

International Energy Agency
Implementing Agreement on
Hybrid and Electric Vehicle Technologies and Programmes

Hybrid and electric vehicles

The electric drive takes off

February 2007

Progress towards sustainable transportation

Cover photo:

Heavy-duty hybrid truck, subject of new Annex XII.

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International Energy Agency
Implementing Agreement on
Hybrid and Electric Vehicle Technologies and Programmes
Annual report of the Executive Committee and Annex I
over 2006

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The electric drive takes off

Progress towards sustainable transportation

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Report structure

This report consists of four main parts. Part A ‘About IA-HEV’ describes the Implementing Agreement 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 can be read as a summary of this report. Chapter 2 shows the relationship between IA-HEV and the International Energy Agency (IEA), it describes the history and strategy of IA-HEV and it presents the IA-HEV clean vehicle award.

Part B ‘Activities of IA-HEV’ presents the results of the work that is performed under this Agreement in the form of Annexes. It also gives the plans for new Annexes.

A general picture of hybrid and electric vehicles (HEVs) around the globe is painted in part C ‘HEV’s worldwide’. The first chapter (12) in this section gives worldwide HEV statistical information and developments in 2006. The developments section includes current regulations, programmes and research topics. New in this years’ developments section are boxes that help finding the IA-HEV countries that have these regulations in place, in which these programmes are running or where organizations work on these research topics. More detailed information can then be found in the IA-HEV member country chapters (13-20) that describe activities on hybrid and electric vehicles in each country. Chapter 21 highlights HEV issues in IA-HEV non-member countries and part C is concluded with a look to the future of hybrid and electric vehicles.

Part D gives practical information related to HEVs and the Agreement: a list of IA-HEV publications, conversion factors for HEV related units, the abbreviations that are used in this report and contact information of the IA-HEV participants.

1

Chairman's message

Successful start of the 3rd phase of the Hybrid and Electric Vehicles Implementing Agreement: new Annexes and new members!

1.1

First results after years of preparation

The year 2006 was the most successful year in the history of the Implementing Agreement Hybrid and Electric Vehicles (IA-HEV) since it started in 1994. Since the Executive Committee meeting in Beijing 1999 and after years of fact-finding, brainstorming, discussions and preparations we could launch three new Annexes in 2006:

- Electric cycles (Annex XI).
- Heavy-duty hybrid vehicles (Annex XII).
- Fuel cells for vehicles (Annex XIII).

Additionally the Annex 'Market deployment of hybrid and electric vehicles: Lessons learned' will be launched in these days. The last new Annex on our current list 'Renewable energies for hybrid and electric vehicles' is being prepared and is looking for participating countries. Considering the facts presented in the 'World energy outlook' of the IEA in December 2006, the combination of renewable energies and the electric motor, the most efficient drivetrain, will be the winning team of the future. All these new Annexes are attractive offers for new member countries.

International collaboration needs contents and participants. I am very happy to report that another wish for 2006 -at least one new participating country- was successful too. In Annex XI 'Electric cycles' one sponsor and a subtask leader from non-member countries could be integrated. Additionally Turkey could be invited as a new member, after an unanimous vote of the IA-HEV members, and other countries show great interest to join our Agreement.

1.2

What a great time to work on hybrid and electric vehicles

After years of step back or stagnation, the market for vehicles with electric drivetrains speeds up. Hybrid vehicles are selling well. It is interesting to see them showing up in traffic and in public perception. We could observe that during our Executive Committee meeting in the facilities of the Electric Power Research Institute (EPRI) in Palo Alto (USA). I did the 'hybrid test', which works like this: you stand at a crowded street corner or on a parking place and look for at least one hybrid vehicle. In Silicon Valley you will always find one. Here in Switzerland

we are working on it - and we are progressing, adding some electric vehicles and many electric two-wheelers to the vehicle mix. These are 'hot spots', and we have to work towards making this a reality all over the world.

Another interesting fact is the public perception of hybrid vehicles. The discussions about climate change and excellent communication activities like Al Gore's movie 'An inconvenient truth' reach new people. After Hollywood stars switched to hybrid vehicles, this movement is now expanding into broader market segments.

It is very well noticed when a car driver switches to a hybrid vehicle. This pushes his image as a progressive and responsible citizen, especially in business. The Swiss re-insurance company 'Swiss Re' pays a remarkable contribution to those employees that buy a hybrid vehicle instead of a gas-guzzler. All the U.S. sales staff of the company 'Novartis' now uses hybrid vehicles for visiting their customers. Hybrid vehicles have arrived in the cartoon series 'The Simpsons' and also in public relations campaigns, which is the best proof that they have had a breakthrough in the mass market.

But this is only the beginning, and we will face other challenges in technology, applications and use. To be ahead of the progress will be exciting for our Implementing Agreement.

1.2.1

The EV returns

This was the headline of several articles in European newspapers like the 'Neue Zürcher Zeitung'. No surprise for me, I predicted it in my chairman's message in last year's IA-HEV annual report (page 6). No doubt that the market breakthrough will not be achieved as fast as in the case of the hybrid vehicle. But compared with technical alternatives, an electric vehicle with advanced components like high-energy batteries will have a promising future. We will have to deal with the best configurations of electric drives in all applications many years from now.

1.2.2

Plug-in hybrids (PHEVs): a new promising concept

The 'plug-in hybrid vehicle' is the next step forward. This concept offers many advantages. During our spring meeting at EPRI in Palo Alto (USA) we got an impression of the potential of this concept. In a world of surplus and need of electricity, 'plug-in hybrids' could work as short time storage systems for load levelling in the electricity grid. A car that has a value while standing on a parking space is a revolutionary concept for car drivers. To exploit this potential, additional phases of this Implementing Agreement will be needed.

This year I learned that wind energy specialists of small utility companies in the Swiss Alps are discussing PHEVs as a mean to avoid peaks in electricity production. PHEVs offer more advantages than any conventional car. The planned Annex 'Renewable energies for hybrid and electric vehicles' could play an important role in this discussion. The working group in our Annex VII 'Hybrid vehicles' is investigating all these aspects of the PHEVs. Please check their results in this annual report!

1.2.3

Give the customer what he wants to drive

In my daily work I met two young entrepreneurs owning a successful company that produces special metals for the Swiss watch industry. As entrepreneurs they are interested in future technological trends. They believe that saving energy is crucial for the future. Their company building is heated by a cogeneration plant supported by solar collectors and wood firing. Grid connected solar panels are installed on the façade and the roof.

What kind of car do they use? For years they drove the small French electric vehicle Microcar. Then they looked for something better. For a short time they tested the Swiss prototype SAM. Finally they found a way to organize two Th!nk EVs powered by photovoltaic (PV) electricity produced by the façade and the roof. They are very satisfied with the performance of these vehicles.

Those two are global players used to organize things from all over the world. But what is the choice for the normal car driver? Actually I drive a VW Lupo TDI 3 l making annually 40'000 km and consuming about 3 litres per 100 km. If I had to replace this car, the 'new best' vehicle would consume more than 1 litre diesel more per 100 km. Is that the progress within the automotive industry?

It seems that this industry has not yet noticed what people want to drive. No wonder that car companies offering new vehicle technologies like hybrids expand, and those that try to sell the old stuff -even heavier than before- are suffering.

Customers are ready to buy advanced products, but they must be better in performance and offer additional advantages. Electric and hybrid vehicles are better and offer advantages - and it is fun to drive them!

1.3

The influence of promotion measures is still crucial

The influence of political measures to promote electric and hybrid vehicles is still crucial. The drop in sales of some hybrid models in the USA can directly be linked to the limits of subsidies. This is also an indicator how fragile the market still is. In addition, there are still many countries where hybrid vehicles meet barriers. Often an inappropriate tax system is the reason for that, e.g. in Denmark or Finland. We have to discuss how we can direct the focus of the politicians on the importance of such questions.

1.4

Six Annexes running and two Annexes in preparation

1.4.1

Running Annexes

After the successful launch of three Annexes in 2006, now six Annexes are active - more at the same time than ever before. Our next effort is to increase the number of member countries in these Annexes.

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 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 participation is only available for the member countries. Argonne National Laboratory (ANL) in the USA is the Operating Agent of this Annex.

Hybrid vehicles (Annex VII)

This is a group of specialists from the USA and Europe that works on new trends concerning components and vehicles. Members of this group have been the first promoters of the current trend to plug-in hybrid vehicles. This has been discussed already in 2001, on the occasion of the IA-HEV Executive Committee meeting in Long Beach. The knowledge of this group enables the governments to influence the model policy of automakers of their country. The Operating Agent of this group is TNO, the Netherlands.

Electrochemical systems (Annex X)

This working group is a continuation of the working group 'Batteries' of the first phase of this Agreement (1993-1999). It focuses on special technical details that are not discussed within the battery community or special battery conferences, like experiences with specific test protocols or the abuse of batteries. The Operating Agent is the 'Department of energy storage for vehicles' of the Department of Energy (DOE), USA.

Electric cycles (Annex XI)

In several countries electric two-wheeled vehicles became a huge market segment in the transportation field, especially in China. In several European countries electric bicycles are used for commuter trips and are a small special market niche. Because of different quality standards, vehicles do not necessarily match for both market fields, and there are still a lot of open questions concerning standards,

licensing or market deployment. This group has started its work in March 2006 and is still open for new participants. AVERE in Belgium is the Operating Agent of this Annex.

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 heavy-duty hybrid vehicle technologies. Besides the obvious vehicle types like buses and trucks, other applications of conventional heavy-duty vehicle technology -like dedicated and off-road vehicles- may be candidates for hybridisation. Additionally to this study of the application area of hybrid technology, the Annex will also study the current situation of existing hybrid prototypes and standard vehicles. The information gathering will focus on the applied technology, the costs and the merits. This subtask will broaden the insights in these applications and provide essential information for future hybrid vehicle deployment projects. The launching workshop is held in February 2007. The Operating Agent is the Belgian research institute VITO.

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 and 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 heavily in the development of this technology. Nevertheless, limited lifetime as well as high production costs due to noble metal catalysts have until now impeded the broad market introduction of fuel cells beyond special niches like space applications. But in the last years cheaper and more stable materials for separators and electrodes have helped achieving major improvements for fuel cell technologies. Rising costs of after-treatment equipment for internal combustion engine emissions due to tightening emissions standards will bring fuel cell vehicles closer to competitiveness. This new Annex will concentrate its activities not 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 will be 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 cells in road vehicles. In this respect boats, aeroplanes and mining vehicles could be an interesting niche preparing the market introduction of fuel cell, electric and hybrid road vehicles. The Operating Agent is the Austrian Agency for Alternative Propulsion Systems (A3PS).

1.4.2

New Annexes in preparation

We hope to add new activities to the Agreement by the following planned new task forces (Annexes).

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 raising of additional funds is necessary. After a first successful workshop in Paris in 2002, the benefit of such co-ordination was clear. But the financing of such a task that connects developing countries with energy efficient transport technologies is a challenging task.

Market deployment of hybrid and electric vehicles: Lessons learned (new Annex in preparation)

IA-HEV Annex VIII '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. However, the evaluation did not include success- or failure stories of clean vehicles themselves. In a follow up of this Annex the reasons for success and failure in introducing electric and hybrid vehicles onto the market will be analyzed. This is even more important as car manufacturers (and users) have several options for the choice of a clean propulsion technology (alternative fuels like natural gas, biogas and ethanol; fuel cell vehicles). The last 20 years saw a coming and going of new electric vehicle models and EV manufacturers. To know what happened during the market deployment of these vehicles is a precondition to learn from these stories and to avoid the repetition of mistakes. The interim Operating Agent for this Annex is Ms. Kleindienst Muntwyler from Switzerland.

Renewable energies for hybrid and electric vehicles (new Annex 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 demand to use renewable energies. The planned new working group will focus on the electricity production for battery electric vehicles and plug-in hybrid vehicles; biofuels for hybrid electric vehicles and an updated overview on well-to-wheel analyses of energy efficiencies, greenhouse gas emissions and costs of different pathways. The interim Operating Agent from Denmark is developing a work plan and is looking for participants.

1.5

New participants are welcome

Each Annex is financed by contributions from the participants in that Annex to the Annex common fund. This joint financing makes the benefit of participation much higher than the costs. For research institutes and industry it is also possible to collaborate as sponsor or subtask leader. Please contact the Operating Agent (OA) or the IA-HEV secretary in case you are interested. It is possible to participate in a workshop free of charge, if an interest in further participation in the work of an Annex is expressed.

1.6

Dissemination activities

Because more and more decision makers in governments, states and communities are interested in -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 have 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 view in the activities in our member countries. Interesting non-member countries are covered by correspondents from Annex I 'Information exchange'. The Annual report will be sold to the public or can be ordered from the national delegates.
- Electronic Newsletter.
The IA-HEV Newsletter is distributed via e-mail. It informs about our work and IEA-related activities in our field. It can be ordered at our secretariat!
- New website.
The new website presents interesting results of our work and news flashes from the EV and HEV market. The webmaster is a specialist from the Argonne National Laboratory.
- Insight newsletter.
This monthly electronic newsletter informs about the work within our Implementing Agreement; for members only!
- IA-HEV clean vehicle awards (since 2005).
This is a medium to point out to the necessity of a large clean vehicle share in transportation and the commitment of the automotive industry in clean vehicle production. There is not only the pressure of air quality standards or energy economy issues, but it is 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. Annually, three awards are granted:
 - for more than 25'000 (bronze), 50'000 (silver), 100'000 (gold) and 250'000 (platinum) sold vehicles,

- for the best application of HEV and fuel cell vehicles,
- for a dedicated person in the field of HEV and fuel cell vehicles.
- Outlook for hybrid and electric vehicles.
The Executive Committee increases the value of the Implementing Agreement by elaborating an 'outlook' chapter in the IA-HEV annual report (since 2006). This 'outlook' will show 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 and symposia.
The results of the work of the Implementing Agreement are presented at conferences and symposia such as EVS-22 in Yokohama, Japan, and EET-2007 in Brussels, Belgium.
- Workshops.
Our Annexes organise many workshops. These events are normally for IA-HEV member countries only. This is the most important platform for information exchange. Workshops are held in the following Annexes:
 - Annex I (Information exchange): 2 workshops per year.
 - Annex VII (Hybrid vehicles): about 2 workshops 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): launching workshop in February 2007.
 - Annex XIII (Fuel cells for vehicles): workshop in planning for 2007.
 - Several pending Annexes are preparing workshops for 2007!
 In 2006 more than 10 workshops have been organized in the USA, Japan and Europe. If you are interested to participate as an observer, please ask our secretary or the Operating Agent of the Annex.

1.7

G8+5 initiative and the NEET-activity of the IEA - the initiative 'Climate change, clean energy and sustainable development'

1.7.1

IEA's G8 Gleneagles 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. Brazil, China, India, Mexico and South Africa were also represented at the 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. The Plan of Action focuses on six broad areas:

- Alternative energy scenarios and strategies.

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

For the IEA G8 Plan of Action, the Implementing Agreements (IA) will provide their relevant activities and studies. In our case, the strategic group will work out this paper by the end of the year 2007. Many of our planned Annexes e.g. Clean city vehicles, Renewable energies for HEVs and the Outlook are in line with the G8 Plan of Action. The detailed report on IEA's G8 Gleneagles Programme will be presented at the next G8 meeting in Yokohama, Japan, in 2008. For more information please visit: www.iea.org (click on the link 'G8 related work').

1.7.2

IA-HEV contribution to the six areas

The IA-HEV touches the six areas of the Plan of Action as follows:

- Alternative energy scenarios and strategies.
HEVs do not need fossil fuels if the electricity is produced by renewable or nuclear energies. HEVs will be a backbone in the post-fossil era.
- Energy efficiency in buildings, appliances, transport and industry.
As mentioned above, the energy efficiency must be increased. Up to a factor 3 is technically possible; even the '1-litre car' (1 litre fuel consumption per 100 km) and the '1 kWh/100km car' can be made today. This was demonstrated by several projects in our member countries. By the use of electric two- and three-wheelers, less efficient 4-wheeled vehicle trips can be avoided. This results in a dramatic improvement in energy consumption. Several projects in our member countries demonstrated that the electricity needed can be produced by renewable energies at low costs.
- Cleaner fossil fuels.
Hybrid vehicles can use cleaner fossil fuels or can run with alternative motor fuels.
- Carbon capture and storage.
Electric vehicles make these expensive technologies unnecessary, but they could enable production of electricity with carbon containing feedstock, e.g. coal, oil and gas, for HEVs.
- Renewable energy.
The high efficiency of full or partly electric propulsion has the effect that less renewable energy is consumed. This makes it even economical sensible to use photovoltaics for the production of the electricity.
- Enhanced international co-operation.
Only only a few companies worldwide produce cars. The barriers for a new technology therefore are very high. International implementation is crucial. Adapted national guidelines could lower this hurdle.

Unfortunately some of the G8+5 countries like Canada, Germany, the UK, Japan and South Africa left our collaboration programme on hybrid and electric vehicles some years ago. We hope to bring them back in. Otherwise the effects of international collaboration are limited.

1.7.3

Contributions of the Implementing Agreement on Hybrid and Electric Vehicles

Mobility is one of the big energy consumers. The Implementing Agreement on Hybrid and Electric Vehicles works on the drivetrain with the highest efficiency: the electric motor. Electric motors are used in:

- Hybrid electric vehicles (HEVs): a short-term solution where the electric motor is added to an internal combustion engine (ICE). It enhances the efficiency of these vehicles. The ICE could run on alternative motor fuels (see IA-AMF). This would result in a hybrid car using no fossil fuel and showing a higher efficiency than today's road vehicles.
- Electric vehicles (EVs): a middle term solution with the highest efficiency of all actual propulsion technologies, without producing emissions. The electric energy is stored in batteries or supercapacitors. This results in a high energy efficiency but adds some weight and costs to the car. No fossil fuel is needed if the electricity is produced by non fossil fuel plants in the form of renewable energies or nuclear power. With clean electricity (hydro, wind, solar etc.) the energy efficiency can be up to three times higher than today.
- Fuel cell vehicles (FCVs): a long-term solution that stores the energy by liquid energy carriers -like hydrogen- and transforms this energy into electricity by a fuel cell. The efficiency is lower than with a battery electric vehicle but the stored energy can be much higher.

For all these technologies a clean production of the energy or electricity is crucial. This differs from country to country. Electric and hybrid vehicles can be used to level variations in the demand or in the production (load levelling). This is of special interest in case the electricity is produced by renewable energies like wind and solar.

Because of the high efficiency of the electric drivetrain, the future car will be electric!

1.7.4

The NEET - Initiative

In Mai 2006, the IEA launched the Networks of Expertise in Energy Technology initiative, the NEET initiative. The NEET initiative is a response of the IEA to the G8+5 request in Gleneagles. The NEET initiative's programme includes workshops up to 2008 in major energy-consuming economies. They will bring the expertise of the more than 5'000 experts in the IEA-network -mainly in the Implementing Agreements- to policy makers, the business community, researchers and other stakeholders. First workshops are scheduled in Mexico,

South Africa, Brazil and China. Workshops in Russia and India are planned. More information about the NEET initiative can be found under: www.iea.org/neet.

1.7.5

Activities to the IEA G8+5 Plan of Work (POW)

For IA-HEV, the G8+5 is a challenge from the outer world. We have to discuss and define our position in this programme. The IA-HEV ExCo discussed this very intensively during its two meetings in 2006. It seems obvious to concentrate first on the non-member countries of the G8+5 group. For 2007, working on the G8+5 Plan of Work (POW) includes:

- invite the missing G8 countries Canada, Germany, the UK and Japan to our IA,
- invite the '+5 countries' with relevant activities in our field, especially China and India, to IA-HEV,
- prepare the final report of Annex VII on hybrid vehicles,
- develop Annex XI 'Electric cycles', which could touch developing countries,
- bring the new Annex on renewable energies for hybrid and electric vehicles into operation,
- integrate the 'HEV outlook' in the annual report,
- bring the 'Clean city vehicles' Annex into operation,
- proceed with the information exchange with the new members from the G8+5 countries,
- cover the whole field of vehicle applications from 2-wheelers to heavy-duty vehicles.

More activities will be discussed in the spring 2007 IA-HEV ExCo meeting.

1.8

Participation in the HEV Implementing Agreement: a chance for decision makers and researchers

The call for a co-ordinated action is one thing. This needs information for decision makers and politicians. 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 is one goal of our work.

Additional goals in the 3rd phase of operation 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 that is produced in working groups -called 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 (IAs) with transportation aspects such as the IA on 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.

1.9

More benefits for participating countries

At the Executive Committee-meeting in Rome (2005) several measures have been discussed to enhance the benefits for members, so that they get a higher value for their money and their participation. The most important are:

- The membership in the two Annexes 'Annex I: Information exchange' and 'Annex X: Electrochemical systems' is free for members.
- Thanks to sponsoring of the U.S. Department of Energy (DOE), the membership fee could be lowered for the year 2006.
- Several new Annexes attract more specialists, researchers and decision makers.

1.10

Specialists of the future winning technology

The declining interest in electric vehicles and shifts in national budgets caused several countries to leave the Implementing Agreement during its second phase of operation (1999-2004). The success of the hybrid technology and the interest in fuel cell vehicles now increases their interest. We offer the specific knowledge and platform for information exchange, especially in Annex VII 'Hybrid vehicles', Annex X 'Electrochemical systems', Annex XII 'Heavy-duty hybrid vehicles' and Annex XIII 'Fuel cells for vehicles'.

In the application field, market introduction is a very tricky issue. By our work in Annex VIII 'Deployment strategies' and the follow-up in the new 'Lessons learned' Annex, we help decision makers and politicians to support a smooth transition in the mass market. This makes it interesting for countries that have to attain the environmental or energy targets.

By the topics that are investigated in Annex IX 'Clean city vehicles' or Annex XI 'Electric cycles', especially those countries are addressed that are just transforming their transport system to the individual use of cars, e.g. China, India and Indonesia. Integrating these countries in our co-operation group could be beneficial for both sides.

1.11

Support for specialists from developing countries

To enable specialists from developing countries -that are interested in IA-HEV membership- to participate in our meetings, we have a dedicated budget for travelling costs. Please contact the secretary!

1.12

Can you imagine a future world without electric or hybrid vehicles?

After the breakthrough of hybrid vehicles, the success of small EVs in market niches and the renaissance of advanced electric vehicle concepts, this Agreement has changed its approach. In future transport concepts, hybrid- and electric vehicles will occupy a greater share in many fleets. Many questions will arise and many countries, producers and scientific institutions will discuss solutions. Information exchange on these issues will be of crucial importance. This will be reflected in the working method of our Implementing Agreement. In 2007 we have to discuss this in the preparation of the 4th phase of our Agreement, which will start on the 1st of December 2009! For interested countries 2007 is the right moment to jump on the train and to participate in the discussion on the future direction of the Implementing Agreement for Hybrid and Electric Vehicles. I hope that in 2007 I can welcome several new countries that support our activities in this great time for hybrid and electric vehicles.

1.13

Final remarks: words of thanks

In 2006 I have to say “thank you” to our very active ExCo members, Operating Agents, subtask leaders and workshop organizers. This year we could establish fruitful collaborations with many organizations from outside the IEA and their members in a very productive way. I want to mention especially EPRI, ITRI, JARI, WEVA and AVERE that supported us mainly in the organization of workshops and meetings. Especially Annex XI ‘Electric cycles’ could integrate partners from the industry, and we can now learn a lot from this side about the technologies, the applications and the deployment of hybrid and electric vehicles.

Also the small ‘staff’ of the Implementing Agreement did an excellent job, starting with the bookkeeping folks and the IA-HEV secretary Martijn van Walwijk. Most of our Operating Agents are new in their job, they bring in a lot of ideas and new approaches, and I thank them for ‘breathing new life’ into our Agreement.

Last but not least, my special thanks go to my colleagues of the Executive Committee that lead this Implementing Agreement. They travel long distances

and spend their precious time to participate in our meetings and to share their experiences to improve this programme.

January 2007
Urs Muntwyler
IA-HEV chairman

2

The IEA Implementing Agreement on Hybrid and Electric Vehicles

This chapter describes the Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) of the International Energy Agency (IEA), its activities and its relationship with the IEA. Section 2.1 describes the IEA and the role of its Implementing Agreements in general and section 2.2 addresses IA-HEV in more detail.

2.1

The International Energy Agency

2.1.1

Structure of the IEA

The International Energy Agency (IEA) is an autonomous body that was founded in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. The basic aims of the IEA are:

- to maintain and improve systems for coping with oil supply disruptions;
- to promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organizations;
- to operate a permanent information system on the international oil market;
- to improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- to assist in the integration of environmental and energy policies.

The IEA brings together policy-makers and experts through its Working Parties and Expert Groups and provides a legal framework for international collaborative research projects, known as Implementing Agreements (IAs).

Research under the more than 40 Implementing Agreements ensures co-operation in energy technology RD&D (Research, Development and Deployment), information dissemination and technology transfer. Technologies covered range from fossil fuels, renewable energy, efficient end-use and fusion power to electric power, technology assessment methodologies to climate change and technology transfer to developing countries. Implementing Agreement participants undertake collaborative research, the benefits of which include pooled resources and shared costs, harmonisation of standards and hedging of technical risks.

The IEA Office of Energy Technology and R&D (ETO) focuses on dissemination of energy technologies and implementation policies. ETO collaborates with the IEA Committee on Energy Research and Technology (CERT) and its four active

Working Parties/Committees that cover technologies for renewable energies, end-use technologies, fossil fuels and fusion. In this setting, ETO helps to oversee the international collaborative activities in the Implementing Agreements.

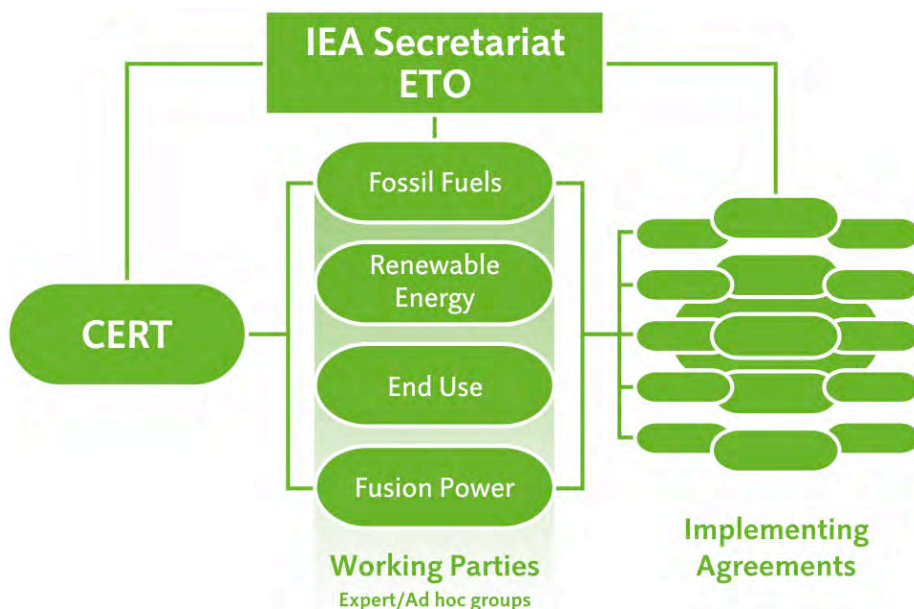


Fig. 2.1 IEA energy technology collaboration programme structure.
(Source: www.iea.org/Textbase/about/eto.asp)

Current Implementing Agreements cover a wide range of technology areas from Advanced Fuel Cells to Wind Energy Systems. The Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) is one of them. A full list of current Implementing Agreements is available at the internet website: www.iea.org/Textbase/techno/ia.asp.

At their Gleneagles Summit in July 2005, the G8 leaders addressed the challenges of climate change and securing clean energy and sustainable development. A plan of action was adopted during the summit, and a dialogue open to other significant energy consumers was started. The G8 non-member countries Brazil, China, India, Mexico and South Africa were also present during the Gleneagles summit, and these countries participate in the dialogue. The International Energy Agency accepted the invitation by the G8 leaders to be a partner in this dialogue and to play a major role in delivering the plan of action. The plan focuses on six broad areas:

- Alternative energy scenarios and strategies.
- Increased energy efficiency, especially in buildings, appliances, transport and industry.
- Cleaner fossil fuels.
- Carbon capture and storage.

- Renewable energy.
- Enhanced international co-operation.

The first results of the IEA activities were reported at the G8 summit in St. Petersburg, July 2006. More information about plan of action, the role of the IEA and the progress can be found at the website: www.iea.org/G8/index.asp.

2.1.2

IEA Implementing Agreements

Sustained development and deployment of cleaner, more efficient energy technologies are fundamental requirements within any strategy for energy security, environmental protection and economic growth. But national efforts alone no longer suffice to build bridges to an energy-efficient, low-carbon future. International collaboration has therefore become an indispensable part of technology's response to today's energy challenges.

Since its creation in 1974, the International Energy Agency (IEA) has provided a structure for international co-operation in energy technology research and development (R&D) 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 40 active programmes, known as the IEA Implementing Agreements. 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 harmonisation 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 provides uncomplicated, common rules for participation in Implementing Agreements. It is a legal structure that actually simplifies international co-operation between national entities, business and industry. 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 2.1.

Box 2.1 Benefits of International Energy Technology Co-operation in IEA Implementing Agreements
<ul style="list-style-type: none"> • 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 fall into two 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.

Some Implementing Agreements, including IA-HEV, use a combination of these two mechanisms.

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. The OPEN Bulletin regularly highlights -among others- the activities of IA-HEV. The IEA also issues two different publications that present bi-annual updates on the Implementing Agreements' major achievements:

- Energy Technologies at the Cutting Edge - International energy technology collaboration IEA Implementing Agreements.
- Mobilising Energy Technology - Activities of the IEA Working Parties and Expert Groups.

These reports are available at the IEA headquarters in Paris or can be downloaded free of charge from the internet website:

www.iea.org/Textbase/publications/free_all.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 (HEVs). This means that there is a sound basis for an IEA Implementing Agreement (IA) on HEVs. The IEA Implementing Agreement 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 eight active Contracting Parties (member countries) per January 2007 are Austria, Belgium, France, Italy, the Netherlands, Sweden, Switzerland and the USA. Finland formally is a member, but it is currently not active. In December 2006 Turkey was invited to become a member and Turkey is expected to join IA-HEV in 2007.

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 and the plans for new Annexes are described in part B (chapters 3 through 11) of this report. The activities regarding hybrid and electric vehicles in IA-HEV member countries can be found in part C, chapters 13 through 20.

The next subsection (2.2.1) briefly reports on IA-HEV activities and results in its second term of operation (phase 2). The subsequent subsections of this chapter focus on phase 3: the strategy is presented in subsection 2.2.2, topics for new Annexes are highlighted in 2.2.3 and subsection 2.2.4 presents the IA-HEV clean vehicles awards.

2.2.1

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

The second phase of the Implementing Agreement on Hybrid and Electric Vehicles (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 & 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 D of this report presents the most important publications of phase 2. Many of them are available on the IA-HEV website: www.ieahev.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 organized 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 summarize 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 one between two 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 organized 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 may construct 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 have been sold in China).
- Three-wheel electrically driven taxis (variously called rickshaws, tuk-tuks, tempo's) as used in Nepal.
- Improved infrastructure for non-motorized 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 will continue in phase 3 to overcome these barriers.

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 coordinating 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 term 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 the Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes (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 introduction of hybrid 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 term, 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, assessment, 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 term of the Agreement will be on collecting objective general information on hybrid, electric and fuel cell vehicles. More specific information will be collected in the subject area of each Annex. Priorities for topics to be addressed during the third term are shown in box 2.2.

Box 2.2
Topics to be addressed in the third term of IA-HEV
<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 decentralized 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 can expect many benefits resulting from the third term. 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**
Almost all Annexes of the Implementing Agreement (IA) organise expert meetings to exchange information. There is also an interaction between different IAs of the International Energy Agency, especially between IAs with transportation as an item in their work programme. Within the IA-framework there are seven IAs with such a transportation aspect. Again, value is added by bringing together information from several areas of expertise and exchanging it in a meeting or in written reports.
- **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 participating countries of the IA 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

Topics for new Annexes

Box 2.2 in subsection 2.2.2 shows the topics for the third IA-HEV term of operation. Besides the topics that are already addressed in running Annexes, two other topics are currently under consideration for starting new Annexes. Both are addressed in a separate chapter in this report. The two new Annexes are:

- Market deployment of hybrid and electric vehicles: Lessons learned (chapter 10).
- Renewable energies for hybrid and electric vehicles (chapter 11).

Starting a new Annex is a dynamic process and the information presented in this report may already be outdated by the time you read this. The most recent information on the status and contents of these new Annexes can be found on the IA-HEV website or it can be obtained from the interim Operating Agents. Contact details of the interim OAs can be found in the respective chapters that are mentioned above.

Interested parties are invited to contact one of the IA-HEV members, the chairman, the secretariat or the interim Operating Agent to discuss their possible role in these new activities. Participating organizations can contribute to shaping the final work plan of these new Annexes, so it can be tuned to their needs.

2.2.4

IA-HEV clean vehicle awards

Since 1993 -when the IEA Implementing Agreement for Hybrid and Electric Vehicles was established- clean vehicle technologies and their components have gone through a remarkable development progress. Today, the first series vehicles have achieved their market breakthrough. This progress is driven by committed people, teams and manufacturers. It fits the information dissemination goals of the HEV Implementing Agreement to make this commitment public and therefore it has introduced the 'IA-HEV clean vehicle awards' for those who dedicate their work to the dream of a clean, efficient vehicle technology. The awards cover three categories:

- The 'Clean vehicle award' is granted to a manufacturer with outstanding sales figures.
- The 'Best practice award' is granted to the organisers of an outstanding promotion project.
- The 'Personal award' is granted to a person that has dedicated his or her work to the development or promotion of clean vehicles in an outstanding way.

The first round of IA-HEV clean vehicle awards was presented on April 3rd, 2005. The ceremony took place at the exhibition of the Electric Vehicle Symposium

EVS-21 in Monaco. The IA-HEV award-committee had decided to honour three outstanding commitments for clean vehicles by the following awards:

- the 'Clean vehicle award' for the Toyota Prius (Japan),
- the 'Best practice award' for Reggio Emilia in Italy, and
- the 'Personal award' for professor René Jeanneret (University of Applied Science Berne - Biel branch, Switzerland).

EVS-22 in Yokohama, Japan, on October 25th, 2006, was the venue of the second round of awards. This time the IA-HEV award-committee had decided to honour three car manufacturers in the vehicle category. The awarded exceptional commitments were this year:

- **Clean vehicle award - Honda, Lexus, Ford**

The 'Clean vehicle award' is granted for achievements that contribute substantially to the clean and energy efficient transportation objective of this Implementing Agreement. Only high numbers of clean, efficient cars on the road guarantee a substantial impact on the transportation sector. Meanwhile hybrid technologies have made an astonishing career and consequently the first 'Clean vehicle award' was last year presented to Toyota for their model Prius. This year's winners show the large market potential of sophisticated clean vehicle technologies.

Honda (Japan)

Honda's commitment to clean vehicle technology has a long history. Electric concept cars have been shown since the early nineties (for example the EVX in 1994 and the CUV-4 in 1995). Their solar vehicle winning the World Solar Challenge in 1993 and 1996 surely had a great motivation effect on the company. In 1997 Honda launched the electric vehicle 'EV plus'. In the same year also a commuter system was introduced, called 'Intelligent Community Vehicle System' (ICVS). This system should link public and private transport. For this system small commuter electric vehicles PAL (especially the City PAL of 1998) have been developed. Finally Honda decided to concentrate on the in-house development of a hybrid propulsion system, the Integrated Motor Assist (IMA), first shown in the concept car VV in 1999. This system was commercially launched in the Honda Insight (2000) for the Californian market and subsequently adapted for the models Civic and Accord. This strategy is crowned with market success and the worldwide sales figures prove the acceptance of this vehicle technology.

By these achievements Honda is an outstanding example for effective hybrid and electric vehicle promotion, and therefore we are glad to honour this commitment by the 'Clean vehicle award', for more than 135'000 hybrid models sold worldwide.

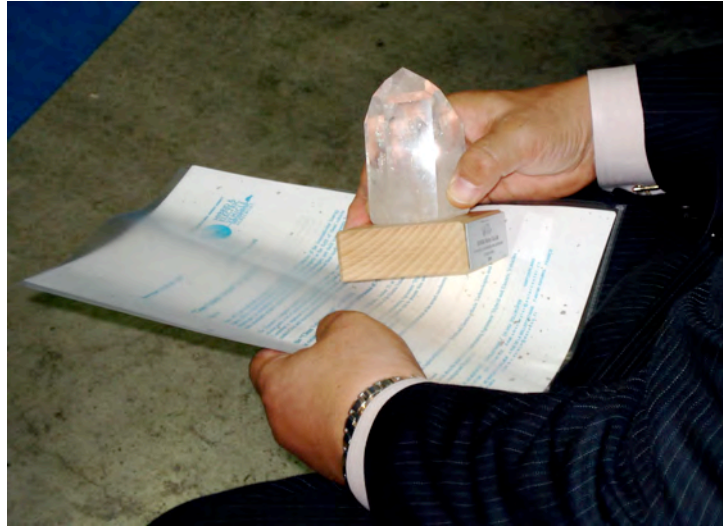


Fig. 2.2 The 'IA-HEV clean vehicle awards' come in the form of clear crystals from the Swiss Alps, home of the IA-HEV chairman. (Photo: M. van Walwijk.)

Lexus (Japan)

Lexus is a success story because it shows that a SUV and a large limousine both can be operated with low fuel consumption without losing any comfort or performance. This success is achieved by the adaptation of Toyota's 'Synergy drive' hybrid technology for the Lexus models. The Lexus hybrid vehicles meet a large market demand, which is proven by the great acceptance and good sales figures.

By these achievements the Lexus division of Toyota shows an outstanding example of an effective hybrid vehicle promotion, and therefore we are glad to also honour this commitment by another 'Clean vehicle award', for more than 50'000 hybrid models sold worldwide.

Ford (USA)

The Ford Motor Company played an important role as innovator in the early nineties, which is shown -among others- by the development of their 'Ecostar' model. The purchase and transformation of the Th!nk electric vehicle into a Ford also has been an important experiment to explore the market acceptance of advanced vehicles. By developing and marketing of the hybrid Ford Escape, the Ford Motor Company has been a pioneer among the US manufacturers to introduce a sports utility vehicle with hybrid drive to the marketplace, and this pioneering effort has led to a well-earned success in the market.

These achievements make the efforts of the Ford Motor Company an outstanding example of effective hybrid vehicle promotion, and we are therefore glad to honour this commitment by a third 'Clean vehicle award', for more than 30'000 hybrid models sold worldwide.

- **Best practice award - China**

The People's Republic of China is a fascinating example of how by the implementation of a regulation a niche market for small electric vehicles (electric bicycles and scooters) can become a million vehicle market. The new regulation prohibits small gasoline tanks in courtyards and by that it prohibits parking of gasoline mopeds (that are used for commuting) in courtyards. The strong traditional bicycle industry understood its opportunity and started a huge effort in marketing electric bicycles. Users can now choose from a wide range of price levels and technologies, which is a prerequisite for a competitive market.

Of course also the great commitment of the People's Republic of China in developing clean vehicle models from car-size to buses and trucks has to be mentioned. This effort will be an important step towards cleaner transportation in China and it will stimulate the market for clean vehicles worldwide.

By these achievements the People's Republic of China gives an outstanding example of an effective electric vehicle promotion close to the users, and we therefore are glad to honour this commitment by the 'Best practice award'.

- **Personal award - Hans Tholstrup (Australia)**

Born in 1942, Hans Tholstrup followed his early fascination for technology, at first as a motor racer in adventurous projects. After the oil crisis in the seventies, Hans was a committed participant in fuel economy runs. His tendency towards perfection led to two victories in the car and truck categories.

In 1982 Tholstrup drove the solarmobile Quiet Achiever -together with Larry Perkins- in 20 days from Perth to Sydney, a distance of 4052 km. This experience encouraged him to organize an event in which solar vehicles should compete and thus push the development of clean vehicles. In 1987 the first World Solar Challenge (WSC) was run, from Darwin to Adelaide. Surely Tholstrup has been lucky with the first WSC winner: the GM Sunraycer, which was a high-tech development designed by aircraft specialist Paul McCready and nominated by GM. This entrance pushed the high level of technology and the following versions of the WSC saw a lot of highly motivated teams showing the latest technological developments. Dozens of students involved in solar racing teams trained their skills and acquired knowledge in designing solar electric propulsion systems and thus became a pool of highly specialized engineers that today can be found in many clean vehicle projects in the automotive industry.

Hans Tholstrup is one of the outstanding personalities whose commitment encourages and inspires generations of technicians involved in clean vehicle development and marketing, and we therefore are glad to honour his commitment by the 'Personal award'.

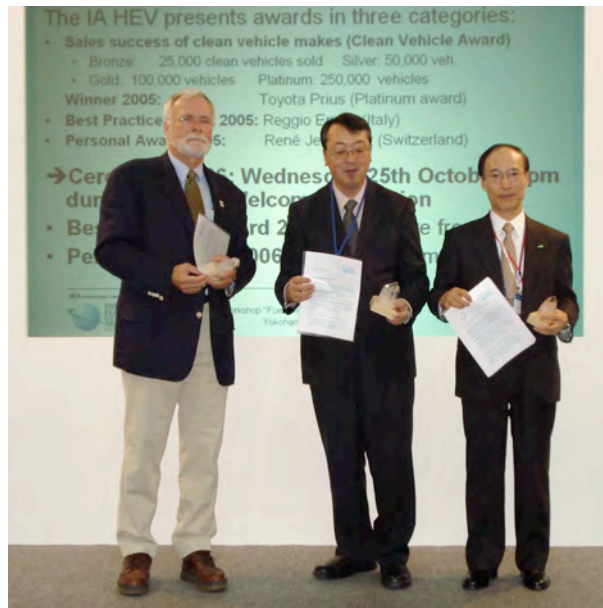


Fig. 2.3 Three of the 2006 IA-HEV Clean vehicle award winners. From left to right: Mr. Hans Tholstrup (Australia), Mr. Akira Fujimura (Honda, Japan) and Mr. Masatami Takimoto (Toyota Motor Corporation and Lexus, Japan). (Photo: M. van Walwijk.)

The third award ceremony is scheduled for December 2007, during the 23rd Electric Vehicle Symposium and Exhibition EVS-23 in Anaheim, California, USA. If you have suggestions for candidates for the IA-HEV clean vehicle awards, please contact your national IA-HEV delegate or the IA-HEV chairman before July 30, 2007.

3

Information exchange (Annex I)

3.1

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 since its inception in 1993. To that end, a task force (Annex I) dedicated to the purpose of facilitating such exchange was formed at the outset of phase 1 and has remained a key component of the Agreement into the current phase 3. 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.

The responsibilities for the week-to-week affairs of the Annex are co-ordinated by an Operating Agent, with input and material contribution from the country experts who comprise the membership. The specific goals, responsibilities and working methods of Annex I are discussed below.

3.2

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 cars, trucks and buses (which could also include mobile off-road equipment). 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. The work of collecting and analyzing this HEV information is carried out by the respective country experts, who then make it available to other members at both experts' meetings, held semi-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

Fig. 3.1 Welcome page of the improved IA-HEV internet website at www.ieahev.org.

the Executive Committee (ExCo) annual report. The OA also acts a chief liaison to the OAs for other Annexes and, through the Executive Committee Secretary, to the ExCo chair and the cognizant IEA Desk Officer.

3.3

Working method

A major part of the information exchange for the Annex occurs at the semi-annual experts' meetings, in which participants who have spent time compiling the relevant reports, facts and statistics from their home countries brief the other attendees. These presentations generally cover developments since the previous meeting in the 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. At the first experts' meeting conducted in a given year, a special topic is identified for specific consideration and coverage for that year, to be discussed in depth at the following (generally, late autumn) meeting. Thus, a portion of the agenda of the second experts' meeting in the year is devoted to that year's special topic, and may include separate country presentations. The special topic for Annex I in 2006, the second full year of phase 3, was 'Trends in R&D funding for EV and HEV-related technologies in member countries'. When approved at the spring 2006 meeting of the Annex experts in Palo Alto, California, the purpose of this topic was to examine the commitment member countries retained in expanding and diversifying the hybrid vehicle market. Experts were to collect data on research

funding and topics from both public and private entities in their home countries to better define the thrust and magnitude of ongoing research efforts with respect to hybrid and electric vehicle and component technologies, with special attention to the question of whether the emerging emphasis on fuel cell propulsion technologies in many countries was either synergistic with or detracting from support of advances in the hybrid vehicle market. Experts attending the autumn meeting of Annex I in Yokohama, Japan reported on their findings.

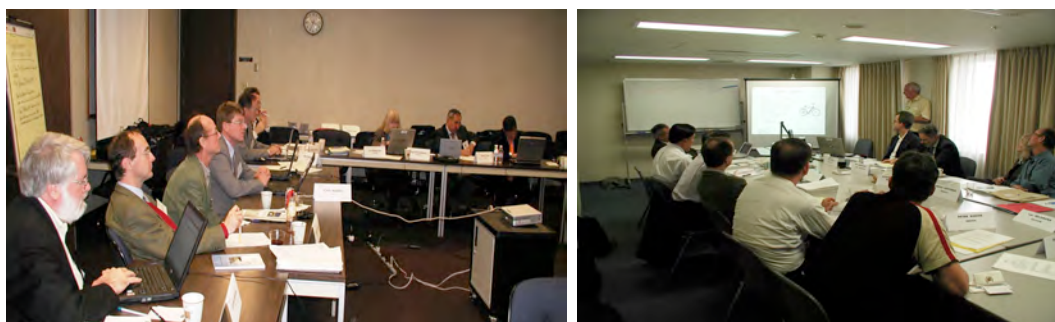


Fig. 3.2 Annex I experts convene in Palo Alto, California, USA, April 2006...and in Yokohama, Japan, October 2006. (Photos: C. Saricks.)

An ongoing but no less important role of this Annex is the direct collection of less formal original-source data, the availability of which to members of the Implementing Agreement might otherwise be limited. Where permission to do so is granted (given that permission is necessary), these data may be compiled and posted in either tabular or graphical form in the members-only-access area of the IA-HEV website, providing an added element of value of membership to the vested participants of the IA and its Annexes. 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 in the absence of 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 Japanese and Taiwanese institutions focused on vehicular technologies attended the autumn 2006 meeting.

3.4 Results

Twenty-four experts' meetings have been conducted since the inception of the IA-HEV. As many as ten nations have participated in Annex I and sent experts to these meetings during the first two 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 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 added to the news page of the website that, on a monthly basis, recapitulates for a lay audience recent developments of interest in the area of electric and hybrid vehicle technologies and policy.

3.5

Outlook

The objective of assuring that the information and data posted on the IA-HEV / Annex I combined internet website are as timely and accurate as possible will continue during 2007. Access to proprietary data and other 'late breaking' information will be limited to participating members as an inducement to non-member countries to join. Items from both member and non-member nations may be posted. In addition, the Annex I OA 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.

3.6

Contact details of the Operating Agent

The Operating Agent of Annex I is Mr. Chris Saricks. He can be contacted at:

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4

Hybrid vehicles

(Annex VII)

4.1

Introduction

Hybrid electric vehicles (HEVs) are considered as an opportunity to reduce emissions of greenhouse gas and other pollutants and for achieving policy goals concerning air quality, energy efficiency and energy independence.

‘Plug-in’ hybrid vehicles (PHEVs) for instance can significantly reduce imported oil requirements, if they become a major part of a national vehicle fleet. In addition, they could provide a capability for consumers to switch from oil to electricity as a function of respective price, thereby creating an ability to mitigate and deal with oil price shocks.

In the third phase of Annex VII, the IEA Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) studies a wide range of topics related to hybrid vehicles. These topics include objectives related to hybrid vehicle components and plug-in hybrid vehicles.

Currently experts from Austria, Belgium, France, the Netherlands, Sweden and the United States participate in Annex VII. TNO | Science & Industry in the Netherlands is Operating Agent (project leader) of this Annex.

4.2

Objectives

This Annex has three main objectives. The first goal is to exchange information and prepare a series of reports or papers on the following subjects related to components for hybrid vehicles:

- Fuel converters.
- Drives for HEVs.
- Energy storage for HEVs.
- Auxiliaries for HEVs.

The second goal is to exchange information and to prepare one or more reports on the following topics related to plug-in hybrid vehicles:

- Vehicle requirements.
- Merits/motivation.
- Costs.
- Market.
- Infrastructure.

The third goal of this Annex is to exchange information on hybrid electric vehicles and programmes among the participants of the Annex, the target group for this part of the work. Subjects that are studied include hybrid vehicles and alternative fuels, state of the art in HEVs and HEV components (fig. 4.1).



Fig. 4.1 Components for hybrid drives on display: gearboxes, electric motors and power electronics. (Photo: M. van Walwijk.)

The focus of this Annex is on (hybrid) vehicles with four (or more) wheels. At first, both light-duty vehicles (e.g. passenger cars) and heavy-duty vehicles (e.g. busses and trucks) were included. However, since the start of Annex XII ‘Heavy-duty hybrid vehicles’ early 2007, Annex VII now only considers light-duty vehicles.

The overall objectives of the task force in the third phase of this Annex are to make further progress on the improvement and market introduction of hybrid vehicle technologies, which in turn support national objectives of reduced oil consumption and greenhouse gas emissions, and improved urban air quality.

4.3

Working method

TNO | Science & Industry, part of the Netherlands Organization for Applied Scientific Research, acts as Operating Agent of this Annex. The Annex revived with an initial workshop in Eskilstuna, Sweden, in June 2004. This was the start of the current phase III of this Annex. In Sweden the task force agreed on a three-

year basic work plan. The work plan was finalised at the 1st expert meeting of the task force in Mol, Belgium, in November 2004. In 2005 and 2006 the progress was discussed in a total of five expert meetings.

The task force performs several major international studies on the subjects of components for hybrid vehicles and plug-in hybrid vehicles, in this phase of operation. Furthermore the Annex allows the participants to exchange information among each other.

The current participants in Annex VII are:

- Austria (Arsenal Research),
- Belgium (VITO),
- France (INRETS and EDF),
- The Netherlands (SenterNovem),
- Sweden (STEM and the University of Lund),
- USA (Argonne National Laboratory and EPRI).

The work in this Annex is split in three subtasks that are directly related to the three goals of this Annex. The subtask leaders are shown in box 4.1.

Box 4.1			
Subtasks and subtask leaders in Annex VII			
	Subtask	Country	Company
A	Components for hybrid vehicles	Austria	Arsenal Research
B	Plug-in hybrid vehicles	USA	Argonne National Laboratory
C	Information exchange	NL	TNO Science & Industry

The final work plan, as agreed on in the 1st expert meeting, clearly sets out how the three objectives related to hybrid vehicle components, plug-in hybrid vehicles, and information exchange will be achieved. The task force produces objective, unbiased information on hybrid vehicles that can be used as a basis for decision-making by officials in governments and automotive research organizations.

The Operating Agent organises two or three expert meetings per year. These two-day meetings (organised in co-operation with a participating country that hosts the meeting) give the participants the opportunity to discuss and work on the three subtasks. Furthermore a technical visit, often to the facilities of the organization that hosts the meeting, is included. Box 4.2 shows the expert meetings that have taken place to date.

Box 4.2			
Expert meeting history of Annex VII			
#	Date	Place	Country
1	November 15 th - 16 th , 2004	Mol	Belgium
2	March 31 st - April 1 st , 2005	Lyon	France
3	September 22 nd - 23 rd , 2005	Chicago	USA
4	January 19 th - 20 th , 2006	Vienna	Austria
5	April 27 th - 28 th , 2006	Palo Alto	USA
6	September 6 th - 7 th , 2006	Delft	The Netherlands
7	February 5 th - 6 th , 2007	San Diego	USA

4.4

Results

The main deliverables for phase I and II were the ‘Overview report 2000’ and its update, the ‘Overview report 2002’. In this report the following special topic reports are included, which are selected and written by the experts of this Annex:

- Definition of hybrid vehicles.
- Charge and discharge characteristic of capacitors for hybrid electric vehicles.
- Costs of hybrid vehicles.
- Trend from charge depleting to charge sustaining hybrids.
- Fuel economy and exhaust emissions test procedure for hybrid electric vehicles.
- Comparative assessment of different HEV configurations using ADVISOR.
- Analysis of emissions of hybrids.
- Alternative motor fuels and hybrid vehicles.
- HEVs and regulations.
- Energy consumption and emissions of hybrid vehicles.

In 2006 the following papers have been presented:

- *Energy storage* at the Global Powertrain Congress. This paper gives an overview of the advantages and disadvantages and practical aspects of battery technologies and ultra capacitors that can be used in hybrid electric vehicle applications.
- *Global prospects of plug-in hybrids* at EVS-22 in Yokohama. The topics that are addressed in this paper are the potentials of PHEVs and their ability to use charge depletion in conjunction with hybrid mode operation to displace gasoline use. Multiple charge depletion strategies are considered.
- *Components for hybrid vehicles* at EVS-22 in Yokohama. The paper describes the international collaboration in modelling validation and testing between the

IA-HEV Annex VII participants, considering the complex characteristics and internal non-linear interactions of HEV components.

These papers were prepared and presented by Annex VII participants.

The automotive research organizations participating in phase III are among the most prestigious in the world. They broaden and deepen their own expertise in hybrid vehicles by participating in the third phase of this Annex, and they strengthen the network among themselves. This gives them access to research that they have not done themselves, and it keeps them informed on recent developments in other countries and about the state of the art of the technology.



Fig. 4.2 Toyota Prius I, Honda, Nissan and Toyota Prius II hybrid cars. (Photo supplied by TNO.)

The result of Annex VII phase III -being reports, papers and presentations- will be first disseminated in the countries that participate in this Annex. Dissemination is co-ordinated by the organizations that represent their governments in the Implementing Agreement. At the end of this Annex the results will be made available to a broader public through the IA-HEV website: www.ieahev.org.

To facilitate information dissemination, a website dedicated to Annex VII has been established. More information about this Annex and its results can be obtained from this website at: www.vito.be/ieahev.

4.5 Outlook

Because of their potential to reduce fuel consumption and emissions, hybrid vehicles are at the centre of interest for governmental officials and automotive research organizations. The increasing popularity is also shown by record braking sales numbers for several years successively. To retain this growing success, the focus should be on efficiency - in both costs and components of hybrid vehicles. This is necessary in order to get hybrid vehicles to a wider public, because only if they become an important share of a country's car fleet, they can make a significant impact on reducing oil imports and on reducing greenhouse gas and noxious gas emissions. Therefore it is important for governmental officials and automotive research organizations to obtain reliable, objective information on hybrid vehicles. This Annex produces such information.

4.6

Contact details of the Operating Agent

Mr. Robert van Mieghem is the Operating Agent of this Annex. Please feel free to contact him with your questions regarding this Annex at:

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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 HEV Implementing Agreement (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 these problems. 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 Månsson (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.

The HEV Implementing Agreement 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, 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 hundreds of other cities in dozens of other countries can become aware of these opportunities and they can use some of the ideas themselves.

5.5

Outlook

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). 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 most welcome to contact the IA-HEV chairman or the IA-HEV secretary. IA-HEV contact information can be found in part D of this report.

6

Electrochemical systems

(Annex X)

6.1

Introduction

Fuel cells, batteries and electrochemical capacitors all fall within the technical domain of electrochemistry, and each will have a key role to play in developing sustainable transportation technologies. Because within this Implementing Agreement there is Annex XIII on fuel cells for vehicles and because there are separate Implementing Agreements that address issues related to fuel cells and their fuels, Annex X does not focus any of its activities on fuel cells, nor will this chapter contain significant comments on the state of fuel cell technology. The focus of this Annex is on rechargeable batteries and electrochemical capacitors, also known as supercapacitors or ultracapacitors. In vehicular applications these devices are often described as Energy Storage Systems (ESS). They share the ability to provide electrical energy to the vehicle during the process of discharge and to store energy from an outside source during charge. Energy Storage Systems are critical components of all of the vehicle configurations covered by the Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV): electric/internal combustion engine (ICE) hybrids (such as the Toyota Prius), electric/ICE hybrids that have the option of charging their batteries from an outside source (often called plug-in hybrids), battery electric vehicles (BEVs) and fuel cell vehicles. As reported in other chapters of this report, over 400'000 ICE hybrids have been manufactured and sold. Plug-in hybrids and fuel cell vehicles exist as prototypes and are in very low volume production. Several thousand electric vehicles (EVs) have been built over the last two decades, but relatively few, new, full-function EVs are now being sold.

In each vehicle configuration, the energy storage devices must provide power to a variety of systems. In a battery EV, the battery must provide power to the electric traction motor(s) in order to move the vehicle; all of the vehicle's traction is dependent upon energy from the battery. In EVs the battery must also be able to power all of the accessory loads such as lighting, ventilation, heating, etc. An EV battery must be able to accept charging currents from both an external charger and from the regenerative braking system within the vehicle. While external charging can be designed to span several hours, regenerative braking requires that the battery accept very high power charging pulses. In an electric/ICE hybrid, the energy storage system supplies an electric motor that shares the traction demands with the ICE. In an ICE hybrid, the energy storage system must still be able to power the accessory loads because most ICE hybrid vehicles are designed to shut-down the ICE when the vehicle is stopped. (This function is often called stop/start

mode and is found in even the mildest of hybrids.) In an ICE hybrid, charging is done both by a generator driven by the internal combustion engine and by regenerative braking. (In practical applications, a combination motor/generator is often used.) Because the internal combustion engine supplies much of the traction power -especially when the vehicle is cruising- the ESS in an ICE hybrid does not have to store as much electrical energy as in an EV, but the ESS must still be able to deliver high power pulses and to accept similar charging pulses. The characteristics of the ESS in a plug-in hybrid are between those of an EV and of an ICE hybrid. The ESS will typically store less energy than an EV battery but more than an ICE hybrid, and it still must be able to deliver and accept high power electrical pulses. Most developers agree that a fuel cell vehicle will require an ESS in order to maximize operating efficiency and the life of the fuel cell system, but there is still a spirited discussion as to the best characteristics of the ESS for a fuel cell vehicle.

Because the ESS is a critical component of all types of hybrid and electric vehicles, batteries and capacitors have been identified as perhaps the single most important enabling technology to make these vehicles more attractive to the consumer. Advances in battery and capacitor technology are necessary to reduce their cost, improve their calendar life, improve their low temperature performance and address their behaviour under abusive conditions. These advances must be made without adversely affecting the outstanding power and energy characteristics of state-of-the-art products.

The electrochemical systems chosen for use in advanced vehicles are evolving. Lead/acid, especially in its valve regulated format, is used in some 'mild' hybrids and in many of the lightweight, limited performance EVs on the market. Unfortunately, lead/acid batteries tend to be very heavy and have limited calendar and cycle lives, especially under the use profiles of an HEV or EV. Nickel/metal hydride (NiMH) batteries are used in the majority of hybrids currently on the market as well as in more advanced, full-function EVs. NiMH batteries can meet many of the requirements of advanced vehicles. The NiMH batteries in a fleet of five EVs operated by a utility company in the United States have all lasted for over 100'000 miles. NiMH batteries in the HEVs being sold today are warranted for 8 years or 80'000 miles in most markets, and in some markets the warranty is even longer. Unfortunately, many scientists think that NiMH technology is approaching its practical limits. If one wants batteries that are lighter, smaller, last longer and are less expensive, alternative chemistries must be used. The alternative chemistries under advanced development in Europe, North America and Asia are all within the family of systems called lithium-ion. Lithium-ion batteries are already being used in a limited number of commercial HEVs, such as the Toyota Vitz. These batteries are being used in many of the plug-in hybrids being built by small companies. Major governmental research programs in the

United States, Japan and other countries are focused on advancing lithium-ion technology for use in vehicles. Ultracapacitors are used in only a relatively small number of vehicles today, but they are being considered for use in both fuel cell vehicles and in mild hybrids. They offer the advantage of good performance at high power over many cycles. Their disadvantages include low specific energy and high self-discharge.

6.2

Objectives

Annex X is titled 'Electrochemical power sources and energy storage systems for electric and hybrid vehicles', which is often abbreviated to 'Electrochemical systems'. The 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. Topics related to the integration of an ESS into a vehicle are covered under IA-HEV Annex VII. For example Annex VII is addressing issues related to plug-in hybrids, including questions related to the battery in such a vehicle.

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 Annex functions by organizing a series of working groups. Each working group focuses on a single aspect of the Annex's areas of interest. Examples of working group foci include the following:

- the abusive testing of batteries and capacitors,
- the effect of electrode interfacial phenomenon on low temperature performance of Lithium-ion cells,
- the next generation of materials for cell electrodes.

A typical working group has 15-25 members, all of whom are experts in the specific subjects under discussion. The working groups are supplemental to the many scientific and technical conferences related to batteries and capacitors. Each group schedules one or two meetings to address their topic. At the end of these meetings, an appropriate report is issued. The working group meetings are designed to encourage discussion and the exchange of ideas rather than as venue for the presentation of formal papers. No single individual or organization is expected to participate in every working group. Each group's membership reflects the specific topic under discussion. Topics for each working group are chosen by

the OA after consultation with the members of the IA-HEV's Executive Committee and other experts in the field. The goal is to cover a range of topics from basic science to advanced engineering over the course of this phase of the Implementing Agreement.

The work of the Operating Agent of this Annex is funded directly by the US Department of Energy and therefore the Annex does not assess its members for funds to support the OA. Each member organization is expected to cover the incidental costs of their participation, costs such as labour and travel.

6.4 Results

The first working group focused on 'the abusive testing of batteries and capacitors'. This working group has held its two meetings in 2006. About twenty experts participated in the discussions. Participants were from Europe, North America and Asia. Members work for automobile manufacturers, battery and capacitor companies, and governmental agencies. Although many organizations conduct abusive testing of batteries and capacitors, there is a wide variation in the details of the tests. Subtle observations and test methods developed through trial and error are rarely communicated outside of an individual laboratory. In this group, participants had the opportunity to discuss the 'how and why' of each of the common abusive tests, such as overcharge, short circuit, high temperature exposure, and crush. An important feature of the meetings of this working group was that all discussions were 'off the record'. This approach is necessary to allow candid discussions of a subject that some organizations view as being very sensitive. Because each member organization has its specific needs and constraints, the working group did not define standards for testing, rather the goal of the group was to allow each member to learn information that will help them to design the best possible test procedures for their specific situation. A summary of the discussions and a compilation of published test protocols were distributed to all participants.

6.5 Outlook

Conversations with scientists from several countries that are members of the Implementing Agreement have produced enthusiastic responses to the concept of working groups, and several individuals have offered to help organize and host meetings in Europe. This positive response and the results of the first working group show that the Annex is able to meet its goal of fostering discussion and the transfer of technical information in relatively informal settings.

The OA expects to organize one or two working groups each year. The next working group of the Annex will focus on another topic that is related to the basic

science of batteries and/or supercapacitors. The meetings of this group will be held in Europe. The specific technical topic and location of the meetings will be chosen in the first half of 2007.

6.6

Contact details of the Operating Agent

Individuals interested in helping organize a future working group on a focus of interest to them are urged to send the OA 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 oil consumption. The limited available space per vehicle, traffic safety, and noise reduction make urban mobility become a key issue. Therefore city governments have to take a wide range of measures, including the improvement of public transit, facilitation of non-motorized transport like walking or cycling, and improvement of roads and parking facilities for vehicles. Many solutions have to be adopted and the interface among these solutions has to be convenient and smooth, so that inhabitants are not affected and 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, cause no pollution, and they produce no noise. They are therefore perfectly fitted to replace specific short car trips.



Fig. 7.1 Use of an electric bicycle. (Photo supplied by U. Schwegler.)

Regarding the energy issue, electric two-wheelers are champion in two ways. First they reduce energy consumption compared to the use of cars, and second they can also run on renewable energies. But why then are they not more to be seen on the roads? One of the main reasons is that some important actors are not committed enough. The overlapping of the three major actors -users, industry and governments- doesn't 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 recognize the benefits, but they can obviously not take the 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 the existing transportation systems, but it is essential that these different actors and their various activities should be better co-ordinated. In this context, the IEA Implementing Agreement on Hybrid and Electric Vehicles has decided to set up an Annex dealing with electric cycles and to foster the market to take off.

7.2

Objectives

The objectives of this Annex are to identify barriers that hindered the market penetration until now, and to develop and test ways to overcome them. 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 subject of the subtasks that are undertaken in this Annex:

- Assessing the role that two-wheeled electric vehicles can play in improving urban mobility, and their interaction with other transportation modes.
- Identifying energy saving potentials as justification of governmental support.
- Recommending market introduction strategies directed at manufacturers, importers and dealers, as well as authorities at all levels.
- Identifying needed technology improvements.
- Identifying infrastructure requirements.
- Sharing experience and information obtained from ongoing and completed projects (extended dissemination).

7.3

Working method

The objectives of this Annex will be achieved thanks to well-integrated work of five subtasks, which are co-ordinated by the Operating Agent. The five subtasks, the respective subtask leaders and the topics that are addressed in each subtask are listed below.

Subtask 1: Energy saving and market potentials

Subtask leader: Mr. Ed Benjamin, CycleElectric (USA).

- Inventory on vehicles (market offer and prototypes).
- Successful application fields.
- Benefits of electric cycles for users and the public.
- Success factors regarding market introduction.
- Justification of governmental support.

Subtask 2: Market introduction

Subtask leader: Mr. Urs Schwegler, NewRide (CH).

- 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

Subtask leader: Mr. Bing-Ming Lin, ITRI (Taiwan).

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

Subtask 4: Infrastructure

Subtask leader: to be appointed.

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

Subtask 5: Sharing experiences

Subtask leader: Mr. Frédéric Vergels, AVERE (Belgium).

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

7.4

Results

Particular attention was paid to market potentials and the group identified as critical issues to be addressed:

- 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.

A list of minimal requirements for an 'affordable' product will be issued, mainly based on safety technology as well as market requirement aspects.

A lot of information was gathered so that the group now has a broad vision on the electric cycle market and its actors, as well as on market situations and governmental support. An extensive investigation of products' technical specifications was made, as well as on 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.

7.5

Outlook

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

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

IA-HEV Annex XI aims at becoming a permanent platform to help relevant and interested parties to exchange information and to develop synergies.

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 reason for initiating this Annex was the wish of some participants to have a specific Annex focusing on heavy-duty hybrid vehicles. This idea originated from the gap between the more general approach of Annex VII towards hybrid cars and the diversity of heavy-duty vehicle applications. This leaves room for treating heavy-duty hybrid vehicles and their distinct characteristics in a separate Annex.

At the Executive Committee meeting in October 2006, this Annex has been approved. Consequently, this Annex has formally started on January 1st, 2007 and is scheduled to end on November 30th, 2009, which is the end of the third phase of the Hybrid and Electric Vehicles Implementing Agreement.

8.2 **Objectives**

In its first phase, this Annex aims to report a 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 organize the required information, three subtasks are proposed for the participants to elaborate.



Fig. 8.1 40-foot BAE Systems-Orion diesel hybrid bus in San Francisco. (Photo courtesy BAE Systems ©.)

The first -technology oriented- subtask aims at structuring the information about heavy-duty hybrid vehicle components, systems and configurations. At all levels this subtask needs to identify and illustrate 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 will be 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 will be 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.



Fig. 8.2 Hybrid electric utility truck. (Photo courtesy WestStart ©.)

In the third subtask, this Annex will also study the application area of hybrid technology for heavy-duty vehicles. First the current situation of existing hybrid prototypes and standard vehicles needs to be investigated. The information gathering will focus on the applied technology, as well as the costs and the merits in a broad sense. In this way it complements the first subtask.

This third subtask also aims at increasing the insights in these applications and providing 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 a lot of 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.

The Operating Agent will gather general information about heavy-duty hybrid vehicles and distribute it to the participants. The collected information will also be structured in a report.

8.3

Working method

The Operating Agent organizes two expert meetings per year 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 will prepare 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.



Fig. 8.3 FedEx hybrid fleet (18 trucks). (Photo courtesy Eaton ©.)

A subtask leader will be 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 will be assigned once the tasks are fully defined. Their task is to prepare a working plan for each topic. This allows for distributing the efforts in each subtask over all participants. The subtask leader co-ordinates the progress for his/her subtask and completes the report.

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.

Each subtask will result each year in a report internal to the project. The subtask reports as well as other documents will be accessible for the members through an Annex XII website. By using a document management system, the exchange of working documents, final reports and other information will be 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 will initially only be made available to member countries. A timing as well an approval system to make these reports publicly available will be established.

8.4

Status

This Annex has been approved at the IA-HEV Executive Committee meeting in October 2006, so there are no specific results to be reported yet. The Annex is scheduled to run until the end of 2009. Experience from other Annexes has shown that this period of almost three years is required to gain sufficient momentum.

Belgium, the Netherlands and the United States are participating in this Annex from the start. Other countries such as Austria, Canada, France, Italy, Sweden, Switzerland and Turkey are possibly interested to join at a later stage.

8.5

Outlook

The kick-off expert meeting was held in San Diego on February 9th 2007, in connection with the Annex VII expert meeting (February 5th-6th) and the SAE symposium on hybrid vehicle technologies (February 8th-9th).

Organizations that are interested in the work on heavy-duty hybrid vehicles in this new Annex are invited to contact the Operating Agent to discuss their possible role in this Annex. The work plan is in an early phase so there is still room to tune it to the needs of the participants.

8.6

Contact details of the Operating Agent

For more information on how to join this Annex or in case of 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 tremendous 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 are not limited by thermodynamic restrictions of combustion processes. Therefore they offer unique advantages concerning energy efficiency 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 are investing strongly in the development of this technology.

Nevertheless, limited lifetime as well as high production costs due to noble metal catalysts have impeded 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. More restrictive emission standards will raise costs for after treatment of internal combustion engine emissions. This will bring fuel cell vehicles nearer to competitiveness.

9.2

Objectives

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 poorly efficient 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 fits nicely to the efficient base load capability of fuel cells.

The different types of fuel cells actually under development dispose of an extreme variety of technical properties. Therefore a thorough analysis of all kind of fuel cells regarding their capability to fulfil propulsion requirements of different vehicles is the first task in this new 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. This new 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, costs, lifetime and range of vehicles powered by fuel cells, batteries and all kind of hybrid solutions are the main reason why the Executive Committee of the Hybrid and Electric Vehicle Implementing Agreement (IA-HEV) of the International Energy Agency decided in fall 2005 to expand its activities and to prepare a new Annex on 'Fuel cells for vehicles'. Nevertheless, IA-HEV aims for a strong tie and co-operation with the IEA Implementing Agreement on Advanced Fuel Cells (IA-AFC).

The HEV Implementing Agreement will concentrate its activities in this new Annex on tuning fuel cell properties as well as using their high potential for their successful application in vehicles. The main focus will be 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. In this respect boats, airplanes and mining vehicles could be an interesting niche preparing the market introduction of fuel cell, electric and hybrid road vehicles.

This Annex will not only concentrate on polymer electrolyte membrane (PEM) fuel cells as dominating technology for fuel cell research for vehicles today, but it will analyze the potential of other fuel cell types as well. Because many scientists believe that auxiliary power units (APUs) might be the first economically viable niche for the market introduction of fuel cells in vehicles, this Annex will study the potential of fuel cells for this market segment, after the preliminary investigation of all fuel cells mentioned above.

Another important issue with 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 will play an important role in this Annex.

The choice of the most suitable fuel and how to store it on board is probably the most important question for fuel cell vehicles. Therefore all fuel options like hydrogen, methanol or even liquid fossil fuels for solid oxide fuel cells (SOFCs) will be investigated, taking the specific limitations of a mobile application in vehicles into account.

A special added value of this Annex will be to analyze 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 could open up interesting niches and the chance for a unique selling position for Annex participants. To minimize development risks, the Annex will also address 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 will predominantly exist of foresight studies and technology assessments. The cost for these activities will be strongly reduced compared to independent investigations by each country, due to shared costs and broader data records. The danger 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 this 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 will facilitate their decisions on how to organize their fuel cell research in the most efficient way and how to embed it in international research co-operation.

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.

9.4

Results

During its meeting in October 2005 in Rome, the IA-HEV Executive Committee (ExCo) decided to develop a working plan for a new Annex on 'Fuel cells for vehicles' and appointed the Austrian delegate in the Agreement, Mr. Andreas Dorda, as the interim Operating Agent of this Annex. In November 2006 the ExCo decided officially to start the new Annex as Annex XIII of the Implementing Agreement.

Organizations that are interested in the work on fuel cells for vehicles in this new Annex are invited to contact the Operating Agent to discuss their possible role in this Annex. As the Annex is still in its starting phase, there is still room to tune it to the needs of new participants.

9.5

Outlook

A kick-off meeting is scheduled for April 2007 to identify the specific interests of the participating countries in the field of fuel cells in vehicles.

The collection and detailed analysis of existing technological solutions as well as pursued research pathways for combining fuel cells with other energy sources in hybrid drivetrains is planned until December 2007.

Foresight analyses of future options and opportunities of integrating fuel cells in vehicles overcoming their limitations by hybridisation on a smoother and quicker timescale: questionnaires, personal interviews and several workshops with industry (in- and outside automotive companies, academia, user organizations, technology and innovation policy experts) are scheduled for the year 2008.

9.6

Contact details of the Operating Agent

The Operating Agent of this Annex is Dr. Andreas Dorda. If you have any questions concerning this Annex please feel free to contact him at:

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10

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

10.1

Introduction

The last 25 years saw a coming and going of EV manufacturers and new electric and a few hybrid vehicle models, with a few success- and many failure-stories. Many reasons for market success or failure of HEVs (hybrid electric vehicles) and EVs are well identified in the stakeholders' field of 'politics' (by the study 'Deployment strategies for hybrid, electric and alternative fuel vehicles' that was performed under Annex VIII of this Implementing Agreement [10.1]) and in the stakeholders' field 'users' (market response to the vehicle performance, e.g. range, charging methods, application etc.). Not identified is the role of the automotive companies as a factor for success and failure.

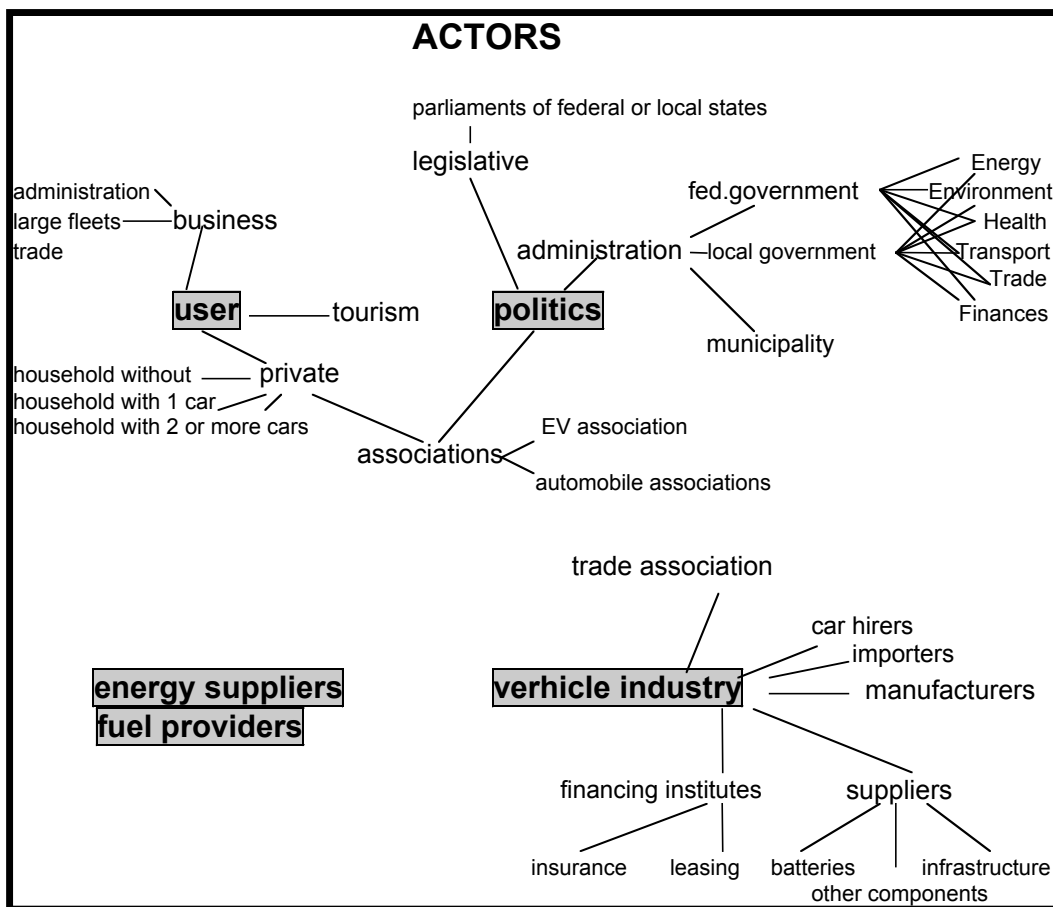


Fig. 10.1 Stakeholders network: the field in which advanced clean vehicle technologies have to compete.

Market deployment of clean vehicles today

The automotive industry keeps announcing advanced ‘cleaner’ vehicles (in the nineties electric, hybrid and fuel cell vehicles; currently vehicles using biofuels, ethanol E85, synfuels). This sequence of announcements creates confusion in the market and for the customers, and it makes governmental strategic planning more difficult. Consequently customers will be cautious to buy and use the next advanced vehicle generation - they cannot be sure whether the company still exists or whether the fuel will be still available a few years after their purchase. It also strains the goodwill of governments that aim at supporting the market introduction of advanced clean vehicles.

Additionally, there is a mismatch in politics and the model policy of the automotive industry. On one hand automotive companies are global players, whereas governments act within the boundaries of their country. On the other hand there is also an incompatibility on the time axis: one of the two players takes the first steps, the 2nd player reacts, etc. For example in the nineties: by the announcement of the Californian ZEV-mandate, in some European countries even before, governments started ‘the game’ → the car manufacturers offered a few EV models → the ZEV-mandate was delayed and then has been modified → the car manufacturers stopped producing EVs → the governments implemented demonstration schemes and supporting measures like green taxing, subsidies, green fleet mandates for public fleets etc., but now no EV models were available on the market anymore. Up to now there is no attempt to bring political demands and those of the automotive industry in line.

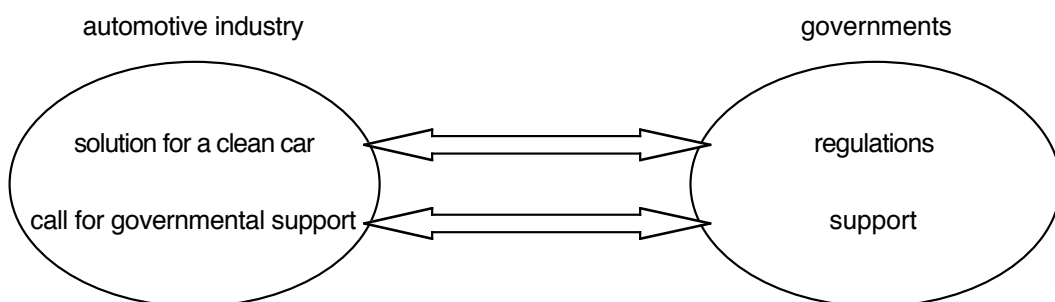


Fig. 10.2 Interplay between the automotive industry and governments.

Different types of HEV/EV-manufacturers = different stories

Success and failure in the electric vehicle market of the nineties also depended on the background of the vehicle manufacturer. In the nineties two types of EV manufacturers could be distinguished:

1. Small teams of non-automotive engineers, but specialists in electronics, electrical engineers, battery specialists, specialists in lightweight materials, lightweight design, etc. They had hardly money, they had all the knowledge to develop a prototype but no idea about mass production. In case they found

- financial partners they could start manufacturing, but (in case the company survived) only could produce niche products for niche market segments.
2. In the case of a large automotive company, the starting point was a decision to market a HEV/EV at top management level; the development and production team was formed within the company. Special know-how and/or components had to be bought from outside the company (batteries, electronics). This resulted in a great dependency that affected questions of warranties, delivery periods, responsibilities for service and maintenance. The fact that the know-how on the specific HEV/EV components was not within the company also had effects on the motivation of the production as well as the sales staff.



Fig. 10.3 Honda EV Plus: Honda decided to concentrate on hybrid vehicles and stopped the production of EVs. (Photo supplied by Muntwyler.)

10.2

Objectives

Before clean vehicles with advanced propulsion systems (fuel cell vehicles!) are introduced on the market, the reasons for success or failure of electric and hybrid vehicles in the markets of the nineties must be well understood to learn lessons for future clean vehicle marketing. This is the aim of the study in this new planned Annex 'Market deployment of hybrid and electric vehicles: Lessons learned'.

In short, the objective of this new Annex is to understand the role of the HEV/EV producers in the market deployment process regarding:

1. The decision on marketing a clean vehicle.
2. The decision which propulsion technology should be developed (electric? or hybrid? or fuel cell?).
3. The availability of competence within large automakers concerning this advanced propulsion technology.
4. The financing of the HEV/EV production and marketing.
5. The interplay between politics/administrations and the automotive industry.

The study will focus on hybrid and electric vehicles projects between 1985 and 2005.

Target public for the results

The members of the Hybrid and Electric Vehicles Implementing Agreement are representatives of governments and therefore they are the firstly ranked addressees. Interest of other stakeholders can be expected, depending on the decision of the working group about the dissemination of the results.

10.3

Working method

The evaluation will base on answers to a questionnaire focussing on the following questions:

1. On which basis do companies decide on a clean vehicle technology they want to produce?
Three illustrating examples are:
 - Toyota decided to go into the development of a hybrid propulsion technology and stopped EV projects. There are many assumptions why; some think that it was because the well-to-wheel analysis showed that EVs run on the Japanese electricity mix had no advantages concerning emissions, some others think it was because Honda was ahead with EV technology.
 - Most of the Western automakers decided because of the threatening Zero Emission Vehicle (ZEV) mandate in California or other legislative regulations or subsidy programmes.
 - In France there was a certain political pressure with EDF (Électricité de France) acting as the representative of the government. EDF was interested in consumers that use off-peak electricity. In addition, the French automakers hoped for advantages in the Californian market due to the ZEV mandate.
2. Are problems caused by the dependence on components that are not produced by the vehicle manufacturer itself? (Storage systems like batteries, electronics, fuel cells).
3. Is the problem caused by the fact that automotive engineers have fixed ideas about what a car has to be like?
4. The other way around: are the ideas of engineers that are not automotive technicians (e.g. specialists in composite materials and lightweight design, in electronics and informatics) too early for the conservative car market?
5. How can co-operation between the traditional car industry with the large brands and innovative 'outsiders' be initiated? This also weakens traditional hierarchies and demands more flexibility than usual.
6. Is the problem caused by too great promises by the manufacturers resulting in too high user expectations, who thus had to end up being disappointed?

7. Which role does motivation of production, sales and service staff play? What about distribution channels?
8. What happened concerning financing?

The list is of course not complete. It is task of the new Operating Agent together with the experts of the participating countries to finish the questionnaire.



Fig. 10.4 VW Golf CityStromer: too heavy, too expensive, not for the Golf customers segment, so production stopped after about 500 items were sold. (Photo supplied by Muntwyler.)

The questionnaire will be the basis of interviews with:

1. Programme directors of HEV/EV projects.
2. Responsible technical staff.
3. Developers of components.
4. (has to be completed by the working group).
5. It is of special importance to integrate the knowledge of persons that follow the development for decades and know a lot of background stories.

On the basis of the answers a list of ‘Lessons learned’ will be elaborated. The Executive Committee of the Hybrid and Electric Vehicle Implementing Agreement attaches importance to an outlook chapter that outlines which consequences the lessons learned may have on the decision making on future successful vehicle technologies, deployment strategies, etc.

10.4

Status and outlook

This new Annex is in a preparatory phase. The Institute of Transportation Studies of the University of California Davis will act as the Operating Agent. The formal start of the Annex is planned for spring 2007.

A kick-off workshop planned in the first half of 2007 will mark the start of the work. At this workshop, the working group will settle the working tools and allocate the tasks among the participating experts.

10.5

How to join

IA-HEV member countries have to confirm their participation by signing a notification of participation and by delegating a country expert for this Annex. Non-member countries may participate on the basis of a special agreement (e.g. as sponsors), which has to be negotiated with the Operating Agent and confirmed by the Executive Committee of the Implementing Agreement.

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10.6

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11

Renewable energies for hybrid and electric vehicles

(New Annex)

11.1

Introduction

Surging oil prices, the dependency of transportation on oil products, and efforts to reduce greenhouse gas emissions have caused significant interest in developing alternative transport technologies and fuels. Many governments wish to increase the share of renewable energies in both electric power production and the transportation sector. These objectives can support each other in the area of research and technology development. The use of 'green' electricity for battery electric vehicles and biofuels for hybrid electric vehicles increases their sustainability. However, many questions still have to be answered to get a clear picture of the most promising combinations of renewable energy sources and clean vehicle technologies.

Existing systems and systems based on renewable energies must be compared on a well-to-wheel basis for a valid assessment of their advantages and disadvantages. For hybrid electric vehicles (HEVs) and electric vehicles (EVs) this means analysing the role of renewable electricity. For HEVs that combine an electric motor and an internal combustion engine, the renewable fuel for the engine must also be included in the comparison.

In many countries there is a strong demand for objective information that makes it possible to get an overview and to compare the different combinations of renewable energy sources and clean vehicle technologies.

Against this background the Executive Committee (ExCo) of the HEV Implementing Agreement (IA-HEV) decided to prepare a new Annex on renewable energies for hybrid and electric vehicles.

11.2

Objectives

The goal of the task force in this Annex is to support research, to share new information and to establish working relations among organizations in the world that are working on key topics in this area. This Annex will provide objective information to support decision makers in participating countries to decide on strategies based on locally available renewable energy resources.

In the first phase this Annex will concentrate on the following areas:

1. Electricity production from renewable sources for battery electric vehicles and 'plug-in' hybrid electric vehicles (PHEVs).
2. Biofuels for hybrid electric vehicles.
3. An updated overview of well-to-wheel analyses of energy efficiencies, greenhouse gas emissions and costs of the different pathways from renewable energy sources to electric and hybrid vehicles.

The information obtained can be used by participating countries as a basis for analysing effects in the total energy system of the contribution of renewable energies that 'fuel' a considerable number of electric and hybrid vehicles.

This Annex is aiming at members of government authorities, local authorities, utilities, energy agencies, environment agencies and end-users.

11.3

Working method

Reduction of the oil dependency and greenhouse gas emissions of transportation faces several challenges:

- A shift to renewable/low carbon energy sources may offer significant greenhouse gas (GHG) reduction potential but generally requires more energy.
- A shift to renewable/low carbon energy sources is currently expensive.
- Transport applications may not maximize the GHG reduction potential of renewable energies.
- Optimal use of renewable energy sources such as biomass and wind requires consideration of the overall energy demand including stationary applications.

Battery electric vehicles and hybrid electric vehicles represent new clean vehicle technologies that may contribute to meet these challenges. The following subsections will briefly describe the main focus areas that are scheduled to be analysed in this Annex.

Electricity production from renewable sources

Several renewable sources of electricity production are available: hydropower, wind power, solar power and combined heat & electricity production from biomass. Some of these sources have already been used for decades, while others are still in a stage of development to improve efficiency and to reduce costs. They have different characteristics as elements in the electricity power and distribution system. The possibilities to increase the electricity production from these renewable sources to meet an increased demand in the transport sector may vary between countries.



Fig. 11.1 Intermittent electricity production from offshore wind turbines is an important source of renewable energy for plug-in hybrids and electric vehicles. (Photo supplied by Esben Larsen.)

Battery electric vehicles and plug-in hybrid electric vehicles are options for a very energy efficient use of electricity in road transport. Additionally, the storage capacity of the batteries in these vehicles may represent interesting load levelling capabilities in an electricity system with a large share of intermittent wind power.

Biofuels

Biofuels for road transport are currently expensive and the production processes are often energy consuming. In many countries the resources of biomass are limited. Biofuels can be used in neat form, or in blends with conventional fuels in existing infrastructure and vehicles. With surging oil prices there is a growing interest to develop new and more efficient production processes (the 2nd generation processes), which may reduce costs and energy consumption, and use cheaper raw materials. Promising results have been obtained when the production of biofuels is combined with existing processes in industry and power plants.

Plug-in hybrid electric vehicles represent an interesting possibility that combines a very energy efficient use of electricity with a limited consumption of biofuels, and hereby eliminates the current range limitations of the battery electric vehicle.

Well-to-wheel analysis of energy efficiencies, greenhouse gas emissions and costs

A large amount of information on well-to-wheel comparisons is available in the public domain. The intention of this task is to combine that information with new results from electricity production and biofuels, and to apply it to HEVs and EVs to estimate their potential in reducing fossil energy consumption and greenhouse gas emissions from transportation. The focus will be on energy efficiencies, greenhouse gas emissions and costs.

Comprehensive analysis of an energy system with a considerable share of renewable energy for hybrid and electric vehicles

Optimal use of renewable energy sources such as biomass and wind requires consideration of the overall energy demand including stationary applications. Comprehensive analysis of the total energy system of a country or region is necessary to get a clear picture of the overall impact of the different combinations of renewable energy sources and clean vehicle technologies.

One important aspect is to analyse the possible interaction between intermittent renewable energy production and the electricity storage capabilities of EVs and plug-in hybrid electric vehicles. The charging pattern and the storage capacity of electric vehicles represent very interesting load levelling possibilities.

Demonstration projects to analyse the potential synergies between battery EVs and PHEVs and the electricity grid, and to detect barriers for these synergies could be an important focus area.

The well-to-tank pathways of renewable energy resources may be very different between countries. The working method of this Annex will be organised to permit each participating country to contribute information and to obtain new results for those renewable energy sources that are most relevant for that specific country.

11.4***Status and outlook***

During its meeting in Yokohama on October 31 and November 1, 2006, the IA-HEV Executive Committee discussed the scope of this new Annex on renewable energies and decided to continue the detailed planning phase. It is the intention to start the work of the Annex in the first half of 2007.

A detailed work plan will be presented to the IA-HEV Executive Committee during its first meeting in 2007. The ExCo will decide if this new Annex can enter the approval phase, in which formal participation will be solicited.

Interested parties are invited to contact one of the IA-HEV members, the chairman, the secretariat or the interim Operating Agent, to discuss their possible role

in the activities of this Annex. Participating organizations can contribute to determine the actual content of the work, so it can be adapted to their needs.

11.5

How to join

Further information on the possibilities to join this Annex can be obtained by the interim Operating Agent:

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12

An overview of hybrid and electric vehicles in 2006

This chapter presents (in section 12.1) data on worldwide hybrid electric vehicle (HEV) and electric vehicle (EV) populations for the four years up to the end of 2006. Section 12.2 presents some developments in the year 2006 that may influence overall growth of HEV and EV populations in years to come, grouped per theme. Boxes in section 12.2 show which countries are working on the different themes, and thus indicate in which of the country chapters more in-depth information on each theme can be found.

12.1

Statistical information

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

Year Vehicle type	2003		2004		2005		2006	
	EV (1)	HEV	EV (1)	HEV	EV (1)	HEV	EV (1)	HEV
Austria	533	0	515	0	517	75	n/a	100
Belgium	n/a	0	n/a	131	n/a	602	n/a (ca. 0)	1'493
France	10'706	144	11'013	650	11'000	n/a	11'000	> 7'000
Italy (2)	95'162	247	112'481	220	131'381	1'969	n/a	4'100
Netherlands	500	1'000	500	2'000	500	3'000	500	5'100
Sweden	471	624	422	1'355	373	3'300	n/a	6'100
Switzerland	10'686	472	12'201	1'021	13'110	2'469	n/a	n/a
USA	45'656	113'300	55'852	197'100	68'000	404'400	76'200	656'300
Total IA-HEV	163'714	115'787	192'984	202'477	224'881	415'815	235'000	680'193
China (3)	6'400'000	n/a	13'000'000	n/a	23'000'000	n/a	33'000'000	n/a
Denmark	360	0	300	15	650	35	650	50
Japan	5'600	91'200	n/a	120'000	n/a	150'000	n/a	200'000
Taiwan	55'000	n/a	75'000	n/a	94'000	n/a	100'000	n/a
Grand total (3)	6'625'000	207'000	13'268'000	322'000	23'320'000	566'000	33'336'000	880'000

n/a not available

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

(2) The 2004 EV number for Italy includes HEV cars. Separate data is not available for this year. The 220 HEVs in 2004 are only buses.

(3) Estimates.

Table 12.1 shows data (available as of 31 January 2007) for the past four years on the growth of EV and HEV vehicle fleets. When new data become available, they are included in a similar table that can be found on the IA-HEV internet website (www.ieahev.org).

The EV population as presented in table 12.1 is dominated by China, but Taiwan and Italy have significant two-wheeler EV populations. The EV fleet in the United States appears to be growing as the market for specialty vehicles serving resorts, universities, government installations and gated communities increases. EV population growth in Europe -which is hardly supported anymore by direct incentives- has essentially ended for all but e-bikes and e-scooters, and the 4-wheeler EV park has been declining for several years (although the European EV fleet for 2006 might be slightly underestimated here because of a lack of data).

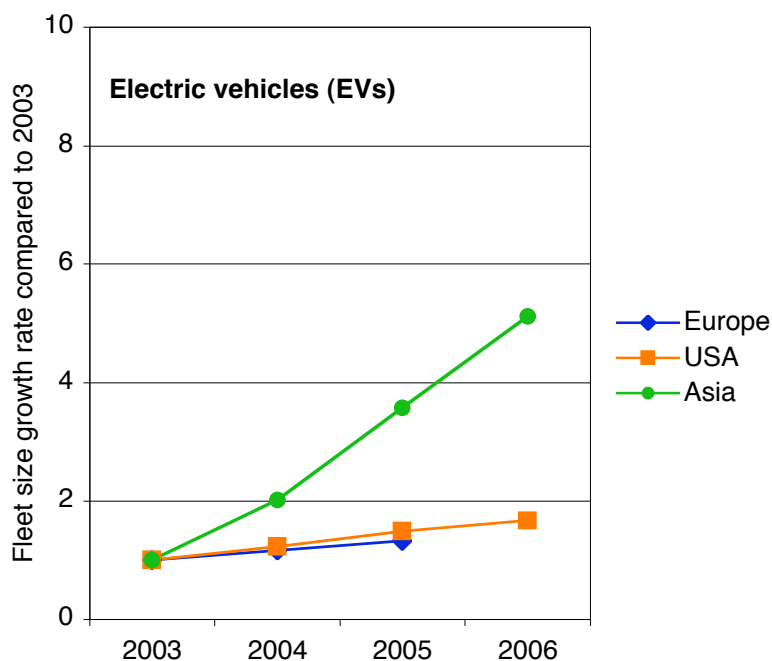


Fig. 12.1 Fleet size growth rate of electric vehicles (EVs) in the countries that are listed in table 12.1, beginning in 2003. (Europe 2006 is not shown due to lack of data.)

According to table 12.1, most of the HEV population in 2003 could be found in Japan and the United States, and vehicle numbers in those two countries were very similar. The European HEV fleet in 2003 was very small and only started growing significantly in 2004 (see fig. 12.2). The HEV growth rate in Europe was about four times that in Japan, but in vehicle numbers, Japan's HEV fleet is still 10 times larger than Europe's HEV fleet. Over the last four years, the HEV fleet in the United States has been the largest in both absolute increase and number of vehicles.

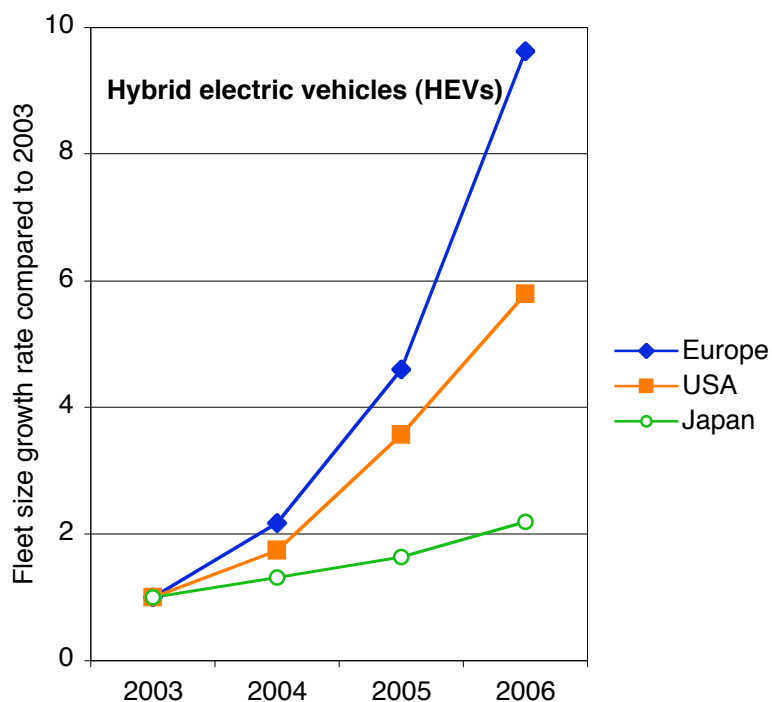


Fig. 12.2 Fleet size growth rate of hybrid electric vehicles (HEV) in the countries that are listed in table 12.1, beginning in 2003.

12.2 Worldwide developments in 2006

Brief overview

During 2006, the growth of markets and technologies for EVs and HEVs continues unevenly distributed across different countries, including the IA-HEV member countries. Despite explosive growth in (1) hybrid vehicle populations in a handful of countries and (2) e-bike sales in China, most IA-HEV members report relatively quiet, although steady, developments in research and technological production that remain focused on emerging propulsion systems (chiefly fuel cells and non-petroleum combustion fuels, including hydrogen and renewables).

Periodic petroleum shortages and speculation about the reliability of supplies as a result of ongoing armed conflict in critical production regions (such as the Middle East) have kept finished gasoline and diesel fuel prices relatively high through the year, and thus the interest in deploying more efficient transportation alternatives (such as HEVs) in both IA-HEV member and non-member countries has not diminished.

Synopsis of activities in IA-HEV member countries

Activities, incentives, green vehicle programmes, technology developments and clean vehicle deployment programmes are predominantly driven by environmental objectives. Box 12.1 shows the objectives of such programmes and lists in which countries this type of programmes are running. More detailed information on the respective programmes can be found in the country chapters of this report.

Box 12.1	
Governmental environmental objectives for clean vehicle technologies in IA-HEV member countries	
Objective	Country
Reduction of CO ₂ emissions	Belgium, Italy, the Netherlands, Switzerland
Reduction of energy consumption	Switzerland, United States
Improving local air quality	Italy, the Netherlands

Tax and subsidy incentives

Several countries have become very proactive in taxation policies that favour fuel-efficient vehicles, especially EVs and HEVs. On 30 December 2005, the *French* government implemented a new tax credit for the purchase of clean vehicles by private persons. The credit is € 2'000 for the purchase of EVs, HEVs, liquefied petroleum gas (LPG) vehicles and natural gas vehicles (NGVs), which increases to € 3'000 if the transaction includes destruction of a vehicle built before 1997. Property taxes of passenger cars are now modulated according to their emission standards and engine/motor power. *Italy* grants a significant reduction in property tax levies for cleaner cars, such as NGVs, LPG vehicles, HEVs and EVs. For example, owners of EVs pay no property tax for the first 5 years after registration and subsequent property tax is discounted 75% with respect to an analogous conventional vehicle. The notional taxation on the registration of hybrid or electric company cars in *Sweden* is reduced by 40% relative to the closest comparable gasoline model, subject to a maximum reduction of US\$ 2'000 per year. By comparison, a 20% reduction is granted for company cars running on E85, natural gas or biogas, subject in these cases to a maximum reduction of US\$ 1'000 per year. In *Belgium*, buyers of vehicles emitting low levels of CO₂ will obtain a reduction on their income tax amounting to 15% of the purchase price of vehicles with CO₂ emissions equal to or lower than 105 g/km and 3% for vehicles with CO₂ emissions equal to or lower than 115 g/km. There is an absolute cap on the return of € 4'080. Owners are credited only when income taxes are finalized, which is approximately two years after the acquisition of the vehicle.

The *Netherlands* has enacted special tax rules to encourage the purchase and ownership of EVs and hybrid vehicles. Electric vehicles are exempted from road tax. Since mid-2006, the purchase of a hybrid vehicle qualifies for a substantial rebate (up to € 6'000) to encourage sales. Also, regardless of fuel or technology, very energy efficient cars get a tax bonus that may reach € 1'000, depending on the fuel efficiency category label the specific model has earned. *Switzerland* plans implementation of a bonus-malus system on vehicle import taxes that is based on the EU consumption label for light-duty vehicles. The tax will rise for cars in the label categories C to G, cars of the category A will get a rebate of CHF 2'000 (€ 1'350) and cars of category B earn a CHF 1'000 (€ 675) rebate. Cantonal governments continue to have the legal authority to finance promotion measures for electric and hybrid vehicles, and several cantons provide a vehicle tax reduction for 'clean' vehicles: 16 of 26 cantons exempt EVs from the vehicle taxes or grant reductions and 8 cantons reduce the taxes for hybrid vehicles. The canton of Ticino's VEL2-programme was completed in June 2005 after it had subsidized 2'785 efficient vehicles, which included 75 hybrids.

A limited federal tax credit is available in the *United States* for light-duty HEVs placed in service between December 31, 2005, and January 1, 2011. The expiration date is January 1, 2010, for medium- and heavy-duty vehicles. The tax credits are capped at 60'000 vehicles per manufacturer and above that cap, the vehicles sold during the next four calendar quarters will only be eligible for a decreasing percentage of the full tax credit. The U.S. Internal Revenue Service recently completed its quarterly audit for the automakers. As of June 2006, the credit amounts for Toyota hybrids have been cut in half as the company has met the first hybrid sales threshold. All other manufacturers, however, still qualify for the full tax credit amounts. Eleven states in the United States have their own tax and/or rebate schemes to encourage HEV market development, while an additional 9 states offer waiver/privilege-based incentives for HEVs on the road or have imposed some form of state mandate for fleet HEV purchases. On January 24, 2007, U.S. President G.W. Bush issued to federal agencies an Executive Order that requires -among other items- a 2% reduction -in fleets larger than 20 vehicles- of consumption of petroleum products per year through the end of 2015. The order also requires the use of plug-in hybrid vehicles (PHEVs) when they become commercially available at a cost reasonably comparable -on a life-cycle basis- to that of non-PHEVs.

'Green' vehicle progress

In *Austria*, year 2006 funding for the A3 R&D program (described in the last IA-HEV annual report) was € 5 million, with 23 projects selected from 35 proposals. In the overall evaluation process of four proposal calls under this scheme between 2002 and 2006, roughly 80 projects with 350 partners have been funded at a total budget of € 22 million, with an additional allocation € 5 million for pilot and

demonstration projects. A second call for the ‘Lighthouse projects’ initiative (also described in the last annual report) opened in 2006. Four projects were selected from an evaluation of nine proposals, with total funding of € 2 million. This second call focused on alternative propulsion systems and alternative fuels.

In *Belgium*, Green Propulsion -an independent specialist firm developing cleaner prototype vehicles- offers proprietary software systems for complete vehicle integration: mechanical design, thermal management, electric wiring, electronic card development, vehicle tuning and monitoring. Recent projects include the development of (1) an electric superkart capable of accelerating from 0 to 100 km/h in 2.5 s, (2) a prototype parallel hybrid VW Lupo[®], (3) an electric/series hybrid Microbus, (4) a prototype combined series/parallel hybrid Renault Kangoo, and (5) an Imperia Revival sport concept car.

In the *Netherlands*, a programme called ‘CO₂ reduction in personal transport and in goods transport’ is in operation, providing rebates for investments in fuel-efficient vehicles and transportation systems. A companion programme supports the use of biofuels in vehicles. In addition to affixing the energy rating (energy consumption in litres per 100 vehicle-km), Dutch car dealers must now also report the CO₂ emission rate in grams per vehicle-kilometre on the energy label of the new cars in their showrooms. This label has become very well known and accepted by the public.

Sweden’s Green Vehicle Programme (the objective of which is to develop cleaner vehicles) is jointly supported by the automotive industry and the government. The total budget of the second phase -which began in 2006- is approximately US\$ 20 million. The administrator is VINNOVA (Swedish Governmental Agency for Innovation Systems) and the programme will extend to 2008, with about US\$ 35 million budgeted for specific electric, hybrid and fuel cell vehicle research. This will include work in the following areas linked to hybrid systems: hybrid systems architectures, drive systems and energy storage technology.

The *United States* National Highway Traffic Safety Administration (NHTSA) has developed special safety standards for Neighbourhood Electric Vehicles (NEVs), which 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 or less. As the various states adopt and incorporate these standards, such zero-emission vehicles become more eligible to operate on local roadways with lower posted speeds, and their numbers are growing.

Box 12.2 summarises the governmental incentives for clean vehicle technologies in IA-HEV member countries, sorted by programmes that stimulate research and

by market introduction measure. More detailed information about these programmes can be found in the respective country chapters of this report.

Box 12.2	
Governmental incentives for clean vehicle technologies in IA-HEV member countries	
Programmes that stimulate research	
Topic	Country and programme
Advanced (clean) automotive (propulsion) technology	Austria (IT2S - A3) France (PLAN VPE) Italy (National Research Plan) Sweden (Green Vehicle Programme, Energy Systems in Road Vehicles, SHV) Switzerland United States (FreedomCAR)
Batteries	Sweden (Energy Systems in Road Vehicles) United States
Fuel cells	Austria (IT2S - AHFI) Italy (National Research Plan) United States (FreedomCAR)
Hydrogen	Austria (IT2S - AHFI) Italy (National Research Plan) United States (FreedomCAR)
Market introduction programmes/stimulation	
Measure	Country
Agreements	Belgium, Sweden, United States
Allowance to circulate in restricted zones	Austria, Italy, Switzerland
Reduced circulation/road tax	Belgium, the Netherlands
Reduce income tax	Belgium, France
Reduced purchase tax	Switzerland, United States
Reduced registration/property tax	Belgium, Italy, the Netherlands, Sweden, United States
Subsidies/support/incentives	Italy, Sweden, Switzerland, United States

Driveline and component technologies

The detailed assessment performed by *Belgium's* VITO automotive research institute investigating the possibilities and opportunities for ultracapacitors in EV and HEV applications (cited in the previous IA-HEV annual report) showed that -in combination with all battery technologies considered (valve-regulated lead-

acid (VRLA) batteries, NiMH, Li-ion and LiP (lithium-phosphate))- the energy pack (the combination of ultracapacitors and batteries) demonstrated characteristics superior to those of the standard battery pack. This research resulted in new electronic components for energy pack management (cell balancing, equalization, vitalization, state of charge, state of health, and thermal management) that have been implemented in several applications in 2006. 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 and renamed it Punch Powertrain, with the goal of developing hybrid powertrains based on the continuous variable transmissions (CVTs) developed and built in this plant. Punch Powertrain will modify its existing CVTs to become the core of a new parallel hybrid powertrain to be commercialized by 2009.

During 2006, supercapacitors and Li-ion batteries both attained industrial-scale production in *France* with the completion of two new production plants, one in Quimper for supercapacitors manufactured by batScap, and the other in Nersac to produce Johnson Control - Saft batteries. In *Italy*, Altra -a joint venture between IVECO and Ansaldo- is one of the larger suppliers of electric and hybrid buses, as well as complete electric drivetrains for small and large EVs and HEVs. The main contribution of Italian industry is electronics for battery management and system integration. *Dutch* automotive suppliers are now developing and producing components based on programmes of requirements as formulated by the car industry at large, and the concept and practice of 'co-makership' (joint production) is getting stronger. *Swedish* component suppliers support hybrid vehicle advancement: (1) ETC, Battery and Fuel Cells AB develops batteries for hybrid vehicles, primarily nickel metal hydride; (2) Actia Nordic AB provides power electronics for electric and hybrid vehicles; and (3) LiFeSiZE AB has scaled up production and sale of low-cost Fe-based cathode materials for EV/HEV Li-ion batteries, especially $\text{Li}_2\text{FeSiO}_4$.

An important technology research component of the *United States* Department of Energy FreedomCAR programme is that of Advanced Power Electronics and Electrical Machines. This activity 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 is on the thermal control of inverters and motors with two-phase cooling technologies.

Box 12.3 presents an overview of organizations with research activities on hybrid, electric and fuel cell vehicles that are addressed in the IA-HEV member country chapters of this report.

Box 12.3	
Research on hybrid, electric and fuel cell vehicles in IA-HEV member countries	
Type of organization	Country
Component manufacturers	Austria, Belgium, France, Italy, the Netherlands, Sweden, Switzerland, United States
Vehicle manufacturers	France, Italy, Sweden, United States
Research institutes	Austria, Belgium, Italy, the Netherlands, Sweden, Switzerland, United States
Universities	Austria, Belgium, Italy, the Netherlands, Sweden, Switzerland, United States

Deployments and demonstrations

During 2006, DAF Trucks of the *Netherlands* demonstrated a prototype hybrid distribution truck. Development of this prototype vehicle teamed DAF engineering with the research capabilities of TNO Automotive and the University of Eindhoven. The *French* company Venturi has launched its Eclectic, an urban 3-seater electro-solar vehicle that explores the concept of partial energy autonomy by recharging its liquid-cooled NiMH battery with solar energy during the vehicle's moments of immobilisation. Eclectic offers a peak speed of 50 km/h at a range of up to 50 km, of which solar recharging at full sun exposure can provide approximately 7 km per day. Combined wind (from turbine) and solar recharging can provide 15 km per day of range in windy areas. Production of 20 pre-series vehicles has begun, and a limited edition of 200 vehicles with specific equipment will be launched in June 2007. *Sweden's* Volvo Construction Equipment began development of a hybrid wheel loader (heavy equipment) prototype in 2006, for which the Swedish Energy Agency is financing 33% of the project.

13 Austria

13.1 Introduction

Austria is a significant player in the automotive industry, hosting many automotive suppliers and vehicle production plants, such as Magna Steyr in Graz. More than 170'000 people work in more than 700 enterprises in the Austrian automotive industry. Although hybrid electric vehicles (HEVs) and electric vehicles (EVs) play only a subsidiary role in the Austrian vehicular market, researchers at the Technical Universities of Vienna and Graz and researchers in such enterprises as AVL List in Graz are active in the field of alternative automotive drivetrains. Universities in Vienna and Graz, extramural research institutes like ECHEM (Competence Centre for Applied Electrochemistry), and the Christian Doppler Laboratory for Fuel Cell Systems conduct research in the field of batteries and fuel cells. As hybrid vehicles start to play a more significant role in the vehicular market, as shown by the success of Toyota's Prius, Austrian interest in this technology is expected to grow.

13.2 Policies and legislation

Research, development and technological innovation provide the basis for economic growth, competitiveness, employment, and (ultimately) the prosperity of a country and its citizens. The Federal Ministry for Transport, Innovation and Technology (BMVIT) promotes research at all levels, from basic research to the industrial application of research results.

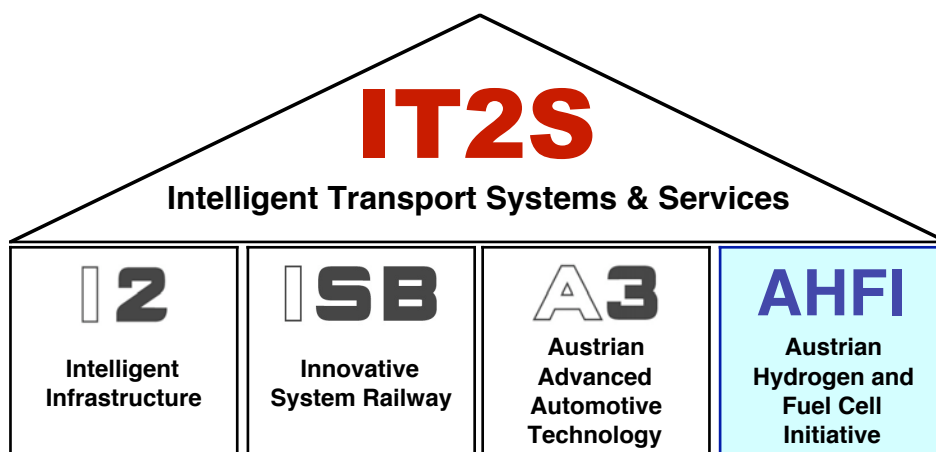


Fig. 13.1 Scheme of programmes in IT2S.

Mobility plays a key role within a modern society. Therefore, the BMVIT has launched a research programme called 'Intelligent Traffic Systems and Services'

(IT2S), which has four components (see fig. 13.1). This programme will target strategically important topics and topic areas in transport on both a continuing and quick-response basis. The two components ‘A3’ and ‘Austrian Hydrogen and Fuel Cell Initiative’ (AHFI) are highly relevant for EV and HEV research in Austria.

In 2006, the BMVIT opened the fourth call for proposals for the R&D programme called Austrian Advanced Automotive Technology (A3), which is a component of IT2S (fig. 13.1). The call was open for proposals in the fields of:

- alternative propulsion systems and fuels,
- materials research, and
- vehicle electronics.

The funding for this R&D programme was € 5 million for 2006, and 23 projects were selected from 35 proposals. In the overall evaluation process for four calls between 2002 and 2006, BMVIT funded roughly 80 projects with 350 partners at a total budget of € 22 million, with an additional allocation of € 5 million for pilot and demonstration projects.

A second call for the ‘Lighthouse projects’ initiative of the BMVIT was opened in 2006. Four projects were selected from evaluation of nine proposals, with total funding of € 2 million. This second call focused on alternative propulsion systems and alternative fuels.



Fig. 13.2 Fuel cell powered forklift truck, developed under an A3 lighthouse project. (Photo courtesy Fronius International.)

The Austrian Hydrogen and Fuel cell Initiative (AHFI) is an initiative for the development of a full spectrum of alternative propulsion systems and fuels (including hybrids, H₂, fuel cells, compressed natural gas and biofuels). Three instruments exist to support the initiative:

- (1) the already mentioned A3 program for collaborative R&D projects;
- (2) the 'Lighthouse projects' for large demonstration and pilot efforts; and
- (3) the Austrian Alternative Propulsion Systems Council (APSC), which supports R&D beyond funding by providing information, analyzing technological trends, optimising legal framework conditions, eliminating barriers to innovation, and pursuing trans-national co-operation.

From the experience of three prior calls in the A3 program of the BMVIT, the following trends and achievements are apparent:

- convergence and good synergies between selected topics (alternative propulsion systems and fuels, material research, vehicle electronics);
- high interest in hydrogen because of major industrial original equipment manufacturer (OEM) clients and existing infrastructure, despite some opposition questioning its sustainability;
- continued interest in fuel cells, including SOFC; and
- good coverage of other topics (hybridisation, battery research, biogas, bio-ethanol, biodiesel, compressed natural gas (CNG), gas-to-liquid (GTL), biomass-to-liquid (BTL)), including strategic studies.

Following the principles of modern technology policy, the BMVIT is convinced that public authorities can facilitate the development of new technologies far beyond the specific financial assistance they provide. Therefore, the BMVIT has decided to establish a new institution called the Austrian Agency for Alternative Propulsion Systems (A3PS). The A3PS is a public-private partnership between the BMVIT and partners from industry, small and medium enterprises, academic research organizations, and research facilities in Austria. The agency has 19 stakeholder/participants at present, and further expansion is planned in the current year. The new agency started its work in autumn 2006 and will undertake the following activities.

- Build up interdisciplinary research, co-operation, and comprehensive and trans-sectoral demonstration projects.
- Stimulate the co-operation of complementary partners to overcome the 'chicken and egg problem'.
- Adopt supportive legal framework conditions (like fuel taxation, privileged access to sensitive areas, and emission or technical standards) to avoid barriers for innovation.
- Discuss topics and organisation of programme calls with all relevant stakeholders to optimise the funding instruments.

- Inform extensively and in detail about all national and international funding opportunities.
- Analyse technological trends and evaluate technology foresight and assessment studies.
- Support the definition of interesting niches for Austrian research institutions in technological development.
- Facilitate integration of national and international networks, as well as participation in FP6 projects and other research activities.
- Represent Austria's position on FP7, EU-technology platforms, ERA-NET, IEA and other activities.
- Co-ordinate regional research activities to avoid duplication of efforts and to achieve critical mass of international perception.
- Give Austrian research institutions long-term security in planning and investments by clear public commitment beyond elections.

The A3PS will broadly promote the development and employment of alternative propulsion systems and fuels by supporting Austrian research institutions in their technological development projects and serving as a platform for their national and international activities. Internationally, the A3PS is the Austrian representative to the new IA-HEV Annex XIII 'Fuel cells for vehicles', acting therein as an agent for interests of Austrian enterprises, universities and research institutes.

13.3

Research

Research on electric vehicles, batteries and fuel cells takes place primarily 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 organizations are working co-operatively with members of the automotive industry, like Plansee, AVL List, BMW and Magna Steyr, on projects in these research areas:

- Solid oxide fuel cells (SOFC) in auxiliary power units (APU).
- Propulsion systems for PEM fuel cell cars.
- Hydrogen-fuelled internal combustion engines.
- Fuel cell catalysts.
- Catalyst recycling.
- Onboard storage systems.
- Tank isolation.
- SOFC for fuel cell-battery hybrid vehicle.
- Control systems for hybrid vehicles.
- Lithium batteries.



Fig. 13.3 Fuel cell powered vehicle, developed under the A3 'small traction' programme. (Photo courtesy ECHEM.)

13.4

Industry

Austria has more than 700 automotive and automotive component companies. The main involvement of the industry in hybrid and electric vehicles is the development of onboard hydrogen storage and propulsion systems for fuel cell vehicles. A few enterprises (such as the Banner Company) are active in the improvement of lead acid propulsion batteries.

13.5

On the road

There have been no formal EV or HEV market introduction programmes in Austria, possibly because of the strong presence of diesel technologies in the national economy. However, some tourist resorts and villages have begun to allow the use of electric vehicles (only) on their premises. Table 13.1 gives a breakdown of the electric vehicle fleet in Austria for the years 2003-2005, and also for the total fleet in 2005.

Statistics show the vehicle population of Austria to be increasing. The number of electric vehicles is more or less constant after a decrease from 2003 to 2004. Motor-assisted bicycles, which do not require a driver's licence to operate, are the most numerous component of the Austrian EV fleet.

Table 13.1 Characteristics and population of the Austrian vehicle fleet. (Data provided by Statistics Austria.)

Vehicle type	2003	2004	2005	
	EV fleet	EV fleet	EV fleet	Total fleet
Light vehicles (no driver licence)	213	199	204	300'174
Small and light motorcycles	2	2	2	128'578
Motorcycles and small vehicles	12	19	21	198'959
Cars	135	128	127	4'156'743
Buses	109	108	108	9'301
Trucks and vans	26	22	17	358'049
Tractors	15	18	18	425'278
Self-propelled machinery	21	19	20	69'800
Total	533	515	517	5'646'882

13.6

Developments

As mentioned previously, the Austrian government is funding several research projects on alternative propulsion systems and fuels. Perception of global warming, the need for energy security, high energy prices and the search for pathways to sustainability work synergistically to promote the importance of EVs and HEVs worldwide and encourage industry and research facilities to undertake greater effort in developing EV, HEV and fuel cell technology. The Austrian government is actively supporting such activities with funding and promotion of cross-linking activities. Although the market for EVs and HEVs is very limited in Austria, the public is becoming more aware of alternatives to conventional propulsion, thanks to high gasoline prices and public information campaigns.

13.7

Benefits of participation

The benefits to Austria from participation in IA-HEV are:

- Remaining informed about technology developments regarding EVs and HEVs and their drivetrains in other countries, with the objective of transferring this knowledge to Austrian industry.
- Participating 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 regarding hybrid and electric vehicles can be found at the following websites:

- www.arsenal.ac.at (in English and German).
Austrian Research Centres Arsenal Research.
- www.avl.com (mainly in English, some pages in Chinese, French, German, Italian, and/or Spanish).
AVL List GmbH.
- www.a3ps.at (in English and German).
Austrian Agency for Alternative Propulsion Systems (A3PS).
- www.banner.at (in English and German).
Lead acid batteries and traction battery systems.
- www.bmvit.gv.at/innovation/verkehrstechnologie/a3/index.html (in German).
Austrian Advanced Automotive Technology Programme of the Federal Ministry for Transport Innovation and Technology (BMVIT).
- www.echem.at (in German).
Competence Centre for Applied Electrochemistry.
- www.energyagency.at (in English and German).
The Austrian Energy Agency (E.V.A.).
- www.energytech.at (in English and German).
Platform for innovative technologies in the area of energy efficiency and renewables.
- www.magnasteyr.com (in English and German).
Engineering and vehicle assembly company.

14 Belgium

14.1 Introduction

Belgium is an important player in the automotive industry. It hosts several car assembly plants, such as 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 associated research activities.

Belgium boasts key players in the field of R&D of electric and hybrid vehicles, including VITO (Vlaamse Instelling voor Technologisch Onderzoek - Flemish Institute for Technological Research), the Vrije Universiteit Brussel (VUB) and Green Propulsion. New players, like Punch Powertrain, are starting to develop new concepts in hybrid transmission. Two European organizations focusing on electric and hybrid vehicles, namely CITELEC (Association of European Cities interested in Electric Vehicles) and AVERE (European Association for Battery, Hybrid and Fuel Cell Electric Vehicles), have been headquartered in Brussels for many years.

The transportation sector's energy consumption reached 208.9 petajoules (PJ) in Flanders in 2005, corresponding to 12.9% of Flemish total energy consumption. During 1990-2000, total energy consumption of the Belgian transportation sector increased by 23%, but only by 2% from 2000 to 2005, indicating that stabilization may be occurring. Road traffic accounts for the lion's share of this energy consumption: 57% passenger transport and 40% goods transport. Since 2000, the energy consumption of passenger transport on the road has increased by only 0.6%, but highway goods transport is up by 5.6%. The reason for this significant

Table 14.1 Number of new sold passenger cars in Belgium and the EU, and average fuel consumption per fuel type.

		Belgium (VITO)				EU (ACEA)	
		2002	2003	2004	2005	2003	2004
Number of vehicles (x 10³)	Gasoline	154	135	143	128	6'000	5'375
	Diesel	288	303	342	351	5'446	6'061
	Total	442	438	485	479	11'447	11'459
Average fuel consumption [l/100km]	Gasoline	7.1	7.0	6.9	6.7	7.2	7.2
	Diesel	5.8	5.8	5.7	5.6	5.8	5.8
	Total	6.3	6.2	6.0	5.9	6.5	6.4

difference is the continuing transition to more efficient diesel vehicles, together with increased availability and acquisition of more fuel-efficient vehicles, as shown in tables 14.1 and 14.2.

Table 14.2 New car sales in Belgium by CO₂ class/rating. (Data © VITO.)

CO ₂ - class	Gasoline vehicles				Diesel vehicles			
	2002 %	2003 %	2004 %	2005 %	2002 %	2003 %	2004 %	2005 %
A 0 - 100 g/km	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B 100 - 130 g/km	1.0	2.2	4.9	5.1	4.1	6.2	5.9	5.0
C 130 - 160 g/km	46.2	49.9	50.9	55.0	34.9	35.5	38.7	40.1
D 160 - 190 g/km	34.7	32.9	30.0	27.4	39.5	38.4	35.9	36.1
E 190 - 220 g/km	10.0	7.7	8.0	7.3	16.6	14.0	14.1	13.3
F 220 - 250 g/km	4.8	4.3	3.2	2.6	2.5	3.3	3.5	3.4
G > 250 g/km	3.3	3.0	3.1	2.6	2.5	2.6	2.0	2.0

The electric vehicle fleet in Belgium is limited to a small number of passenger cars and some dedicated-use (utility) vehicles. User experience has not been very positive, because -in most cases- battery problems result in high maintenance cost because of unsatisfactory post-sales service. This problem prevents electric vehicles from gaining market momentum.

For the Belgian consumer, price is the most important criterion in the purchase of a vehicle. Because there is little knowledge of the total cost of the life cycle, which is normally lower for hybrid vehicles, the market introduction of hybrid vehicles is still limited.

14.2

Policies and legislation

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

Effective from 2005, buyers of vehicles emitting low levels of CO₂ will obtain a reduction on their income tax amounting to 15% of the purchase price of vehicles with a CO₂ emission equal to or lower than 105 g/km and 3% for vehicles with a CO₂ emission equal or lower than 115 g/km. These amounts are limited to 4'080 Euros for the 15% tax reduction and 760 Euros for 3% tax reduction. In each case, reduction amounts are permitted only when income taxes are finalized, which is approximately two years after the acquisition of the vehicle.

An ongoing policy classifies electric vehicles as fiscally equal to the smallest vehicle available in the tax sheets, regardless of their power, and thus implies that they are subject to the lowest registration and circulation tax.

Currently, there are several systems that may define the environmental friendliness of a vehicle, including fuel type, CO₂ emission level, or homologation legislation (e.g., Euro-4), but these approaches are not sufficient to describe its complete impact on the environment. For this reason, VITO and other partners, including the VUB, have developed the Ecoscore[®] methodology. Climate change effect counts for 50% in a vehicle's final score, health effects 20%, impact on ecosystems 20%, and noise impact 10%. Pollutants considered are CO₂, CH₄, N₂O, CO, NMVOS (non-methane volatile organic substances), PM₁₀, NO_x and SO₂. This overall environmental evaluation thus combines different effects in one indicator in a methodology that is based on full well-to-wheel analysis (rather than just vehicle operation). The Belgian government is evaluating how this method can be incorporated into regulations.

A co-operative agreement exists between the Flemish region and its municipalities and provinces called 'Environment as the stepping stone to sustainable development'. This co-operative agreement offers municipalities and provinces a framework upon which to improve the environmental friendliness of all aspects of their operations. One aspect of the agreement deals with improving the environmental performance of public fleets. A tool developed by VITO screens fleets to generate recommendations for improving the efficiency of fleet utilization.

14.3

Research

VITO, the Vrije Universiteit Brussel and Green Propulsion are the key organizations 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 are companies and governmental organizations for which VITO provides solutions and advice for their problems and needs. The multidisciplinary skills and technological know-how of more than 500 researchers make this organization a crossroads of technology, where state-of-the-art and cutting-edge technologies are successfully blended into practical applications.

Energy Technology is one of VITO's centres of expertise. Effects of traffic on energy supply and the environment are investigated by the Vehicle Technology subgroup at the level of both the vehicle and the traffic system. Demonstration

and evaluation projects that test new technologies in alternative fuels and vehicles have been designed and conducted for industry, as well as for public authorities. VITO has more than 10 years of experience in emission measurement under real traffic conditions, with similar and deep experience not only in engineering/technical areas but also in issues related to the market introduction of new technologies (such as infrastructure, information, economics, policy and user acceptance).

In past years, VITO participated in Flanders' DRIVE project 'Development of a knowledge platform for hybrid vehicles', which is supported by the Flemish government. The main objective of the project is to develop a Flemish knowledge platform for the design and manufacture of vehicles with hybrid powertrains (including fuel cells, which will become more relevant in the longer term) and the subsystems/components for such hybrid powertrains. The general objective is to initiate, engage and technically support the development of hybrid vehicles and components by industry. Fields of current interest include system engineering, energy management, battery management, vehicle management, vehicle integration components and subsystems, simulation and testing.

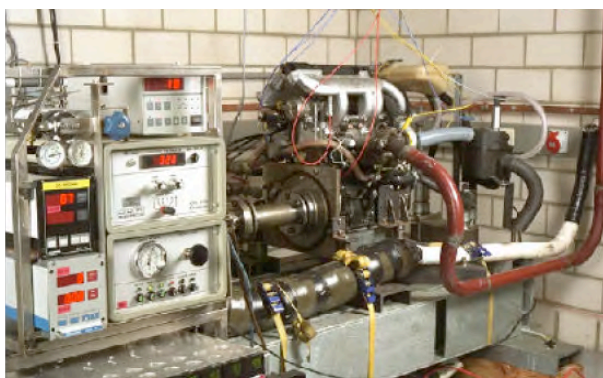


Fig. 14.1 Test bench for testing hybrid and electrical drivetrains and components at VITO. (Photo © VITO.)

VITO has a state-of-the-art test bench for hybrid and electrical drivetrains and its components (shown in fig. 14.1). The modular structure of this test bench allows the assessment of both entire drivetrains and individual components. Energy consumption, emissions and energy flows of all components are measured dynamically. Some of the recent technological projects are focused on the development of a hybrid van concept, Hevan (shown in fig. 14.2). This van also serves as a test and development bed for hybrid components and systems in real-life conditions.

VITO has upgraded three series-hybrid buses (electric low-floor Midi[®] city buses with range extender from Scania) and enhanced the durability and lifespan of a



Fig. 14.2 Hybrid van developed by VITO. (Photo © VITO.)

fast-charge station to ensure its proper long-term operation. Another completed bus project involved upgrading two series-hybrid buses (electric low-floor Midi[®] city buses with range extender from Van Hool) and their associated charging infrastructure by introducing the latest technology in energy storage and propulsion systems.

In 2005, VITO performed a detailed assessment of the possibilities and opportunities for ultracapacitors in electric vehicle and hybrid electric vehicle applications. Several ultracapacitors were tested with different battery technologies - valve regulated lead acid (VRLA), NiMH, Li-ion, and lithium polymer (LiP) batteries. In all cases, the energy pack (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 (cell balancing, equalization, vitalization, state of charge (SOC), state of health (SOH) and thermal management) that have been implemented in several applications in 2006.

Another project related to energy storage technologies concerns adaptive learning of state-of-charge applied on a lithium polymer battery pack. Here, the embedded controller does not need to be specifically 'initialized' when integrated into the battery pack, and the time when the battery pack is out of service (self-discharging) does not need to be tracked.

VITO is also participating in several international (mainly EU) projects, such as HyHEELS (FP6: ultracapacitor energy storage for use in hybrid- and fuel cell vehicles), and undertaking hybrid vehicle development projects with industrial partners to produce demonstration fleets of hybrid vehicles. Each fleet will be backed by an industrial consortium providing full service to vehicle users.

Vrije Universiteit Brussel

VUB (Vrije Universiteit Brussel) is a Dutch-language university located in the Brussels Capital Region. Created in 1969 as a partition of the (French-language) Université Libre de Bruxelles, it has more than 9'000 students and 2'000 personnel. In its Faculty of Engineering, the Department of Electrical Engineering (ETEC) has established since 1974 a tradition of R&D in electric, hybrid and fuel cell vehicles. ETEC's work emphasises characterising, testing and demonstrating electric, hybrid and fuel cell vehicles and components (such as electric drives and batteries). Since the early 1990s, simulation techniques have been developed to determine the dynamic behaviour (consumption, emissions) of thermal (gasoline, diesel, CNG) and electric (battery, hybrid, fuel cell) vehicles. A software tool (VSP) was developed to design and assess these types of powertrains of passenger cars, as well as of two-wheelers or heavy-duty applications. Evaluation of power management strategies in hybrid powertrains is a VSP speciality.

ETEC has a laboratory infrastructure available for testing, development and design of vehicles and components (especially DC/DC converters and ultra-capacitors for hybrid drivetrains) consisting of a roller test bench; two mobile data acquisition systems, which allow tests to be performed on a variety of vehicles; a test bench for electric two-wheelers; a battery test station; and laboratory test equipment for electric machines, electric drives, and power electronics. The system is shown in figure 14.3. The installed power is 800 kW, and the industrial test potential is up to 300 kW.

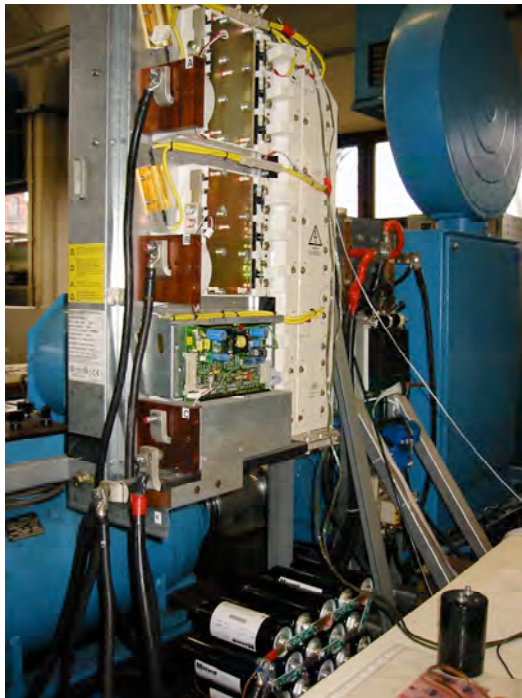


Fig. 14.3 Test bench at ETEC. (Photo © Vrije Universiteit Brussel.)

EU-funded projects in the field of electric, hybrid and fuel cell vehicles carried out by ETEC are for the FP5 (PRAZE, E-TOUR, and ELEDRIVE) and for FP6 (SUBAT, HARMONHY, INTELLICON and HyHEELS). ETEC is also active in standardisation in the field of electric vehicles (including IEC TC69, ISO TC22 SC21, CEN TC301 and CENELEC TC69X).

Green Propulsion

Founded in 2001 as a spin-off of the University of Liège, Green Propulsion is an independent specialist firm developing cleaner prototype vehicles - specifically, alternative fuel, electric, hybrid and fuel cell vehicles. Green Propulsion's in-house developed Metropol software can simulate and optimise a tailored vehicle to save time and money before actual hardware development. Green Propulsion thus offers proprietary software systems for complete vehicle integration: mechanical design, thermal management, electric wiring, electronic card development, vehicle tuning and monitoring. Recent projects include the development of an electric superkart having acceleration of 0-100 km/h in 2.5 s, a prototype parallel hybrid VW Lupo, an electric/series hybrid Microbus, a prototype combined series/parallel hybrid Renault Kangoo, and an Imperia Revival sport concept car (shown in fig. 14.4).



Fig. 14.4 Imperia Revival sport concept car. (Photo © Green Propulsion.)

14.4 Industry

The Belgian light-duty automotive industry consists principally of assembly plants (Ford Genk, Volkswagen Vorst, Opel Antwerpen and Volvo Gent) and suppliers of components. Regarding heavy-duty vehicles, Belgium has two bus and coach builders. One -Van Hool- specializes in bodies and chassis. Since building three A308H 9 meter hybrid public transport buses in the mid 1990s, Van Hool has not developed any other hybrids. However, it has recently developed a fuel cell bus for the U.S. market and plans to develop another for Europe.

Punch International -a Belgian technology company- plans to become an important player in hybrid vehicle technology. In 2006, it took over the Belgian ZF Getriebe subsidiary and renamed it 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 a 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. Market introduction of the parallel hybrid is scheduled for early 2009.

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

EV and HEV deployment in Belgium is limited. Because the taxation of diesel fuel is lower than that of 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 to Europe from sister companies, because its vehicle allocation to Belgium is too small.

Currently, no electric vehicles are sold in Belgium, although there have been in the past, as shown in figure 14.5.

Table 14.3 gives an overview of the different hybrids sold in Belgium for 2004-2006. The number of hybrids sold is increasing, but it is still marginal (only 0.17% in 2006) compared to the total car market.

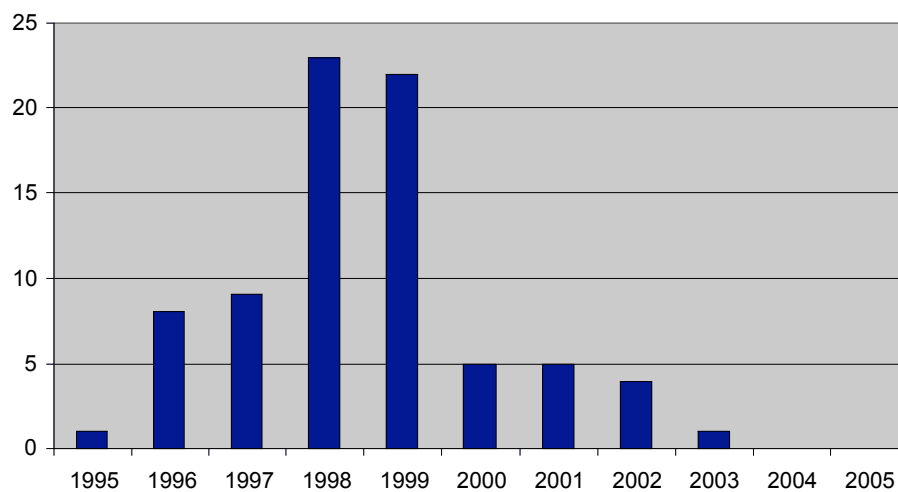


Fig. 14.5 Number of electric vehicles sold in Belgium for the period 1995-2005. (© Febiac.)

Table 14.3 Hybrid sales in Belgium for the period 2004-2006. (Data © Febiac.)

Make	Model	2004	2005	2006
Honda	Civic	5	3	86
Lexus	GS 450h	-	-	51
Lexus	RX 400h	-	106	289
Toyota	Prius	126	362	465
Total		131	471	891
Total car market		484'757	480'088	526'141
Share of hybrids		0.03%	0.10%	0.17%

14.6 Developments

Tax incentives, as well as high petroleum fuel cost, 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, zero emission vehicular performance and silent operation may be an impetus for implementing hybrids. Below are two examples of cases for potential users to help drive heavy-duty hybrid vehicle development:

1. In goods distribution, a big supermarket chain wants to avoid road congestion by supplying its shops from the central warehouse during the night, in which

case hybrid electric trucks could provide silent operation in urban and suburban areas in electric mode.

2. Similarly, in some cities, public transport companies can deploy hybrid buses to decrease noise levels and emissions in sensitive areas.

VITO and the other Belgian research organizations are actively seeking development projects for hybrid vehicle technology. These projects will target the development of components and powertrains, as well as complete vehicles, and can leverage the established 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 Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) has several advantages:

- Exchange of information among and experience with relevant public research and development programs in the transport sectors of various countries allows better preparation of Belgian national programs and projects.
- Informal personal contacts with experts from different countries and various organizations are a source of new ideas, collaboration and expanded co-operation in various scientific, technological and regulatory/standardization fields.
- 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://etec.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.

Other organizations with concerns in the hybrid and electric vehicle area and headquartered in Belgium are described in brief below.

AVERE

The European Association of Battery, Hybrid and Fuel Cell Electric Vehicles (AVERE) was established in 1978 under supervision of the European Community. It consists of 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 organises the yearly Electric Vehicle Symposium, EVS (1'500 participants). AVERE is divided in 15 national sections, and its Belgian section is ASBE.

The AVERE secretariat is now established at the Vrije Universiteit Brussel. For more information, see www.aver.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 electric and hybrid vehicles can make to help solve 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 realisation of the needed infrastructures.
- Organising 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 standardisation concerning electric vehicles and their infrastructure.

For more information, see www.citelec.org (in Dutch, English and French).

EPE

Department ETEC of the Vrije Universiteit Brussel was responsible for the founding -in 1985- of the European Power Electronics and Drives Association and Conference; this represents the world's largest annual event in the field of power electronics and electric drives (1'000 participants). A specialist work group is involved with (fast growing) electric and electronic aspects in the automotive industry, and EPE has a special chapter devoted to electric and hybrid vehicles.

For more information, see www.epe-association.org (in English).

Flanders' DRIVE

Flanders' DRIVE aims to strengthen the product development capabilities of Flemish suppliers to the automotive industry; the goal is to safeguard and to enhance the strategic competitiveness of this industry in Flanders on a European and global level.

For more information, see www.flandersdrive.be (in English).

VSB - Flemish Cooperative on Fuels Cells

The objectives of VSB (Vlaams Samenwerkingsverband Brandstofcellen - Flemish Cooperative on Fuels Cells) are to exchange information and define joint projects.

For more information, see www.vsb-vzw.be (in Dutch).

15 France

15.1 Introduction

Following a year (2005) characterized by vigorous R&D activity but few industrial programs in France, a significant improvement in synergy emerged in 2006 between these two principal agents of technological development. Because the selection of commercially available electric vehicles (EVs) and hybrid electric vehicles (HEVs) is limited, sales of EVs and HEVs have remained low. Nevertheless, new industrial initiatives begun in 2006 indicate improved markets in the near future.

15.2 Policies and legislation

On 30 December 2005, the French government implemented a new tax credit for the purchase of clean vehicles by private persons. The tax credit is € 2'000 for the purchase of EV, HEV, liquefied petroleum gas (LPG) vehicles and natural gas vehicles (NGV). The tax credit increases to € 3'000 if the transaction includes the destruction of a vehicle built before 1997.

Taking into account this new tax incentive, and in order to remain in compliance with the rules of the European Community, the French Agency for Environment and Energy Management (ADEME) has modified its financial support system. The current support programme is shown in table 15.1.

Table 15.1 Characteristics of the ADEME electric vehicle (EV) support programme.

Vehicle type	Incentive (€/EV)	Programme scope
Electric mopeds and scooters	400	Max. 1'000 EVs supported from 01/01/2005 to 31/12/2007 (ADEME-approved vehicles)
Specific electric vehicles	2'000 for payload under 500 kg 3'000 for payload over 500 kg	Max. 200 EVs supported from 01/01/2005 to 31/12/2007 (ADEME-approved vehicles)
Passenger cars and light utility EVs	Communities and companies: 3'200 Private persons: 1'200	Max. 1'000 EVs supported from 01/01/2005 to 31/12/2007

15.3 Research

The year 2006 was rich in new R&D projects focusing on EVs and HEVs. No fewer than 19 proposals have been received in response to the 2006 call for

proposals under the French R&D plan for clean and efficient vehicles (Plan VPE), which is funded at € 50 million this year (2007). These proposals may be categorized as follows:

- 3 projects on power electronics,
- 5 projects on electrochemical storage,
- 8 projects on hybrid architecture, and
- 3 projects on drivetrains.

15.4

Industry

Société de Véhicules Electriques (S.V.E.) has devised a high-performance electric traction system. This system benefits from the latest technological advances made in both range and drivability. It comes in two versions: the 'all electric' and the 'rechargeable hybrid'.

After perfecting its first prototype (the Cleanova I), S.V.E. decided to integrate its electric traction system into ordinary cars that are manufactured in France and elsewhere. Working this way, it has developed the Cleanova II (based on a Renault Kangoo platform) and the Cleanova III (based on a Renault Scenic platform).

Beginning in 2005, the Cleanova II has been chosen by the French government for a nationwide demonstration program dedicated to clean vehicles. Thirty vehicles are on the road today in different fleets. After one year of this demonstration, all users declared satisfaction with the product. Based on this positive experience 'La Poste' (the French postal service) is now working on a five-year plan to replace the majority of the 48'000 vehicles in its fleet with electric cars. Meanwhile, S.V.E. continues its developments with a view to industrial production in collaboration with technological partners, and it plans to market a vehicle commercially later in 2007.

After introducing two hybrid demonstration cars in January 2006, the French carmaker PSA Peugeot Citroën launched a massive industrial development program in mid-2006 to enable commercialization of diesel hybrid vehicles in 2010. Diesel hybrid vehicles combine a 1.6 litre HDi diesel engine, particulate filter (DPF) and new-generation Stop & Start system, with an electric motor, a power converter, high-voltage batteries and an electronic control unit. The vehicles are equipped with an automated manual gearbox. On average, hybrid HDi vehicles consume 3.4 litres of diesel per 100 km and emit 90 g CO₂/km. Over a combined cycle, hybrid HDi vehicles consume one litre of fuel per 100 km less than similar vehicles fitted with a gasoline hybrid drivetrain - a reduction of nearly 25%.

During the year, supercapacitors and lithium-ion batteries both attained industrial-scale production in France with the completion of two new production plants: one in Quimper for supercapacitors manufactured by batScap and the other in Nersac to produce Johnson Control - Saft batteries.

The EV maker Venturi revitalized its presence by participation in the 'Mondial de l'automobile 2006' exhibition. Venturi has launched production of the Eclectic, an urban 3-seater electro-solar vehicle that explores the concept of partial energy autonomy. Most vehicles are idle or passive for the 90% of the time they are stationary. However, unlike other vehicles, the Eclectic recharges its liquid-cooled nickel metal hydride (NiMH) battery with solar energy during the vehicle's moments of immobilisation. Eclectic offers peak speed of 50 km/h at a range of up to 50 km, of which solar recharging at full sun exposure can provide approximately 7 km per day. The Eclectic can optionally be recharged with one or more wind turbines, either affixed to the car roof when the car is stationary or to the ground with a mast. The combined wind and solar recharging can provide 15 km per day of range in windy areas. Full vehicle recharging from the grid requires 5 hours using a standard 16 A connection.

Production of 20 pre-series vehicles has begun, and a limited edition of 200 vehicles with specific equipment will be launched in June 2007. The purchase price will be € 24'000 plus VAT before a State subsidy of € 2'000. Higher levels of production are foreseen for 2009, with an estimated base price declining to € 15'000 plus VAT before a State subsidy of € 2'000.



Fig. 15.1 The Venturi Eclectic. (Photos supplied by ADEME.)

At the 2004 Paris Mondial, Venturi had unveiled its Fétish prototype, which projected a new departure in the image of the electric car that combined high performance, driving pleasure and environmental friendliness. The production version of the Fétish has now been made available after a two-year demonstration around the world. With its engine placed in the rear central position and a carbon

monocoque chassis, the Fétish architecture is comparable to that of a racing car. The monocoque is complemented by two deformable aluminium cells positioned at the front and rear of the vehicle. The Fétish uses liquid lithium-ion batteries, and the carbon chassis developed by Venturi is specifically designed to accommodate a large volume of batteries and provide exceptional collision protection for its occupants. This ultra-rigid design ensures the integrity of the battery pack in an accident.



Fig. 15.2 The Venturi Fétish. (Photos supplied by ADEME.)

The engine's 180 kW (disconnectable anti-skid), combined with the vehicle's road-holding quality, make the Fétish a homogeneous sports vehicle that accelerates from 0 to 100 km/h in under 5 s. Fétish offers a range of 250 km and -thanks to its onboard charger- completely recharges in 1 hour (under 30 kW three-phase) and in 3 hours if charged on the grid. Handmade and built to order in the Principality of Monaco, the Venturi Fétish is reserved for a very limited number of 25 buyers worldwide. The sale price of the Venturi Fétish is € 297'000 + VAT, with a 4-month construction wait.

15.5

On the road

Tables 15.2-15.4 present the number of hybrid and electric vehicles registered in France during 2006. Because the main French manufacturers (PSA Peugeot

Table 15.2 Registrations of electric passenger cars in France.

Electric passenger cars		
Registrations		
Make	Model	2006
Renault	Kangoo	6
Heuliez	Kangoo	3
Ford	Fusion	5

Citroën and Renault) have discontinued production, very few electric passenger cars have been sold in 2006. By contrast, the market for specialty light-duty EVs is growing. These vehicles are built by small companies for well-targeted niche applications that meet specific needs. Thanks to their greater availability, sales of hybrid cars are an order of magnitude greater than those of pure EVs.

Table 15.3 Registrations of electric light-duty goods vehicles in France.

Electric light-duty goods vehicles			
Make	Model	Payload [kg]	Registrations 2006
Carre Galo	Loustic	240	7
Citroën	Berlingo	500	2
Ecoville	Ecoville	210	7
Effedi	Elettrone	1'150	1
EVF	TE600A	720	1
Goupil	G3	1'090	179
Heuliez	Kangoo	460	4
Innovep	Original	520	12
JC Andruet	444	370	1
JC Andruet	666	600	3
Mega	Worker	540	9
Motrec	Original	1'000	1
Piaggio	Porter	530	8
Renault	Kangoo	510	13
Total			248

Table 15.4 Registrations of hybrid electric vehicles in France.

Hybrid electric vehicles		
Make	Model	Registrations 2006
Toyota	Prius 1.5	4'955
Lexus	RX 400h	1'111
Lexus	GS 450h	79
Honda	Civic 1.4 IMA	266
Total		6'411

15.6

Developments

Considering industrial and R&D activities together, 2006 has drawn a promising picture for the development of EVs and HEVs in France and Europe. Carmakers and their suppliers have embarked on an industrial dynamic, the goal of which is to market EVs and HEVs at a large scale by 2010.

15.7

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.

15.8

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 covering multiple clean solutions for transportation (EV, HEV, FCEV, etc.).
- <http://transports.edf.fr> (in French).
EV pages of the French utility 'Electricité de France' (EDF). Content: all activities of EDF in the EV domain, plus some technical and economical information.
- www.predit.prd.fr/predit3/homePage.fo (in English and French).
PREDIT is a program of research, experimentation and innovation in land transport. Although the website contains detailed institutional information in English, it does not provide a full English version of all content.

- www.psa-peugeot-citroen.com (in English and French).
The site of the French carmaker PSA Peugeot Citroën contains many documents on clean vehicles, EVs and HEVs.
- www.venturi.fr (in English and French).
The site of the carmaker Venturi contains all technical specifications of Eclectic and Fétish models, plus a vision of clean vehicles of the future.

16 **Italy**

16.1 **Introduction**

In recent years, interest at all levels of government in the introduction of cleaner vehicles in Italy has been growing, as has interest from citizens living in large urban areas. For instance, the April 2006 change in the Italian government (at both central and local levels) resulted in a further increase in government attention on the effect of energy and transport policies on climate change and the environment. New initiatives for subsidizing and promoting the use of cleaner vehicles and reducing the overall impacts of the transport sector on greenhouse gas (GHG) emissions respond to both global issues and local air quality. The Kyoto protocol commitment and the control of air quality under more severe emission limits (in compliance with national and European Union standards) drive political efforts. The growth of GHG emissions -well beyond the pathway expected to meet the Kyoto commitment- has required a revision of the 'National plan for CO₂ emissions', while continuous air quality emergencies in urban areas push local authorities to new restrictions in the transport sector. As a consequence, Italian citizens living in urban areas must comply with new rules aimed at reducing pollution and traffic congestion that include restricted circulation areas, 'car-free' days and dedicated parking lots for cleaner cars, among other measures.

Hybrid electric vehicles (HEVs) and battery-powered electric vehicles (EVs), including fuel cell vehicles (FCVs), are considered by political decision makers as well as by the general public to be prominent technological players but -at least as short- and medium-term prospects- not key problem solvers. Nevertheless, there are actions and efforts that favour the introduction and promotion of research and development (R&D) for these electrically propelled vehicles. The major Italian carmaker Fiat -thanks to recent positive market results- is enlarging its line by offering cleaner vehicles that burn natural gas (natural gas vehicles - NGVs) or liquefied petroleum gas (LPG) in mono- or dual-fuel configurations. But Fiat does not yet consider HEVs, EVs and FCVs ready for the market, and so it limits its major efforts on these vehicles (HEV and FCV) to R&D. By contrast, there are various small enterprises that take advantage of different political initiatives to develop, produce and commercialise EVs and HEVs in limited numbers. In addition, the 6th Framework Programme of the EU -formally closed on December 2006- has expanded the availability of financial resources to various Italian industries, research organizations and municipalities so that they can join efforts and explore synergies for the R&D and demonstration of these vehicle technologies.

The results of these efforts are apparent in some market numbers for 2006, which show a significant increase in the share of energy-efficient vehicles (in the last two years, the sale of diesel passenger cars exceeded 58% of the total Italian market, and the sale of gas-fuelled vehicles tripled from the 2004 figure). Sales of hybrid passenger cars sales are growing -although there are still less than 4'000 on Italian roads- and sales of EVs are growing as well, mainly in the category of quadri-cycles (light 4-wheel EVs) and power-assisted bikes. These numbers validate the growing perception and participation of the general public in initiatives favouring a better environment.

16.2

Policies and legislation

Italian transport policy is driven primarily in two main directions that are in line with the agreed EU policy for the protection of the environment:

1. Reduction of CO₂ emissions to meet the Kyoto Protocol target of 6.5% reduction in 2010 compared to 1990.
2. Improvements of air quality in urban areas by combating traffic congestion and restricting private mobility in polluting cars.

A set of regulations and initiatives has been put in place to assure sustainable mobility as part of the general environmental plan. The introduction of more severe emission standards (EURO-4 in 2005) and the preparation for the application of EURO-5 emission standards for 4-wheel vehicles and EURO-3 for motorcycles have been the basis for implementation of specific fiscal and financial actions by central and local governments. Vehicle park renewal (fleet turnover to lower emissions) is still a chief objective of these initiatives.

- Voluntary agreements have been signed to favour the diffusion of gaseous-fuelled vehicles and the substitution of older motor vehicles with cleaner ones.
- Car-sharing initiatives with cleaner vehicles are promoted in various cities.
- Property taxes of passenger cars are now modulated according to their emission standards and engine/motor power. Owners of cleaner cars -such as NGVs, LPG vehicles, HEVs and EVs- benefit from significant reductions in property tax levies: owners of EVs pay no property tax for the first 5 years after registration and subsequent property tax is discounted 75% in comparison with an analogous conventional vehicle.

Another important policy instrument is the National Research Plan, which has provided financial resources in the last several years to support R&D and production programmes for vehicle technology in the areas of components (engines, hydrogen storage, batteries, fuel cells) and complete vehicles (HEV and FCV).

Subsidies and non-financial incentives

In the last decade, overall financial commitments to promoting sustainable mobility have exceeded € 400 million directly from the central government and -in some cases- in collaboration with local authorities. About 35-40% has been dedicated to the introduction of HEVs and EVs. During 2006, central and local governments continued to promote fleet turnover (renewal) by scrappage or ‘cleaning’ of polluting, older vehicles. The financial support for HEVs and EVs of various types is summarised in table 16.1.

Table 16.1 Major subsidy schemes launched or in place in 2006 for the introduction of cleaner vehicles.

Action	Budget [million €]	Incentive	Promoter
Promotion of sustainable mobility	8.34	Depends on city size	Ministry of Environment
Public fleet renewal	90	Up to 60% for EVs	Ministry of Environment
Car park renewal	--	€ 2'000 + lower property tax	Ministry of Economic Development
Renewal of public regional fleets	1.5	Up to 50% of retail price	Lombardia Region
Renewal of public taxis	0.85	€ 6'000 up to 35% of retail price	Lombardia Region
Renewal of commercial vehicles	8.0	Up to 30% of retail price	Lombardia Region

In addition to those in table 16.1, there were other funding schemes sponsored by local authorities (Region of Lazio, Province of Milan and cities of Catania, Florence, Milan, Modena, Naples, Palermo, Reggio Emilia and many others). In many cities, improvements in air quality have been pursued through measures aimed at limiting private car circulation. Traffic restrictions for defined weekdays and over continuous periods -together with the enlargement of ZTL (restricted traffic zones) areas- have been thoroughly applied, accompanied by measures that favour cleaner vehicles. For example, EVs and HEVs can freely circulate in most cities of Italy on days and in areas restricted for conventional vehicles. Some cities have created dedicated parking lots for EVs with a free-of-charge ‘electric refuelling’ and parking service (in Florence, Rome and Milan). In 2006, the city of Milan created a network of 20 EV parking stations with a total of 92 recharging facilities free to EV users.

Law 166/02 - Ministry of Environment and Territory

Law 166/02 made subsidy funding of about € 90 million available for reducing emissions of public fleets. Of the funding, 60% was dedicated to the purchase or leasing of EVs and HEVs of any category, except heavy-duty vehicles (large buses and trucks). Financial support was directed at public fleet users in the form of a discount rate varying from 30% to 65% of acquisition cost in order to achieve approximate equality of the retail price of these vehicles and those of similar conventional vehicles. In absolute terms, the maximum subsidy varies from about € 300 (minimum) for power-assisted bikes to about € 41'000 for electric or hybrid-electric minibuses. As of autumn 2006, about 2'300 HEVs and EVs had been acquired through this funding scheme.

Municipal subsidy

The year 2006 saw both continuation and completion of schemes by municipal authorities to provide financial support for the introduction of EVs and HEVs. A few of the most recent initiatives show the increased interest and effort of local authorities for these technologies:

- The city of Rome -with a total funding of about € 1 million over 3 years- has been able to support the purchase of almost 3'000 electric scooters and power-assisted bikes.
- The city of Modena's project 'Speed Bike' -initiated in 1997- has been able to put in service an EV fleet of about 1'500 units, with only limited funding. This number is 30 times greater than the number of EVs it had in service in 1997.

16.3**Research**

Research and development activities are carried out under various supporting instruments. European Union (EU) research programmes -especially the 6th Framework Programme formally completed in 2006, but with many projects still ongoing- have been the primary source of funding and research integration at European level. Table 16.2 summarizes major EU projects ongoing in 2006 that enjoyed large or significant participation by Italian research organizations and industry.

Table 16.2 Major EU projects in 2006 with Italian participation.

Project title	Topic	Italian participants
HYCEPS	Novel HEV configurations	CRFiat
ILHYPOS	Advanced supercapacitors with ionic liquids	ENEA, Arcotronics, University of Bologna, Microvett
ILLIBATT	Novel Li batteries with ionic liquids	ENEA
ZERO REGIO	Lombardia and Rhein-Main towards zero emission: Development and demonstration of infrastructure systems for hydrogen as an alternative motor fuel	City of Mantova, CRFiat, EniTecnologie, Lombardia Region, Sapio, University Luigi Bocconi
HyWays	Development of a European hydrogen energy roadmap, through a comparative analysis of regional hydrogen supply options and energy scenarios, including renewable energies	ENEA, GE Oil & Gas Nuovo Pignone
HarmonHy	Assessment of the activities on hydrogen and fuel cell related regulations and standards on a worldwide level	ENEA
HYSYS	Fuel cell hybrid vehicle system component development	CRFiat, ENEA, Rivoira, Selin Sistemi
HY-CO	Co-ordination of national R&D programmes in the field of hydrogen and fuel cells to established a European research area - <i>support to the Italian Ministry of Research</i>	Italian Ministry of Research and Education
INNOHYP-CA	Innovative high-temperature routes for hydrogen production	ENEA
FCTESTQA	Fuel cell testing and standardization	Ansaldo FC, CESI, ENEA
FEMAG	Flexible Ecological Multipurpose Advanced Generator	Labor, AGT, Azienda Sanitaria Locale Roma E, Nouva Fima, Università degli Studi di Roma Tor Vergata

Efforts of Italian central and local governments have also concentrated heavily on hydrogen and fuel cell R&D. Figure 16.1 briefly sketches most projects on fuel cells, hydrogen and EVs/HEVs (as fuel cell hybrids) now running in Italy.

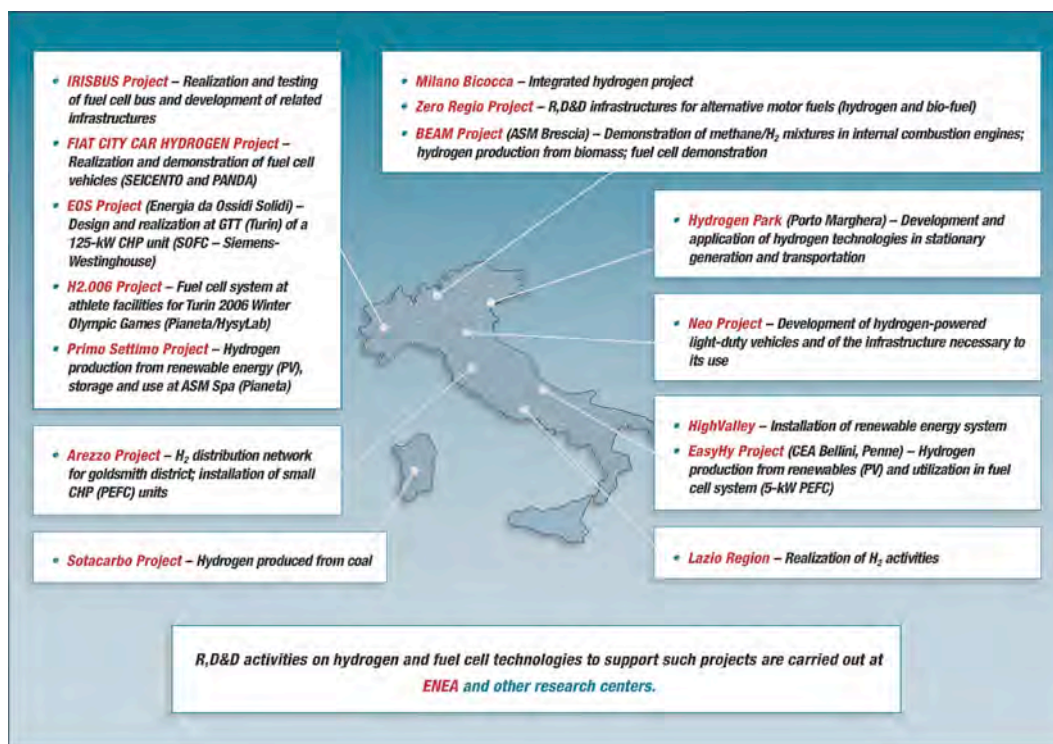


Fig. 16.1 Summary of Italian RD&D projects on hydrogen and fuel cells that are running in Italy.

Hydrogen and fuel cells R&D in the National Research Plan

In July 2005, the large programme ‘New systems for energy production and management’ was begun formally, upon the approval by the Ministry of Research and Education of 14 projects that range from basic research to application-oriented analyses. These projects are summarised in tables 16.3 and 16.4. The projects have a duration of almost 3 years at an overall public funding of about € 90 million. All 14 generated preliminary results in 2006.

Table 16.3 Hydrogen projects approved in 2005 as part of the National Research Plan.

Co-ordinator	Project title	Public funding [million €]
ENEA	New technologies and innovative processes for the future of hydrogen economy	10.668
Fiat Research Center	Microcombustor matrices for hydrogen	6.056
Consorzio Interuniversitario per lo Sviluppo dei Sistemi a Grande Interfase	Hydrogen production and storage in nanomaterials	4.296
Consorzio IPASS	Innovative systems for hydrogen production from renewables	6.882
Consorzio Pisa Ricerche	Integrated systems for hydrogen production and utilization in distributed power generation	5.506
University of L'Aquila	Hydrogen production from light multi-fuels and storage in porous materials	6.882
University of Padoa	Hydrogen production from biological processes	5.506
University of Perugia	Hydrogen production by refinery off-products and utilization in transportation (railways) and distributed power generation	4.818
Total public funding [million €]		50.614

Table 16.4 Fuel cell projects approved in 2005 as part of the National Research Plan.

Co-ordinator	Project title	Public funding [million €]
ENEA	Development of fuel cell technologies and systems for their applications	7.484
CNR-ITAE	PEFC and SOFC development New materials and applications	9.729
University of Genoa	Development of a pressurized molten carbonate fuel cell (MCFC) system and 500 kW demonstration plant	4.989
University of Perugia	New MCFC systems for distributed generation	7.484
University of Rome 'La Sapienza'	Development of protonic membranes for PEFC applications	4.294
INSTM	Hybrid and inorganic nano-systems for the development of fuel cells	4.365
Total public funding [million €]		38.345

Hydrogen storage in metal hydrides for fuel cell vehicles

This project -which was co-ordinated by the Italian National Agency for New Technology, Energy and the Environment (ENEA) and with the participation of SAES Getters, CNR-ITAE and CNR-INFN- has been completed with the development of a hydrogen storage prototype, shown in fig. 16.2. A complete test facility for the study and setup of full-scale systems was also a product of this work.

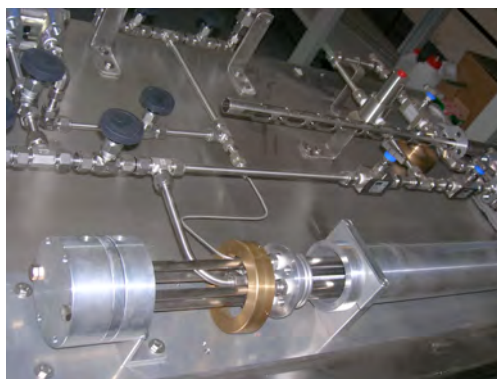


Fig. 16.2 Prototype of hydrogen storage tank in metal hydride, developed by ENEA. (Photo supplied by ENEA.)

HYSYLAB research

The research laboratory HYSYLAB (Hydrogen System Laboratory) -part of the Environment Park in the Piemonte Region- is involved in a variety of hydrogen projects. In the field of fuel cell electric vehicles (FCEVs), the laboratory is developing a hybrid hydrogen scooter called HYSYRIDER[®] (see fig. 16.3), a flexible, clean, non-polluting means of transport. Proof tests in outdoor as well as in indoor application have yielded good results in measures of safety, stability, autonomy, flexibility and comfort. HYSYRIDER[®] is based on a hybrid architecture: the fuel cell (300 W, 20 cells) works in parallel with a battery pack (7.2 Ah). The hydrogen is stored in a hydride vessel (200 ml) that has the capacity to allow a couple of hours of operation at maximum speed (20 km/h).



Fig. 16.3 HYSYRIDER[®] hybrid hydrogen scooter developed by HYSYLAB. (Photo supplied by ENEA.)

Fiat Group

The Fiat Group has been significantly restructured during 2006 as a new company and new business units. Activities in HEVs are concentrated mostly in EU projects, while corporate R&D is devoted primarily to FCVs. A full-power (no hybrid) Panda Hydrogen has been further developed and optimised (fig. 16.4), and a fleet of these to be used in the city of Mantua is under construction for the EU project Zero Regio.



Fig. 16.4 Full-power fuel cell Fiat Panda and the fleet under realization for the Zero Regio project. (Photos supplied by ENEA.)

In addition, Irisbus, the bus and truck manufacturer of Fiat group, has followed up development of the fuel cell powered city buses for Turin and Madrid with its Daily hybrid FCV, a 7.5 m minibus named Europolis that features 12 h operating capability between refuelling, a payload of 40 passengers, a Zebra battery, six carbon-fibre pressurized hydrogen storage bottles (149 litres at 350 bar), an AC asynchronous 3-phase (93 kW - 1'000 Nm) electric motor and a polymer electrolyte membrane (PEM) fuel cell (60 kW max).

ENI Group

The Italian oil company ENI is strongly committed in upgrading its refuelling stations to include new fuels in the distribution network. In 2006, two AGIP



Fig. 16.5 AGIP MultiEnergy station for hydrogen refuelling. (Photos supplied by ENEA.)

MultiEnergy stations for hydrogen refuelling were completed and made operational: the first in July at Collesalveti and the second in November for the Zero Regio project at Infraserp Höchst Industry Park in Frankfurt, Germany. Figure 16.5 is a view of the AGIP MultiEnergy station for hydrogen refuelling in Frankfurt.

The AGIP MultiEnergy station at Collesalveti -partially funded by the Tuscany Region- is an integrated generation and refuelling station that brings together renewable energy sources (photovoltaic and wind systems and a micro-turbine) into a fully energy independent system. Figure 16.6 presents a complete layout of the MultiEnergy station.



Fig. 16.6 AGIP MultiEnergy station at Collesalveti (Tuscany Region). (Picture supplied by ENEA.)

Piaggio

Piaggio is one of the largest manufacturers of scooters in the world and is strongly committed to developing cleaner vehicles (even commercial vans). Its engine research is focused on an ambitious medium-term project: the hybrid HyS (Hybrid Scooter). Two HyS prototypes were unveiled in April 2006 and made available to the city of Milan for a joint demonstration.

The HyS has been developed in two versions, which are based on the Vespa LX 50 and the Piaggio X8 125. In this vehicle, a 4-stroke engine is combined with an electric motor in order to attain the same velocity on the open road as that attained by standard gasoline engine power. The vehicle has no emissions in limited traffic areas, where it functions as an electric, and it has the added advantage of being

able to recharge its batteries while in motion. Figure 16.7 shows the dashboard of the Vespa HyS with two fuel gauges: one for the gasoline and the other for the state of the charge of the battery.



Fig. 16.7 Vespa hybrid scooter dashboard. (Photo supplied by ENEA.)

NEO van

Micro-vett -a small enterprise that is leader in the production and commercialisation of commercial vans- is working in collaboration with Arcotronics fuel cells, ENEA and Sapio on a fuel cell powered commercial van (fig. 16.8) called NEO.



Fig. 16.8 NEO (No Emission Outfit) hybrid fuel cell commercial van. (Photo supplied by ENEA.)

NEO (No Emission Outfit), which is funded by the Emilia Romagna Region, is a hybrid vehicle with a PEM fuel cell (60 kW) combined with a Zebra battery (32-42 kWh, according to the use) and equipped with a hydrogen tank of 60 litres (at 300 bar). Figure 16.9 shows a tentative vehicle layout.

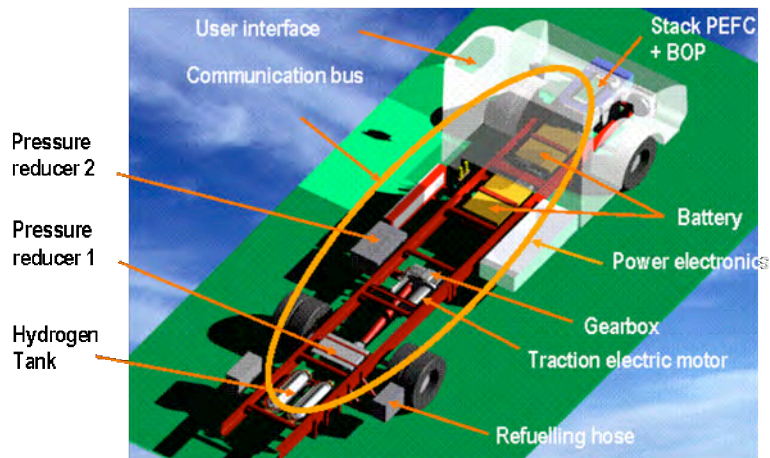


Fig. 16.9 Layout of the NEO hybrid fuel cell vehicle. (Picture supplied by ENEA.)

FAAM

FAAM is a producer of batteries and 2- and 4-wheeled EVs that -over the last few years- has independently as well as in collaboration with foreign partners conducted research into new vehicle solutions. FAAM earlier developed a 2-wheel fuel cell vehicle with hydrogen stored in metal hydrides, but in 2006 it brought out a lightweight FCV (fig. 16.10) based on the pure EV Smile, of which 50 were deployed in a special version at the 2006 Turin Winter Olympics. In this FCV, hydrogen is stored in a pressurised tank and a small PEM fuel cell (3.6 kW) is employed in hybrid connection with a small lead acid battery. This combination enables about 150 km range.



Fig. 16.10 FAAM fuel cell vehicle Smile. (Photo supplied by ENEA.)

16.4

Industry

EV and HEV industrial activity in Italy fluctuates according -in large measure- to public funding. A recent survey of the Italian EV Association CIVES has confirmed that a large number of industrial concerns in Italy are involved with the production and/or commercialisation of EVs and HEVs. A complete range of such vehicles is available, from power-assisted bikes to 12 metre hybrid buses. Apart from the large vehicle manufacturers (IVECO, BredaMenarini, Toyota, Honda, Peugeot, Piaggio), there is a large group (about 50) of small and medium enterprises that produce and commercialise most of the EVs and some small HEVs sold in Italy.

Italy's components producing sector features only lead-acid batteries (various companies), electric motors and electronics for EV and HEV application. For example Altra -a joint venture between IVECO and Ansaldo- is one of the larger suppliers of electric and hybrid buses, as well as complete electric drivetrains for small and large EVs and HEVs. New technology batteries (e.g. Zebra: sodium-nickel chloride and lithium) have been installed in various vehicles, but they all come from foreign manufacturers. The main contribution of Italian industry is to electronics for battery management and system integration.

16.5

On the road

The overall vehicle fleet in Italy has been growing almost constantly over the last few years, reaching about 45 million on the road. The share of EVs is quite negligible but has gradually increased over the last 15 years. Starting from early 1980s through 1991, a total of 33'000 EVs had been sold, but this is less than one-third of the total EVs in service according to CIVES estimations as of the end of 2005. A steep growth in sales occurred with the increase of subsidies and promotional incentives at the close of the 1990s.

Large EVs (passenger cars, commercial and specialty vehicles, minibuses and buses) are used mostly in fleets heavily supported by public subsidies. Private users -with a few exceptions- are buying mainly electric scooters and power-assisted bikes with -in many cases- public financial support. This situation is mostly determined by the significant price premium (in most cases, cost multiples by a factor 2 to 3) of EVs in comparison with similar conventional vehicles.

Until 2004, the only HEVs on the market were hybrid buses and minibuses. The population of HEVs is now growing with strong momentum thanks to the introduction of hybrid passenger cars from Honda, Lexus and Toyota during 2004 to 2006. In 2004 495 HEVs were sold, in 2005 this number was 1'112 and in 2006

the number of HEVs sold was 2'170. The limited (partially subsidised) price premium over comparable conventionally powered passenger cars has opened up this market, and future subsidies may be unnecessary. CIVES and the Ministry of Environment estimate that about 50% of HEVs have been subsidised until today.

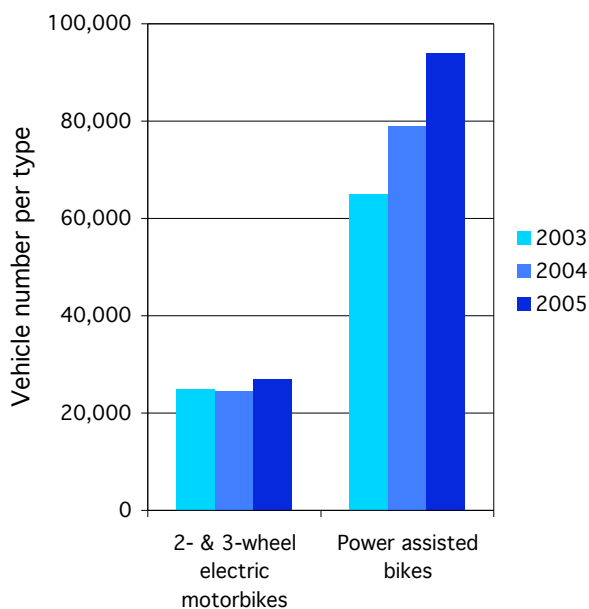


Fig. 16.11 Estimated populations of light electric vehicles (EV) in Italy as of December, for the years 2003-2005. (Sources: CIVES and ENEA.)

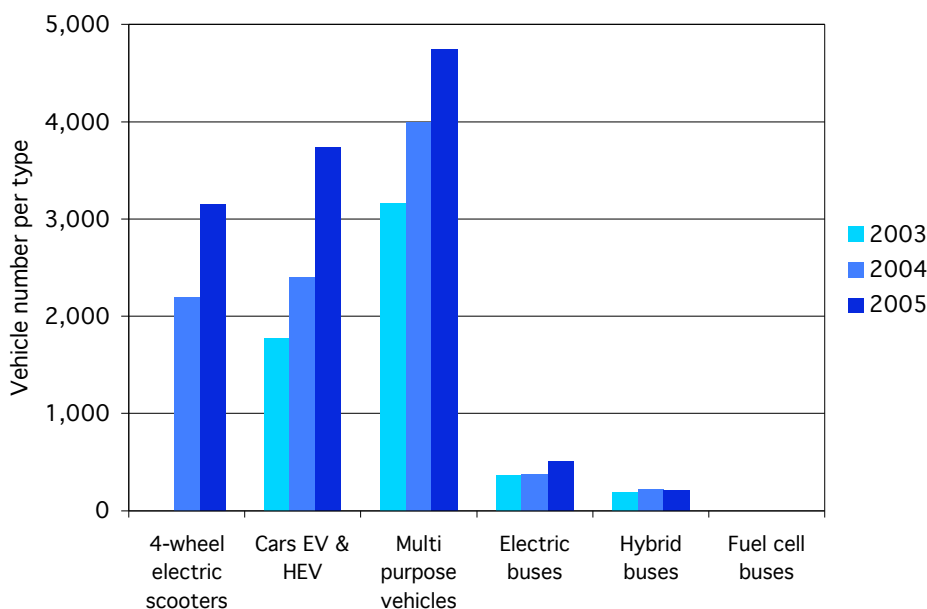


Fig. 16.12 Estimated populations of electric vehicles (EV) and hybrid electric vehicles (HEV) in Italy as of December, for the years 2003-2005. There is no data for 4-wheel electric scooters in 2003. The number for fuel cell buses is 1 for all years. (Sources: CIVES and ENEA.)

Figures 16.11 and 16.12 present estimates made by CIVES of EVs and HEVs totally sold in Italy through December 2005. More detailed statistics are difficult to obtain because not all EV categories are officially registered, so CIVES periodically surveys manufacturers and importers to update its market figures.

The population of EVs and HEVs is accelerating, given the estimated benchmark population of 95'000 such vehicles as of the end of 2003.

16.6

Developments

CIVES is analysing the situation and market outlooks will be estimated for various scenarios. Prospects for the near term (up to about 2012) are positive, given the initiatives already approved for promoting the renewal of the vehicle fleet by cleaner cars, such as the financial incentives to private users for 2007. Various non-monetary incentives also favour the circulation of cleaner cars in urban areas: parking lots with free recharge for EVs and no limitation in restricted areas and days. Attention is being paid to specific market niches, their requirements and their advantages. Political plans and financial incentives have been allocated for supporting the use of cleaner taxis and commercial vans. Deployment of new e-scooters and power-assisted bikes are central to local authority strategies for removing polluting older motorbikes and scooters.

In this generally positive climate, there is general expectation that a self-sustained market (mainly for large EVs) will now develop, enabling producers gradually to reduce (through volume production) the price differential to a minimal gap for private users, a differential that could be closed by the relatively small subsidy now available to private buyers (10-20% of retail price).

16.7

Benefits of participation

Participation in the activities of IA-HEV can help meet the needs of industry and expectations of the general public for vehicle availability, suitability and R&D targets. Specific benefits include:

- Acquisition and sharing of information on relevant R&D programmes that can better assist in the definition of national activities and priorities.
- Comparison of experiences and case studies, particularly in promotional and demonstration programs, to accelerate the introduction of the parallel activities in different contexts.
- Engagement in informal personal contacts with experts from different countries and from various organizations to gain new ideas, collaborate and enlarge co-operation in various scientific, technological, and regulatory/standardization fields.

- Potential establishment of complementary relationships responsive to the European framework programmes for EU members and to the International Partnership for a Hydrogen Economy (IPHE) for the international member countries.

16.8

Further information

Further information regarding EV and HEV related activities in Italy can be obtained from the following websites.

- www.ceiuni.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 National Section of the European Association for Battery, Hybrid and Fuel Cell Electric Vehicles (AVERE). The website gives a lot of information about the market offerings of vehicles, the status of laws and the major initiatives at national and local levels. It is also a source for contacts and addresses of all members of CIVES of 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, which is located at the University of Genova. The information contained in the website addresses all public transport, not only electric/hybrid road vehicles. There are statistics and technical description of buses.
- www.enea.it (in English and Italian).
The ENEA website presents programs, projects and activities in general terms, but it also includes special reporting about energy and environment.
- www.minambiente.it (in Italian).
The website of the Ministry of the Environment and Territory Safeguard contains up-to-date information about environmental legislation, initiatives and press releases. A specific area is dedicated to sustainable mobility, renewable energy and the report on status of the environment.
- www.regione.lombardia.it (in Italian).
This is the website of Lombardia Region. The website is mainly in Italian and 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 working on hydrogen in the region. It contains information about projects, programmes and events.

17

The Netherlands

17.1

Introduction

Hybrid vehicles have been commercially available in the Netherlands for several years, and the Toyota Prius II that entered the market in 2004 has proven quite a sales success. Lexus and Honda hybrids are now entering the market as well. Electric vehicles (EVs) have been in the market for many years, but sales are almost nil now and commercial availability is very limited. Transport application of EVs was mainly as utility vehicles in cities and as delivery vans by local grocery sellers in urban areas. Electric scooters have been introduced into the market, but success has been very limited because of -in part- unacceptable product quality, creating a negative image. The principal barrier to increased sales of hybrid vehicles remains the limited availability of models.

Ongoing policies and legislation of the Dutch government for reducing CO₂ emissions and improving air quality will encourage society and research institutes to devote more attention to the hybridization of vehicles and transportation systems. Relevant automotive research and development organizations are concentrated in the southeast part of the country and have good relationships with automotive production plants in Germany and Belgium.

17.2

Policies and legislation

Policies

A principal policy of the Dutch government is to reduce CO₂ emissions and improve air quality. The effect of this policy on the transportation sector is that the combustion emissions of particles from such diesel powered vehicles as public transport buses, trucks and distribution vehicles must be reduced. Financial support through government subsidies encourages the installation (retrofitting) of particulate filters on diesel vehicles.

Government programmes with financial support also focus on general aspects of reducing CO₂ emissions in transportation, reducing emissions of particles and reducing noise levels in cities. A programme called 'CO₂ reduction in personal transport and in goods transport' is in effect, and it provides rebates for investments in fuel-efficient vehicles and transportation systems. A programme for supporting the use of biofuels in vehicles is also now active.

The concept of 'eco-driving' has been reinforced by the introduction of an intensive publicity campaign targeting not only car drivers but truck and bus drivers as well. Obtaining a driving license is now conditional on taking a course on the principles of eco-driving (fuel efficient driving behaviour). More information on this programme is available at www.ecodrive.org. A speed limiter (acceleration pedal governor) and cruise control are among the fuel-efficient vehicle modifications encouraged by this programme.

Legislation

Special tax rules have been introduced to encourage the purchase and ownership of electric vehicles and hybrid vehicles. Electric vehicles are exempted from road tax. Since mid 2006, the purchase of a hybrid vehicle qualifies for a substantial rebate (up to € 6'000) to encourage sales. Also, regardless of fuel or technology, very energy efficient cars get a tax bonus that may reach € 1'000, depending on the fuel efficiency category label the specific model has earned. Car dealers in the Netherlands are required to post an energy consumption label on the new cars in their showrooms to provide data on energy consumption (in litres per 100 vehicle-km) and the CO₂ emission rate (in grams per vehicle-km).

Under the rubric of improving air quality in cities, the government is considering establishing so-called urban environmental areas that are subject to specific vehicle entry rules.

17.3

Research

The Netherlands boasts several automotive research institutes:

- TNO Industry & Technology/Automotive.
- Technical University Eindhoven.
- HAN University of applied sciences, Arnhem.
- Automotive Technology Centre (ATC).
- Competence Centre for Automotive Research (CCAR).
- Drive Train Innovations (DTI).

These institutes have now been concentrated around the city of Eindhoven in the southeast part of the country, with good connections to the automotive production and component supplier areas both in Belgium and near Aachen in Germany. Numerous co-operative ventures are under way - not only with research institute partners but also with car and truck manufacturers in those countries.

Most car manufacturers with which Dutch enterprise is involved have been modifying their strategies for developing components and subsystems, shifting research and development activity toward the support of component supply companies. Suppliers are now developing and producing components on the basis

of requirements formulated by the car industry at large, and the concept and practice of ‘co-makership’ (joint production) is getting stronger.

The Energy research Centre of the Netherlands (ECN) researches fuel cells in general, but also includes work on specific applications such as vehicles.

Research in the Netherlands covers not only components and vehicle systems, but also transportation systems at large. Universities, as well as several small consultant firms, are performing such transportation systems research.

Public-Private-Co-operation (PPS)

According to its website, PPS Automotive is a market-driven innovation programme set up and steered by the Dutch automotive industry to focus automotive innovation on technologies that match the strengths and ambitions of the Dutch automotive sector, as well as the future opportunities for and challenges facing the international automotive industry. Within specific areas in the automotive industry, the Netherlands plays a significant role by leading innovative companies that are involved in automotive activities worldwide. Such focused innovation will contribute positively to both international competitiveness and the economic position of the Dutch automotive sector. More information on this programme may be found at www.pps-automotive.nl.



Fig. 17.1 Dashboard instrument indicating operation modes of a hybrid electric powertrain. (Photo courtesy PPS Automotive.)

17.4 Industry

The automotive industry has:

- a truck manufacturer: DAF Trucks (a PACCAR company),
- a manufacturer of public transport buses and touring cars,
- an assembly factory for DaimlerChrysler (‘smart’) and Mitsubishi cars,
- various manufacturers of semi trailers, trailers and truck bodies, and
- various automotive component manufacturers.

The one Dutch truck manufacturer -DAF Trucks- is fully integrated into the U.S.-based PACCAR company, making it a worldwide player in the truck industry. The market share of DAF Trucks in Europe has grown steadily over the last decade.

As co-development and co-makership have expanded dramatically over the past 10 years, the Dutch automotive institutes and component industry may have an opportunity to participate significantly in the European arena of vehicle manufacture.

17.5

On the road

Vehicle fleet registration in the Netherlands (as of January 1, 2006) is shown in table 17.1. The population of approximately 7 million cars is equivalent to 1 car per 2.3 inhabitants.

Table 17.1 Vehicle registration in the Netherlands as of January 1, 2006.

Vehicle category	Approximate number
Mopeds	600'000
Motorcycles	550'000
Cars	7'000'000
Distribution vans	900'000
Trucks	142'000
Buses	11'000
Total	9'203'000

Electric vehicles

The electric vehicle population is approximately 500, which consists of mainly cars and utility vehicles (electric vehicles licensed to operate on public roads). The electric vehicle market still encounters significant barriers, including high purchase price, relatively short driving range and limited availability of service support. However, the Netherlands can boast a manufacturer of electric bikes, Sparta, that produces the Ion, a pedal-assist e-bike, for approximately € 2'000. This bike is very popular, which is not surprising in a country with about 20 million bicycles - more than the number of inhabitants in the country.

Hybrid vehicles

Hybrid vehicles include only a few commercially available models of cars: Toyota Prius II and Honda Civic, which were recently joined by the Lexus RX

400h and GS 450h. Of these, the Toyota Prius enjoys the highest sales in the country, with about 5'000 units on Dutch roads at the end of 2006. No hybrid goods vehicles or hybrid buses are commercially available. Advanced technology vehicles are used only in demonstration projects, such as the fuel cell buses in the European CUTE (Clean Urban Transport for Europe) project, of which three buses are operational in Amsterdam, the capital city of the Netherlands.

17.6

Developments

During 2006, DAF Trucks demonstrated a prototype hybrid distribution truck. Development of this prototype vehicle teamed DAF engineering with the research capabilities of TNO Automotive and the University of Eindhoven.



Fig. 17.2 DAF Trucks presented a prototype hybrid distribution truck in 2006. (Photo supplied by SenterNovem.)

Several initiatives for demonstrating advanced production techniques for biofuels are under way, and demonstration projects for the use of these fuels in vehicles are in preparation. The government will support these projects with subsidies.

17.7

Benefits of participation

The Netherlands identifies the following key benefits of participating in IA-HEV:

- Obtaining information from other countries around the world on their advanced transportation and automotive technology developments.
- Jointly producing studies and having opportunities to get national research bodies involved in international/cross-sectional work.
- Developing guidance for preparing Dutch national programmes from the results of programmes undertaken by other countries and cultures.
- Participating in a worldwide network of transportation experts, research institutes and government officials responsible for transportation.

17.8

Further information

Further information on Dutch activities in advanced automotive (and hybrid) technologies may be obtained from the websites listed below.

- www.atcentre.nl (in Dutch and English).
Automotive Technology Centre.
- www.ccar.nl (in English).
Competence Centre for Automotive Research.
- www.ecn.nl (in Dutch and English).
Energy research Centre of the Netherlands.
- www.ecodrive.org (in English).
Website of the European Ecodrive campaign.
- www.han.nl (in Dutch with some pages in English and German).
HAN University of applied sciences.
- www.pps-automotive.nl (in English).
PPS Automotive innovation programme.
- www.senternovem.nl (in Dutch and English).
Dutch Energy Agency SenterNovem.
- www.sparta.nl (in Dutch, English, French and German).
Bicycle manufacturer that produces the electric bicycle 'Sparta Ion'.
- www.tno.nl (in Dutch and English).
Website of the Netherlands Organisation for Applied Scientific Research TNO, including automotive activities.

18 Sweden

18.1 Introduction

In Sweden, 2006 was a good year for 'green' -environmentally friendly- vehicles. The market share of green private cars increased from 5.2% to 13.5%. Public awareness of climate change may have been an important driver of this trend, but financial imperatives -like high oil prices and legislation providing real incentives for the purchase of green vehicles- have also been influential. Ethanol-fuelled (E85) vehicles account for most of the green vehicle population, but hybrid vehicles sales were increasing through 2006.

Two centres for the development of hybrid vehicles were established in 2006: Volvo Cars has taken on the challenge of developing hybrid platforms for all of Ford Europe (its parent company), and the Swedish vehicle industry will work in collaboration with five universities to build a competitive centre of excellence for hybrid electric vehicle technology.

The 2006 City of Göteborg International Environment Prize was jointly awarded to Takeshi Uchiyamada at Toyota Motor Corporation, Takehisa Yaegashi at Toyota Technical Development Corporation and Yuichi Fujii at Panasonic EV Energy. This award recognized their outstanding, purposeful and critical contributions to development of the Prius, the first commercial hybrid automobile available in Europe. Worldwide, over half a million units have been sold.

18.2 Policies and legislation

Taxation

In December 2001, the Swedish government reduced the national taxation burden on certain green vehicles to encourage their sale. The rules have subsequently been changed several times, with the present set defined in the government's December 2003 'Budget Bill'. Under these, the notional taxation on the registration of hybrid or electric company cars is reduced by 40% relative to the closest comparable gasoline model, subject to a maximum reduction of US\$ 2'000 per year. By comparison, a 20% reduction is granted for company cars running on E85, natural gas or biogas, subject in these cases to a maximum reduction of US\$ 1'000 per year.

These are the approximate notional benefits (annual tax reductions) for some common green vehicles:

- Toyota Prius hybrid electric car: about US\$ 2'000 per year.
- Volvo's bi-fuel models: about US\$ 1'000 per year less than corresponding gasoline models.
- Mercedes E200 NGT: about US\$ 1'000 per year less than the corresponding gasoline model.
- Volkswagen Golf BiFuel: about US\$ 1'000 per year less than the gasoline Golf.
- Ford Focus Flexifuel: about US\$ 750 per year less than the gasoline Focus.
- Opel's CNG models: about US\$ 750 per year less than corresponding gasoline models.

Rules for public purchasing of vehicles

Sweden's rules governing public purchasing and leasing of vehicles have been changed by promulgation of the Ordinance Concerning Public Purchasing and Leasing of Green Vehicles, which is legislation intended to encourage the purchase and leasing of 'green' passenger cars in order to increase the proportion of such vehicles in use by public bodies. Effective on 1 January 2005, this ordinance applies only to public authorities and specifically requires that at least 75% of the total fleet of cars purchased or leased by a public authority during a calendar year be green vehicles. The National Road Administration in 2006 published a definition of the types of vehicles that qualify as green vehicles in accordance with the requirements of the ordinance.

Grants for green vehicles

No national grants are available for the purchase of green vehicles. However, a number of local authorities can provide local grants from funding from various national environmental projects. Within the framework of these projects, companies or private individuals can qualify for grants that will assist them with the purchase of green vehicles costing more than equivalent gasoline vehicles. Some local authorities have reduced parking charges for green vehicles, although rules vary from one authority to another.

From January 2006 to 31 July 2006, the capital city of Stockholm tested a congestion-charging scheme operated by the National Road Administration at the instruction of the government. Green vehicles -defined in this case as those powered partly or wholly by electricity, alcohol or any gas other than LPG- were exempted from the charge. Following a positive evaluation, it was decided to revive the scheme starting in 2007.

18.3

Research

There are -in principle- four 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 working areas and overall synergy among them. They also share a common business intelligence, monitoring and analysis element. Each of the programmes is briefly described below.

The Green Vehicle Programme (the objective of which is to develop cleaner vehicles) is a joint programme between the automotive industry and the government. The total budget of the second phase -which began in 2006- is approximately US\$ 120 million, the administrator is VINNOVA (Swedish Governmental Agency for Innovation Systems), and the programme will extend to 2008. About US\$ 35 million is budgeted for specific electric, hybrid and fuel cell vehicle research to include work in the following areas linked to hybrid systems: hybrid systems architectures, drive systems and energy storage technology.

Energy Systems in Road Vehicles is a programme administered by the Swedish Energy Agency that addresses energy-related issues in vehicles. Several research projects are under way that deal with batteries, fuel cells and other components for vehicles using electricity as a means of improving energy efficiency. The programme entered its second phase in 2004 and continued through the end of 2006 at an additional budget of about US\$ 11 million. Of the total budget, US\$ 6 million is devoted to hybrid vehicles and fuel cells. To date, several doctoral students in the field of hybrid vehicles and fuel cells have been trained and a number of patents have been taken out for a new type of hybrid driveline. When the results were evaluated, it was decided that -in the future- the program should concentrate on hybrid vehicles instead of addressing many areas at the same time. The programme covers the following areas linked to hybrid systems: architecture of hybrid systems, drive systems, diesel reformers for fuel cells, and battery technology. In co-operation with the other initiatives, this programme operates a simulation centre for pulling together the results of all the national programmes.

Fuel Cells in a Sustainable Society is the second part of a programme that started in 1997, was slightly modified during 2002, and ended in 2006. The administrator is MISTRA (the Foundation for Strategic Environmental Research), and the programme includes research projects on fuel cell system components, materials and systems. The total budget is approximately US\$ 10 million and -in addition to investigating fuel cell manufacturing methods- the programme is concentrating on reducing the cost of fuel cells and increasing their lifespan. It is a joint programme between universities and industry.

The new Swedish Hybrid Vehicle Centre aims to establish an internationally competitive centre of excellence for hybrid electrical vehicle technology, facilitate education and research to meet industrial and societal needs in the area and form a natural framework for co-operation between industry and academia. Participating in the centre are AB Volvo, Scania CV AB, Saab Automobile AB with 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 with a budget for the first period (2007-2010) of projects set at approximately US\$ 14 million.

18.4 Industry

Sweden is one of the world's countries very dependent on its automotive industry. Including those working with the about 1'000 subcontracting companies to the industry, it employs about 140'000 in the sector.

The major manufacturers are Volvo AB, Volvo Cars, SAAB Automobile and Scania, all of which have developed and demonstrated electric and/or hybrid concept vehicles. As the hybrid vehicle sector -in particular- has passed from prototype to commercialisation and is now entering its maturity phase, it is no

Box 18.1	
Subcontractors 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. Various activities in the fuel cell sector.
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 $\text{Li}_2\text{FeSiO}_4$).
Powercell	Development and commercialization of fuel cell auxiliary power unit (APU) for heavy-duty trucks.
Cell Impact AB	Development and sale of bipolar plates for PEM fuel cells.

longer possible to obtain figures on R&D activities from the companies because of concerns about competition and proprietary information.

Subcontractors that participate in electric vehicle, fuel cell and/or hybrid vehicle development and markets are shown in box 18.1.

18.5

On the road

The numbers of green vehicles in the country at the end of years 2000 to 2006 are shown in table 18.1.

Table 18.1 Numbers (rounded) of green vehicles in Sweden at the end of the years 2000 to 2006.

	2000	2001	2002	2003	2004	2005	2006
Private cars							
Electric vehicles	600	-	500	450	400	360	NYA
Hybrid electric vehicles	250	350	530	620	1'350	3'300	6'100
Low consumption vehicles, max 120 g CO ₂ /km	280	840	970	1'260	2'080	2'300	7'000
Natural gas/biogas vehicles	1'500	1'640	2'500	3'440	4'500	6'500	9'900
Ethanol vehicles, E85	250	890	3'500	7'980	13'300	21'400	47'000
Heavy vehicles							
Ethanol buses	-	-	-	400	380	370	NYA
Natural gas/biogas buses and trucks	-	-	-	680	780	900	1'100
Electric and fuel cell buses and trucks	-	-	-	17	18	13	NYA

NYA Not yet available

Nearly 4.6 million private cars and heavy vehicles were on the roads of Sweden at the end of 2006. About 20% of new registered private cars had diesel engines. The registered 'green' private car total reached a record 36'611 in 2006, an increase of 156% over 2005, as reflected in the market share growth cited in the introduction of this chapter (section 18.1).

18.6

Developments

Interest in hybrid vehicles really took off in 2006. Several R&D programmes are approaching start-up stage, with the difference that -whereas earlier the state has been the main driving force- industry now leads the discussions. As an example, the 'Green Vehicle 2' project will devote greater emphasis on hybrid vehicle

technology than before. Also, industry participates and shows great interest in the start-up Swedish Hybrid Vehicle Centre.

Stockholm City Transport was involved in the CUTE fuel cell bus trials, which enjoyed excellent results: reliable availability, pleased drivers and satisfied passengers. Nevertheless, the City Council has decided not to take part in the planned CUTE 2 fuel cell bus project and has sold the buses and their hydrogen refuelling station. The final report on results was issued in 2006.



Fig. 18.1 In 2006, Volvo Construction Equipment began prototype development of a hybrid wheel loader. (Photo supplied by STEM.)

In 2006, Volvo Construction Equipment began prototype development of a hybrid wheel loader. The Swedish Energy Agency (STEM) is financing 33% of the project.

18.7

Benefits of participation

Sweden considers the following to be benefits of its participation in IA-HEV:

- Informally exchanging information as part of establishing a worldwide network of contacts provides a means of finding out what other countries are doing (or not doing) and how they are doing it, in a cost-efficient manner. This network also provides a way of benchmarking national efforts against the benchmarks of other countries in order to improve the cost-benefit ratio of Sweden's own efforts.
- Spreading the costs of major worldwide work helps leverage costs. Many investigations have been carried out within the framework of the work of IA-HEV investigations that would have been impossible for any one country to perform on its own for reasonable cost. It is also important that any work be carried out by the best scientists in the particular field, and it is much easier to find them when working in a group with representatives from several countries, each with its own networks.
- Giving national scientists the opportunity to participate in international groups -tackling points that are not only of interest in Sweden- creates an inward flow of information and strengthens the international network of scientists. It is also

important that those involved bring home new thoughts and new ideas that can lead to new R&D projects and/or opportunities for business.

18.8

Further information

The following websites publish several reports covering cleaner vehicle issues:

- www.mtc.se (in English).
AVL MTC AB has a few reports covering test results on cleaner vehicles, mainly in English.
- www.stem.se (in English and Swedish).
The Swedish Energy Agency (STEM) 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. Most of the material is in Swedish:

- www.h2forum.org (in English).
The main forum for those concerned with hydrogen energy in Sweden.
- www.miljofordon.org (in English and Swedish).
This website is 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.milore.nu (in Danish and Swedish).
The Öresund region's information site covering cleaner vehicles.
- www.sveva.org (in English and Swedish).
The Swedish Electric and Hybrid Vehicle Association website.

19 Switzerland

19.1 Introduction

Among European nations, Switzerland is especially affected by the prospect of global warming because its settlement and infrastructure reach alpine regions where glacial melting, thawing of subsoil permafrost and extreme weather conditions have all been on the increase and are perceived as a real threat. Thus, concern about the generation of CO₂ and other greenhouses gases influences the national approach to clean vehicle technologies at least as significantly as do rising oil prices. This results in a general focus on total energy consumption in Switzerland. The white paper 'Steps towards a 2'000 W per capita society' (2002) is a major driver of the political discussion. For combating climate change, daily power consumption must decrease from today's 6'000 W/capita to 2'000 W. Personal mobility should only consume one quarter of this total, or 500 W/person-day maximum.


The needed transformations are beginning at the level of cantons and municipalities - not rapidly but incrementally. Several cities and towns have exchanged diesel for biogas buses or acquired small electric-powered utility vehicles for street cleaning and waste collection. Some cantons have changed the taxation criterion for motor vehicles from unit mass to CO₂ emissions. The federal government is preparing to enact legislation to raise the tax on imported vehicles on the basis of energy consumption labelling.

Government policy promotes the use of alternative fuels (compressed natural gas, biogas and ethanol), as well as 'slow traffic' means of transport (walking, cycling), which -in turn- creates market niches for special electric vehicles, such as small lightweight vehicles for commuting and special vehicles for 'car-free' resorts. Hybrid vehicles have recently made inroads in the conventional passenger car market. Switzerland's power generation infrastructure is extremely advantageous for electric and hybrid vehicles, with energy production free of CO₂ and pollutant emissions (a mix of 60% hydropower and 40% nuclear power). This means that in Switzerland, electric vehicles are powered to a large extent by renewable energy.

19.2 Policies and legislation

Since the beginning of 1995, the Federal Office of Energy has conducted a campaign in the energy field called EnergieSchweiz ('Swissenergy') that aims to lower overall national energy consumption. This campaign includes transportation

activity, which accounts for almost 40% of overall energy demand in Switzerland. Efforts to lower the energy consumption of vehicles are concentrated in the 'EcoCar' campaign, which is run by an agency called e'mobile. EcoCar measures effects of the electric and especially the hybrid vehicle markets. However, after a 10-year period of active promotion of electric vehicles (EVs) by the Swiss government, an energy law implemented in 1999 transferred the responsibility for EV promotion from the federal government to the local governments (cantons).

Box 19.1			
Summary of the Swiss EcoCar project			
			
Measure	Implemen- tation	Description	Effect
EcoCar labelling	In planning	Inclusion of a bonus-malus system is intended.	Difficulties with scoring and implementation.
Declaration of goods	2003	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%/year (= -24% by 2008). CO ₂ taxes to be imposed on fuels if 2008 target not met.	Actual achieved values: 2002: - 2.3% 2003: - 1.35% 2004: - 1.3% Thus, targets have not been met.
Regulations	Climate rappen: 1 Oct. 2005	Pilot tax of 0.7¢/L until June 2007 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 sector, until now no effect in the transportation sector. Projects admitted by September 2006 save 3.6 million t CO ₂ .

As a result of their evaluations of the EcoCar approach, scientists at Swiss research institutes agree that higher energy efficiency is a competitive advantage only in the heavy-duty vehicle segment and predict that higher energy efficiency will have no effect on the light-duty vehicle segment. According to the scientists, only the 'bonus-malus' approach is promising. The first step in this direction is

the planned implementation of a bonus-malus system on vehicle import taxes, which are based on the EU consumption label for light-duty vehicles. The tax will rise for cars in the label categories C to G, cars of the category A will get a rebate of CHF 2'000 (€ 1'350), and cars of category B earn a CHF 1'000 (€ 675) rebate.

As mentioned above, the cantonal governments now have the legal authority to finance promotion measures for electric and hybrid vehicles. Until 2005, it was primarily the canton of Ticino that has been active in this area, consistent with its role as 'heir' to the Federal Promotion Programme VEL1 ('Large scale test for lightweight electric vehicles' conducted in Mendrisio from 1995 to 2000). The cantonal promotion programme called VEL2 has also qualified conventional car models that have lower CO₂ emissions for subsidy. The effect of this change was that many owners of EVs sold their EV that was bought during VEL1 and shifted to a small conventional car with low energy consumption, even though subsidies for pure EVs were still high (up to 59% of the purchase price) and -at least at the beginning of the VEL2 programme- EV models like the Peugeot 106 électrique were still available in the Ticino region's marketplace.

The VEL2 programme was completed in June 2005 after subsidizing 2'785 energy efficient vehicles that included 75 hybrids. For VEL1 and VEL2 combined, about 1'300 EVs were subsidized: 935 electric bicycles, 280 electric scooters, 10 three-wheeled electrics and 85 light-duty models (like the Peugeot 106 électrique and Citroën Saxo électrique).

A recent evaluation study showed that the VEL2 promotion programme had a positive effect on the sales of clean vehicle models in the canton of Ticino, but at a public cost quite high for the relatively small increase over the share of clean

Enrolment of vehicles promoted by VEL2

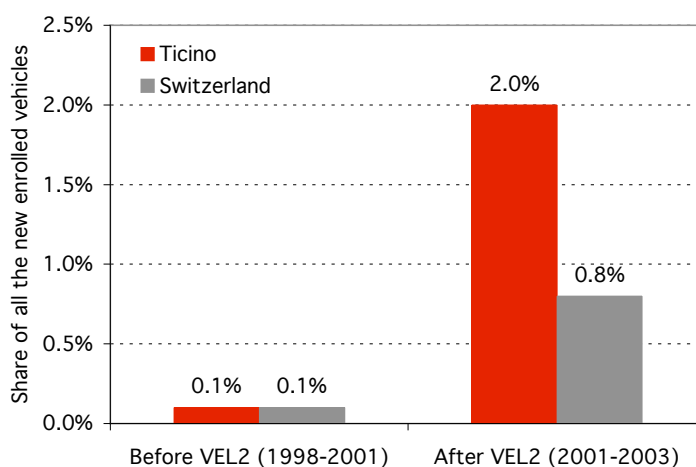


Fig. 19.1 Share of clean vehicles in Swiss sales figures. (Source: Rapp Trans.)

vehicle sales in the rest of Switzerland (see figure 19.1). However, with respect to the savings in emissions, the results are remarkable (see table 19.1). The study estimates that during the overall life of all 2'400 energy efficient vehicles -and depending on vehicle occupancy rates- 12'000-20'000 tons CO₂ will be saved in Ticino.

Table 19.1 Estimation of the annual reduction of emissions and fuel consumption by the use of 2'400 efficient cars in the canton of Ticino. (Source: Rapp Trans.)

	Emissions / energy consumption		Difference	
	Before	After	Absolute	Relative
	purchase of efficient vehicles	purchase of efficient vehicles		
t CO₂	8'200	6'400	- 1'800	- 22.0%
kg NOx	12'900	8'800	- 4'100	- 31.8%
kg PM₁₀	389	409	+ 20	+ 5.1%
1000 l gasoline equivalent*	3'300	2'600	- 800	- 23.0%

* Figures do not match exactly due to various calculation methods in different data sources.

The second promotion initiative in Switzerland is directed at electric two-wheeled vehicles. Within a programme called 'NewRide', municipalities in 10 cantons apply a variety of measures to support the purchase and use of electric bicycles or electric scooters. Purchases are subsidized in some of the cantons (Zürich, Basel, Neuchâtel), while others support exhibitions and test-driving events or two-wheeler use in such special application niches as hospitals or tourism. A few pilot projects operated electric bicycles for home-delivery services. This promotion programme has resulted in annual increases in the purchase of electric two-wheelers from 2003 through 2006 (respectively, an additional 1'850, 1'900, 2'300 and greater than 4'000 above the sales figures attained outside the scope of 'NewRide').

The cost-effectiveness of reducing emissions of CO₂ by one ton has been estimated for each of these programmes by calculating the expenditure rate of public subsidy.

Table 19.2 Cost-benefit ratio to reduce CO₂ by subsidizing efficient vehicles. (Source: Rapp Trans.)

Promotion programme	Cost-benefit ratio
VEL2 (Canton of Ticino)	220 - 630 CHF/t CO ₂
NewRide Basel	800 - 2'000 CHF/t CO ₂
NewRide Zürich	1'000 - 2'900 CHF/t CO ₂

The use of electric bicycles clearly reduces CO₂ emissions by a lower amount than that achievable by a clean vehicle (like a hybrid car), because the annual mileage of bicycles is usually much lower than the annual mileage of cars. Consequently, saving 1 ton of CO₂ requires that more electric two-wheelers need to be subsidized than the number of clean vehicles that is necessary to save the same amount of CO₂ emissions. In addition, electric two-wheelers obviously do not meet the needs of 'car drivers' to the extent that is necessary for a significant reduction of car trips and thus of CO₂ emissions. On the other hand, a relatively small subsidy prompted car drivers in the canton of Ticino to shift to smaller, more efficient vehicles that do have lower CO₂ emission levels, but at the cost of increased PM₁₀ (emissions of particulate matter) because of the increased operation of diesels.

Switzerland has adopted the European guidelines to increase to 10% by 2020 its population of vehicles powered by compressed natural gas (CNG), which is about 350'000 vehicles. The official targets are more modest: the agency EcoCar cites a goal of 30'000 natural gas and biogas vehicles by 2010. As of the end of 2005, about 2'500 natural gas vehicles had been licensed and 70 CNG refuelling stations were available. Several city authorities have substituted CNG for diesel in their public transport bus fleets, as well as communal service vehicles like garbage trucks. Ethanol is being promoted as a biofuel option, with the first ethanol filling stations now in operation.

Several cantons provide a vehicle tax reduction for 'clean' vehicles: 16 of 26 cantons exempt EVs from the vehicle taxes or grant reductions, and 8 cantons reduce the taxes for hybrid vehicles.

19.3 Research

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

- Lightweight design.
- Propulsion systems of highest efficiency.
- 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.
- Shifting to smaller vehicles.

Benefits should include:

- Enhanced safety.
- Reduced space requirement for transport infrastructure.

- Strengthened Swiss industrial initiative 'location Switzerland'.
- Strengthened Swiss educational initiative 'location Switzerland'.

Research in transport-related projects is centred at the Swiss Federal Institute of Technology (ETH Zürich) and its research institutes: the Paul Scherrer Institut (PSI) and the Federal Laboratories for Materials Testing and Research (EMPA). The Institutes of Appliance Engineering (FH) in Biel and Luzern also participate in transport-related research. The natural gas prototype vehicle developed in the research project 'Clean engine vehicles' of the EMPA just has been awarded by the innovation award of the German Gas Association.

Projects are or will be initiated to develop a 1.5 l/100km equivalent fuel cell prototype, while efforts remain under way in the field of ultracapacitors, and to achieve a mass reduction of 30% (project LIVIO). Development projects also focus on 'intelligent' batteries with adequate charging procedures, combined systems with batteries and supercapacitors, and basic research on conductive materials and nanostructures for advanced batteries.

Research is end product oriented, given the official position that research must lead toward marketable products. Therefore, the Swiss Federal Office of Energy also supports research undertaken by private companies, with an emphasis on battery research.

19.4 Industry

The only Swiss manufacturer of EVs is BikeTec, which produces the high-speed electric bicycle Flyer. Products originally developed in Switzerland but now manufactured by licensees in Germany include the TWIKE three-wheeler and 'swizzbee' e-bike (formerly the Dolphin).



Fig. 19.2 BikeTec Flyer. (Photo supplied by Muntwyler AG.)

The automotive supplier MES DEA is converting the Renault Twingo Quickshift and the Fiat Panda to an EV platform and is seeking a manufacturer. Recently, a Swiss energy supplier operating one of the largest pumped storage power stations announced the start-up of small-scale production and marketing in Switzerland of the Renault Twingo Quickshift Elettrica. A target of 120 MES Twingo Quickshift

Elettricas are to be manufactured and operated by Swiss utilities as service vehicles. This is to be a starting point for EV production together with Fiat Brazil, which has already converted the Fiat Palio to an electric car.

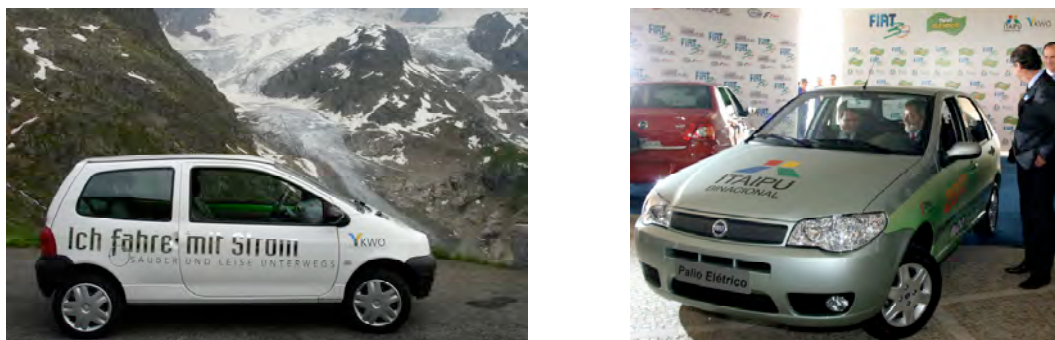


Fig. 19.3 Series production of the Twingo Quickshift Elettrica planned for the use as utility service car (left). Brazil's president Lula da Silva in a Fiat Palio Elettrica (right). (Photos courtesy Kraftwerke Oberhasli.)

In May 2006, MES DEA introduced a plug-in hybrid vehicle on a Fiat Idea platform, displaying it at the VEL-EXPO in Lugano. MES is also looking for a licensee for this vehicle.



Fig. 19.4 Plug-in Fiat Idea by MES DEA. (Photo supplied by Muntwyler AG.)

Brusa Electronics -a specialist in the development of control systems for EVs- has developed a track-based unmanned electric vehicle system named Coaster, which is now marketed by a licensee. The first commercial application will be installed in Arosa in spring 2007.

The development and manufacturing of components for hybrid and electric vehicles is concentrated within the Swiss companies MES DEA (ZEBRA NaNiCl batteries, and polymer electrolyte membrane (PEM) fuel cells in the range of 500 W to 3 kW), Horlacher, ESORO (composite parts) and Brusa Electronics (control systems). All of these companies are also active in research projects. Research on the improvement of ZEBRA batteries concentrates on lowering their operational temperature, and laboratory testing of suitable solvents has confirmed the feasibility of lowering the temperature. Nevertheless, near-term availability of a low-temperature ZEBRA battery remains unlikely. The high-temperature ZEBRA

battery is already used successfully in various electric and hybrid vehicles, especially in buses (e.g., Irisbus, Gruau Microbus).

Regarding fuel cell propulsion, the Swiss industry is interested in the development of components like electronics, control systems and system management. Fuel cell systems are not only developed and tested by research institutes, but also by private companies. As long ago as 2002, ESORO demonstrated a fuel cell vehicle in hybrid configuration and a prototype still used as a company car (fig. 19.5).



Fig. 19.5 HyCar and HyStation, developed by ESORO. (Photo supplied by Muntwyler AG.)

Swiss industry is still influenced in its approach to propulsion research by its experiences during the first worldwide solar mobile races -the Tour de Sol (1985-1993)- in which the competition was 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 into Swiss industrial strengths.

Thus, the approach of the LIVIO (lightweight vision) project by Rieter/Horlacher appears especially promising. The objective is to assemble a vehicle from a few parts, each of which can perform more than one structural function. For example, instead of using separate platforms for acoustical and thermal insulation and



Fig. 19.6 Project LIVIO by Rieter/Horlacher. (Picture supplied by Muntwyler AG.)

interior body surface (basically assembling three components for one function), one ‘intelligent’ and lightweight component integrates all three features. In addition, some parts can be interchanged easily to meet specific customer needs.



Fig. 19.7 Ultra light vehicle concept by Walter Janach. (Pictures supplied by Muntwyler AG.)

Another spin-off of the Tour de Sol philosophy of lightweight efficient design is the recent initiative of the Walter Janach’s consultancy company ‘Leichtbau Engineering’, which is designing an extremely inexpensive, simple and lightweight two-seater vehicle assembled from a sandwich platform and a cabin consisting of pneumatically pressurized plastic cells. An electric hub motor of 3 kW and a small battery package should enable speeds of up to 50 km/h with a 50 km range, which is sufficient for commuting. The target publics are those in densely populated developing countries -like China and India- that are experiencing rapid economic growth and that possess limited reserves of oil. Janach seeks industrial partners in China to launch small-scale production.

19.5 On the road

The Swiss electric vehicle market is small and dominated by small, lightweight vehicles, such as e-bikes, e-scooters and three-wheeled vehicles (such as TWIKE and City-el, which are licensed as motor bikes). Table 19.3 reports data on the Swiss car park, current as of the end of 2005.

Table 19.3 Swiss vehicle population data, as of the end of 2005.

Vehicle type	Electric vehicles	Hybrid vehicles	Total vehicles
Two- and three-wheelers	licensed 2'000 + ca. 10'000 e-bikes	--	592'194 + 230'000 mopeds + 3 mio bikes
Light-duty	710	2'469	3'863'807
Buses and trucks	ca. 400	--	353'049
Others (industrial, agricultural)	4'448 industrial + 30 agricultural	--	233'953
Total	ca. 13'110 + 4'448 industrial + 30 agricultural	2'469	5'043'003 + 230'000 mopeds + 3 mio bikes

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 four years. 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 still resulted in great interest in used EVs, and the market for electric two-wheelers is growing fast. In 2006, sales of more than 4'000 electric bicycles and scooters were expected, thanks in part to the VEL2 programme described above.

Market niches for EVs can only be stable 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 EVs in Switzerland are used for commuting in urban agglomerations. This results in the great success of small, lightweight EVs, especially three-wheeled and two-wheeled vehicles that can easily be parked and for which recharging stations exist at privileged parking spots in the centres of several cities and towns. Drivers of three-wheelers (like the 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 that are 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 own a vehicle, and hotels must have more than 30 beds to get permission to operate a motor vehicle. In addition, there is a general speed limit of 20 km/h. Local manufacturers produce special vehicles designed for battery exchange for these villages.

As a result of evidence of climate change in the Alpine locations, the example of car-free resorts increasingly influences vehicle procurement preferences of Swiss municipalities. Several authorities are now exchanging conventionally powered communal vehicles for electrics.



Fig. 19.8 Electric Mega multitruck used by the 'services industrielles' Yverdon. (Photo: H. Ammann.)

The hybrid vehicle market is developing satisfactorily for importers. As of December 2005, about 2'500 hybrid cars were licensed (Toyota Prius I and the new Prius II, Honda IMA and Civic, and some Lexus RX 400h) and importers expected that this sales figure would double by the end of 2006 in spite of the supply limitation (especially for the Toyota Prius). Remarkably, the two Lexus hybrid models -RX 400h and GS 450h- are finding many buyers, possibly an indicator of a 'typical' Swiss niche market for upmarket products.

A market study by the Federal Institute of Technology Zurich comparing buyer segments of Toyota Corolla, Aventis and Prius found that lower motor vehicle taxes in some of the cantons have resulted in a 20% increase in Prius purchases. In addition, Prius buyers had a weaker brand/model loyalty than Corolla and Aventis buyers and -on average- drove bigger car models before they bought the Prius. Significant differences in decision making are shown by the fact that Prius buyers prefer its advanced propulsion technology and lower fuel consumption (at times of high gasoline prices), while the most important criteria in selecting the other Toyota models have been horsepower, design, luggage space and the availability of air-conditioning.

19.6 Developments

The greatest success in sustaining market niches for EVs has been achieved where they offer clear advantages in use. Niches based on subsidies only 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

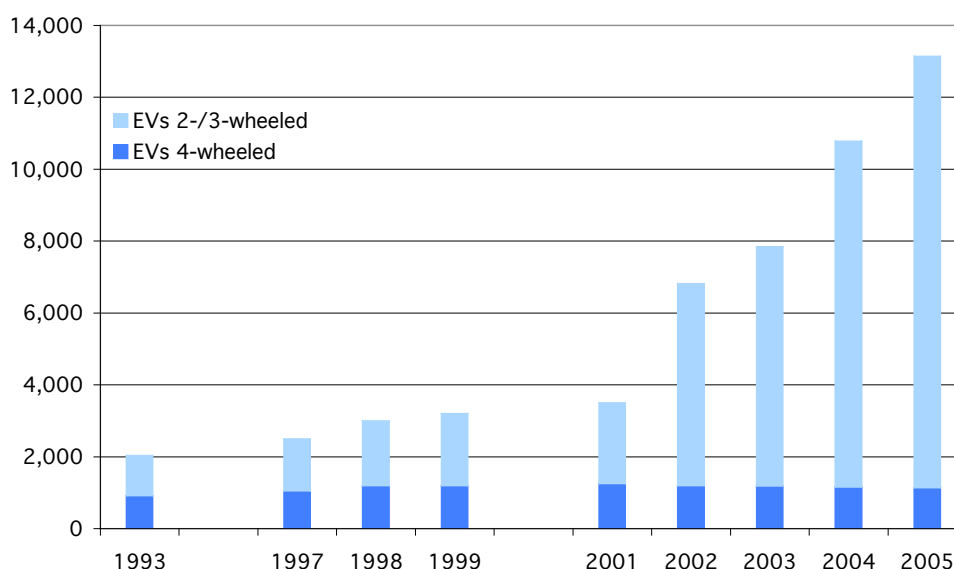


Fig. 19.9 Swiss EV fleet: increase in EV numbers due to sales of electric cycles.

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 (perhaps because of design, 4-wheeled vehicles do not communicate these advantages). Sustainable niches can also be established by regulations (e.g., Swiss 'car-free' resorts). The great increase in sales figures of EVs in Switzerland can be attributed to the success of electric two-wheelers (see fig.19.9).

The hybrid vehicle market is gaining momentum, thanks to great sensitivity toward ecology in Switzerland, a good knowledge about alternative vehicles (especially electrics, because of the Tour de Sol races and the VEL2 promotion programme in Mendrisio) and the performance of the hybrid vehicle models available in Switzerland, which is comparable to that of conventional vehicles. Hybrid vehicles also show an agreeable price/performance ratio.

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

- Several small and medium companies (Brusa, ESORO) specialize in these fields.
- Larger Swiss automotive suppliers see a chance to lead in some sectors (e.g., composite automotive parts, ZEBRA batteries).
- Research projects -especially in the field of fuel cell propulsion systems- enable identification of future needs in electronics and control systems.

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

- Too much know-how is kept within research institutes.
- The step from demonstration to production is difficult.
- Development of standardized products is neither supported nor existing.
- An efficient profit chain is lacking.

19.7

Benefits of participation

Switzerland has participated in the Implementing Agreement for Hybrid and Electric Vehicles since its inception in 1993 and -in ensuing years- has been one of the member countries most active in the promotion of EVs. Most EV manufacturers have ceased production of new EVs, resulting in decreased EV development activities in Switzerland, so information exchange with experts from other countries has become more important by providing insight into many key issues, including:

- Development of new batteries (such as those based on lithium technology) and progress in component development. New batteries could precipitate a resurgence of all-electric vehicles -at least for specific market niches- so the

ability of the government to identify the right moment to consider active support will be enhanced.

- Realization that hybrid vehicles will succeed in the market without government support.
- Recognition of political realities (CO₂, oil price) that will demand a shift to clean vehicle technologies in the relatively short term. The activities of other member countries -as well as the information provided by the International Energy Agency itself- provide insight into possible CO₂ mitigating measures and real market opportunities for clean vehicle technologies.

19.8

Further information

Websites

- www.e-mobile.ch (in English, French and German).
Swiss association for electric and efficient vehicles. Project EcoCar/Swiss Programme 'EnergieSchweiz' of the Federal Office of Energy.
- www.energie-schweiz.ch (in English, French German and Italian).
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- www.horlacher.com (in English, French and German).
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Tohyco Rider mini bus.
- www.hycar.ch (in English and German).
Fuel cell-prototype ESORO HyCar.
- www.maxwell.com (in English).
Supercapacitors.
- www.mes-dea.ch (in English).
Twingo Quickshift Elettrica, plug-in hybrid Fiat Idea, ZEBRA batteries.
- www.newride.ch (in French and German).
Project NewRide (electric two-wheelers).
- www.paccar.ethz.ch (in English and German).
PAC-Car II energy efficient fuel cell vehicle project of the ETH Zürich.
- www.psi.ch/medien/Medienmitteilungen/mm_hy_light (in German).
Fuel cell prototype HYlight.
- www.rapp.ch/roote/e_trans.html (in English, French and German).
Studies by Rapp Trans.
- www.vel2.ch (in Italian, soon also in English).
Project VEL2 of the canton of Ticino.

Reports

- Project Lightweight Electric Vehicles in Mendrisio: Synthesebericht, full report on cd-rom. Order at: EDMZ CH-3000 Bern.
- Martin Pulfer: Konzept 2004-2007 Technologiebereich Verkehr & Technologiebereich Akkumulatoren. Bundesamt für Energie 2006.
- Rapp Trans, Gianni Moreni: EVS-21 Monaco.
- Rapp Trans, Gianni Moreni/Interface, Ueli Haefeli: Finanzielle Anreize für effiziente Fahrzeuge. In: Jahrbuch der Schweizerischen Verkehrswirtschaft 2005/06.
- Rapp Trans, Gianni Moreni: Finanzielle Anreize für effiziente Fahrzeuge. Presentation VSS/SVI 3-4 May 2006, Lugano.

20

United States

20.1

Introduction

The United States -through the U.S. Department of Energy (DOE)- actively supports research and development (R&D) for innovative vehicle technologies. In particular, FreedomCAR -a government-industry partnership for the advancement of high-efficiency vehicles- focuses on fuel cells and on hydrogen produced from renewable energy sources. It envisions affordable full-function cars and trucks -and freedom from imported oil and harmful emissions- without sacrificing safety, freedom of mobility, or vehicle choice. Energy efficiency appears to draw broad popular support in the United States.

20.2

Policies and legislation

20.2.1

Federal

The United States is committed to developing alternative fuels, as well as the infrastructure for their commercialization. The DOE works with industry to develop and deploy advanced transportation technologies toward that end. For example, DOE's Clean Cities Program supports public-private partnerships that deploy alternative fuel vehicles (AFVs) and build supporting infrastructure. The program features information about local coalitions and clean corridors, alternative fuel news and events, fleet success stories, support and funding, and available AFVs.

The provisions of the Energy Policy Act of 1992 (EPACT), P.L.102-486, included a requirement that state and federal government fleets and the providers of alternative fuels (including electric utilities, natural gas utilities and other producers/suppliers) convert an increasing percentage of their vehicle fleets to AFVs over time. Currently, 90% of new light-duty vehicle acquisitions by energy providers and 75% of such acquisitions by state agencies must be AFVs. Hybrid electric vehicles (HEVs) -which were still in the developmental stage when EPACT was adopted in 1992- were not included in the definition of AFVs and are not recognized as meeting the credit requirements of the EPACT Alternative Fuel Transportation Program (10 C.F.R. Section 508). In contrast, dual-fuel vehicles -which may use either an alternative or conventional fuel- are eligible for credits toward EPACT mandates. The 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 through 2010 to implement and enforce the CAFE standards. Also -as part of its provisions- all automakers will have to label new fuel flexible vehicles in the United States to remind buyers that they can use either gasoline or an ethanol blend.

A limited federal tax credit is available for light-duty HEVs placed in service between December 31, 2005, and January 1, 2011. The expiration date is January 1, 2010, for medium- and heavy-duty vehicles. The tax credits are capped at 60'000 vehicles per manufacturer, above which the vehicles sold during the next four calendar quarters will only be eligible for a decreasing percentage of the full tax credit. The U.S. Internal Revenue Service (IRS) recently completed its quarterly audit for the automakers. As of June 2006, the credit amounts for Toyota hybrids have been cut in half as the company has met the first hybrid sales threshold. All other manufacturers, however, still qualify for the full tax credit amounts, as they have not yet met the requisite sales levels.

In January 2006, President Bush announced the Advanced Energy Initiative (AEI), which provides for a 22% increase in funding for clean energy technology research and outlines the U.S. fuelling of vehicles and powering of homes and businesses in the future. The near-term solutions are primarily regulatory (e.g., CAFE standards, tax incentives and switching to alternative fuels like ethanol), with emphasis on cellulosic production from agricultural waste and purpose-grown biomass (and -later on- hydrogen). The long-term solutions require accelerating efforts to develop radically improved technologies for 'plug-in' hybrid electric vehicles (PHEVs). Current hybrids only use the gasoline engine (in addition to regenerative braking) to charge the onboard battery and can only run 1 or 2 miles in the battery mode, often at significantly reduced performance. PHEVs can run either on electricity or on gasoline and can be plugged into the electric grid at night to charge the batteries and operate for an extended range (tens of miles) on battery power.

On January 24, 2007, President Bush issued an Executive Order to federal agencies that -among other items- requires a 2% reduction in the consumption of petroleum products per year through the end of 2015 in fleets larger than 20 vehicles. The order also requires the use of PHEVs, when commercially available at a cost reasonably comparable -on a life cycle basis- to that of non-PHEVs.

The U.S. National Highway Traffic Safety Administration (NHTSA) has developed special safety standards for Neighbourhood Electric Vehicles (NEVs), 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 (about 900 kg), and a top operating speed of 40 miles per hour (64 km/h) or less. A Federal Motor Vehicle Safety Standard (FMVSS)

-number 500- requires such vehicles to incorporate certain devices (e.g., three-point restraints, safety glass, 3 mph bumpers, rear-view mirrors, horns, parking brakes and lighting, and reflector equipment) to appropriately address safety issues. Some states have laws to allow certain NEVs on city streets, generally with posted speed limits of 35 mph or less.

The Environmental Protection Agency (EPA) established a new method of estimating fuel economy under which most vehicles will have lower values than before. But HEVs will likely be downgraded the most - as much as 30%. (For example, a rating for the Prius would decline from 60 miles per gallon to 45 mpg.) Most of these changes are effective with the 2008 model year.

20.2.2

State

As shown in table 20.1, at least 20 U.S. states maintain regulations that provide for HEV incentives -including high occupancy vehicle (HOV) privilege- waiving of emissions inspection, tax credits/rebates or purchase directives. Usually, such regulations are actively promoted by environmental groups. Some attempts have been made to bring about state-level adoptions of California-like clean air standards, which would require automakers to reduce greenhouse gas emissions from their vehicles by 30% before 2016. For example, New York, New Jersey, Massachusetts, Connecticut, Rhode Island, Vermont and Maine have adopted California's clean air rules. Washington would be the ninth such state.

The New York State Energy Research and Development Authority (NYSERDA) Program issued a solicitation for the New York State PHEV Technology Initiative, which is aimed at accelerating the adoption and use of PHEVs in that state. The program will provide funding for businesses to develop, test, demonstrate and ultimately supply to selected New York state government fleets the hardware and services necessary to convert existing state-owned hybrid electric passenger cars and light trucks to plug-in hybrid operation.

Table 20.1 U.S. state-level incentives to purchase hybrid electric vehicles.
 (Source: Table developed from information at the Electric Drive Transportation Association website www.electricdrive.org.)

State	Law/Date	HOV privilege	Waived emissions inspection	Tax/ Rebates	State-level purchase directive
Arizona	SB 1429 (6/1/01)	X			
California	Chapter 737 (10/8/03)		X		
Colorado	SB 91 (4/22/03) HB 1067 (5/00)	X		X	
Connecticut	Public Act 04-231 (10/04)			X	
Florida	Chapter 2003-45 (5/27/04)	X			
Georgia	HB 719 (5/31/03)	X			
Maine	MRSA Title 36 §1752 and §1760-79			X	
Maryland	HB 61 (5/13/03) HB 20 - (5/00)		X	X	
Michigan	HB 5443 (6/00) SB 2675 (4/4/02)			X	
Minnesota	SB 2675 (4/4/02)				X
New Jersey	HB 2351 (1/14/04) SB 16/HB 2586 (5/00)		X		
New Mexico	SB 86 (3/6/04) SB 18 (3/4/02)			X	
New York	AB 11749 (7/02) EO 111 (6/10/01) Chapter 413 (11/96)			X	
Oklahoma	HB 1085 (5/8/03)			X	
Oregon	HB 2041 (7/8/03)			X	
Pennsylvania	Act 178 of 2004			X	
Utah	Utah state tax form TC-40V			X	
Virginia	HB 887 (4/15/04)		X		
Washington	Chapter 285 (4/1/02) Chapter 24 (3/24/02)		X		X
Wisconsin	HB 155 (Act 183) (4/22/04)				X

20.3

Research

20.3.1

Barriers

The realization of an advanced high-fuel-economy vehicle that both meets design targets and is acceptable in the marketplace faces significant barriers of cost, emission standards and fuel infrastructure.

Cost

High cost is a serious barrier in almost every research area for advanced vehicle technologies, and the current costs of most HEV, battery electric vehicle (EV) and fuel cell vehicle (FCV) components are higher than cost-effective targets. For example:

- Lightweight body construction, compression ignition direct injection (CIDI) engines, batteries and electronic control systems all increase vehicle cost.
- Emission control systems for high-efficiency direct injection gasoline and diesel engines -when developed- would be more expensive than current systems.
- No concept cars in their present forms are equipped with an affordable set of components compatible with similar-mission vehicles, although these prices could decline with large-scale manufacturing.

Emissions standards

The U.S. Environmental Protection Agency (EPA) Tier 2 NO_x and particulate matter standards (now being phased in) are significantly more stringent than prior standards and may pose a barrier to early introduction and widespread use in the United States of certain advanced engine technologies for passenger cars.

Fuel issues

Successful introduction of either compression ignition (CIDI) or spark ignition (SIDI) direct injection engines or fuel cell propulsion systems will be critically dependent on widespread availability of suitable fuels. The large capital expenditures and long lead time required to manufacture and distribute a significantly modified fuel means that the petroleum industry must be fully aware of the needs well in advance of the production of the first automobile that requires such a fuel. Furthermore, the change must make economic sense for the petroleum companies or be mandated by regulation. A 2001 U.S. EPA regulation required refiners to produce highway diesel fuel with a maximum sulphur content of 15 parts per million by June 1, 2006, and represented significant progress toward realization of lower emissions. However, the development of cost-competitive combustion and emission control systems that will 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 -in turn- requires major infrastructure changes by the energy industry.

20.3.2

Enabling technologies

To address the obstacles cited above, the United States supports research efforts to enhance the state of enabling technologies for AFVs. Funding is provided for research at the DOE's national laboratories and by private industry through DOE departmental programs and government-industry partnership programs. The enabling technologies may be categorized under the rubrics of hydrogen and fuel cells, advanced energy storage technologies, vehicle systems research, advanced combustion engines R&D, lightweight materials, and advanced power electronics. Each of these technology research initiative areas is described below.

Hydrogen and fuel cells

A polymer electrolyte membrane (PEM) fuel cell converts chemical energy into electricity and heat through the electrochemical reaction of hydrogen and oxygen. The DOE Hydrogen Program conducts basic and applied research, technology development and learning demonstrations, and education and outreach activities. The program focuses on addressing key technical challenges for fuel cells and hydrogen production, delivery and storage, as well as institutional barriers. It works with public- and private sector partners, including automotive and energy companies, manufacturers, utilities, government agencies, universities, laboratories and other stakeholders, and it integrates hydrogen activities for various federal agencies. In fiscal year (FY) 2006, Congress appropriated US\$ 235.9 million for the President's Hydrogen Fuel Initiative to support hydrogen and fuel cell R&D across four DOE offices and DOT (Department of Transportation). The FY 2005 appropriation was US\$ 222 million. The President's FY 2007 request for the Hydrogen Fuel Initiative is US\$ 289.5 million. Currently, over 300 projects are under way that are supported by this program. Additional information appears in the 2006 Annual Progress Report (www.hydrogen.energy.gov/annual_progress06.html).

Some recent highlights include:

- The National Hydrogen Learning Demonstration Project -which includes 69 first-generation fuel cell vehicles and 10 hydrogen refuelling stations- completed the second full year of data collection. Recent results show fuel cell systems with 53-58% efficiency, vehicle range of 103-190 miles, and durability of 950 hours (~30'000 miles).

- Significant advances took place in (1) the development of low- and non-platinum catalysts, membranes, electrodes and membrane electrode assemblies and (2) the analysis of water transport and freeze effects. For the first time, a non-precious metal catalyst with promising activity and stability (comparable to the platinum-based oxygen reduction catalysts) has been identified - opening the possibility of using non-precious metal catalysts in fuel cells.
- The program selected over 40 new projects -amounting to over US\$ 140 million (over US\$ 170 million with cost-share)- to overcome barriers to the development of fuel cell transportation systems and making them commercially viable. The program also identified alternative pathways for the production of hydrogen.
- Nine new patents were issued for research and development discoveries emerging from these projects and 38 more applications were in process.

Advanced energy storage technologies

For successful commercialization of EVs, HEVs and PHEVs, the battery system must meet several requirements simultaneously. These include high energy (for EVs), high power (for HEVs), both high energy and high power (for PHEVs), rechargeability, long life, safety and low cost. The three primary battery research areas funded by DOE include (1) the developer program, performed in close collaboration with the industry through the United States Advanced Battery Consortium (USABC), which assesses, benchmarks and develops advanced batteries for EVs and high-power batteries for HEVs, (2) applied battery research, which provides near-term assistance to developers of high-power batteries to overcome the calendar life, abuse tolerance, low-temperature performance and cost barriers associated with lithium-ion batteries for light- and heavy-duty vehicles, and (3) focused fundamental research, which will develop the next generation of battery technologies for both EV and HEV applications.

Recent significant accomplishments of DOE-funded energy storage research included:

- A new extremely high-rate, potentially low-cost and abuse-tolerant lithium titanate material was developed at Argonne National Laboratory (ANL) and is being transferred to the Enerdel Corp. under a USABC contract.
- Under contract to USABC, the new joint venture of JCI/Saft has estimated that it can reduce the cost of its Li-ion full HEV battery system by almost 50%.
- Maxwell Technologies Inc. successfully completed design validation and delivery of 2.85 V, 3'600°F ultracapacitors, more than doubling cell energy density, increasing cold cranking power by ~50% and reducing system cost (also by ~50%).
- $\text{Li}(\text{Ni}_{0.5}\text{Mn}_{0.5})\text{O}_2$ is a high-energy material that has the potential to be low-cost, but it is unable to sustain high storage rates. A new ion-exchange method of sample preparation results in it retaining 50% of its C/20 capacity at 2C rates.

- A composite electrolyte composed of a conducting (PEO-based) polymer to provide Li conduction, together with a non-conducting (polystyrene based) hard polymer to inhibit dendrites, offers significant promise for Li metal batteries.

Vehicle systems research

This activity provides support and guidance for many cutting-edge automotive and commercial vehicle technologies under development. Research is focused on understanding and improving the way in which various new components and systems of tomorrow's automobiles and commercial vehicles will function together in a vehicle to improve fuel efficiency. It also supports the development of advanced automotive accessories and the reduction of parasitic losses (e.g., aerodynamic drag, thermal management, friction and wear, and rolling resistance). Recently, simulation studies by the National Renewable Energy Laboratory's Vehicle Systems Analysis Team showed that a fleet of plug-in hybrid passenger vehicles with a 20 mile electric range could almost double fuel economy, compared to a conventional fleet.

Advanced combustion engines R&D

This activity is focused on removing critical technical barriers to commercialization of higher-efficiency, advanced ICEs in light-, medium- and heavy-duty vehicles. It seeks to improve engine efficiency, while meeting future federal and state emissions regulations, through a combination of combustion technologies that minimize in-cylinder formation of emissions and aftertreatment technologies that further reduce exhaust emissions. Work is done in collaboration with industry, national laboratories and universities. Recently -in collaboration with industry partners- this activity completed development of advanced clean diesel engine technologies for pickup trucks, vans and sport utility vehicles (SUVs), achieving an improvement in fuel economy of 50% over current gasoline fuelled trucks while demonstrating Tier 2 Bin 5 emission levels for a limited duration.

- Recently, Oak Ridge National Laboratory (ORNL) identified an approach for increasing the durability of Lean NO_x Traps (LNTs). LNTs are a leading candidate for diesel engine NO_x control but are limited by periodically required desulphurization - the removal of sulphates from the trapping material. Research identified a precursor form to the sulphate that can be targeted for pre-trap desulphurization, thus improving LNT life.
- Researchers at the Pacific Northwest National Laboratory invented a new desulphurization strategy that minimizes irreversible platinum sintering and thus could potentially increase the durability of LNTs.

Lightweight materials

The reduction of vehicle mass through the use of improved design, lightweight materials and new manufacturing techniques is a key to meeting fuel economy

targets for commercially viable FCVs, HEVs and EVs. The DOE Automotive 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 (e.g., safety, performance, recyclability and cost). DOE is pursuing five areas of research: 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 significant accomplishments in this area included the following:

- The Automotive Metals Division of the United States Council for Automotive Research's (USCAR's) United States Automotive Materials Partnership completed a five-year 'Structural cast magnesium development' project and demonstrated that large, safety-critical, cast magnesium components can be cost-effectively produced and used in exposed exterior applications. Magnesium has weight reduction potential of at least 60% compared to currently used steels.
- The USCAR's Automotive Composite Consortium demonstrated a low-cost fabrication process for volume production of large, safety-critical automotive components from carbon-fibre-reinforced polymer-matrix composites with a similarly high weight-reduction potential.

Advanced power electronics and electrical machines

This activity 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 is on the thermal control of inverters and motors with two-phase cooling technologies. Recent significant accomplishments include:

- Ballard Power Systems completed the development of a 5 kW DC/DC converter for FCVs and HEVs that meets the FreedomCAR 2010 targets for power and efficiency at 105°C coolant temperature.
- ORNL demonstrated a silicon/silicon-carbide hybrid inverter that increased efficiency and operational temperature range, achieved a 20% reduction in losses, required a smaller heat sink, increased switching capability and thus resulted in a reduction in size of passive inverter components.
- National Renewable Energy Laboratory researchers -under subcontract at the University of Colorado at Boulder- achieved growth of carbon nanotubes on a copper foil. Carbon nanotubes represent a promising thermal interface material that could be used in high-temperature inverters and converters.

20.4

Industry

Various U.S. manufacturers previously made battery powered EVs available to consumers. These past offerings for model years 1999-2002 are listed in the IA-HEV annual report 2004 [20.1]. The battery technologies have included lead acid, nickel metal hydride, nickel cadmium and lithium-ion. Currently, these (discontinued) vehicle models are not widely available as manufacturers have shifted focus to HEVs and FCVs. HEVs have entered the market in significant numbers recently and have shown greater promise of success. Other current products include hybrid buses, industrial vehicles and bikes/scooters.

Table 20.2 An overview of current EV and HEV products in the United States.

(Source: Electric Drive Transportation Association website www.edta.org.)

Product	List																		
Hybrid Electric Vehicles	<table border="0"> <tr> <td style="text-align: center;"><u>Currently on market:</u></td> <td style="text-align: center;"><u>Upcoming:</u></td> </tr> <tr> <td>Ford (Escape hybrid)</td> <td>Cadillac Escalade</td> </tr> <tr> <td>GMC (Sierra Classic ext. cab, Silverado Classic ext. cab)</td> <td>Chevy (Malibu, Tahoe, Silverado crew cab)</td> </tr> <tr> <td>Honda (Accord hybrid, Civic hybrid)</td> <td>Dodge (Durango, Ram TTR)</td> </tr> <tr> <td>Lexus (RX 400h, GS 450h)</td> <td>GMC (Yukon, Sierra crew cab)</td> </tr> <tr> <td>Mazda (Tribute hybrid)</td> <td>Lexus (LS 430h, LS 600h)</td> </tr> <tr> <td>Mercury (Mariner hybrid)</td> <td>Nissan (Altima)</td> </tr> <tr> <td>Saturn (VUE Green Line, Aura Green Line)</td> <td>Toyota (Sienna)</td> </tr> <tr> <td>Toyota (Highlander hybrid, Camry hybrid, Prius)</td> <td></td> </tr> </table>	<u>Currently on market:</u>	<u>Upcoming:</u>	Ford (Escape hybrid)	Cadillac Escalade	GMC (Sierra Classic ext. cab, Silverado Classic ext. cab)	Chevy (Malibu, Tahoe, Silverado crew cab)	Honda (Accord hybrid, Civic hybrid)	Dodge (Durango, Ram TTR)	Lexus (RX 400h, GS 450h)	GMC (Yukon, Sierra crew cab)	Mazda (Tribute hybrid)	Lexus (LS 430h, LS 600h)	Mercury (Mariner hybrid)	Nissan (Altima)	Saturn (VUE Green Line, Aura Green Line)	Toyota (Sienna)	Toyota (Highlander hybrid, Camry hybrid, Prius)	
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Toyota (Highlander hybrid, Camry hybrid, Prius)																			
Battery Electric Vehicles	GEM E825 4-Passenger Measures IT Neighbourhood Electric Vehicle Maya Electric Vehicle ZAP Intimidator L.U.V.™ Neighbourhood Electric Car ZAP WORLDCAR L.U.V.™																		
Buses	Methanol Reformer Fuel Cell Electric Bus EVI-22 Battery Electric Bus 30–40-ft Thundervolt Hybrid Electric Bus ZEBus Ballard Power Systems / XCELLSIS Fuel Cell Bus DE40LF Diesel Hybrid Electric Bus Orion VII Hybrid Electric Bus New Flyer Gasoline Hybrid GE40LF New Flyer Diesel Hybrid DE60LF RTS Hybrid Electric Bus Trolley/Shuttle Battery Electric Bus Gillig Corp.																		
Industrial	John Deere: Fuel Cell Hybrid Commercial Work Vehicle E825 Utility ECRV Postal Delivery Vehicle 4x2 Electric Gators Gorilla: e-ATV																		

Several companies still manufacture and sell electric bicycles, including US-Prodrive and Zap. Zap also markets motorcycles, scooters and NEVs. The Global Electric Motorcars (GEM) -subsidiary of Daimler-Chrysler Corp.- manufactures a NEV called the GEM in two-, four- and six-seat configurations. An overview of currently available products -for which more information is available at the Electric Drive Transportation Association (EDTA) website- is presented in table 20.2.

The following summarizes 2006 industry highlights related to EVs and HEVs.

Ford

- Mercury delivered the first Mariner hybrids to U.S. dealerships. Mariner's hybrid drivetrain consists of a 2.3 litre four cylinder engine rated at 133 hp, a 70 kW electric motor, nickel-metal hydride batteries and a one-speed continuously variable transmission. It is rated 32 mpg in city traffic and 29 mpg on the highway.
- A hybrid version of the Tribute is planned for 2007. Ford also announced hybrid versions of the Ford Fusion and Mercury Milan sedans, due in 2008.
- Ford signed a contract with Delphi Corp. to provide battery packs for the next generation of hybrids, due around 2008. The batteries would be manufactured by Sanyo Electric Co. of Japan.
- Ford plans to offer a more fuel-efficient version of the Expedition SUV. The vehicle could be powered by either a new European V-8 diesel engine or a gasoline electric hybrid powertrain. It could be ready for production around 2010.
- Ford demonstrated an Explorer powered by a fuel cell that allows it to travel 350 miles on a single tank of gaseous hydrogen. This SUV has electric four-wheel drive with transverse motors on the front and rear axles.
- Ford unveiled the revamped 2008 Escape hybrid, which highlights improvements in fuel economy, hybrid software and interior/exterior design. Fuel economy improvements to the 2008 Escape and Mariner hybrids earned IRS approval of an increase in their federal tax credits for purchase under EPACT. Credits for front wheel drive models were increased from US\$ 2'600 to US\$ 3'000 and for four wheel drive models from US\$ 1'950 to US\$ 2'200.
- Ford unveiled its concept EV -the Ford Airstream- powered by a plug-in hydrogen hybrid fuel cell drivetrain. The fuel cell operates in steady state, charging the vehicle's lithium-ion battery pack as needed and thus working like a portable generator. In pure electric mode, the Ford Airstream concept can travel 25 miles before the fuel cell begins operating to recharge its 336 V lithium-ion battery pack. After the hydrogen-powered fuel cell kicks in, range increases another 280 miles, for a total of 305 miles.

Toyota

- Toyota stated it will integrate a less expensive, smaller hybrid system into its HEVs before the end of the decade.
- The company also expected its hybrid sales volume to increase significantly (about 40% in 2007), mostly as a result of its hybrid Camry. It planned to produce 4'000 a month -or 50'000 a year- at its plant in Kentucky, starting mid-year. Its other hybrid models would still be imports, including the hybrid Lexus GS sedan.



Fig. 20.1 2007 Toyota Highlander hybrid. (Photo courtesy Toyota.)

General Motors

- GM stated that starting in 2007, it will build fleets of fuel cell test vehicles for the United States, Europe, Korea and China as a run-up to offering a zero-emissions powertrain in part of the GM vehicle line-up. It will build 100 fuel cell Chevrolet Equinox SUVs to be tested by consumers in New York, California and Washington D.C., and is considering whether to lease most of them to consumers. The company has stated its intention to deliver by 2010 a commercially viable fuel cell vehicle that will be competitive with the durability and performance of current internal combustion engine vehicles and that can ultimately be produced at a scale of affordability.
- The Saturn Vue Green Line became commercially available in 2006. Its battery pack -including the case and a cooling fan- comes from Cobasys, a joint venture between Energy Conversion Devices Inc. of Troy, Michigan and Chevron Technology Ventures, a unit of Chevron Corp. These are the first

North American-made nickel-metal hydride batteries used in a HEV. GM also announced it is working on a Saturn Vue plug-in hybrid production vehicle.



Fig. 20.2 2007 Saturn Vue Green Line hybrid. (Photo courtesy General Motors.)

- Belt-alternator start hybrid technology and a nickel metal hydride (NiMH) battery pack will be used in both the Saturn Aura Green Line and Malibu hybrid sedans, beginning in 2007.
- GM said its two-mode hybrid transmission -a conventional four-speed automatic transmission with two electric motors used to boost fuel economy in the city and on the highway (to be optional in the Cadillac Escalade, Chevrolet Tahoe, GMC Yukon and Chevrolet Silverado/GMC Sierra crew cab pickups)- increases the fuel economy of full-size SUVs by 25%. It is co-developing the technology with DaimlerChrysler and the BMW Group, to debut in the Tahoe/Yukon in 2007.
- GM unveiled its new EV concept sedan -the Chevrolet Volt- at the North American International Auto Show in January 2007. The Volt has a battery-powered electric motor that can achieve 40 city miles on a single charge. Then, a gasoline powered, one litre, three-cylinder engine can generate electricity to power the vehicle and replenish the battery, providing a range of up to 640 miles.

Honda

- Honda will introduce an entry level, four-door hybrid positioned below the Civic for the 2009 model year. The hybrid may be built at a new Honda plant in Indiana that will begin producing four cylinder engine vehicles in 2008. Honda hopes to sell at least 100'000 of these units annually.
- Honda discontinued production of its pioneering two-passenger commercial hybrid vehicle -the Insight- at the end of 2006.

- Honda plans to market an improved FCV in the United States and Japan in 2008. The car will incorporate an all-new design that places the fuel cell in the car's central tunnel down the middle of the car. The company plans to market more than 100 in Japan and the United States in 2008. It would be sized similar to the Acura RL. A concept version has been test driven by international and U.S. journalists.



Fig. 20.3 2007 Honda Accord hybrid. (Photo courtesy American Honda Motors.)

- Honda presented three concept vehicles at auto shows in 2006 and early 2007. The FCX fuel cell concept is close to the production model that will go on sale in Japan and the United States in 2008. In the new vehicle, the fuel stack is located under the centre console and flows vertically, allowing for more efficient water drainage and better performance. It has a range of about 270 miles, which is about 30% greater than the current vehicle.
- Honda demonstrated sub-freezing start-up capability in Japan and the United States for its newest fuel cell model being introduced in 2008, slated to have a 270 miles range at 350 bar (about 5'000 psi) gaseous hydrogen tank pressure.

Others

- DaimlerChrysler and BMW are collaborating with GM on a rear wheel drive hybrid transmission system. DaimlerChrysler plans to use the GM-designed transmission in the Dodge Durango SUV in 2007.
- Audi, VW and Porsche are developing hybrid versions of their SUVs, which share a common platform. An Audi Q7 hybrid may appear by 2008.

- Johnson Controls formed a partnership with Saft in 2005 to produce lithium-ion batteries, possibly in North America. Johnson Controls is drawing up plans for a lithium-ion plant to supply hybrids sold in North America.
- A Canadian company plans to begin U.S. sales of its US\$ 10'000 Zenn EV.
- Tesla Motors Inc. of California started signing up prospective buyers for its US\$ 89'000 performance electric roadster - a reworked Lotus Elise EV with Taiwanese-built batteries, electric motors and a promise of a 200 miles range.
- Nissan showed its Altima hybrid model. It is expected to go on sale in 2007 and will use the Toyota-developed hybrid drive being installed in Camry hybrids. Nissan is developing its own hybrid technology.
- Nissan Motor Co. said it will sell a hybrid car using its own technology in the United States and Japan sometime in 2010. It will also launch a test EV early in the next decade and accelerate development of plug-in hybrid technology.
- Mitsubishi Motors Corp. said it plans to sell a small electric car in the United States, powered by a lithium-ion battery and to be launched in Japan.
- Mitsubishi Motors Corp. plans to bring its electric car to North America. It expects this model to be able to travel about 100 miles on a single charge with its 330 V lithium-ion batteries providing 16 kWh of energy. Improvements to the battery are expected to increase energy content to 20 kWh.
- Mitsubishi Motors Corp. said it is considering selling a hybrid car smaller than its Lancer model in the United States.

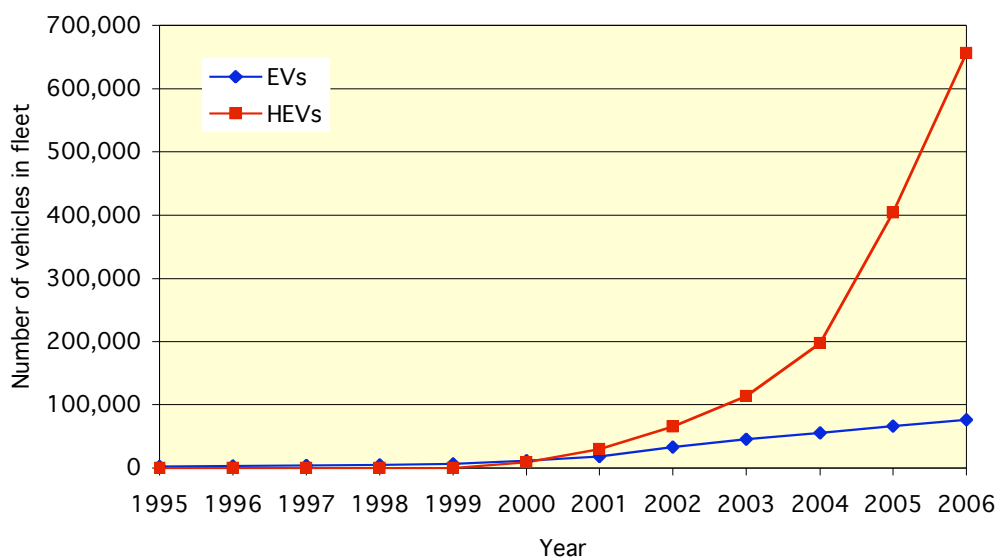


Fig. 20.4 Number of EVs and HEVs present in the United States.

EV data from Energy Information Administration (EIA)

(http://www.eia.doe.gov/cneaf/alternate/page/datatables/aft1-13_03.html).

EV data for 2004 through 2006 are estimates (2005 and 2006 data are extrapolated).

HEV data from Electric Drive Transportation Association website (<http://www.electricdrive.org>).

(Cumulative numbers estimated from annual sales.)

- BMW AG plans to put 50 hydrogen powered 760Li cars on U.S. roads in 2007. These 'Hydrogen 7' models have an internal combustion engine that runs on liquid hydrogen or gasoline. They will be driven by selected consumers in Washington and Los Angeles at company cost, starting in mid-2007. They offer 260 hp and a range of 125 miles on hydrogen plus 310 miles on gasoline.

20.5

On the road

Compared to its total inventory of vehicles (over 230 million), the United States has a relatively small -but growing- number of HEVs. These are designed to compete with conventional on-road gasoline and diesel vehicles. Batteries for these vehicles include nickel metal hydride and lithium-ion. Both AC and DC motors are being used. Figure 20.4 on the previous page shows the number of EVs and HEVs in the United States over the past few years. HEV sales for 2005 and 2006 and U.S. registrations of HEVs in 2004 appear in table 20.3.

Table 20.3 HEV sales and registrations in the United States.

Vehicle	2004 Registrations ¹	2005 Sales ²	2006 Sales ²
Ford Escape	2'566	15'800	24'562
Honda Accord	653	16'826	5'598
Honda Civic	25'586	25'864	31'253
Honda Insight	587	666	722
Lexus GS 450h	NA	NA	769
Lexus RX 400h	NA	20'674	20'161
Mercury Mariner	NA	1'580	3'057
Toyota Camry	NA	NA	27'336
Toyota Highlander	NA	17'989	31'485
Toyota Prius	53'761	107'897	106'971
Total U.S. HEV sales	--	207'296	251'914
Total U.S. light vehicle sales	--	16'997'203	16'559'625
Total U.S. HEV sales percent	--	1.2%	1.5%

¹ R.L. Polk, as published on the EDTA Electric Drive Transportation Association website (www.electricdrive.org).

² Data through December 2006; except for Escape, Mariner and GS 450h, which are estimated. Insight and Prius sales data are from J.D. Power; other data from EDTA. The Mariner hybrid sales are taken as 10% of Escape sales in 2005.

NA Not available / Not applicable

20.6

Developments

At this time, the U.S. population of battery EVs appears to be stable because of the lack of new personal mobility EVs. The HEV population is growing and projected to grow more. The forecasting firm of J.D. Power-LMC Automotive has projected that HEVs will account for 3% of the U.S. light vehicle market by 2010 -which is about a half-million annual sales- but the hybrid market share will plateau, mostly because of the expected US\$ 3'000-4'000 premium that hybrids command over standard vehicles. Other projections -based on a lower premium- have indicated a larger market share. Regulatory steps can also affect the eventual number of such vehicles. The California Air Resources Board estimated that more than 850'000 Partial Zero Emission Vehicles (PZEVs) will be on California roads by 2010 and there may be more than 1 million by 2015.

20.7

Benefits of participation

The numerous benefits of U.S. participation in various IEA IA-HEV Annexes include:

- Obtaining information on advanced transportation technologies (not available from other sources), as well as being a source for such information.
- Producing joint studies and reports for mutual benefit.
- 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.

20.8

Further information

Further information for:	Website address (all websites are in English)
DOE FreedomCAR and Vehicle Technologies Program	www.eere.energy.gov/vehiclesandfuels/
DOE Hydrogen and Fuel Cells Program	www.eere.energy.gov/hydrogenandfuelcells/resources.html
Electric Drive Transportation Association (EDTA)	www.electricdrive.org
Energy Information Administration (EIA)	www.eia.doe.gov
United States Advanced Battery Consortium (USABC)	www.uscar.org/guest/view_team.php?teams_id=12
United States Consortium for Automotive Research (USCAR)	www.uscar.org

20.9**References**

- [20.1] *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.

21

Developments in selected IA-HEV non-member countries

As of the end of 2006, at least 20 IA-HEV non-member countries hosted manufacturers of electric cars, electric bicycles, electric scooters or three-wheelers, electric motorcycles (collectively, light electric vehicles - LEVs) and/or hybrid electric vehicles (HEVs), according to SourceGuides.com. These countries are listed in box 21.1.

Box 21.1				
IA-HEV non-member countries that host manufacturers of electric cars, electric bicycles, electric scooters or three-wheelers, electric motorcycles and/or hybrid electric vehicles				
Australia	Czech Republic	Hungary	Korea	Singapore
Bulgaria	Germany	India	Malaysia	Taiwan
Canada	Greece	Israel	Panama	Thailand
China	Hong Kong	Japan	Philippines	United Kingdom

Sales data are not uniformly available for these countries. With some exceptions, their production facilities are limited and most of their actual LEV trade may be based on importation. Among IA-HEV non-members, Japan is currently the only non-member mass-producing HEVs, China is beginning to ramp up domestic production (initially for export, primarily) and Korea will soon open its own production facility. However, Australia, Canada, the Czech Republic, Hungary, India and the United Kingdom all claim small specialty manufacturers of (possibly not road-legal) HEVs and/or hybrid auxiliaries. The last IA-HEV annual report profiled eight of the larger players in electric vehicle (EV) or HEV markets. This year, we revisit China, Denmark, India, Japan, Norway and Taiwan, and three other non-member nations boasting EV production and marketing activities are included in this chapter.

21.1

Australia

Two Australian manufacturers are making notable and, in some ways, unique contributions to the world of electric propulsion.

Currie Technologies is the manufacturer of the world-famous US ProDrive propulsion system for bicycles. The US ProDrive kit allows the user to convert most standard 26 inch (66 cm), 36-spoke bicycles to electric power, and the system has the maximum amount of power allowable for Australian roads without the need for license or registration. The kit includes all items necessary to convert most bikes, including a battery pack, the motor/electronics unit and the speed

controller, all of which takes less than half an hour to install. A US ProDrive-equipped bicycle has a range of 20-30 km and a cruising speed of 25 km/h.

In the pursuit of producing 'greener' usable technology, Varley Electric Vehicles has designed the MA100, an electric tow vehicle built for airport baggage handling. The MA100 addresses current community and environmental concerns, because it is virtually noise-free and has zero emissions. This technology is a major step forward in revolutionising industrial vehicles and their impact on the environment.

21.2

China (including Hong Kong)

The e-bike market in the People's Republic of China (PRC) continues its impressive expansion -especially in mid-size cities- because of an abundance of customers among the elderly and those needing short-distance transportation. However, in some larger cities, new regulations attempt to ban e-bikes, primarily for safety concerns because -although e-bikes are regulated to a maximum speed of 25 km/h so that they can share bike lanes with regular bikes- their manufacturers have developed ways to enable users to reach a top speed of about 35 km/h. This speed can create a safety concern for regular bike riders. Nevertheless, e-bikes are seen generally as an effective measure to mitigate growing congestion problems caused by automobile traffic in the capital, Beijing.

China is expanding international partnerships as well. The program between GM and Shanghai Auto cited in the previous annual report focuses on heavy-duty hybrids, with buses as the initial market. The Toyota and First Auto joint effort for Prius production previously reported is not yet in full swing, partly because Toyota must import the majority of parts from Japan, and there is a tariff of 35% on imported parts that Toyota seeks to have the government eliminate or significantly reduce. Private communications have indicated that Toyota does not consider China itself to be a hybrid market, so the vehicles produced by this partnership may be intended chiefly for export. Geely Company maintains an R&D program for hybrids in-house, but the partnership with Tonji University mentioned in last year's report does not appear to be moving forward.

ZAP Corporation -a California-based manufacturer of street-legal electric three-wheelers- has placed a procurement with Shandong Jindalu Vehicle Co. Ltd. of China (PRC) for more than 500 units of the new Xebra four-seater 'city car'. The lead-acid-powered 110 V chargeable Xebra can achieve 40 mph (64 km/h) and has a range of 40 miles (64 km). Shandong Jindalu has indicated that as part of ZAP's exclusive 10-year distribution U.S. contract, it is providing the capacity to produce up to 1'000 of these units per month. This car will be the first production EV made in China that is designed specifically for U.S. roads.

China is now ranked third in the world in production and sales of automobiles. In the 10th national five-year plan (2001-2005), China identified EVs as the national key development project. Major automobile manufacturers and universities were mobilized to develop battery-powered EVs, HEVs and fuel cell EVs. The Tang Hua concept electric car is one example (fig. 21.1). Several cities have launched EV demonstration and commercialisation programmes. China has become the world's largest producer of electric bicycles, electric scooters and electric motorcycles. Total production in 2005 was 15 million and is predicted to reach 30 million in 2010. In China's 11th five-year plan period (2006-2010), the central government will continue to invest heavily in electric drive technologies (hybrids, EVs and FCVs), but alternative-fuel vehicles (compressed natural gas (CNG), liquefied propane gas (LPG) and biofuels) will also enjoy significant R&D funding.



Fig. 21.1 Tang Hua concept electric car. (Photo: M. van Walwijk.)

Urban congestion has stimulated the production of e-bikes and e-scooters in the former British colony of Hong Kong, now part of the PRC. Among notable manufacturers are Barlic Company, Fantastic Int. Co. Ltd., Gas-Skateboard.com and Millennium Scooters.

21.3

Denmark

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

The objective of the government is that the actual share of renewable energy of 15% should be at least doubled to 30% by 2025. In 2005, biomass accounted for almost half of the use of renewable energy and wind turbines produced about 20% of the total electricity consumption. In 2025, 50% of the electricity consumption might be produced by wind turbines through expansion of the total capacity from 3'000 MW to about 6'000 MW.

This strategy faces several challenges. A major one is to adapt the electricity system to manage a considerable higher share of intermittent electricity production 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 have a very important role. The Danish Energy Association has already stated a new interest in demonstration projects with plug-in hybrid and battery electric vehicles.

21.3.1

Danish experiences with battery electric vehicles

In 2005, the Danish Environmental Protection Agency (Ministry of Environment) published the report 'Experience with electric cars in Denmark'. The report collates and assesses the practical experience of electric cars in Denmark from 1998-2001, and it also includes user experience from later years. Emphasis has been on user experience with the new generation of Citroën and Th!nk electric cars, which have been marketed in Denmark since 1997. The report also describes the current status of electric vehicle technology. (See also the third reference in subsection 21.3.3.)

As part of the study a large number of public and private owners of electric cars were subsequently contacted for their practical in-use experience. A section in the report includes a representative selection of users' own descriptions of their experiences as pioneers with electric cars.

Battery problems

During the first years, users were very pleased with the new electric cars 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. 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.

User experiences

About 150 Citroën and about 20 Th!nk electric cars have been sold in Denmark, mostly between 1998 and 2002. 75% of these vehicles were bought by municipalities and electricity 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. Subsequently there has been a pattern that more private individuals have purchased second-hand electric cars.

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

The limited range of electric cars has given rise to uncertainty for new or potential users. However, most users quickly learn the limitations and are able to adapt their driving to take account of the short range. However, almost all users place a larger range at the top of their priorities for the electric cars of the future.

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 public users. This difference is primarily caused by the fact that private owners use their electric car in daily commuting to and from work.

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

There have been no direct purchase subsidies for electric vehicles in Denmark, and most of the new electric cars from PSA Peugeot Citroën were bought by municipalities and electric power companies. However, private owners have been more successful in the daily use of the electric cars, resulting in a considerable higher annual mileage. The experiences of the private owners are very useful as a

background for an assessment of the potential of new improved technologies. These experiences could be an indication of the potential of the possible share of the electrically driven mileage of 'plug-in' hybrid vehicles with a similar electric range.

21.3.2

The market of hybrid and electric vehicles in Denmark

Denmark has no conventional car industry but it houses many component suppliers. Denmark was one of the first countries to produce and market electric vehicles. Production of the small 'Ellert' -that became the most sold electric vehicle in the world- started in 1987, and in 1991 production of the KEWET El-Jet commenced. To facilitate sales of these vehicles in Denmark, electric vehicles were exempted from registration tax and the annual car tax based on weight. However, today both manufacturers have moved their production from Denmark to Germany and Norway, respectively.

The number of vehicles on the road in Denmark is quite stable. The total number of passenger cars is around 1.9 million and slightly increasing. The number of electric cars can be estimated to be near 300. Additionally, there are about 350 City-el vehicles, and a few electric scooters and electrical bicycles (e-bikes). There are very many bicycles in Denmark (on average more than 1 per person, which means a total of more than 5 million bicycles in the country), but e-bikes are still not selling in large numbers.

The number of electric cars on the road in Denmark is slightly decreasing. There are no sales of new vehicles and some cars have been taken out of service due to technical problems with batteries, electric equipment, etcetera. Many electric cars that were originally bought and owned by companies and public authorities have been sold for private use or have been exported.

The Toyota Prius hybrid car is available on the Danish market since May 2004, but only a very limited number has been sold until now. It is estimated that about 30 Toyota Prius have been registered in Denmark, of which the majority is registered by the Toyota Company. The most important barrier is the high price of the Prius for the customer, and that there are no special incentives such as a reduced registration tax. Due to the high registration tax, the price of the Prius is about € 60'000 (about US\$ 80'000), which is considered too high by almost all potential customers. There is a political will to find a solution that will make it possible to sell the Prius in Denmark at a price that is acceptable for the customer, but it seems that a solution would require a total change of car taxation, which is politically difficult to achieve.

The sales of the Lexus RX 400h hybrid sports wagon started in September 2005. Due to the Danish registration taxation rules this car in a configuration as a van with only front seats can be sold at a lower price than the Toyota Prius passenger car. The available stock of Lexus RX 400h has already been sold and there is a considerable waiting time between ordering and actual delivery of this vehicle.



Fig. 21.2 The Lexus GS 450h was introduced to the Danish market in 2006. (Photo courtesy Toyota Denmark.)

In 2006, sales of the new Lexus GS 450h hybrid luxury sedan started in Denmark. The price for the customer is more than US\$ 200'000, but this segment of the car market seems to be less sensitive to higher costs related to new advanced technology.

21.3.3

Further information

Further information about electric vehicles in Denmark may be obtained from the following internet websites:

- www.danskelbilkomite.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.mst.dk/udgiv/publikationer/2005/87-7614-619-7/html (in Danish, a summary in English is also provided on this website).
This is a report on electric vehicles in Denmark.

21.4

India

India boasts the world's largest population of gasoline (petrol) scooters and three-wheelers. Because its domestic market for vehicles of these configurations is so enormous, it could eventually become a world leader in electric two- and three-wheeler production and sales, but production there is only beginning to focus on non-petroleum technologies as the national electricity transmission grid becomes better established. Notable producers of electric-powered transportation equipment and components (primarily e-bikes) include Callidai Motor Works of Tamilnadu; Radha Energy Cell of Ludhiana, Punjab; Birionic Private Ltd. of Bangalore; and Planet-7 International of Vapi, Gujarat; and the electric car manufacturer REVA of Bangalore.

One example of the application of electric vehicles (EVs) in India can be found in the city of Mumbai. Electric tow tractors are used in collecting public vegetable waste for recycling (fig. 21.3). An urban management program for Clean Air Island, South Mumbai, is under development, in which EVs form part of an integrated approach to improve urban air quality and to reduce CO₂ emissions from transportation. The program includes:

- improved logistics for reduced transportation distances of public waste and the application of 44 EVs to do this job,
- the introduction of 55 electric mini-buses for public transport in the Mumbai heritage area for drivers who park their vehicles at the border of one of the areas, and
- 48 electric tow tractors that traffic police will use to tow away vehicles parked improperly.



Fig. 21.3 Electric tow tractor used in vegetable waste collection, Mumbai, India. (Photo courtesy Clean Air Island, Mumbai, India.)

21.5

Japan

Japan continues to lead the world in the production of HEVs and is second only to the United States in sales. This success has prompted expansion of efforts to develop HEV technology into a growing emphasis on heavy-duty vehicular applications, including railroads. For example, the Japan Railroads (Northeast) is developing a concept for series hybrid passenger railcar traction that will become a suitable power source for Northeast's operations. A hybrid diesel engine generation system has been tested and demonstrated, thereby verifying the system's ease of maintenance and superior cost efficiency when applied to electrified motive unit (EMU) technology. Northeast has also been able to engineer a fundamental control strategy that will incorporate a fuel cell system for the second step in the development of its train. A commercial train with a fully incorporated diesel engine hybrid system will be released in 2007.

A Japanese corporation has also developed an in-wheel motor drive system for large buses (22.5 inch wheels) that consists of 4 inch wheel motors, two water-cooled pulsed-wave-modulation inverters, one water-cooled chopper, 22 lithium ion batteries, and 12 electric double-layer capacitors. The in-wheel motor is a type of direct-drive permanent magnet motor without reduction gear, mounted inside a wheel. Maximum torque and maximum power of each in-wheel motor is 2'000 Nm and 75 kW, respectively. The power of an inverter is 50 kW at a continuous rating, and maximum power is 75 kW. The two units of this inverter are constructed in a box, cooled by water. The mass of the experimental bus demonstrating this system is about 9'030 kg, and its acceleration time to 40 km/h is about 7.2 seconds.

Toyo Corporation has produced two hybrid electric buses experimentally - one with a generating system consisting of an engine-generator, lithium ion battery and electric double-layer capacitor and another with an engine-generator and electric double-layer capacitor. The two buses were manufactured with 4-wheel steering and 2-wheel drive. A series hybrid city bus is also under development to meet targets for low emission (75% improvement over Japan's JP05 standard) and low fuel consumption (50% reduction in city driving mode). To realize these targets, a system using a special diesel engine with new combustion technology, a high-efficiency all-electric auxiliary drive system and a high-performance lithium-ion battery was developed and installed in a prototype vehicle. Testing confirmed that the vehicle met not only the low exhaust emission and fuel consumption targets but it also performed practicably as a city bus.

21.6

Malaysia

The combined demand for increased mobility, improved urban air quality and greater energy security has begun to stir greater interest in clean/green propulsion across Southeast Asia. Thailand had invested heavily in natural gas buses for Bangkok, Myanmar is seeking to convert most of its vehicular fleet to natural gas, and neighbour Malaysia steps up the pace of electrifying smaller personal vehicles, like e-scooters and e-bikes. Two Malaysian manufacturers specialising in electric two-wheelers are Membranes Systems (Sdn. Bhd.) of Batu Caves and Revolution Cycles (Sdn. Bhd.) of Shah Alam, Selangor. The latter manufacturer also produces electric excursion buses, batteries (including nano-colloid type) and golf buggies.

21.7

Norway

21.7.1

Electric vehicles in Norway

In Norway, interest in electric cars is growing rapidly in recent years. The use of electric cars in Norway started later than in Denmark, and the problems with the first generation of NiCd batteries in Norway were limited compared to the Danish experience.

The Norwegian authorities have step by step implemented a number of initiatives and regulations in order to create a market for electric cars. Electric cars are generally exempt from VAT and annual owner taxes, and they have a very low registration tax. In the Oslo area and in other larger towns, electric cars are exempt from road tolls and parking charges. Several parking spaces with rechargers have been established for electric cars only. In addition, the price of electricity in Norway is significantly lower than for example in Denmark. Starting in 2005, electric cars were permitted to use bus lanes and this has increased EV demand significantly. There are still waiting lists for buying an electric car in Norway.

In relatively few years, Norway has become the country with the second largest number of electric cars in Europe, only exceeded by France. The market in Norway has grown in a period when only a small number of new electric cars has been produced. However, a large number of second-hand electric cars has been imported, primarily from France but some originate from Denmark. The former Danish KEWET El-Jet is now being produced and further developed in Norway, by the company ElBil Norge.

The interest in electric cars has also provided the conditions necessary for EV dealers to establish themselves in the Oslo area, specialising in sales and maintenance of electric cars. Thus an expertise -in which the public has confidence- has been built up.

Norway is an example that shows how demand for electric cars can be created under market conditions. The example also shows that this can take place with electric car technology that is primarily developed 15-20 years ago. Significant improvements can be achieved with today's technology.

21.7.2

Industry

The public interest in battery electric vehicles is to some extent related to the production of the Norwegian developed PIVCO car and the newer model CityBee, produced in Aurskog near Oslo. The company went bankrupt in 1999 and was bought by Ford, who developed the new model Ford Th!nk City. However, in August 2002 Ford decided to stop production. Recently the production facilities have been bought by Norwegian investors, and the production of a new and improved model of the Th!nk City is scheduled to start in 2007. The new Th!nk City will be equipped with Zebra batteries to achieve a range of about 180 km.



Fig. 21.4 KEWET Buddy electric cars. (Photo courtesy EIBil Norge AS.)

In 2006, the company ElBil Norge was still the only producer of electric cars in Norway. The company has further developed the Danish KEWET El-Jet, and has started the production of the 6th generation model called KEWET Buddy. In 2005, the company moved to new and larger production facilities and is planning to produce 250-400 units annually in the coming years. As a development and demonstration project the company is working on a version with lithium-ion batteries.

21.7.3

On the road

It is estimated that there were approximately 1'700 battery electric cars running in Norway by the end of 2006. During 2006, more than 300 battery electric cars were newly registered in Norway. The major sources of supply to the market were:

- 130 KEWET Buddy, new cars produced in Norway.
- 100 Citroën Saxo/Peugeot 106 électrique and Citroën Berlingo/Peugeot Partner électrique, second hand cars imported mainly from France.
- 80 Ford Th!nk City, second hand cars imported from the United States.

21.7.4

Further information

Further information about electric vehicles in Norway may be obtained from the following internet websites:

- www.elbil.no (in Norwegian).
Norsk Elbil Forening Norstart. Site of the Norwegian Electric Vehicle Association Norstart.
- www.elbilnorge.no (in Norwegian, with one page in English).
Site of the electric vehicle manufacturer ElBil Norge AS.

21.8

Taiwan

While the 'small light electric scooter' remains a signal component of its vehicle manufacturing industry, Taiwan's leading transport research organization -the Industrial Technology Research Institute (ITRI)- is devoting major effort to the development of a 'light-duty neighbourhood hybrid vehicle'. This vehicle will be a parallel hybrid configuration designed to deliver ultra low emissions with low fuel consumption (28 km/l) and deliver 15-20 kW of power and a range capability greater than 200 km. It will couple a lean-burn engine with an AC brushless motor to full electrical drive and a lithium-ion battery system. The 18 kW hybrid powertrain that may ultimately be part of this vehicle package (and already is installed in a Formosa Matiz and a smart for-two) will deliver 0-60 km/h acceleration in less than 10.8 seconds and achieve maximum speed of 90 km/h.

The hybrid powertrain would ultimately be upgraded to a 100 kW power-assist system with the advantage of a 288 V lithium-hydrogen battery.

A longer-term objective for ITRI is to equip high-quality Taiwanese-branded electric scooters (such as the E-Ton) and market an HEV scooter in 2007, with ITRI's 45 V, 4 kW polymer electrolyte membrane (PEM) fuel cell hybrid power system.

Despite inroads made in recent years by the PRC, Taiwan still provides the majority of e-bikes sold in the United States and the European Union.

21.9

United Kingdom

Great Britain is becoming more actively involved in both component supply and manufacturing for electric propulsion and is a showcase for new ideas. The British International Motor Show in August 2006 culminated with the launch of two new battery electric cars: the smart ev (from the manufacturers of the smart car) and the NICE (No Internal Combustion Engine) city vehicle. The smart ev has a 30 kW output and can reach 115 km/h, with a driving range of just under 120 km.

Always at the forefront of public transport concepts -and now more focused on environmental mitigation- the United Kingdom is investing in the development of a Personalised Public Transport (PPT) system that uses automated vehicle modules to provide sustainable mobility within large metropolitan areas. It has been designed to address the major challenges associated with congestion: air quality and energy use. In this system, a 5 m long vehicle will offer up to 12 seats, including one wheelchair space, and carry 12 standing passengers, giving a capacity of 24. These modules can operate in platoons of up to six units, for a total capacity of 144 passengers, thus rivalling the capacity of rail-based systems per direction-hour at a fraction of the rail's roll-out time and infrastructure cost.

The module -which comes in three versions- has a series hybrid drive using a lithium-ion battery energy storage system. The first version employs a biofuel internal combustion engine (ICE), the second stage uses a hydrogen ICE and the third uses a low-power hydrogen fuel cell. Each version combines the benefits of low power ratings, low noise and increased safety. The service operation is planned initially in closed communities -such as at exhibitions or airports- and later will be deployed in exclusive lanes, like Bus Rapid Transit. Ultimately, a mature system would cover the majority of Britain's central city areas. Beginning in 2008, a batch of six 'seed' vehicles is set to operate a trial service at a selected exhibition centre to ferry visitors on a shuttle service between the halls and the car parking areas. Further applications are currently being planned for airports,

national expos and large sporting installations, plus systems are being integrated into new retail and residential developments.

Also interested in heavy-duty applications, British industrial R&D has developed two new machines with hybrid propulsion for high traction and generation applications. Power densities higher than 1.4 kW/kg have been achieved for a maximum output of 200 kW. Integrated liquid cooling allows for a very compact design with high efficiency.

Notable British manufacturers involved in EV and HEV manufacturing and component supply include Connaught Motor Co. Ltd., Green Motorsport Limited, Ace Scooters, Batricar Ltd., Frazer-Nash Research, Zutter Electric Vehicles Inc., EV Select, Kinetics, and Powabyke Ltd.

22

Outlook for hybrid and electric vehicles

The IA-HEV Executive Committee intends to regularly present an outlook for hybrid and electric vehicles. This chapter explores an outlook, a first part is based on recent developments and future expectations of hybrid and electric vehicle markets (in section 22.1) and a second part is based on a preliminary investigation how hybrid and electric vehicles may fit in a future sustainable transportation system (in section 22.2). In section 22.3 first conclusions are drawn. This chapter has been prepared by the Operating Agent of IA-HEV Annex I (Mr. Chris Saricks) and the IA-HEV secretary (Mr. Martijn van Walwijk) with support from some of the ExCo members, and it does not necessarily reflect the ideas and opinions of all ExCo members. The material presented here serves as a basis for future work and it will contribute to shaping an outlook that includes the expertise of all IA-HEV participants.

22.1

Recent developments in hybrid and electric vehicle markets

The year 2006 witnessed the continued strong momentum of worldwide growth in the population of vehicles with electric and electric-assisted propulsion. The hybrid electric light-duty vehicle continued its unprecedented rate of increase of units in service, adding configurations in the midsize and luxury sedan and sport utility vehicle (SUV) markets (the last accounting for over 100'000 unit sales worldwide) that increased the diversity of this fleet. Balancing this greater wealth of choice was the loss of the Honda Insight - a two-seater and first commercially available on-road hybrid in North America- which ceased production during the

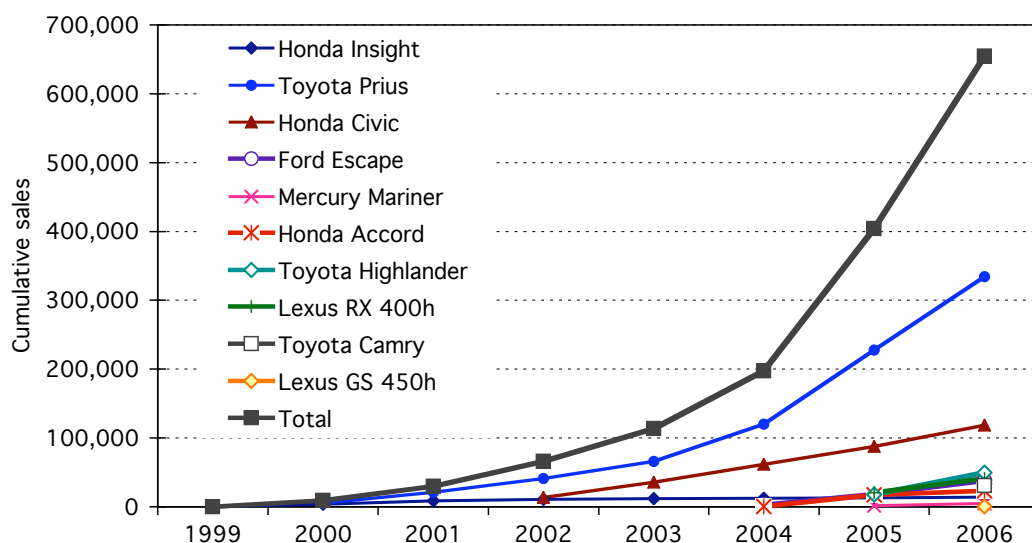


Fig. 22.1 Sales trend for light-duty hybrid vehicles in the United States (through December 2006).

year. All manufacturers were stimulated by new tax credits for hybrid purchase made available in the United States by the Energy Policy Act of 2005. Toyota was initially the greatest beneficiary of these credits, thanks to the very high fuel economy ratings and clean engine certification of its hybrids. Despite its hybrid buyers exhausting Toyota's 2006 full tax credit eligibility by late spring -when the manufacturer reached the annual sales volume (60'000) stipulated in the legislation- the company has sold over 330'000 of its Prius models (Prius I, 2000-2004 and Prius II, 2004-) in the U.S., some 20'000 in Europe and over 100'000 in Japan. Toyota enjoyed over 105'000 in U.S. sales of the Prius II in 2006 alone. (2006 U.S. sales estimates for all available hybrid models shown in table 22.1 were compiled by J.D. Power and Associates and the Electric Drive Transportation Association.) The Honda Civic hybrid with Integrated Motor Assist™ mild hybrid technology is in second place, trailing the Toyota Prius with about 120'000 U.S. and 40'000 Japanese sales, but gaining rapidly in the sales race are the SUV models Toyota Highlander and Ford Escape, each with total sales nearing 50'000.

Table 22.1 Sales data for light-duty hybrid vehicles in the United States.

Hybrid make/model	2006 Sales ^a	1999 - 2006 Cumulative sales ^a
Toyota Prius	106'971	334'723
Honda Civic	31'253	118'608
Ford Escape (SUV)	24'562	42'928
Mercury Mariner (SUV) ^b	3'057	4'637
Lexus RX 400h (luxury SUV)	20'161	40'835
Lexus GS 450h (luxury sedan) ^b	769	769
Honda Accord	5'598	23'077
Toyota Camry ^b	27'336	27'336
Toyota Highlander (SUV)	31'485	49'474
Honda Insight	722	13'886
Total	251'914	656'273

a) 2006, 2005 and some 2004 data courtesy J. D. Power and EDTA; 2003 and earlier data from manufacturers.

b) New offering in late 2005-2006.

Not all models shown in table 22.1 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. Sustained interest in new luxury/performance editions such as the Lexus RX 400h and Lexus GS 450h keeps sales relatively robust among up-market purchasers, for

whom the tax burden is less of an impediment. Worldwide, light-duty hybrid fleet growth has exceeded 50 percent per year over the past four years (that is, the in-use population more than quintupled over a four-year period). A breakdown of this growth by IA-HEV country (plus Denmark and Japan) through late 2006 is shown in figure 22.2.

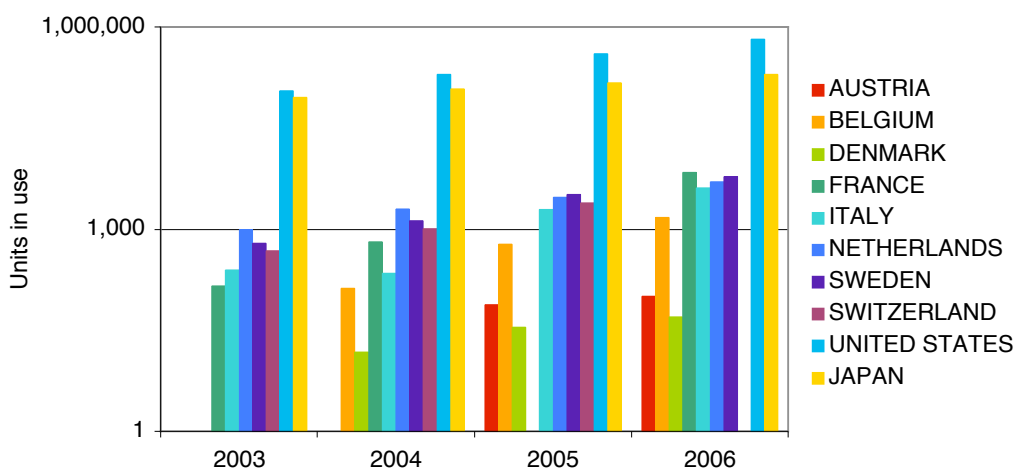


Fig. 22.2 Hybrid vehicle fleet size growth in IA-HEV countries, Denmark and Japan. (Please note the log scale on the vertical axis.)

The year 2007 promises further gains over the preceding year, with new hybrid rollouts promised from General Motors, Mazda and Nissan. Toyota moved up its planned 2008 introduction of the hybrid Camry model to late 2006, and this model enjoyed robust sales (table 22.1). New platforms announced for introduction within the present decade include SUVs and/or light trucks from Saturn (GM), GMC, Mazda and Porsche, and new sedan models from Ford, Hyundai, Nissan and Toyota. The Georgetown, Kentucky manufacturing facility of the Toyota Corporation has rolled the first Toyota hybrids manufactured in North America off of its assembly line. The Kentucky plant is targeted to produce 48'000 Camry hybrids each year, about 10 percent of its total production capacity of 500'000 units. Table 22.2 lists the makes and models that have been announced for commercial release through approximately the end of the current decade.

All-electric bikes, scooters and four-wheelers continued to make news in 2006 beyond the explosive two-wheeler growth in the Peoples' Republic of China (PRC) cited in the previous IA-HEV annual report. World interest in road-legal electric three-wheelers and automobiles (EVs) is tending to centre on niche vehicles such as the GEM (Global Electric Motorcars) -a small low-speed four-wheeler 'neighbourhood electric vehicle' from DaimlerChrysler- and on local shuttles, jitneys, trolleys and light utility vans. The Energy Research Centre of the Netherlands (ECN) has mounted its in-house developed proton electrolyte membrane (PEM) fuel cell propulsion system onto the two-seater GEM car

Table 22.2 Planned and announced light-duty hybrid vehicle rollouts.

Year of introduction	Manufacturer	Model/Type
2007	General Motors	GMC Silverado/Sierra (pick-up trucks)
	General Motors	Saturn VUE Green Line (SUV)
	Mazda	Tribute (SUV)
	Nissan	Altima (sedan)
2008	Ford	Fusion (sedan)
	General Motors	Chevrolet Silverado/GMC Sierra (pick-up trucks)
	Hyundai	Accent (sedan)
	Lexus	LS 600hL (luxury sedan)
2009	Porsche	Cayenne SUV (VW/Audi hybrid drive)
Unspecified	Daihatsu	HVS (sports car)
	General Motors	Tahoe/Yukon (SUVs)
	General Motors	Chevrolet Malibu (luxury sedan)
	Toyota	Sienna (minivan)

platform for low-speed operations. GEM has already captured important EV market share in both Europe and the U.S., especially for cargo-haul and four-passenger versions in France and Italy as well as the United States Sun Belt, but heretofore all available units on the GEM platform have been exclusively battery-powered. The Dutch 'HydroGEM' carries a 76 litre, 3'000 psi (about 200 bar) hydrogen storage tank mounted behind the rear wheels. Coupled with the 5 kW fuel cell and the original 6.5 kWh battery pack, it can handle payloads of up to 400 kg and achieve an operating range of 200 km. ZAP Corporation -a California manufacturer of street-legal electric three-wheelers which has reported a backlog of US\$ 500'000 in orders- has placed a procurement with Shandong Jindalu Vehicle Co. Ltd. of China (PRC) for more than 500 units of the new Xebra four-seater 'city car'. The lead-acid-powered 110 V chargeable Xebra can achieve 40 mph (64 km/h) and has a range of 40 miles (64 km). Shandong Jindalu has indicated that as part of ZAP's exclusive 10-year distribution U.S. contract it is providing the capacity to produce up to 1'000 of these units per month. This car will be the first production electric vehicle (EV) made in China that is designed specifically for U.S. roads. The British International Motor Show in August saw the launch of two new battery EVs: the smart ev (from the manufacturers of the smart car) and the NICE (No Internal Combustion Engine) city vehicle. The smart ev has a 30 kW output and can reach 115 km/h, with a driving range of just under 120 km.

Component research and development for personal and public electric propulsion continues to focus on improved, lighter-weight batteries and battery materials to increase range, efficiency improvements to motor/controllers that enable downsizing with no loss in rated power, and higher delivered power especially for heavy-duty applications. Recent breakthroughs include a power module from Infineon Technologies (a relative newcomer in hybrid components supply) that is only half the size and weight of current installed control systems but increases efficiency up to 20 percent, thanks in part to reduced cooling requirements. Infineon expects these modules to be installed in production hybrids within two years. Other high-tech suppliers such as Renesas Technology America, Inc., and International Rectifier have introduced, respectively, a 32-bit microcontroller specialized for HEV motors, and a significant upgrade to its high-reliability hybrid motor control module that enables sensor-free digital control of permanent magnet motors. Johnson Controls and Saft have won a joint 24-month 50% cost-sharing contract from the U.S. Advanced Battery Consortium (USABC) to develop advanced lithium-ion batteries for HEV propulsion. In an effort in part to meet automakers' cost and customization demands, Maxwell Technologies, Inc., is one of several manufacturers of ultracapacitors to ramp up introduction of product, promising more than 30 new configurations by 1 January 2007. Cell sizes will range from 140 to 3'000 farads, with the higher-capacitance (>500 °F) cells designed to an operating voltage of 2.7 V, thus enabling reduction in the number of cells required per application. About 39% of Maxwell's business in 2006 was expected to come from hybrid transit bus producers, but increased opportunities in forklifts and auxiliary power applications for highway vehicles loom on the horizon.

Many manufacturers are pinning future hopes on the success of the lithium-ion battery sized for transportation applications. If ongoing durability and reliability tests prove successful, lithium-ion technology could offer a quantum jump in battery life and range relative to current storage technologies (i.e., lead-acid, nickel-metal hydride) with the added benefit of a significant increase in power density (W/kg).

Hybrid technology research and applications increasingly embrace medium- and heavy-duty truck and bus applications, in which electric drivetrains work in tandem with compression ignition (diesel) engines in both parallel and series configurations. Because much of the idle and low-speed load of these hybrids is carried by the electrical system, excess emissions of harmful direct-exposure pollutants such as the fine particulate matter of combustion may be significantly reduced. Moreover, it now appears this can apparently be accomplished at a cost penalty comparable to or less than that of standard diesel vehicles equipped with the emission controls required under 2007 and later U.S. emission standards and possibly the Euro-4 and Euro-5 standards. Heavy hybrid utility and specialty

vehicles are currently in deployment and testing (24 hybrid trucks built by International and Eaton went to 14 participating fleets), parcel delivery vehicles are in pre-production which includes a test of hydraulic hybrid technology, refuse collection vehicles are nearing the pre-production stage), and shuttle bus applications are at the stage of characterizing market needs. Diesel hybrid buses have been in service in a handful of metropolitan transit fleets for two to three years.

It was a noteworthy year for promotion and technical advancement of the concept of hybrids with direct plug-in capability. In addition to endorsing -in a general sense- alternative fuels such as ethanol as a pathway to easing the U.S. 'addiction to oil', President G.W. Bush in transportation-focused addresses delivered in April and October specifically pointed to the promise of the emerging plug-in hybrid vehicle (PHEV) technology as a potential major player in the quest to decrease America's petroleum reliance. It was likely the very first exposure of most Americans to news and information about PHEVs, and interest in the research community remains high (see more details in the USA country chapter of this report). Legislation introduced in the state of Minnesota would require the state to begin purchasing plug-in hybrid vehicles for the state fleet, and stipulates purchase inducements for small and large private fleets, whenever such vehicles become commercially available. The USA's largest-volume automotive retailer has joined the Plug-in Partners campaign in calling for manufacturers to put PHEV development on the fast track. Almost 60 U.S. cities currently participate as Plug-in Partners. Saturn Motors has announced that the model year 2008 Saturn VUE -while continuing to offer its hybrid option based on GM's 'belt alternator starter' system- also will be the launch platform for the first front wheel drive version of an advanced 'two-mode' hybrid system that can be configured as a plug-in hybrid. This officially constitutes the first step in GM's commitment to complete development and marketing of a plug-in hybrid production vehicle that will use an advanced battery (possibly lithium-ion). There is a group of 30+ fleets in North America now looking at PHEV variants of heavy-duty hybrids across different work groups. A critical focus at this point is defining user expectations and performance requirements for PHEVs to be commercially successful.

22.2

The future of hybrid and electric vehicles

22.2.1

Introduction

Today's level of mobility and the growth that is expected in travel of people and goods raises concerns about the future of our transportation system, in terms of capacity and environmental impact. Globally, transportation is responsible for about a fifth of anthropogenic CO₂ emissions and road transport contributes substantially to local air pollution in urban areas. The increasing amount of time

spent in traffic jams and waiting for delayed trains and planes shows that our current transportation systems are reaching the limits of their capacities. Quick solutions do not seem to exist, but today's ultimate long-term goal of most organizations that are working on transportation is sustainable mobility. Key elements of sustainable transport systems are independency of fossil energy carriers, no pollutant and greenhouse gas emissions, no accidents, low noise production and acceptable travel times. Fully achieving these objectives may never be possible, but when coming close enough, transport systems can be considered sustainable. This chapter focuses on road transport, the working area of IEA's Implementing Agreement on Hybrid and Electric Vehicles (IA-HEV).

Can hybrid and electric vehicles play a role in sustainable road transport? If the answer is 'yes', there will be a future for this type of vehicles; if not, they will disappear from the scene. The role of hybrid and electric vehicles in sustainable road transport systems is the subject of this section.

22.2.2

Setting the stage

First, a few words are spent on terminology here, because not everybody is using the same definitions for the different vehicle types. A hybrid vehicle is a vehicle with more than one propulsion system. In practice, what is named a hybrid vehicle is most often a hybrid electric vehicle, which is equipped with an internal combustion engine and with an electric motor to drive the wheels. In this case the electric energy to drive the electric motor is stored in batteries. The wheels of an electric vehicle are always powered by an electric motor. The electric energy may be supplied by batteries or by a fuel cell. Fuel cell vehicles are also equipped with a battery and therefore some consider the fuel cell vehicle to be a hybrid vehicle, because it can be powered from the batteries and/or from the fuel cell. In the remainder of this chapter the term 'hybrid electric vehicle' stands for a vehicle that is equipped with an internal combustion engine and an electric motor that is powered by batteries. An 'electric vehicle' can be a battery electric vehicle or a fuel cell vehicle.

Considering all different types of vehicles that are used in road transport, it appears that the relevant characteristics of hybrid and electric vehicles regarding the key elements of sustainable mobility are the energy carriers, the well-to-wheel emissions, and the (sometimes zero) tailpipe vehicle emissions. Regarding safety and travelling time, hybrid and electric vehicles do not differ from vehicles with other propulsion systems. The powertrain of battery electric vehicles and fuel cell vehicles produces less noise than the internal combustion engine, but here the difference in total vehicular noise production is considered too small to clearly distinguish hybrid and electric vehicles from other types of vehicles. Therefore this chapter further concentrates on energy and emission issues, because these are

the areas where hybrid and electric vehicles may stand out compared to road vehicles with other propulsion systems.

All stages in vehicle life come with energy consumption and emissions. One can distinguish vehicle production, vehicle maintenance, driving the vehicle and dismantling/recycling of the vehicle at the end of its service life. Driving the vehicle (vehicle use) is responsible for the majority of the energy consumption during its life cycle. Therefore this first version of an outlook for hybrid and electric vehicles concentrates on vehicle use. However, it is recognised that for example production and recycling of the batteries of an electric vehicle may play a significant role in the life cycle analysis (LCA) of this type of vehicle, so it might be worth to include this kind of issues in a future -more extensive- version of this outlook.

Coming back to the question if hybrid and electric vehicles can play a role in a sustainable transport system, for electric vehicles it can be stated that they do fit in such a system when the electric energy is produced in a sustainable manner. For battery electric vehicles this means that the electricity to charge the batteries is supplied from a sustainable source. For fuel cell vehicles it means that the fuel (usually hydrogen) for the fuel cell is produced in a sustainable manner.

Hybrid electric vehicles will also fit in a sustainable mobility system when they use sustainable energy carriers -like renewable hydrogen or biofuels- for their non-electric propulsion and when their emissions can be kept at very low levels. The latter is possible by using optimised combustion processes and/or advanced exhaust catalysts.

The brief analysis above does not include statements about the share of hybrid and electric vehicles in a sustainable transport system. Especially in stop-and-go traffic, hybrid electric vehicles are more energy efficient than their 'combustion engine only' counterparts. Additionally, the electric drive is very energy efficient and when it is combined with batteries it offers the possibility of brake energy recuperation. Further it should be mentioned that charging and discharging of vehicle batteries comes with some energy losses, and when operating under part load the fuel cell is more energy efficient than the internal combustion engine. These are all elements that determine the well-to-wheel energy efficiency of hybrid and electric vehicles. It is clear that higher well-to-wheel energy efficiencies enable higher shares of hybrid and electric vehicles -that are powered by sustainable energy- in the total vehicle fleet.

These first, general observations lead to the conclusion that the role of hybrid and electric vehicles in sustainable mobility can be substantial. The electric motor

appears to be a key component; it is mounted in pure electric vehicles, in hybrid electric vehicles and in fuel cell vehicles.

From these observations it appears that the question ‘Can hybrid and electric vehicles play a role in sustainable road transport?’ can be answered with ‘yes’ under the conditions that sustainable energy is used, and additionally for hybrid electric vehicles that adequate treatment is applied to the exhaust emissions of the internal combustion engine.

In spite of their potential to contribute to sustainable transport, today the share of hybrid and electric vehicles in the worldwide vehicle fleet is very small. The future of hybrid and electric vehicles predominantly depends on governmental policies and visions in the automotive industry. Therefore the IA-HEV delegates made a first inventory of policies and performed a first round of interviews with people working in the automotive industry -including suppliers- to build a basis for an outlook for hybrid and electric vehicles. The results were presented during the 25th IA-HEV Executive Committee (ExCo) meeting in October 2006 and the main findings -combined with information from literature- are reported in the next two sub-sections.

22.2.3

Governmental policies in IA-HEV member countries

During their 25th meeting, the IA-HEV ExCo members presented the governmental policies related to transportation in their respective countries. Other countries may be added in a later phase. It appears that governments of IA-HEV member countries tend to steer on results and to a much lesser extent stimulate certain technologies. For example goals are set for emissions from road transport, and the actors in the field can to a large extent determine themselves how to reach these goals. There is not much regulation directly aiming at hybrid and electric vehicles. Therefore relevant existing regulations for road transport in general are presented below, supplemented with remarks about their impact on hybrid and electric vehicle utilisation. European policies are addressed first, followed by policies in the United States.

Europe

European governments are currently focusing on measures to reduce global warming. For the transportation sector this means that reducing (well-to-wheel) CO₂ emissions has high priority. Two different types of measures exist:

- Increasing vehicular energy efficiency.

Vehicles that are relatively energy efficient in their category receive tax incentives in countries like Belgium and the Netherlands. New vehicles in the showroom show a label with their fuel consumption compared to other vehicles in the same category.

Hybrid electric vehicles may qualify for tax incentives that are based on relative energy efficiency of combustion engine vehicles. Electric vehicles may qualify for tax incentives that are based on (low levels of) vehicle emissions.

- Using biofuels and other renewable fuels.

Directive 2003/30/EC of the European Union prescribes that on an energy basis, 5.75% of gasoline and diesel fuel in transportation must be substituted by biofuels or other renewable fuels in 2010. This Directive is currently under revision because it appears difficult to meet its objectives, but it is clear that biofuels will gain importance in Europe the coming decades.

There are no technical barriers to make the fuel system of hybrid electric vehicles compatible with biofuels. This Directive does not directly affect electric vehicles.

There are no regulations yet, but hydrogen is considered to be an interesting long-term energy carrier for road transport in Europe. It can be used to fuel both combustion engines and fuel cell vehicles. For example Italy has therefore its 'Hydrogen and fuel cells' national R&D programme. On a European level, there are different activities to develop hydrogen as a future transport fuel. It is recognised that hydrogen will only contribute to sustainable transport when it is produced in a sustainable/renewable way. Technical hurdles regarding hydrogen storage still have to be overcome and the question if sufficient sustainable hydrogen can be made available needs to be answered before hydrogen can play a substantial role as an energy carrier for road transport. Therefore a breakthrough of hydrogen as a vehicle fuel is not expected before the year 2020.

Electric vehicles (EVs) seem to be out of the focus of European policy makers, although some countries have financial incentives for purchase and/or use of electric vehicles. In Belgium EVs fall in the lowest tax categories. However, although they are offered on the market, electric vehicle sales in Belgium have been about zero in recent years. In France a limited number of electric vehicles can receive financial purchase support up to 3'200 Euros. Electric vehicles are allowed to circulate in cities on 'car free days' in Italy. In the Netherlands EVs are exempt from road tax. After a 10-year period of active promotion of electric vehicles by the Swiss government, in 1999 the responsibility for the promotion of EVs was transferred from the federal government to the local governments of cantons. Most of the cantons now grant tax exemptions or reductions for electric vehicles. Currently the majority of the electric vehicles on European roads are electric bicycles.

United States

Policies in the USA focus on increasing energy security, and on reducing costs and environmental impact. Through the FreedomCAR and Fuel Initiative,

development and deployment of transportation technologies that reduce the dependency on imported oil and improve air quality are supported. Starting in 2006 and for a period of five years, purchasers of efficient, advanced technology vehicles (like hybrid electric vehicles and vehicles with lean burn engines) receive a federal tax credit. This system focuses more on 'advanced technology' and less on CO₂ emissions. After a manufacturer has sold 60'000 eligible hybrid and lean burn vehicles, the credit is phased out. While in the past the purchase of electric vehicles was stimulated, these incentives have now expired.

Plug-in hybrid electric vehicles (PHEVs) have recently emerged as an option to reduce energy consumption and emissions from road transport, while at the same time offer the possibility of 'peak shaving' in the electricity grid when a sufficient large number of PHEVs is connected to the grid. PHEVs are considered a promising way forward, and thus there is federal support being made available for initiating research on technologies needed for cost effective PHEVs with different all-electric driving ranges.

Regarding transportation fuels in the USA there are currently two initiatives.

- The Biofuels Initiative.

This initiative serves to accelerate the pathways using cellulosic residues and dedicated biomass crops to displace imported oil and gasoline.

Like mentioned earlier, there are no technical barriers to use biofuels in hybrid electric vehicles. Biofuel compatible hybrid electric vehicles contribute to reducing well-to-wheel CO₂ emissions and to reducing foreign oil imports.

- The Hydrogen Initiative.

This initiative serves to develop hydrogen technologies and fuel cells for vehicles as steps moving closer towards a hydrogen economy.

This initiative clearly aims at stimulating the development of fuel cell vehicles. In a hydrogen economy there may also be room for the use of hydrogen as a fuel for internal combustion engines (ICEs), either in hybrid electric vehicles or in ICE-only vehicles, although this is not the direct aim of this initiative.

22.2.4

The automotive industry

A number of vehicle manufacturers and automotive suppliers has been interviewed by the IA-HEV delegates. For this first round, the number of interviews was limited and more interviews are envisaged during future work on the IA-HEV outlook. To obtain the general impression of the views in the automotive industry that is reported in this subsection, information from recent literature is used in addition to the interviews by the IA-HEV delegates.

Large car manufacturers like DaimlerChrysler, Ford, General Motors and Toyota all see the hydrogen powered fuel cell vehicle as the long-term solution (say 2030 and beyond) to solve the environmental problems related to road transport. Others like Honda, Hyundai, Nissan, Suzuki and Volkswagen are currently also developing fuel cell vehicles. But the fuel cell vehicle is not the only possible long-term solution. Renewable fuels and advanced combustion systems may also play their role in a sustainable road transport system. BMW for example also sees hydrogen as the fuel for the future, but it concentrates on its use in internal combustion engines. Besides that, a diversification in powertrains is expected: different applications may have different propulsion systems. The electric drive may be important for urban applications, while the (compression ignition) internal combustion engine may remain the preferred drive for long distance road transport. However, today the automotive industry generally estimates that the future role of battery electric vehicles will be minor. Just one example is given by Mr. Rudi Menne, chief technical officer at Ford Europe, who says about electric vehicles: "... there is a market but it's not a mass market." [22.1].

An automotive supplier with an interesting long-term view that is worth mentioning here is Siemens VDO. Group vice president Dr. Klaus Egger states: "The hybrid drive is only an intermediate step on the path to future drive solutions. We consider the electric motor to be the actual long-term drive solution that will meet even the most stringent future emissions regulations." The company has the vision that by the year 2020 the combustion engine, transmission, steering column and hydraulic damping in some car models have been replaced by two or four independent electric wheel hub motors with electric wedge brakes, active suspension and electronic steering, in drive-by-wire vehicles. Siemens VDO has started working on an electronic wedge brake as a first step to realise its vision [22.2]. The 2004 GM Sequel prototype fuel cell vehicle represents a similar vision for the car of the future, substituting traditional mechanical systems by 'by-wire' technology [22.3, 22.4]. Also Toyota must be thinking along these lines, given

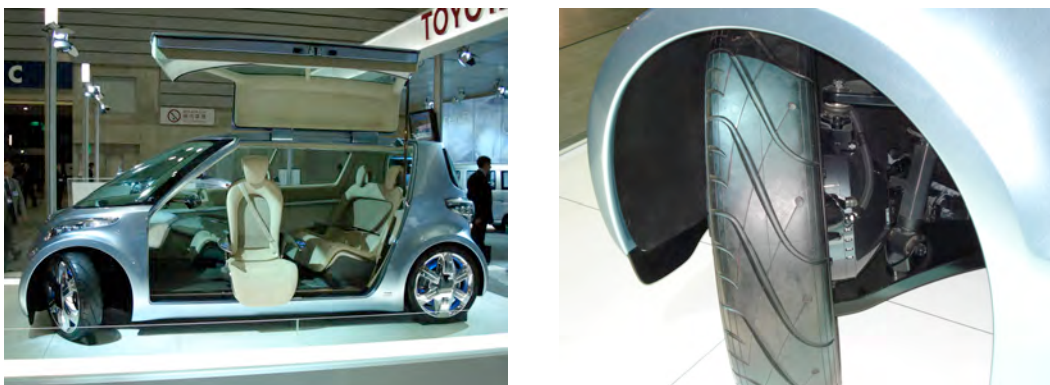


Fig. 22.3 Toyota Fine-X fuel cell concept car, and a detail showing a wheel hub motor. (Photos: M. van Walwijk.)

that it recently presented its Fine-X concept fuel cell vehicle with electric wheel hub motors housed in each of the four wheels.

The energy supply and the emissions from today's road transport system -which is dominated by gasoline and diesel engine powered vehicles- are not sustainable and it will require major efforts to make the transition to a sustainable system. How to get from today's situation to a sustainable system? To be able to supply an adequate technology in all possible future market circumstances, currently most vehicle manufacturers keep all options open. They work in parallel on different technologies like hydrogen, the fuel cell and hybrids, but also on advanced valve timing and homogeneous charge compression ignition (HCCI) for internal combustion engines, biofuels, etc. However, a first concrete step has been taken. Toyota (including Lexus), Honda and Ford now offer hybrid vehicles on the market, and others like General Motors, Hyundai, Mazda and Nissan have announced to follow soon. It seems that hybrid electric vehicles will certainly be part of the automotive product folio for at least the coming decade. Besides these gasoline electric hybrid vehicles, PSA Peugeot Citroën for example announces to bring diesel electric hybrid vehicles on the market by the end of this decade.



Fig. 22.4 Citroën C Metisse diesel electric hybrid concept vehicle. (Photo: M. van Walwijk.)

Not only car manufacturers, but also heavy-duty vehicle producers have started working on hybrid electric propulsion systems. Especially in urban goods distribution and in city bus applications, the hybrid electric drive can bring substantial fuel savings. For example in Japan, Hino already offers a hybrid electric distribution truck on the market. Other truck manufacturers like DAF



Fig. 22.5 Hino Dutro diesel electric hybrid distribution truck. (Photo: M. van Walwijk.)

Trucks and Nissan are today also developing hybrid electric powertrains for their distribution trucks. The BAE Systems-Orion diesel hybrid bus is an example of the application of hybrid electric propulsion in a city bus.

22.3

Conclusions

What can be concluded regarding the outlook for hybrid and electric vehicles? The hybrid electric vehicle will certainly gain market share in the coming decade. The first ones are available on the commercial market today and many others -both in the light-duty and heavy-duty market segments- will follow in the coming years. When in a later phase the energy carriers for transportation shift towards sustainable alternatives, the internal combustion engine of hybrids can be adapted for the new fuels. Compared to their non-hybridised counterparts, hybrid electric vehicles can play their role in a sustainable transport system when their additional costs are amortised by reduced fuel costs resulting from energy efficiency gains.

The electric motor has driving and efficiency characteristics that are favourable for vehicle propulsion in sustainable road transportation systems. Besides its use in hybrid electric vehicles, the electric drive is used in battery electric vehicles and in fuel cell vehicles. Significant developments in life and costs of batteries and

fuel cells are necessary to make these vehicles economically viable. Else (governmental) enforcement will be necessary for a substantial role in future sustainable transportation. However, the electric drive itself may be expected to play an important role in future sustainable transportation systems, in any vehicle configuration that best meets actual requirements.

It is worth noting that besides the aspect of sustainability, many other aspects play a role in shaping future road transport, for example customer's expectations regarding performance, vehicle legislation other than energy and emission requirements (on safety for instance) and costs. While hybrid and electric vehicle technologies mature, also conventional and maybe other vehicle propulsion technologies will develop and improve. Hybrid and electric drives will have to be competitive with and should perform better than other vehicle technologies in meeting all the different requirements to become the future technology of choice.

This chapter presents a general outlook for hybrid and electric vehicles, based on preliminary data that is obtained from a first set of interviews. Future steps in further shaping the IA-HEV outlook will include collecting more detailed information on governmental policies and views of the automotive industry, adding other stakeholders like the oil industry and organizations of vehicle users to the list of interviewees, including additional aspects like recycling of batteries, and broadening the scope of the outlook to include IA-HEV non-member countries.

22.4

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Conversion factors

This chapter presents conversion factors for quantities that are relevant for hybrid and electric road vehicles, such as kilometre 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	mile	mile	1 mile = 1.60934 km	1 km = 0.62137 mile
Volume	barrel (petroleum)	bbl	1 bbl = 159 l	--
Volume	gallon	gal (UK)	1 gal (UK) = 4.54609 l	1 l = 0.21997 gal (UK)
Volume	gallon	gal (US)	1 gal (US) = 3.78541 l	1 l = 0.26417 gal (US)
Speed	miles per hour	mph	1 mph = 1.609 km/h	1 km/h = 0.621 mph

Table 5 Energy and power.

Quantity	Unit	Symbol	Conversion	Reverse conversion
Energy	British thermal unit	Btu	1 Btu = 1055.06 J	1 J = 0.0009478 Btu
Energy	kilowatt-hour	kWh	1 kWh = $3.6 \cdot 10^6$ J	1 J = $277.8 \cdot 10^{-6}$ kWh
Power	horse power	hp	1 hp = 745.70 W	1 W = 0.001341 hp
Pressure	pound-force per square inch	psi	1 psi = 0.0689 bar	1 bar = 14.5037 psi

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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Abbreviations

A	Ampere
AC	Alternating Current
ACEA	European Automobile Manufacturers Association
ADEME	Agency for Environment and Energy Management (France)
AEI	Advanced Energy Initiative (USA)
AFV	Alternative Fuel Vehicle
AGV	Automatic Guided Vehicle
Ah	Ampere-hour
AHFI	Austrian Hydrogen and Fuel cell Initiative
ALM	Automotive Lightweight Materials
ANL	Argonne National Laboratory (USA)
APRF	Advanced Powertrain Research Facility (at ANL)
APSC	Austrian Alternative Propulsion Systems Council
APU	Auxiliary Power Unit
AVEM	Avenir du Véhicule Electrique 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)
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
CEI	Italian Electrotechnical Commission
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CERT	Committee on Energy Research and Technology (IEA)
CEU	Commission of the European Communities
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
CNG	Compressed Natural Gas
CNR	National Research Council (Italy)

CO	Carbon monoxide
Co.	Company
Corp.	Corporation
CO ₂	Carbon dioxide
CUTE	Clean Urban Transport for Europe
CVT	Continuous Variable Transmission
DC	Direct Current
DOE	Department of Energy (USA)
DOT	Department of Transportation (USA)
DPF	Diesel Particulate Filter
ECN	Energy research Centre of the Netherlands
EDF	Électricité de France
EDTA	Electric Drive Transportation Association
EIA	Energy Information Administration (USA)
EM	Electric Motor
EMPA	Swiss Federal Laboratories for Materials Testing and Research
EMU	Electrified Motive Unit
ENEA	Italian National Agency for New Technology, 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)
ESS	Energy Storage Systems
ETH	Eidgenössische Technische Hochschule Zürich (Swiss Federal Institute of Technology Zürich)
ETO	Office of Energy Technology and R&D (IEA)
EU	European Union
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
ExCo	Executive Committee
E85	Fuel blend of 85 vol-% ethanol and 15 vol-% gasoline
FC	Fuel Cell
FCEV	Fuel Cell Electric Vehicle
FCV	Fuel Cell 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
FY	Fiscal Year
GEM	Global Electric Motorcars
gge	gallon gasoline equivalent
GHG	Greenhouse Gas
GM	General Motors
GMC	General Motors Corporation
GTL	Gas-to-liquid (fuel)
h	hour
HCCI	Homogeneous Charge Compression Ignition
HEV	Hybrid Electric Vehicle
HOV	High Occupancy Vehicle
hp	horsepower
H ₂	Hydrogen
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 Hybrid and Electric Vehicle Technologies and Programmes
ICE	Internal Combustion Engine
IEC	International Electrotechnical Commission
IEA	International Energy Agency
IGBT	Insulated Gate Bipolar Transistor
IMA	Integrated Motor Assist™ (by Honda)
Inc.	Incorporated
INRETS	Institut National de Recherche sur les Transports et leur Sécurité (France)
IPHE	International Partnership for a Hydrogen Economy
IRS	Internal Revenue Service (USA)
ISO	International Organization for Standardization
ITRI	Industrial Technology Research Institute (Taiwan)
ITS	Intelligent Transport System
IT2S	Intelligent Traffic Systems and Services research programme (Austria)
JARI	Japan Automobile Research Institute
kWh	Kilowatt hour

LCA	Life Cycle Analysis
LEV	Light Electric Vehicle
Li	Lithium
LiP	Lithium Phosphate
LiP	Lithium Polymer
LMP	Lithium Metal Polymer
LNT	Lean NO _x Trap
LPG	Liquefied Petroleum Gas
MATT	Mobile Advanced Technology Testbed
MCFC	Molten Carbonate Fuel Cell
MH	Metal Hydride
min	minute(s)
mpg	miles per gallon
mph	miles per hour
NEET	Networks of Expertise in Energy Technology (IEA initiative)
NEV	Neighbourhood Electric Vehicle
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
NREL	National Renewable Energy Laboratory (USA)
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
ORNL	Oak Ridge National Laboratory (USA)
P.A.	Power-Assisted
PEFC	Polymer Electrolyte Fuel Cell
PEFC	Proton Exchange Fuel Cell
PEM	Polymer Electrolyte Membrane
PEM	Proton Exchange Membrane
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter
PM ₁₀	Particulate Matter, size < 10 μm (10 ⁻⁶ m)
POW	Plan of Work (of the G8+5 and IEA collaboration)
ppm	parts per million

PR	Public Relations
PRC	People's Republic of China
PSAT	Powertrain Systems Analysis Toolkit
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 Deployment
R&D	Research and Development
SAE	Society of Automotive Engineers
SAM	Super Accumulator Module
SC	Sub-Committee
SCR	Selective Catalytic Reduction
SEK	Swedish Crown
SI	Système International (International System of Units)
SIDI	Spark Ignition Direct Injection
SOC	State Of Charge (battery)
SOFC	Solid Oxide Fuel Cell
SOH	State Of Health (battery)
SO ₂	Sulphur dioxide
STEM	Swedish Energy Agency
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
TLVT	Technology Life Verification Test
TNO	The Netherlands Organisation for Applied Scientific Research TNO
UK	United Kingdom
UNDP	United Nations Development Programme
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)
VUB	Vrije Universiteit Brussel (Belgium)
VW	Volkswagen
WEVA	World Electric Vehicle Association
WSC	World Solar Challenge (race for solar powered vehicles)
ZEV	Zero Emission Vehicle

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The website of the IEA Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) can be found at www.ieahev.org.

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