound basis for the continuation of the Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) after November 2009, and therefore during 2008 the IA-HEV Executive Committee (ExCo) has prepared a Strategic Plan for a new phase of the Agreement. This fourth phase is scheduled to run from December 2009 until November 2014. In 2009, the Strategic Plan will be presented to the IEA End-Use Working Party and to the IEA Committee on Energy Research and Technology, to ask for 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. Some Annexes that were active in phase 3 will continue in phase 4. Annex I on information exchange, Annex X on electrochemical systems and Annex XV on plug-in hybrid electric vehicles will certainly continue in phase 4. Other Annexes that are active until the end of phase 3 might continue their work in phase 4, depending on developments in society and interest for participation. Examples are Annex XI ‘Electric cycles’, Annex XII ‘Heavy-duty hybrid vehicles’ and Annex XIV ‘Market deployment of hybrid and electric vehicles: Lessons learned’. 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 to develop a new Annex are invited to contact the IA-HEV chairman, secretary or one of the country delegates to discuss the possibilities.

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 / 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 / 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

In chapter 12, section 12.2, the example of trolley buses as potential topic for a new IA-HEV Annex in phase 4 is explored in some more detail.

3

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 quickly turns 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 Awards be candidates from the region in which the World Electric Vehicle Association (WEVA) Electric Vehicle Symposium is being held. (It was held Europe in 2005, Asia in 2006, and the Americas in 2007; it was not held in 2008 but will be held again in Europe in 2009.) 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 2008 awards

The 2008 award ceremony took place at the Geneva International Motor Show in the booth of e'mobile Switzerland, surrounded by a variety of electric, hybrid, and

natural gas vehicles. At the time of the award ceremony in March, no hybrid or electric vehicle (EV) model had reached any of the target production numbers set in the regulations for the Clean Vehicle Award, so that award was not granted. The Best Practice award was given to Electricité de France (EDF) for its successful promotion initiatives to open the market for EVs and hybrid electric vehicles (HEVs). The Personal Award was given to Karl Kordesch (Austria/USA) for his decades of commitment to developing battery technologies for electric, hybrid, and fuel cell vehicles and pushing their production. Details on the awards follow here.

3.3.1

Best Practice Award for Electricité de France

EDF has been an active participant in efforts to develop an EV industry and market in France since the ‘Accord-Cadre sur le Developpement du Véhicule Electrique’ was signed in 1992 by the French Ministries of Industry and Environment, EDF, PSA Peugeot Citroën, Renault, and the Groupe Interministériel Véhicules Electriques. EDF first felt responsible for the recharging infrastructure, but then it also became a partner in rental and EV-sharing projects like ‘Praxitèle’ in La Rochelle. In France, more than 6'000 EVs are in use, mostly in communal or utility fleets. In addition, more than 9'000 hybrid vehicles had been licensed by the end of the year 2007. And although the French automotive industry has been reluctant to continue the production of electric and hybrid vehicles, EDF has continued to push their development, especially vehicles that would be useful for city administrations (such as small buses or utility vehicles for street cleaning or waste collection).



Fig. 3.1 On behalf of EDF, Gilles Furet receives the Best Practice Award.
(Photo: Muntwyler.)

EDF co-founded BatScap (subsidiary of the Bolloré Group) to develop and demonstrate lithium metal polymer batteries and run the first fleet tests. It is committed to the development of electric light trucks (3 to 30 tons), the target being to enable a shift to environmentally friendly goods and service deliveries within cities. And in 2006, EDF and Toyota started a programme for testing Toyota Prius cars that were converted to plug-in hybrid vehicles (PHEVs) by Toyota. The vehicles were integrated into the EDF fleet so experience in their everyday use could be gained. In addition, EDF has developed advanced charging systems that facilitate the operation of public charging stations where EV users pay for the electricity they draw.

The above information describes only a portion of EDF's commitment to electric transportation, which also includes support of electric rail and trolley vehicles and industrial vehicles.

3.3.2

Personal Award for Karl Kordesch (Austria/USA)

Karl Kordesch may not be that well known in the EV community, but he is very well known in the community of electric energy storage specialists. After studying in Vienna, he worked on developing batteries for almost 20 years, most of the time with the Union Carbide Corporation. He invented the alkaline primary battery cell, which now holds the greatest share in the primary battery cell market. In addition, he was one of the first people to develop fuel cells. In 1966, his group had already built a 150 kW alkaline fuel cell for GM's 'Electrovan'. Kordesch himself drove a fuel-cell-powered motorbike, and in 1970, he built an alkaline fuel cell hybrid vehicle on the basis of an Austin A40, with the hydrogen tanks on the roof of the car (figure 3.2). Since that time, he has believed that the future car will have an electric motor with a smart energy storage device that is either a battery or a fuel cell.



Fig. 3.2 Karl Kordesch on his fuel cell motorbike in 1970 (left); converted Austin A40 with hydrogen tanks on the roof (right). (Photos supplied by Muntwyler.)

Kordesch became the head of the Institute of Inorganic Technology and Analytic Chemistry of the University of Technology Graz in 1977. His knowledge and experience not only encouraged hundreds of students but also served battery manufacturers and applicants like the European Space Agency (ESA). He was part of the further development of the alkaline fuel cell into today's MARS fuel cell, a direct methanol fuel cell that eliminates the need for a reformer.

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

4**Information exchange
(Annex I)****4.1****Introduction**

Maintenance of a forum and facilitating platform for 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 has been a cornerstone of the Implementing Agreement in all three of its phases. To this function was assigned the first designation (Annex I) as an official task force of the Agreement. Any member country of the Implementing Agreement automatically becomes eligible for membership of 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 is entitled to voting representation at each meeting by a designated country expert.

The responsibility for the week-to-week affairs of the Annex is co-ordinated 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 force (Annex) 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). Because of recent technological developments, it is expected that a subset of one or more of these categories will soon include a plug-in hybrid form able to obtain at least twenty percent of its operation range from purely electric power delivered from charging off of the AC transmission grid or from renewable local installations including wind and solar 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 this EV and HEV information within respective nations is carried out by the country experts, who then make it available to other members at both experts' meetings, held generally once annually in conjunction with meetings of the IA-HEV Executive Committee, and through the IA-HEV website (www.ieahev.org), on which data may be updated more frequently. The Operating Agent (OA) is responsible for co-ordinating these activities, maintaining the IA-HEV website, and contributing to 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 the 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 (figure 4.1). These presentations generally cover developments since the previous meeting in the respective statistical and market situations for EVs and HEVs (national sales and fleet penetration, by vehicle type); the progress of international, governmental, 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. On occasion, special topics with a common focus will be an agenda item, such as at the autumn 2008 meeting of Annex I in Vienna, Austria, where delegate country experts presented a compendium of national and regional taxation policies among the member countries that specifically target and encourage -or not- the growth of electric propulsion.



Fig. 4.1 Annex I experts and guests convene in Vienna, Austria, October 2008. (Photo: C. Saricks.)

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 posting on the website 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, but has frequently included experts on local activities invited to discuss these programmes and sit in as observers. For example, guests from Japan, New Zealand and Spain presented informative updates on activities related to electric propulsion in their respective countries at the autumn 2008 meeting.

4.4

Results

Twenty-seven 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 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 is expected to be issued for the duration of phase 3 and possibly into phase 4; this approach eliminates 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 Operating Agent eliminates considerable duplication between the two predecessor sites. It also facilitates the presentation of HEV information to a broader audience spanning the various Annexes, the Executive Committee and interested persons within the International Energy Agency. A product of this broader outreach effort is the 'Expanding HEV universe' feature on the news page of the website which -on a monthly basis- recapitulates for a lay audience recent developments of interest in the area of electric and hybrid vehicle technologies and policy.

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 will continue during 2009. Access to proprietary data and other 'late breaking' information will be limited to participating members as an inducement to non-member countries to join the Agreement. Items from both member and non-member nations may be

posted. In addition, the Annex I Operating Agent expects to be able to 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 are highlighted and up to date.

4.6

Contact details of the Operating Agent

Argonne National Laboratory is the Operating Agent of IA-HEV Annex I. Your contact person there is:

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5

Clean city vehicles (Annex IX)

5.1

Introduction

Urbanization is occurring very rapidly in many developing countries at all levels of the income scale. Today, China and India are striking examples spurred by their rapid economic growth. More and more cities around the world are passing the 1 million population mark and even the number of cities with more than 10 million inhabitants is increasing steadily. In many of these cities air quality is a serious problem that affects the health of all their inhabitants, and traffic is often an important contributor to this pollution.

There are also economic reasons for introducing alternative transportation technologies in developing countries. Some of these countries spend more than 50% of their very scarce foreign exchange on importing cars and fuels. If such countries could substitute imported oil by -for example- locally produced ethanol fuel or electricity, it would have important economic benefits.

These are the reasons why the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) has been addressing the topic ‘hybrid and electric vehicles in developing countries’ for several years. Annex IX was created to contribute to the mitigation of the problems that are mentioned above. The Annex is in its identification phase, which means that the final work plan still has to be established and that the Agreement is seeking participants. The relevance of the Annex has already been proven by a highly successful workshop at the IEA (International Energy Agency) headquarters in Paris. Important results from that workshop are included in this chapter.

5.2

Objectives

The purpose of this Annex is to exchange information among cities around the globe on how to reduce air pollution from road traffic. For those cities that are suffering from this problem, learning from each other’s experiences helps in choosing adequate measures and effectively implementing them. To achieve this goal, the Annex aims to create a network of persons and organizations in developing and industrialized countries that have experience with innovative solutions for traffic problems, who will co-operate in high priority projects that meet urgent transportation and air quality needs of particular cities or countries.

5.3

Working method

As a first step in the work of this Annex, Mr. Tommy Måansson (EnEN AB, Sweden) -on behalf of IA-HEV and together with the IEA headquarters- organised a workshop on ‘Clean city vehicles’ in Paris, in September 2002. The Swedish International Development Agency (Sida) generously contributed travel and accommodation funds to enable representatives from developing countries to participate. The countries represented included: Bangladesh, China, Colombia, Costa Rica, India, Indonesia, Kenya, Mexico, Nepal, Peru and Thailand. The workshop was highly successful and that proves that it would be fruitful to organise similar workshops in the future.

This kind of workshops would be a major constituent of this Annex, because they are scheduled to bring about two types of activities:

- (1) People and organizations from cities with traffic related air quality problems meet others who have found solutions for these problems under similar circumstances. They can team up to solve the problems efficiently, taking future traffic growth into consideration, so the co-operation is fruitful for all parties involved.
- (2) The identification of topics that are of general interest for everyone involved in reducing traffic related air quality problems, and forming teams to address these topics. The work of these teams should contribute to making the changes that are needed happen.

IA-HEV can play a facilitating role in both kinds of activities. The specialists working in the Agreement can contribute with their knowledge and with their network of contacts in the field. Also the results of Annex VIII on deployment strategies for clean vehicles can be used in Annex IX.

5.4

Results

The Paris workshop clearly demonstrated the added value of discussing the topic in a group of people with different backgrounds. In addition to the results that the workshop was aiming for, other valuable outcomes emerged. Some of the results of the Paris workshop are highlighted here to show what kind of unexpected outcomes may emerge, and to illustrate both types of activities that are mentioned above in the ‘working method’ section.

An eye opener was that in many areas of the transportation sector the developing countries are in fact ahead of the industrialized ones. The ‘Bus rapid transit’ systems in Bogotá and Curitiba are world leaders. Brazil is a world leader in the use of

ethanol as a transportation fuel, and Argentina is leading in the conversion of vehicles to CNG. China is world leader in the use of electric bicycles. Over 600 electric three-wheel passenger vehicles ply the city streets in Kathmandu, Nepal, mainly as taxis. Many cities in developing countries have a system of communal taxis or small vans that is highly energy efficient and low cost. There is a large potential for replicating this kind of success stories of one city or country to another.

A success story of a type (1) activity (see section 5.3) is the plan to study a ‘Bus rapid transit’ system for Dhaka in Bangladesh. After the Paris workshop, Annex IX arranged for city officials from Dhaka to visit the TransMilenio bus rapid transit system in Bogotá, Columbia, with the financial support of the Swedish International Development Agency (Sida). Because of this visit, the officials from Dhaka have now set up a task force to study the possibility of constructing a similar bus system in their city.

An important general topic (see (2) in section 5.3), which was recognised by the participants in the Paris workshop to be a challenge for everyone, is how to bring the necessary changes about. Many types of clean vehicles are available on the market, but it appears to be difficult to actually get a significant number of these vehicles on the road. The workshop came up with a four-step approach to solve this problem:

1. It was generally agreed that the first step should be to raise public awareness, and to provide information for mayors, city councils, and central governments so that they give a high priority to improving urban transportation and cleaning up the air. Among the most effective ways of convincing urban decision makers is to bring them in contact with other cities that have successful projects, and to let them speak to all those responsible for it. This should be backed up by evaluation studies that discuss what went right and what went wrong with the project. The internet can also be a useful source of information, but it does not have the same impact as printed documents or face-to-face meetings.
2. The next step is institution building, changing laws and regulations, educating stakeholders, training managers and technicians, and establishing or changing the organizations that will be responsible for enforcing the new regulations and introducing and maintaining the new technologies. Donor organizations can play a very positive role during this phase by providing information and analysis of practical experience, good practice guides, evaluation studies of other similar projects, training of personnel, information exchanges among regulators, etc. The networks that have been formed among cities in South America and Asia are good examples of how institution building can be supported.

3. The third step is to implement projects and programmes, such as conversion of engines, construction of public transit projects, enforcement of emission regulations, etc. Often a pilot project is done first, before moving to full-scale implementation. Projects need to be financially viable, even after the completion of eventual donor involvement. An exchange of information among cities with pilot projects can also be very useful, because it allows for success stories to be replicated and for failures to be avoided.
4. A last step is to do evaluation studies of projects and programmes and to disseminate the results widely. For example, the TransMilenio project in Bogotá or the ethanol industry in Brazil are highly beneficial for those countries and by making a video available or by maintaining a website other cities in dozens of other countries can become aware of these opportunities and they can use some of the ideas themselves.

5.5

Further work

The workshop and follow-up meetings have shown that there would be strong advantages to creating a world-wide network of persons and organizations working on urban transportation issues. Innovative solutions for air quality and transportation problems have been found in many different cities throughout the world, and a lot could be gained by a better exchange of information and experience. The network would be somewhat exceptional because innovation would very much flow in two directions, from the developing countries to the IEA countries as well as in the other -more usual- direction. An improved innovation flow between developing countries would also be very beneficial.

The scope of workshops aiming to reduce mobility problems and air pollution cannot be limited to HEVs, but should include other technologies -for instance renewable energy and transport systems- as well. Some of these technologies are covered by three different IEA Implementing Agreements (Hybrid and Electric Vehicles, Advanced Motor Fuels, Bio-energy) whereas others are not covered by any Implementing Agreement (for example: bus rapid transit systems, non-motorized transport). However, challenging forms of co-operation within the IEA seem to be possible.

During its third phase of operation, IA-HEV will continue its efforts assisting developing countries with their mobility and air quality problems. The scope for technology transfer to non-IEA member countries is very large, but at present efforts in this direction are limited by a lack of financial resources. More parties need to be

involved, both inside and outside the IEA. Work for the International Energy Agency (IEA) is usually financed by Ministries of Industry and Energy. These ministries generally do not have a mandate to finance development assistance. Obtaining financial support of government development agencies is one option to create a broad basis for the continuation of Annex IX.

A wide range of organizations is necessary to make the workshops of this Annex successful and is also required to create a sufficient financial base for a sustained continuation of the work. Developing countries, donor organizations, multinational companies and other interested organizations are invited to participate in this Annex. Participants have a voice in the topics that will be addressed, they can contribute to the success of the Annex and they are the first to profit from the results.

5.6

Contact details

Organizations that are seeking further information or that are interested in participating in Annex IX are invited to contact the IA-HEV chairman or the IA-HEV secretary. IA-HEV contact information can be found in part E of this report.

6

Electrochemical systems

(Annex X)

6.1

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.

6.2

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.

6.3

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 was represented at several major technical meetings during 2008, including the Advanced Automotive Battery Conference, the First International Conference on Batteries for Automotive Applications, and the Power and Energy Workshop. An Annex X working group meeting on the world's supply of lithium was held in Charlotte, North Carolina, USA in early December 2008. This location was chosen because Charlotte is the home of two of the world's major lithium companies.

6.4

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 decision to hold the workshop was prompted by the fact that there has been extensive discussion about whether there is enough lithium in the world to allow the use of lithium-ion batteries in a significant number of hybrid electric vehicles (HEVs), PHEVs and electric vehicles (EVs). Some of the discussions that suggested that the world's supply of lithium was not sufficient were available on public internet sites, but many negative comments were made in informal settings. Examples that were mentioned to the Annex X Operating Agent included a venture capital company who questioned a battery company's business plan because "there would not be enough lithium to make a significant number of batteries". In another meeting, a company marketing a non-lithium battery asserted that their technology should be adopted because "the world was going to run out of lithium". 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), MaxPower (USA).
- Vehicle manufacturers: GM (USA/global).
- Battery recycling industry: RSR Technologies (USA/global).

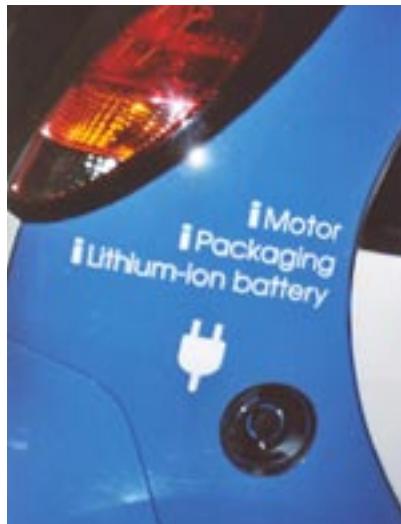


Fig. 6.1 Car manufacturers are counting on lithium-ion batteries for their near future electric vehicles. Can sufficient lithium be made available to meet the anticipated demand? In December 2008, IA-HEV Annex X has organised a workshop on the world's supply of lithium to answer this question. Shown here is the charging plug connector of the Mitsubishi iMiEV electric car. (Photo: S. Kleindienst.)

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.

6.5

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.

6.6

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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7

Electric cycles (Annex XI)

7.1

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 become a key issue. City governments have to take a wide range of measures, including the improvement of public transport, facilitation of non-motorised 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 inhabitants are not affected and they 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, they do not cause pollution and they do not make noise. They are therefore perfectly suited to replace specific short vehicle trips.

Regarding the energy issue, electric two-wheelers are champion in two ways. First, they reduce energy consumption compared to other transport modes, and second they can also run on renewable energies. So why then are they not more seen on the roads? One of the main reasons is that some important actors are not sufficiently committed. The overlap of the three majors actors -users, industry and governments- does not work in a satisfying way. First to be mentioned are the potential customers. They just misjudge the benefits of these vehicles. In addition, importers and dealers are not prepared to engage in active marketing efforts. Secondly, authorities at national and local levels may recognise the benefits, but they obviously cannot take leadership in market introduction. Last but not least are the manufacturers -the supposed leaders in market introduction- that seem to have insufficient insight in the market systems. A probable reason is that 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 it is essential that 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 take off.

7.2

Objectives

The objectives of this Annex are to identify barriers that so far 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 energy saving potentials to justify governmental support.
- Recommending market introduction strategies directed at manufacturers, importers and dealers, as well as to 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).

7.3

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 on electric and hybrid drive systems for 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 took 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 is coming to an end and more work should be done to further integrate electric two-wheelers into existing transportation systems. Therefore plans for a second phase of this Annex are being developed.

7.4

Results

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

- 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, inducing a very 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 I, 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 optimise investments by manufacturers, particular attention was paid to identify the elements of highest leverage, i.e. the bigger customer satisfaction increase for the lowest investment, while also highlighting the main technological constraints.

Phase I is now coming 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, ...).
- 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,
 - 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.

7.5

Further work

Urban transport is more and more 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.

Starting from the observation that most of the two-wheeler conferences and trade-shows are mainly marketing oriented and nothing is provided in terms of scientific discussions on electric propulsion, the task force has decided to launch an international conference on this topic. This will enable the numerous specialists in the field to meet each other on a regular basis and to join forces for the promotion of the technology.



Fig. 7.1 E-scooter day in Berne, Switzerland, August 21, 2008. (Photo: U. Schwegler.)

The electric cycle is clearly crucial for a 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 open to be reinforced by additional partners, to become an as large as possible permanent exchange platform.

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

- structure the related information and to become premier reference source for electric cycles,
- organise dedicated workshops that focus on topics like batteries, safety, efficiency, drivetrains, standards, ... ,
- work on the popularization of electric cycles,
- educate consumers, dealers, industry and authorities,
- organise education meetings with dealers and other interested parties.

7.6

Contact details of the Operating Agent

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

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8

Heavy-duty hybrid vehicles (Annex XII)

8.1

Introduction

The gap between the more general approach of Annex VII on hybrid cars and the diversity of heavy-duty vehicle applications was recognised by some members of the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV), and therefore an Annex focusing on heavy-duty hybrid vehicles was initiated. This Annex was approved at the IA-HEV Executive Committee meeting in October 2006. The work of Annex XII has formally started on January 1st, 2007 and is scheduled to end on November 30th, 2009, which is at the end of the third operating phase of the Agreement.

8.2

Objectives

At first, this Annex aims to report the current status of the heavy-duty hybrid vehicles ‘playing field’. Next to a general description of the heavy-duty hybrid vehicle situation, the status report will focus on the available as well as emerging hybrid vehicle technologies, and on the market situation and trends. To collect and organise 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. At all levels 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.

Based on existing experience and insights, possibly successful hybrid vehicle applications are being identified in the second subtask. For each of these applications the expected optimal configuration will be explained. A more in-depth approach may involve simulations to back performance expectations and identify which technology/configuration combination best fits each application.

In the third subtask, this Annex studies the application area of hybrid technology for heavy-duty vehicles. First the current situation of existing hybrid prototypes and standard vehicles is investigated. The information gathering focuses on the

applied technology, as well as the costs and the merits in a broad sense. In this way it complements the first subtask.



Fig. 8.1 Hybrid bus in France. (Photo: M. van Walwijk.)

The third subtask also aims at increasing 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, ...) 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. Today in many heavy-duty applications the gearbox PTO (power take off) of the powertrain is used to provide power for auxiliary systems. In most cases, this is a cheap but energy inefficient solution. Here hybrid vehicle technology may provide a solution that is more energy efficient. When considering other benefits like lower emissions and noise levels, the advantage of choosing a hybrid version becomes more apparent. In this way the barrier to switch to hybrid vehicles for these applications can be lowered.

8.3

Working method

After the kick-off meeting, the Operating Agent organizes two expert meetings per year, predominantly in participating countries. Each meeting includes 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.

To increase the attractiveness of participating in the Annex, the Operating Agent prepares papers and presentations dealing with the contents and the results from this Annex to be presented at relevant conferences. The preparation of papers summarizing the whole topic or highlighting certain aspects is on a voluntary basis, but should be encouraged. By publication in international journals and presentation at conferences, the Annex as well as the Implementing Agreement gain exposure to a wider professional public.

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 subtask and complete the respective reports.

All participants in the Annex take part in the information exchange concerning the other objectives and subject areas, participation and contribution are on a voluntary basis. Additionally, the Operating Agent gathers general information about heavy-duty hybrid vehicles and distributes it to the Annex participants. The collected information will also be structured in a report.

Each subtask annually produces an internal report for the Annex participants. The subtask reports as well as other documents are accessible for the members through the Annex XII website (www.vito.be/ieahhev). By using a document management system, the exchange of working documents, final reports and other information is enhanced.

The papers and presentations are public matter once 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. Therefore they 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.

8.4

Results

Five expert meetings have been organized and successfully executed so far (see box 8.1). The first expert meeting in San Diego was combined with a heavy-duty hybrid vehicle workshop. One of the 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.)

Box 8.1 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

Below is a listing of the information that has been collected and reviewed during the execution of the different subtasks, associated with specific action items.

Subtask I: Heavy-duty hybrid vehicle technologies.

- Overview systems - heavy hybrid vehicles (bus and niche applications).
- Overview components (batteries, supercapacitors).
- Overview configurations (series, parallel, idle-off).
- Presentation and reports from NREL have been secured.
- Information from the Hybrid Truck User Forum.
- Description/classification of heavy-duty vehicles in the USA.
- Types of hybrid technologies.
- Review of the heavy-duty hybrid vehicle market in the USA.
- Feedback of demonstration projects worldwide.

Subtask II: Heavy-duty hybrid vehicle market situation, trends and potential.

- Overview and update of current trends and market perspectives of heavy-duty hybrid vehicles worldwide.

- Definition of scope, vehicle categories.
- Current situation hybridization of heavy-duty vehicles.
- Vehicle supply, manufacturers.
- Future developments in heavy-duty hybrid vehicles.
- Market deployment of heavy-duty hybrid vehicles.
- General public's opinion: "Several hybrid prototypes have been developed, but why is there hardly any series production?"
- Requirements for the hybridization of heavy-duty vehicles.
- Several papers/presentations have been provided.

Subtask III: General information gathering and dissemination.

- Overview and update of current trends and cases of heavy-duty hybrid vehicles worldwide.
- Review draft proposal on EURO VI from the EC.
- Review presentation of the IEA workshop on 'Fuel efficiency of heavy-duty vehicles'.
- Update dedicated website.

Belgium, Canada, the Netherlands and the United States are participating in this Annex since 2007. Finland has joined Annex XII in 2008.

8.5

Further work

New expert meetings to bring the work in this Annex further will be scheduled for 2009. 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.

8.6

Contact details of the Operating Agent

Research institute VITO is the Operating Agent of this Annex. For more information about this Annex or in case of comments/questions please contact the Operating Agent at the following co-ordinates:

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9

Fuel cells for vehicles (Annex XIII)

9.1

Introduction

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

Fuel cells offer a number of interesting options for the vehicle design. Fuel cells are not limited by thermodynamic restrictions of combustion processes. Therefore they offer 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 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 invest strongly in the development of this technology (figure 9.1).



Fig. 9.1 Daimler's vision on the pathway to fuel cell vehicles. (Photo: K. Maruo, edited by A3PS.)

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 like 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. On the other side, more restrictive emission standards

will raise costs for aftertreatment of internal combustion engine emissions, thereby improving cost-competitiveness of fuel cell vehicles.

Fuel cells are a highly relevant technology for an Implementing Agreement dedicated to hybrid and electric vehicles, as they complement battery or other energy storage devices by silent, clean and efficient energy conversion technology with the capability to substitute the noisy, polluting and poor efficiency internal combustion engine. An ‘all-electric vehicle’ will exploit the full potential of the electric drivetrain. The recuperation and peak power capacity of batteries and supercapacitors nicely complements the efficient base load capability of fuel cells.

9.2 Objectives

The different types of fuel cells currently under development dispose of an extreme variety of technical properties. Therefore a thorough analysis of all kinds of fuel cells regarding their potentials to fulfil 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 will enable its participants to investigate new and innovative combinations of energy storage and energy conversion technologies. The Annex will enable 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 specific demands for power, cost, lifetime and range of vehicles powered by fuel cells, batteries and all kinds of hybrid solutions are the main reason to run this Annex on ‘Fuel cells for vehicles’. Nevertheless, the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) aims for strong ties and co-operation with the IEA Implementing Agreement on Advanced Fuel Cells (IA-AFC).

IA-HEV Annex XIII concentrates its activities on tuning fuel cell properties 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 be an interesting intermediate step for the 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.



Fig. 9.2 Impression of the Honda FCX Clarity fuel cell car. (Photo: K. Maruo, edited by A3PS.)

This Annex concentrates on polymer electrolyte membrane (PEM) fuel cells as dominating fuel cell technology for vehicles today, but will it analyze the potential of other fuel cell types as well. Since many scientists believe 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 issue of specific importance for the transport sector is the quick cold start capability. On the other hand, overheating can threaten the performance of fuel cells and batteries. Therefore thermal management of fuel cells and batteries 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 several fuel options like hydrogen, methanol or even liquid fossil fuels for solid oxide fuel cells (SOFCs) are being investigated, taking the specific limitations of a mobile application in vehicles into account.

A special added value of this Annex is analyzing 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 minimise development risks, the Annex also addresses components that offer multiple benefits for other areas of technology (such as efficient electric motors), regardless of the success of fuel cells.

9.3

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. The risk to overlook regional technological trends or results in the global development process is much lower in this international co-operation than in single country investigations.

This shared activity allows combining the strengths of different partners in a co-ordinated R&D process. The huge task of changing the transport system surpasses the resources of even the biggest countries or companies. Therefore the international split of labour not only saves large amounts of money to the participants, but it also saves a lot of time by developing tasks in parallel and by assigning responsibilities to partners with the highest expertise related to a specific problem. IA-HEV and its Annex 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 facilitates their decisions on how to organise 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 (IA-AFC) has already been established. The co-operation on one hand ensures that information and knowledge from fuel cell experts is integrated into this Annex and on the other hand avoids duplication of work that is 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 like the technology platform ‘Hydrogen and fuel cells’ of the European Union. Ongoing international trends in regional activities are also monitored within this Annex.

9.4

Results

In November 2006, the IA-HEV Executive Committee has formally started Annex XIII. The Annex started 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. Resources of each partner in this Annex are limited, and therefore a focused work plan with a limited number of topics was created. These topics are:

- The fuel cell vehicle system.
- Hybridization.
- System integration and behaviour.
- Cross cutting issues (especially in collaboration with IA-AFC Annex XX).

There is common interest on these topics among all participants. A deeper look into these issues might also bring a new and comprehensive understanding of commercial scenarios for hybrid and electric vehicles when entering the mass market.

Two IA-HEV Annex XIII expert meetings were held in 2008. The first expert meeting and a separate workshop on cold start behaviour of fuel cell vehicles were organised in parallel to the Geneva International Motor Show and the International Advanced Mobility Forum (IAMF) in March 2008.

All participants of the ‘cold start behaviour’ workshop appreciated the open and interesting discussion on this topic. The background of the participants was a well-balanced mixture of research and industry institutions. The main conclusions of this workshop are:

- A lot of work on degradation mechanisms of components due to freezing has already been done, and the degradation models are suitable for special applications.
- More basic research in the area of membranes, catalysts, stack design and degradation mechanism 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.).

During the second 2008 expert meeting in November at NREL (Golden, CO, USA) the structure of the final report was discussed. 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 technological relevant issues, it will be important to address vehicle components such as the fuel cell as well as the whole system.

9.5

Further work

At least two expert meetings are planned for 2009. Additionally, a workshop on the current status of fuel cell vehicle technology and worldwide demonstration and deployment activities is scheduled for this year.

Further, to collect input for foresight analyses of future options and opportunities of integrating fuel cells in vehicles overcoming their limitations by hybridization on a smoother and quicker timescale, questionnaires, personal interviews and several workshops with industry (inside and outside automotive companies, academia, user organizations, technology and innovation policy experts) are planned for the future.

9.6

Contact details of the Operating Agent

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10

Market deployment of hybrid and electric vehicles:

Lessons learned

(Annex XIV)

10.1

Introduction

Electric vehicles made a comeback in 2008. Major world events are pushing this comeback: oil prices soared to over 150 dollars per barrel. For the first time in a generation, Americans with big vehicles found themselves paying US\$ 100 to fill their gasoline tank. Sales of small economical and hybrid vehicles rose, while big vehicles sat on lots. Additionally, the world's scientists issued increasingly stern warnings of increased global warming. Europeans began pushing hard to reduce the CO₂ per kilometre of vehicles and Americans reconsidered their resistance to higher CAFE fuel economy standards and began new energy planning anticipating a new presidency.

This year almost every major vehicle manufacturer announced their intention to develop or manufacture electric vehicles (EVs). EVs have been at every car show. Notably, Nissan and a new partner 'Project better place' announced innovative EV deployment efforts in Israel, Denmark, Portugal, San Francisco, Australia and Toronto. Mitsubishi announced plans to deliver several thousands of their electric car iMiEV to fleets in the U.S. and Japan. Several national and regional governments announced new incentive plans, for example the United States announced tax credits for 250'000 battery powered vehicles. General Motors, who had formerly 'killed' the EV1 electric car program, has made the Chevy Volt (a decidedly EV like hybrid car) its most public development program. The Olympic games in Beijing featured electric buses. Later, the Chinese government announced a broad set of electric vehicle initiatives, including a plan to deploy thousands of EVs in ten major Chinese cities. Hardly a week passed in the latter half of 2008 without an announcement of a major deal by battery makers. Indeed, in December 2008 there were billions of dollars in battery company buyouts, investments, and marriages between automakers and battery makers.

Finally, the year closed with a tumultuous crash of the credit market, and sales of vehicles worldwide plunged as much as 30-40%. Hit hard by both high gasoline prices and the credit crunch, American automakers looked as if they might not survive the next year. As the roller coaster continued, the crude oil price plummeted to US\$ 40 per barrel in December, the lowest level in 7 years, as a result of world economic depression.

And during this tumultuous year, the ‘Lessons learned’ Annex travelled the world, speaking with veterans of previous EV deployments in California, Geneva, Tokyo, and Stockholm, seeking out lessons learned in previous deployments. It was an interesting year.

10.2 Objectives

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



Fig. 10.1 Parking with option to recharge electric vehicles. Why do we see so little of these signs along the road? What needs to be done for future deployment? IA-HEV Annex XIV is designed to capture and report important lessons learned in past deployments of electric vehicles. (Photo: M. van Walwijk.)

10.3 Working method

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

- Workshops in former deployment areas (United States, Switzerland, Sweden, Japan, England) that bring together experts from these regions with a range of experiences and perspectives on the lessons they have learned so far in the deployment of electric and hybrid vehicles. These will include those with experience in 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 and other material will be evaluated.

During 2008 the main researchers from IA-HEV member countries in Annex XIV were:

- Björn Budde, Systems Research, Austria.
- Sigrid Kleindienst, Muntwyler Energietechnik AG, Switzerland.
- Kanehira Maruo, ETC Battery & FuelCells Sweden AB, Sweden.
- Danilo Santini, Argonne National Laboratory, USA.
- Tom Turrentine, Operating Agent, University of California at Davis, USA.

Box 10.1 presents an overview of the seven workshops that have been organised to date, and box 10.2 lists the participants in these workshops.

Box 10.1 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	Gothenburg, Sweden.	September 19, 2008
7	Stockholm, Sweden.	September 22, 2008

Box 10.2 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
James Barnes, US Department of Energy.	1 2 3
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
Andrew Burke, University of California, Davis.	4
Tom Cackette, CARB, presided over the 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
Hans Folkesson, the Swedish Hybrid Vehicle Center.	6
Yuichi Fujii, former president of Panasonic EV Energy.	5
Masato Fukino, Nissan.	4
Bernt Gustafsson, Swedish Energy Agency.	7
Tomohiko Ikeya, CRIEPI.	4
Professor Ishitani, Keio University.	4
Bengt Jacobson, Volvo Car Corporation.	6
Marie-Loise Karlsson, Embassy of Sweden.	4 5
Magnus Karlstrom, Hydrogen Sweden.	6
Peter Kasche, Swedish Energy Agency.	7

Box 10.2 (continued)		Workshop no.
Participants in IA-HEV Annex XIV workshops		
Edward Kjaer, EV deployment veteran, Southern California Edison.	2	
Sigrid Kleindienst, Muntwyler Energietechnik AG, Annex XIV.	1 2 3 4 5 6 7	
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	
Akiteru Maruta, TECHNOVA.	5	
Arno Mathoy, Brusa Electronics.	3	
Takeshi Miyamoto, Nissan.	4	
Urs Muntwyler, IA-HEV chairman.	1 2 3	
Mr. Ono, President & CEO Tokyo R&D.	4 5	
Marco Piffaretti, Managing Director, Protoscar.	3	
Hans Pohl, Vinnova.	6 7	
Danilo Santini, Argonne National Laboratory.	1 2 3 4 5 6 7	
Chelsea Sexton, a front lines EV1 sales person for GM.	1 2	
Joachim Skoogberg, Fortum Markets AB.	7	
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	
Dr. Yaegashi, Toyota.	4	
Sigvard Zetterstrom, Royal Institute of Technology, Stockholm.	6	

10.4

Results: Lessons learned

The workshops have resulted in the compilation of practical lessons for future deployments in the area 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 result 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 a few of the lessons collected so far:

Lessons about manufacturing and deploying EVs

- Automaker participants shared a number of important lessons, including the need to protect EV R&D programs from market ups and downs.
- Automakers needed to develop closer partnerships with power utilities, and understand the utility business better.
- EVs required much more consumer education, and OEMs must make better use of 'pioneer' communities of drivers to assist in that marketing effort.

Lessons from power utilities in regards to assisting and organizing deployment, with a focus on recharging networks

- Some utilities over-marketed EVs at the beginning, leading to too high expectations by consumers.
- Utility was ignorant of the automotive business, in particular the competitive aspects.
- Too much money was spent on public recharging infrastructure relative to the deployment scope. Expensive public recharging often added little value to deployment and incurred high maintenance costs.
- The addition of qualifying and installing recharging equipment in homes impaired sales and leasing processes. Additionally, home charger systems were over-subsidised.

Lessons from governments about regulating and encouraging EV deployment

- It proved difficult for regulators in California to justify the requirement of electric vehicles when the potential air quality impacts of demonstrations and early markets would be negligible. In particular, low speed and other niche markets of EVs do not have enough impact to regulate.
- But regulatory and other EV deployment efforts resulted in research investments, particularly in battery research.

- Additionally, the electric vehicle regulation encouraged vehicle makers to develop other technologies, notably partial zero emission vehicles (PZEVs) in California, and hybrid vehicles, which had very large impacts on emissions and efficiencies.

Lessons from academic and other research groups about markets for EVs

- Providing solid information about potential markets for EVs has proven to be difficult, requiring innovations in market research methods and acceptance of much uncertainty.
- Markets for EVs will be shaped by specific geographical variables related to the regional production of electricity, urban or road design, and local lifestyles (commute distances, activity and recreation opportunities).

10.5

Further work

The second year of Annex XIV will continue to collect lessons learned, including at least three more workshops, in Eastern North America, England and Canada, as well as specific interviews with experts who have been unable to attend the workshops.

The results of the workshops and interviews will be synthesised into a final report in 2009.

10.6

Contact details of the Operating Agent

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11

Plug-in hybrid electric vehicles (Annex XV)

11.1

Introduction

Transportation is a major contributor to air pollution and specifically to urban smog. This is also true for greenhouse gas (GHG) emissions. Among member countries to this Implementing Agreement, the transportation sector ranks high in GHG emissions. In Canada, the transportation sector is the second largest consumer of energy, and the largest if electric power generation is considered separately from industrial processes. Similar statements can be made by most, if not all of the participating member countries.

Any efforts to improve energy efficiency, energy security, and to mitigate negative health and environmental effects from transportation-related emissions for future generations will only succeed if significant advances are made in increasing fuel efficiency and reducing consumption of liquid and gaseous hydrocarbons by the transportation sector. Technologies that appear to offer benefits on all three fronts (criteria air contaminants (CAC) emissions, GHG emissions and energy efficiency) are those seen in electric vehicles (EVs), hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs).

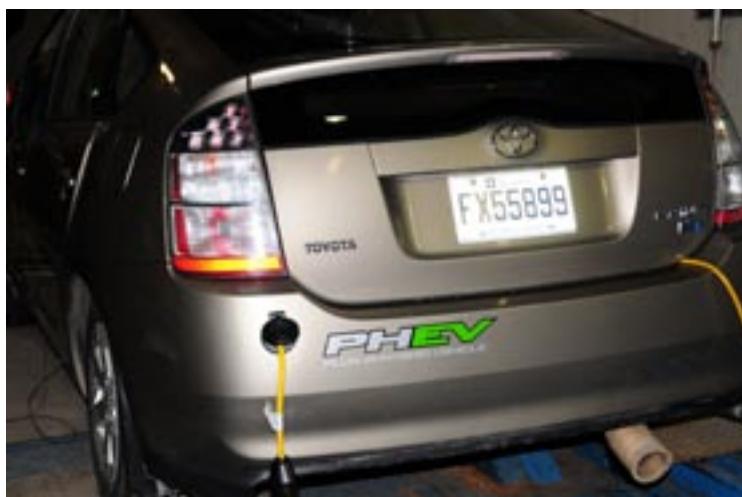


Fig. 11.1 Plug-in hybrid electric vehicle conversion in Environment Canada's test laboratory.
(Photo: S. Furino.)

The plug-in hybrid electric vehicle concept (an example is shown in figure 11.1) 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.

11.2

Objectives

The main goals and objectives of the first 3 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's 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 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 and 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.

11.3

Working method

The Canadian Federal Government through its Department of Natural Resources (NRCan) acts as Operating Agent (OA) of this Annex and organises two expert meetings per year in participating countries, and makes the practical arrangements in co-operation with the host organization for each meeting. 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. Concerning the other objectives and subject areas, participation and contribution 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 total task force the participating organizations are expected to set aside appropriate time and resources.

11.4

Results

Annex XV is just finishing its first year of operation. One of the most important results to date is having established an Annex group which contains members with backgrounds and knowledge in modelling, economics, automotive and battery research and development, as well as experts from the electricity generation and distribution sector. Having such a wide variety of experts working together and providing different points of view will ensure a better understanding of the issues related to PHEV technology.

With this important accomplishment, Annex XV is well on its way to meet its objective, to identify and address the R&D needs as well as issues related to the manufacturing, introduction and use of PHEVs as they relate to the identified subtasks of this group.

11.5

Further work

Having such a wide scope to work from, certain 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. Both approaches will make for a truly international perspective and should yield some worthwhile findings.

11.6

Contact details of the Operating Agent

For more information on this Annex and possibilities to join, please contact the Operating Agent:

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12

Overview of hybrid and electric vehicles in 2008

This chapter presents data and developments for hybrid and electric vehicle fleets around the world in section 12.1. This year, the next section focuses on trolley buses, a type of electric vehicle that is not much in the spotlights today but that holds a promise for clean transportation that uses renewable energy.

12.1

Statistical information and fleets

The year 2008 began with burgeoning promise for continued expansion of electric propulsion into a variety of new areas of application in heavy-duty and off-road missions, along with unparalleled growth in the on-road population of hybrid cars and light trucks, but about mid-year markets encountered the cyclical or possibly recession-triggered downturn in vehicular sales afflicting all propulsion technologies.

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.

Vehicle type	Year 2005		2006		2007		2008	
	EV ¹	HEV	EV ¹	HEV	EV ¹	HEV	EV ¹	HEV
Austria	517	75	565	481	691	1'264	n.a.	n.a.
Belgium²	1'058	602	990	1'560	1'030	2'900	1'109	n.a.
Canada	11	6'053	18	13'253	21	25'783	n.a.	n.a.
Denmark	650	35	650	50	650	76	10'600	300
Finland	n.a.	n.a.	n.a.	n.a.	404	303	470	1'142
France	11'000	n.a.	11'000	> 7'000	n.a.	n.a.	n.a.	n.a.
Italy	131'381	2'415	153'695	4'285	206'300	11'218	n.a.	n.a.
Netherlands	n.a.	3'000	20'450	5'003	30'450	6'005	60'452	20'005
Sweden	373	3'300	> 335	6'100	3'320	9'400	3'370	13'500
Switzerland³	13'140	2'469	17'590	4'722	23'400	7'762	n.a.	10'700
Turkey	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	130
USA	51'398	403'000	53'526	655'000	55'654	1'006'000	57'782	1'322'000
Total IA-HEV	209'500	421'000	259'000	698'000	322'000	1'071'000	430'000	1'450'000

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 2008 HEV figure is for September 2008.

The result was that the close of the year saw a dramatic plunge in new hybrid acquisition rates that echoed the economic woes affecting almost all industrialised western and Asian economies. Even a continuation of the previously successful

stimuli afforded by generous tax incentives in many countries could not stem the downward tide. Table 12.1 shows the recent trends in electric vehicle (EV) and hybrid electric vehicle (HEV) fleets in IA-HEV member countries. Table 12.2 contrasts 2008 November-December USA sales figures (all hybrid makes and models) against their values of a year previous.

Table 12.2 Comparison of November and December hybrid vehicle sales (all makes/models) in the USA for 2007 and 2008.

11/07 sales	11/08 sales	'07-'08 Δ monthly sales	12/07 sales	12/08 sales	'07-'08 Δ monthly sales
33'233	16'571	-50.14%	30'871	17'698	-42.67%

Figures 12.1 and 12.2 report the actual sales values of light-duty hybrid electric vehicles in the United States for 2008 and previous years. Not all models shown in this figure are universally available, and in some countries latent demand for imports continues to be suppressed by tax policies unfavourable to hybrids despite their benefit as high-efficiency vehicles.

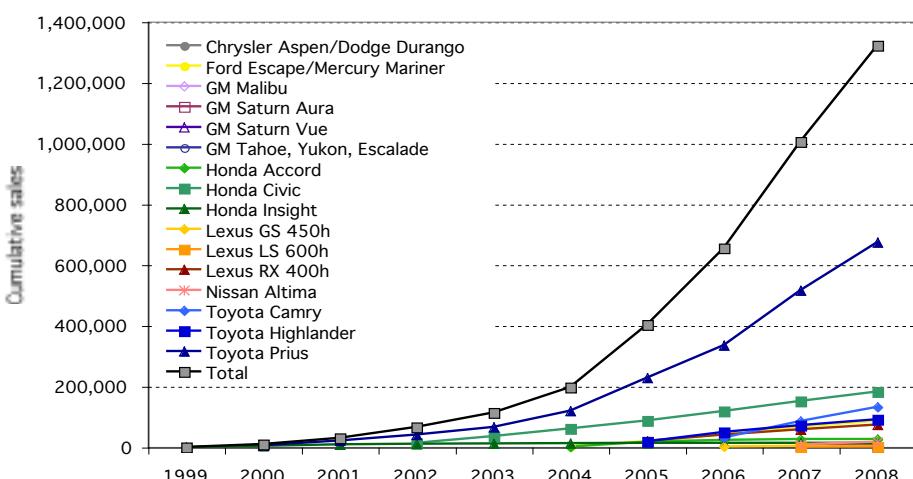


Fig. 12.1 Cumulative sales for light-duty hybrid electric vehicles in the United States (to December 31, 2008).

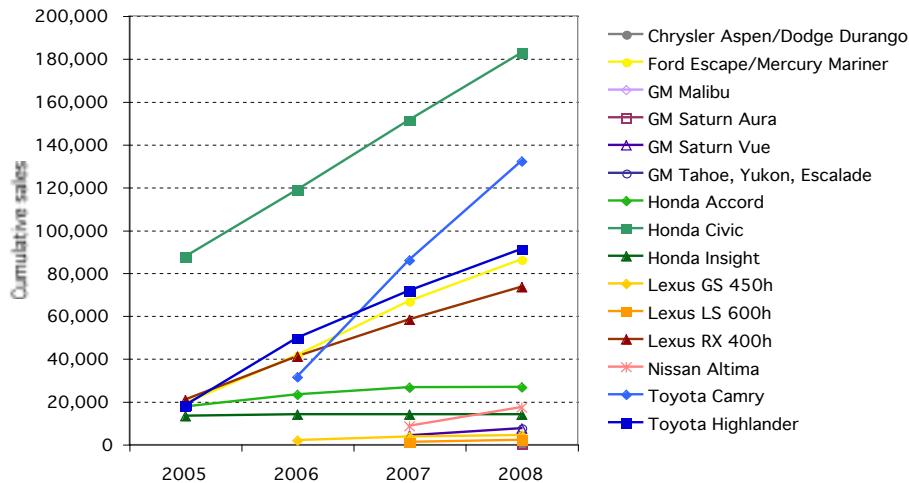


Fig. 12.2 Detail of fig. 12.1. Cumulative sales for light-duty hybrid electric vehicles in the United States 2005-2008 (Toyota Prius and total sales are not shown).

New platforms announced for introduction through 2010 include sedan models from Ford, Hyundai and Nissan. Table 12.3 lists currently planned and announced hybrid rollouts by size class, manufacturer, and intended application through about 2010.

Table 12.3 Planned and announced hybrid rollouts through 2010, by manufacturer.

Size class	Manufacturer/model	Application
Automobile	General Motors/Volt	Multi-fuel hybrid
	Toyota/Camry	CNG hybrid
	Hyundai/Sonata	Lithium polymer battery system hybrid
	BYD Auto (China)	Lithium-ion battery system dual-mode PHEV
	Toyota/Matsushita Electric	Lithium-ion battery system dual-mode PHEV
Light truck	Chrysler/Aspen; Dodge/ Durango	CVT HEMI full hybrid (2'700 kg payload)
Heavy truck & bus	Navistar/International DuraStar Hybrid	USA weight class 7 general freight haulage
Specialty	Volvo	Parallel hybrid wheel loader

All-electric propulsion continued to advance in niche markets through 2008, as Denmark, Australia and the USA state of Hawaii joined Israel as testing grounds for the ‘Better place’ scheme of matching leased EVs with charging station infrastructure. The BMW Group rolled out its 204 hp (150 kW) lithium-ion powered battery EV ‘Mini E’ line at the Los Angeles Auto Show. Smart Corp. announced

plans to build all-electric vehicles for Europe by the end of the decade, and Renault Motor Corp. reversed a long-standing corporate no-EV policy by announcing it would build a pure electric version of its Fluence, a mid-size sedan, and sell as many as 40'000 of the model in 2011.

Meanwhile, the promise for electricity-intensive plug-in hybrid electric vehicle (PHEV) applications was bolstered, among other factors, by findings of an Argonne National Laboratory study that employed ‘total energy cycle’ methodology to identify the superior charging option for future PHEVs, with respect to distance travelled per unit of electric power feedstock. The best option is combined-cycle electricity generation and vehicles operating in charge-depletion (CD) mode. Moreover, “... regardless of which abundant domestic fuel one would wish to use, use of the fuel to serve a PHEV in CD mode would provide more kilometres of service than (all) competing options evaluated”, including fuel cell vehicles powered by hydrogen produced by the same types of electric power plants. More hybrid fleets appeared: in Washington, DC, one cab company rolled out the first all-hybrid taxicab fleet in the USA; transit agencies in Washington, DC, Philadelphia, and Minneapolis/St. Paul USA have placed orders for over 1'700 of GM-Allison's full-size series hybrid buses; twelve eight-meter hybrid-electric buses in the Abruzzi region of Italy and three buses for the Italian Ministry of the Protection of the Environment have gone into service; and United Parcel Service (UPS), North America's most prominent private package and parcel delivery service, has placed an order for 200 hybrid delivery vehicles, representing the largest commercial order of such trucks by any company. Ten Fuso Canter Eco Hybrid (6'800 kg) trucks designed by subsidiary Mitsubishi and issued by Daimler AG are now on the streets of London, UK, in the largest pilot demonstration of diesel-electric hybrid drive technology active in Europe. Hyundai has announced plans to launch an outlet-rechargeable hybrid vehicle sometime after 2013, in a bid to remain technologically competitive with its principal commercial rivals in Asia, the Japanese hybrid vehicle manufacturers.

12.2

Trolley buses

A trolley bus is powered by an electric motor and receives its electric energy via an overhead wire. It was invented in 1882 by the German engineer Werner von Siemens. The era of modern trolley bus systems began around 1930, when reliable overhead wire contact systems were introduced. Since then, this principle has constantly been optimised and developed further. Today, about 40'000 trolley buses are being operated in about 350 cities worldwide, in countries such as China, the Czech Republic, Ecuador, Greece, New Zealand and Russia, to name just a few. The number of trolley bus systems is growing, but still very slowly. In recent years, new

systems have been taken into operation, e.g. in Merida and Barquisimeto (Venezuela) and Castellón (Spain), have been re-opened (e.g. Rome, see figure 12.4) or extended, e.g. in Lyon (France), Salzburg (Austria) and Bratislava (Slovakia). New networks are being proposed for cities such as Valenciennes (France) and Leipzig (Germany). Today, Moscow has the biggest trolley bus fleet with more than 1'200 vehicles in operation. Landskrona in Sweden is the smallest operator and owns 3 trolley buses. With a total of 13 trolley bus systems, Switzerland is the country with the highest density of trolley bus operators per inhabitant (figure 12.3).



Fig. 12.3 25 metre long double articulated trolley bus in Zurich, Switzerland. (Photo: H. Schaffer.)

Some of the most important reasons to choose for a trolley bus system are:

- The energy consumption of a trolley bus is about 50% lower than of a diesel bus of comparable size.
- No vehicular exhaust emissions, and the possibility to use electricity that is generated by renewable sources.
- Less noise and vibrations, both inside and outside the buses, compared to buses with internal combustion engines.
- Trolley buses offer the possibility of brake energy recuperation by feeding it back into the overhead wire or by onboard storage in supercapacitors.
- They are cheaper and need less time to construct than light rail transit (LRT) systems. Operational costs of trolley bus systems are less than 50% of LRT systems.

Some people don't like to see the overhead wires, especially in old city centres. On the other hand, the overhead wire provides a high 'easy to find factor', it brings confidence that there will be transport tomorrow, and it acts as a continuous advertisement for the system.

Trolley bus technology is developing further, and today some research and demonstration projects are focusing on enabling the buses to drive short distances without being connected to an overhead wire, to cross intersections or to pass through certain streets in city centres (see figure 12.4). This requires onboard storage of electricity, which can be done with batteries or supercapacitors. Trials with supercapacitors are currently underway in China, Europe and the USA. For example a batch of appropriately equipped trolley buses has been placed into experimental service in Shanghai. The onboard supercapacitors are charged at several stops via a short section with overhead wires. These trolley buses can operate about 1 km without being connected to an overhead wire power supply system. After this distance, the supercapacitors have to be recharged.



Fig. 12.4 As part of a policy for cleaner urban air, in March 2005 the Italian capital city of Rome re-installed a trolley bus line. The new trolley buses have onboard batteries powerful enough to allow as much as 3 km of unwired operation through the city centre. (Photo courtesy TrolleyMotion.)

In spite of all advantages, why are trolley buses not used on a larger scale? The most important reason might be that the investment costs for the power supply system with substations and overhead wires are substantially higher than the investment costs for diesel bus systems. However, in countries with low labour costs this cost issue might be less important (see also figure 12.5).



Fig. 12.5 Trolley bus rapid transit system in Quito, Columbia, constructed between 1995 and 2000. (Photo: H. Schaffer.)

The promise of locally emission free, low noise transport that can use renewable energy that trolley buses can provide, combined with the fact that only a limited number of trolley bus systems are in operation worldwide seems to justify a new IA-HEV Annex on this topic. Such an Annex could start by making an overview of existing systems, current technology developments and barriers for introduction. The next step could be generating recommendations for strategies and policies to overcome the existing hurdles. Results from IA-HEV Annex XII on heavy-duty hybrids and Annex XIV on lessons learned from market deployment could be used to the advantage of work on trolley buses, it would ensure an efficient project and it shows that it would be logic that this kind of work is embedded in the IA-HEV environment.

13 **Austria**

13.1 **Introduction**

Austria is a significant player in the automotive supply industry. It is host to a number of automotive suppliers and vehicle production plants; an example is Magna Steyr in Graz. More than 175'000 people work in more than 700 enterprises in the Austrian automotive industry.

Against a background of steadily rising greenhouse gas (GHG) emissions, imminent and visible climate change, and increasing dependence on energy resources from politically unstable regions, policymakers have set ambitious goals to secure the energy supply and reduce GHG emissions, including those from the transport sector. Both the biofuel directive approved by the European Union (EU) in 2003, COM 2003/30/EC, and the year 2008 directive on the use of renewable energy, COM (2008) 30 final, aim to reduce the use of fossil energy in order to decrease GHG emissions and European dependence on oil imports.

To achieve these goals requires, in addition to the substitution of biofuels for fossil fuels, a noteworthy increase in vehicle energy efficiency. From the wide range of technical options, hybrid electric vehicles (HEVs) and electric vehicles (EVs) offer improved energy efficiency and added value in terms of emissions and noise. To optimise the ecological balance sheet, electricity obtained from renewable sources could be used to power these vehicles.

Beginning in 1995, a common strategy for reducing CO₂ emissions from passenger cars, officially called COM 261 from 2005, was presented by the European Commission. The target was to reduce average CO₂ emissions from new passenger cars to a level of 120 grams per kilometre (gCO₂/km) by 2012, which corresponds to consumption of about 5 litres of gasoline or 4.5 litres of diesel per 100 kilometres. The strategy was based on three major approaches:

1. Automobile manufacturers practicing self restriction (1998).
2. Giving consumers information on CO₂ emissions from passenger vehicles.
3. Promoting lower fuel consumption through fiscal measures.

An evaluation of this approach revealed that this voluntary agreement has so far not met the designated targets.

Although HEVs and EVs play a subsidiary role in the Austrian vehicle market, researchers at the Technical Universities of Vienna and Graz and in enterprises

such as AVL-List in Graz are actively working in the field of alternative automotive drivetrains. These two universities, as well as extramural research institutes like ECHEM (Competence Centre for Applied Electrochemistry) and the Christian Doppler Laboratory for fuel cell systems, conduct research on batteries and fuel cells. It is expected that as hybrids start to play a more significant role in the vehicle market (a trend that is indicated by the success of Toyota's Prius), Austrian interest in hybrid technology will grow.

13.2

Policies and legislation

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, the Federal Ministry for Transport, Innovation and Technology (BMVIT) promotes research at all levels, from basic research to the industrial application of research results.

Fostering innovation for efficient and sustainable transport systems, 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; its aims are to secure the competitiveness of the Austrian supply industry and solve urgent environmental problems through clean and innovative vehicle technologies.

Governmental programmes

Mobility plays a key role within a modern society. Therefore, BMVIT conducted the IV2S (Intelligent Vehicular Transport Systems and Services) research programme from 2002 to 2006, followed by the IV2Splus programme in 2007. The Impuls, A3 and A3plus programmes (within IV2S and IV2Splus, respectively) are highly relevant with regard to EVs and HEVs in Austria.

A3 programme Austrian Advanced Automotive technology

The A3 programme concentrates on highly innovative research projects with an increased development risk, providing them with higher levels of funding than are usually provided by technology promotion programmes. The goal is to achieve real technological breakthroughs and not incremental improvements in existing technologies. Grants are awarded according to the competitive principle, through calls for proposals. A3 covers the entire innovation cycle and offers funding for projects from basic research to demonstration projects. Furthermore, it funds projects that adapt education and training to address new requirements and result in an adequate supply of well-qualified people. Another pillar of the programme supports

international networking, mobility, and co-operation among researchers. A3 strives for the synergies that can result from interdisciplinary co-operation among industry, universities, and research centres and between suppliers and users of technologies in joint R&D projects.

Between 2002 and 2006, there were four A3 calls for proposals for projects that would involve the development of alternative propulsion systems and vehicle electronics and materials research and production technologies. The focus was on technologies for road vehicles, but opportunities for alternative propulsion systems for rail and waterborne vehicles were investigated as well. From the 152 proposals submitted, 77 projects were adopted and carried out after evaluation, with a funding budget of €20.2 million out of a total budget of about €40 million.

Lighthouse projects are another BMVIT instrument supporting the market introduction of new vehicle technologies. Complementary to the A3 proposal calls, BMVIT uses lighthouse projects to support large pilot and demonstration projects. The lighthouse instrument brings together technology providers and users and all other relevant stakeholders under a single project, proves the successful operation of new vehicle technologies, optimises the technologies under real-life conditions, and prepares the public for them through educational outreach. The single focus of lighthouse projects is the market introduction of alternative propulsion systems and fuels. In two calls for lighthouse projects in 2005 and 2006, 25 proposals were submitted, and eight projects were selected in a two-stage evaluation process. The total budget was €7.4 million, with a funding budget of €3.3 million.

The IV2S (and thus also the A3 technology programme) expired in December 2006. One outcome from the research program is now entering the vehicle market. The Austrian motorcycle company KTM presented its zero emission electric cycle (ZEMC), which is a lightweight electric enduro bike (figure 13.1).



Fig. 13.1 KTM's ZEMC electro enduro bike. (Photo © KTM.)

Follow-up IV2Splus programme

IV2Splus, which operates as a continuation of the successful forerunner IV2S programme (2002-2006), transcends it in some significant aspects. It establishes new emphases and core content areas. The programme focuses on expanding R&D excellence through stronger international embedding of successfully established Austrian R&D competencies. Its goal is to increase the integration of these competencies into international value-added production activities and supply chains. Through this programme, Austria expects to make a significant contribution toward developing future transport and mobility solutions for Europe.

Within the innovation cycle, the IV2Splus strategy programme diagrammed in figure 13.2 spans the arc from problem-oriented basic research to demonstration and pilot projects, with differences in core areas depending on the particular programme line. While the A3plus Impuls programme operates mainly in the areas of applied research and experimental development, the core focus of the IV2 Impuls programme rests in experimental development, because the technologies in this area are already advanced. The action lines ‘ways2go’ and ‘impuls’ primarily address problem-oriented basic research and focus on the future.

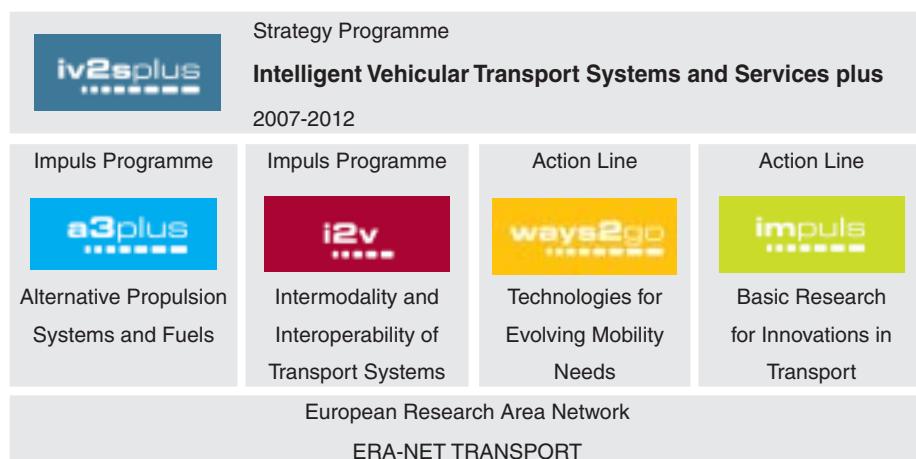


Fig. 13.2 Overview of Intelligent Vehicular Transport Systems and Services plus (IV2Splus) strategy programme. (Logos © BMVIT.)

A3plus programme line

Background

In 2007, BMVIT continued its funding of A3plus. A3plus is striving to make future transport significantly more energy-efficient and environmentally friendly by promoting R&D in innovative propulsion technologies and alternative fuels. Groundbreaking innovations could trigger technological leaps that would pave the way for entirely new propulsion concepts. These could yield previously unachievable reductions in the energy consumed by surface transport vehicles and the emissions from them as well.

In the first A3plus call for proposals, €5 million was available for funding co-operative R&D projects. This call was open from the end of July to mid-October 2007, and 23 proposals were submitted. After evaluation by an international jury, 18 projects involving 42 partners were accepted. This call was transnational and open to foreign partners. Within ERA-NET TRANSPORT (ENT, a network of national transport research programmes in Europe), the A3plus call was tuned to 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

Transport in the future must not only be more environmentally friendly but it must also be much more energy-efficient. Biofuels and natural gas in gaseous, liquid, and liquefied form increasingly gain market share, requiring new propulsion concepts that need to exhibit less energy consumption and fewer emissions. Alternative combustion concepts and fuels will gradually replace the current combinations of Otto or diesel engines that utilise conventional gasoline and diesel fuels.

The recent successes of hybrid vehicles will significantly accelerate the development of drive systems with combinations of several different energy converters and storage media. In the longer term, combustion-free drive systems (e.g., electric engines and fuel cells) will reduce energy consumption, pollutant emissions, and noise even more. The required conversion of the entire power chain to electric components (which is already emerging in hybrid vehicles) is facilitated through considerable advances in battery technologies.

According to the scenarios set forth by the automotive industry, hydrogen will be sustainably produced either from methane (by means of biomass recycling) or by the electrolysis of water using electricity from renewable energy sources. Before this

point is reached, however, a series of technological barriers must be overcome. For that reason, the A3plus programme line is focusing on alternative propulsion systems and fuels. The programme is also aiming to develop such systems for rail transport and inland waterway transport.

The A3plus programme line is intended to support co-operative proposals involving industrial, university, and non-university research across the entire R&D cycle.

These partnerships should strengthen the innovativeness and competitiveness of the Austrian propulsion technology industry. Beyond this, promotion of technological innovation should help increase the social and ecological sustainability of surface transport. The transfer of technologies and knowledge across the different modes of transport should strengthen the development of interdisciplinary know-how in alternative propulsion technologies in Austria. Supplementing the European research programmes and harmonizing with the European Commission's transport and energy policy, the A3plus programme line will support system solutions and genuine advances in technology in the Austrian engine-construction 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 transport sector.

Calls for proposals for research projects are scheduled annually over the time frame of the IV2Splus programme. In addition, strategic lighthouse projects will support the demonstration and implementation of larger-scale proposals in alternative propulsion systems and fuels (including the infrastructure facilities required for this work) and will involve developers, producers, downstream operators, and future users.

Core areas

The BMVIT A3plus programme, which covers all modes of transport, has the following research areas:

Alternative propulsion systems and their components.

- Scope: Drive systems and drivetrains for road transport, rail transport, and inland waterway transport, including electronic management of such drives.
- Examples: Highly specialised mono-valent or highly flexible multi-valent combustion engines with alternative combustion processes and fuels or innovative hybrid solutions, electric motors, and fuel cells.
- Objectives: Increased motor efficiency and energy efficiency (including energy recuperation), and reduced energy consumption and emissions.

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; environmental friendliness; and compatibility with existing distribution infrastructures.

Innovative energy storage concepts.

- Scope: Tanks for liquids and gases, electrical storage.
- Examples: High-pressure storage tanks, cryotanks, metal hydrides, ionic liquids, batteries, and high-performance condensers.
- Objectives: High specific storage density, low storage and conversion losses, capacity for rapid energy uptake and supply, and safety.

Development and support for the supply infrastructures needed to refuel and operate alternative propulsion systems.

- Examples: Hydrogen, biofuel, natural gas, and liquefied gas stations; distribution networks; and on-site synthesis.
- Objectives: Cut development costs, use existing distribution networks, ensure flexible use for various alternative energy modes, ensure safety, and improve operational cost efficiency.

Concepts for embedding alternative drivetrains in overall vehicle design.

- Scope: Optimizing the spatial arrangement of alternative drive systems.
- Objectives: Reduced weight, volume, and energy consumption by matching the drive, bodywork, and other components; development of (full) hybridization concepts; increased overall vehicle efficiency (energy management and emissions); and improved safety and comfort standards.

First call for proposals for the A3plus programme line

In the first A3plus call for proposals in 2007, which was funded at €7 million, 17 R&D projects and three lighthouse projects were selected, eight of which involved hybrid and electric vehicles. These eight projects, which are listed below, cover a wide range of areas: freight and passenger transport; lightweight vehicles and working machines; two- and three-wheel vehicles for regional delivery services; zero emission vehicles in local public transport; electrical-mechanical power distribution transmissions; battery and fuel cell hybrid vehicles with a decentralised hydrogen infrastructure; use of renewable energy sources; analysis of the market potential of EVs; creation of supportive ecological, environmental policy, and technical framework conditions; and development of scenarios to investigate the effectiveness of different policy instruments.

1. Austrian electric vehicle road map.
Prospects for a demonstration vehicle fleet as part of an Austrian Road Map for battery-powered EVs.
2. Elek-tra.
Development of scenarios for the spread of vehicles with partly and fully electric drivetrains under various policy framework conditions.
3. Enporter.
Electric drive for an inclining charge wheel for postal and regional delivery services.
4. EVT-Drivetrain.
Drivetrain with electrical-mechanical power distribution transmission.
5. Heliostar.
Ultra-efficient, light, integratable solar modules to reduce HEV fuel consumption and exhaust emissions.
6. Hybrid wheel loader.
Concept development of hybrid drives for mobile working machines, using the wheel loader as an example.
7. Hycart.
Use of fuel cell vehicles with decentralised hydrogen infrastructure under real conditions so they will achieve the maturity for series manufacture.
8. Klima Mobil (Air quality plus mobility).
Zero emission vehicles in local public transport.

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

I2V programme line

I2V is the Austrian Impuls programme to promote co-operative R&D projects in the area of intermodality and interoperability of transport systems. The goal is to increase the efficiency of the overall transport system by improving the smooth interoperation of different modes of transport, increasing integration of environmentally sustainable modes of transport, 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.

Impuls action line

The Austrian Impuls action line aims to promote basic research for innovations in transport. The goal is rapidly to take scientific and technological findings and problem-solving approaches from the widest range of appropriate disciplines and apply them in the transport sector.

A3PS - Austrian Agency for Alternative Propulsion Systems

Following the principles of modern technology policy, BMVIT is convinced that public authorities can facilitate the development of new technologies far beyond their financial contributions. Therefore, in 2006, it established the Austrian Agency for Alternative Propulsion Systems (A3PS) as a strategic public-private partnership for close co-operation among industry, research institutions, and the ministry, with a common goal of developing and launching alternative propulsion systems and fuels. Independently from the R&D funding programmes of the BMVIT, the A3PS offers its 29 members the following broad portfolio of additional support services:

- Stimulating collaboration between complementary partners and developing interdisciplinary research co-operation and cross-sector pilot and demonstration projects.
- Providing support for procuring, compiling, and analyzing information (e.g., technology predictions and assessments; comparative evaluations of studies; analyses of international R&D trends and strategies; organization of lectures and seminars; publication of reports after participation in conferences; provision of information about EU, national, and other R&D funding opportunities).
- Creating framework conditions that promote innovation in order to overcome barriers to market entry (e.g., regulatory and fiscal policies, fuel duties, funding endowments for R&D programmes, technical and safety standards, values for emission limits, ordinances regulating access to garages, differentiated access restrictions for sensitive areas).
- Giving members opportunities for international networking and 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 EU or IEA committees and in drafting of the seventh EU research Framework Programme.

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

Internationally, the A3PS is the Austrian representative in the IA-HEV Annex XIII, ‘Fuel cells for vehicles’. In that capacity, it acts as an agent for the interests of Austrian enterprises, universities, and research institutes.

13.3

Research

Research on EVs, batteries, and fuel cells takes place mostly at Austria’s universities and research centres: Vienna University of Technology, Graz University of Technology, University of Leoben, Joanneum Research Forschungsgesellschaft mbH, ARC Seibersdorf research GmbH, Arsenal Research, HyCentA Research GmbH, and ECHEM (Competence Centre for Applied Electrochemistry). 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 cars, simulation of drivetrains and vehicle systems, fuel cell catalysts, power electronics, onboard storage systems, tank isolation, SOFCs for a battery hybrid vehicle, control systems for hybrid vehicles, and lithium batteries.

13.4

Industry

Austria has more than 700 automotive and automotive component companies. The main part of the industry related to HEVs and EVs is onboard hydrogen-storage and fuel cell propulsion systems. A few companies, such as Banner, are active in work on lead acid batteries. Magna Steyr is deeply involved in developing a lithium-ion battery system for automotive applications, especially for a hybrid sports utility vehicle (HySUV) (figure 13.3).



Fig. 13.3 Under the hood (left) of the lithium-ion battery equipped HySUV from Magna Steyr. (Photos: M. van Walwijk.)

In addition to Magna Steyr, the Austrian company AVL is very active in developing diagnostic tools and real-time hardware-in-the-loop (HIL) testing equipment and software. Figure 13.4 shows the AVL battery testing solution based on the RT (real-time) HIL system with RT models in cruise mode. That approach is part of the TÜV-certified safety concept for testing lithium-ion batteries.

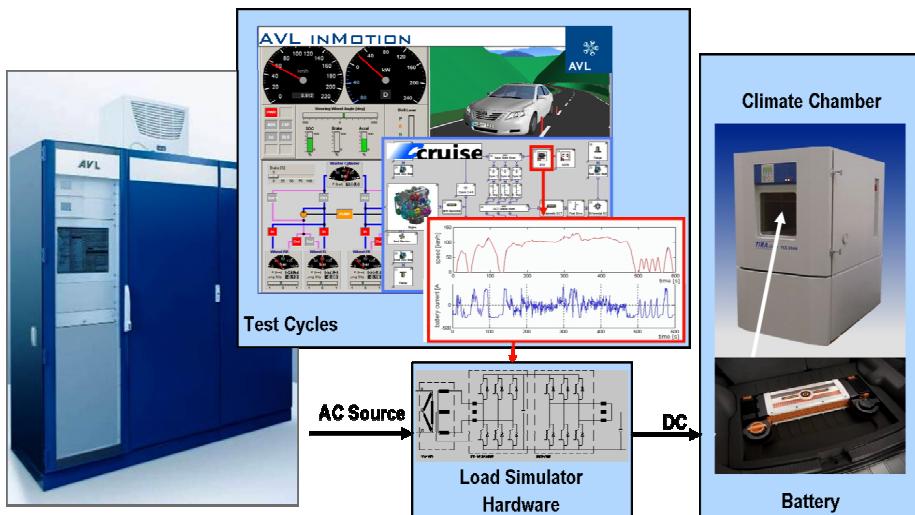


Fig. 13.4 Battery test bed with real-time hardware-in-the-loop simulation and safety concept.
(Picture © AVL.)

13.5 *On the road*

Although no formal market introduction or inducement programmes for EVs or HEVs have been attempted in Austria, some tourist resorts and villages allow only EVs to be used on their premises. Table 13.1 profiles the EV fleet in Austria as of the ends of 2006 and 2007.

Statistics show that the total number of vehicles in Austria is increasing. The number of EVs is increasing slightly after a relatively steep decline from 2003 to 2004. Motor-assisted bicycles, which can be operated legally on the streets without the need for a driver's license, are the largest share of the Austrian EV fleet and more or less represent the increase in the total number of EVs on the road. The number of HEVs (bivalent gasoline/electric cars) is increasing as well; in fact, the 2007 total was more than double the number in 2006. Table 13.2 gives an overview on the HEV fleet in Austria. Six HEV models are available on the market. December 31, 2007, the Toyota Prius had a fleet share of 60%, followed by the Lexus RX 400h with 27% and the Honda Civic with 10%.

Table 13.1 Characteristics and population of the Austrian motorised vehicle fleet per December 31, 2006 and 2007.

Vehicle type	December 31, 2006			December 31, 2007		
	EV fleet	HEV fleet	Total fleet	EV fleet	HEV fleet	Total fleet
Motorised bicycle						
(no driver licence)	246	n.a. / 0	439'189	367	n.a. / 0	452'692
Motorbike	22	n.a. / 0	206'124	26	n.a. / 0	214'885
Passenger vehicle	127	481	4'204'969	131	1'264	4'245'583
Multipurpose pass. vehicle	0	0	0	0	0	0
Bus	110	n.a. / 0	9'297	101	n.a. / 0	9'299
Truck	21	n.a. / 0	364'323	29	n.a. / 0	372'645
Industrial vehicle	39	n.a. / 0	498'722	37	n.a. / 0	501'869
Total	565	481	5'722'624	691	1'264	5'796'973

n.a. not available

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

Table 13.2 Hybrid car fleet in Austria, 2007. (Source: Statistics Austria 'Statistik der Kraftfahrzeuge 31.12.2007'.)

Make	Model	December 31,
		2007
Honda	Civic	121
Lexus	GS 450h	25
Lexus	LS 600h	13
Lexus	RX 400h	346
Toyota	Camry	1
Toyota	Prius	758
	Total	1'264

13.6 Outlook

As already mentioned, the Austrian Government is funding research projects aimed at advancing alternative propulsion systems and fuels. 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 car 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's awareness of alternatives to pure petroleum propulsion, the market for EVs and HEVs, now very limited in Austria, should certainly continue to grow.

In addition to addressing important research topics, the Austrian Government is strongly interested in the deployment and market introduction of EVs in the country. Recently, the Austrian Climate Fund, which is a multimillion Euros RD&D fund, has sponsored a large-scale EV demonstration project in Vorarlberg (westernmost area of Austria). In this 'model region', with more than 250'000 inhabitants, electric mobility will be demonstrated and further developed in an integrated mobility concept that goes beyond electric passenger cars.

13.7

Benefits of participation

The benefits to Austria from participating in the IA-HEV are as follows: it will stay informed about EV and HEV technology and drivetrain developments in other countries; transfer this knowledge to local industry; and participate in a network of well-known automotive laboratories, research organizations, and governmental agency representatives to produce joint studies and reports.

13.8

Further information

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

- www.arsenal.ac.at (in English and German).
Austrian Research Centres - Arsenal Research. Arsenal works on research questions in the areas mobility and energy.
- www.avl.com (in English).
AVL-List GmbH is the world's largest privately owned and independent company for the development of powertrain systems with internal combustion engines, as well as instrumentation and test systems.
- www.a3ps.at (in English and German).
Austrian Agency for Alternative Propulsion Systems (A3PS). A3PS is a public-private partnership between the BMVIT and Austrian industry and research institutes. It is the Austrian platform for all alternative propulsion systems and fuels, including hybrid and electric vehicles.
- www.banner.at (in English and German).
Lead acid batteries and traction battery systems.

- www.bmvit.gv.at/innovation/verkehrstechnologie/iv2s/a3/index.html (in German).
Austrian Advanced Automotive Technology Programme of BMVIT.
- www.echem.at (in German).
Competence Centre for Applied Electrochemistry.
- www.energyagency.at (in English and German).
The Austrian Energy Agency.
- www.energytech.at (in English and German).
Platform for innovative technologies in the area of energy efficiency and renewables.
- www.fronius.com (in English and German).
Fuel cell propelled logistic vehicle.
- www.ktm.at (in English).
Electric enduro-bike.
- www.magnasteyr.com (in English, German and Japanese).
Engineering and vehicle assembly company.
- www.verkehrstechnologien.at (in German).
Information about funded projects from the various program lines of the BMVIT.

14 Belgium

14.1 **Introduction**

Belgium is an important player in the automotive industry. The country hosts several car assembly plants, including Ford Genk, Volkswagen Vorst, Opel Antwerpen and Volvo Gent. The Flanders' DRIVE knowledge network and engineering centre has been established to support automotive suppliers and their research activities.

Belgium boasts some key players in the field of research and development (R&D) of electric and hybrid vehicles, including VITO (Flemish Institute for Technological Research), the Vrije Universiteit Brussel and Green Propulsion. Industrial players seeking high volume -such as Punch Powertrains and Van Hool- are continuing to develop hybrid vehicle technologies. Furthermore, two European organizations related to electric and hybrid vehicles -namely CITELEC and AVERE- have been headquartered in Brussels for many years.

In 2006, the energy consumption of the transportation sector in Flanders amounted to 212 PJ (peta Joules, equals 10^{15} Joules). This corresponds to 13% of the total energy consumption of Flanders. The majority of this energy consumption was the result of road traffic: 57% passenger transport and 40% goods transport. Since 2000, the energy consumption of passenger transport on the road has increased by only 0.6%, while for goods transport this figure was 5.6%. An increased share of diesel vehicles and the greater availability and acquisition of more fuel-efficient vehicles explain the low figure for passenger transport, as shown in tables 14.1 and 14.2.

Table 14.1 Number of new sold passenger cars and average fuel consumption per fuel type, in Belgium. (Data © VITO.)

Belgium							
		2002	2003	2004	2005	2006	2007
Number of vehicles (x 10³)	Gasoline	154	135	143	128	133	94
	Diesel	288	303	342	351	392	430
	Total	442	438	485	479	525	524
Average fuel consumption [l/100km]	Gasoline	7.1	7.0	6.9	6.7	6.6	6.6
	Diesel	5.8	5.8	5.7	5.6	5.6	5.6
	Total	6.3	6.2	6.0	5.9	5.8	5.8

Table 14.2 Percentage of new car sales by CO₂ class in Belgium. (Data © VITO.)

		Gasoline vehicles				
		2002	2003	2004	2005	2006
		%	%	%	%	%
A	0 - 100 gCO ₂ /km	0.0	0.0	0.0	0.0	0.0
B	100 - 130 gCO ₂ /km	1.0	2.2	4.9	5.1	9.1
C	130 - 160 gCO ₂ /km	46.2	49.9	50.9	55.0	54.9
D	160 - 190 gCO ₂ /km	34.7	32.9	30.0	27.4	25.2
E	190 - 220 gCO ₂ /km	10.0	7.7	8.0	7.3	6.7
F	220 - 250 gCO ₂ /km	4.8	4.3	3.2	2.6	2.0
G	> 250 gCO ₂ /km	3.3	3.0	3.1	2.6	2.3

		Diesel vehicles				
		2002	2003	2004	2005	2006
		%	%	%	%	%
A	0 - 085 gCO ₂ /km	0.0	0.0	0.0	0.0	0.0
B	85 - 115 gCO ₂ /km	4.1	6.2	5.9	5.0	2.5
C	115 - 145 gCO ₂ /km	34.9	35.5	38.7	40.1	46.9
D	145 - 175 gCO ₂ /km	39.5	38.4	35.9	36.1	34.3
E	175 - 205 gCO ₂ /km	16.6	14.0	14.1	13.3	9.6
F	205 - 235 gCO ₂ /km	2.5	3.3	3.5	3.4	3.9
G	> 235 gCO ₂ /km	2.5	2.6	2.0	2.0	2.8

For the Belgian consumer, price is the most important criterion for purchasing a vehicle. Since little is known by consumers about the total cost of the life cycle of hybrid vehicles (which normally carry lower costs), the market introduction of such vehicles is still limited.

14.2

Policies and legislation

Belgian policy toward environmental friendly vehicles and transport does not favour selected technologies, but it rewards good results.

Individual consumers

Buyers of vehicles that emit low levels of CO₂ receive a tax reduction at purchase. This reduction is 15% of the purchase price for vehicles with CO₂ emissions equal

to or lower than 105 g/km (e.g., Toyota Prius with 104 g/km) and a 3% reduction for vehicles with CO₂ emissions between 105 and 115 g/km (e.g., Honda Civic with 109 g/km). These amounts are maximised to, respectively, 4'270 Euros and 800 Euros for the 15% and 3% price reductions. Effective since July 2007, this sum is now directly applied at the moment of purchase and is no longer returned to the owner only when income taxes are finalized, which is approximately two years after the acquisition of the vehicle.

As ongoing policy, electric vehicles (EVs) are classified as fiscally equal to the smallest vehicle available in the tax sheets (2 fiscal horsepower), regardless of their actual power. This results in them being subject to the lowest registration and circulation taxes.

Belgium company car taxation

When an employer gives an employee a company car that is subsequently used for private transport, this usage is taxed in two ways. The employee must state the net benefit-in-kind received from the employer, which is a value calculated on the basis of the average mileage and the fiscal horsepower of the car. For the employer, the benefit-in-kind is treated as a form of salary on which social security contributions must be paid. Since January 2005, the social security contribution is calculated on the basis of the CO₂ emissions of the car, rather than on fiscal horsepower [14.2]. The calculation of the annual social security contribution is as follows (in Euros):

Gasoline cars: (CO₂-emission * 9€) - 768€

Diesel cars: (CO₂-emission * 9€) - 600€

LPG cars: (CO₂-emission * 9€) - 990€

As of April 2007, the percentage of costs for the purchase of a company car that the company can deduct from its taxable income also depends on the CO₂ emissions of the car - a calculation that replaces the overall tariff of 75%. The percentages per CO₂ category and fuel type are given in table 14.3.

Table 14.3 Deductible percentage of costs of company cars, as a function of CO₂ emission level.

CO ₂ class [g/km]		Deductible % of purchase cost
Diesel	Gasoline	
0 - 105	0 - 120	90
105 - 115	120 - 130	85
115 - 145	130 - 160	75
145 - 175	160 - 190	70
> 175	> 190	60

Since April 2008, the percentages that can be deducted are applied to the total costs of the company fleet [14.1]. (Note that this legislation does not favour the larger hybrid vehicles on the market, such as the Lexus RX 400h, Lexus GS 450h and Lexus LS 600h.)

Other

Currently, there are several systems 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% in 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 can be incorporated in the regulations.

A co-operative agreement exists between the Flemish region and municipalities and provinces, called ‘environment as the stepping stone to sustainable development’. This co-operative agreement offers municipalities and provinces a framework in which to improve the environmental friendliness of all aspects of their operations. One aspect of the agreement deals with improving the environmental performance of the public fleet. A tool developed by VITO allows for fleet screening and gives recommendations for improving fleet utilization efficiency.

14.3

Research

VITO, the Vrije Universiteit Brussel and Green Propulsion are the key organizations involved in Belgian research on hybrid and electric vehicles.

VITO

VITO (Flemish Institute for Technological Research) implements client-driven research projects and develops innovative products and processes in the fields of energy, environment and materials. Its clients -companies and governmental organizations- are provided with solutions and advice for their problems and needs. The multidisciplinary skills and technological know-how of more than 550 researchers make this organization a crossroad of technology, where state-of-the-art technologies are successfully blended into practical applications. Energy technology is one of the centres of expertise.

In past years, VITO has participated in the Flanders' DRIVE project 'Development of a knowledge platform for hybrid vehicles', supported by the Flemish Government. The main objective of the project is the development of a Flemish knowledge platform for the design and development of vehicles with hybrid powertrains (including the long-term relevant fuel cells) and the subsystems/components for such hybrid powertrains. The general objective is to initiate, enrol and technically support the development of hybrid vehicles and components for the industry. Currently, the covered fields are system engineering, energy management, battery management, vehicle management, vehicle integration components and subsystems, simulation and testing.

Some of the recent technological projects are concerned with the development of hybrid heavy-duty vehicles. VITO -with its industrial partners- is preparing hybrid vehicle development projects to produce demonstration fleets of hybrid vehicles. Each fleet will be backed by an industrial consortium that provides full service to vehicle users. Two announced projects are a hybrid refuse lorry and a hybrid distribution truck that allows transportation in the inner city in all-electric mode.

VITO has also upgraded three series-hybrid buses (electric low-floor midi-city buses with range extender from Scania) and an electric fast-charging station. These projects introduced technical enhancements that emphasize durability and longer lifetime with proper operation. Another completed bus project involved the upgrading of two series-hybrid buses (electric low-floor midi-city buses with range extender from Van Hool) and charging infrastructure with introduction of the latest technology for energy storage and propulsion systems.

In 2007, VITO performed a detailed assessment of the possibilities and opportunities for ultracapacitors in EV and hybrid electric vehicle (HEV) applications. Several ultracapacitors were tested with different battery technologies (i.e., valve-regulated lead acid, nickel metal hydride, lithium ion and lithium polymer). In all cases, the energy pack (i.e., combination of ultracapacitors and batteries) showed characteristics superior to those of the standard battery pack. This research resulted in new electronic components for energy pack management (i.e., cell balancing, equalization, vitalization, state of charge, state of battery health, and thermal management) now implemented in several applications (see www.vito.be/mipcub, in Dutch).

VITO is also participating in several international projects -mainly with the European Union- such as HyHEELS, which focuses on ultracapacitor energy storage for the use in hybrid and fuel cell vehicles and which is running under EU FP6 (see www.vito.be/hyheels, in English).

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 9'000 students and 2'000 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 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.

Since the early 1990s, simulation techniques have been developed to determine the dynamic behaviour (i.e., energy consumption and emissions) of thermal (i.e., gasoline, diesel, and compressed natural gas) and electric (i.e., battery, hybrid, and fuel cell) vehicles. A software tool VSP (Vehicle Simulation Programme) was developed to design and assess these types of powertrains in passenger cars, as well as in two-wheelers or heavy-duty applications. The innovative approach is especially dedicated to the evaluation of power-management strategies in hybrid powertrains.

The ETEC has a test infrastructure available for the testing, development and design of components (especially DC/DC converters and ultracapacitors for hybrid drivetrains) and vehicles. This test infrastructure consists of a roller test bench, two mobile data acquisition systems that allow tests to be performed on a variety of vehicles, a test bench for electric two-wheelers, a battery test station, laboratory test equipment for electric machines, electric drives and power electronics (installed power 800 kW, industrial test potential up to 300 kW).

The ETEC is also active in standardization in the field of electric vehicles (i.e., IEC TC69, ISO TC22 SC21, CEN TC301 and CENELEC TC69X).

The EU-funded projects in the field of electric, hybrid and fuel cell vehicles carried out by the ETEC are for the FP5: PRAZE, E-TOUR and ELEDRIVE; and for the FP6: SUBAT, HARMONY, INTELLICON and HyHEELS.

Green Propulsion

Founded in 2001 as a spin-off of the University of Liège, Green Propulsion is an independent specialist that develops cleaner prototype vehicles, such as alternative fuel, electric, hybrid and fuel cell vehicles.

With Metropol software -developed in-house- the simulation and optimization of a tailored vehicle saves time and money before any development occurs.

Green Propulsion consequently offers homemade complete vehicle integration, including mechanical design, thermal management, electric wiring, electronic cards development, vehicle tuning and monitoring.

Recent projects include the development of an electric superkart with an acceleration of 0-100 km/h in 2.5 seconds, a prototype parallel hybrid VW Lupo, an electric/series-hybrid Microbus, a prototype combined series/parallel hybrid Renault Kangoo, an Imperia revival sport concept car and a hybrid bus.

14.4

Industry

The Belgian light-duty automotive industry consists principally of assembly plants (Ford Genk, Volkswagen Vorst, Opel Antwerpen and Volvo Gent) and components suppliers. In heavy-duty vehicle markets, Belgium has two bus- and coachbuilders. One builder -Van Hool- specializes in bodies and chassis. Since building three A308H 9-meter hybrid public transport buses in the mid 1990s, Van Hool has recently developed a fuel cell bus for the U.S. market and introduced that model also into the European market.

Punch International -a Belgian technology company- plans to become an important player in the hybrid vehicle technology field. In 2006, it took over the Belgian ZF Getriebe subsidiary -now called Punch Powertrain- with the ambition to develop hybrid powertrains based on the continuous variable transmissions (CVT) developed and built in this plant.

Punch Powertrain will modify its existing CVTs to become the core of this new parallel hybrid powertrain. The first development project aims at powering B-segment passenger cars and small vans. Punch Powertrain is partnering with battery and electric motor technology providers to combine good performance and improved fuel consumption with a low cost premium. The market introduction is scheduled for early 2009.

The Belgian industry has more to offer in hybrid vehicle components. Suppliers of components for conventional vehicles -as well as non-automotive suppliers that seek new markets- are looking for opportunities. These suppliers are active today in the following markets:

- Batteries.
- Electric motors and generators.
- Power electronics.
- Transmissions.
- Electronic controllers.
- Data communication.

14.5

On the road

The EV and HEV deployment in Belgium is limited. Because diesel fuel carries a lower taxation than gasoline, the passenger car market is dominated by diesel vehicles. Belgium has one of the highest market shares of diesel passenger cars in Europe.

The income tax benefit for vehicles with low CO₂ emissions partially compensates for the price premium of the Toyota Prius. Also, the new Prius II seems to appeal to a broader spectrum of car buyers than its predecessor. Consequently, sales figures for the Prius have risen substantially.

At the higher end of the model range, the Lexus hybrids RX 400h and GS 450h are a success. For these models, Lexus will need to source vehicles from sister companies to Europe, because the number of vehicles allocated to Belgium is too small.

Currently, no electric cars (passenger vehicle category in table 14.5) are sold in Belgium, although a total number of almost 80 EVs has been sold during the years 1995-2003. The number of electric cars in the Belgian vehicle fleet is diminishing over the years.

Table 14.4 provides an overview of the different hybrids sold in Belgium for the period 2004-2007. Thus, the number of hybrids sold is increasing, but it remains marginal compared with the total car market (i.e., 0.26% in 2007).

Table 14.4 Hybrid car sales in Belgium for the period 2004-2007. (Data © Febiac.)

Make	Model	2004	2005	2006	2007
Citroën	C3	-	-	56	56
Honda	Civic	5	3	86	149
Lexus	GS 450h	-	-	47	101
Lexus	RX 400h	-	106	283	264
Toyota	Prius	126	362	486	778
	Total	131	471	958	1'348
Total car market		484'757	480'088	526'141	524'795
Share of hybrids		0.03%	0.10%	0.18%	0.26%

Motorised vehicle fleet data for Belgium is presented in table 14.5. Separate data for hybrid electric vehicles was not available at the time of writing.

Table 14.5 Characteristics and population of the Belgian motorised vehicle fleet per August 1, 2004-2008. (Source: FOD Economie - Algemene Directie Statistiek en FOD Mobiliteit en Vervoer.)

Vehicle type	2004	2005	2006	2007	August 1, 2008	
	EV fleet	EV fleet	EV fleet	EV fleet	EV fleet	Total fleet
Motorised bicycle (no driver licence)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Motorbike	6	5	8	10	20	388'280
Passenger vehicle	30	22	13	8	10	5'130'578
Multipurpose pass. vehicle	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bus	2	n.a.	21	19	19	15'992
Truck	78	66	62	51	56	711'889
Industrial vehicle	937	965	886	942	1'004	235'294
Total	1'053	1'058	990	1'030	1'109	6'482'033

n.a. not available

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

14.6 Outlook

Tax incentives -as well as the high cost of petroleum fuel- are expected to increase the popularity of hybrid vehicles. Additionally, car manufacturers are expected to introduce new hybrid vehicles, including diesel hybrids.

In the heavy-duty market, potential users may help to push the development of hybrid buses and trucks. Next to improved fuel economy, the performance and silent operation of zero emission vehicles may be a driver for implementing hybrids. The following are two examples of how users may help to drive heavy-duty hybrid vehicle development:

- In goods distribution, a large supermarket chain may seek to avoid road congestion by supplying its shops from a central warehouse during the night. Hybrid electric trucks in EV mode could provide silent operation in urban and suburban areas.
- Similarly, in some cities public transport companies could deploy hybrid buses to decrease noise levels and emissions in sensitive areas.

VITO is actively seeking development projects for hybrid vehicle technology. These projects will target the development of components and powertrains -as well as complete vehicles- with VITO's network of industrial partners and other research institutes.

14.7

Benefits of participation

Participation in the activities of the International Energy Agency Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) has several advantages:

- The exchange of information among and experience with 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.
- The contact between researchers and specialists results in synergies.

14.8

Further information

More information about the Belgian organizations that are active in the field of hybrid and electric vehicles can be obtained from the following internet websites:

- www.greenpropulsion.be (in English and French).
Green Propulsion, a spin-off of the University of Liège, is an R&D centre for clean vehicles.
- www.vito.be (in Dutch and English).
VITO is a research institute located in Belgium's Flemish region. In its Energy Technology Centre, the Vehicle Technologies Group develops HEVs and supports the introduction of energy-efficient and clean vehicles.
- www.vub.ac.be and <http://etecmc10.vub.ac.be> (in Dutch and English).
The Vrije Universiteit Brussel has 30 years of experience in the field of battery, hybrid and fuel cell electric vehicles, making it the premier electric vehicle research facility in Belgium.

AVERE

The European Association for Battery, Hybrid and Fuel Cell Electric Vehicles AVERE was established in 1978 under supervision of the European Community. It gathers automobile manufacturers and suppliers, electric utilities, public organizations and research institutions active in the field of electric and hybrid vehicles. It is part of the World Electric Vehicle Association WEVA, which organizes the yearly Electric Vehicle Symposium EVS (1'500 participants). AVERE is divided in 15 national sections; its Belgian section is ASBE.

The AVERE secretariat is now established at the Vrije Universiteit Brussel. More information is available at www.avere.org (in English).

CITELEC

The international association CITELEC is also established at the Vrije Universiteit Brussel. CITELEC is an association of European cities interested in the use of electric and hybrid vehicles. It was founded on February 2, 1990, under the aegis of the European Community. The association now has 60 members in several countries. CITELEC and its members study the contribution that electric and hybrid vehicles can make to the solution of traffic and environmental problems in the city. CITELEC's main missions are:

- Informing the cities on the characteristics of battery electric, hybrid electric and fuel cell vehicles (referred to henceforth as 'electric vehicles').
- Accompanying the deployment of electric vehicles in the cities and training the users.
- Contributing to the realization of the needed infrastructures.
- Organizing test demonstrations for electric vehicles: '12 Electric Hours' and 'Transeuropean' (www.transeuropean.org).
- Submitting electric vehicles to test programs.
- Performing studies concerning the influence of electric vehicles on traffic and environment in the city.
- Taking part in international standardization concerning electric vehicles and their infrastructure.

More information is available at www.citelec.org (in Dutch, English and French).

EPE

The Department ETEC of the Vrije Universiteit Brussel is at the basis of the founding -in 1985- of the European Power Electronics and Drives Association (EPE) and its conference. This conference represents the world's largest event in the field of power electronics and electric drives (1'000 participants). A specialist work group is involved with the (rapidly growing) electric and electronic aspects in the automotive industry. The EPE has a special chapter related to electric and hybrid vehicles.

More information is available at www.epe-association.org (in English).

Flanders' DRIVE

Flanders' DRIVE strives to strengthen the product development capabilities of the Flemish suppliers to the automotive industry, with the aim of safeguarding and enhancing the strategic competitiveness of this industry in Flanders on a European and global level.

More information is available at www.flandersdrive.be (in Dutch and English).

VSWB - Flemish Cooperative on Hydrogen and Fuels Cells

The objectives of VSWB (Vlaams Samenwerkingsverband Waterstof en Brandstofcellen - Flemish Cooperative on Hydrogen and Fuels Cells) are the exchange of information and the definition of joint projects.

More information is available at www.vswb.be (in Dutch).

14.9**References**

- [14.1] Enviodesk. *Milieumaatregelen beslist op federale top te Leuven.* Newsflash, March 20, 2007.
- [14.2] Willems, M. *Het nieuwe stelsel van CO₂-bijdragen.* Magazine Fleet, January 2005.

15 Canada

15.1 *Introduction*

Since 2006, the Canadian Government, industry, and the public have had an increased awareness of and interest in electric mobility. The government of Canada has been actively supporting research and development (R&D) in advanced transportation fuels and technologies. Statistics for 2006 show that only 25% of Canada's electricity was generated from fossil fuels, 60% was from renewable resources, and 15% was from nuclear sources. Almost all of Canada's current renewable generation is from hydro sources, but there is a potential for increased generation from other renewable sources, such as wind, solar, and geothermal. The opportunity to reduce greenhouse gas (GHG) emissions by electrifying the transportation system is significant.

In 2007, the Canadian Government started a new R&D program that focuses on plug-in hybrid electric vehicles (PHEVs). Some electric utilities in Canada have begun to consider EVs and PHEVs as important elements in the evolution of the electrical distribution network, and a number of them are now investigating the challenges associated with connecting these vehicles to the electrical grid so they will be ready when the vehicles arrive. In addition, many Canadian consumers are pondering the purchase of a hybrid car as way to save money at gasoline stations and to address the negative environmental impacts from burning fossil fuels.

Current hybrid technology already provides an alternative that reduces fuel consumption, and PHEVs are seen as the most proactive next step toward achieving further reductions. Canadian consumers know that the current hybrid technology does not require one to recharge a car by plugging the batteries into an electrical outlet. However, they may not realise that next evolution of HEVs will require this type of recharging. PHEVs will offer more electric-only operability and reduce fuel consumption. Educating consumers about the different types of hybrid vehicles continues to be a priority of several Canadian Government programs.

15.2 *Policies and legislation*

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_tsds/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. In 2005, the 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. 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 risen substantially over the last two decades. For this reason, the government has announced its intent to regulate, following the termination of the MOU.

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 ecoAUTO, ecoFREIGHT, ecoMOBILITY, and ecoTECHNOLOGY for Vehicles (www.tc.gc.ca/programs/environment/ecotransport):

- ecoAUTO. This rebate program was introduced in 2007 to encourage Canadians to buy new fuel-efficient vehicles. It offered rebates from \$1'000 to \$2'000 to people who bought or entered a long-term lease (12 months or more) for a fuel-efficient vehicle that met the required criteria. Rebates were applicable only on eligible 2006, 2007, and 2008 model-year vehicles purchased or leased between March 20, 2007, and December 31, 2008.
- 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

Provinces and territories regulate vehicle licensing and the use of vehicles on their roads. With respect to LSVs, provinces and territories may designate areas for use

of LSVs or may otherwise regulate the use of LSVs on public roads. Power-assisted bicycles, in addition to meeting federal requirements, must also comply with the requirements of provincial and territorial regulations. Each province or territory may adopt the federal definition as is or add further restrictions to meet its own specific needs. Policy makers across Canada have identified hybrid vehicles as a technology that could reduce fuel consumption and GHG emissions from the transportation sector. As a result, some provincial governments offer tax incentives for purchasing a hybrid vehicle.

15.3

Research

The Program of Energy Research and Development (PERD) is a federal, interdepartmental program operated by Natural Resources Canada (NRCan). PERD funds 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 PERD and other such programs administered by NRCan will fund research, development, and demonstration (RD&D) endeavours in a wide array of energy portfolios. For example, the ‘Clean transportation systems portfolio’ supports the development of hydrogen and fuel cell technologies, EVs, emission reduction technologies, advanced fuels, and advanced structural materials needed to break through to a clean transportation system. PERD also strives to generate the new scientific knowledge that is needed to support the proposed regulatory approach to the Clean Air Agenda; this effort includes providing a sound scientific and technical background for establishing meaningful codes and standards. PERD will conduct EV R&D that concentrates on PHEVs and will focus its efforts on the range of opportunities and challenges that these vehicles present. As do the other advanced vehicle technologies explored in this portfolio, the PHEV concept has great promise for significantly reducing air pollutants, GHG emissions, and oil consumption. Led by the National Research Council of Canada (NRC), PERD’s EV R&D activities will focus on four areas: energy storage systems, electric drive components, powertrain optimization, and development of regulations for emissions and fuel efficiency.

15.4

Industry

The automotive industry is Canada’s largest manufacturing sector, accounting for 12% of manufacturing gross domestic product (GDP) and 26% of manufacturing trade in 2006. The industry consists of 23 passenger/commercial vehicle assembly plants and more than 640 auto parts plants. It directly employs about 158'000 people in automotive assembly and component manufacturing. Manufacturing is clustered in central Canada, while distribution is spread across the country.

In 2008, the government of Canada established a new Automotive Innovation Fund (AIF) that will provide automotive firms with \$250 million over five years to support strategic, large-scale R&D projects to build innovative, greener, more fuel-efficient vehicles. Eligible projects will include vehicle and powertrain assembly operations that are associated with significant automotive innovation and R&D initiatives (www.ic.gc.ca).



Fig. 15.1 Batteries: cylindrical cell product line. (Courtesy of E-One Moli Energy Ltd.)

Canadian EVs represent a large potential market for a wide range of component suppliers, especially since the interest in PHEV technology has been rising. For some time, Canada has been in the list of the top 10 worldwide countries that produce motor vehicles. The auto sector is the manufacturing sector that contributes the most to Canada's GDP, no doubt because of its parts suppliers and manufacturers. Thus, with its already well-established manufacturers in the EV industry, Canada is well positioned to benefit from the continued growth of HEVs and future PHEVs.

In 2008, the government of Canada supported development of the first edition of the 'Directory of electric mobility resources Canada 2008', meant to list all Canadian organizations currently involved in electric mobility. The number of organizations -large and small private and public entities from coast to coast- shows that Canada has a strong base from which to pursue opportunities to meet the growing need for electric drive transportation, domestically and internationally (figures 15.1 and 15.2). The directory was produced by Electric Mobility Canada and can be found at www.emc-mec.ca/en.



Fig. 15.2 Electrovaya battery pack. (Courtesy of Electrovaya.)

Also in 2008, the Canadian EV industry, in collaboration with the government of Canada, began developing an EV Technology Roadmap (evTRM). The evTRM, which is near completion, is the product of a consultative process designed to help industry, its supply chain, academic and research groups, and governments jointly identify and prioritise the technologies needed to support strategic R&D, marketing, and investment decisions. The process gave the various players the opportunity to build links and interact (www.evrm.gc.ca).

15.5

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 2007, as of July each year, are shown in table 15.1.

Table 15.1 Light-duty vehicle registrations in Canada, as of July each year. (Source: Desrosiers Automotive Consultants Inc.)

Type of fleet	2004	2005	2006	2007
EV fleet ^(a)	14	11	18	21
HEV fleet	2'939	6'053	13'253	25'783
Total fleet ^(b)	18'709'017	18'882'567	19'365'344	20'242'775

- (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.).

15.6

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. Regarding the introduction of PHEVs, the potential for increased fuel savings will have to outweigh the incremental cost of these vehicles in order for growth in their sales to continue. To date, owners of HEVs have not purchased these vehicles on the basis of financial savings. In order for these new-technology vehicles to achieve a larger market share, financial savings will have to be a much greater part of the equation.

15.7

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 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.

15.8

Further information

The following websites may be consulted for further information:

- www.ec.gc.ca (in English and French).
Environment Canada. Its work includes: to preserve and enhance the quality of the natural environment; and to co-ordinate environmental policies and programs for the federal government.
- www.nrc-cnrc.gc.ca (in English and French).
The National Research Council (NRC) is the government of Canada's premier organization for research and development, active since 1916.
- www.nrcan-rncan.gc.ca/com (in English and French).
Natural Resources Canada (NRCan) homepage.
- www.nrcan.gc.ca/eneene/science/index-eng.php (in English and French).
The Office of Energy Research and Development (OERD) is the government of Canada's co-ordinator of energy research and development activities.
- www.nrcan.gc.ca/eneene/science/perdprde-eng.php (in English and French).
Program of Energy Research and Development (PERD).
- www.tc.gc.ca (in English and French).
Transport Canada.

16 **Denmark**

16.1 **Introduction**

In January 2007, the Danish Government announced a new energy strategy aimed at a higher share of renewable energy in the Danish energy system. It is Denmark's long-term vision to obtain independence from fossil fuels such as coal, oil, and natural gas.

It is the goal of the government that the actual share of renewable energy at 15% should be at least doubled to 30% by 2025. As of 2008, biomass accounted for almost half of the use of renewable energy, and wind turbines produced 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 to about 6'000 MW.

This strategy faces several challenges. A major one is to adapt the electricity system to manage a considerably higher share of intermittent electricity produced from wind turbines. Flexible electricity consumption will be an important factor, and, in this context, battery, plug-in hybrid, and fuel cell electric vehicles could play a very important role.

16.2 **Policies and legislation**

Policies

The new energy strategy of January 2007 has included the transport sector. To reduce oil dependency and CO₂ emissions from the transport sector, the main focus has been to promote more energy-efficient vehicles and the use of biofuels. The Danish Government decided to give priority to the development of second-generation biofuels, mainly those produced from waste products from agriculture.

In August 2007, the Danish Energy Authority published a report on alternative fuels in the transport sector. One of the report's conclusions is that from a long-term perspective, battery electric vehicles (EVs) have the potential for achieving the highest energy efficiency and, at the same time, for providing important advantages for the local environment, such as no local emissions and a very low noise level. The electricity storage capabilities of the batteries also have a very interesting potential to optimise the integration of intermittent renewable energy, such as wind power, in the electricity system.

To support the development and demonstration of new energy technologies to realise the energy strategy, the Danish Government initiated a new Energy Technology Development and Demonstration Programme (EUDP) in 2008.

During 2008, hybrid and electric vehicles were more often identified in and a focus of political and public discussions as an optimal and realistic answer to the challenges of the transport sector. The energy sector especially has shown a high interest in EVs and plug-in hybrid electric vehicles (PHEVs) as an important means for meeting the future challenge to integrate 50% of wind power in the electricity system. The energy sector advocates for demonstration programmes for EVs with new advanced technology.

In February 2008, a new Climate and Energy Agreement was entered into by almost all political parties in the Danish parliament. As an element in this agreement, the parties decided to allocate 30 million DKK (4 million Euros) to promote demonstration programs for battery EVs. This promotion program started in December 2008; however, there is a problem in that very few battery EVs are available for sale on the market.

Legislation

The Danish registration tax for passenger cars is very high (180%) and 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 increase the tax for less energy-efficient cars. The reduction is 4'000 DKK for each km/l over 16 km/l the efficiency is, 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 cars -especially diesel cars- has increased considerably.

During several years, the annual tax has been based on energy consumption and CO₂ emissions - also to promote sales of energy-efficient cars.

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

Battery EVs and fuel cell vehicles are exempted from the registration tax and annual tax, but there are actually no vehicles for sale on the market.

There are no tax rules for PHEVs. The new Climate and Energy Agreement states that tax rules to promote PHEVs will be decided before the end of 2009.

16.3

Research

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

Denmark has two world-leading companies -Novozymes and Danisco- in the development and production of enzymes to produce biofuels. In 2007, the construction of a full-scale production plant for second-generation bio-ethanol based on agricultural waste products began with support from the above-mentioned EUDP.

During several years, the Danish Energy Authority has conducted a hydrogen and fuel cell programme that focuses on research and development (R&D) of solid oxide fuel cells (SOFCs) and polymer electrolyte membrane (PEM) fuel cells. The use of SOFCs is demonstrated and tested as micro-CHP (combined heat and power) units running on natural gas, and the use of PEM fuel cells is demonstrated and tested as micro-CHP units running on hydrogen produced from off-peak wind power.

The company H2 Logic is working on a project with Th!nk in Norway to develop a hybrid storage system with batteries and PEM fuel cells for the new Th!nk electric car. The aim is to combine highly energy-efficient batteries with the possibility of fast refuelling with hydrogen. To demonstrate this solution, the Danish Hydrogen Link network is working to establish a hydrogen infrastructure. This work is a part of the Scandinavian Hydrogen Highway Partnership, which is aiming to establish an early hydrogen refuelling infrastructure.

In 2008, several activities and research projects designed to analyze the potential of vehicle-to-grid (V2G) services from PHEVs and battery EVs were initiated. These activities are expected to expand considerably in the coming years. In March 2009, the so-called EDISON project will start. Several national and international partners will co-operate in this three-year project whose aim is to pave the way for integrating transportation into the power grid. The immediate objective is to prepare demonstration projects that will be analyzed under realistic conditions to examine how these vehicles can support and benefit from the Danish electricity system with a high share of wind power.

16.4 Industry

As mentioned in the previous section, although Denmark has no conventional car industry, it has many component suppliers. Denmark was one of the first countries to produce and market EVs. Production of the small Ellert -which became the most sold EV in the world- started in 1987, and in 1991, production of the Kewet El-Jet began. To facilitate the sales of these vehicles in Denmark, EVs were exempted from the registration tax and the annual car tax based on weight. By now, however, both manufacturers ceased production in Denmark. Improved versions of the vehicles are currently produced in Germany and Norway.

16.5 On the road

The total number of passenger cars in Denmark just passed 2 million and is increasing slightly. The number of electric cars, however, is decreasing slightly; it is estimated to be about 250. These cars mainly consist of the French Citroën Saxo and Berlingo Électrique and the Danish Kewet El-Jet. In addition, there are about 350 City-el vehicles and a few electric scooters and e-bikes. There are very many bicycles in Denmark (more than one per person, which means more than 5 million), but e-bikes (i.e., electric bikes) are still not selling in large numbers, even though their quality improved during 2008. Many e-bikes are now equipped with lithium-ion batteries.

Table 16.1 Characteristics and population of the Danish motorised vehicle fleet per December 31, 2008. Estimates are in *italic*.

Vehicle type	December 31, 2008		
	EV fleet	HEV fleet	Total fleet
Motorised bicycle			
(no driver licence)	10'000	0	n.a.
Motorbike ^(a)	350	0	200'000
Passenger vehicle	250	250	2'000'000
Multipurpose pass. vehicle ^(b)	0	50	25'000
Bus	n.a.	0	15'000
Truck	n.a.	0	50'000
Industrial vehicle	n.a.	0	n.a.
Total	10'600	300	2'290'000

n.a. not available

(a) Motorbikes include City-el.

(b) Not including vans. Many MPVs and sport utility vehicles (SUVs) are registered as vans in Denmark.

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

There have been no sales of new electric cars in Denmark, and some cars have been taken out of service due to technical problems with batteries, electric equipment, etc. Many electric cars that were originally bought and owned by companies and public authorities have been sold for private use or have been exported.

Only Toyota is marketing hybrid vehicles in Denmark. The Toyota Prius hybrid has been on the Danish market since May 2004, but only a very limited number have been sold: as of the end of 2007, only 25 Toyota Priuses were registered in Denmark. However, due to the recent changes in registration taxation, vehicle sales in 2008 numbered about 210. The most important barrier to customers 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 started 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 2008, a total of about 50 vehicles were registered and on the road.

Sales of the Lexus GS 450h started in Denmark in 2006. 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. As of the end of 2008, about 10 Lexus GS 450hs were on the road.



Fig. 16.1 Nissan EV. (Photo courtesy of Better Place Denmark.)

The Lexus LS 600h was introduced to the Danish market in 2007. Sales in this market segment are very limited in Denmark. As of the end of 2008, five Lexus LS 600hs had been sold.

In January 2009, project Better Place and DONG Energy closed an agreement in which they invested 103 million Euros in the Danish electric car infrastructure. The Renault-Nissan alliance will commercialise a range of EVs adapted to Danish customer requirements. This EV from Nissan is one of the possibilities for the Better Place fleet (figure 16.1).

Danish experiences with battery EVs

In 2005, the Danish Environmental Protection Agency (Ministry of Environment) published the report 'Experience with electric cars in Denmark'. The report collates and assesses practical experiences with electric cars in Denmark from 1998 to 2001, and it also includes user experiences from later years. The emphasis is on user experiences with the new generation of Citroën and Th!nk electric cars, which were marketed in Denmark from 1997 to 2004. These experiences might be valuable to study with regard to the introduction of next-generation EVs.

User experiences

About 150 Citroën and about 20 Th!nk electric cars have been sold in Denmark, mostly between 1998 and 2002. Of these vehicles, 75% were bought by municipalities and electric companies, 5% by government agencies, 15% by private enterprises, and 5% by private individuals. The city of Copenhagen acquired almost one-third of these electric cars. After 2002, the pattern has been that more private individuals have purchased second-hand electric cars.

Almost all electric car users stated that they are very pleased with the performance of the cars, especially in city traffic. Driving an electric car in congested urban traffic involving traffic jams and frequent stops is far less stressful than driving a conventional car. The electric cars accelerate well and can keep up with the traffic. The low noise level inside the car is considered a great advantage.

For all groups of users, electric cars have shown that they are well suited to carry out the functions for which they were acquired. Private users have driven significantly more kilometres in their electric cars than have public users. This difference is primarily because private owners use their electric cars in daily commutes to and from work.

Most users have found electric cars to be more reliable, have fewer breakdowns, and require fewer visits to the repair shop than conventional cars. However, when problems have arisen, many users have been dissatisfied with the service from repair shops. Users have had to wait a long time for spare parts, repairs have been expensive, and often there has been a lack of expertise to solve the specific problems of electric cars. An important reason for the unsatisfactory service is that it is difficult to establish a satisfactory service organization for the very limited number of electric cars operating throughout Denmark.

Battery problems

During the first years, users were very pleased with the new electric cars equipped with NiCd batteries. However, reliability was later disappointing, and in many cases the batteries completely broke down. The problem turned out to be related to the Saft STM5-100 NiCd batteries produced from the mid-1990s up to 1999. In early 1999, the problem was resolved, and the batteries produced later have not suffered from these breakdowns. Private users have now driven for more than seven years and a distance of more than 130'000 km without battery problems.

The battery problems have had a negative effect on the overall image of electric cars in Denmark. This is unfortunate considering that the problems seem to have been resolved and the cars are otherwise well made and reliable.

Private owners

There have been no direct purchase subsidies for EVs in Denmark. Most of the new electric cars from Peugeot and Citroën were bought by municipalities and electric power companies. However, private owners have been more successful in using their electric cars every day, resulting in considerably higher annual mileages. The experiences of private owners make a very interesting background for assessing the potential of new improved technologies. These experiences could indicate the potential magnitude of the total electrically driven travel distance (accrual) of the fleet of PHEVs having a similar all-electric range of 70 to 100 km.

16.6

Outlook

In the period 2001-2006, electric cars were not considered a realistic possibility for future road transport. However, the market success of hybrid vehicles and the new concept of PHEVs have changed the public's opinion. In the light of the new Danish target stating that 50% of the electricity consumed in 2025 should come from wind power, the combination of using PHEVs and renewable energy from wind is seen as a very strong solution to some future challenges in the electricity and the transport sector.

Demonstration projects with PHEVs and the development of V2G (vehicle-to-grid) technologies are expected to be the focus in the coming years. The project Better Place Denmark full-scale introduction of battery EVs will also be a focus.

16.7

Benefits of participation

Participation in IA-HEV activities has several advantages.

- It allows for the exchange of information on the latest developments in hybrid and electric vehicles and technologies.
- It offers opportunities to make personal contacts with experts from different countries and organizations, which are a source of new ideas that goes beyond the information that is available through written communication.
- It offers the possibility of making informal contacts with experts from other countries to discuss and evaluate new findings related to hybrid and electric vehicles and new issues that come up in the member country

16.8

Further information

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

- www.danskbilkomite.dk (in Danish).
The site of the Danish Electric Vehicle Committee.
- www.danskenergi.dk (in Danish and English).
The site of the Danish Energy Association.
- www.hydrogennet.dk (in Danish).
Danish hydrogen and fuel cell working group.
- www.mst.dk (in Danish and English).
Danish Environmental Protection Agency.
- www.scandinavianhydrogen.org (in English).
The site of the Scandinavian Hydrogen Highway Partnership (SHHP).

17 Finland

17.1 *Introduction*

Year 2008 was remarkable for transportation in Finland in several aspects. The biggest change nationally was the reform of the car tax (a purchase tax) from a price-based to a CO₂ emission-based scheme. This change promoted the sales of hybrid and diesel cars, and sales of new cars, in contrast to their sales in the rest of the European Union (EU), increased from the previous year.

Over the first half of 2008, the rapid increase in oil prices, along with the ongoing debate about climate change, stimulated discussions on alternative fuel and hybrid electric technology policies and played a role in the increased activity of the research and development (R&D) departments of manufacturers of mobile machinery. By year's end, however, the rapid downturn in the world economy and concomitant reduction in oil prices considerably dampened optimism.



Fig. 17.1 Cargotec's Kalmar business unit presented the world's first straddle carrier equipped with a hybrid drive system in June 2008. (Photo supplied by the Helsinki University of Technology.)

In the industrial sector, the most interesting development of relevance was Valmet Automotive's contract to begin manufacturing the Fisker Karma plug-in hybrid electric vehicle (PHEV) at its plant in Uusikaupunki. In addition, Kabus displayed its prototype parallel hybrid bus (figure 17.3), and Kalmar Industries (Cargotec) displayed its prototype serial hybrid straddle carrier (figure 17.1).

The Ministry of Employment and the Economy (TEM) and the Ministry of Transport and Communications plan to set up a working group to review progress in the field of electrically propelled vehicles (with HEVs as an example) and to provide policy recommendations for the Finnish Government.

The Finnish Funding Agency for Technology and Innovation (TEKES), a financing arm of TEM, seeks new possibilities to finance HEV research carried out by research laboratories as well as by Finnish industry, which now seems to be ever more willing to invest in R&D efforts in this field.

17.2

Policies and legislation

Finland must comply with EU policies and legislation. Only its taxation policy has differed from the EU frame. Vehicle and fuel taxes make up a remarkable component of the state budget: car taxes in Finland (together with Denmark) are the highest among the EU countries. Beginning in 2008, the purchase tax of 26% of the retail price was replaced by an emission-based tax whose percentage is calculated according to the following formula: % rate = [CO₂ emissions (g/km)/10] + 4. For example, a car emitting CO₂ at a rate of 160 g/km is taxed at 20% of its retail price. The effect of this taxation shift was major, especially for high-price, low-emission cars. For example, the purchase cost of a Toyota Prius (II) declined from € 39'800 to € 29'950. The new tax generally succeeded in its goal of reducing the average emissions of new cars, as shown in figure 17.2, which compares the emissions of cars registered in 2008 to the average of 2007.

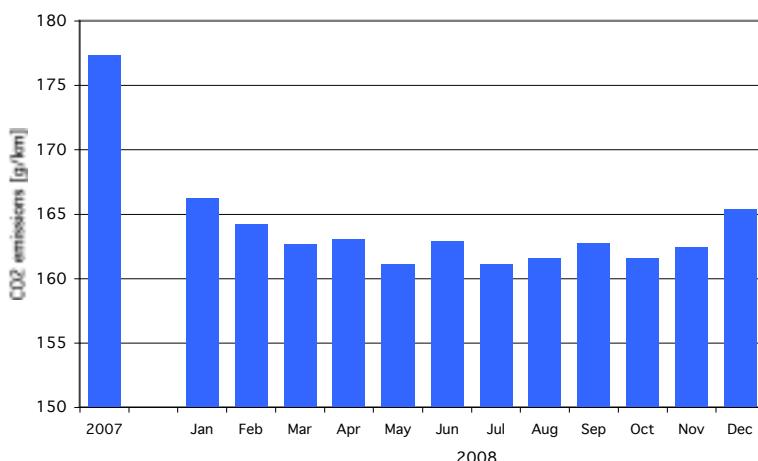


Fig. 17.2 Average CO₂ emissions of new passenger cars in 2007, and by registration month in 2008. Note the consistent reduction from the year 2007 average. (Source: Finnish Vehicle Administration AKE.)

The new tax has opened the door for hybrids in Finland. The total registration of hybrid cars at the end of 2007 was 302; during 2008, 839 new hybrids were registered. At the start of 2010, the annual property tax on vehicles will also be changed to an emission-based scheme. Instead of being fixed at € 127.75 per year, the new tax will range from € 20 (on cars emitting 66 g/km or less of CO₂) up to € 605.90 (on cars emitting 400 g/km or more). It is expected that this structure will generate about the same total tax revenue as its predecessor.

In the autumn of 2008, the Ministry of Finance began a project to evaluate further measures to link environmental performance and taxation. The committee charged to report on this subject was to evaluate fuel and energy taxes, CO₂ taxation, and vehicle taxation (both a purchase tax and an annual tax). HEVs, PHEVs, and battery electric vehicles were to be covered in this work. A report is expected in mid 2009, and resulting changes in taxation will occur at the beginning of 2011.

17.3

Research

Consistent with the other industrial and economic emphases of the country's manufacturing base, HEV research in Finland is focused mainly on mobile machinery. Typically, research projects are financed by the Finnish Funding Agency for Technology and Innovation (TEKES) and by national industrial corporations. HEV development is a component of TEKES's fuel cell programme for the years 2007-2013. The total budget of the programme is € 144 million. At the end of 2008, the TEKES programme board decided to redirect the research emphasis from fuel cells to HEV technologies. Most of this research work is performed 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 academic research partner specifically advancing car technology is Metropolia University of Applied Sciences, which has developed an innovative city car demonstrator based on the Toyota Prius and a full electric racing car referred to as the 'Electric RaceAbout'.

The energy company Fortum has inaugurated a field test of electric cars (battery electric vehicles - BEVs) operated by city employees in the city of Espoo. Five charging stations have been activated for the test. Fortum is also testing PHEVs in a similar deployment in Stockholm, Sweden.

17.4

Industry

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

- Axco Motors. Special motors and generators.
www.axcomotors.com (in English, Finnish and German).
- European Batteries. Manufacturer of lithium-ion batteries.
www.europeanbatteries.com (in English and Finnish).
- Finnish Electric Vehicle Technologies (FEVT). Large-capacity electrical energy storage.
www.fevt.fi (in English, Finnish and Swedish).
- Hybria. HEV system integration and software development; start-up from Helsinki University of Technology.
www.hybria.fi (in English).
- Hydrocell. Manufacturer of fuel cells and hydrogen storages.
www.hydrocell.fi (in English and Finnish).
- Kabus. Bus operator and manufacturer; introduced a parallel hybrid city bus prototype by the end of 2007 (figure 17.3).
www.kabus.fi/etusivu/96-etusivu/2151-briefly-in-english (in English and Finnish).



Fig. 17.3 Kabus launched a hybrid city bus in 2007. The bus has a lightweight full aluminium body and a parallel hybrid drive with supercapacitor energy buffer. It consumes 30% less fuel than a traditional city bus with similar capacity and performance. (Photo supplied by the Helsinki University of Technology.)

- Kalmar Industries. Part of Cargotec Corporation, manufacturer of terminal machines, including several EVs; introduced a prototype serial hybrid straddle carrier in June 2008 (figure 17.1).
<http://kalmarind.com> (in English).

- Konecranes. Manufacturer of industrial cranes and terminal machines, including several EVs.
www.konecranes.fi/portal (in English and Finnish).
- MSc electronics. Power electronics, energy storage converters.
www.mscelectronics.fi/sivut (in English and Finnish).
- Rocla. Forklifts and automatic guided vehicles (AGVs).
www.rocla.com/default.asp?lang=eng (in English).
- Sandvik Mining and Construction. Mining machines, including several electric models.
www.miningandconstruction.sandvik.com (in English).
- Valmet Automotive. Service provider for the automotive industry; manufacturer of Fisker Karma PHEV, first deliveries of which will be at the end of 2009.
www.valmet-automotive.com/automotive/cms.nsf/pages/indexeng (in English, Finnish and German).

17.5

On the road

The share of hybrid and electric vehicles in the total Finnish motorised vehicle fleet is small, but increasing. Table 17.1 presents an overview for the years 2007 and 2008.

Table 17.1 Characteristics and population of the Finnish motorised vehicle fleet per December 31, 2007 and 2008. Estimates are in *italic*. (Source: Finnish Vehicle Administration AKE.)

Vehicle type	December 31, 2007			December 31, 2008		
	EV fleet	HEV fleet	Total fleet	EV fleet	HEV fleet	Total fleet
Motorised bicycle						
(no driver licence)	300	0	185'200	370	0	215'415
Motorbike	0	0	188'000	0	0	203'698
Passenger vehicle	104	302	2'553'556	100	1'141	2'682'831
Multipurpose pass. vehicle	0	0	n.a.	0	0	13'030
Bus	0	1	11'500	0	1	12'230
Truck	0	0	96'610	0	0	105'106
Industrial vehicle	n.a.	n.a.	n.a.	n.a.	n.a.	404'727
Total	404	303	3'034'866	470	1'142	3'637'037

n.a. not available

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

17.6 **Outlook**

Year 2008's tax policy shift proved to be a promising example of how taxation could redirect consumer behaviour, and it also raised consciousness about CO₂ emissions. Year 2009 is likely to be a watershed year for Finland with regard to its acceptance of hybrids and more environmentally friendly cars. The worldwide economic crisis and associated likely downturn in vehicle sales may slow down or postpone hybrid development projects, but it is unlikely that development work will come to a full halt. In rare cases, there may even be new investments in research, thanks to the greater availability of engineering personnel within companies.

At the national scale, two interesting questions relate to whether there will be greater penetration of hybrids in the Finnish vehicle market:

1. What will the total sales volume of over-the-road hybrid vehicles be in 2009? Do the results for 2008 indicate a short-lived 'early adopter' phenomenon or the beginning of a true upsurge in sales? The distortions introduced by a generally negative economic situation will make it difficult to obtain a reliable answer simply by following developments.
2. What will the after-market price point be for used hybrid cars? Will they retain their value and attractiveness to customers who want to buy pre-owned cars? Again, the general economic situation will make a reliable assessment of the situation difficult.

There is also an interesting question at the global scale. Will younger customers with a high level of technical interest and competence turn to factory-produced (original equipment manufacturer - OEM) hybrid and/or electric cars in the future, or will they prefer to perform their own conventional-to-hybrid conversions?

At the moment, all major mobile machinery manufacturers are either developing or planning hybrid powertrains for their vehicles. The course of the economic downturn and trends in oil prices in the near future will strongly determine when these new hybrid technology components are brought to market.

17.7 **Benefits of participation**

Because Finland became an active IA-HEV member in 2008, it seemed premature to include a 'benefits of participation' section in this years' annual report.

17.8 **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 17.4 'Industry'.

18 France

18.1 *Introduction*

Regarding industrial and R&D activities that are under way, a promising picture emerged for the development of electric vehicle (EV) and hybrid electric vehicle (HEV) markets in France and Europe. Carmakers and their suppliers were involved in industrial projects with the goal of marketing EVs and HEVs on a large scale by 2010.

18.2 *Policies and legislation*

Le Grenelle de l'Environnement

The purpose of the Grenelle programme is to implement counter-strategies to climate change, preserve biodiversity, enhance natural resources and implement an environmental democracy. The Grenelle Environment Forum submitted its conclusions on October 25, 2007, after four months of consultation that brought together institutional actors, representatives of civil society and citizens. French president Nicolas Sarkozy announced that a four-year, major national sustainable development programme is to be launched to develop energy, biodiversity and environmental health. The Economic and Social Council is to be reformed to give environmental non-governmental organizations a place alongside social partners. The public procurement code will be revised to make environmental clauses compulsory.

Regarding transport, France is radically altering its past strategy, with priority now going to rail and waterway transport. An additional 2'000 kilometres of track will be built by 2012 for the Train à Grande Vitesse (TGV) high-speed rail system. The lines thus freed up will be allocated to freight transport. Inland waterway transport will also be promoted. The objective is to reduce the emissions of the entire transport sector by 20% by 2020 and return them to the 1990 levels. To reach this goal, several actions will have to be implemented, including improvement of passenger cars by:

- Reducing the average CO₂ emissions from the total fleet from 176 gCO₂/km (today) to 130 gCO₂/km in 2020.
- Encouraging the strengthening of European new vehicle limits on CO₂ emissions from 130 gCO₂/km to 120 gCO₂/km.
- Developing new technologies of clean vehicles like EV/HEV plug-in vehicles.
- Promulgating incentives for the purchase of low emission vehicles (see Bonus/Malus, below).

Table 18.1 shows the details of the Bonus/Malus system put into force on January 1, 2008. This new incentive system based on CO₂ emissions replaces the previous tax credit for the purchase of clean vehicles. The purchase tax relief (green) or penalty (orange) shown in table 18.1 is a function of CO₂ emission rate per kilometre. On December 4, 2008, the extra 300 Euro bonus that is offered for the destruction of a vehicle older than 15 years was announced to increase to 1'000 Euros for cars older than 10 years, as part of the plans to support the French economy.

Table 18.1 Bonus/malus system effective January 1, 2008.

	Bonus			Null	Malus			
CO ₂ emissions [g/km]	<60	60 to 100	101 to 120	121 to 130	131 to 160	161 to 165	166 to 200	201 to 250 >250
Bonus or malus [Euros]	-20% Max 5'000	- 1'000	- 700	- 200	0	+ 200	+ 750	+ 1'600 + 2'600

18.3 Research

Following the conclusions of the Grenelle Forum, 33 Operational Committees have been established to carry out the different actions. Operational Committee number 8 (Comop 8) is an ad-hoc committee in charge of the industrial development of clean road vehicles.

The Comop 8 has defined five main axes of work:

- Stop-start operation.
- Hybrids and plug-in hybrids.
- Specifically designed electric vehicles.
- Urban trucks.
- Electric and hybrid buses.

Concurrently, the third edition of the research programme PREDIT (Programme National de Recherche et d'Innovation dans les Transports Terrestres) (2002-2007) concluded with the preparation of the plan for its fourth edition (PREDIT 4). PREDIT is a programme of research, experimentation and innovation in land transport, started and implemented by the ministries in charge of research, transport, environment and industry, the ADEME and the Agence Nationale de Valorisation de la Recherche (ANVAR). By stimulating co-operation between the public and private sectors, this programme aims at encouraging the creation of transportation systems that would be economically and socially more effective, safer and more energy saving.

Considering the possible time gap between phases 3 and 4 of the PREDIT programme, the National Agency for Research (ANR) launched its own research programme on land transport, called ‘Véhicules pour les Transports Terrestres’ (VTT).

The VTT programme covers several scientific and technological fields; moreover, it relates to all land surface means of transport (chiefly road and rail) and all their uses (private individuals, professionals, travellers and goods). The VTT call for projects comprises two main axes or themes. The first is centred on the environmental effectiveness of transport in terms of reduction of emissions (greenhouse gases, pollutants, noise). The second axis is centered on the efficiency of the systems of transport in terms of regulation of flow and networks, safety and security.

18.4 Industry

Johnson Controls-Saft

In January 2008, Johnson Controls-Saft Advanced Power Solutions officially opened its new lithium-ion automotive battery manufacturing facility. The plant, based in Nersac, France, is dedicated to the manufacture of advanced lithium-ion batteries for hybrid, plug-in, fuel cell and electric vehicles. Johnson Controls-Saft initially invested 15 million Euros in the facility, which produces batteries for global automotive customers. It has been built to be scaleable, so that as customer and market demands increase it can increase production capacity to meet them.

At the same time, Johnson Controls-Saft has been selected to supply lithium-ion batteries for the Mercedes Class S 400 hybrid. Promising negotiations are ongoing with one other European carmaker and two Chinese (SAIC, Chery) carmakers.

BatScap

After having bought AVESTOR (its only competitor in lithium metal polymer (LMP) battery production) in 2006, BatScap announced in December 2007 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 LMP battery developed by Bolloré, and it will have a range of 250 km (155 miles) in an urban environment. The Pininfarina electric vehicle will be marketed simultaneously in Europe, the United States and Japan in 2009. The production capacities -which depend on the number of batteries produced by Bolloré- will allow the delivery of 1'000 vehicles by mid 2009. Total capital investment in the Bolloré-Pininfarina project is about 150 million Euros (US\$ 216 million).



Fig. 18.1 BatScap electric car, as presented in March 2008. (Photo: M. van Walwijk.)

BatScap took a new step in its corporate development by announcing their commercial launch of supercapacitors. At this stage, the total investment is 36 million Euros. The first industrial production line -with a maximum capacity of one million units per year- has been installed at the Bolloré group's Ergué-Gabéric site. This initial production line covers a surface area of 2'100 m² and currently employs around 50 technical and support staff. This commercial launch is the culmination of more than ten years of research and development.

With a nominal rating of 2.7 V and designed to achieve ultra-low resistance values, BatScap's supercapacitors show remarkable performance with regard to energy density (up to 6 Wh/kg) and lifecycle (several million charge/discharge cycles). BatScap is commercialising its supercapacitors as single cells, as well as multi-cell modules with voltage balancing electronics included. Two cells with capacitances of 2'600 F and 5'000 F are commercially available.

Valeo

Valeo's LowCO2MOTION programme aims to improve vehicle gasoline engine efficiency on the one hand and the proper management of the energy used by the vehicle on the other hand, especially during the slowing down and stopping phases. This programme will contribute in the long run to reducing CO₂ emissions and diesel engine pollutants.

This programme focuses on two new products:

- 1) The camless valve actuation system enables control of the valves of the internal combustion engine -thanks to electromagnetic actuators- and it replaces the camshaft. It also optimises combustion for all gasoline engine speeds, as it will for the diesel engine in a subsequent version.
- 2) The mild hybrid system, conceived on the basis of an alternating current car starter, enables management of the energy used by the vehicle and applies to all types of motorizations and fuels. This stop-start system features a regenerative braking function; energy generated during braking is recovered and is used again when the car starts to move. The system suppresses all fuel consumption when the car is at a standstill. This programme integrates the development of a new high efficiency, high power alternator technology. The partnership for this mild hybrid system includes PCA (PSA Peugeot Citroën group), BatScap (Bolloré Group) for electricity storage by ultracapacitors, and TNO (the Netherlands).

The LOwCO2MOTION programme represents a 211.6 million Euros global investment in research and development that will extend over the 2007-2011 period.

Peugeot Citroën Automobiles (PCA)

In mid 2006, the French carmaker PCA launched an industrial development programme in order to pave the way to commercialization of diesel hybrids by 2010. Originally, its hybrid HDi target was intended to be a mid-class vehicle combining a 1.6-litre HDi diesel engine, a particulate filter (DPF) and a new generation stop-start system, together with an electric motor, a power converter, high-voltage batteries and an electronic control unit, with emission goals of 90 gCO₂/km. However, early in 2008, the manufacturer announced the reduction of the mid-class development programme and its intent to re-focus on a top class vehicle that would be better able to accept the extra cost of the hybrid powertrain.

Renault

Renault has announced plans to develop an electric vehicle by 2010. The development -part of Renault's efforts to reduce greenhouse gas emissions- falls under their Renault Commitment 2009 environmental plan. The electric vehicle is being jointly developed with Nissan as part of their corporate alliance. Research has focused on looking into a solution that will emit zero CO₂ emissions in use and will be ideally suited to city driving.

The project has reached an advanced stage, with the company already working on all the future vehicle's components. Renault and Nissan are also working together on lithium-ion battery technology and packaging, the electric motor and the software

needed to manage the solution. As to commercialization, the joint company's wide variety of markets offers the potential for high sales volumes, says Renault. The fleet market in France and Europe will be the main focus for the vehicle in 2010.

18.5

On the road

La Poste

In April 2007, La Poste (the French mail service) invited electric vehicle manufacturers to bid for a contract to supply the first 500 vans, with a view to ordering a further 9'500 over the next five years. This whole scale backing of electric vans follows successful trials of the vehicles in Paris and Bordeaux in the rubric of the Société des Véhicules Electriques (SVE) project funded by ADEME. The trials showed that the vehicles were well suited to the role, particularly in built-up areas where restrictions on polluting diesel and gasoline vehicles are in place. Unfortunately, due to the lack of industrial production it has been impossible to conclude the bid in 2007. Nevertheless, negotiations continued and La Poste has now ordered two pre-series of five vehicles each for testing, which is scheduled to start early in 2009. The suppliers of these vehicles are Micro-Vett/Newteon (in association with Fiat) and Venturi Automobiles (in association with PSA).

La Poste has a fleet of 1'200 electric assist bicycles for mail distribution, with another 1'000 of these two-wheelers ordered in 2008.

EDF and Toyota

In September 2007, EDF (Électricité de France) and Toyota announced a partnership to evaluate plug-in hybrid electric vehicles (PHEVs) in Europe. The objective is to develop practical solutions for the commercialization of Toyota's prototype vehicle technology, which can further reduce the environmental impact of vehicles, especially in urban areas. Under the joint agreement, a small number of PHEVs is integrated into EDF's fleet, being tested on public roads in France under everyday driving conditions. Road trials of the PHEV have been expanded to the United Kingdom in September 2008.

The vehicles use Toyota's hybrid technology, but with the added benefit that their batteries can be recharged using a standard electrical plug. 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

Hybrid car sales in France for the different models on the market in 2008 are shown in table 18.2.

Table 18.2 Hybrid car sales in France. (Sources: CCFA; Toyota Motor Europe Corporate Communications January 27, 2009; www.avem.fr.)

Make	Model	2008
Honda	Civic	1'061
Lexus	GS 450h	139
Lexus	LS 600h	70
Lexus	RX 400h	1'317
Toyota	Prius	6'559
	Total	9'146
Total car market		2'050'283
Share of hybrids		0.45%

18.6 Outlook

A French outlook was not available at the time of printing.

18.7

Benefits of participation

Keeping in touch 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.

18.8

Further information

More information about hybrid and electric vehicles in France may be found on the following websites:

- www.avem.fr (in French).
‘Avenir du Véhicule Electrique Méditerranéen’ (AVEM) is an association based in the South of France that aims to promote the usage of EVs. Content: local info, EV events, 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 backup power supply.
- www.clean-auto.com (in French).
Site of the clean@uto magazine. Very rich site about clean solutions for transportation (EV, HEV, FCEV, etc.).
- <http://transports.edf.fr> (in French).
EV pages of the French utility ‘Électricité de France’ (EDF). Content: all activities of EDF in the EV domain, plus 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 Eclectic and Fétilsh models, plus a vision of future clean vehicles.

19 Italy

19.1 *Introduction*

In 2008, the weakness of the international economy significantly affected the Italian automotive market, which experienced a decrease of more than 10%. Financial incentives offered by the central government have partially helped to remedy this critical situation. The purpose of these incentives is to ‘clean’ the vehicle park by replacing old, heavily polluting vehicles with those that are more efficient and less polluting.

This market situation, together with certain regulatory measures established in large metropolitan areas to mitigate road transport pollution, has been beneficial for products such as electric vehicles (EVs) and hybrid electric vehicles (HEVs). The overall attention given to such clean technologies is improving due to greater interest by the general public, increased government-supported initiatives and the launch of a large project on sustainable mobility to support industrial innovation in the sector. In addition, various industrial projects are further stimulating public interest and opening new market prospects for such vehicles.

19.2 *Policies and legislation*

In 2008, the Italian policy in the transport sector aligned with the international commitments defined in the Kyoto protocol, which has revisions under consideration, and European Union targets to significantly reduce emissions and pollution by 2020. Some regulatory activities for dedicated standards for HEVs and related components (e.g., lithium batteries 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).

The national policy primarily supports technological innovation in transport through a twofold approach:

1. The first approach stimulates car park ‘cleanliness’ with financial incentives. These incentives are aimed at scrapping old cars and replacing them with new vehicles that meet more recent emission standards (i.e., Euro-4 and Euro-5) or retrofitting them with cleaner technologies, such as converting the gasoline engine in bi-fuels types by using natural gas or liquefied petroleum gas - LPG).

The present target is to introduce more efficiency, with carbon dioxide (CO₂) emissions below 120 grams per kilometre (g/km). The financial incentives have included the renewal of commercial vans and motorcycles. The maximum subsidy of € 2'800 has been slated for cleaner cars, such as natural gas vehicles (NGVs), liquefied petroleum gas vehicles, EVs and HEVs, or hydrogen-fuelled vehicles. In 2008, the available budget of approximately 50 million Euros was fully used by June.

2. The second approach promotes industrial innovations by means of specific projects, as part of the national program called INDUSTRY2015. In September 2008, the call for proposals for the ‘Sustainable mobility’ project closed with 50 large proposals that totalled 1'434 million Euros and involved 420 companies and 225 research organizations.

In addition, new regulations were applied by local authorities to reduce pollution in urban areas by favouring the use of public transport and reducing the circulation of private cars in urban areas. For example, in January, the city authority of Milan introduced the City Ecopass, a special payment card for city entrance based on car pollution. In Rome and other cities, the circulation of private cars (excluding cleaner cars) has been completely banned on some weekdays and in cases of environmental emergency.

Moreover, local authorities have tried to further support cleaner private mobility by financially promoting the purchase of electric bicycles and motorcycles. The Regions of Lazio and Lombardia have subsidised private citizens living in selected urban areas for purchases of power-assisted bicycles and electric scooters.

Finally, despite a stagnating interest in hydrogen-fuelled vehicles, the regions of Lombardia and Piemonte have created a dedicated alliance to concentrate efforts and define a joint program.

19.3 Research

The Italian research infrastructure in the transport sector is quite large and involves national research organizations, such as the Italian National Agency for New Technologies, Energy and the Environment (ENEA) and the National Council of Research, various universities, and some dedicated research consortia. Most of these organizations are involved in national (and even regional) and international (mostly funded by the European Commission through the 6th and 7th Framework Programmes) projects, also together with industry research laboratories.

ENEA

ENEA has continued activities in various European-funded projects aimed at developing electrically propelled vehicles that use novel electrochemical devices and/or fuel cells. The Ionic Liquid-based Hybrid Power Supercapacitors (ILHYPOS) project, with contributions from research organizations and industries from France, Germany, and Italy, has produced the first prototypes for materials, component production, and assembly process validation. Figure 19.1 shows six non-optimised symmetric lab cells of carbon/carbon configuration using an ionic liquid-based electrolyte. More than 22'000 charge/discharge cycles have been carried out, with an average specific power that exceeds 1 kilowatt per kilogram (kW/kg).



Fig. 19.1 ILHYPOS symmetric carbon/carbon prototype cells using ionic liquid in the electrolyte. (Photo supplied by ENEA.)

ENEA also is continuing research activities on fuel cells and hydrogen. An experimental test campaign was carried out to verify the possibility of using transition technology by combining hydrogen with natural gas. An IVECO Daily CNG van was tested according to standard procedures. Figure 19.2 shows the van on the roller bench during the controlled tests.



Fig. 19.2 IVECO Daily van on the ENEA roller bench during testing of hydrogen-methane fuel blends. (Photo supplied by ENEA.)

In the last few years, ENEA also has been involved in the research and development of original HEV prototypes with very low consumption and emissions. In December

2008, a city car prototype, named Urb-e (Urban easy), was officially unveiled at the Bologna Motor Show. Figure 19.3 shows Urb-e in the ENEA booth. Urb-e is a hybrid electric city car, combining a low-consumption engine (250 cc swept volume) with a bank of supercapacitors, with a fuel economy target of 50 kilometres per litre (km/l).



Fig. 19.3 ENEA Urb-e prototype hybrid city car. (Photo supplied by ENEA.)

CIRPS

CIRPS, an academia consortium of the University of Rome, is part of a European project named HOST. In co-operation with various European partners, HOST has developed a multipurpose hybrid vehicle prototype. Various versions of this prototype are presented in figure 19.4.



Fig. 19.4 HOST hybrid multipurpose vehicles with various versions. (Picture supplied by ENEA.)

With an opening ceremony on November 28, 2008, the consortium activated the ‘Lazio Region Hydrogen Center’. A first fuel cell bus is being tested at this center.

Fiat Research Center

The Fiat Research Center (CRF) strongly supports the Fiat strategy to concentrate on low-emission vehicles that use natural gas and to improve the overall efficiency of conventional engines. However, it still maintains a set of targeted research activities on EVs and HEVs, some of which are included in European projects, such as HYSYS (fuel cell vehicle components development) and HI-CEPS (novel hybrid

drivelines development). In 2008, as a result of the Fiat Group commitment in the sector, some new concept prototypes were shown.

The Fiat Brazilian branch has developed an electric concept car, named Fiat Bugster (shown in figure 19.5), that uses lithium-ion (Li-ion) batteries. Various components and the body are made from recyclable materials.



Fig. 19.5 Fiat Bugster electric concept car. (Photo supplied by ENEA.)

In addition, in collaboration with Micro-Vett (discussed below), Fiat presented a pure electric Fiat 500 at the London Motor Show. Furthermore, CRF has continued testing the fuel cell Fiat Panda in the city of Mantova, under the European project Zero Regio. Three hydrogen Pandas have been recharged in an ENI refuelling station with on-site hydrogen production. They have travelled for approximately 42'000 km and consumed 505 kg of hydrogen, with a 7.2-ton CO₂ emission reduction. A hydrogen Panda is shown in figure 19.6.



Fig. 19.6 Hydrogen Fiat Panda used in the Zero Regio project. (Photo supplied by ENEA.)

Italian Auto Designers

In 2008, more than in previous years, the commitment of Italian car designers toward ecological cars has been much more than a design exercise. With the B° electric car (shown in figure 19.7), Pininfarina has shown the results of the partnership

established with the Bolloré Group at the end of 2007. The car, with full-scale production scheduled for 2011, is a fully electric four-seat vehicle with a targeted range of 250 km and a limited top speed of 130 kilometres per hour (km/h). It is powered by electrochemical devices (supercapacitors and lithium metal batteries) produced by Bolloré in France and Canada.



Fig. 19.7 Pininfarina electric car B°. (Picture supplied by ENEA.)

Italdesign by Giugiaro has designed the NICE MyCar electric car (shown in figure 19.8), which is produced in the UK. The car is intended to be a low-cost EV (about € 11'000), suitable for urban uses. In addition, Italdesign also has developed a concept hybrid prototype, named Giugiaro Quaranta, based on the Toyota Hybrid Synergy Drive. The vehicle also has solar panels in the body to increase the overall vehicle efficiency (see figure 19.9).



Fig. 19.8 NICE MyCar electric vehicle, by Italdesign. (Picture supplied by ENEA.)



Fig. 19.9 Italdesign Giugiaro Quaranta hybrid concept car. (Photo supplied by ENEA.)

IVECO

This European market leader in the sector of heavy-duty vehicles (trucks and buses) and commercial vans, through its ALTRA division, has continued development of electric- and hybrid-driven vehicles. A road test project was started in 2008 in collaboration with the Italian branch of Federal Express. A fleet of 10 Daily hybrid vans (see figure 19.10) will be used in two cities (Milan and Turin), with the aim of saving 6'000 litres per year of diesel fuel and eliminating 15 tons of CO₂ emissions.



Fig. 19.10 IVECO Daily hybrid van. (Photo supplied by ENEA.)

Micro-Vett

The research and development activities of this small enterprise, with the largest share of the Italian EV market for commercial vans, has mainly concentrated on the adaptation of lithium batteries from various producers in their commercial products. Moreover, it has contributed to modifications of an electric version of the Fiat 500 (see figure 19.11).



Fig. 19.11 Under the hood of the electric Fiat 500 prototype, modified by Micro-Vett. (Photo supplied by ENEA.)

ZEV-Veicoli

At the end of the year, this small company unveiled a new bus, named ALÉ. The bus is available with two different electric drivelines: a hybrid with a fuel cell generator

combined with a Li-ion battery and a pure electric version that uses the same Li-ion battery.

ENEL

At the end of 2008, ENEL, the largest Italian electric utility, extended its long commitment to the field of EVs by establishing a formal agreement with Daimler company ‘smart’ for one of the world’s largest electric mobility projects. This project, named e-Mobility Italy, will integrate a complete recharging network of 400 charging points in three Italian cities (Rome, Milan and Pisa) to assist a fleet of 100 smart EVs. The project will be fully operative by 2010 and will use only certified renewable energy sources for charging the vehicle batteries. Figure 19.12 shows an example of an ENEL charging post.



Fig. 19.12 ENEL charging post for electric vehicles. (Photo supplied by ENEA.)

Piemonte Region

The commitment of regional authorities, such as that of the Piemont Region, also covers research and innovation by supporting the development of innovative vehicles. An urban concept EV has been developed, with funding of the Region by the Turin Polytechnic and Environment Park (a research centre). The EV, named



Fig. 19.13 Phylla electric vehicle concept urban car. (Photo supplied by ENEA.)

Phylla, uses Li-ion batteries and has a total range of 220 km and a top speed of 130 km/h. Part of the energy also comes from a set of solar panels installed in the EV. The initial plan is to transform the regional fleet by introducing a total of 200 Phylla EVs. The Phylla is shown in figure 19.13.

19.4 Industry

The Italian industry did not significantly change in 2008 with respect to 2007, confirming the last survey by the Italian Electric Road Vehicle Association (CIVES) of approximately 50 producers, assemblers, and importers. Only a few large manufacturers are included on the list (BredaMenarini, Piaggio, Cacciamali and IVECO), which indicates that most companies are small- and medium-size enterprises. The production covers practically any type of vehicle, including power-assisted bikes, scooters (with two, three, or four wheels), light- and heavy-duty pure electric and hybrid buses, and electric boats. The number of EVs and HEVs exceeds 100 types and covers almost all vehicle categories for road and off-road use. The commercial versions increase this number to thousands of available vehicles on the market, with retail prices ranging from a few hundred Euros for power-assisted bikes to hundreds of thousands of Euros for hybrid buses. The model flexibility entails all possible applications, from passenger cars to goods delivery vans and garbage trucks.

A component industry also is active in Italy. This industry works mainly on power electronics, complete electric and hybrid drivetrains, electric motors, conventional batteries (lead acid), and battery recharging systems.

19.5 On the road

The total fleet of clean vehicles increased in 2008, while the overall market had a strong decrease of approximately 15% with respect to 2007. The most significant increase in sales was related to NGVs and LPG vehicles, which jumped from about 30'000 vehicles in 2006 to more than 151'000 vehicles at the end of 2008. The market for EVs and HEVs is still strongly subsidised and remains at the same level of sales as 2007. The park renewal policy and the greater emotional appeal of driving cleaner vehicles in urban areas have resulted in a positive impact on EV and HEV niche markets, but the impact has been even more significant on gaseous (natural gas, LPG) -fuelled vehicles. Table 19.1 provides statistical data on the vehicle fleets in Italy.

Table 19.1 Characteristics and population of the Italian motorised vehicle fleet per December 31, 2006 and 2007.

Vehicle type	December 31, 2006			December 31, 2007		
	EV fleet	HEV fleet	Total fleet	EV fleet	HEV fleet	Total fleet
Motorised bicycle						
(no driver licence)	113'000	0	5'063'000	160'000	0	3'850'000
Motorbike	32'300	0	5'288'818	36'200	0	5'590'259
Passenger vehicle	2'085	4'065	35'297'282	2'600	10'964	35'680'097
Multipurpose pass. vehicle	5'700	0	568'654	6'760	0	594'643
Bus	610	220	96'099	740	254	96'419
Truck	0	0	3'763'093	0	0	3'842'995
Industrial vehicle	0	0	1'315'198	0	0	1'173'022
Total	153'695	4'285	51'392'144	206'300	11'218	50'827'435

For information: 70 electric boats have been sold in 2006, and 80 in 2007.

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

The CIVES estimations at the end of 2008, which also covered the estimations for 2007, show a substantial increase in the total number of EVs and HEVs on Italian roads compared with the 2006 figure (217'000 versus 158'000 vehicles). The market share of HEV passenger cars still remains small in Italy compared with other countries, but it reached 0.15% in 2008, with almost the same level of sales (3'351 passenger cars in 2008). Large EVs and HEVs were purchased mostly by fleet users, such as public service utilities. Private users were motivated to buy scooters and power-assisted bikes, which are strongly supported by public authorities and carry level purchase prices with respect to analogous conventional vehicles.

Finally, the air quality control initiatives established in various cities may have a positive impact on the recharging stations. The number of these stations is increasing in major and minor cities throughout Italy.

19.6 Outlook

The current policy and the strategy of the government and local authorities are not yet completely defined because of changes in government resulting from the political election in 2008. 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 will require dedicated interventions and assistance geared toward stabilizing the market. At the same time, the industry must maintain international commitments, as stated by the European Union and the Kyoto protocol.

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 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 Euros 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 2-3 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 configuration.
- 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 give some chance for EVs, HEVs, and, to a much lower degree, plug-in hybrids for effect of the combined support to the demand (financial incentives and enlarged infrastructure) and to the offer of new vehicles (financial incentives and funding for research, development and innovation).

The time horizon may be substantially differentiated for HEVs already on the market and an increasing share of EVs with less interest for plug-in HEVs (in general) and longer time possibilities for fuel cell hybrid vehicles.

19.7

Benefits of participation

Recently, the possible benefits derived from participation in the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) have been further recognised by the Ministry of Economical Development, which has decided to financially support 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).
- Local authorities and end users focused on learning more about the status of the technology and its possible applications.

19.8

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.

- Ronchetti M. *Celle a Combustibile. Stato di sviluppo e prospettive della tecnologia*. ENEA, January 2008. Available at www.enea.it/produzione_scientifica/volumi/V2008_02_cellecomb.html (in Italian).
- www.c-dispatch-frosinone.it (in English and Italian).
This is the official website of the C-Dispatch project. The website describes the complete project and the major results, includes miscellaneous news about the progress of the work, and provides photos.
- 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 is a source for contacts and provides the addresses of all members of CIVES, major Italian manufacturers, importers, research organizations, and users.

- 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, not only electric/hybrid road vehicles. It also provides statistics and technical descriptions of buses.

- www.enea.it (in English and Italian).

This is the website of ENEA. The 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 is the website for sustainable mobility. The website was initiated by the University group that organises the yearly H2 Roma event.

- www.minambiente.it (in Italian).

This is the website of the Ministry of the Environment and Territory Safeguard. The website contains up-to-date information about environmental legislation, initiatives, and press releases. A specific area is dedicated to sustainable mobility, renewable energy, and the status of the environment.

- www.regione.lombardia.it (in Italian).

This is the website of the Lombardia Region. The 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 the ‘Sistema Piemonte Idrogeno’, an initiative of the Piemonte Region to create a network of stakeholders to work on hydrogen-related issues in the region. The website contains information about projects, programs, and events.

- <http://srvweb01.softeco.it/LIFE-CEDM/> (in English and Italian).

This is the website of LIFE CEDM, a pilot project in Lucca, Italy, aimed at the realization of innovative e-logistics solutions for the start of the Centre for Eco-Friendly City Freight Distribution and efficient, sustainable goods delivery in the historic centre of Lucca.

20 *The Netherlands*

20.1 *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 have also introduced hybrid models, and in 2008, 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 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. This market is helped by the fact that charging points for bicycle batteries are available at restaurants in tourist areas.

The Dutch Government has ongoing policies and legislation for reducing CO₂ and NO_x emissions and improving air quality. The objectives are to (1) encourage consumers and research institutes to devote more attention to improving the efficiency of transportation systems and practices and (2) facilitate the hybridization of vehicles. The relevant automotive research and development (R&D) organizations are concentrated in the southeast part of the country, and they benefit from good relationships and collaborations with their automotive counterparts in Germany and Belgium.

20.2 *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, and another programme encourages investment in refuelling stations for alternative fuels.

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 behaviour are incorporated in the training

course required for earning 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 electric vehicles and hybrid vehicles.

- Electric vehicles are exempt from the yearly road tax. Since mid 2006, hybrid vehicles have qualified for a substantial bonus/tax reduction (as high as € 6'400 in 2008, see table 20.1) to encourage their sales.
- Conventional cars that are very energy efficient also earn a tax reduction, depending on their fuel efficiency, which is based on the fuel-consumption rating as shown on the specific model's energy label (table 20.1). Effective as of February 1, 2008, the credit can be as high as € 1'400. Also since the same date, less fuel-efficient vehicles are subject to an extra tax that can be as high as € 1'600.

Table 20.1 Energy label (A to G = highest to lowest fuel economy) and Dutch sales tax reductions/additions, effective February 1, 2008.

	A	B	C	D	E	F	G
General [Euros]	-1'400	-700	0	+400	+800	+1'200	+1'600
Hybrid [Euros]	-6'400	-3'200	0	+400	+800	+1'200	+1'600

Beginning February 1, 2008, buyers must pay an additional sales tax of € 110 per gram of CO₂ emitted per kilometre travelled above a specific level that depends on the type of fuel (gasoline or diesel) used by the vehicle. And under these regulations, vehicles with a CO₂ emission rating of less than 110 g/km for gasoline and 95 g/km for diesel earn a 50% reduction in the yearly road tax.

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'.

20.3

Research

The Netherlands has several automotive research institutes:

- TNO Industry and Technology - Automotive.
- Technical University Eindhoven.
- Technical College, Automotive Division, Arnhem.

- Automotive Technology Centre (ATC).
- Competence Centre for Automotive Research (CCAR).
- Drive Train Innovations (DTI).

All of them are located around Eindhoven, in the southeast, which has good connections to the areas associated with the automotive industry near Aachen in Germany and in Belgium. Substantial co-operative efforts involving Dutch, Belgian and German research institute partners and car and truck manufacturers are taking place.

Most 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 one that involves converting waste biomass to biogas and then upgrading it to natural gas of near-pipeline quality, which is then used to fuel vehicles with compressed natural gas (CNG) spark-ignition engines.

High Tech Automotive Systems (HTAS) programme

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. More information is available on the website at www.htas.nl.

Hydraulic series hybrid propulsion system

Innas, a Dutch research company, has developed a hydraulic series hybrid propulsion concept (figure 20.1). A brochure that is available from the website at www.innas.com/Assets/files/Hydrid%20brochure.pdf has more information on this system.

Electrical Variable Transmission (EVT)

TNO Industry and Technology - Automotive has developed an EVT (figure 20.2). The electrical port makes the EVT especially suited for use in hybrid vehicles. Drive energy can be powered by both the combustion engine and the electric system. The EVT replaces the starter motor, clutch, dynamo, and transmission. More information is available at www.tno.nl/content.cfm?context=markten&content=case&laag1=196&item_id=646&Taal=2.

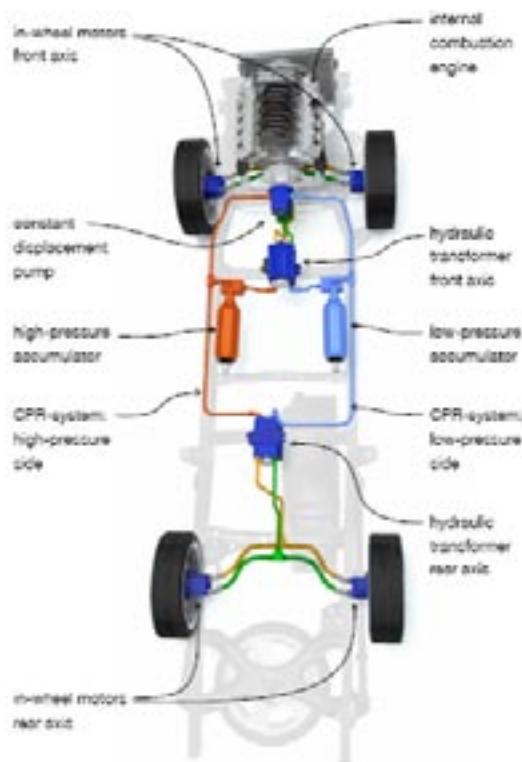


Fig. 20.1 Schematic of hydraulic series hybrid propulsion system. (Picture supplied by SenterNovem.)

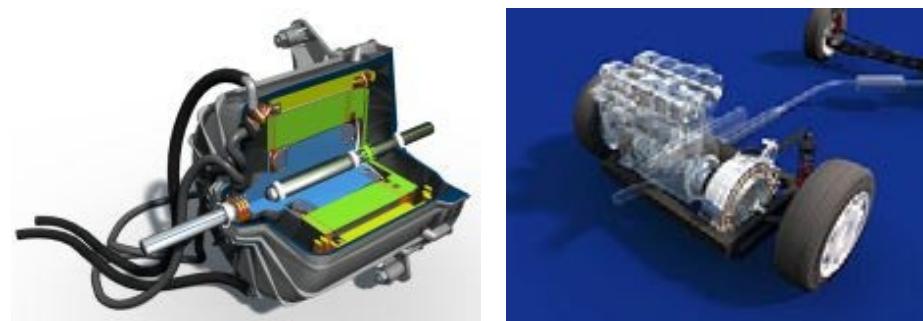


Fig. 20.2 EVT Electrical variable transmission: (left) schematic cutaway; (right) system mounted on chassis. (Pictures supplied by SenterNovem.)

Electrically powered distribution van

DuraCar has developed a fully electrically powered distribution van that uses an integrated set of innovative technologies. The van, developed specifically for inner-city traffic, carries the name QUICC! (brand name) DiVa (short for distribution

van) (see figure 20.3). All QUICC! cars are fitted with lithium-ion iron-phosphate battery packs. The QUICC! DiVa, which is the first of the family, has a top speed of 120 km/h and range of 150 km. Its advantages over counterparts with conventional combustion engines include low energy consumption, zero CO₂ and particulate matter (PM₁₀) emissions at the tailpipe, and completely silent operation. The target market is commercial distributors of goods, mainly in the inner city. An average inner-city distribution van travels 50 to 70 km per day in an environment with most air quality problems. More details are provided on the website at www.quicc.eu.



Fig. 20.3 QUICC! DiVa distribution van. (Photo supplied by SenterNovem.)

20.4 *Industry*

The Dutch automotive industry consists of:

- The truck manufacturer DAF Trucks N.V. (subsidiary of PACCAR Inc.).
- A manufacturer of public transport buses and touring cars.
- A car assembly factory.
- Various manufacturers of semi-trailers, trailers, and truck bodies.
- Various automotive component manufacturers.

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 co-makership among all the entities have intensified during the last decade. Research institutes and the automotive components industry will have good opportunities to be part of the European vehicle manufacturing arena.

20.5

On the road

The vehicle park (in-use population) in the Netherlands is shown in table 20.2. Car density is 1 car per 2.3 inhabitants.

Table 20.2 Characteristics and population of the Dutch motorised vehicle fleet per December 31, 2007 and 2008. Estimates are in *italic*.

Vehicle type	December 31, 2007			December 31, 2008		
	EV fleet	HEV fleet	Total fleet	EV fleet	HEV fleet	Total fleet
Motorised bicycle						
(no driver licence)	30'000	0	535'000	60'000	0	530'000
Motorbike	0	0	570'000	0	0	590'000
Passenger vehicle	50	6'000	7'200'000	50	20'000	7'400'000
Multipurpose pass. vehicle	0	0	0	0	0	0
Bus	0	5	11'000	0	5	11'000
Truck ^(a)	0	0	995'000	2	0	1'013'000
Industrial vehicle	400	n.a.	n.a.	400	n.a.	n.a.
Total	30'450	6'005	9'311'000	60'452	20'005	9'544'000

n.a. *not available*

(a) *Numbers include vans and minibuses. Minibuses are vehicles carrying up to nine people, with a GVW up to 3.5 tons. This category cannot be separated from vans up to 3.5 tons in Dutch statistics. Their estimated number on December 31, 2008, is 865'000.*

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

The in-use population at the end of 2008 was at about the same level as it was at the beginning of the year. As a result of the financial crisis, in the last three months of 2008, sales of new vehicles declined, and sales of smaller vehicles tended to increase.

About 450 battery electric vehicles remain in service; these are mainly cars and utility vehicles (electric vehicles that require a license plate to be used on public roads). Barriers to greater sales and use of electric cars include their purchase price, driving range and the limited availability of service support.

The Netherlands is a bike-friendly country, with about 20 million bicycles - more than the number of inhabitants (figure 20.4)! 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% (as of the end of 2008).



Fig. 20.4 Bicycles crowd the streets in the Netherlands. (Photo supplied by SenterNovem.)

Only a few models of hybrid cars are available for sale in the Netherlands: Toyota Prius II, Honda Civic hybrid, and Lexus RX 400h and GS 450h. The Prius is the most often sold hybrid in the country (in 2008, about 6'500 were sold), while the Honda Civic IMA had a sales volume of about 5'000 units.

Hybrid buses and goods vehicles are not commercially available in the Netherlands; 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; they are operated by TNT N.V.

20.6 Outlook

Current trends

Although most of the car manufacturers in the world are doing 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 (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 started.

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 (a) the need for consistent regulations within the European Union, (b) the need to encourage demand for clean and fuel-efficient vehicles, and (c) 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 are to be executed 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’ behaviour 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 picture 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 (environmental zones in cities). Research, development, and demonstration plans have triggered research projects, and project plans for the 2009-2015 period are in place.

Core technologies

The Netherlands does not have a national car manufacturer. DAF Trucks (a U.S.-based PACCAR company) is the only truck manufacturer that has its own 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 all over the world. In an institutional sense, the HTAS programme will play a major role in the future development of core technologies.

Market developments

The average annual sales volume of cars in the Netherlands over the last 5 years (through 2008) was about 500'000 units. In 2008, the sales share of hybrids was about 3%, a sharp 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.

Plug-in hybrid vehicles (PHEVs)

During 2008, the technical possibility of using the electrical grid more for plug-in charging of HEV batteries came closer to feasible commercial production. Some issues still need to be resolved; they 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 that HEV use would have on electricity production and the 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 (distribution vans and distribution trucks) and public transport buses will also have a positive effect on air quality in cities, but for these vehicles to dominate the market, substantial development of both the products themselves and the production machinery will have to occur.

20.7

Benefits of participation

The benefits of participating in the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) from the perspective of the Netherlands include these:

- Obtain available information on advanced transportation and automotive technologies from around the world.
- Partner to produce joint studies and take advantage of opportunities to involve national research bodies in the work.
- Use results from programmes of other countries and cultures as guidance in preparing national programmes.
- Participate in a worldwide network of transportation experts, research institutes, and government officials responsible for transportation. This dimension of having an international perspective is important.

20.8

Further information

Further information can be obtained from the various websites listed here.

- www.atcentre.nl (in Dutch and English).
Automotive Technology Centre.
- www.ccar.nl (in English).
Competence Centre for Automotive Research.
- www.han.nl/kc/automotive_eng (in English).
HAN University of applied sciences, automotive expertise centre.
- www.htas.nl (in English).
HTAS (High Tech Automotive Systems) is the innovation programme of the Dutch automotive industry in which industry, knowledge institutes and government participate.
- www.senternovem.nl (in Dutch and English).
Dutch Energy Agency SenterNovem.
- www.tno.nl (in Dutch and English).
Website of the Netherlands Organisation for Applied Scientific Research TNO, including automotive activities.

21

Sweden

21.1

Introduction

In 2008, 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 17.8% to 33.3%. 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) had the largest share of the eco vehicle market, but hybrid vehicle sales also increased. Table 21.1 shows 2007 and 2008 eco vehicle sales shares by vehicle type.

Table 21.1 Relative sales shares (in %) for 'green' vehicles in Sweden.

Category	2007	2008
E85 (ethanol)	64.9	68.4
Max 120 gCO ₂ /km, gasoline	13.7	12.9
Max 120 gCO ₂ /km, diesel	12.1	12.8
Hybrids	6.2	4.3
Gas	3.1	1.6
Total	100.0	100.0
Eco share of total private car sales	17.8	33.3

A major new programme in vehicle research that focuses on traffic safety, energy efficiency, and the environment started on 1 January 2009. Called the Strategic Vehicle Research and Innovation Initiative (FFI), it is co-ordinating Swedish Government and private-sector research efforts, with a pronounced emphasis on electrification.

Volvo and Scania started development and demonstration projects for hybrid buses and garbage trucks in 2007 with grants from the Swedish Energy Agency. The first vehicles from these projects -garbage trucks- were presented in the spring of 2008. During the spring of 2009, Scania will begin field testing its serial hybrid buses in the Stockholm city public transportation system (figure 21.1). Volvo will start serial production of its hybrid buses during 2009.



Fig. 21.1 Hybrid prototype bus from Scania. (Photo supplied by the Swedish Energy Agency.)

In 2008, several of the major Swedish power companies came together in a joint initiative promoting electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs). The goal is to bring 600'000 vehicles to the market by 2020. One ongoing subproject involves converting 10 Toyota Priuses to PHEVs and field testing them. Volvo Cars, ETC Battery and Fuel Cells AB, and Vattenfall (electricity power producer) run another project in which they demonstrate three Volvo plug-in hybrid electric cars in practical use.

21.2 **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. Since then, the rules have changed a number of times. 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 21.2 presents some examples.

Table 21.2 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 rules governing public purchasing and leasing of vehicles have also changed, as set out in the ‘Ordinance concerning public purchasing and leasing of eco vehicles’. The changes are intended to encourage the purchase and leasing of ‘green’ passenger cars and thus increase the proportion of eco vehicles used by public bodies. The application of the ordinance to public authority fleets came into force on 1 January 2005. The current requirement 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. 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.

Grants for eco vehicles

Any private individual who buys a new eco car between 1 April 2007 and 30 June 2009 will receive an ‘eco car subsidy’ of SEK 10'000 = US\$ 1'100. The criteria for an eco car subsidy 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 consumption is due to the carbon dioxide requirement).
- 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.

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) was tested in Stockholm from 1 January to 31 July 2006. After evaluation, it was decided that it should continue, and in the summer of 2007, it was restarted and made permanent. 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. 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.

21.3 Research

There are, in principle, six national research programmes dealing with issues related to electric, hybrid, or fuel cell vehicles. 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, here they are:

- The **Green Vehicle Programme** (the objective of which was to develop cleaner vehicles) was a joint programme of the automotive industry and the Swedish Government. The total budget of the second phase was about US\$ 90 million, the administrator was VINNOVA (Swedish Agency for Innovation Systems), and the programme ran from 2006 to 2008. About US\$ 27 million was budgeted for specific research on electric, hybrid, and fuel cell vehicles, including work on hybrid system architectures, drive systems, and energy storage technology.
- **Strategic Vehicle Research and Innovation Initiative (FFI)** started on 1 January 2009, as soon as the Green Vehicle Programme and many other vehicle research programs ended on 31 December 2008. The FFI is split into five parts:
 - (1) sustainable production technology,
 - (2) vehicle development,
 - (3) transportation efficiency,
 - (4) vehicle and traffic safety,
 - (5) energy and environment.The yearly budget is US\$ 100 million, of which half is funded by the Swedish Government. One-third of the resources focus on safety, and two-thirds focus on energy.
- **Energy Systems in Road Vehicles**, administered by the Swedish Energy Agency, addresses energy-related issues in vehicles. It has involved 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 period in 2007 and will run until the end of 2010 with an additional budget of about US\$ 12 million. US\$ 7 million is 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.

- **Fuel Cells in a Sustainable Society** is the third part of a joint programme between universities and the fuel cell industry that started in 1997, was slightly modified during 2002, and will end in 2009. The administrator is the Foundation for Strategic Environmental Research (MISTRA). The total budget of the programme, which includes research projects on fuel cell system components, materials, and systems, is about US\$ 14 million. In addition to investigating manufacturing methods, it is concentrating on reducing the cost and increasing the life of fuel cells.
- The aim of the new **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 **Environment Vehicle Development Programme** started in June 2007 and will run to 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).

21.4 **Industry**

Sweden's economy is very dependent on its automotive industry. The sector employs about 140'000 people, which includes the 1'000 or so automotive subcontractors. During 2008, the industry laid off 12'000 people, and the outlook for 2009 is not any better.

The major manufacturers are Volvo AB, Volvo Cars, SAAB Automobile, and Scania, all of which 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 21.1.

Box 21.1	
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.
Effpowert	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.
True Electric	After-market conversion to electric drive.
Cell Impact AB	Development and sale of bipolar plates for PEM fuel cells.

21.5

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 2008 (see also table 21.3). About 35% of newly registered private cars had diesel engines. In January 2009, there were 198'570 eco cars in Sweden. The number of newly registered ones reached a record level in 2008 at 84'575 private cars, an increase of 55% over the number in 2007. The market share of eco cars increased from 12.9% in 2006, to 17.8% in 2007, and to 33.3% in 2008.

Table 21.3 Characteristics and population of the Swedish motorised vehicle fleet per December 31, 2007 and 2008. Estimates are in *italic*.

Vehicle type	December 31, 2007			December 31, 2008		
	EV fleet	HEV fleet	Total fleet	EV fleet	HEV fleet	Total fleet
Motorised bicycle						
(no driver licence)	3'000	0	220'000	3'000	0	250'000
Motorbike	0	0	430'000	0	0	450'000
Passenger vehicle	310	9'400	4'300'000	310	13'500	4'300'000
Multipurpose pass. vehicle	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bus	9	0	13'000	10	0	13'000
Truck	1	0	510'000	50	0	505'000
Industrial vehicle	n.a.	0	500'000	n.a.	0	500'000
Total	3'320	9'400	5'973'000	3'370	13'500	6'018'000

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 2008, interest in hybrid vehicles has been high. Industry has been the main force behind continuing discussions on several R&D programmes, whereas the state was before. For example, in the Green Vehicle 2 project, there is more emphasis on hybrid vehicle technology than there was in the earlier period, and industry shows great interest in building up the SHC and FFI.

21.6

Outlook

In Sweden, opinions are divided about the definition of eco cars and associated legislation. The market share of eco private cars increased to 33.3%, with the major portion of that share being ethanol cars (68%). There was recently a public discussion on whether using ethanol fuel is the right 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. 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, 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. In the future, plug-in hybrids, pure electric vehicles, and perhaps fuel cell vehicles will be seen as viable alternatives.

21.7

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 summarised 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.

21.8

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 link to the CUTE project in which Stockholm has participated is:

- www.fuel-cell-bus-club.com (in English).

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.sweva.org (in Swedish).
The Swedish Electric and Hybrid Vehicle Association's website.

22 Switzerland

22.1 *Introduction*

Among European nations, Switzerland is especially affected by the prospect of global warming because its settlement and infrastructure reach alpine regions. In these regions, glacial melting, thawing of subsoil permafrost, and extreme weather conditions have been on the increase and are perceived as a real threat.

Switzerland's power generation is completely carbon dioxide (CO_2)- and pollutant-emission free, with a mix of 60% hydropower and 40% nuclear power. The share of CO_2 emitted by transportation is therefore rather high, reaching 34% in 2007. Government measures resulted in an annual reduction of 4.6% of CO_2 emissions in the household, service, and industry sectors, while emissions of the transportation sector increased (figure 22.1). One of the reasons for this discrepancy is the extremely high growth of leisure traffic, which now accounts for 45% of all trips (figure 22.2). This combines with the 11% of travel that is shopping trips to constitute 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. Leisure trips are also by far the longest, averaging 16.7 kilometres.

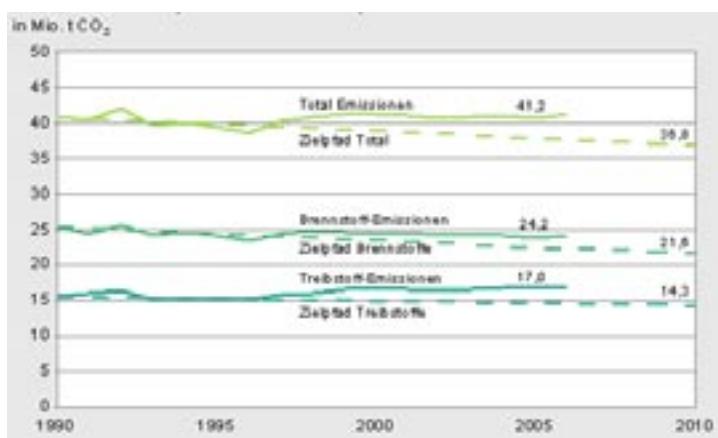


Fig. 22.1 CO_2 emissions in Switzerland.

There is a growing gap between reduction targets (dotted lines) and actual CO_2 emissions (solid lines). The gap is wider for fuels for transportation (bottom lines, labelled 'Treibstoff-Emissionen') than for fuels for heating and industrial processes ('Brennstoff-Emissionen').

Source: BAFU / CO_2 - Statistik. (Picture supplied by Muntwyler AG.)

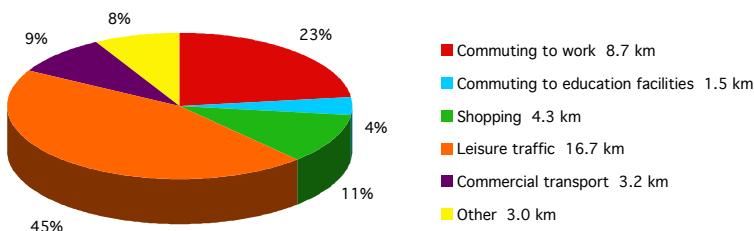


Fig. 22.2 Mobility in Switzerland. (Leisure trips are the most important 'mobility producers'.)

The Swiss trend toward large and heavy cars results in higher average CO₂ emissions compared with countries in the European Union (EU). During the last 10 years, the average vehicle weight has increased from 1'300 to 1'500 kilograms (see also figure 22.3), and the average fuel consumption of a Swiss car has been 7.6 l/100km. The car fleets of EU countries average 6.7 l/100km, with average CO₂ emissions of 161 grams per kilometre (g/km); in Switzerland, that value is 187 gCO₂/km. Only in the second half of 2008, sales of small cars with lower average fuel consumption have started increasing.

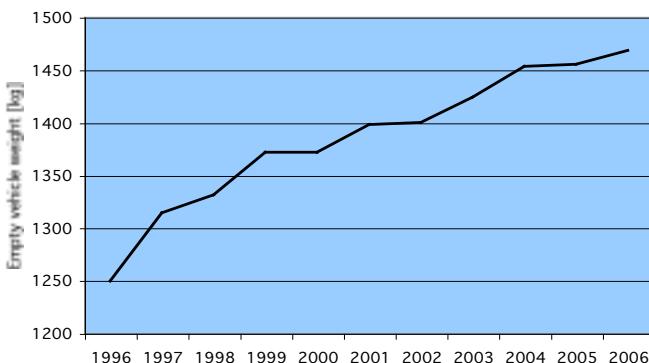


Fig. 22.3 Average empty vehicle weight of new cars in Switzerland. (These values are higher than for the average western European car park.)

Switzerland has larger and more powerful motor vehicles than its neighbours. In fact, it has Europe's biggest, most powerful, and highest-engine displacement cars.

22.2

Policies and legislation

Since 2000, government policy has pursued a strategy to negotiate voluntary agreements with car importers (figure 22.4). As of 2003, the fuel consumption of each model must be declared in the showroom, as well as in advertisements.

Monitoring revealed that most dealers violated this regulation. According to a spot check in May 2007, only 3 of 252 advertisements published the data as stipulated by the law, adding to the difficulty of achieving CO₂ reduction targets. Over this period, CO₂ emissions caused by transportation increased by 9.1%, and thus failed to achieve the planned decrease of 8% laid down in the Kyoto agreement. Policy measures enacted from 2000 to the present are shown in box 22.1.

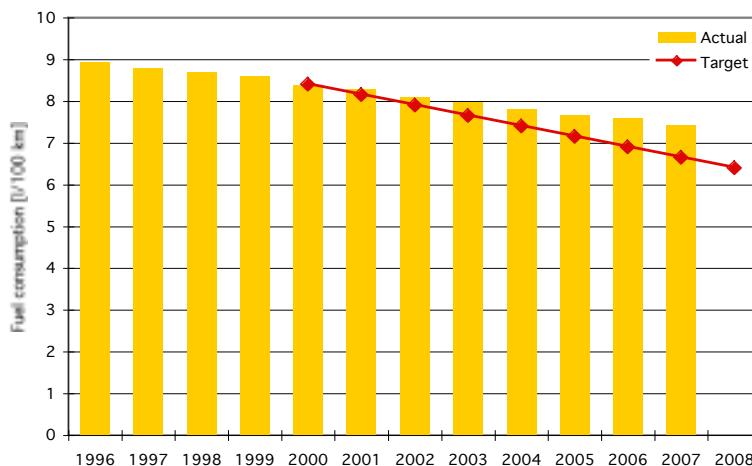


Fig. 22.4 Results of the voluntary agreement on the lowering of average fuel consumption in Switzerland. (Source: auto-schweiz.)

In 2004, the Swiss Government promulgated a law that raised duties on CO₂ emissions. As of 2008, the duty per litre of oil or kilogram of gas is € 0.18, a levy that will be doubled in 2009 and tripled in 2010. The duty is returned by tax rebate to the Swiss population (about € 9.50/person). Due to the ongoing resistance of the automotive sector to actual levies, another voluntary agreement has replaced the CO₂ duty for fuels for transportation. This ‘climate Rappen’ (a duty of about 0.01 €/l on petroleum fuels) is used to feed a fund for projects that reduce CO₂ emissions. Although the goals of the ‘climate Rappen’ agreement will be achieved, the effect in the transport sector will be minimal, as most projects are undertaken in the construction sector. Carbon dioxide reduction will occur through both technological and economic developments, such as the current economic recession, but policy makers will be tempted to credit these incremental reductions to the climate Rappen, which is not legitimate. In addition, the government proposes that federal car import taxes switch to a bonus-malus system based on the CO₂ emissions of the relevant car model. The tax will rise for cars in label categories C through G. Cars in category A will receive a bonus of CHF 2'000 (€ 1'350), and cars in category B will receive CHF 1'000 (€ 675). The approval by parliament is still pending.

Box 22.1
Summary of the Swiss EcoCar project



Measure	Implemen-tation	Description	Effect
EcoCar labelling	In planning	Inclusion of a bonus-malus (incentive-penalty) system is intended.	Difficulties with scoring and implementation.
Declaration of goods	2003	The energy consumption of each light-duty vehicle model must be declared on the basis of 7 consumption categories in 8 weight categories. Pure EVs excluded.	Since 2006 weight criteria are tightened. Label A hardly attainable by heavy vehicles.
Target values	2002	Voluntary agreement with car importers to reduce fuel consumption in new-vehicle fleets by 3% per year (= -24% by 2008). Taxes on CO ₂ will be imposed on fuels if the 2008 target is not met.	Actual achieved values: 2002: - 2.3% 2003: - 1.35% 2004: - 1.3% 2005: - 0.9% 2006: - 0.65% 2007: - 2.49% Targets have not been met in any year.
Regulations	Climate Rappen: 1 Oct. 2005	Tax of 1 ¢/l on petroleum fuels, to feed a fund of € 67 million for projects to reduce CO ₂ and the purchase of CO ₂ certificates. Reduction target: 1.6 million t CO ₂ /year.	Almost all projects are in the building or industrial sector, with hardly any effect in the transportation sector.

To accelerate the turnover of the car fleet, car importers are pressing for a scrapping bonus, following the example of Italy. Proponents expect a reduction of CO₂ emissions. Opponents believe that old cars are replaced by bigger and heavier vehicles with greater fuel consumption, and therefore the scrapping bonus will not result in a reduction of CO₂ emissions. Presently, there is no initiative from the government or parliament to comply with this proposal.

Vehicle taxes and promotion measures are the responsibility of the cantons. Several cantons provide a vehicle tax reduction for ‘clean’ vehicles. For example, 16 of 26 cantons exempt electric vehicles (EVs) from vehicle taxes or grant reductions, and 8 cantons reduce the taxes for hybrid vehicles. A few cantons have already changed the taxation criterion for motor vehicles - from unit mass to CO₂ emissions. In addition, a few cities and towns, such as the city of Lucerne, provide modest grants for the purchase of hybrid or natural gas vehicles or electric bicycles.

The new paradigm has now manifested in the cities and towns of Switzerland. Some have exchanged diesel buses for biogas buses in public transport services or acquired small electric-powered utility vehicles for street cleaning and waste collection. The private user segment has accepted hybrid vehicles as a viable alternative. With more than 10'700 hybrid vehicles on its roads as of September 2008, Switzerland has gained the lead in European per-capita hybrid vehicle ownership. (Although in absolute figures, the UK is on top, with more than 32'000 hybrid vehicles in use, according to the UK's Vehicle Licensing Statistics for 2007).

Since 2000, the cantonal governments have held the legal authority to finance promotion measures for electric and hybrid vehicles. Prior to 2005, it was primarily the canton of Ticino that had been active in this area, consistent with its role as ‘heir’ to the Federal VEL1 Promotion Program (Large-scale test for lightweight electric vehicles), conducted in Mendrisio from 1995 to 2000. The cantonal promotion program, VEL2 (2001-2005), has also qualified conventional car models with lower CO₂ emissions for subsidy. In this second phase, a total of 2'785 efficient electric and conventional vehicles have been subsidised, including 75 hybrid vehicles. For VEL1 and VEL2 combined, about 1'300 EVs were subsidised: 935 electric bicycles, 280 electric scooters, 10 three-wheeled EVs, and 85 light-duty four-wheelers (e.g., Peugeot 106 electric or Citroën Saxo electric). Meanwhile, most of the EVs converted by the company MES DEA are sold in Ticino under branding as the Fiat Panda Elettrica or the Twingo Quickshift Elettrica.

Switzerland has adopted the European guidelines to increase to 10% by 2020 (i.e., to about 350'000 vehicles) its population of vehicles powered by compressed natural gas (CNG). Official targets are more modest, however - the agency, EcoCar, cites a goal of 30'000 natural and biogas vehicles by 2010. As of the end of 2007, almost 6'000 CNG vehicles had been licensed, and 100 natural gas refuelling stations were available. Several city authorities have substituted CNG for diesel in their public transport bus fleets, as well as in communal service vehicles such as garbage trucks. Ethanol is being promoted as a biofuel option, with the first ethanol filling stations now in operation. The eco-balance of ethanol remains highly disputed.

Swiss domestic ethanol production is based on whey and the waste products from slaughtering, resulting in a 60% reduction of the overall ecological damage and a minimum of CO₂ emissions on a produced-energy-equivalent basis compared with gasoline processing, but the output is limited. For imported ethanol, the Swiss Institute for Material Sciences and Technology Development (EMPA) has published an eco-balance calculation that will guide future government policy regarding biofuels.

22.3

Research

The Swiss Federal Office of Energy provides support for projects focusing on:

- lightweight design,
- propulsion systems of highest efficiency, and
- purchase decisions.

The Office sponsors research and development that will contribute to the reduction of fuel consumption and CO₂ emissions in personal transportation by means of:

- using alternative fuels (diversification),
- improving efficiency, and
- shifting to smaller vehicles.

Benefits should include:

- enhanced safety,
- reduced space requirements for transport infrastructure, and
- reinforced industrial initiative to locate in Switzerland (the ‘location Switzerland’ initiative).

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 EMPA. Projects are or will be initiated to develop a 1.5 l/100km equivalent fuel cell prototype. In May 2008, the Paul Scherrer Institut signed a contract with Belenos Clean Power to develop a commercial ‘Swiss fuel cell’.

The ETH Zürich has undertaken a project to use dynamic programming methods to optimise the control strategy (algorithms) for a defined driving cycle in hybrid vehicles. Additionally, the Clever Project from EMPA continues, with the target of optimizing an engine for natural gas/biogas through optimization of the combustion process (downsizing of the engine combined with direct gaseous injection).

Hybridization through the addition of an electric motor is planned as a second developmental step.

Efforts are continuing toward achieving a 30% reduction in vehicle mass. Project LIVIO 21, which concluded at the end of 2007, showed enormous potential in this direction through improvements in structure, materials, and assembly. However, the monocoque design of lightweight vehicles results in a lack of a crash zone, thus aggravating the effects of a collision with pedestrians. Therefore, the LIVIO prototype has been used to study an outside airbag that will prevent pedestrians from being injured by flipping into somersaults (figure 22.5). This development has been supported by the ETH Zürich and the Winterthur insurance companies, and the Horlacher Company has patented the principle of a pedestrian airbag.



Fig. 22.5 Two-part outside airbag. (Photo supplied by Muntwyler AG.)

Mass reduction is also a focus of the Institute of Synthetic Materials IWK (Institute of Technology Rapperswil). Its lightweight EV prototype, the e-motion, is based on an aluminium space frame. The body is made of compounded steel resins and glass fibre and the windshields of polycarbonate, altogether resulting in a weight of 340 kg unloaded and without batteries (figure 22.6). The vehicle is driven by two in-wheel electric motors of 3.5 kW each. Crashworthiness testing was performed in 2008, and IWK intends to begin selling this vehicle in 2009.



Fig. 22.6 The e-motion by IWK of the Institute of Technology Rapperswil. (Photo courtesy IWK Rapperswil.)

At the University of Applied Sciences FH Biel, a team of students and teachers has embarked on the project '500 Electra' in which a Fiat Cinquecento is converted to

an EV while maintaining performance of the ICE version, and a range of 200 km per battery charge (figure 22.7). The students will perform detailed development of the whole propulsion system and all aggregates. System layout is based on a rear-wheel-drive platform (with a 400 V hybrid synchronous motor by Brusa, rated 40 kW) that will be commercialised in the next phase. This design will create the space under the hood necessary for the (Texx) lithium-ion cells and electronics.



Fig. 22.7 Fiat Cinquecento Electra (converted by the University of Applied Sciences FH Biel). (Photo supplied by Muntwyler AG.)

Swiss industrial development in supercapacitors emphasizes ‘intelligent’ batteries with adequate charging procedures, systems with batteries and supercapacitors combined, and basic research into conductive materials and nanostructures for advanced batteries. The FH Biel has developed an aging detector for batteries that warns the operator of silting up of the positive active mass or corrosion of the grid plates as a result and indicator of too many deep discharges.

Research is end product oriented, given the official position that research must lead toward marketable products. Consequently, the Swiss Federal Office of Energy also supports research undertaken by private companies with an emphasis on battery research. For example, the automotive supplier MES DEA has now achieved a profit stream from marketing its government-supported improvements to ZEBRA batteries.

22.4 Industry

Electric cycles (pedelecs) are already a mass product. In Switzerland, the sales figures rise annually. In the first half of 2008, more than 6'000 e-cycles were sold, equalling sales for the entire year of 2007. BikeTec, the manufacturer of a high-speed electric cycle, the Flyer, is building a large production plant to meet this rising demand. The Swiss Federal Office of Energy acknowledged this contribution

to clean commuting by bestowing the Watt d'Or 2009 Award in the category of Energy Efficient Mobility. Products originally developed in Switzerland, but now manufactured by licensees in Germany, include the TWIKE three-wheeler and the SwizzBee Dolphin e-bike (figure 22.8).



Fig. 22.8 Dolphin izip. (Photo courtesy SwizzBee.)

The automotive supplier MES DEA is converting the Renault Twingo and the Fiat Panda to an EV platform and is seeking a manufacturer. A Swiss energy supplier, which operates one of the greatest pumped storage power stations in partnership with the Institute of Applied Sciences FH Biel, started small-scale production of the Twingo Quickshift Elettrica. These EVs will be operated by Swiss utilities as service vehicles. Also, through partnerships, the additional ties of this Swiss utility to Brazil have been exploited to establish a co-operative venture of Fiat Brazil with Th!nk Norway. Switzerland expects the first Th!nk vehicle deliveries in 2009.

HESS, a company that specialises in bodywork for buses, has developed a hybrid bus (also in a trolley version) in partnership with the German propulsion specialist, Vossloh Kiepe (figure 22.9). The drivetrain features two electric asynchronous motors of 160 kW on axles two and three, a biodiesel engine rated 250 kW in the rear, and supercapacitors as the electric storage system. In January 2008, this project was awarded the Watt d'Or 2008 by the Swiss Federal Office for Energy in the category of Energy Efficient Mobility.



Fig. 22.9 Swiss lighTram. (Photo courtesy HESS.)

Brusa Electronics, a specialist in the development of control systems for EVs, has developed a track-based unmanned EV system, named Coaster, which is now marketed by a licensee. The first commercial application began operation in Arosa in the spring of 2007 (figure 22.10).



Fig. 22.10 Coaster in Arosa. (Photo courtesy Brusa.)

The development and manufacture of components for hybrid and electric vehicles are concentrated within these Swiss companies: MES DEA (ZEBRA sodium nickel chloride batteries and proton exchange membrane fuel cells in the range of 500 W to 3 kW), Horlacher and ESORO (composite parts), and Brusa Electronics (control systems). These companies are also active in research projects. Research on the improvement of ZEBRA batteries concentrates on lowering the operating temperature. Suitable solvents have been tested, and the feasibility of lowering the temperature has been confirmed by 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 buses (e.g., Irisbus and Gruau Microbus).

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’ 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 actors and sensors. This project, called

HyCarPRO, includes the development of the interface between the fuel cell stack and the electronics.

Swiss industry is still influenced in its approach to propulsion research by experiences during the worldwide solar vehicle races -the Tour de Sol series (1985-1993)- which could be won only by achieving maximum efficiency through highly efficient components and lightweight construction. The current tendency in the worldwide automotive industry to improve the efficiency of cars plays well to Swiss industrial strengths. Thus, the approach of the LIVIO (lightweight vision) project by Rieter/Horlacher is especially promising. The target is to assemble a vehicle from a few parts, each of which also integrates more than structural function. For example, instead of adding acoustical and thermal insulation plus the interior surface to the body-in-white structure, and therefore assembling three components, one ‘intelligent’ and lightweight component integrates all these features. In addition, some parts can be easily interchanged to meet specific customer needs. The project was concluded at the end of 2007.

The same approach is pursued by the Swiss car designer Frank Rinderknecht. His Rinspeed car prototypes, developed with ESORO, feature lightweight design and more than typical automotive functions (i.e., the potential for transformation into boats, or straightforward size scaling). Rinderknecht’s 2009 prototype, the iChange, has an electric drive system (after many years of natural gas drives). The one-seat cab can be extended to a three-seater by lifting the back (figure 22.11).



Fig. 22.11 Rinspeed iChange. (Picture courtesy Key.)

Mindset, a company founded in 2007, has introduced its prototype car, the Mindset (figure 22.12). 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 € 50'000 from mid 2009 - current economic crisis permitting.



Fig. 22.12 Mindset. (Photos courtesy Mindset.)

The Swiss subsidiary of Texx has opened the first 400 V three-phase charging station at the Gotthard service area, along the most important international road transport route in Switzerland.

22.5 On the road

Vehicle density is rather high in Switzerland. As of September 2007, almost 4.4 million light-duty vehicles have been licensed, translating to a density of 586 cars per 1'000 inhabitants. In 2007, 32.5% of all new cars had a diesel drive (85% of them with a particle filter). The Swiss EV 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 22.1 presents data on the Swiss car park as of December 2007. Figure 22.13 illustrates the development of EV and hybrid electric vehicle (HEV) deployment in Switzerland.

Table 22.1 Characteristics and population of the Swiss motorised vehicle fleet, 2007.

Vehicle type	December 31, 2007		
	EV fleet	HEV fleet	Total fleet ^(e)
Motorised bicycle			
(no driver licence) ^(a)	20'000	0	70'000
Motorbike ^(b)	2'000	0	699'938
Passenger vehicle	1'000	7'762	4'388'184
Multipurpose passenger vehicle ^(c)	350	0	350
Bus	50	0	
Truck	0	0	} 374'713
Industrial vehicle ^(d)	n.a.	n.a.	n.a.
Total	23'400	7'762	5'533'185

(a) Swiss high-speed electric cycles are licensed as small motorbikes (mopeds) with a speed limit of 40 km/h. Drivers must have a licence. The total fleet includes about 50'000 mopeds.

(b) Lightweight, three-wheeled vehicles (TWIKE, City-el) are licensed as motorbikes.

(c) Special vehicles in the car-free resorts. Speed limit 20 km/h.

(d) From September 2006, no longer counted statistically.

(e) Total fleet figures per September 30, 2007.

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

Because almost no commercially produced EV model is available in the Swiss market, the population of four- and three-wheeled EVs has been decreasing over the last five years (figure 22.13). Most of the in-use EV population is more than 10 years old, and it is almost impossible to replace vehicles that can no longer be repaired. However, the lack of new EV offerings has resulted in great interest in used EVs, and the market for the electric two-wheelers is growing. In 2007, more than 6'000 electric bicycles and scooters were sold, with the same number sold just in the first half of 2008. In addition, about 200 e-scooters are sold annually. The promotional campaign, Newride, focuses on e-scooters to increase sales. In 2008, the Swiss postal service decided to exchange mopeds used for postal delivery with Oxygen Cargo Scooters, and 200 of these units have already been ordered.

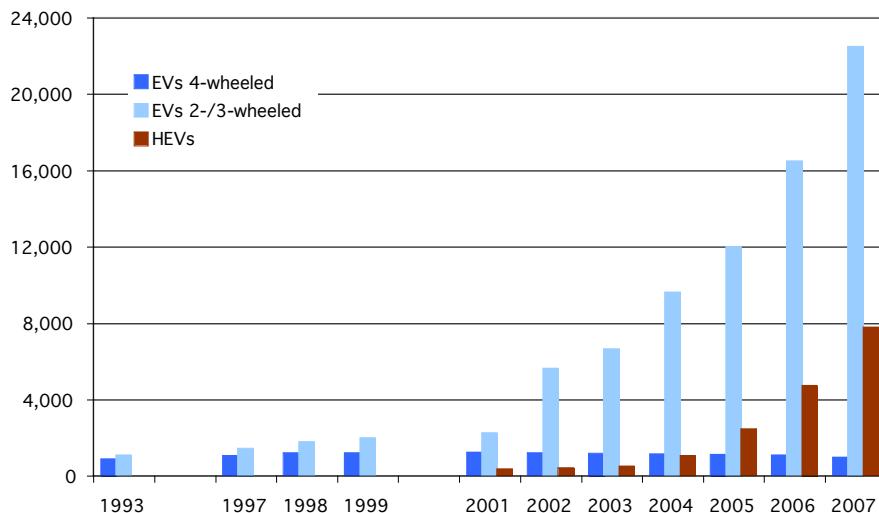


Fig. 22.13 Development of electric vehicle and hybrid electric vehicle deployment in Switzerland.

Market niches for EVs can be stable only if users continue to enjoy real advantages in their applications, or if special regulations compel their use. Switzerland has two important niche market segments:

1. Commuters

Most of the EVs in Switzerland are used for commuting in urban agglomerations. This results in the great success of small lightweight EVs - especially two-wheeled and three-wheeled vehicles. These vehicles can easily be parked, and recharging stations exist at privileged parking spots in the centres of several cities and towns. Drivers of three-wheelers, such as City-el, are even allowed to park

in bicycle parking spaces. In a few cases, drivers of small lightweight EVs are permitted to use roads closed to conventional cars.

2. Car-free resorts

In nine resorts in the Swiss Alps, the use of conventional cars is partly or even completely forbidden. The most famous and strictest car-free resort is Zermatt. There, no private person is allowed to operate a vehicle, and hotels must have more than 30 beds to receive permission to operate an EV. In addition, the general speed limit is 20 km/h. Local manufacturers produce special vehicles designed for battery exchange for these villages (figure 22.14).



Fig. 22.14 Electric taxi in car-free resort Zermatt. (Photo courtesy Klingler.)

The hybrid vehicle market continues to develop satisfactorily - for importers. By September 2008, about 10'700 hybrid cars were licensed (Toyota Prius I and II, Honda Civic IMA, and all hybrid Lexus models). The importers expect a steadily growing market for the next several years, especially for the Prius III.

Recently, insurance companies have begun to grant a bonus for vehicles with low CO₂ emissions and low fuel consumption. The reductions can amount to as much as 20% of the standard annual coverage rates. For example, the driver of a Prius (at 104 gCO₂/km) can save about US\$ 200 annually on the insurance premium.

22.6

Outlook

The Swiss approach to sustainable transportation policy is integral: individual trips should be taken by using public transport, ‘slow transportation’ such as walking and cycling is supported, and goods should be transported on rail. This approach demands close co-operation among federal, cantonal, and city administrations. It already works on the local level, especially in city agglomerations like Zürich, Basel, and Bern. Commuting by car 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 current 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 2009, the Swiss population will vote on an initiative that will institute a ban of four-wheel-drive operation off road. However, the extraordinarily growth in leisure trips will continue to militate against reduced 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 EU has shifted to implementation of more stringent emission standards and the taxation of CO₂ emissions. This creates market opportunities for clean vehicle technologies, but they must find the most promising market segments to achieve sales figures adequate to bring about a meaningful reduction in pollutants and CO₂ emissions. As of this writing, Switzerland has not yet decided on reduction targets beyond 2010 (140 gCO₂/km, according to the Kyoto commitment), and it still avoids stricter measures, such as CO₂ taxes on fuels for transportation. In view of the continued rise in transportation’s share of CO₂ emissions, the governmental executive branch, as well as the parliament, will have no choice in the short term but to approve the motion of the Federal Office of Energy to extend the CO₂ taxation on fuels for transportation. This taxation scheme, which is expected to pass the parliament, covers imported vehicles and will reduce CO₂ emissions by 3.1-3.9%, according to a simulation carried out by the Federal Institute of Technology (ETH Zürich).

The greatest success in sustaining market niches for EVs has been achieved where their use offers clear advantages. Niches based only on subsidies are not sustainable. Real advantages to EV users include faster commuting, easier access to city centres,

easier parking, lower operating costs, and, in some cases, a positive image. Here, image includes all ‘soft’ factors, such as the more ‘futuristic’ look of the vehicles, their symbolization of ‘ecology’, the ‘individuality’ of the user, and so forth. In Switzerland, these advantages are provided by lightweight three-wheelers and high-speed electric bicycles. Four-wheeled vehicles do not generally boast these advantages, with respect to either access to congested city centres or parking lots, or in view of their design. Sustainable niches for EVs can also be established by regulations (e.g., car-free resorts in Switzerland). The great increase in the sales figures of EVs in Switzerland can be attributed to the success of electric two-wheelers. Advanced electric purpose designed vehicles -such as the new Th!nk- will find a market in Switzerland, which is already well prepared for their introduction.

The hybrid vehicle market is a success because of the great sensitivity toward ecology in Switzerland; a good knowledge about alternative vehicles (especially electrics, as a result of the earlier Tour de Sol races and the promotion programs, VEL1 and VEL2, in Mendrisio); and the performance of the hybrid vehicle models available in Switzerland, which is known to be as good as or better than that of conventional cars. Hybrid vehicles also show an agreeable price/performance ratio.

The Swiss automotive and component suppliers are an important industrial sector, with about 16'000 manufacturing facilities and a turnover of about 10 billion Swiss Francs. These companies have profited from their specific knowledge about the design of lightweight parts, which was inspired by the experience with EV prototyping in Switzerland. However, the current sales crisis of the international car industry will have negative effects on their businesses. In addition, car manufacturers tend to internalise the development and production of key components, such as batteries or electronic devices for vehicles with electric drives, and this trend will likely reduce the opportunities for the small, highly specialised Swiss companies to supply their products.

The governmental commitment to the research and development of vehicles is remarkable and has shown some positive results:

- Several small and medium companies (e.g., Brusa and ESORO) could specialise in these fields.
- Larger Swiss automotive suppliers have an opportunity to lead in high tech component niches (e.g., composite automotive parts and ZEBRA batteries).
- Research projects, especially in the field of fuel cell propulsion systems, enable the identification of future needs in electronics and control systems.
- Not least, these projects train young students to be specialists in fields of future technologies.

However, representatives of the small specialised industry in Switzerland are concerned that:

- The research and technical know-how is kept primarily within research institutes.
- The step from prototype to production is difficult.
- The development of standardised products is neither supported nor existing.
- The industry lacks an efficient profit chain.

22.7

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 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.

22.8

Further information

Websites

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Flyer electric bicycle.
- www.e-mobile.ch (in English, French and German).
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Fuel cell prototype Hy-Light.
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- Martin Pulfer. *Konzept 2004-2007, Technologiebereich Verkehr & Technologiebereich Akkumulatoren.* Bundesamt für Energie 2006.
- Rainer Zah, et al. *Ökobilanz von Energieprodukten: Ökologische Bewertung von Biotreibstoffen.* EMPA study to the score of biofuels. Download the full report in German or a summary in English or French under www.bfe.admin.ch/dokumentation/energieforschung/

23 Turkey

23.1 *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 announced that it is considering selling hybrids in Turkey. In addition, some companies have been introducing their hybrids on their websites, but there is no sales activity at the moment. Electric two-wheelers have also begun to be sold in the last few years, but they have not yet achieved significant market penetration.

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.

23.2 *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.

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 summarised in table 23.1.

Table 23.1 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 (see figure 23.1), on posters and other promotional material, and in specific guides. The vehicle's official specific CO₂ emission class, as specified in table 23.2, must also be given.

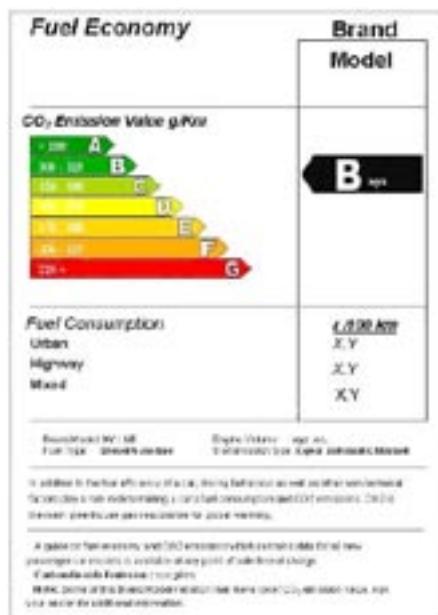


Fig. 23.1 Fuel economy label for passenger vehicles.

Table 23.2 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 23.3 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 23.3 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								

23.3 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 TÜBITAK MRC Energy Institute, OTAM, MEKAR, and Mekatro.

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 co-ordinate

R&D activities in fields consistent with the priorities for Turkey's development. The scientific and technological R&D activities of TÜBİTAK 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 emphasises 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 pet 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.

In 2008, TÜBİTAK MRC Energy Institute completed its HEV electronic control unit (HECU) project. The HECU communicates with the controller for all of the HEV subsystems and operates the control algorithm (figure 23.2). A user-friendly display and touch screen provide the interface for HEV system monitoring. The display informs the driver about various parameters (e.g., temperature, voltage, current) of the electric motor(s) and battery systems that are components in the HEV's electric system. In addition, it shows the HEV's current operating modes in an energy flow animation screen.



Fig. 23.2 HEV electronic control unit (HECU) and user interface developed by TÜBİTAK MRC Energy Institute. (Photos supplied by TÜBİTAK MRC.)

At the MRC Energy Institute, a Hybrid Vehicle Excellence Center (figure 23.3) is being planned for testing HEVs 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, electric motor dynamometer, battery test systems, an engine dynamometer, and 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.



Fig. 23.3 TÜBITAK MRC Energy Institute Hybrid Vehicle Excellence Center. (Picture supplied by TÜBITAK MRC.)

OTAM - Automotive Technology Research and Development Center

OTAM was established in 2004 in partnership with the Automotive Manufacturers Organization (OSD), TÜBITAK, 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 versus current exhaust emission regulations) (figure 23.4).



Fig. 23.4 OTAM vehicle acoustics laboratory, exhaust emissions laboratory, and chassis dynamometer. (Photo supplied by TÜBİTAK MRC.)

One research focus has been on HEV development. Recently, OTAM completed an HEV development project in collaboration with Ford Otosan, MEKAR (i.e., the automotive control and mechatronics research centre in ITU's Department of Mechanical Engineering), and TÜBİTAK MRC Energy Institute. OTAM took the lead in designing regenerative braking systems, modifying power flows, testing emissions and performance, and supporting all other aspects of HEV development.

Mekatro

Mekatro is an R&D company whose goal is to transfer academic expertise and research findings to industry in order to develop innovative products in the field of automotive mechatronics. This effort includes designing electromechanical actuators and both rotary and linear brushless electric motors, developing control systems (e.g., actuators, power electronic drives, and control hardware and software), running control systems in real time through a software/hardware interface (e.g., digital signal processing), employing the rapid control prototyping method, achieving flexible control system design capability, and designing and prototyping mechatronic

systems. Some projects are the ELIT-2 HEV, a vehicle power seat, and a sliding vehicle door.

In 2008, Mekatro, supported by TÜBİTAK, focused on a direct-drive wheel project. In the project, two 15 kW, brushless, direct current (DC) machines, along with their power electronic supplies and control units, were designed, manufactured, and inserted in the rear wheels of a Fiat Linea vehicle. This technique, known as hub drive, allows each wheel to be controlled separately. During the project, the electronic differential and compatibility with an antilock braking system (ABS) were also studied. A battery charging system was developed for facilitating regenerative braking and plug-in supply. Figure 23.5 gives two views of the brushless DC machine, one before and one after being mounted on the vehicle.



Fig. 23.5 Views of the Mekatro brushless DC machine before and after it was mounted on a vehicle. (Photos supplied by TÜBİTAK MRC.)

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's 6th Framework Programme, 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.

In FOHEV Project-I, Ford Otosan converted a front-wheel-drive Ford Transit light-duty commercial vehicle with a manual transmission to a four-wheel-drive HEV. MEKAR did the modelling and control algorithm development and implementation. In FOHEV Project-II, Ford Otosan formed a consortium to develop its second-generation HEV research prototype (named FOHEV II), again based on a Ford

Transit van. MEKAR worked on the concept study and simulations, integration of the electrical interface, vehicle control and implementation, development of and implementation of the regenerative braking algorithm, control of the electromechanical clutch, data capture, and engineering support.

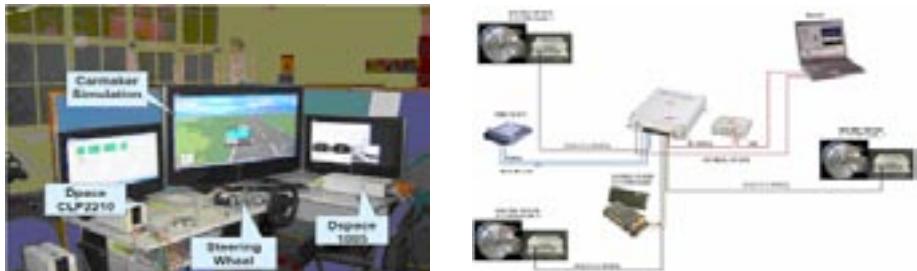


Fig. 23.6 Hardware-in-the-loop HEV simulator. (Picture supplied by TÜBİTAK MRC.)

In another project, a hardware-in-the-loop HEV test rig (figure 23.6) was prepared to validate the effectiveness of the hybrid controllers designed. The dSPACE MicroAutoBox and DS1005 system and its associated hardware and software are being used with the CarMaker program, MEKAR controller, and vehicle dynamic model in a real-time simulation using driver input.

23.4 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. At first its focus was on agricultural vehicles. Then 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. The intense integration of the global companies that collaborated with their Turkish partners to produce in Turkey started this process and has improved it. The manufacturing methods and technologies now used in the Turkish automotive industry are equivalent to the international-level processes and technologies used by the main companies. Furthermore, R&D facilities and capacity have recently improved, and they support automotive industry production methods and product development efforts.

OSD, the Automotive Manufacturers Association, represents the 17 manufacturers (Anadolu Isuzu, Askam, B.M.C., Ford Otosan, Hattat, Honda Türkiye, Hyundai Assan, Karsan, M.A.N. Türkiye, M. Benz Türk, Otokar, Oyak Renault, Temsa, Tofas, Toyota, Türk Traktör, Uzel) 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 260 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 automotive supply industry manufactures parts and pieces for vehicles manufactured in Turkey and in the global marketplace, as well as for the original equipment manufacturers and after market. It complies with international standards, and it conducts manufacturing and sales processes to address with the needs (e.g., quality, price, delivery details) of its customers (i.e., main industry companies).

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.

23.5

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 130 vehicles in 2007 and 263 in 2008.) The number of road vehicles presented in table 23.4 is based on figures published by the Turkish Statistical Institute.

Most passenger cars in Turkey had previously been 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 23.5. 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 23.6 profiles the makeup of the Turkish in-use fleet as of the end of 2007.

Table 23.4 Number of vehicles on the road in Turkey from 2002 through 2007. (Source: Turkish Statistical Institute.)

	2002	2003	2004	2005	2006	2007
Passenger vehicle	4'600'141	4'700'343	5'400'440	5'772'745	6'140'992	6'472'156
Minibus	241'700	245'394	318'954	338'539	357'523	372'601
Bus	120'097	123'500	152'712	163'390	175'949	189'128
Light-duty truck	875'381	973'457	1'259'867	1'475'057	1'695'624	1'890'459
Truck	399'025	405'034	647'420	676'929	709'535	729'202
Motorbike	1'046'907	1'073'415	1'218'677	1'441'066	1'822'831	2'003'492
Tractor	n.a.	n.a.	1'210'283	1'247'767	1'290'679	1'327'334
Others	191'793	198'444	28'004	30'333	34'260	38'573
Total	7'475'044	7'719'587	10'236'357	11'145'826	12'227'393	13'022'945

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.

n.a. not available

Table 23.5 Types of fuel used by motor vehicles* in Turkey from 2002 through 2007. (Source: Turkish Statistical Institute.)

	2002	2003	2004	2005	2006	2007
Gasoline vehicle	5'044'259	5'130'400	4'366'622	4'175'709	4'122'134	3'986'145
Diesel vehicle	1'192'084	1'317'328	2'198'490	2'635'509	3'121'797	3'557'981
LPG vehicle	n.a.	n.a.	818'127	1'297'542	1'568'158	1'877'604
Other	n.a.	n.a.	396'154	317'900	267'534	231'816
Total	6'236'343	6'447'728	7'779'393	8'426'660	9'079'623	9'653'546

n.a. not available

** Motorcycles, special purpose vehicles and road construction and work machinery and trucks are excluded.*

Table 23.6 Characteristics and population of the Turkish motorised vehicle fleet per December 31, 2007.

Vehicle type	December 31, 2007		
	EV fleet	HEV fleet	Total fleet
Motorised bicycle			
(no driver licence)	n.a.	n.a.	n.a.
Motorbike	n.a.	n.a.	2'003'492
Passenger vehicle	n.a.	130	6'472'156
Multipurpose pass. vehicle	n.a.	n.a.	n.a.
Bus ^(a)	n.a.	n.a.	561'729
Truck	n.a.	n.a.	2'619'661
Industrial vehicle	n.a.	n.a.	1'365'907
Total	n.a.	130	13'022'945

n.a. not available

(a) Includes minibuses.

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

23.6 Outlook

As mentioned previously, the hybrid vehicle market in Turkey is just starting. The Honda Civic hybrid is being offered for sale, and Toyota announced it is considering selling hybrids. Other companies are introducing hybrids on their websites. 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 increase. Also, because of the 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 English and Turkish:

- www.dpt.gov.tr/ing/
Turkish Republic Prime Ministry State Planning Organization.
- 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.mekatro.com
R&D company in the field of automotive mechatronics.
- www.osd.org.tr/index-english.htm
Automotive Manufacturers Association.

- www.otam.itu.edu.tr/Eindex.php
Automotive Technologies Research and Development Center.
- www.taysad.org.tr
Association of Automotive Parts and Components Manufacturers.
- www.turkstat.gov.tr
Turkish Statistical Institute.
- www.ubak.gov.tr/eubak/eubak-ana-sayfa
Republic of Turkey, Ministry of Transport.

24 United States

24.1 *Introduction*

The United States, through the U.S. Department of Energy (DOE), actively supports the research and development (R&D) of innovative vehicle technologies. Government and industry partnerships for the advancement of high-efficiency vehicles envision the development and deployment of affordable full-function cars and trucks, a decrease in the import of oil, and a reduction in emissions. Energy efficiency appears to draw broad popular support in the United States.

24.2 *Policies and legislation*

Federal

The United States is committed to developing alternative fuels and the necessary infrastructure for their commercialization. The DOE works with industry to develop and deploy advanced transportation technologies. For example, the DOE Clean Cities Program supports public-private partnerships that would deploy alternative fuel vehicles (AFVs) and build the supporting infrastructure. 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 and 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. Also, automakers now must label new flexible fuel vehicles to remind buyers that they can use either gasoline or an ethanol blend.

A limited federal tax credit was made available for light-duty hybrid electric vehicles (HEVs) placed in service between December 31, 2005, and January 1, 2011. The tax credits for medium- and heavy-duty vehicles, which expire on January 1, 2010, are capped at 60'000 vehicles per manufacturer, beyond which the vehicles qualify only for a decreasing percentage of the full credit over the subsequent four quarters. For the model year 2008, varying amounts of tax credit (US\$ 1'300 - US\$ 3'000) were available for assorted HEVs manufactured by General Motors (GM), Chevrolet, Nissan, Saturn, Ford, Mazda, and Mercury.

The U.S. National Highway Traffic Safety Administration has developed special safety standards for Neighbourhood Electric Vehicles (NEVs). The NEVs are defined as electric-powered 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 (mph) 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.

In December 2007, an energy bill that raised fuel economy standards by about 40% was signed into law. Besides requiring cars and light trucks to average 35 miles per gallon (mpg) by 2020, it would allow automakers to trade fuel economy credits among fleets (and with others), extend fuel economy credits for some automakers, and facilitate separate standards for 'work trucks' and for medium and heavy trucks. The fuel economy provisions would start in 2011. Preliminary rules issued in April 2008 indicate that, for the 2011-2015 model years, mandated CAFE standards for cars and trucks combined will rise to average at least 35 mpg by 2020. Currently, cars and trucks are measured separately. Cars must meet an average of 27.5 mpg. The light-truck standard is rising modestly under a previous set of regulations - to 23.1 mpg in 2009 and 23.5 mpg in 2010.

In 2008, as part of its ongoing initiative to develop commercially competitive plug-in hybrid vehicles (PHEVs), the federal government announced that it will fund US\$ 30 million in projects aimed at assessing the operational performance of PHEVs.

State

As shown in table 24.1, at least 26 U.S. states (and the District of Columbia) maintain regulations that promote HEV usage - including high-occupancy vehicle (HOV) privileges, waived emissions inspection, tax credits and rebates, or preferential purchase directives. Thirteen states (Connecticut, Florida, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington) have attempted to adopt clean air standards similar to those of California, which would require automakers to reduce greenhouse gas emissions for their vehicles by 30% before 2016. Automakers and dealers are currently litigating some of those rules (for conflict with federal fuel economy standards). These include state greenhouse gas rules in New Mexico, Rhode Island, Vermont, and California. In 2008, California regulators were preparing to expand greenhouse gas emissions rules adopted for the 2009-2016 model years. Cars and trucks sold in that state would have to average almost 44 mpg by 2020. The prior U.S. Environmental Protection Agency (EPA) administrator's decision to block California (and others) from enforcing its own greenhouse gas rules on vehicles may receive a review by the current administration.

Table 24.1 2008 status of U.S. state-level incentives for hybrid electric vehicles.

Source: Electric Drive Transportation Association (www.electricdrive.org) and HybridCenter.Org (<http://go.ucsusa.org/hybridcenter/incentives.cfm>).

State	Law (date)	HOV privilege	Waived emissions inspection	Tax/ Rebates	State-level purchase directive
Arizona	SB 1429 (6/01)	X			
California	Chapter 737 (10/03), AB2600 (11/06)	X	X		
Colorado	SB 91 (4/03), HB 1067 (5/00)	X		X	
Connecticut	Public Act 04-231 (10/04)			X	
Delaware	SB17 (04/07)		X		
D.C.	DMV Ref Act 2004			X	
Florida	Chapter 2003-45 (5/04)	X			
Georgia	HB 719 (5/03)	X			
Idaho	HB586 (04/08)		X		
Louisiana	Revenue Ruling No. 02-019 (11/02)			X	
Maine	MRSA Title 36 §1752 and §1760-79			X	
Maryland	HB 61 (5/03), HB 20 (5/00), Ch.111 (04/07)		X	X	
Michigan	HB 5443 (6/00)			X	
Minnesota	SB 2675 (4/02)				X
Nevada	Ch.231 (5/07)		X		
New Jersey	HB 2351 (1/04), SB 16/HB 2586 (5/00)		X		
New Mexico	SB 86 (3/04), SB 18 (3/02)			X	
New York	AB 11749 (7/02), EO 111 (6/01), Ch.413 (11/96)			X	
Oklahoma	HB 1085 (5/03)			X	
Oregon	HB 2041 (7/03)			X	
Pennsylvania	Act 178 of 2004			X	
Tennessee	Ch.532 (6/07)				X
Texas	HB 2293, HB 3319 (06/07)		X	X	
Utah	Utah state tax form TC-40V			X	
Virginia	HB 887 (4/04)		X		
Washington	Chapter 285 (4/02), Chapter 24 (3/02)		X		X
Wisconsin	HB 155 (Act 183) (4/04)				X

24.3 **Research**

Barriers

The realization of a high fuel-economy vehicle -one that could meet design targets and also be acceptable to the market- faces the 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.
- In their present form, many concept cars do not represent an affordable alternative compared with conventional vehicles with a similar mission, although the prices could be reduced with large-scale manufacturing.

Emissions standards

The EPA Tier 2 nitrogen oxide (NO_x) and particulate matter standards (now being phased in) are significantly more stringent than prior standards. Implementation of these new standards could delay the early introduction and widespread use 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 the widespread availability of suitable fuels. Because of the large capital expenditures and long lead times required to manufacture and distribute a significantly modified fuel, the petroleum industry must be fully aware of the anticipated needs well before the production of the first automobile that will use such a fuel. Furthermore, the change must be cost effective for the petroleum companies (or mandated by regulation). A 2001 EPA regulation, which required refiners to produce highway diesel fuel with a maximum sulphur content of 15 parts per million (ppm) by June 1, 2006, represented 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 sulphur 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.

Enabling technologies

The United States supports research efforts to promote technologies for AFVs.

Funding is provided for relevant research by the national laboratories and by private industry through government and 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 and electrical machines, all of which are described below.

Hydrogen and fuel cells

A polymer electrolyte membrane fuel cell converts chemical energy into electricity and heat through the electrochemical reaction of hydrogen and oxygen. The National Research Council, in a March 2008 study, concluded that hydrogen research remains “justified by its potentially enormous benefits to the nation”. The DOE Hydrogen, Fuel Cells, and Infrastructure Technologies (HFCIT) Program conducts basic and applied research, technology development and demonstrations, and related education/outreach activities; focuses on addressing key technical challenges for fuel cells and hydrogen production, delivery, and storage, as well as institutional barriers; works with public- and private-sector partners, including automakers and utilities, manufacturers, government agencies, universities, laboratories, and other stakeholders; and integrates hydrogen activities for various federal agencies.

In fiscal year (FY) 2008, Congress appropriated US\$ 281 million for the HFCIT Program. The FY 2009 budget request for the program is US\$ 268 million. The program works with industry through the FreedomCAR and Fuel Partnership, which includes DOE; the U.S. Council for Automotive Research (whose members are Ford Motor Company, GM Corporation, and Chrysler LLC); five major energy companies (BP America, Chevron, ConocoPhillips, ExxonMobil, and Shell); and two electric utilities (Southern California Edison and DTE Energy). Additional information on the program is available in the 2008 Annual Progress Report (www.hydrogen.energy.gov/annual_progress08.html). Some recent highlights include:

- The fuel cell sub-program made significant advances in increasing the durability of membrane electrode assemblies (MEAs); reducing the projected cost of fuel cell systems; improving membrane performance under hot, dry operating conditions; and characterizing fuel cell materials and components. 3M has mechanically stabilised the membrane used in its MEA, extending its durability in the lab to more than 7'300 hours with voltage cycling.
- Progress made this year in reforming biofuels helped to reduce the cost of bio-derived hydrogen. The National Renewable Energy Laboratory (NREL) improved the hydrogen yield and system efficiency of bio-oil reforming. Similarly, Ohio

State University demonstrated hydrogen yields greater than 90% during bio-ethanol steam reforming over non-precious metal catalysts, at temperatures below 500 °C, under neat reaction conditions.

- The hydrogen storage sub-program made continued progress in all three classes of materials under investigation - hydrogen sorbents, reversible metal hydrides, and chemical hydrogen carriers.
- Eleven new patents were issued for discoveries or technologies developed in DOE hydrogen program projects; 39 applications were filed or were being awarded.

Advanced energy storage technologies

For successful commercialization of electric vehicles (EVs), HEVs, PHEVs, and extended-range electric vehicles (EREVs), their battery systems must meet several requirements simultaneously. These requirements include high energy for EVs; high power for HEVs; both high energy and high power for PHEVs and EREVs; and rechargeability, long life, safety, and low cost for all the vehicles.

To reach the required goals, DOE funds three primary areas for battery research. The ‘developer program’, which works in close collaboration with the industry through the United States Advanced Battery Consortium, assesses, benchmarks, and develops advanced batteries for vehicles. ‘Applied battery research’ provides near-term assistance to developers of high-power batteries to overcome the barriers (i.e., calendar life, abuse tolerance, low-temperature performance, and cost) associated with lithium-ion batteries for light-duty and heavy-duty vehicles. ‘Focused fundamental research’ conducts research into the next generation of battery technologies for vehicle applications. Recent significant accomplishments of DOE-funded research on energy storage include:

- Cycling and aging data on cells with Gen3 electrodes indicated that both positive and negative electrodes contribute to impedance rise (which reduces life) when the cell contains the baseline electrolyte, and the LiF₂BC₂O₄ electrolyte additive reduces capacity-fade and impedance-rise during 55 °C aging.
- Researchers observed that lithium-ion power loss at low temperatures is inherent to lithium-ion kinetics and requires engineering design approaches to address this issue.
- A new redox shuttle, designated pentafluorophenyl-tetrafluoro-1,3,2-benzodioxaborole (PFPTFBB), showed stable overcharge shuttle ability at 4.2 volts (V) at C/10 for more than 100 cycles and 100% overcharge.
- Research on increasing the use of (low-cost) manganese in place of (high-cost and rare) cobalt as the cathode material established that up to 50% manganese can be used along with a minimum of 10% cobalt in advanced lithium-ion batteries, while still maintaining high capacity and rate.

- Johnson Controls-Saft (JCS) announced that it will supply lithium-ion batteries to Mercedes (for the S-class HEV). Currently, JCS is completing a US\$ 14 million DOE lithium-ion battery (the VL6P cell) development contract. JCS also manufactures batteries for the Sprinter Van, and it has been awarded a contract to develop a prototype battery for the Saturn Vue Greenline.
- A123 Systems secured contracts to develop prototype HEV and PHEV batteries for GM. A123 Systems previously received funding from DOE, via Small Business Innovation Research (SBIR) contracts, to develop a nano-phase iron phosphate cathode material.

Vehicle systems research

This research 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:

- Simulation studies by the National Renewable Energy Laboratory's vehicle systems analysis team have shown that, compared with a conventional fleet, a fleet of plug-in hybrid passenger vehicles with a 20-mile electric range could almost double fuel economy.
- Emissions testing of the BMW Hydrogen 7 prototype has established that the car's hydrogen-powered 12-cylinder engine surpasses the super ultra low emission vehicle (SULEV) level - the most stringent emissions performance standard to date.
- The Idaho National Laboratory (INL), as part of its advanced vehicle testing activity, has been conducting real-world tests of the capabilities of PHEVs. The INL has teamed with public and private agencies in the states of Washington, New York, Hawaii, California, and Arizona for such tests.

Advanced combustion engines R&D

The Advanced Combustion Engines R&D subprogram focuses on removing critical technical barriers to the 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 NO_x and particulate matter (PM) to near-zero levels, and use clean hydrocarbon (petroleum- and non-petroleum-based fuels) and hydrogen.

The R&D efforts are accomplished in collaboration with industry, national laboratories, and universities. For example, combustion and aftertreatment technologies incorporated in the 2009 Dodge Ram were made possible by collaborative programs with DOE and the national laboratories. The new Ram is equipped with Cummins-proven cooled EGR and VG Turbo, a diesel particulate filter, and a breakthrough NO_x adsorber catalyst to reduce NO_x and PM to 2010 levels. The horsepower and torque have been increased, and noise has been reduced by 50% from previous levels.

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, PHEVs, and EREVs. 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 areas of cost reduction, manufacturability, design data and test methodologies, joining, and recycling and repair. Priority lightweight materials include aluminium, magnesium, titanium, and carbon fibre composites. Recent research efforts include:

- In August 2008, GM, Ford, Chrysler, Cosma, and Camanoe completed the first design iteration of the Mg front-end and the technical cost modelling for the unibody steel front-end (baseline).
- Researchers at Oak Ridge National Laboratory (ORNL) developed two experimental techniques for observing previously unobservable phenomena and obtaining the high quality experimental data needed for models used to predict the serviceability and lifetimes of advanced polymer composite structures. A new technique to measure fibre length distribution as a function of thickness established that fibre length varies significantly as a function of thickness.
- GM launched a project to reduce the cost of carbon fibre and increase its use. One approach is to switch to industrial-grade carbon fibre instead of the more expensive aerospace-grade carbon fibre, which currently accounts for about 40% of the usage. GM also is working with suppliers to develop new types of carbon-fibre-laminated materials pre-impregnated with plastic, or 'pre-pregs'.

Advanced power electronics and electrical machines

This research develops new technologies for power electronics and electric machinery, which include 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 centres on the thermal control of inverters and motors with advanced cooling technologies. Recent significant accomplishments include:

- At ORNL, a prototype 55 kilowatt (kW), plug-in traction drive inverter with a charging capability of 20 kW was designed, fabricated, and tested. The efficiency attained was in the 92% to 97% range. Total harmonic distortion of the AC current was less than 10%.
- Also at ORNL, a 30 kW continuous, 55 kW peak buck/boost DC-DC converter also was designed, assembled, and tested. Efficiencies were in the 97% to 98% range. The power density of the unit was 17.8 kilowatts per litre (kW/l), and the specific power was 8.5 kilowatts per kilogram (kW/kg). A second-generation silicon-on-insulator, high-temperature gate drive chip was developed and successfully tested.
- At NREL, two air-cooled test articles were fabricated and tested, with excellent agreement performance validation of the test results. Heat flux levels up to 180 Watts per square centimetre (W/cm^2) were achieved, while the surface temperature remained below 130 °C.

24.4

Industry

During the 1990s, a number of battery EVs became available to U.S. consumers. (Additional details about these vehicles have appeared in previous International Energy Agency reports). Chrysler, Ford, GM, Honda, Nissan, and Toyota produced limited numbers of EVs for lease to customers. Some impetus for such vehicles may have originated from the California Air Resources Board's zero-emissions vehicle mandate, which later was successfully challenged in court. Subsequently, the EV leases were not renewed, and no new EVs were manufactured for consumers.

Recently, however, there has been a resurgence of interest in EVs, and some manufacturers have started working on newer generations of EVs. The existing market also includes hybrid buses, industrial vehicles, and bike-scooters. Over the past few years, HEVs have entered the market in significant numbers, crossing a cumulative figure of one million in 2007.

In 2008, U.S. consumers experienced historically high (and subsequently, relatively low) gasoline prices that rose, for a period, to levels not seen since the early 1980s. Partially as a result of those high gasoline prices, sales of HEVs remained strong - roughly at the 2007 level. As such, several automakers announced plans to introduce PHEVs as well as EVs. The total HEV sales account for approximately 2-3% of all vehicle sales. An overview of currently available HEV/EREV products is presented in table 24.2. In addition, based on information announced by individual manufacturers, a listing of the HEVs, PHEVs, and EVs expected to be entering the market in the near term is shown in table 24.3.

Table 24.2 2008 overview of current HEVs/EREVs in the United States.

Source: Electric Drive Transportation Association (www.electricdrive.org).

Manufacturer	Model(s)	
Chrysler	Dodge Durango ^(a)	Chrysler Aspen ^(a)
Ford	Escape/Mariner hybrid	
General Motors	Cadillac Escalade	Chevrolet Tahoe hybrid
	Chevrolet Malibu hybrid	GMC Yukon hybrid
Honda	Accord hybrid	Civic hybrid
Lexus	GS 450h	LS 600h
	RX 400h	
Nissan	Altima hybrid	
Saturn	Saturn Aura Green Line	Saturn Vue Green Line
Toyota	Camry hybrid	Highlander hybrid
	Prius	

(a) Being discontinued.

Table 24.3 Overview of planned HEVs, PHEVs, and EVs (based on information announced by the manufacturers).

	From	Model(s)	Expected market introduction
Plug-in hybrid electric vehicle	Ford	(Unnamed PHEV)	2012
	GM	Chevy Volt Saturn Vue PHEV	November 2010
	Toyota	(Unnamed PHEV)	Late 2009
Hybrid electric vehicle	Ford	Ford Fusion Mercury Milan	2010
	GM	Silverado (two-mode) Sierra (two-mode)	2009
	Honda	Honda Insight	2009
	Toyota	Toyota Prius (redesigned)	2010
	BMW	Diesel engine based	2010-2011
	Mercedes-Benz	Diesel engine based	2010-2011
Battery electric vehicle	Chrysler LLC	(Wrangler) Jeep EV (Town and Country) Chrysler EV Dodge EV	Late 2010
		Electric Mini	
		iMiEV	
		GT2012 ^(a)	
	Nissan		2010 (fleet); 2012 (retail)
	Chrysler and Lotus Cars	Chrysler Dodge EV	2010

(a) Plans for this vehicle were put on hold in February 2009.

The 2008 industry highlights for EVs, HEVs, and PHEVs are summarised below.

Toyota

- Toyota plans to unveil Toyota and Lexus nameplate hybrid models in 2009, in addition to a third-generation Prius. It will put lithium-ion PHEVs in demonstration fleets in 2010. Toyota will use improved nickel metal hydride battery packs in the HEVs and lithium-ion batteries in the PHEVs. Additionally, Toyota will expand its battery plant -a joint venture with Panasonic- by adding an assembly line dedicated to lithium-ion batteries.
- Toyota aims to produce 70% more Prius hybrids (figure 24.1) after the 2009 vehicle remodelling, bringing the annual output to at least 480'000 units. However, plans to make the Prius hybrid at its new plant in Mississippi are now being reviewed by a Toyota task force. The U.S. production of the Prius, originally scheduled to begin in 2010, could be pushed back to 2011 or later.
- Toyota intends to open a US\$ 100 million research institute at its technical centre in Ann Arbor, MI. The research institute will focus on energy, environment, safety, and mobility.
- Toyota dealerships in four U.S. metropolitan areas are offering to convert customers' Priuses into plug-in hybrids by using batteries from A123 Systems.



Fig. 24.1 2009 Toyota Prius. (Photo courtesy Toyota.)

General Motors

- General Motors (GM) plans to have vehicles with lithium-ion batteries ready to demonstrate by June 2009. It also expects to begin production of the Chevrolet Volt by 2010. GM has been seeking tax credits for the EREV.
- GM intends to build Opel- and Vauxhall-branded versions of the Chevrolet Volt in the United States for export to Europe. It will introduce the European versions of the vehicle in 2012. GM will build the Volt at its Detroit-Hamtramck assembly plant.

- GM successfully marketed the GM-Allison two mode system for diesel buses. More than 1'000 buses have been delivered to transit systems. Late last year, three transit authorities agreed to buy an additional 1'700 buses.



Fig. 24.2 2009 Cadillac Escalade hybrid. (Photo courtesy General Motors.)

- GM committed US\$ 370 million for a new plant in Flint, Michigan, to build a 1.4-litre engine. The two versions of the engine will include a turbocharged version for the Chevrolet Cruze compact and a non-turbo version for the plug-in Volt. Those vehicles, with shared architectures, are due in late 2010.
- GM plans to establish an engineering organization dedicated to HEVs, EREVs, and advanced battery technologies. The organization will focus on the upcoming Saturn Vue PHEV, other HEVs, and the Chevrolet Volt.
- GM decided to reduce its product development budget for the next two years, with as much as 80% of the cuts coming in 2009. This reduction will postpone delivery of several vehicles, but will not delay delivery of the Chevrolet Volt.

Ford

- Since 2004, Ford has experienced a near 30% reduction in the cost of manufacturing the Escape (figure 24.3), Mercury Mariner, and Mazda Tribute hybrid SUVs. The improvement areas include batteries and the electrical system for the hybrid powertrain.
- Ford continues to examine HEVs with its EcoBoost system, which uses a turbocharger and direct fuel injection and offers a smaller gasoline engine without reduced performance.
- Ford intends to introduce the Fusion hybrid in 2010.



Fig. 24.3 2009 Ford Escape hybrid. (Photo courtesy Ford.)

Nissan

- Nissan plans to introduce a pure electric car that uses lithium-ion batteries developed in Nissan's joint venture with NEC Corporation. The car will be available to fleet customers in Japan and the United States in 2010 and to retail customers in 2012.
- Nissan projects global sales of 10 million electric cars per year in cities such as New York, Washington, London, Paris, and Mumbai. The electric cars will be distributed to U.S. fleet users in 2010 and to retail customers in 2012.
- Nissan's first in-house hybrid, due in 2010, will be an Infiniti. Currently, Nissan's only hybrid is a version of the Altima (figure 24.4) that uses a system developed by Toyota.



Fig. 24.4 2009 Nissan Altima hybrid. (Photo courtesy Nissan.)

Honda

- Honda plans to debut a new HEV, with standard nickel metal hydride power packs, in 2009. The HEV is expected to compete with the Toyota Prius. Also, Honda's fourth hybrid, the hybrid Fit, will enter the market by 2015.

- Honda will launch a five-door, hybrid-only hatchback in 2009 in North America. It expects to build about 200'000 of the hatchbacks globally, with about 100'000 vehicles targeted for import into North America.

Chrysler

- Chrysler plans to release a hybrid Dodge Ram pickup in 2010.
- Chrysler's first EV likely will be a cargo version of one of its minivan twins (Town & Country or Dodge Caravan). The EV will be available to fleet customers in late 2010.
- Chrysler began producing Chrysler Aspen and Dodge Durango Hemi hybrid SUVs in August 2008. The vehicles were introduced for sale in October 2008. However, those lines were terminated when Chrysler later closed its plant in Newark, Delaware.

Other developments

- Panasonic negotiated to buy Sanyo Electric Company. A combined Panasonic-Sanyo could dominate the field for both nickel metal hydride and the next-generation lithium-ion batteries. Sanyo is the world's top producer of lithium-ion batteries, albeit mostly for cell phones and computers. Globally, Panasonic supplies 83% of the nickel metal hydride batteries used in vehicles.
- Panasonic plans to produce 800'000 HEV batteries in 2009 - about 95% of which will go to Toyota. (Nissan has teamed with NEC Corporation, and Honda has joined with Sanyo Electric Company.) Mitsubishi Motors Corporation and GS Yuasa Corporation formed a joint venture, Lithium Energy Japan, to manufacture lithium-ion batteries.
- Mitsubishi Motors Corporation intends to build a plant to meet an expected fivefold increase in battery demand. The new factory will be operated by Lithium Energy Japan.
- Subaru intends to begin fleet sales of a four-seat electric car in 2009.
- Hyundai plans to market its first U.S. hybrid, a version of its mid-sized Sonata sedan, in 2010. Hyundai maintains a partnership with LG Chem for lithium-ion batteries.
- Volvo expects to introduce stop-start technology in vehicles in 2009 and a diesel hybrid in 2012.
- Tesla closed its recently opened engineering centre in suburban Detroit. It is delaying development of the new electric sedan while it consolidates operations at its headquarters in San Carlos, California.

24.5

On the road

Compared with its total inventory of vehicles (over 240 million), the United States has a relatively small, but growing, number of HEVs, while PHEVs remain under development. These vehicles are designed to compete with conventional on-road gasoline and diesel vehicles. The number of EVs and HEVs present in the United States for the past few years is shown in figure 24.5. The HEV sales for 2005-2008 are listed in table 24.4.

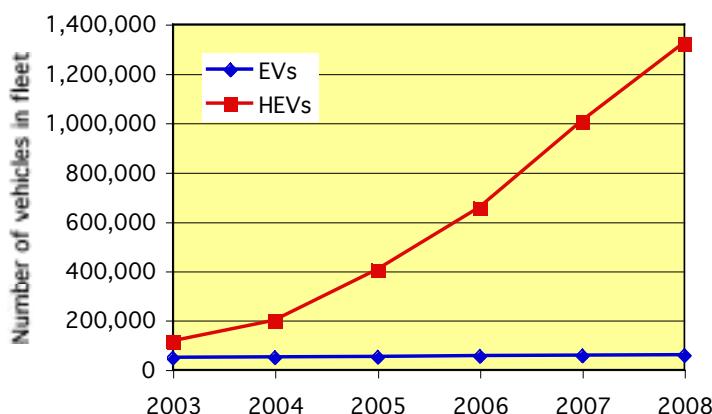


Fig. 24.5 Number of EVs and HEVs present in the United States.
 EV data from Energy Information Administration (EIA) (www.eia.doe.gov/cneaf/alternate/page/atftables/afvtrans_v1.xls).
 2007 and 2008 data for EVs are extrapolated.
 HEV data from Electric Drive Transportation Association website (www.electricdrive.org) and other sources. Cumulative numbers estimated from annual sales.

Table 24.4 HEV sales in the United States.

Vehicle	Sales			
	2005	2006	2007	2008 ^(a)
Chrysler Aspen / Dodge Durango	--	--	--	81
Ford Escape / Mercury Mariner ^(c)	15'960	22'549	25'108	19'522
GM Malibu	--	--	--	3'118
GM Saturn Aura	--	--	--	310
GM Saturn Vue ^(d)	--	--	3'969	3'399
GM Tahoe, Yukon and Escalade	--	--	--	7'612
Honda Accord ^(b)	16'826	5'598	3'405	198
Honda Civic ^(b)	25'864	31'253	32'575	31'297
Honda Insight	666	722	3	0
Lexus GS 450h ^(c)	--	1'784	1'645	678
Lexus LS 600h	--	--	937	980
Lexus RX 400h ^(c)	20'674	20'161	17'291	15'200
Nissan Altima	--	--	8'388	8'819
Toyota Camry ^(c)	--	31'341	54'477	46'272
Toyota Highlander ^(c)	17'989	31'485	22'052	19'391
Toyota Prius	107'897	106'971	181'221	158'886
Total U.S. HEV sales	205'876	251'864	351'071	315'763
Total U.S. light vehicle sales	16'946'611	16'518'686	16'114'815	13'212'467
Total U.S. HEV sales percent	1.2%	1.5%	2.2%	2.4%

(a) Through December 2008. Insight and Prius sales data are from J.D. Power. Other data are from EDTA and the Green Car Congress.

(b) Honda Accord and Civic hybrid sales are from EDTA and the Green Car Congress.

(c) The Escape, GS 450h, RX 400h, Camry and Highlander hybrid sales represent registrations from EDTA through 2006. The 2007 sales of Escape and GS 450h are from Green Car Congress.

(d) January-May 2007 sales are from EDTA. The 2008 sales are from the Green Car Congress.

24.6 Outlook

Currently, the U.S. population of battery EVs appears to be stable due to the lack of new personal mobility EVs. The EV population is projected to grow as new technologies are introduced.

In 2008, despite high gasoline prices (as much as US\$ 4 per gallon), sales of hybrids dropped significantly during the summer. Although the total number of vehicles sold decreased, the hybrid vehicle percentage rose to an all-time high of approximately 2.4%.

In a November 2008 survey for Automotive News, the R&D chiefs of six automakers were questioned about their predictions regarding the sale of electric-powered vehicles as a percentage of total new car sales in the United States, Europe, and Japan. With one exception, all believed that the electrification ramp-up of a majority of vehicles could be slow and the market share low for the next 10 years - at about 5%. Increasing the production volume of batteries to high-enough levels was considered the major constraint. They also maintained that, because of the inherent higher cost, customers would initially have to make a conscious decision to pay a higher price to drive an eco-friendly car. For urban drivers, driving a 40-mile-range scenario, full EVs may work well, but they may not work for everybody. Potential life-style adjustments may include adapting to changes in refuelling/recharging habits and altering perceptions regarding car sharing. While some additional cost and inconvenience could be unavoidable, a cleaner environment could result.

According to an earlier outlook statement from Japan's Nomura Research Institute, by 2012, the global market for hybrid vehicles could more than triple to 2.19 million units a year, up from an estimated 619'000 units in 2007, and the value of its worldwide parts business could double to US\$ 7 billion. The demand for hybrid vehicles will surge as automakers experience increased pressure to cut carbon dioxide emissions. Lower cost and the expansion of hybrid offerings also will fuel the market increase. The United States was seen as leading this demand, with 1.68 million units.

24.7

Benefits of participation

The numerous benefits of U.S. participation in various Annexes of the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) 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.
- Participating in a network of well known automotive research entities (while providing information regarding work at U.S. national laboratories) and government officials responsible for advanced transportation issues.

24.8

Further information

Specific sources of further information on the internet are listed below.

- www.eere.energy.gov/hydrogenandfuelcells/resources.html
DOE Hydrogen and Fuel Cells Program.
- www.eere.energy.gov/vehiclesandfuels/
DOE Vehicle Technologies Program.
- www.eia.doe.gov/
Energy Information Administration (EIA).
- www.electricdrive.org/
Electric Drive Transportation Association (EDTA).
- www.uscar.org/guest/index.php
United States Consortium for Automotive Research (USCAR).

25

Developments in selected IA-HEV non-member countries

Hybrid and electric vehicles are receiving more and more attention worldwide, because they can contribute to reducing petroleum based fuel consumption and CO₂ emissions of road traffic. In parallel, interest in the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) is increasing. In 2008, IA-HEV welcomed Japan, New Zealand and Spain as observers in its ExCo meetings. There were also guests from Germany and India. Additionally Ireland showed an interest in activities of the Agreement. This year we profile these six countries, in alphabetic order.

25.1

Germany

Electric vehicles (EVs) have been used for decades in Germany. Enthusiastic users promote the benefits of improving and driving small lightweight EVs. The two most popular electric three-wheelers in Europe are the City-el, originally from Denmark, and the TWIKE, developed by the Swiss. These vehicles are still produced in Germany.

On November 25 and 26, 2008, four ministries of the German Government presented the 'Nationale Entwicklungsplan Elektromobilität' (the National Electric Mobility Roadmap) at the National Strategy Conference on Electric Mobility. Germany now has the advantage of a steadily growing share of carbon dioxide (CO₂)-free electricity produced by wind energy and photovoltaics - two technologies in which Germany is world leader. According to the 'Erneuerbare Energie Gesetz' (law on renewable energy) regulation, German utilities must pay a special tariff (production bonus) for electricity produced by solar and wind generators. As a result, this renewable source share of total electricity production could triple to 15% within 10 years, and then possibly increase to 30% by the early 2020s and 45% by 2030. This gives promoters of the electric drivetrain a strong new argument for the promotion of all types of EVs. The minister of the environment, Sigmar Gabriel, promised that all electricity for electric mobility will be produced by new renewable energies.

In a joint effort between the German car industry and the utilities, Germany has established a plan to take the lead in the production and use of electric drivetrains for all types of vehicles. The plan, which specifies 19 goals within 5 sections, is detailed below.

Electric mobility must support the energy and climate goals

1. Electric mobility should significantly contribute to the reduction of greenhouse gases.
2. The combination of renewable energies and EVs should stabilise the grids.

3. The overall efficiency of the grid should be improved by the ‘grid connection’ of EVs.
4. The increased use of EVs should not increase emissions.

Germany strives to be the leading market for electric mobility

5. The leading position of the German original equipment manufacturers (OEMs) should be secured.
6. The government should stimulate the technology by the use of EVs.
7. German industry should produce and recycle batteries.
8. The integration of new business models into the context of electric mobility should create opportunities for the growth of new products and services.
9. Internationally standardised technologies should foster the international use of electric mobility and bring German industry into a strong position.

Innovation is the key to an internationally competitive position

10. A close co-ordination of research activities between science and the economy should be the primary goal.
11. Research should be strengthened in all fields to achieve this goal.
12. Excellent competence and innovative dynamics in the area of electric mobility should be secured. For this purpose, a formation initiative for young scientists will be established.

New mobility

13. Germany should follow its strategy of ‘away from oil’ by adhering to the National Electric Mobility Roadmap (i.e., hybrid, battery, and fuel cell vehicles).
14. Electric mobility should support the breakthrough of a new culture of mobility and modern city planning.
15. The market introduction of EVs, especially for short distances, should be escalated. The German Government holds the ambitious goal of having 1'000'000 EVs on the road by 2020. A total of 5'000'000 electric vehicles could be on the road by 2030. Transportation in cities should be effected mainly without fossil fuels by 2050. This includes the infrastructure for EVs.
16. In addition to individual mobility, the application of electric drivetrains for trucks, buses, and two-wheelers should be advanced.

Building a social framework

17. As the basis of the change process, the government should maintain a culture of openness with the public.
18. Therefore, the government should strive to relay transparent information and achieve a broad dialogue regarding the goals of the National Electric Mobility Roadmap. The changes, challenges, and goals should continually be evaluated.

19. The acceptance and market development of electric mobility should be supported by incentives and a regulatory framework.

The conclusion is that Germany should take a strong position in the international competition.

The plan describes in detail how the government and industry will support this new strategy. At the National Strategy Conference on Electric Mobility, the government invited several hundred participants to present and discuss details and recommendations. During one of the panels, the delegate for the German wind industry, Mr. Ralf Bischof, mentioned that the electricity needed for one million EVs in 2020 would be half of the annual production capacity of newly built wind farms in Germany.

25.2

India

India has the second largest population in the world. The vehicle fleet is growing quickly, and this growth is expected to continue. In 2005, India had 49.1 million motorised vehicles on the road. In 2008, the number was already 64 million vehicles. It is estimated that these numbers will increase to 121.3 million by 2015 and 372.7 million by 2035. These vehicles can be categorised in five different classes, as shown in table 25.1

Table 25.1 Recent motorised road vehicle fleet numbers in India, and expectations for the future. Expressed in millions of vehicles.

	2005	2008	2015	2025	2035
Car, SUV	6.2	8.8	18.0	41.6	80.1
LCV	2.4	3.2	5.7	12.5	26.9
HCV	2.4	2.9	4.6	9.1	16.2
3-wheeler	2.3	3.0	5.3	8.8	13.1
2-wheeler	35.8	46.1	87.7	174.1	236.4
Total	49.1	64.0	121.3	246.1	372.7

LCV Light Commercial Vehicle

HCV Heavy Commercial Vehicle

The Indian car industry is looking for international market opportunities for hybrid vehicles. However, actually no car manufacturer has a product ready for the market. Buses are another application for hybrid and electric drivetrains in which India is interested. In Mumbai the NGO ‘Clean Air Island’ plans to start a demonstration project with a small electric bus on a circular course in the central part of the city.

The energy needed for operation will be produced by a photovoltaic installation. This would be a novelty in Mumbai.

In 2008, two Indian companies produced electric bicycles. In the period of April until November 2008, Electrotherm (India) Ltd. sold 11'423 electric cycles; the TVS Motor Company Ltd. sold 7'100 electric cycles. This has been a growth of 44% compared to the previous year.

The best known electric vehicle (EV) produced in India is the 4-seater REVA. This car is being produced in Bangalore for 10 years, and 3'000 items have been sold in 10 countries. Today, the REVA is offered in four different models, and in 2009, a new version with a Li-ion battery will be introduced on the market. The range is said to be 120 km, and 80 km/h is given as the maximum speed. This perfectly fits the traffic situation of big European cities, small islands and big Indian metropolises. The REVA is available in 6 Indian states.



Fig. 25.1 REVA car at EET-2007 Brussels. (Photo: Muntwyler AG.)

The electricity mix with nearly 70% produced from coal is not very favourable if the CO₂ emissions are allocated to EVs. But in Indian cities EVs improve the local air quality, which is a huge problem. Actually India is one of the leading countries in wind energy worldwide. Therefore the combination of renewable energies and electric drivetrains offers big opportunities for India.

25.3

Ireland

The Republic of Ireland, being an island and a relatively small country, has a huge potential for producing renewable wind and wave energy. At the ‘Electric vehicle policy conference’ held on February 18, 2009, the Irish Government agency Sustainable Energy Ireland (SEI) and the state-owned utility company ESB announced a new strategy for electric mobility. The conference was to be the starting point for electric vehicle (EV) dissemination in Ireland (figure 25.2).



Fig. 25.2 A wide range of electric vehicles was shown at the electric vehicle policy conference in Dublin on February 18, 2009. (Photo: U. Muntwyler.)

Because of its fossil-fuel-based production of electricity, ESB is the biggest producer of CO₂ emissions in Ireland. Actually more than 90% of the country's electricity comes from fossil fuels (mainly natural gas). ESB's goal is to become CO₂ neutral and therefore it plans investments that would total € 20 billion by 2020. The objectives are to provide smart metering, CO₂ storage, heat pumps, EVs, and plug-in hybrid electric vehicles (PHEVs) and to produce renewable energy for 2 million users. One of the first targets is to produce 40% of the electricity from renewable energy sources, mainly wind. 'Smart electric consumers' (e.g., users of EVs and heat pumps) will help level the surplus production during the night.



Fig. 25.3 REVA electric car. In Ireland it costs less than € 10'000. (Photo: U. Muntwyler.)

Ireland has 2.5 million motorised vehicles (excluding two-wheelers), 2 million of which are cars. To meet the Kyoto protocol targets, the government has signed a voluntary agreement to lower the CO₂ emissions from cars.

The goal of the Irish Government for EVs is a 10% share of the market in 2020. EVs are exempted from value-added tax (VAT) over the purchase price. In January 2009,

the Irish car market decreased by more than 60%. The Society for Irish Motoring Industry (SIMI) thinks this decrease indicates a challenge for the EV project, because customers will not ‘start new adventures’ as they try to overcome the current financial crisis. However, the market is expected to recover. In the meantime, the introduction and increasing production of renewable energy technologies can begin. The potential production capacity of wind energy in Ireland is three times higher than its current total electricity production. Promoting wind energy offers good opportunities to start new businesses, create new jobs, and stimulate the national economy - all goals that have a high priority in Ireland in 2009.

25.4

Japan

A highlight of Japan’s national policy that is driving current transport research and development (R&D) efforts is the Cool Earth 50 Program of the Japanese Ministry of Economy, Trade and Industry (METI), announced by the Prime Minister in May 2007. It targets a 50% reduction in greenhouse gas (GHG) emissions by 2050. To achieve this objective, 21 innovative technologies, of which at least 8 have direct ramifications for transport, will be necessary on both the supply and demand sides, as shown in figure 25.4.

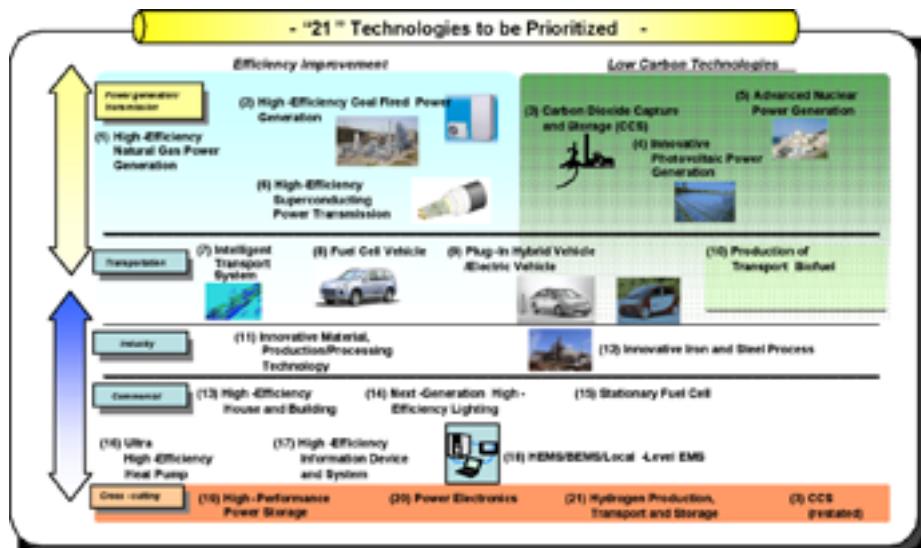


Fig. 25.4 21 technologies in METI's Cool Earth 50 innovative energy technology program in March 2008. (Picture supplied by NEDO.)

Plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs) were selected as priorities in this initiative. The targets for the battery capacity, cost, and travelling distance (on a full charge) are shown in figure 25.5. In fiscal year (FY) 2030, the final

targets are seven times the battery capacity of current baseline, 1/40 of the battery cost, and 500 km in travelling distance. To achieve these targets, Li-ion battery performance will have to improve, and post-Li-ion batteries need to be developed.

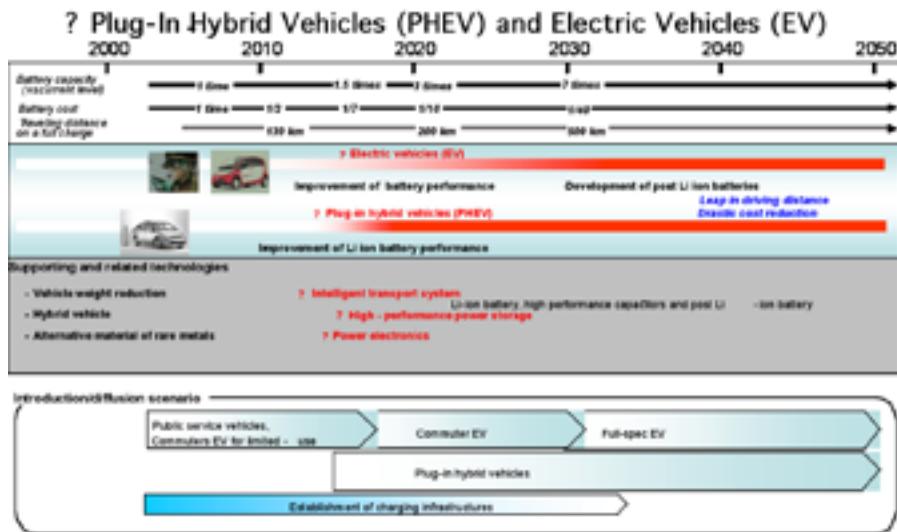


Fig. 25.5 Targets in METI's Cool Earth 50 innovative energy technology program in March 2008. (Picture supplied by NEDO.)

Since 1980, the focus of Japan's New Energy and Industrial Technology Development Organization (NEDO) has been on battery technology R&D, as shown in figure 25.6. Currently, NEDO is developing a high-performance battery system for next-generation vehicles in the Li-ion and Excellent Advanced Batteries Development (Li-EAD) Project. The project began in FY 2007 with very challenging performance targets.

The evolution of battery performance is being monitored by the Central Research Institute of Electric Power Industry (CRIEPI). International automotive codes and standards are being monitored by the Japan Automobile Research Institute (JARI). The associated degradation mechanism analysis and development of technologies to suppress degradation are materials issues for which the National Institute of Advanced Industrial Science and Technology (AIST) and Tohoku University are responsible. See figure 25.7 for details.

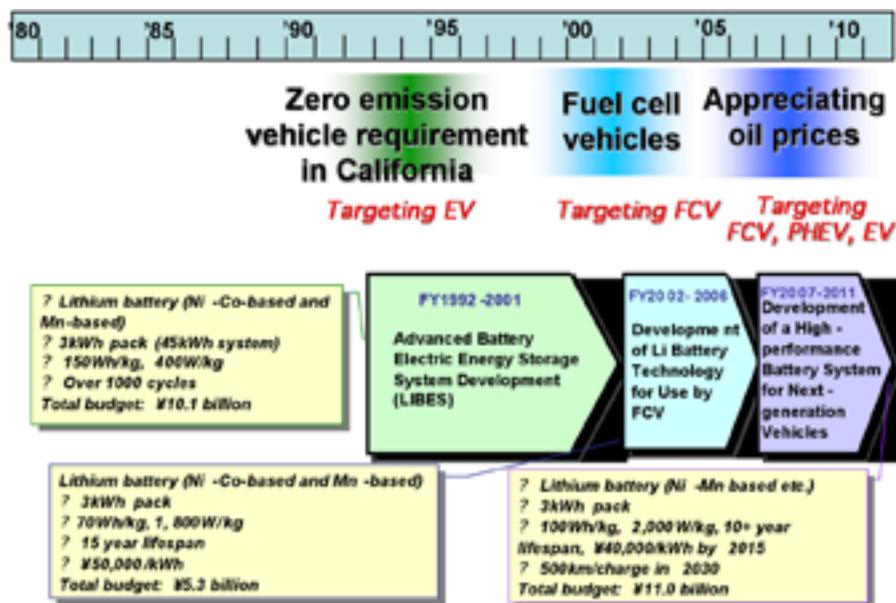


Fig. 25.6 Direction of NEDO's development of vehicle batteries. (Picture supplied by NEDO.)

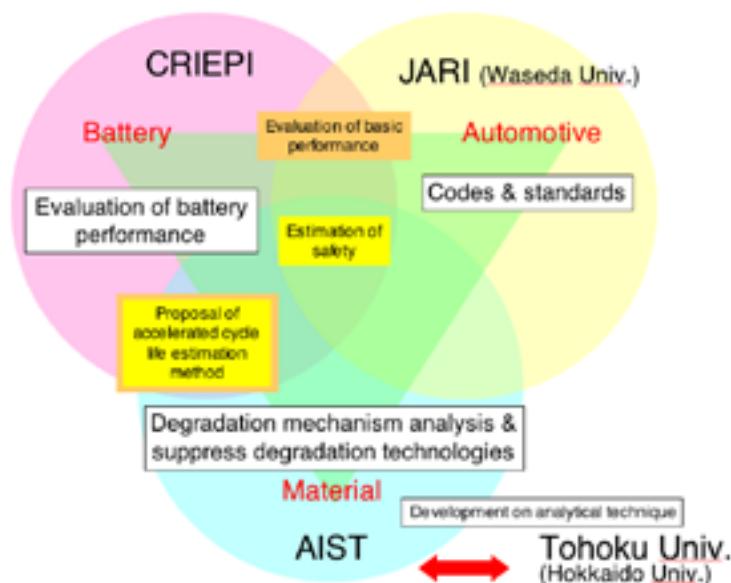


Fig. 25.7 Co-operative system for developing fundamental technology. (Picture supplied by NEDO.)

25.5

New Zealand

It is somewhat surprising that, given New Zealand's isolated Pacific location and its lack of a significant vehicle manufacturing industry, its car ownership rate is one of the highest in the developed world. New Zealanders' attraction to their motor vehicles leads to oil consumption that accounts for about 50% of consumer energy demand. New Zealand's indigenous oil production meets about 35% of this requirement, but the majority of oil refined at the country's lone refinery is imported. Electricity accounts for a further 30% of consumer energy demand; 67% of this electricity is generated from renewable sources, including hydro (55%), geothermal (8%) and wind (just over 2%). New Zealand, a signatory of the Kyoto Protocol, had energy-sector carbon-dioxide-equivalent emissions that totalled about 33 million tonnes in 2007. Emission totals have flattened since 2003 but are still 39% above 1990 levels. Meanwhile, emissions from transport have grown some 70% since 1990 and amount to 15 million tonnes.

New Zealand published its new Energy Strategy (NZES) policy document in 2007. The NZES's overarching objective is to produce a resilient, low-carbon energy system that, in the area of transport, will yield demand reductions and mode shifts, improve vehicle efficiency, and increase use of new fuels, including biofuels, electricity, and hydrogen.

Targets specified in 2008's National Transport Strategy include cutting per-capita greenhouse gas (GHG) emissions from domestic transport in half by 2040 and becoming one of the first countries in the world to have a 'major' use of electric vehicles. This target, combined with the NZES goal of 90% renewable electricity by 2025, would result in a transport future with low carbon intensity. This strategy also introduced a biofuel sales obligation that began in October 2008, established an expert advisory group to look at future vehicle technologies and fuels (e.g., biofuels and electric cars), encouraged further international dialogue on the role and potential for alternative fuels, and required the development of a detailed action plan that would include a work plan for EV promulgation by March 2009.

The current hybrid fleet in New Zealand is composed largely of Toyota Prius hybrids, with smaller numbers of Honda Civic and Lexus hybrids. The current hybrid fleet population is estimated at about 3'000 vehicles, making up 0.15% of the light-duty fleet. Sales in 2008 were spurred by the growth of the innovative Greencabs taxi company, whose entire fleet is Prius hybrids (see figure 25.8).



Fig. 25.8 Toyota Prius Greencabs taxi. (Photo supplied by ANL.)

The country's major corporate player in hybrid propulsion is Designline, established in Ashburton in 1985. It has developed hybrid buses since the mid 1990s. The company recently evolved to Designline International and moved its headquarters to North Carolina in the United States, but the manufacturing base remains in New Zealand. Designline's ECOsaver IV is a series hybrid (see figure 25.9) with an auxiliary power unit for which the company has claimed a 50% reduction in fuel use and a 75% reduction in noise relative to its conventional omnibus counterpart. It has plug-in capability for 2 hours of running time. Recently New York City placed an order for 90 buses.



Fig. 25.9 Designline's ECOsaver IV series hybrid bus. (Photo supplied by ANL.)

A new participant in the electric propulsion market is a Palmerston North company, Zero Emission Vehicles Limited, which has announced plans to design, construct, and commercialise a heavy electric vehicle. It is planning to develop a battery electric rolling chassis (wheels, suspension, and chassis) for light trucks and buses, with an expected range of 200 to 300 km per charge.

New Zealand's advanced interest in EVs and PHEVs is supported by relevant research projects. Examples are (a) the Ultra-Commuter research project at Waikato University, whose objective is to construct a lightweight EV with development

potential (see figure 25.10); (b) Meridian Energy's EV Trial, in which the company is collaborating with Mitsubishi to bring Mitsubishi's iMiEV to New Zealand (scheduled for February 2009); and (c) Auckland University's project to improve inductive power transfer (IPT) and wireless charging for EVs.



Fig. 25.10 Lightweight EV from the Ultra-Commuter research project at Waikato University.
(Photo supplied by ANL.)

25.6 **Spain**

Spain is pursuing many ambitious objectives in advanced transport technologies. The following data indicate why. The country relies on external sources for 80% of its energy, and oil consumption accounts for almost half of its total energy use. The transportation sector consumes the most petroleum of all the sectors (at 38.2%), and total consumption has grown 240% since 1988. Since 1973, Spain has experienced, by far, the greatest percentage increase in highway miles and cars per inhabitant in Western Europe, with road transport accounting for more than 23% of national carbon dioxide emissions.

To address these realities, Spain has inaugurated a two-stage (2005-2007, 2008-2012) energy efficiency and emissions control plan to bring it into line with the overall European strategy by 2020. Up to 9'000 kilotons of excess emissions of carbon dioxide could be reduced by adopting the most stringent measures. This plan will require (a) shifting to more efficient transport modes, (b) improving the efficiency of all transport modes, and (c) using existing modes more efficiently. The following 15 priority measures span these three categories:

1. Implement urban mobility plans (PMUss).
2. Implement transport plans for activity centres (PTEs).

3. Promote collective ways for road borne person and goods transport.
4. Promote use of railways for interurban transport.
5. Promote use of short sea shipping (sea transport).
6. Improve management of transportation infrastructures.
7. Improve management of road transport fleets.
8. Improve management of air transport fleets.
9. Implement ecodriving practices for cars.
10. Implement ecodriving practices for trucks and buses.
11. Implement ecodriving practices for airplanes.
12. Upgrade road transport industrial vehicles.
13. Upgrade airplanes for greater efficiency.
14. Upgrade ships for greater efficiency.
15. Rejuvenate automobile transport on roads for greater efficiency.

Employing each of these measures will require agreements with and co-funding by regional administrations. The Institute for the Diversification and Saving of Energy (IDAE) is taking a lead role in setting up these programmes.

In addition to the electric vehicles (EVs) and hybrid electric vehicles (HEVs) on Spanish roads, there are vehicles powered by liquefied petroleum gas (LPG), bio-ethanol, and biodiesel. While EVs currently receive the best tax provisions and support priorities in Spain, hybrids are gaining ground, especially under the second phase of the master plan. A car and industrial vehicle renewal/replacement scheme that is underway provides up to 15% of the purchase cost and 30% of the inversion cost for new EVs and hybrids. The Movele Project (currently budgeted at € 10 million) will, over the course of 3 years, place 2'000 EVs of various categories into service in one or more Spanish cities; they will be supported by about 500 charging points. Extrapolation of the results of this project indicates an estimated shift in energy demand from petroleum to electricity of about 10'000 MWh/day.

26

Outlook for hybrid and electric vehicles

Predicting the future is very difficult, if not impossible. Only two years ago, did you for example foresee the current worldwide economic crisis? So an outlook cannot be a prediction of the future. This outlook for hybrid and electric vehicles is a set of expectations for the future (until 2015) and factors that may influence these expectations.

Introduction and context

This outlook presents the views of a group of hybrid and electric vehicle experts (IA-HEV) collaborating under the framework of the International Energy Agency (IEA). IA-HEV is the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes. The twelve current member countries are Austria, Belgium, Canada, Denmark, Finland, France, Italy, the Netherlands, Sweden, Switzerland, Turkey and the United States. The participants in the Agreement are governmental bodies and research institutes that are appointed by their governments. This outlook is a synthesis of inputs of IA-HEV member country delegates; it does not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

Governmental policy makers and governmental bodies are the main target audience for this outlook, but it is also meant for research institutes working in the area of road transport, energy and environment, and for the energy sector.

This outlook starts with a small recapitulation why hybrid and electric vehicles are currently in focus. Then the car market is discussed, including the role of hybrid electric vehicles (HEVs) and pure electric vehicles (EVs). Plug-in hybrid electric vehicles (PHEVs), young customers and heavy-duty hybrids as specific topics for the market are elaborated in more detail. Next, the role of costs and the impact of the economic crisis on the outlook are discussed. After briefly addressing the environmental impact of hybrid and electric vehicles, the public opinion on these vehicles is elaborated. This outlook rounds off with the role of governments in all these issues and governmental possibilities to stimulate the transition towards clean and energy-efficient vehicles such as HEVs, PHEVs and EVs.

Why hybrid and electric vehicles?

It is clear that the current road vehicle transportation system is not sustainable. It consumes fossil fuels of which reserves are not endless, and its gaseous emissions cause air pollution and contribute to climate change. Among others, hybrid and electric vehicles are options to reduce energy consumption and emissions from road vehicles compared to conventional vehicles.

So why, in spite of these advantages, are hybrid and electric vehicles not used on a larger scale? The most important reason is their higher purchase costs. A hybrid vehicle for example has at least two propulsion systems so it can use at least two different energy carriers, which makes it more expensive to manufacture than a conventional vehicle. (In this outlook, a vehicle with internal combustion engine and only a stop-start system is not considered a hybrid vehicle.) Also batteries for electric vehicles are still expensive. Other reasons are for example that a production and maintenance infrastructure is not yet in place, and for battery EVs the vehicle range is usually perceived as being too small.

In spite of the price disadvantage, the market for hybrid vehicles has started to take off. This was possible because vehicle manufacturers with a long-term vision on energy efficiency have started producing hybrids and governments have created incentives for clean and energy-efficient vehicles.

The next section presents expectations for the car market, while other vehicles are discussed in the heavy-duty applications section.

The car market

The year 2008 showed a remarkable change in car sales. The trend of increasing sales of larger and heavier cars, including sports utility vehicles (SUVs), was broken in favour of smaller and more energy-efficient cars. During the first half of 2008 the surging oil price was driving this change, while in the second half of the year the worldwide economic crisis had its impact. The economic crisis not only led to an increasing interest in small and fuel-efficient cars, but it also caused a sharp decline in total vehicle sales. Remarkably, the share of hybrid electric vehicles in total car sales continued to grow in many countries. This trend is expected to continue because of the following reasons:

- Hybrid electric cars are more fuel-efficient than conventional cars, especially in urban traffic.
- More hybrid models will become available on the market.
- Higher production volumes may lead to lower hybrid vehicle costs and prices.
- Incentives for energy-efficient and low CO₂ emitting cars, such as tax reductions and entry rules for urban areas.

The growth of the sales share of hybrids is expected to continue in established markets (today 2-3% share in new vehicle sales) as well as in markets where hybrid sales are in their infancy. Although most car manufacturers are planning to bring new hybrid models on the market in the coming years, it is expected that total hybrid car sales will be limited because of limited supply. Especially the production volume of batteries might be a bottleneck. Box 26.1 presents some more detail.

Box 26.1**Hybrid and electric vehicle markets until 2015****Hybrid Electric Vehicles (HEVs)**

The worldwide HEV share in new vehicle sales is expected to continue its growth. However, the total production volume might be insufficient to meet demand, due to practical restrictions such as a limited production volume of batteries.

By 2012, the global sales figure for hybrid vehicles may have tripled to 2.2 million units. The share of hybrid cars in 2015 new car sales is expected to be below 10%.

Electric Vehicles (EVs)

The share of electric cars in new car sales in 2015 is expected to be well below the share of HEVs at that time.

Electric bicycles are expected to remain the dominant EV category. If current trends continue, the worldwide electric bicycle fleet will be well over 100 million units in 2015.

As mentioned earlier, it is impossible to predict the car market of 2015. Today's economic uncertainties may slow down the growth of the hybrid market share. On the other hand, a crisis offers opportunities for change and implementing new, better adapted technologies such as hybrid and electric vehicles.

Compared to hybrids, the market of pure electric cars is still very small. It appears that subsidies are not sufficient to create a sustainable electric car market. Nevertheless, electric vehicles (EVs) are a success in a number of market niches where they offer a clear advantage for the user. In countries like Norway and Switzerland, EV drivers profit from real advantages such as faster commuting, easier access to city centres, easier parking, lower operating costs, and -in some cases- a positive image. It should be noted that these advantages are not always offered by 4-wheeled electric cars, but they may be provided by lightweight three-wheelers and high-speed electric bicycles (see also box 26.1). The EV population may be expected to grow when new technologies that meet customers' demands are introduced on the market. Car manufacturers are developing EVs today and they are announcing the introduction of electric cars from 2010 onwards.

Plug-in hybrid electric vehicles (PHEVs)

A special category of hybrid vehicles is the plug-in hybrid electric vehicle (PHEV). Before addressing the reasons why PHEVs receive much attention lately, two different PHEV options are briefly described here. One type of PHEV is essentially a 'parallel' hybrid electric vehicle with additional batteries, giving the vehicle an all-electric drive capability in some urban driving conditions, and battery charge

depletion capability in all driving conditions. A ‘parallel’ hybrid primarily means that both the electrical and mechanical portions of the complex drivetrain can provide traction power to the wheels together, at the same time. Another PHEV design is the so-called ‘extended-range electric vehicle’ (EREV) where the vehicle only operates all-electrically while the grid-supplied battery charge is depleted. The EREV internal combustion engine comes on to drive the vehicle and extend the operating range after the battery charge is depleted. The drivetrain used is termed a ‘series’ powertrain. ‘Series’ is a form of hybrid where the internal combustion engine never provides mechanical power to the wheels, but its mechanical power is converted into electricity, which in turn is fed to batteries and/or directly used to propel the vehicle. The power to the wheels is always provided by an electric motor. Since the battery in a charge depleting series EREV must provide all needed power in all driving conditions, the EREV will have a much more powerful battery than the PHEV derived from modification of a parallel hybrid. The EREV can operate all-electrically, even on high speed limited access highways. Both types of PHEVs have a plug to connect and recharge their batteries from the electricity grid.

A major advantage of PHEVs is that they can be charged overnight, when most electric utilities have capacity available because of declining power demands. Thus, PHEVs can make use of existing generation and distribution capacity of electrical utilities, a feature considered very attractive by the utilities. PHEVs are gaining interest from utilities for other reasons as well - they offer electric storage capacity that utilities could use for their grid management.

When driving in all-electric mode, PHEVs have no tailpipe emissions. Additionally, when solar, wind or hydropower is used for electricity production, PHEVs will contribute to using renewable and clean energy in the transportation sector. Box 26.2 gives more information about PHEVs.

Most PHEVs are currently in the prototype phase. PHEVs modified from existing parallel HEVs are being developed by Toyota, from its Prius HEV, and by Ford, from its Escape HEV. These PHEVs will be capable of operating all-electrically in neighbourhoods and in less aggressive urban driving.

General Motors has announced that it will introduce an EREV PHEV, the Chevrolet Volt, on the market in 2010. This is a purpose-built new design, not derived from an existing vehicle body and powertrain. It will be capable of operating all-electrically in all driving conditions. Given the promise of PHEVs, other manufacturers are expected to follow. However, the share of PHEVs in new vehicle sales in 2015 will certainly be small compared to the conventional hybrid electric vehicle sales share.

Box 26.2**Plug-in Hybrid Electric Vehicles**

A plug-in hybrid electric vehicle (PHEV) is essentially a hybrid electric vehicle (HEV) with additional batteries and a plug, giving the vehicle an ability to use electricity from the grid to move the vehicle. While the charge of the PHEV's larger battery pack is depleted, some PHEVs may operate all-electrically, while others may use both battery electric and internal combustion engine mechanical power to move the vehicle. A variety of design options for PHEVs are possible, but all will use electricity from the grid to replace liquid fuels used by internal combustion engines in vehicles.

One of the advantages of PHEVs is a potential increase in energy efficiency. This could then result in a reduction of greenhouse gas emissions, fuel consumption and dependency on fossil fuels. However, the full energy cycle result is highly dependent on the type of electricity generation capacity (solar, wind, coal, etc.), which varies greatly in IA-HEV member countries. Also, the time of charging can influence the source of the additional electricity needed to power PHEVs.

IA-HEV Annex VII's final report already mentioned that over the last decade in both the U.S. and Europe there has been a significant increase in the amount of generation of electricity by natural gas. This is a positive trend for full fuel cycle greenhouse gas emissions if the recently constructed combined cycle natural gas power plants -which are highly efficient, intermediate load plants- are used to generate electricity for PHEVs. 'Intermediate load' means that the plants increase in power output during the day and are throttled back or shut down at night. So in particular these plants are available to charge the first PHEVs that will appear on the market, when those PHEVs are charged in the evening and overnight. On the other hand, today's coal generation brings the risk that PHEVs using coal electricity emit more greenhouse gases over the full fuel cycle than conventional vehicles.

Sustainable electricity production capacity -such as wind and solar power- is increasing around the globe and will continue to grow in the coming decades. Using this kind of electricity for PHEVs is a very promising option to convert road transport to using renewable energy without greenhouse gas emissions.

These and other issues will be tackled by the newest IA-HEV task force that is collaborating on plug-in hybrid electric vehicles in Annex XV.

Young customers

Teenagers and today's young vehicle customers will form a substantial share of the people buying vehicles in 2015 and beyond. Their references may be different from the majority of today's customers. They have grown up with electronics and are used to electric powered equipment. Electric vehicles may be appealing for them, although these vehicles may offer fewer possibilities for customizing and tuning the 'engine'. It appears that young people prefer to live in cities and that makes them potential users of battery electric vehicles with limited range.

Heavy-duty applications

Besides in cars, hybrid electric drives can be used in heavy-duty applications such as trucks and buses, but also in mobile machinery such as forestry equipment, forklift trucks and wheel loaders. Hybrid drives are very well suited for stop-and-go traffic, where they can bring substantial fuel savings and emission reductions. This means that hybrid drives can be advantageously applied in vehicle categories such as city buses and goods distribution trucks. Hybrid city buses have gained a substantial fleet share in certain cities in the USA, but in Europe they are in an early development phase and only used in some demonstration projects. Hybrid goods vehicles such as delivery vans and trucks are still in the prototype phase. Today all major mobile machinery manufacturers are either developing or planning hybrid powertrains for their machines. Machines with stop-and-go use and/or with vertical load handling -such as forklift trucks, straddle carriers and wheel loaders- may especially gain in energy efficiency by using hybrid drives.

The application of hybrid powertrains in heavy-duty applications is behind in comparison with the application with cars, and consequently the worldwide market share of heavy-duty hybrids is estimated to be still small in 2015.

The role of costs

Relatively high purchase costs have already been mentioned as the most important barrier for a high share of hybrid and electric vehicles in the current vehicle fleet. This section brings more nuances and addresses other cost issues as well.

To date, owners of HEVs did not purchase these vehicles based on financial savings. A green image or just being different were more important driving forces. For a larger market share of hybrids, financial savings will have to play a much larger role in purchase decisions. The reselling price on the used car market, which to date is largely unknown, may play an important role in the total costs and savings of operating a hybrid car. When more hybrid car models will be offered on the market,

total production numbers will go up and consequently production costs and purchase price may be expected to come down.

In 2008, an increasing sales share of fuel-efficient hybrid vehicles could be observed, in parallel with surging oil prices. In some countries hybrid car sales increased sharply when taxes for this kind of vehicle categories decreased. Also CO₂ emission based financial bonus/malus systems have positively affected hybrid sales. How costs of competing technologies -that meet customers demands for reduced fuel consumption and that simultaneously meet increasingly stringent emission requirements- compare to the costs of hybrid technology will play a role in the market success of hybrids. Finally, the overall economic situation will have an impact on the costs and market share of hybrid vehicles. This issue is addressed in the next section.

The impact of the economic crisis

The bad economic situation is one of the reasons why the trend of buying heavy vehicles with high fuel consumption is declining. This may be advantageous for fuel-efficient hybrid and electric vehicles when they can be offered to the customer at competitive price levels. The current economic situation makes it difficult to say how the growth of the HEV market will continue and it is almost impossible to give a reliable numerical estimation of future sales.

The economic crisis is likely to slow down or postpone hybrid vehicle development, but it is unlikely that this development work will come to a halt. The actual crisis in the car industry will also have negative effects on their suppliers. At this stage it is not clear how the automotive industry will recover from this dip. Nevertheless, some see opportunities arising from the current situation. In rare cases there might be new investments in research because companies now have labour available.

Environmental impact of hybrid and electric vehicles

Using hybrid and electric vehicles reduces CO₂ and pollutant emissions compared to conventional vehicles, where a precondition for EVs is low carbon electricity production. For example hybrid goods distribution trucks and hybrid buses will have a positive effect on air quality in cities. However, for the time being the relatively small market penetration of hybrid and electric vehicles limits their impact on the environment.

Besides hybridization, using electric vehicles or using biofuels, other energy-efficient vehicle technologies such as diesel engines and fuel cell cars are ways of reducing

CO₂ emissions. When energy-efficient technologies are combined with low CO₂ fuels, these technologies become even more interesting.

Public opinion

Society in general has started moving towards more sustainable behaviour and consumption patterns, including mobility. Campaigns have raised public awareness about the negative consequences of consumption, including petroleum based vehicle propulsion. The use of public transport is increasing, acceptance of large inefficient vehicles is declining, and sales of smaller cars are increasing, not only due to fiscal measures. The market success of hybrid vehicles by itself has contributed to change the public opinion. The popularity of HEVs is expected to further increase when more models become available. The general public has started showing interest in plug-in hybrids.

Nevertheless, there are still consumer satisfaction issues for a large-scale deployment of vehicles with an electric drive. For example, the charge depleting range of PHEVs and EVs would be sufficient for most commuter trips in North America and in Europe. However, for EVs in particular, their range using grid electricity is still perceived as being insufficient. For PHEVs initially developed from parallel HEVs, more power may later be needed to allow all-electric driving capability in more circumstances. For EREVs in early configurations, the cost of the battery to provide universal all-electric operations capability may limit the size of the market. Using EVs and PHEVs would require some lifestyle changes, particularly to refuelling and recharging habits.

Governments can play a role in raising public awareness and informing about possibilities of changing mobility related behaviour. These and other options for governments to play a role in the deployment of hybrid and electric vehicles form the subject of the next, last section of this outlook.

The role of governments in the deployment of hybrid and electric vehicles

Hybrid and electric vehicles can play a role in achieving governmental objectives to reduce CO₂ emissions, to improve air quality, to reduce energy dependency and to increase energy efficiency. These vehicles may even contribute to help countries climbing out of the economic dip by creating new business with eco-friendly technology.

Regarding vehicle development, governments can contribute to funding research projects that are aiming at advancing propulsion systems and fuels. Stringent

CO₂ emission regulations can push the car industry towards developing more energy-efficient vehicles. Innovation can be promoted by funding PHEV and EV demonstration projects.

The demand for clean and fuel efficient vehicles can be encouraged by specific policies such as fiscal measures, entry rules for urban areas and free parking for clean vehicles. Dedicated tax reductions have proven to be effective to increase the demand of energy-efficient, low CO₂ emitting cars. Regulations can be used to establish sustainable market niches such as car free resorts. Directives and laws may be used for renewing car fleets requiring improved vehicle drivetrains and fuels. Finally, it seems crucial that governments help lowering the hurdle to use clean, efficient vehicles by supporting the construction of the required refuelling/recharging infrastructure.

Non-technical measures to support the introduction of clean and energy-efficient vehicles include public awareness campaigns and making information available that can be used when making vehicle purchase decisions.

Governments are also in a good position to help creating integrated concepts for sustainable mobility that go beyond vehicle technology. This may include for example changing the modal split, avoiding certain displacements of people and goods, combining hybrid technologies with low carbon fuels, and using PHEVs to help integrating high shares of renewable energies such as solar, wind and hydropower in electricity production. Establishing programmes that partner industry, trade organizations, universities, research institutes and the public sector, with the objective to create a joint vision and to make that vision a reality seem to be an effective way to create integrated, sustainable mobility systems.

IA-HEV publications

IA-HEV publications during the third term, 2004 - 2009

- *Annual report 2004 - Final report for phase 2. Progress towards sustainable transportation.* Report by the IEA Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes for the year 2004. Angers, France. March 2005.
- *Hybrid and electric vehicles 2006. Past - present - future. Progress towards sustainable transportation.* Annual report by the IEA Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes for the year 2005. Angers, France. February 2006.
- *Hybrid and electric vehicles. The electric drive takes off. Progress towards sustainable transportation.* Annual report by the IEA Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes for the year 2006. Angers, France. February 2007.
- *Hybrid and electric vehicles. The electric drive gains momentum. Progress towards sustainable transportation.* Annual report by the IEA Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes for the year 2007. Angers, France. March 2008.
- *IA-HEV electronic newsletter.*
2005, issued in January, May and November.
2006, issued in September.
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Vehicle categories

In the ‘on the road’ sections of the country chapters on Austria, Belgium, Denmark, Finland, Italy, the Netherlands, Sweden, Switzerland and Turkey, fleet numbers of motorised road vehicles are as much as possible presented in a standardized table. The definitions of the vehicle categories that are used in these tables are given below.

Vehicle	Description
Motorised bicycle (no driver licence)	Two-wheeled motorised (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 kilometres 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	Metre	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 J = N•m
Force	Newton	N	1 N = 1 kg•m/s ²
Power	Watt	W	1 W = 1 J/s
Pressure	bar	bar	1 bar = 10 ⁵ N/m ²
Time	hour	h	1 hour = 3600 s
Volume	litre	l	1 litre = 0.001 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•10 ⁶ J	1 J = 277.8•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	foot pounds	lb-ft	1 lb-ft = 1.35582 Nm	1 Nm = 0.73756 lb-ft

Table 6 Fuel consumption.

x mile/gal (UK)	↔	282.48/x l/100 km
x l/100 km	↔	282.48/x mile/gal (UK)
x mile/gal (US)	↔	235.21/x l/100 km
x l/100 km	↔	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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Glossary

This glossary of terms related to hybrid and electric vehicles also includes information on the ‘competition’ to the electric drive, because now that plug-in hybrid electric vehicles get major attention, there are many ways to mix and match electric and conventional drive, 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 metre of length. Ampere is symbolised by ‘A’.

Ampere-hour capacity

The quantity of electricity measured in Ampere-hours (Ah) that may be delivered by a cell or battery under specified conditions.

Typical conditions for EV applications are 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 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

Completely functional system, including battery modules, battery support systems and battery specific controls. A combination of one or more battery modules, possibly with an added

cooling system, 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 $C_s/20$ discharge current for a battery rated at the 5-h discharge rate is: C_s (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 $C_s/20$ 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 symbolised by 'C'.

Capacitor

A device which consists essentially of two conductors (such as parallel metal plates) insulated from each other by a dielectric and which introduces capacitance into a circuit, stores 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-use'. Fuel economy and fuel consumption may for example be expressed in l/100km (litres 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, for accounting 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 RESS on a PHEV, EV or extended-range EV is discharged.

Charge depletion (CDB)

When an 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 (CDE)

When an 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 equalises the battery state of charge of all the modules in an EV during charging. With this measure the voltage of all the batteries will rise equally and the battery with the smallest capacity is not overcharged.

Coal-to-liquids (CTL)

Conversion of coal to a diesel like fuel low in sulphur suitable for use in 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. The unit of measure is the Ampere.

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 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-sulphur

Diesel fuel is a refined petroleum product suitable for use in CIDI engines. In recent years there has been a worldwide movement to reduce sulphur content of diesel fuel in order to improve the reliability of required emissions aftertreatment for vehicles using CIDI engines. The sulphur reduction also reduces emissions of SO_x , which in turn reduces sulphate particle matter in the atmosphere. Costs of diesel fuel have been driven up by the need to remove sulphur from a mix of crude oil that is increasing in average percent of sulphur.

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, Watt-hour efficiency).

Direct-current motor

An electric motor that is energised 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

With an E-bike, cycling 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 throttle and pedals can be used at the same time but -in contrast to a Pedelec- they don't have to. This also means that 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 motor cycle

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. 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)

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 Ampere-hours is usually referred.

Energy consumption

See 'Fuel consumption'.

Energy density

The ratio of energy available from a cell or battery to its volume in litre (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 blended-mode charge-depleting (CDB) operations distance of a PHEV into a lesser '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:

Stand-up scooters. Instead of pushing the scooter forward with one leg you simply turn the throttle on the handlebar and ride electrically. A typical stand-up scooter is a little more than one meter long and weights 12-25 kg.

Sit-down scooters. Small electric vehicles with a seat 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 ones 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 'flexibly fuelled vehicles' or 'fuel flexible vehicles' (FFVs). Brazil, the United States and Sweden produce significant quantities of FFVs. The leading producers of ethanol in the world are the U.S. -which produces it from corn- and Brazil, which produces it from sugar cane. In the future, the U.S. 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

An 'autonomous road vehicle' primarily using electric drive provided by a 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. A more brief term for such a vehicle is 'series PHEV'.

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; E20 contains 20% and so forth. Generally the lowest percentage of gasoline in gasoline-ethanol blends is 15% (i.e. 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)

By FTP here we mean the 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 centigrade. For purposes of developing estimates of 'on-road' fuel economy, accounting for starting in cold temperatures, the U.S. Environmental Protection Agency has recently developed the 'Cold FTP', which is conducted at ~ - 6.7 degrees centigrade.

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

It is the energy consumed by a vehicle per unit distance (in km) and, sometimes, also per unit weight (in ton). It may be expressed as kWh/km and also kWh/(km.ton). 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 litre 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 U.S. 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 U.S. is 'conventional'.

Gas-to-hydrogen (GH2)

Conversion of (natural) gas to a synthesis gas containing hydrogen (H_2) and carbon monoxide (CO), followed by clean-up of the gas to produce pure H_2 . The common process used is steam reforming.

Hourly (hour) battery rate

The discharge rate of a cell or battery expressed in terms of time a fully charged cell or battery can be discharged at a specific current before reaching a specified cut-off voltage:
 $\text{hour-rate} = C/i$, 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.

Hybrid Electric Vehicle (HEV)

UN definition: 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,
- 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 U.S.

Infrastructure

Everything except the vehicle itself that is necessary for its use. For PHEVs or EVs the infrastructure is including: available fuel (electricity), power plants, transmission lines, distribution lines, access to parts, maintenance and service facilities, 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)

1000 Watt-hours of energy. Equals to 1.341 horsepower-hours (or 1.35962 CVh).

Lithium ion (Li-ion)

Lithium ion is actually a family of battery chemistries. Currently used Li-ion chemistries have come down significantly in cost and have increased gravimetric and volumetric energy density over the last 15 years, accelerating in the last seven. Li-ion has nearly completely supplanted NiMH in consumer electronics. NiMH remains the chemistry of choice in HEVs, but is anticipated to be replaced by emerging Li-ion chemistries. Because it has already attained significantly higher gravimetric and volumetric energy density 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. NiMH does also continue to slowly improve.

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 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.

Neighbourhood Electric Vehicle (NEV)

A vehicle defined in U.S. 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 U.S. light-duty vehicles.

Nickel Cadmium (NiCd)

Nickel Cadmium was a common battery chemistry used in many EVs of the 1990s, and in consumer electronics. It is no longer common in use.

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 NiCd.

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 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 or 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). At this time, the U.S. has adopted a method to estimate, and publish for consumers, estimates of on-road fuel consumption that use five different driving cycles. The official U.S. 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 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 riders 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 pedaling and 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.

PHEV_{xk}

A plug-in hybrid electric vehicle with ‘x’ miles or kilometres of estimated CDE range (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 litres (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 C₁ or C₃), temperature and cut-off voltage.

Reactive Organic Gases (ROG)

These are emissions from the tailpipe and/or 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 computerised 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’ hybridization 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’.

Sulphur Oxides (SO_x)

Sulphur oxides - a ‘criteria pollutant’ whose concentration in the air is regulated. Sulphur content of fuel is usually regulated; both in order to reduce conversion of fuel sulphur 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 sulphate. 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, less than 50 mile range.

Type I (as defined by CARB)

City EV, range of 50 miles to 75 miles.

Type I.5 (as defined by CARB)

City EV, range of 75 miles to less than 100 miles.

Type II (as defined by CARB)

Full function EV, range of 100 or more miles.

Type III (as defined by CARB)

ZEV, range of 100 or more miles plus fast refuelling.

Type IV (as defined by CARB)

ZEV, 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 < 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 1 Coulomb of electricity will do 1 Joule of work in going from one point to the other. Volt 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 kilometre

Energy consumption per kilometre at a particular speed and condition of driving. 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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Abbreviations

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 Électrique Méditerranéen (France)
AVERE	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)
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)
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
gCO 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)
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
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
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 (TÜBITAK, 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
NO _x	Nitrogen Oxides
NRC	National Research Council of Canada
NRCan	Natural Resources Canada
NREL	National Renewable Energy Laboratory (USA)
NZES	New Zealand Energy Strategy
N ₂ O	Nitrous Oxide (not considered a NO _x 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
PM ₁₀	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)
SO _x	Sulphur Oxides
SO ₂	Sulphur 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
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)
VTT	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

IA-HEV contact information

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.ieahhev.org.

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