

International Energy Agency

Implementing Agreement for
Hybrid and Electric Vehicles Technologies and Programmes

Hybrid and electric vehicles 2006

Past - present - future

Progress towards sustainable transportation

February 2006

Cover photo:

IA-HEV clean vehicle award winner 2005, the Toyota Prius II, at EVS-21 in Monaco.

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Progress towards sustainable transportation

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Report structure

This report consists of four main parts. Part A ‘About IA-HEV’ describes the IEA Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV), its activities and its plans for the coming years. It also shows how IA-HEV is embedded in the International Energy Agency (IEA). Part B ‘Activities of IA-HEV’ presents the results of the work that is performed under this Agreement in the form of Annexes, and it also gives current plans for new Annexes. A general picture of hybrid and electric vehicles (HEVs) around the globe is painted in part C ‘Country reports’. It starts with worldwide HEV data and relevant general developments. The next chapters describe the activities on hybrid and electric vehicles in IA-HEV member countries, followed by HEV highlights in selected non-member countries. The last chapter of part C is an outlook that addresses the future of hybrid and electric vehicles. Part D gives practical information related to HEVs and the Agreement: a list of IA-HEV publications, the abbreviations that are used in this report and contact information of participants in IA-HEV.

1

Chairman's message

Starting the 3rd phase of the Hybrid and Electric Vehicles Implementing Agreement: A chance for new members

1.1

Into the focus of the public

In the first year of phase 3 (2004-2009) of the Hybrid and Electric Vehicles Implementing Agreement (IA-HEV), we could notice a shift of our subject hybrid and electric vehicles, away from an outdated insiders' topic and into the focus of the media, the industry and the consumers. The environment of our work has changed. This is a great challenge, and the IA-HEV Executive Committee (ExCo) has taken this into account at its 23rd meeting in Rome, October 2005. I am happy to give you an overview of the decisions, new measures, programmes and initiatives. It is the wish of the Executive Committee to motivate more countries, research institutes, researchers and decision makers to join us. Participation in our Agreement provides unique access to insider's information and task forces. This saves time and money, and it accelerates the transition towards sustainable mobility.

1.2

Changes in the environment of IA-HEV

I see five reasons for the noticeable changes in the environment in which the HEV Implementing Agreement operates:

- Hybrid vehicles are a market success in those countries that manage to reduce market barriers. The Japanese car manufacturer Toyota took a risk by launching the Prius for the mass market. The 'New Prius' model meets customer's expectations in many countries, resulting in long waiting lists for delivery. In spite of these delays, the population of hybrid vehicles increased by 45% from 2002 to 2003 and by 55% from 2003 to 2004 in our member countries and Japan.
- Car manufacturers like Honda, Ford, DaimlerChrysler, GM etc. announced their own hybrid models for the next years. I expect hybrid propulsion systems to be a growing option, regarding the number of offers available on the market and in market share, together with diesel, direct injection and the turbo propulsion systems.
- The environmental problems in the USA, Europe, Middle America and Asia, and the signs of a climate change underline the need for CO₂-free technologies. Goals given by politics, the European Commission or the G8-group in 2005 support the transition to new technical solutions.
- The rising oil demand and the constraints in oil supply also ask for a change.

- Finally, rising gasoline prices are a daily issue for everyone. This supports the shift to cars with higher energy efficiency. Hybrid vehicles are a short-term answer to this issue.

1.3

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

The call for co-ordinated action is one thing. This makes information for decision makers and politicians a necessity. To put objective information on electric and hybrid vehicles -and their effects on energy efficiency and the environment- at the disposal of governments, local authorities, fleet users and industries is one goal of our work. Additional goals in the 3rd phase of operation are:

- Provide this information via general studies, assessments, demonstrations, comparative evaluation, market studies, technology evaluations, etc.
- Disseminate the information that is produced in its task forces (called Annexes) among specialists and organizations.
- Collaborate on pre-competitive research projects and related topics, and to investigate the need for further research in promising areas.
- Collaborate with other IEA Implementing Agreements on transportation aspects, e.g. the Implementing Agreement on Advanced Motor Fuels (IA-AMF) and the Advanced Fuel Cell Implementing Agreement (IA-AFC) in Annexes, tasks or joint Annexes.
- Collaborate with specific groups or committees that have an interest in transportation, vehicles and fuels.

1.3.1

More benefits for participating countries and their partners

At its meeting in Rome, the IA-HEV Executive Committee discussed several measures to increase the benefits for members and to offer more value for their money and participation. The most important are:

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

1.3.2

Intensive search for new member countries and partners

By the decreasing interest in electric vehicles and shifts in national budgets, several countries with a car industry left our Implementing Agreement during its second phase of operation (1999-2004). In view of the success of hybrid vehicle technology on the market and the current interest in fuel cell vehicles (FCVs), we

are convinced that membership of IA-HEV is beneficial. Our first priority is to make countries such as Germany, Canada, Japan, the United Kingdom and South Korea rejoin the Agreement. Especially the task forces 'Hybrid vehicles' (Annex VII), 'Electrochemical systems' (Annex X) and the new Annex 'Heavy-duty hybrid vehicles' are interesting for researchers and technology-oriented specialists.

Concerning application of hybrid and electric vehicle technology, the market introduction is a very tricky issue. By the 'Deployment strategies' study (Annex VIII) and the planned follow-up study 'Lessons learned', we help decision makers and politicians to support a smooth introduction on the mass market. Countries that have to attain environmental or energy consumption targets can highly profit from these studies.

Looking into the future, we have to take into account that the majority of the world population has no access to motorized individual means of transport. No doubt that this will change. IA-HEV has shown in a former study that vehicle numbers could rise from 700 million to more than 3 billion worldwide. If countries like China, India, Brazil and Indonesia would join IA-HEV, this could be beneficial for all parties. Task forces like 'Clean city vehicles' (Annex IX) and 'Electric two-wheelers' (Annex XI) especially address those countries.

Membership in the HEV-Implementing Agreement is interesting for all countries that are involved in projects in the field of hybrid-, electric- and fuel cell vehicles. They can participate in sharing experiences with market leaders and decision makers from European countries and the USA.

1.3.3

New dissemination activities to meet the challenge

The market breakthrough of the hybrid technology is a challenge for our small circle of specialists. Hybrid and electric vehicles will more and more become an issue for decision makers in governments, states and municipalities. To meet this demand existing activities in the Agreement have been updated and additional activities will be started:

- Annual report.

The IA-HEV annual report is published regularly in the first quarter of the year. It presents all the task forces (Annexes) and gives an insight view into the activities in our member countries. Interesting non-member countries will be covered by correspondents from Annex I 'Information exchange'.

Additionally, a new 'Outlook' study for hybrid-, electric- and fuel cell vehicles chapter will be added, as well as a presentation of the winners of the 'IA-HEV clean vehicle awards'.

- Electronic newsletter.
An IA-HEV Newsletter is distributed via e-mail. It informs continually about our work and IEA-related activities. For ordering please contact our secretariat!
- New web-site.
The former IA-HEV and Annex I web-sites on the internet have been merged. The new web-site is operated and hosted by specialists of the Argonne National Laboratory in the USA. The most actual issues are only available in the member's area.
- Insight.
This is an internal monthly electronic newsletter to update IA-HEV members on the progress within the Agreement.
- Workshops.
Our task forces regularly organize workshops and the main information exchange happens there. The following Annexes are regularly scheduling or preparing workshops:
 - Information exchange (Annex I).
 - Hybrid vehicles (Annex VII).
 - Electrochemical systems (Annex X).
 - Electric two-wheelers (Annex XI).
 - Heavy-duty hybrid vehicles (new Annex in preparation).
 - Renewable energies for hybrid, fuel cell and electric vehicles (new Annex in preparation).
 - Fuel cells for vehicles (new Annex in preparation).
 - Market deployment of hybrid and electric vehicles - Lessons learned (new Annex in preparation).

To learn more about these workshops, please contact the Operating Agent in charge, or the secretariat. Although these events are in principle for members only, it is possible to participate in a workshop as a guest in case an interest in the work and in a future participation in the HEV Implementing Agreement is expressed.

We have also added the following new activities:

- IA-HEV clean vehicle award.
By the 'IA-HEV clean vehicle award' we encourage the production and use of hybrid-, electric- and fuel cell vehicles. A personal award is presented to an individual with an outstanding engagement in these technologies.
- Hybrid-, electric- and fuel cell vehicles outlook.
By this outlook we provide an assessment of the future development, elaborated by a board of specialists.
- Support for specialists from developing countries.
We have a special fund to provide for travelling costs, to enable the

participation of specialists from developing countries that are interested in IA-HEV membership. Please contact the secretariat!

These various dissemination activities will provide a good return for the contributions and collaboration of our members.

1.4

The three winning technologies of the future

In the future several technological solutions are ready to provide energy for mass transportation. This is reflected by the various Implementing Agreements of the International Energy Agency (IEA). The best energy technology mix will differ from country to country, and it will become more complex in the future than it is today. There will be more locally adapted energy solutions linked to networks -comparable with the internet- than today's single dominant energy solution. This is new and it might be scaring for the actual decision makers, but young people that grew up with the internet are familiar with this kind of networks. Such a situation calls for an information exchange and a global collaboration as fostered in the Implementing Agreements of the International Energy Agency.

The situation concerning vehicles is similar. Different drivetrain technologies will try to replace the combustion engines. But the mass market for vehicles with combustion engines and the perfect infrastructure for gasoline- and diesel cars in Europe and the United States make it difficult to replace them. The customer will only accept solutions that provide advantages in two to three aspects and will not accept clear disadvantages. To do better will be a challenge for car producers and fuel providers.

Actually, we see three different drivetrain solutions in our field. In all of these systems the electric motor plays an important role. Because of its advantageous energy efficiency, the electric motor will be the winner of the future.

1.4.1

Hybrid vehicles: first HEV technology for the mass market

The first new development that was able to enter the vehicle mass market is the hybrid technology. The market opener was the 'Prius' model from Toyota. After that, Toyota decided to offer a hybrid version of each new model within the Lexus and Toyota brands. Secondly, Honda attracts customers by its hybrid model 'Civic IMA'. In 2005, many of the big car producers announced the launch of hybrid models. Ford sold significant numbers of its 'Escape hybrid' in the USA.

I expect that in the future hybrids will be as conventional as direct injection- and turbo engines. Customers will more and more have the choice to choose a hybrid propulsion system in their preferred model. In view of the rising gasoline prices

hybrid vehicles are advantageous, especially for luxurious, heavy and expensive cars. The new 'Lexus' model is a good example. Hybrid vehicles will enter the market via expensive models and then step down to the middle class segment. By that, hybrid vehicles will have a good image as a powerful and sophisticated technical solution for the future. The energy efficiency -in which our Agreement is mainly interested- might be more seen as a side effect.

For an international car manufacturer, hybrid vehicles will become a necessity as an image factor. Technical laggards will get in trouble. The effect of hybrid technology on fuel efficiency is in practice not overwhelming - the same effect could be achieved by other technologies e.g. a sophisticated light diesel vehicle with a direct injected turbo engine, or by using smaller cars. But diesel is not accepted in the U.S. for private cars and small light vehicles are against the trend in the car market. The high performance and torque of parallel hybrid propulsion is more attractive for consumers.

Our specialists in Annex VII on hybrid vehicles are studying further benefits of this technology. Studies have shown that in several regions of the world 'load levelling' could be interesting for utility companies and the users of the vehicle. Via the battery the vehicle can help to stabilize the electricity grid. This is an exciting vision in a world where networks are replacing monopolies. Thus, the car can earn some money while it is parked.

Hybrid vehicles are a first step towards sustainable mobility. The energy efficiency of road vehicles could be improved by a next step: the 'plug-in hybrid'. Here the consumer has the choice to recharge the battery via the grid. A plug-in hybrid can cover a certain distance by only using the electric motor. This improves its credit as a zero emission vehicle (ZEV) in certain areas and it increases the chance to get incentives. The plug-in hybrid vehicle could become a bridge to the electric vehicle.

1.4.2

Electric vehicles

In the general opinion, today electric vehicles (EVs) are 'out'. Governmental research programmes slowed down and the large car manufacturers stopped their EV projects. Electric vehicles did not meet the expectations of the consumers in the past, due to unrealistic expectations and technically insufficient solutions. Nevertheless, EVs are demonstrating their advantages for nearly one hundred years in several market niches. In view of the new battery technologies and improvements in electronics, power electronics and electric drivetrains, it was clear for insiders that the next 'return' was only a matter of time.

But EVs never totally disappeared. Many consumers would buy an electric vehicle if they could find one. In our member countries and Japan, the total EV-number increased by 38% from 2002 to 2003 and even by 40% from 2003 to 2004. In addition to niche market applications, electric two-wheelers are steadily progressing. Their sales figures increase in many countries. In China several millions of electric bicycles are sold annually. In 2005, the Japanese car manufacturers Subaru and Mitsubishi announced new electric passenger car models with lithium-ion batteries, for use in cities. The new battery technologies enable interesting products that will open a new page in the history of the electric vehicle. In the meantime millions of electric two-wheelers will be produced and used. Our task force 'Electric two-wheelers' (Annex XI) will support this process.

1.4.3

Fuel cell vehicles

The market introduction of fuel cell vehicles was overestimated by the media and the politicians in the last years. This technology turned out to be complex and expensive. The advantages regarding the energy efficiency have to be studied carefully. This will be a task of our Implementing Agreement.

Although fuel cell vehicles are far from the mass market, intensive research has brought some good results. Fuel cell drivetrains are now more compact and powerful and would satisfy many expectations of the users. At the Tokyo Motor Show 2005, good progress could be observed. However, the market introduction is still far away. This must be carefully communicated to the public to avoid false expectations and disappointments. The application as an energy storage system in cars is only one side of this technology. Fuel cells can also be used as auxiliary power units in trucks and heavy-duty vehicles. Such an application can help to improve the technology and to lower the costs.

1.5

The main value of the Agreement: the Annexes

The active work of an Implementing Agreement happens in the Annexes. To start an Annex, at least two countries have to find an agreement about a work plan. The work can be done on the basis of cost sharing or task sharing. The latter is most common in IA-HEV. The work in an Annex is co-ordinated by an Operating Agent (OA) who reports to the Executive Committee (ExCo) of the Implementing Agreement.

The more Annexes a country is participating in, the higher its benefits are from the co-operation in the Implementing Agreement. By 2004 we had completed four Annexes. Actually three IA-HEV Annexes are running, and six new ones are in preparation.

1.5.1

Running Annexes

In this subsection I briefly describe the Annexes that are currently active. More information on these Annexes can be found in their individual chapters.

Information exchange (Annex I).

In this Annex data and the status on EVs and HEVs in the member countries as well as in some non-member countries are collected, and presented twice a year. Some of the statistical data are included in the annual report. The details of the country presentations are only distributed among the members. Since 2005 we have a new Operating Agent, Mr. Chris Saricks from Argonne National Laboratory (USA). He is also responsible for the new IA-HEV web-site (www.ieahev.org or www.transportation.anl.gov/ia_hev). All member countries automatically participate in this Annex and there is no participation fee.

Hybrid vehicles (Annex VII).

This is a group of specialists from the U.S. and Europe that studies and analyzes new trends for components and cars. The results are only available for member countries of this Annex. The Operating Agent is Mr. Rob Winkel (TNO, NL).

Electrochemical systems (Annex X).

This Annex deals with batteries, super capacitors and electrochemical systems. Special details are discussed in workshops, like the 'abusive (safety) testing of batteries and capacitors' workshops that are scheduled for 2006. The Operating Agent is Mr. James Barnes from the U.S. Department of Energy.

The dissemination activities 'IA-HEV clean vehicle award' (first awarded in 2005) and the 'Worldwide outlook' (new in 2006) are no formal Annexes, but these activities increase the value of the Agreement for members and non-member countries.

1.5.2

New Annexes in preparation

We hope to add new activities in the Agreement by the following planned new Annexes. Each of these Annexes can be started if two or more countries decide to participate.

Clean city vehicles (Annex IX).

This is a proposal to exchange information on energy efficient transportation between developing countries and the Western hemisphere. Motorized transport in developing countries is based mainly on buses, trucks and very small individual means of transport using two-stroke engines. This creates many problems regarding the environment, infrastructure and energy costs. The transfer of high-

tech solutions often creates big problems (e.g.: exhaust catalysts need high quality gasoline). Therefore the transfer of new electric drivetrain technologies and alternative motor fuels has to be done very carefully. A first workshop in 2002 in Paris with many attendees from Asia, Africa, North- and South America and Europe showed the need for a project. The formal start of this Annex is actually delayed by a lack of funding. The programmes of the IEA are focusing on energy and are less adapted to support a project that calls for co-operation with international foreign aid organizations. Nevertheless, IA-HEV is willing to offer its expertise in case financing would be found. The contacts for this topic are the chair of IA-HEV, Mr. Urs Muntwyler and the IA-HEV secretary, Mr. Martijn van Walwijk.

Electric two-wheelers (Annex XI).

Electric two-wheelers have a high potential in several parts of the world. The range starts with a cheap electric bicycle in China (more than 10 millions sold per year) up to the high speed e-bikes from Switzerland (Flyer, swizzbee) and electric scooters from Taiwan. Electric two-wheelers can replace car trips and by that they save much energy. To bring these vehicles to the market, many open questions regarding market deployment and technical questions have been identified by the interim Operating Agents Urs Schwegler (Switzerland) and Frédéric Vergels (AVERE, Belgium). Three workshops have been organized so far: in Sweden (2004), at the Electric Vehicle Symposium EVS-21 in Monaco (spring 2005) and in Tokyo in conjunction with the Tokyo Motor Show (autumn 2005). Several hundreds of interested people from governments, industry and trade organisations expressed their strong interest in this topic. The work plan schedules a start in spring 2006. Please check the detailed report and do not miss your chance of participating.

Heavy-duty hybrid vehicles (in preparation).

Heavy-duty vehicles application is often perfectly adapted for hybrid and electric drivetrains. The vehicle weight and many in-use starts and stops provide advantages concerning the energy efficiency, especially when combined with brake energy recuperation. This gives the hybrid and electric solution a chance. The potential of the wide application range from buses, trucks, military and communal vehicles should be examined and promoted. The interest of several of our member countries is high, and first contacts have been established with industrial partners. I thank Juhani Laurikko from VTT in Finland for his input in this topic. The new interim Operating Agent is Mr. Patrick Debal from VITO, a research institute in Belgium.

Renewable energies for hybrid, fuel cell and electric vehicles (in preparation).

Because fossil fuels must be saved, electricity production by renewable energies is the long-term replacement. One big advantage of HEVs is that electricity made by

renewable energies and/or biomass for the ICE can be used. Adapted to local conditions, every country and region can develop their best portfolio of renewable energies. This can be hydropower (Austria, Norway, Switzerland etc.), wind energy (Denmark, Germany, Netherlands, Spain etc.), geothermal energy, solar energy, biomass etc. The work of Annex II 'Environmental impacts' showed the great advantage of electric vehicle drivetrains regarding local, regional and global emissions, and the CO₂ situation. EVs and plug-in hybrids can be used to level out surpluses of temporary high electricity production from sources like wind power. The interim Operating Agent from Denmark, Mr. Jørgen Horstmann, works on a detailed working plan and he is also looking for member countries.

Fuel cells for vehicles (in preparation).

The fuel cell vehicle is discussed on a large scale and it is an interesting option. It is an alternative concept to battery EVs. The potential of fuel cells is not only in drivetrains. It could be first applied in auxiliary power units for heavy-duty vehicles. Car and component industry are highly interested in analyses of possible obstacles and solutions for the market introduction of fuel cells. A work plan for this Annex will be prepared by our Austrian ExCo member Dr. Andreas Dorda (Austrian Federal Ministry of Transport, Innovation and Technology).

Market deployment of hybrid and electric vehicles - Lessons learned (in preparation).

The development in the field of hybrid, electric and fuel cell vehicles and other new propulsion technologies is proceeding in waves. To enhance the success rate of future developments, lessons should be learned from successes and failures. A proposal how to structure the evaluation will be produced by the former Operating Agent of Annex VIII on 'Deployment strategies for hybrid, electric and alternative fuel vehicles', Ms. Sigrid Kleindienst Muntwyler.

Hybrid and electric vehicles outlook (envisaged).

Electric and hybrid vehicle numbers show a strong growth in our member countries and in Japan. By the end of 2007, we expect at least 1 million HEVs in use in member countries plus Japan. This saves a relevant amount of energy and it avoids CO₂ emissions. To get an idea of the amount of fossil fuels that are replaced and the avoided amount of CO₂, an outlook will be elaborated, which also will assess vehicle numbers for a long-term future. This will provide ideas about the additionally needed electric power production capacity. Contacts for this task are IA-HEV chairman Urs Muntwyler, IA-HEV secretary Martijn van Walwijk and Operating Agent of Annex I Chris Saricks (Argonne National Laboratory, USA).

1.6

Member countries

The 'customers' of an Implementing Agreement are the member countries and sometimes sponsors from the industry. During the first two phases of IA-HEV, a total number of 15 countries participated. Actually 8 countries are active, and membership of new countries is a very important issue.

In the 3rd phase of the Agreement we will increase the benefit for our members by lowering the membership fee and by adding new Annexes, for some of which participation is even free. This new concept has to be marketed extensively. Contacts in potentially new countries are officials of a relevant governmental authority. If you know such people please contact the secretariat!

1.7

Final remark: words of thanks

Here I would like to thank the ExCo members for their participation and their contributions. Compared to the past, we have a more active group that works hard for the new spirit in the Agreement. I thank especially those members that took over the responsibility for a new Annex. I thank the deputy chairs Arie Brouwer (SenterNovem, NL) and Tien Duong (DOE, USA) for their additional efforts. I also thank Mario Conte from ENEA, Italy, who organized the October 2005 ExCo meeting in Rome.

The other group of hard workers are the Operating Agents (OAs). Sometimes it is hard and tricky to bring the group of specialists together and to start and maintain an Annex. This works better and better, and we have more active OAs and interim OAs than ever before.

We had a very strong support from our desk officer within the headquarters of the International Energy Agency, Jeppe Bjerg. All the time we have good communication with the EUWP by its deputy chairman Peter Finckh and the chairman Peter Cunz. I have to thank our former secretary Frans Koch for his continuing advice when we needed it. Our new secretary, Martijn van Walwijk, has successfully taken over the work, and I wish him great satisfaction for that. Finally I thank Sigrid Kleindienst Muntwyler who supports me in the background at my office.

The launch of new Annexes was financially supported by special grants from Sweden, Switzerland and the United States of America, and I want to thank them for this support.

Finally I thank the researchers and members in the Annexes, and I hope that our work contributes to the progress in the field of electric, hybrid and fuel cell vehicles.

December 2005
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 how it is embedded in the structure of 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 organisations,
- 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, and
- 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 Agreements provide the framework for collaborative research, the benefits of which include pooled resources and shared costs, harmonisation of standards and hedging of technical risks.

Under the stewardship of the IEA Committee on Energy Research and Technology (CERT), the IEA supports four active Working Parties/Committees

that cover technologies for renewable energies, end-use technologies, fossil fuels and fusion.

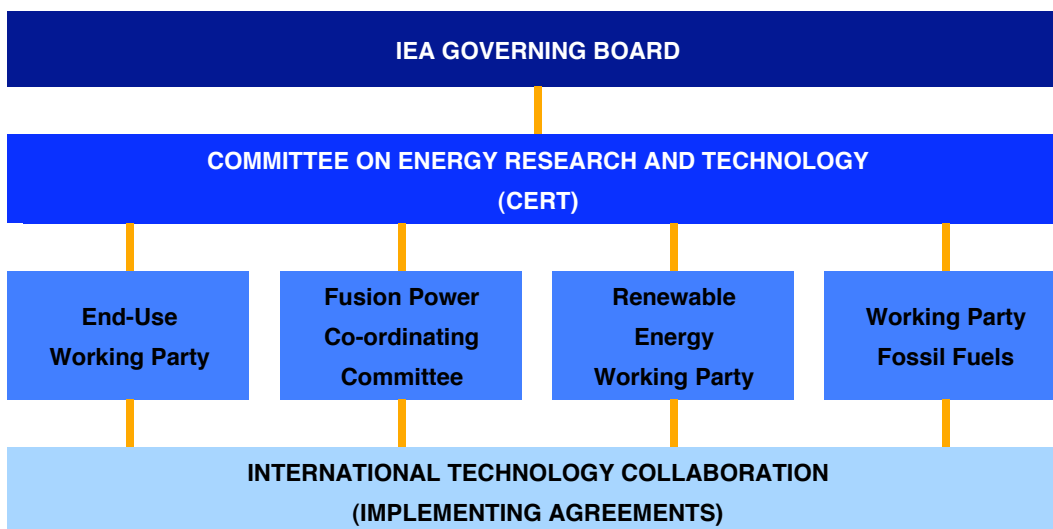


Fig. 2.1 IEA energy technology collaboration programme structure.
(Source: *International energy technology co-operation - frequently asked questions*. IEA, Paris, France 2005.)

Any OECD member, non-member country or international organization can participate in an Implementing Agreement. Current Implementing Agreements cover a wide range of technology areas from Advanced Fuel Cells to Wind Turbine 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 web-site: www.iea.org/Textbase/techno/index.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 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. Implementing Agreements will contribute substantially to the work of the IEA. The plan will focus 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.

More information about the plan of action, the role of the IEA and the progress can be found at the web-site: www.iea.org/G8/index.htm.

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. Using vehicles such as published studies and workshops, these activities are designed to enhance policy approaches, improve the effectiveness of research programmes and reduce costs.

The IEA's Implementing Agreements focus on technologies for fossil fuels, renewable energies, efficient energy end-use and fusion power. 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 includes news of the Implementing Agreements' activities and output. The January 2006 issue of the OPEN bulletin highlights -among others- the activities

of IA-HEV. The IEA also issues publications giving updates on the Implementing Agreements' major achievements. The most recent updates were published in April 2005:

- 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 web-site: www.iea.org/Textbase/publications.

An intensive review -in 2002- of the legal and management structures underpinning the co-operative activities of these IEA Implementing Agreements resulted in the 'IEA Framework for International Energy Technology Co-operation'.

Approved by the IEA's Governing Board in April 2003, 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 organisations.

Participating in IEA Implementing Agreements

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

- Contracting Parties can be governments of OECD member countries, OECD non-member countries or the European Communities, or entities nominated by them. They can also be international organisations in which governments of OECD member and/or OECD non-member countries participate. Contracting Parties from OECD non-member countries or international organisations 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 organisations and 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.

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.

The benefits of international co-operation on energy technologies in Implementing Agreements are shown in box 2.1.

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 nine member countries per January 2006 are Austria, Belgium, Finland (not active), France, Italy, the Netherlands, Sweden, Switzerland and the USA.

Compared to the automotive industry and some research institutes, IA-HEV is a relatively small player in the field. By focusing on a target group of central & local governments and government supported research organisations, 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 of this report (chapters 3 through 11). 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 award. The work in the task forces of the Annexes that are currently active can be found in part B of this report.

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 web-site. 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 web-site: www.transportation.anl.gov/ia_hev/ or 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 web-site, 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 web-site.

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 the 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, Indonesia, India, 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 Dhaka. 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 (millions of 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 and 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. The topics that will 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 • 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 (FCEVs) • 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, organisations 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 to be addressed by IA-HEV during its third term of operation. Four of these topics are currently under consideration for starting new Annexes. Each of them is addressed in a separate chapter in this report. The four new Annexes are:

- Heavy-duty hybrid vehicles (chapter 8).
- Market deployment of hybrid and electric vehicles: Lessons learned (chapter 9).
- Renewable energies for hybrid and electric vehicles (chapter 10).
- Fuel cells for 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 web-site 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 organisations 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'. 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, the 'Best practice award' for Reggio Emilia in Italy and the 'Personal award' for professor René Jeanneret.

- **Toyota Prius - Clean vehicle award**

In March 1997, Toyota officially announced the market introduction of a hybrid vehicle with a 'split-power' propulsion system, the Prius. This configuration allows that the power of the internal combustion engine is either directly acting on the wheels or -via a generator- feeding the batteries. During stand still and at low vehicle speeds the combustion engine is not working. The electric motor is used to propel the vehicle at low speeds and at higher speeds it may function as a power booster. This system combines two motors at their best efficiency. It gives the Prius an extraordinary energy efficiency combined with outstanding driving characteristics.

Important IA-HEV goals are to stimulate high energy efficiency and to reduce fossil fuel consumption of road traffic. Significant contributions can only come from large numbers of fuel-efficient vehicles sold, so that is the focus of this clean vehicle award. The car manufacturer Toyota achieved with the Prius a revolutionary concept with a market success. By April 2005, Toyota had already sold over 300'000 'Prius I' and 'New Prius' cars. This astonishing career of a clean vehicle shows the great market potential of sophisticated clean vehicle technology.

- **Reggio Emilia - Best practice award**

Reggio Emilia may not be a large city, but its commitment to electric vehicles is really great. The problems with air pollution were fought by an action plan that, among others, aimed at the transformation of the public fleet to natural gas, electric and hybrid vehicles. This measure is completed by a long-term rental system of electric vehicles for commercial users and by banning private ICE (internal combustion engine) vehicles from the inner city during certain hours. This mix of regulation and promotion led to a remarkable fleet of more

than 450 electric and hybrid vehicles that not only serves the public services but also serves commercial purposes. With these achievements Reggio Emilia is an outstanding example for an effective hybrid and electric vehicle promotion.

- **René Jeanneret - Personal award**

The Swiss René Jeanneret, former professor at the Engineering School of Biel (Switzerland), is a well-known international specialist on electric drivetrains. He was not only teacher for power electronics but he also led many research projects on electric vehicles, including: electric drivetrains for various vehicles in the 1970s, a hybrid vehicle drivetrain for Volkswagen in 1980 and an European COST project on electric vehicles. After a lecture at the first Tour de Sol conference on ‘drivetrain and power electronics in a solar car’ he decided to build his first racing solar car, against the will of the school director. He accumulated an impressive list with top rankings of his solar racing car developments during the years 1985 - 1993. Since 1987 he collaborated with the Swiss aerospace company Bucher Leichtbau AG in projects on lightweight electric commuter vehicles. He developed a DC-motor for an electric self-launching glider with a retractable motor that is in series production since 2004.

Mr. Jeanneret is now retired but he is still active in calculation of drivetrains/ motors for vehicles, wind turbines, micro turbines etc. He is still convinced that future propulsion systems will show an electric motor, because of its efficiency, the power potential and -last but not least- the environmental benefits.

The 2005 clean vehicle trophies consist of clear crystals from the Swiss Alps, home of the chairman of the Agreement (see figure 2.2).



Fig. 2.2 The IA-HEV clean vehicle award trophies 2005, for Mr. René Jeanneret (Switzerland), Toyota Inc. (Japan) and Reggio Emilia (Italy). (Photo: Muntwyler.)

The second award ceremony is scheduled for October 2006, during the Electric Vehicle Symposium and Exhibition EVS-22 in Yokohama, Japan. Please contact your national IA-HEV delegate or the IA-HEV chairman before June 30, 2006, if you have suggestions for new candidates.

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- and 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 of the Implementing Agreement and has remained a key component of the Agreement into the current phase 3. All members in the Agreement are automatically participant of this Annex, and they designate an agency or non-government organization to represent them. The responsibility for the week-to-week affairs of this Annex is 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 electric (EV) and hybrid electric vehicles (HEVs) and their components. Vehicles in this context are generally classified as electric and electric-assist bicycles, electric scooters, three- and four-wheel light-duty electric vehicles (including small trucks and delivery vans), hybrid gasoline-electric automobiles and light trucks, and hybrid diesel-electric heavier trucks and buses (heavy-duty hybrid vehicles 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.

3.3

Working method

The work of collecting and analyzing the hybrid and electric vehicle information is carried out by the respective country experts, who then make it available to other members at both Annex I experts' meetings -held semi-annually in conjunction with meetings of the IA-HEV Executive Committee- and through the IA-HEV web-site (www.ieahev.org or www.transportation.anl.gov/ia_hev), on

which data may be updated more frequently. The Operating Agent (OA) is responsible for co-ordinating these activities, maintaining the IA-HEV web-site and contributing to the production of the IA-HEV annual report. The OA also acts as a liaison to the OAs for other Annexes and -through the Executive Committee (ExCo) secretary- to the ExCo chair and the cognizant IEA Desk Officer.

A major part of the information exchange for this 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 2005 (which was the first full year of phase 3 of the Agreement) has been 'Lessons learned: What has and has not worked in marketing and commercialization?' It was conceived as a retrospective consideration of developments throughout phase 2 and into the present. Experts reviewed both ongoing research and development efforts and project results in their respective countries as well as their experiences in commercializing two- and four-wheel electric and hybrid vehicles, with emphasis on strengths and weaknesses.

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 (IA) 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 web-site, 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 web-site 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.

3.4 Results

Twenty-two 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, this Annex published an annual report separate from that of the IA-HEV. 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. The Annex I and IA-HEV annual reports have now been combined, effective with the start of phase 3. This 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 and 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.

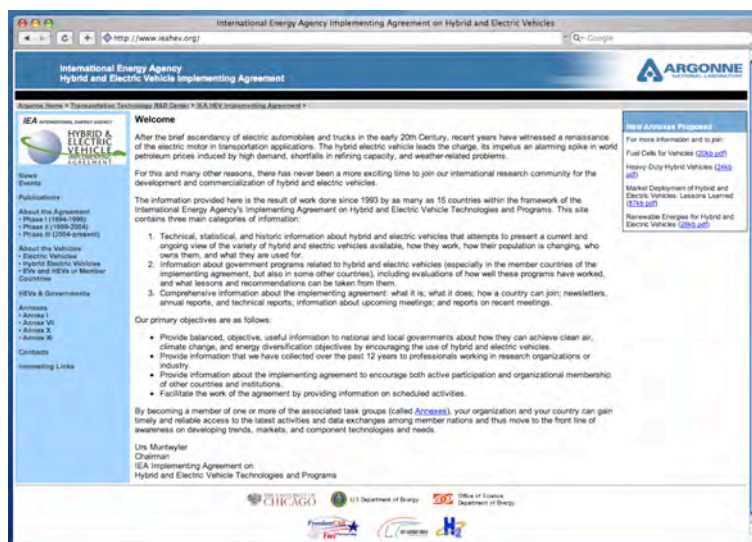


Fig. 3.1 Welcome page of the new IA-HEV internet web-site: www.ieahev.org.

3.5 Outlook

There will be a concerted effort during 2006 to assure that the information and data posted on the IA-HEV/Annex I combined internet site are as timely and accurate as possible, and that access to these data will be limited to participating members. Items from both member and non-member nations will be posted. In addition, the Annex I Operating Agent expects to be able to employ the wide spectrum of international contacts to which he has access to facilitate incorporation into web-site 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

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4

Hybrid vehicles

(Annex VII)

4.1

Introduction

Hybrid electric vehicles (HEVs) can be an important tool for achieving policy goals concerning air quality, greenhouse gas emissions, energy efficiency and energy independence.

For instance if 'plug-in' hybrid vehicles became an important part of a national vehicle fleet, they could have a major impact on reducing imported oil requirements. 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 3rd phase of the IEA Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV), Annex VII 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 Automotive 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.

The focus of this Annex is on (hybrid) vehicles with four (or more) wheels. Both light-duty vehicles (e.g. passenger cars) and heavy-duty vehicles (e.g. busses and trucks) are included.

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 / Automotive, part of the Netherlands Organization for Applied Scientific Research TNO, acts as Operating Agent of this Annex. After a period of two years without many activities, 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.

The task force plans to perform 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.

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 will produce objective,

unbiased information on hybrid vehicles that can be used as a basis for decision making by officials in governments and automotive research organisations.

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 Automotive

The Operating Agent organises 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 organisation that hosts the meeting, is included.

The second expert meeting in the third phase of this Annex was organised by INRETS in Lyon, France, in March 2005. The 3rd expert meeting was hosted by Argonne in Chicago (USA), September 2005.

The Operating Agent continuously tries to attract new participants and sponsors. Interested countries and organisations are most welcome to join the task force.

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: Collection and comparison of different existing definitions of hybrid propulsion systems in relation to different applications for these definitions.
- Charge and discharge characteristic of capacitors for hybrid electric vehicles.
- Costs of hybrid vehicles: Analysis of present and foreseen future costs of hybrid vehicles and their components.
- Trend from charge depleting to charge sustaining hybrids: Analysis of a perceived trend away from using electricity as an input energy carrier for hybrid vehicles.
- Fuel economy and exhaust emissions test procedure for hybrid electric vehicles: Evaluation of present activities concerning the development of test

methods and procedures in Europe, Japan and the USA, and assessment of the needs for harmonization as well as for separate test procedures for type approval purposes and technology evaluation purposes.

- Comparative assessment of different HEV configurations using ADVISOR: Comparison of conventional reference vehicles and different HEV configurations for typical vehicle classes (trucks, buses and passenger vehicles) in Japan, the USA and Europe using the ADVISOR simulation tool.
- Emissions of hybrids: Analysis of the concrete emission benefits of hybrid-electric vehicles.
- Alternative motor fuels and hybrid vehicles: Analysis of the relation between fuel choice and powertrain hybridization. Assessment of the possible benefits of using alternative fuels in hybrid vehicles or vice versa of the opportunities that hybrid vehicles offer for the introduction of alternative motor fuels.
- HEVs and regulations: Assessment of how present and foreseen regulations (e.g. concerning emissions) influence the development and market introduction of hybrid vehicles.
- Energy consumption and emissions of hybrid vehicles: Analysis of available information on energy consumption and emissions of hybrid vehicles, both from measurements on existing vehicles and from simulations. Creating insight and pointing out the need for reliable emission factors for scenario studies and policy evaluations.

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 will strengthen the network among themselves. This gives them access to research that they have not done themselves, and keeps them informed on recent developments in other countries and about the state of the art of the technology.



Fig. 4.1 Welcome page of the IA-HEV Annex VII web-site: www.vito.be/ieahev.

The result of Annex VII phase III, being reports, papers and presentations - e.g. Global prospects of plug-in hybrid vehicles; Impact of plug-in HEV all electric range on fuel efficiency - will be first disseminated in the countries that participate in this Annex. Dissemination is co-ordinated by the organizations that represent their governments in this Implementing Agreement. At the end of the project the results will be made available for a broader public through the IA-HEV web-site: www.ieahev.org.

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

4.5

Outlook

The auto component industry and the automotive industry itself are important sectors of the economy in many IEA countries. If hybrid vehicles become an important share of a country's car fleet, they can make a significant contribution to reducing oil imports, greenhouse gases, and noxious emissions. For these reasons it is important for government officials and automotive research organizations to obtain reliable, objective information on hybrid vehicles. This Annex produces such information.

The fact that hybrid vehicles are becoming more important these days is shown in figure 4.2, which presents the hybrid sales figures in the United States. All the vehicles mentioned in this graph are subject of detailed study in this Annex. HEV sales in Europe and Japan are also subject of study in the task force.

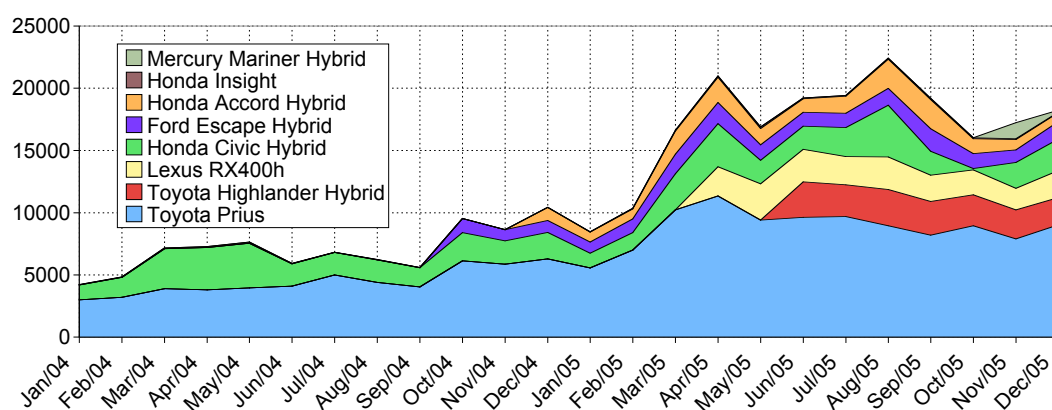


Fig. 4.2 U.S. hybrid vehicle sales in 2004 and 2005. (Source: www.greencarcongress.com.)

4.6

Contact details of the Operating Agent

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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 is a striking example spurred by their rapid economic growth. More and more cities around the world are passing the one 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.



Fig. 5.1 Example of a polluting bus.
(Photo (a detail is reproduced here): Karl Fjellstrom; supplied by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Transport Photo CD-ROM Urban Transport, July 2002.)

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 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, 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 organisations 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 surprises may come up, and to illustrate both types of activities that are mentioned above in the 'working method' subsection.

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 subsection 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 subsection 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 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 web-site 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 a sustained continuation of Annex IX.

A wide range of organisations 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 organisations, multi-national companies and other interested organisations 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

Organisations 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 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 super capacitors 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 Hybrid and Electric Vehicle Implementing Agreement (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 (EVs) 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 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.

The importance of batteries and capacitors in advanced vehicles is reflected by the number of technical meetings that focus on the subject. A new -annual- international meeting that focuses specifically on advanced vehicular batteries attracted over 300 attendees last year. The 46th Battery Symposium in Japan in November 2005 chose to focus all of its invited, English-language papers on electrochemical systems for use in vehicles. Over half of the papers at a recent general battery conference in the United States were associated with vehicular applications.

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

A new Operating Agent (OA) was appointed for this Annex recently. The new OA will introduce a new working method in response to the wide range of topics covered by the Annex and also in response to requests from several potential participants that the extra workload associated with participation in the Annex be minimized.

The Annex will function by organizing a series of working groups. Each working group will focus 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 will have 15 - 25 members, all of whom are experts in the specific subjects under discussion. The working groups will be supplemental to the many scientific and technical conferences related to batteries and capacitors. Each group will schedule one or two meetings to address their topic. At the end of these meetings, an appropriate report will be 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 will be expected to participate in every working group. Each group's membership will reflect the specific topic under discussion. Topics for each working group will be 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 first working group will focus on 'the abusive testing of batteries and capacitors'. Its first meeting will be in San Diego, California, USA at the end of January 2006, and a second meeting is scheduled for May of the same year. About twenty experts are expected to participate in the discussions. Participants are 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 will have an 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 is that all discussions will be '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 will not define standards for testing, rather the goal of the group is 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 will be prepared and distributed to all participants.

The work of the Operating Agent of this Annex is funded directly by the U.S. 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

Because the OA and the approach to operating the Annex are new, there are no specific results that can be cited yet. The fact that the first working group has attracted members from three continents and a wide range of organizations indicates that the approach can result in potentially dynamic and productive meetings. Preliminary comments about the first working group indicate that all of the participants expect it to expand their knowledge and enhance their performance in their home organizations.

6.5

Outlook

Conversations with scientists from several countries that are members of the Implementing Agreement have produced enthusiastic responses to the concept of the next working group and several individuals have offered to help organize and host meetings in Europe. This positive response makes one hopeful that the Annex will be 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 a topic related to the basic science of batteries. The meetings of this group will be held in Europe. The specific technical topic and location of the meetings will be chosen during the spring of 2006.

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 two-wheelers (Annex XI)

7.1 **Introduction**

Electric two-wheelers can be an important component of an overall programme to improve mobility. They require very little space, they cause no pollution, and they produce no noise. They can replace not only bicycle trips, but more importantly they can substitute some specific short vehicle trips. However, some important actors are not committed enough to stimulate a substantial use of electric two-wheelers. The common interest of the stakeholders -users, industry and governments- appears not to be sufficient yet.

Against this background, the IA-HEV Executive Committee (ExCo) decided in spring 2004 to prepare a new Annex on electric two-wheelers.



Fig. 7.1 Policeman on an electric bicycle as a testimonial of e-bikes in the Swiss city Langenthal. (Photo: Langenthal.)

7.2 **Objectives**

The overall objective of this Annex is to identify barriers that hindered the market penetration of electric two-wheelers until now, and to develop and to test ways to overcome these barriers. This will 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 actual version of the work plan contains the following five subtasks:

1. Identifying energy saving potentials as justification of governmental support.
2. Recommending market introduction strategies directed at manufacturers, importers and dealers, as well as authorities.
3. Identifying technology improvements that are needed.
4. Identifying infrastructure requirements.
5. Sharing experiences and information obtained from ongoing and completed projects (extended dissemination).

7.3

Working method

The interim Operating Agent -Mr. Urs Schwegler- has organised two workshops in 2005, to inform potential participants in this Annex and to refine the work plan. These workshops were organised in conjunction with the Electric Vehicle Symposium EVS-21 (early April) and in conjunction with the Tokyo Motor Show (late October).

7.3.1

Electric two-wheelers at EVS-21

The Annex XI workshop was following the five days Electric Vehicle Symposium EVS-21 that was including a 2-days conference, an exhibition and a 'ride & drive'. A promising selection of electric two-wheelers -ranging from power assisted bicycles up to high performance fuel cell motorcycles in different market stages (prototypes to mass production)- was one of the highlights of EVS-21. These vehicles will face new technology challenges and require new marketing strategies, and by that they justified the international collaboration proposed in this Annex.



Fig. 7.2 A fuel cell motorcycle, a hybrid scooter and an electric moped at the Honda booth at EVS-21. (Photo: Urs Schwegler.)

Immediately after the symposium, the interim Operating Agent had organized a half-day workshop on the plans for this Annex. 34 experts from 17 different countries participated in this workshop. They belong to various business sectors such as industry, policy, universities and the media.

In addition to a general introduction on the organisation of the IEA by the IA-HEV chairman and the presentation of the Annex XI work plan by the interim Operating Agent, four representatives from policy and industry presented their views on the market situation and the requirements for international collaboration regarding electric two-wheelers.



Fig. 7.3 Public charging stations for electric scooters in the city of Rome, Italy. (Photo: Fabiana Marconi.)

7.3.2

Tokyo Motor Show 2005

In addition to the well-known car exhibition, the Tokyo Motor Show also contains an important section on motorcycles. There, Yamaha presented the electric moped Passol, which is being commercialized for some years now in Japan. Furthermore, Yamaha presented several electric, hybrid and fuel cell prototypes and studies, thus demonstrating their interest in these technologies.

JARI, the Japan Automobile Research Institute, organized at the Tokyo Motor Show a half day symposium with two connected workshops: one dealing with the state of the art of electric vehicles in general, and the other one with electric two-wheelers, including IA-HEV Annex XI. The latter was attended by more than 100 experts, most of them coming from Japan.



Fig. 7.4 Hybrid motorcycle by Yamaha at the Tokyo Motor Show 2005. (Photo: Urs Schwegler.)

Hisashi Ishitani -professor at the Keio University (Japan) and chairman of the World Electric Vehicle Association WEVA- opened the workshop with a welcome address pointing out the importance of electric two-wheelers in a sustainable transportation system.

After a general introduction of the IEA by the IA-HEV chairman and a presentation of the Annex XI work plan by the interim Operating Agent, four Asian representatives from policy and industry presented their views on the market situation and the requirements for international collaboration regarding electric two-wheelers.

7.4

Results

The two workshops (see section 7.3) that were held during the planning phase of this Annex showed that the following items are important for a successful market introduction of electric two-wheelers:

- Lobby activities at authorities for subsidies, as long as electric two-wheelers are not yet commercially viable.
- Joint research activities: customer profile, customer needs.
- Joint promotion activities for electric two-wheelers.
- Distribution research: what is the most suitable network for electric two-wheelers?
- Industry has little confidence in collaboration with governmental organisations.
- The advantages of electric two-wheelers are not clear from a customers' perspective.

- Unclear specifications and vehicle categorization confuse customers.
- Different homologation standards in different parts of the world complicate developments of new vehicle models.
- Emission standards for ICE motorcycles and increasing fuel prices will favour electric two-wheelers.
- Technology does not sell: customers need reassurance that the products can satisfy their needs, they don't care about technology.
- Fill the gap between demonstration and free market with early customers such as police, military etc.
- An electric drivetrain requires a new vehicle type, the 'small light electric scooter' (Taiwan).
- There is a huge variety of measures available for governments to stimulate the introduction and use of electric two-wheelers:
 - product standards, homologation,
 - regulations (restricted access to inner cities etc.),
 - supply basic, objective information (web-sites etc.),
 - demonstration projects,
 - use electric two-wheelers in governmental fleets (shining example),
 - support an adequate infrastructure,
 - exhibitions with 'ride & drive',
 - co-operation with suppliers (manufacturers, importers, dealers).

7.5

Outlook

Based on expressions of interests, the IA-HEV Executive Committee is expected to approve Annex XI at the beginning of 2006.

AVERE -the European Association for Battery, Hybrid and Fuel Cell Electric Vehicles- represented by its Secretary-General -Mr. Frédéric Vergels- has proposed to manage Annex XI as Operating Agent.

The kick-off meeting for this Annex is planned to be held at the Taipei Cycle Show on March 10 & 11, 2006.

This new Annex is still open for new participants, so please do not hesitate the Operating Agent or the vice Operating Agent when you are interested to join.

7.6

Contact details of the Operating Agent

The following individuals can supply further information regarding this Annex and participation:

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8

Heavy-duty hybrid vehicles (New Annex)

8.1

Introduction

The idea to start a separate Annex dealing with heavy-duty hybrid vehicles 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 as a separate Annex.

This Annex is in a preparation phase. Consequently, all information below is part of a draft work plan and should be considered as such. This draft is prepared in December 2005 and has most probably changed by the time this annual report is published. For the latest information please contact the interim Operating Agent.

8.2

Objectives

This Annex aims at structuring the information about heavy-duty hybrid vehicle components and configurations. An important aspect of this task is to gain insight in existing and possible applications of hybrid vehicle technologies. Besides the obvious vehicle types like buses and trucks, other applications of conventional heavy-duty vehicle technology -like 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 'lessons learned' will not only focus on the technical barriers to overcome but also on the required framework (training, support, ...) for successful implementation projects.

Next to these specific subtasks a more general task of information gathering and dissemination will be co-ordinated by the Operating Agent.

8.3

Working method

The interim Operating Agent VITO -a research institute belonging to the Flemish Region in Belgium and actively involved in hybrid vehicle research and

deployment- is currently preparing a draft work plan for the first phase of this Annex. This draft will be electronically distributed to potential participants for review. It is the intention to have a proposal for the work plan available before the next IA-HEV Executive Committee meeting in April 2006.

Once the work plan is approved and sufficient participants are found, a kick-off Expert Meeting will be held. Currently the target date for the kick-off meeting will be in June or September. The first Expert Meeting will be an introduction of the participants and the work plan. The subtasks will be further elaborated and assigned to a leading participant who will co-ordinate its activities.

Further Expert Meetings will be used to co-ordinate the progress of the subtasks, to exchange information and to plan the activities for the months until the next meeting. Each meeting will allow the host participant to present his capabilities and infrastructure in more detail.

The result of the first phase will be a report containing three sections. Each section will report the results of one subtask:

- structuring the information about heavy-duty hybrid vehicle components and configurations and gaining insight in existing and possible applications of hybrid vehicle technologies,
- producing an overview of the current situation of existing hybrid prototypes and standard vehicles,
- gathering and dissemination of information.

8.4

Status and outlook

This new Annex is currently in the planning phase. That means that an interim Operating Agent has been appointed to prepare the work plan and to identify potential participants. Please contact the interim Operating Agent if you would like to join this Annex or if you need more information. Contact details of the Operating Agent can be found in section 8.5.

The interim Operating Agent will distribute the draft work plan to possible participants and other interested parties to gain feedback and to create interest in this new Annex. The work plan is scheduled for early April 2006, so inform the interim Operating Agent if you are interested in this new Annex as soon as possible. This will enable you to help shaping the work plan to make the results of this Annex suit your needs.

The distribution of the work plan and collecting feedback will be done electronically, and in close collaboration with the IA-HEV secretariat.

8.5

How to join

Mr. Patrick Debal is the interim Operating Agent of this Annex. Please feel free to contact him with your questions and feedback regarding this Annex, or if you are interested to join.

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9

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

9.1

Introduction

Annex VIII 'Deployment strategies for hybrid, electric and alternative fuel vehicles' of this Implementing Agreement on hybrid and electric vehicles (IA-HEV) investigated promotion measures -run by governments and other public and private organizations- to enable the market deployment of clean vehicle technologies. By evaluating about 100 more or less successful promotion strategies, several general weaknesses could be identified and general recommendations have been formulated on how to avoid failures in promotion programmes. The study has been completed in 2002 and is publicly available at the interim Operating Agent of this new Annex. Contact details are mentioned in section 9.5.

The Annex VIII evaluation study on deployment strategies did not focus on the clean vehicles themselves. Nevertheless, the evaluation made some definitions necessary concerning the vehicles, especially that of 'marketable products'. In the study, it has been stated that it is not enough to reduce 'marketable' to the satisfactory functioning of the technology. In the highly competitive vehicle market, 'marketable' includes:

- licensing, compliance with national technical standards,
- a purchasing process with reasonable conditions for the customers, including a reasonable purchase price,
- the reliability and safety of the technology,
- easy access to fuels or other forms of required energy, in an area in line with the range of the vehicles,
- service facilities within a reasonable distance,
- trained staff at the service facilities,
- availability of driving lessons (if necessary),
- access to information on performance, operation and best application of the vehicles.

This list reflects the point of view of the marketing specialist who is focussing on the customers' benefits and the pressure on governments to promote the 'right' product.

The current situation in the clean vehicle market can be characterized by the following elements:

- Hybrid vehicles are available on the market, and in several countries they are very successful.

- The fuel cell vehicle cannot be expected in the mass market before 2020.
- The battery electric vehicle is at the starting line of a renaissance, now that advanced battery technologies that provide a satisfying range and performance are becoming available on the market.

If one adds alternatively fuelled vehicles using -e.g. natural gas- besides hybrid and electric vehicles, a manufacturer has several options for the choice of a clean propulsion technology. This situation calls for an evaluation of success factors at the level of vehicle technology and for an evaluation on the strategy of the vehicle manufacturers to put their products on the market. Therefore the IA-HEV has taken up the idea to establish a new Annex to address these issues. The new Annex will follow up on the work on deployment strategies in Annex VIII.

9.2

Objectives

This new Annex will analyze the ‘stories’ behind introducing electric and hybrid vehicles on the market and it will draw conclusions for future clean vehicle deployment. The results will be interesting for government officials and private entities running promotion measures for clean vehicles, as well as for vehicle producers and their marketing specialists.

9.3

Working method

When we look at the last 20 years of EV and HEV developments, we see a coming and going of new models, and behind each of these attempts to enter the market there was a story. Without any doubt all these individual stories follow patterns that can be identified. This identification of patterns is a pre-condition to learn from these stories and to avoid the repetition of mistakes. A first glance at the background and the effects in the market of all these coming and going vehicle models shows a very mixed picture, see table 9.1.

Nevertheless, some patterns can be distinguished:

1. Manufacturers start with huge optimism, but without sufficient financial backup, the cars are technically promising, but the production never exceeded a small number of pre-serial vehicles, the company disappeared. Examples are: SAM by cree Switzerland, Hotzenblitz Germany.
2. Manufacturers start with great optimism, but without the necessary financial backup, the cars are technically reliable enough for pioneer customers but not necessarily for a mass market. Examples are: TH!NK Norway/Ford USA, Solec France/Switzerland, City-el Denmark/Germany. Some of these vehicles are still manufactured with low market success, but most of the manufacturers/vehicle makes disappeared.

Table 9.1 Effect in the market of different electric and hybrid vehicle models.

Financial basis	Technology	Batteries	Manufacturers hopes	Effect in the market		Examples	
				Effect	Remarks	Model	Sales figures
☹☹	☺☹☹	☺☹☹	☺☺	0	Only pre-series, did not enter the market	SAM by cree Hotzenblitz	
☹	☹	☹	☺☺☺	☹	Pioneer customers	Solec Pinguin THINK City-el	> 200 > 500 > 1'000 > 15'000
☺	☺	☹	☺☹	☹		BMW E1 Audi Duo Ford Ecostar VW CityStromer	prototype < 50 > 100 > 500
☺	☺	☺	☹	0	Manufacturer withdrew	Honda EV Plus GM Impact	
☺	☺	☹	☺☺☺	☹		PSA Renault	
					Special niches	MicroVett Elcat TWIKE Milk carriages Car free resorts Electric 2-wheelers	

- Manufacturers have a good financial backup, the vehicles are technically good but the batteries fail, the production has never been started or has been stopped. Examples are: BMW E1 Germany, Ford Ecostar USA, Audi Duo, VW Golf CityStromer.
- Manufacturers have a good financial backup, the vehicles and batteries are technically good but following an internal strategic decision manufacturing stops. Examples are: Honda EV Plus, GM Impact.
- Manufacturers have a good financial backup, the vehicles and batteries are technically good but the customer did not buy them in satisfying numbers (too expensive?, range?, expectations?). Examples are: EVs by PSA, Renault.
- In special niches the parameters do not count, the advantages in use are to the fore.

This is a not complete list of striking coincidences not going beyond the surface, but we notice some principal factors and a lot of open questions about their reasons and effects. Such a list of questions may be:

1. On which basis do companies decide on a clean vehicle technology they want to produce? (For example Toyota decided to go into the development of a hybrid propulsion technology and stopped EV projects).
2. Is the problem caused by the dependence on components -for example storage systems like battery and fuel cell- that are not produced by the vehicle manufacturer?
3. Is the problem caused by the fact that automotive engineers have fixed ideas about what a car has to be like? This is an assumption of Amory Lovins.
4. The other way round: are the ideas of engineers who are not automotive technicians (e.g. specialists in composite materials and lightweight design, in electronics and informatics) too early for the conservative car market?



GM Impact
GM decided to stop production.

ABB NaS batteries began to burn in at least 2 cases during the recharging process. Ford stopped production after having sold about 110 vehicles.



Ford Ecostar



MicroVett
Concentrates on special vehicle models for communal application, and by that constant sales figures and a good market success.

ZEBRA NaNiCl-batteries caught fire and destroyed the prototype.

BMW E1



Hotzenblitz
No financial backup, problems with Powercell ZnBr-Batteries.

Fig. 9.1 Examples of electric vehicles. (Photos supplied by Muntwyler Energietechnik AG.)

5. How can co-operation between the traditional car industry with the great 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 expectations that necessarily have led to disappointments?
 7. The most important question: financing and distribution channels.
- Certainly also this list of questions gives only some indications and has to be completed.

It is worthwhile to go into these questions. Answers can be found by interviewing the manufacturers, industry historians and technicians that have been involved in vehicle and battery technology development for decades. These answers can lead to a list of lessons learned that may be of great value for the renaissance of the electric vehicle as well as for future clean vehicle technologies like fuel cell vehicles.

Another source for learning lessons is the analysis of market studies that were made during the nineties of the previous century. They have been made on the basis of surveys by assuming fictive electric vehicles with certain features. Two examples are:

1. A study elaborated by the Freedonia Group, Cleveland, in 1993 that predicts 855'000 EVs in 2003.
2. A study of the Business Communication Company, Norwalk CT, in 1994 that predicts 1.1 million EVs only in the USA in 2004.

Of course these studies on market prospects have been made in view of the Californian Zero Emission Vehicle mandate that finally did not come into force as intended. Therefore the assumptions about the vehicle features that served as the basis for these studies are more interesting than the predicted EV numbers. In addition to those market predictions -that have been elaborated above all for investment funds or private investors- several studies tried to assess scenarios about the vehicle features. One of them, as an example, was elaborated by the New York Energy Research and Development Authority in 1994. The results of this study are shown in table 9.2.

Such scenarios help to identify the progress made within the last decade, or show too high expectations (see the column 'charging time' in table 9.2!). This discrepancy may also reveal the boundaries of a technology or, the other way around, the underestimation of technical potentials.

Table 9.2 Scenarios for electric vehicles, according to a study by the New York Energy Research and Development Authority in 1994.

Scenario	Range in kms (miles)	Price US\$	Operation costs US\$/mile	Charging time 100% at 220VAC	Performance (cold weather conditions)
Probable					
1998	96.5 (60)	38'500	0.58	4 h	sufficient *)
2000	96.5 (60)	37'000	0.56	4 h	sufficient
2002	128.7 (80)	27'000	0.43	3 h	sufficient
2004	128.7 (80)	26'600	0.41	3 h	sufficient
Possible					
1998	145 (90)	23'875	0.36	3 h	sufficient
2000	160 (100)	21'700	0.33	2 h	sufficient
2002	177 (110)	17'000	0.27	2 h	good *)
2004	193 (120)	15'500	0.24	2 h	good
Optimistic					
1998	193 (120)	15'750	0.24	90 min	good
2000	240 (150)	14'700	0.22	60 min	good
2002	290 (180)	12'550	0.20	60 min	good
2004	322 (200)	11'900	0.18	30 min	good

*) sufficient = 4-9 failure days/year in New York
good = less than 3 failure days/year in New York

It is quite probable that there are other sources that help to identify the 'internal' barriers of a vehicle technology and wrong estimations of vehicle producers, in view of the market deployment of their products. Market deployment is complex, many factors are playing a role, and it is difficult to understand their inter-dependency. Real stories as well as outdated assessments help to understand these mechanisms.

9.4

Status and outlook

This new Annex is still in a planning phase. The ideas outlined above will be presented at the next Executive Committee Meeting of the IEA Implementing Agreement on hybrid and electric vehicles (IA-HEV) in spring 2006. Then the member countries will decide on modifications, participation and realization of this Annex.

In case the IA-HEV Executive Committee agrees to start this Annex, a workshop will be organized in autumn 2006 to elaborate the work plan and the financial background. Every expert that is interested in the mechanisms of success and failure in clean vehicle markets is invited to add ideas and comments -even before the autumn workshop- so that they can be included in the work plan. Results of the kick-off workshop and the invitation to join this new Annex as a country expert will be published in the IA-HEV Newsletter.

9.5

How to join

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10

Renewable energies for hybrid and electric vehicles

(New Annex)

10.1

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, a lot of 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 HEVs (hybrid electric vehicles) and EVs (electric vehicles) 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, which in the first phase focuses on hybrid and electric vehicles.

10.2

Objectives

The goal of the task force in this Annex is to support research, to share new information and to establish working relations among organisations 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 three areas:

1. Electricity production from renewable sources for battery electric vehicles and ‘plug-in’ hybrid electric vehicles.
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.



Fig. 10.1 Electricity from wind turbines and biofuels are important sources of renewable energies for hybrid and electric vehicles. (Photo supplied by Thomas Ingeman Nielsen).

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

10.3

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 three 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.

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 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, which may reduce costs and energy consumption. Very promising results have been obtained when the production of biofuels are 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, and on other important aspects related to the possible interaction between renewable energy production and vehicle technologies (such as load levelling of wind energy).

In the analysis of the well-to-tank path the renewable energy resources could be very different in participating countries. The working method of this Annex will be organised to permit each member country to contribute and also learn especially about those renewable energy sources that are most relevant for that specific country. If possible all relevant renewable energy sources will be covered.

10.4

Status and outlook

During its meeting in Rome on October 6 & 7, 2005, the IA-HEV Executive Committee discussed the scope of this new Annex on renewable energies and decided to continue into a more detailed planning phase. The focus in the first phase of the Annex should be on renewable energies for battery electric and hybrid electric vehicles. In a second phase hydrogen and fuel cell electric vehicles could be included, in co-operation with other Implementing Agreements that work on those topics.

A draft work plan will be presented to the IA-HEV Executive Committee during its April 2006 meeting. 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 organisations can contribute to determine the actual content of the work, so it can be adapted to their needs.

10.5

How to join

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

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11

Fuel cells for vehicles

(New Annex)

11.1

Introduction

The tremendous success of hybrid vehicles in recent years has strongly boosted the interest for electric vehicles in the vehicle industry as well as in the research community. Electric drivetrains offer unique advantages in torque, power output and starting behaviour. The enhanced comfort of the electric mode of hybrid vehicles -like silent standstill or the shutdown of the internal combustion engine when waiting at traffic lights- has motivated vehicle producers to strongly increase their R&D efforts for the development of other alternative propulsion systems, such as vehicles powered by fuel cells, batteries, biofuels, natural gas (CNG) or synthetic fuels (GTL).

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 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 specialised niches like space applications. But in the last years cheaper and more stable materials for separators and electrodes have achieved major improvements for fuel cell technologies. Rising costs for aftertreatment of internal combustion engine emissions -due to tightening emissions standards- will bring fuel cell vehicles nearer to competitiveness.

11.2

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. Considering the strong differences in power demand and dynamic behaviour necessary for auxiliary power units, passenger-, light-duty or heavy-duty vehicles, it seems clear that this variety of physical characteristics are an asset of fuel cells. Therefore a thorough analysis of all kinds 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. The detailed knowledge of hybrid and electric vehicle characteristics and their specific needs for complementary propulsion properties already existing in the Implementing Agreement will allow to attain a much more comprehensive evaluation of fuel cell technologies and their potential fields of application. Therefore the new Annex will enable a much broader view for the optimisation of the electric drive train than the isolated development of pure fuel cell vehicles pursued in many R&D institutions.

The specific demands for power, cost, lifetime and range of vehicles powered by fuel cells, batteries and all 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 by 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). This could even lead to a joint Annex of both Implementing Agreements where IA-HEV will bring in its expertise in user requirements in order to smoothen the way of these new technologies into the market.

The HEV Implementing Agreement will not concentrate its activities in this new Annex 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 be an interesting intermediate step for the market introduction of fuel cell 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.

Given the broad range of technical requirements for the propulsion of passenger, light-duty or heavy-duty vehicles, auxiliary power units or even other means of transport, the new Annex will not only concentrate on PEM fuel cells as dominating technology for fuel cell research for vehicles today, but the Annex will analyse 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 new Annex will study the potential of fuel cells for this market segment, after the preliminary investigation of all fuel cells mentioned above. The relatively stable power demand of auxiliary power units in the vehicle could enable for example the use of solid oxide fuel cells (SOFCs). The SOFC might be an option not only for APU in passenger cars, but also for boats or even trucks.

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 the new Annex.

Finally, the question how to choose 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 SOFCs will be investigated, taking the specific limitations of a mobile application in vehicles into account. The special requirements for the on board low temperature liquid or the high-pressure gaseous storage of hydrogen demands for specialists in vehicle technologies such as present in the HEV Implementing Agreement.

A special added value of this Annex will be to analyse technological solutions that are outside the mainstream of fuel cell development. Exotic fuels like ammonia or other liquid or gaseous fuels will be examined for their practical relevance as fuel for fuel cells. Because the Annex is not financing research directly but providing advice for the orientation of national R&D activities and industrial research investments, 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 minimise 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.

In IA-HEV highly committed research institutes and national representatives of R&D programmes from Europe, America and Asia co-operate to pave the way for the development and market introduction of hybrid and electric vehicles. The market introduction of alternative propulsion systems and fuels needs a more active technology policy to overcome the 'chicken and the egg problem' between automotive and fuel industry, each waiting for first steps and investments from the partners. Therefore the vehicle and fuel industry together with research institutions developing alternative propulsion systems will strongly benefit from the achievements of this Annex.

For public authorities the market introduction of fuel cells not only offers brilliant employment opportunities for their industry, but it also offers solutions for suppressing ecological and transport problems. Therefore the Annex will provide national representatives with advice for designing R&D programmes. Another public target group are users of these new technologies like communal or regional authorities, transport service providers or tourist areas.

11.3

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 its new 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 organise 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 programmes and participate in regional multilateral activities like the technology platform 'Hydrogen and fuel cells' of the European Union.

11.4

Status and outlook

During its meeting in October 2005 in Rome, the IA-HEV Executive Committee (ExCo) asked the interim Operating Agent to develop a working plan for a new Annex on 'Fuel cells for vehicles'. That means that the new Annex is now in its planning phase before official approval by the ExCo. The formal start of this new Annex is envisaged during the Electric Vehicle Symposium EVS-22 in Yokohama, October 2006.

Organisations that are interested in the work on fuel cells for vehicles in this new Annex are invited to contact the interim Operating Agent to discuss their possible role in this Annex. The work plan is under construction so there is still room to tune it to the needs of the participants.

11.5

How to join

The IA-HEV Executive Committee appointed the Austrian delegate in the Agreement Mr. Andreas Dorda as the interim Operating Agent of the new Annex on 'Fuel cells for vehicles'. For more information on how to join this Annex please contact him at the following co-ordinates.

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12

An overview of hybrid and electric vehicles in 2005

The first section of this chapter gives data on worldwide hybrid and electric vehicle populations for the four years up to 2005. The second section presents some developments in the year 2005 that may influence overall growth of hybrid and electric vehicle populations in years to come.

12.1

Statistical information

Table 12.1 shows data (available as of 31 December 2005) for the past four years on the growth of electric and hybrid electric vehicle fleets. When new data becomes available, it is included in a similar table that can be found on the IA-HEV internet web-site: www.iea.org or www.transportation.anl.gov/ia_hev/.

Table 12.1 Actual or estimated (*estimates for IA-HEV member countries in italic*) electric vehicle (EV) and hybrid electric vehicle (HEV) populations of IA-HEV member and selected non-member countries.

Year	2002		2003		2004		2005	
	EV (1)	HEV	EV (1)	HEV	EV (1)	HEV	EV (1)	HEV
Austria	597	0	533	0	515	0	<i>1'300</i>	<i>75</i>
Belgium	n/a	0	n/a	0	n/a	0	n/a	<i>441</i>
Finland	450	2	450	2	460	102	<i>460</i>	<i>102</i>
France	10'171	0	10'706	144	11'013	650	n/a	n/a
Italy (2)	55'262	210	95'162	247	112'481	220	n/a	n/a
Netherlands	100	1'000	500	1'000	500	2'000	500	3'000
Sweden	500	530	471	624	422	1'355	n/a	n/a
Switzerland	3'500	350	10'686	472	12'201	1'021	<i>ca. 12'000</i>	<i>1'933</i>
USA	33'047	65'615	45'656	113'140	55'852	196'293	<i>68'000</i>	<i>385'000</i>
Sum IA-HEV	103'627	67'707	164'164	115'629	193'444	201'641	<i>210'000</i>	<i>395'000</i>
China	2'200'000		6'400'000		13'000'000		23'000'000	
Denmark	360	0	360	0	300	15	650	35
Japan	4'700	74'600	5'600	91'200	n/a	120'000	n/a	150'000
Taiwan	40'000		55'000		75'000		94'000	
Grand total	2'348'687	142'307	6'625'124	206'829	13'268'744	321'656	<i>23'300'000</i>	<i>550'000</i>

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 yet at the time of printing. The 220 HEVs are only buses.*

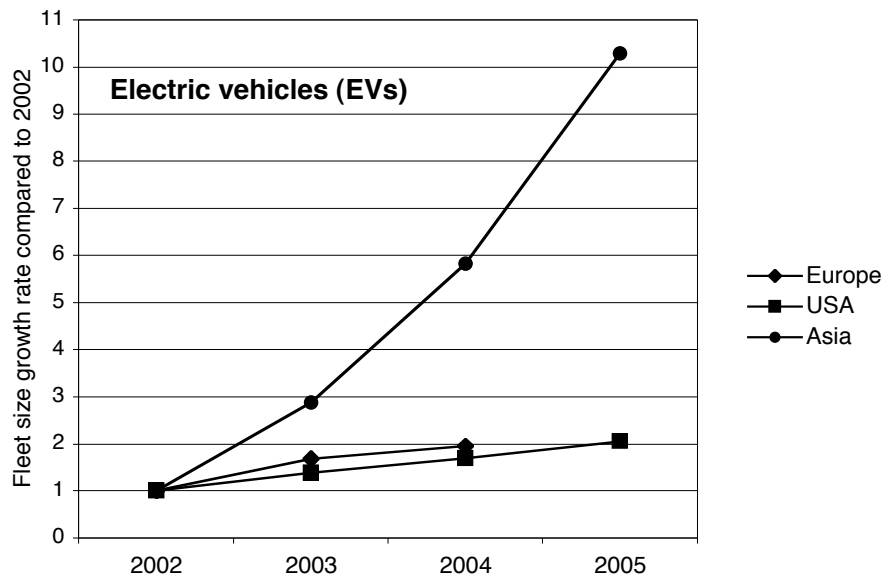


Fig. 12.1 Fleet size growth rate of electric vehicles (EVs) in the countries that are mentioned in table 12.1, from the year 2002 onwards. (Europe 2005 is not shown due to lack of data.)

The electric vehicle (EV) population as presented in table 12.1 is dominated by China and Taiwan, both in number of vehicles and in growth rate during recent years (see also figure 12.1). The EV fleets in those countries are mostly two-wheelers. The electric vehicle fleet in the United States appears to be steadily growing and the growth of the EV population in Europe seems to be levelling off.

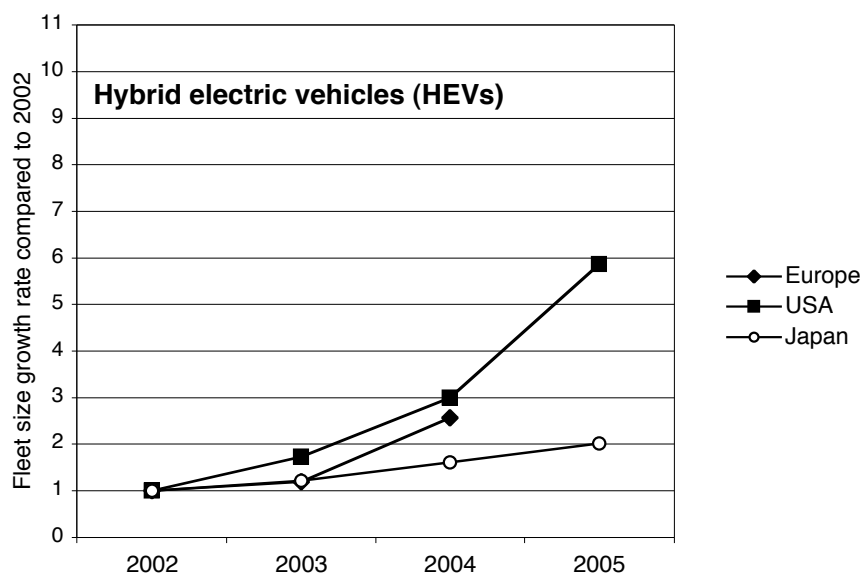


Fig. 12.2 Fleet size growth rate of hybrid electric vehicles (HEVs) in the countries that are mentioned in table 12.1, from the year 2002 onwards. (Europe 2005 is not shown due to lack of data.)

According to table 12.1, most of the hybrid electric vehicle (HEV) population in 2002 could be found in Japan and the United States, and vehicle numbers in those two countries were very similar. The European HEV fleet in 2002 was very small, and only started growing significantly in 2004 (see figure 12.2). The growth rate of the Japanese vehicle fleet between 2002 and 2005 was smaller than in Europe, but in vehicle numbers it is still much bigger. The last four years the HEV fleet in the United States was the largest in both growth rate and number of vehicles.

Comparing the growth rates of the EV and HEV populations shows that they are in the same order of magnitude during the period 2002 - 2005. The electric two-wheeler fleet in China is an exception, in three years the number of vehicles was multiplied by a factor 10.

12.2

Worldwide developments in 2005

General overview

During 2005, the growth of markets and technologies for electric and hybrid electric vehicles has been 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 are focused on emerging propulsion systems (chiefly hybrids, fuel cells, and non-petroleum fuels).

However, storm-related disruptions of distribution infrastructure and speculation about the reliability of petroleum supplies as a result of ongoing instability in critical production regions (such as the Middle East) -in combination with refinery capacity shortfalls during 2005- have sent finished gasoline and diesel fuel prices to near-record highs on the spot market. These developments are likely to catalyze even greater emphasis on efficient transportation alternatives (such as hybrid electric vehicles) in both IA-HEV member and non-member countries well into 2006 and beyond.

Emerging themes and incentives in IA-HEV member countries

This subsection highlights emerging themes and incentives in IA-HEV member countries. More details on each topic can be found in the respective country chapters.

Tax reduction

Several countries have become very proactive in taxation policies that favour fuel-efficient vehicles, especially EVs and HEVs.

- *The Netherlands* has exempted EVs from the road tax and beginning in 2006 will offer a substantial rebate (up to €6'000) to encourage sales of HEVs. Very energy efficient cars will earn the buyer a tax bonus, depending on the energy consumption rating for which the specific model has qualified. This tax bonus may be as high as €1'000.
- In *Sweden*, the taxation levy on hybrid or electric company cars is reduced by 40% relative to the closest comparable petrol model, subject to a maximum reduction of US\$ 2'000 per year.
- The *United States* federal Energy Policy Act (EPACT) of 2005 modified existing purchase requirements for federal automobile fleets to be more favourable toward hybrids. A federal tax credit is available for a limited number of HEVs placed in service before the year 2011.

Subsidies

- The *French* Agency for Environment and Energy Management (ADEME) offers financial incentives of up to €3'200 for the purchase of light-duty electric vehicles.
- Central and local governments in *Italy* have subsidy programmes levelling purchase retail prices between conventional vehicles and electric- (EV) and hybrid vehicles (HEV).
- In *Switzerland*, cantonal governments now have the legal authority to finance promotion measures for electric and hybrid vehicles.
- *Switzerland's* existing VEL1 and VEL2 vehicle subsidy programmes have facilitated the purchase of about 1'300 electric vehicles. Seventy-five hybrid vehicles have also been sold during VEL2.

R&D support

- In *Austria*, a new institution - the Austrian Agency for Alternative Propulsion Systems (A3PS) - has been established to promote the development and employment of alternative propulsion systems and fuels. This initiative augments the Advanced Automotive Technology (A3) government-sponsored research programme to develop alternative propulsion systems and other automotive technologies. The A3 programme continued into its fourth year with a complementary new initiative -lighthouse projects- to support the market introduction of early-emerging new technologies.
- In *Italy*, two large R&D programmes on hydrogen and fuel cells are supported through the 'Special integrative fund for research'.
- Through the 'FreedomCAR and fuel initiative', the *United States* Department of Energy works with industry to develop and deploy advanced transportation technologies that reduce the nation's use of imported oil and improve air quality.

Promotional programmes and measures

- In *Italy*, market introduction programmes of electric and hybrid vehicles focus mainly on service fleets and small vehicles in urban areas.
- Car dealers in *the Netherlands* are required to affix an energy consumption rating label to the new cars in their showrooms, which shows the vehicle's energy consumption in litres per 100 vehicle-km and estimated CO₂ emission rate in kg per vehicle-km.
- An objective of *Sweden's* 2005 'Green vehicle 2' programme is to assure that at least 75% of the total number of cars purchased or leased by a public authority during a calendar year be green vehicles.
- The *United States* Department of Energy's 'Clean Cities' programme supports public-private partnerships that deploy alternative fuel vehicles (AFVs) and build supporting alternative fuel infrastructure.

Demonstrations

- The city of Nantes, *France*, is testing the Gruau electric bus, which has gained popularity with the public and the transport authorities.
- In *France*, the recently created 'Société des Véhicules Electriques' -a joint venture of Heuliez and Dassault Industries- delivered its first vehicles to the French Post and a few other selected users under the rubric of an experimental project.
- The city of Eindhoven, *the Netherlands*, is demonstrating Phileas LPG electric hybrid buses in public transport with a technical goal to successfully operate the buses on a special 15-km track without an active driver.
- A *United States*-based DaimlerChrysler subsidiary, Global Electric Motors, manufactures a line of neighbourhood electric vehicles called GEMCars that will be demonstrated in a coast-to-coast 'road show' between December 2005 and March 2006.

Innovations in driveline technologies

- In 2005, *Belgium's* the automotive division of the VITO research institute performed a detailed assessment of the possibilities and opportunities for ultracapacitors in electric and hybrid electric vehicle applications. VITO has also developed lithium-ion battery packs with ultracapacitors as an integrated system.
- In April 2005, the *Belgian* enterprise 'Green propulsion' presented its hybrid Kangoo at EVS-21 in Monaco, receiving international recognition by winning the 2nd prize for innovation for this vehicle and its innovative powertrain. The company is working to evolve this hybrid drive for application in an urban 12-metre bus to be introduced in May 2006.
- In March 2005, the *French* group Bolloré unveiled its prototype electric car that includes numerous innovations for the drivetrain and for the body.

- The *French* vehicle manufacturer Gruau developed a pure electric version of the hybrid Microbus. To keep the floor as low as possible, the battery storage compartment is integrated into the roof.
- An engineering company in *the Netherlands* has developed a hybrid bus with a 50-kW diesel generator set, electric wheel hub motors on the rear axle, and a body made of lightweight materials and construction.

13 Austria

13.1 Introduction

Austria is a significant player in the automotive industry. It hosts a number of automotive suppliers, and there are vehicle manufacturing plants -such as Magna Steyr in Graz- producing vehicles for many countries. The Technical Universities of Vienna and Graz and the enterprise AVL List in Graz, for example, are active in R&D on automotive drivetrains.

13.2 Policies and legislation

The Austrian Ministry of Transport, Innovation and Technology (BMVIT) is strongly committed to the promotion of technological breakthroughs in the fields of transport and environmental and energy technologies, as their implementation in industrial applications offers not only brilliant employment opportunities, but also solutions for pressing ecological and transport problems. In this regard, fuel cells and hydrogen offer unique advantages concerning energy efficiency, security of energy supply, and the reduction of noise and exhaust emissions.

In recognition of these opportunities, in 2001, the BMVIT launched the R&D programme 'A3 - Austrian Advanced Automotive Technology' (A3) to concentrate on highly innovative research projects with increased development risk that would receive higher levels of funding than is usually provided by technology promotion programmes. The goal is to achieve real technology breakthroughs, not incremental improvements to existing technologies. Grants are awarded according to the competitive principle through invitation for proposals.

A3 covers the entire innovation cycle and offers funding for basic research through demonstration projects. It also funds projects to adapt education and training to the new requirements and create an adequate supply of qualified human resources. Another pillar of the programme supports international networking, mobility, and co-operation among researchers.

A3 also strives for synergies from interdisciplinary co-operation among industrial, university, and non-university research and between suppliers and users of technologies in joint R&D projects. A3 targets support at all developments that one institution cannot carry out alone but that require strategic planning and the expertise of a number of partners. Therefore, only consortia consisting of at least three partners may submit project proposals.

Because of the dramatically increased importance of alternative propulsion systems, the BMVIT extended A3 in 2004 to a new ‘Austrian hydrogen and fuel cell initiative’ in order to stimulate the development of all kinds of alternative engines and fuels, including hybrids, compressed natural gas (CNG), and biofuels. In accordance with Austrian environmental and energy policy, the focus for hydrogen production is on renewable sources of energy. A number of research institutes in Austria are pursuing technological solutions outside the mainstream of international development. This approach opens up interesting niches and the chance for a unique selling position. To minimise development risks, the BMVIT also welcomes projects that offer multiple benefits for other areas of technology, regardless of the success of fuel cells and hydrogen.

Through July 25th, 2005, the third call for proposals in A3 was open for projects to develop alternative propulsion systems, as well as vehicle electronics, material research, and production technologies. Forty-one proposals were submitted. Winners will be selected after evaluation and join the 39 projects funded from the first two calls.

‘Lighthouse projects’ are a new instrument of BMVIT to support the market introduction of emerging technologies. Complementary to the A3 calls, the lighthouse project initiative supports large pilot and demonstration projects in order to:

- prove the successful operation of new technologies,
- assemble providers and users of technologies, as well as all other relevant stakeholders in one project,
- prepare the public for technological change, and
- learn from still-existing problems and improve the performance of these new technologies.

These lighthouse projects focus only on alternative propulsion systems and fuels.

A3 and lighthouse projects have made €15 million in funding available for the years 2005 and 2006; €5 million for the third A3 call 2005, another €5 million for the A3 call in 2006, and € 5 million for lighthouse projects.

The market introduction of alternative propulsion systems and fuels needs a more active technology policy to overcome the ‘chicken and egg’ problem between the automotive and fuel industries, both of which are waiting for the other industry to take the first steps and investments. To overcome this problem, the BMVIT provides not only funding by its programmes, but it offers a broad portfolio of additional support activities for Austrian research institutions.

Following the principles of modern technology policy, the BMVIT is convinced that public authorities can facilitate the development of new technologies far

beyond financial contributions. Therefore, the BMVIT has decided to establish a new institution, called the Austrian Agency for Alternative Propulsion Systems (A3PS), with the following scope of activities:

- Build up interdisciplinary research co-operation with 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 to innovation.
- Discuss topics and organisation of programme calls with all relevant stakeholders to optimise the funding instruments.
- Inform 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 within the spectrum of technological developments.
- Facilitate integration of technology into 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 effort and achieve a critical mass in international perception.
- Provide Austrian research institutions with long-term security in planning and investments as a result of a clear public commitment transcending election terms.

The A3PS aegis will broadly promote the development and employment of alternative propulsion systems and fuels, thereby supporting Austrian research institutions in their technological development projects and platforms for their national and international activities.

Internationally, Austria participated as part of the ERA-Net Transport Work package 'Environmental improvements through vehicle technology', which was the theme for a workshop on 13 & 14 June 2005 in Paris. Six potential topics for co-operation in three broad categories were identified at the workshop, and six Action Groups were initiated. The titles of the Action Groups are (by theme):

- Cleaner vehicles:
 1. Environmental performance indicators for heavy-duty vehicles.
 2. Policy tools to influence vehicle purchasing behaviour.
- Alternative propulsion systems and fuels:
 3. Alternative fuels, propulsion systems, and vehicle technologies - Part 1: European strategy.

4. Alternative fuels, propulsion systems, and vehicle technologies - Part 2: Joint projects (action group leader is from Austria's Ministry of Transport, Innovation and Technology).
 - Noise research:
 5. Improved understanding on noise effects.
 6. 'Quiet areas'.
- More information can be found at the internet web-site: www.transport-era.net/neu/index.php?id=131.

13.3

Research

Research in electric vehicles (EVs) and fuel cell applications takes place mostly at Austria's leading universities and research centres: Technical University of Vienna, Technical University of Graz, Mining University in Leoben, Joanneum Research Forschungsgesellschaft GmbH, ARC Seibersdorf research GmbH, and Arsenal Research and HyCentA Research GmbH. These latter three research companies are working together with representatives of the automotive industry, including AVL List, BMW and Magna Steyr. Research topics include:

- SOFC (solid oxide fuel cell) hybrid cars.
- Propulsion systems for PEM (proton exchange membrane) fuel cell cars.
- Hydrogen-fuelled internal combustion engines.
- Fuel cell catalysts.
- Hydrogen production.
- Onboard storage systems.
- Tank isolation.

13.4

Industry

In Austria, some automotive or component companies -like Magna Steyr and AVL List- are domiciled. The main field of this industry regarding hybrid electric vehicles (HEVs) is onboard storage and fuel cell propulsion systems.

13.5

On the road

There are no EV or HEV market introduction programmes in Austria. However, some tourist resorts and villages only allow the use of EVs on their premises. Table 13.1 provides data on the EV fleet in Austria for 2003 and 2004.

Even though the total number of vehicles is increasing, the number of EVs is decreasing. Light electric vehicles for which no driver licence is required form the highest share in the Austrian EV fleet. About two-thirds of these light EVs are power-assisted bicycles.

Table 13.1 Characteristics and population of the Austrian vehicle fleet.

Vehicle type	2003		2004	
	EV fleet	Total fleet	EV fleet	Total fleet
Light vehicles (no driver licence)	213	299'924	199	295'197
Small & light motorcycles	2	119'974	2	124'799
Motorcycles & small vehicles	12	186'970	19	192'184
Cars	135	4'054'308	128	4'109'129
Buses	109	9'231	108	9'408
Trucks & vans	26	326'087	22	353'055
Tractors	15	439'637	18	422'311
Self-propelled machinery	21	69'796	19	69'614
Total	533	5'505'927	515	5'575'677

13.6

Developments

As already mentioned, the government is funding research projects on alternative propulsion systems and fuels, so industry and research facilities are now very active in EV, HEV and FC car technologies. The public is becoming aware of alternatives to petroleum because of high gasoline prices and advertisement campaigns, but a stable market for non-conventional fuels and vehicles has not yet been established.

13.7

Benefits of participation

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

- Remaining informed about technology developments in other countries regarding hybrid and EVs and their drivetrains, with the objective of transferring this knowledge to local industry.
- Participating in a network of well-known automotive laboratories, research organisations, and governmental officials to produce joint studies and reports.

13.8

Further information

More information on Austrian activities regarding hybrid and EVs can be found on the following example web-sites:

- www.arsenal.ac.at (in English and German)
Austrian Research Centres Arsenal Research.
- www.avl.com (in English)
AVL List GmbH.

- 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

Hybrid electric vehicles (HEVs) and electric vehicles (EVs) currently play a marginal role in Belgian vehicular markets. The electric vehicle fleet in Belgium is limited to about 30 small passenger cars and some dedicated-use (utility) vehicles. User experience has not been very positive because -in most cases- batteries cause practical and technical problems that result in high maintenance cost. This, in turn, prevents EVs from gaining market momentum. This past experience -coupled with the lack of popular and governmental support- stifles new initiatives.

The situation for hybrid vehicles has evolved more favourably. The Toyota Prius I was sold in very low numbers, while the Honda Insight was never introduced to the Belgian market. The advent of the Toyota Prius II and the Honda Civic IMA changed the situation. Today, the hybrid vehicle demand has surpassed the still limited supply. In 2005, all hybrid vehicles allocated to Belgium by Toyota (including Lexus) and Honda have been sold, and a waiting list of several months is standard.

Belgium has two key players in hybrid electric vehicle development: the research institute VITO, and Green Propulsion. VITO has produced hybrid demonstration vehicles and upgraded vehicles from earlier demonstration projects. VITO's current and emerging projects have created a network of local and international industrial partners for hybrid vehicle development. The other key player, Green Propulsion, is a commercial spin-off of the University of Liège, which is establishing itself in national and international HEV development.

14.2 Policies and legislation

Belgian policy towards environmentally friendly vehicles and transport does not favour selected technologies but rewards good results. An overview of the most important legislation and initiatives from the government and related organisations follows.

Electric vehicles are equivalent to the vehicles with the lowest taxes for registration and circulation tax purposes

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

Implementation of new measures will offer income tax reduction for people acquiring vehicles emitting low levels of CO₂

Buyers of vehicles emitting low levels of CO₂ (carbon dioxide) will obtain a reduction on their income tax. Depending on the CO₂ emission level, a part of the acquisition cost of the vehicle -starting at 3% but not exceeding €615 for 115 g/km, up to 15% but not exceeding €3'280 for 105 g/km- will return to the owner when income taxes are finalised, approximately 2 years after a vehicle purchase. This new ruling was promulgated in 2004 to become effective in 2005. Although this measure is not specifically targeted at hybrid vehicles, it is evident that 2005 purchasers of the Toyota Prius will obtain the highest available benefit.

Co-operative agreement between the Flemish region and municipalities and provinces, called 'Environment as the stepping stone to sustainable development'

This co-operative agreement to enhance environmental friendliness offers municipalities and provinces a framework to improve the environmental friendliness of all aspects of their operations. One aspect of the agreement deals with improving the public fleet environmental performance. A tool developed by VITO allows fleet screening and gives recommendations for improving fleet utilisation efficiency.

One example of this framework in action is the city of Ghent vehicle fleet. Ghent and VITO analyzed the fleet's environmental performance. With recommendations from this project, the city council decided to invest €1.9 million above the normal fleet renewal budget to replace vehicles performing poorly with respect to fuel efficiency and the environment. By adopting an improved procurement decision tool that includes the environmental rating of the vehicles, fuel-efficient and environmentally friendly hybrid vehicles can move to the top of the choices in their class.

Other measures and initiatives

Other measures and initiatives that are not specifically aimed to promote hybrids but to improve the environmental impact of transport are the following:

- De Lijn -the Flemish public transport company- introduced diesel particulate filters (DPF) on all of its 869 EURO-II buses, and MIVB/STIB -the Brussels public transport company- equipped 269 EURO-II buses with DPFs in 2005. Furthermore, De Lijn published a tender for approximately 180 extra DPFs.
- In a demonstration project for clean public transport, De Lijn equipped two buses with a combined DPF+SCR (selective catalytic reduction) system to reduce all exhaust emission components. The converted EURO-II buses comply with EURO-V standards, according to VITO's in-depth analysis, assessment and measurements. De Lijn intends to retrofit a large part of its fleet with DPF+SCR systems.

- The Flemish government is continuing a public transport promotion that offers a free subscription for transport by De Lijn if a car license plate has been returned.
- A Eurovignet fee concession also is being continued for heavy-duty vehicles, depending on the level of compliance with the emission standard. Since its creation in April 2001, trucks are required to have the Eurovignet to be allowed to use motorways in Belgium and some other European countries. Registration costs are differentiated according to the EURO standard with which the vehicle complies. Owners of newer vehicles with more stringent emission controls pay less.

14.3

Research

VITO and Green Propulsion are the two key organisations in Belgian research on hybrid and electric vehicles.

VITO

The research institute VITO develops hybrid vehicles for niche applications as well as hybrid vehicle components. Projects typically involve industrial partners who will guarantee the servicing of the vehicles once they are in use. After finishing the technology upgrade of the three hybrid buses operating in Luxemburg, VITO acquired two defective hybrid buses from De Lijn. VITO will overhaul the powertrains and seek new applications for these vehicles.

In 2005, VITO performed a detailed assessment of the possibilities and opportunities for ultracapacitors in EV and HEV applications. Several ultracapacitors were tested with different battery technologies. In all cases, the energy pack (batteries + ultracapacitors) showed characteristics superior to those of the standard battery pack. This research will result in new electronic components for energy pack management.



Fig. 14.1 Testing of the Umicar on the Ford Lommel proving ground. (Photo: VITO.)

One result of the energy pack research is VITO's contribution to the Belgian Solar Team. For the first time, this team participated in the Australian Solar Race with its Umicar. VITO developed the lithium-ion battery packs with ultracapacitors as an integrated system. Although a newcomer to the race, the team managed to finish in the middle of the competition ranking.

VITO is preparing hybrid vehicle development projects to produce demonstration fleets of hybrid vehicles with industrial partners. Each fleet will be backed by an industrial consortium providing full service to the vehicle users. Other development projects aimed at increasing the number of hybrid vehicles in operation are also in the pipeline.

Green Propulsion

In April 2005, Green Propulsion presented its hybrid Kangoo at the worldwide Battery, Hybrid, and Fuel Cell Electric Vehicle Symposium & Exhibition EVS-21 in Monaco. Green Propulsion received international recognition by winning the 2nd prize for innovation for this vehicle and its powertrain. The powertrain -which is described in an EVS paper- offers both series and parallel hybrid modes, depending on the required speed and torque.



Fig. 14.2 Green Propulsion hybrid Kangoo. (Photo: Green Propulsion.)

Since April, Green Propulsion has been working to evolve this combined hybrid drive for application in an urban 12m bus to be introduced in May 2006.

14.4 Industry

The Belgian light-duty automotive industry consists principally of assembly plants and component suppliers. No hybrid or electric passenger cars are currently

produced in Belgium. Also, most conventional suppliers are not active for non-conventional 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 nineties, Van Hool has not developed any other hybrid. However, it has recently developed a fuel cell bus for the U.S. market and plans to develop another for Europe.

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

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

14.5

On the road

EV and HEV deployment in Belgium is limited. Due to the lower taxation of diesel fuel compared to gasoline, the passenger car market is dominated by diesel vehicles. Belgium has one of the highest market shares of diesel passenger cars in Europe, and high fuel cost has helped increase the diesel share. The number of electric cars is about 30 and there are a few hundred hybrid vehicles registered in Belgium.

The income tax benefit for vehicles with low CO₂ emissions partially compensates the Toyota Prius' price premium. Also, the new Prius II seems to appeal to a broader spectrum of car buyers than its predecessor. Consequently, Prius sales figures have risen substantially. To the contrary, the Honda Civic IMA does not sell in Belgium because its CO₂ emissions level cannot qualify it for the tax benefit.

At the higher end of the model range, the Lexus hybrid RX 400h is a success. For this model, Lexus will need to source vehicles from sister companies in Europe, because the number of vehicles allocated to Belgium is too small.

Compared to the total passenger car sales figures, the numbers for hybrid cars are very low.

Table 14.1 Orders and sales figures of hybrid cars in Belgium.

Make & Model	Toyota Prius	Lexus RX 400h	Honda Civic IMA
Orders (Jan-Nov 2005)	400	243	4
Sales (Jan-Nov 2005)	340	97	4

No heavy-duty hybrid vehicles are yet in service, although customer demand and initiatives from the Belgian development centres may change this situation in the near future.

14.6

Developments

Tax incentives as well as high petroleum fuel cost are expected to increase the popularity of hybrid vehicles. Honda's new Civic IMA -to be introduced in spring 2006- will also benefit from the tax incentive, so sales are expected to soar. Other car manufacturers are expected to introduce hybrid vehicles, including diesel hybrids. Hybrids should ultimately become 'regular' vehicles with a market share well above the marginal.

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 vehicle (ZEV) performance and silent operation may be a driver for implementing hybrids. Following are two examples where users may help to drive heavy-duty hybrid vehicle development:

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

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

14.7

Benefits of participation

Participation in the activities of the International Energy Agency Implementing Agreement on Hybrid and Electric Vehicles (IA-HEV) has several advantages:

- The exchange of information among and experience with relevant public research and development (R&D) programs in various countries' transport

sectors allows better preparation of Belgian national programs and projects.

- The informal personal contacts with experts from different countries and various organizations may be a source of new ideas, collaboration, and enlarged co-operation in various scientific, technological, and regulatory/standardization fields.
- The contacts between researchers and specialists may result in synergies.

14.8

Further information

More information about the Belgian organisations that are active in the field of hybrid and electric vehicles can be obtained from the following internet web-sites:

- www.greenpropulsion.be (in English and French).
Green Propulsion, a University of Liège spin-off, is a 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 (in Dutch and English).
The Vrije Universiteit Brussel (VUB) is the cradle of EV deployment in Belgium. As such it is the basis of links to EV-linked organisations such as AVERE, CITELEC and EPE.

15 France

15.1 Introduction

About a decade ago the electric vehicle fleet in France was growing at a substantial pace. However, this growth levelled off during the first years of this century. In 2005, interest in electric vehicles (EVs) in France was rekindled. Although France's three main manufacturers (Citroën, Peugeot and Renault) ceased EV production, the recently created 'Société des Véhicules Electriques' (SVE) delivered its first vehicles to the French Post Office and a few other selected users.

15.2 Policies and legislation

In addition to supporting R&D programmes, the French Agency for Environment and Energy Management (ADEME) offers financial incentives for the purchase of EVs. A new and simplified system has been applied since January 2005, under the agreement of the European Community. Characteristics of the support programme are listed in table 15.1.

Table 15.1 Characteristics of the 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;	Max. 200 EVs supported from 01/01/2005 to 31/12/2007 (ADEME-approved vehicles)
	3'000 for payload over 500 kg	
Passenger cars and light-utility EVs	3'200	Max. 1'000 EVs supported from 01/01/2005 to 31/12/2007

15.3 Research

15.3.1 Light vehicles

The 'Société des Véhicules Electriques' (SVE) -a joint venture of Heuliez and Dassault Industries- delivered its first vehicles to the French Post Office and a few other selected users under the rubric of an experimental project called VAL-VNX.

This SVE-operated project -which aims to validate technological solutions before vehicle commercialization- is divided into three phases:

1. Research and development.
Given that the main design of the vehicle and of its traction chain (powertrain) has been defined, the task is to test different types of advanced batteries and optimize global energy management algorithms (electric and thermal) for the application.
2. Construction of a test fleet.
About 30 electric and hybrid vehicles will be assembled, each separately configured to implement one or more of the different technological solutions to be evaluated.
3. Experimentation.
With the collaboration of the French Post, the French utility EDF (Electricité de France) and some communities, the test fleet will be evaluated under real conditions. For that purpose, all vehicles will be equipped with a data logger that will collect data on all relevant parameters.

After developing a specific body for its new electric vehicle 'Cleanova I', SVE decided -for reasons of economy- to use existing platforms. Therefore -at present- the light 'Cleanova II' utility vehicles are based on a Renault Kangoo chassis. The next step will be the 'Cleanova III', which is a sedan based on a Renault Scenic platform (see figure 15.1). The main Cleanova characteristics are listed in table 15.2.



Fig. 15.1 Cleanova III, based on a Renault Scenic platform. (Photo supplied by ADEME.)



Fig. 15.2 TM4 motor/generator and Lombardini internal combustion engine for the hybrid version of the Cleanova. (Picture supplied by ADEME.)

Table 15.2 Characteristics of Cleanova hybrid and electric vehicles.

Parameter	Electric version	Hybrid version
Energy storage	30 kWh	22 kWh + 20 L gasoline
Driving range (km)		
Urban cycle	245	485
50 km/h steady	280	545
Suburban	180	395
90 km/h steady	175	390
Acceleration time, 0 to 50 km/h (s)	6.7	6.7
Maximum speed (km/h)	130	130

The French group Bolloré unveiled its BlueCar prototype electric car (figure 15.3) at the Geneva Auto Show in March 2005. Developed by the famous ex-Matra engineering team with chief Philippe de Guédon, this small city car (3.05 m) includes numerous innovations for the drivetrain and for the body. The drivetrain

Table 15.3 Characteristics of BlueCar.

Power	30 kW nom. – 50 kW max.
Maximum torque	170 Nm
Battery voltage	243 Vmin – 374 Vmax
Battery mass (kg)	< 200
Energy storage (kWh)	27
Driving range (km)	between 200 and 250
Acceleration time, 0 to 60 km/h (s)	6.3
Max speed (km/h)	125



Fig. 15.3 BlueCar prototype and one of its 2.8 kWh batScap lithium metal polymer battery modules. (Photos supplied by ADEME.)

consists of a 30 kW (nominal) asynchronous motor powered by a 27 kWh lithium metal polymer (LMP) battery pack. The LMP battery is made by batScap (figure 15.3), which is a French subsidiary of Bolloré Industrie based in Quimper. BatScap also develops polymer super-capacitors for automotive and industry applications. The main BlueCar characteristics are listed in table 15.3.

15.3.2

Heavy-duty vehicles

Within the framework of the second call for proposal of the French R&D plan for clean and efficient vehicles (Plan VPE), a pure electric version of the hybrid Gruau Microbus has been developed. The electric vehicle uses the same motor as that of the hybrid. To keep the floor as low as possible, the battery storage compartment -which consists of four packs of MES-DEA ZEBRA batteries- is integrated into the roof. With this equipment, the bus has a driving range from 80 to 120 km, depending on traffic and load. Presently under testing in the city of Nantes, the Gruau electric bus has gained popularity with the public and transport authorities.



Fig. 15.4 View of the Microbus -note the very low and flat floor- and the ZEBRA battery block. (Photos supplied by ADEME.)

15.4

Industry

The large French car manufacturers Citroën, Peugeot and Renault ceased production of their electric vehicles. Today, French electric vehicle production consists of prototypes like they are mentioned in the previous section on research (15.3) and of specific light-duty vehicles like Aixam, Goupil and Bellier.

In January 2006, PSA Peugeot Citroën presented two diesel electric hybrid demonstration cars: a Peugeot 307 Hybrid HDi and a Citroën C4 Hybrid HDi.

15.5

On the road

The electric vehicle fleet in France consists of light-duty vehicles, passenger cars and electric two-wheelers, and counted a total of about 11'000 vehicles in 2004.

The Toyota Prius hybrid car can be seen occasionally on French roads. Citroën for example offers its C3 model equipped with a 'stop and start' system.

15.6

Developments

The interest in electric vehicles was rekindled in 2005. In general, clean road vehicles are gaining interest in France. France is for example also dedicated to meet the European goals on the introduction of biofuels for road transport, even ahead of the European time schedule.

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. It is also a means to exchange experiences achieved in the French automotive industry and in demonstration projects with representatives from other countries that are active in the same field. Participation in the Agreement brings opportunities to inform parties in France working on HEVs about practical experiences in other countries. The personal contacts enable an exchange of experiences that goes beyond the information that is available in writing.

15.8

Further information

More information about hybrid and electric vehicles in France can be found on the following web-sites:

- www.ademe.fr (in French).
Site of the French Agency for Environment and Energy Management. Presents a lot of information about environment plus special pages for transport and financial incentives.
- <http://assoc.wanadoo.fr/avem> (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, which 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 riche site about all the clean solutions for transportation (EV, HEV, FCEV...).
- <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.gart.org (in French).
'Groupement des Autorités Organisatrices de Transport' (Group of Transportation Authorities). Content: information about clean transport, public transportation and goods delivery.

16 Italy

16.1 Introduction

Hybrid and electric vehicles in Italy can play a role in reducing urban air quality problems and they can contribute to reducing greenhouse gas emissions from transportation. The Italian government, local authorities, research institutes and the automotive industry collaborate in different programmes and activities on hybrid and electric vehicles. The large automotive manufacturer Fiat Group is performing R&D on clean vehicles and fuels, including natural gas vehicles, hybrids and fuel cell electric vehicles. Additionally, there are companies producing electric vans, hybrid and electric buses, and electric two- and three wheelers. Compared to other European countries, Italy has a large electric two-wheeler fleet.

16.2 Policies and legislation

Policies

In recent years the national transport policy was further focused on clean vehicles in order to minimize greenhouse gas (GHG) emissions and to improve air quality in major cities, as a consequence of repeated environmental emergencies. This policy was also a significant part of the 'National plan for CO₂ reductions' for the period 2003-2010, aiming at meeting the overall Kyoto protocol targets. The main efforts in the transport sector are concentrated on three sets of measures.

1. Fiscal and technological measures.
 - Car park renewal with cleaner and more efficient transport means, by subsidising private and public purchase. The objectives are passenger vehicles with a fuel economy of at least 20 km/l and average CO₂ emissions below 120 g/km (European and national voluntary agreements).
 - Introduction of more efficient and cleaner heavy-duty vehicles by accelerating the use of new European Directives.
 - Use of bio-fuels as an additive (about 5%) to conventional diesel. This measure does not include bio-ethanol or bio-methanol, due to the higher production costs and the significant economical impact.
 - New calculation of the car property tax based no longer on the power alone but also on vehicle weight, in order to favour lower weight vehicles.
 - Nation-wide annual control of vehicle emissions for the 'Blue label', which is currently limited to a few cities.
 - Fuel quality improvements and standardization.
 - Driver education for cleaner driving.

- Use of advanced information technologies for traffic management and control.
2. Infrastructural measures.
 - Integration of car and train transport.
 - Reorganization of urban transport.
 3. Research and innovation.
 - Advanced natural gas engines.
 - Direct injection LPG engines.
 - Fuel cell systems for road, rail and maritime transport.
 - Production of hydrogen from fossil fuels and renewables, including CO₂ sequestration.

In addition, the efforts of the central government regarding CO₂ reduction are complemented and/or integrated by various initiatives already in place or proposed by regional and municipal authorities that are responsible for the local air quality and pollution control.

Legislation

The use of power-assisted bikes has been difficult in Italy for years because of the lack of a clear definition for this specific vehicle category. After the approval of a European Directive for two-wheelers, the Italian government finally approved and integrated the definition of electrically powered-assisted bikes in the 'National road act', in which the assistance of a small power electric motor is acceptable only during biking and up to a maximum speed of 25 km/h.

In addition, two main regulatory measures have been published to help and improve the safe use of new fuels. Dedicated standards for plugs and sockets for EV charging stations were made available by CEI (the Italian Electrotechnical Commission) and the first draft of a technical regulation for hydrogen refuelling stations was prepared by an ad-hoc committee of the Ministry of Interior Affairs.

Financial incentives

The central and local governments continued the subsidy programmes for low emission vehicles and improved their structure. These programmes levelling purchase retail prices between conventional vehicles and electric vehicles (EVs), and also between conventional and hybrid electric vehicles (HEVs).

Law 426/98 - Ministry of the Environment and Territory

This funding law -aiming at reducing the emissions of vehicles in public fleets used in defined areas- completed its first phase successfully in 2003 and was further funded with €90 million for the subsequent three years. The funds that were available so far for EVs and HEVs have enabled the creation of a large national fleet in excess of 3'000 vehicles. The rules that have been published

allow a substantial cost reduction for battery-powered EVs and declining cost savings for different types of HEVs. All vehicle categories are fundable, with the exclusion of large buses.

Purchase subsidy of low emission vehicles by private users

The Ministry of Production Activities is continuing supporting the purchase of EVs by private users, as part of the ‘Vehicle scrapping – Park renewal programme’ that started in 1999. A few thousands of electric scooters, motorcycles and power-assisted bikes have been supported in recent years.

Regional and city subsidy initiatives

Various regions (Lombardy, Marche, Val d’Aosta, Friuli and Emilia Romagna) have continued to support the purchase of low emission vehicles and the installation of charging stations. In addition, many cities (Milan, Rome, Modena, Naples, Florence and Brescia) are funding the substitution of old 2-wheeled vehicles with electric ones. Specific protocols were defined for such initiatives to assure correct description of technical specifications of the vehicles and to guarantee that they meet the safety standards. These measures are resulting from monitoring the significant contribution to city pollution from such vehicles. More recently, the Lombardy Region approved two new funding instruments for funding the introduction of clean vehicles in the region.

16.3

Research

16.3.1

European and national programmes and projects

In recent years, relevant attention was given to carbon-free fuels such as hydrogen, which was one of the main subjects of two major R&D programmes launched at European and national level: the VI Framework Programme of the Commission of the European Communities (CEU) and the Italian ‘National research plan’. These programmes have been able to streamline the running projects on fuel cells (FCs), batteries and drivetrains, low emission vehicles (EVs, HEVs and FCEVs), demonstration, fuel policy and general technological development. Many Italian universities, research centres and industry are involved in a variety of CEU and national projects with impact in the transport sector.

Hydrogen and fuel cells in national research plan ‘New systems for energy production and management’

Two large R&D programmes on ‘Hydrogen and fuel cells’ have been approved. These programmes contain a total of 14 projects and are supported by the Ministry of Education, University and Research and by the Ministry of Environment through the Special Integrative Fund for Research (FISR). The

overall budget for three years is close to €120 million, of which about 70% is public funding. The projects on hydrogen involve ENEA, Fiat Research Centre, Research Consortium Pisa, IPASS Consortium, Universities of L'Aquila, Padova, Trento, Rome and Perugia, while the projects on fuel cells have the participation of ENEA, Arcotronics Fuel Cells, Nuvera Fuel Cells, CNR-ITAE, INSTM and the Universities of Perugia and Rome 'La Sapienza'.

Programme agreement ENEA - Ministry of research on advanced batteries and fuel cells

This programme of fundamental and applied research on lithium metal with solid components and on a PEM (Proton Exchange Membrane) fuel cells generator was successfully completed by ENEA in collaboration with CNR, Nuvera Fuel Cells, the Universities of Rome and Genoa, Ferrania and Fiat Research Centre. It resulted in the production of prototypes of Lithium metal batteries with polymeric components of 710 mAh with a specific energy in excess of 165 Wh/kg, and a 15 kW PEM fuel cell system fuelled by natural gas.

2000 special research funds of the Ministry of Research

Two special research projects -funded under the programme FISR of the Ministry of Research- on technologies for the transport sector were awarded to ENEA, as co-ordinator of two consortia involving industry and research organisations.

Hydrogen storage in metal hydrides for fuel cell vehicles

This 2.5 year project involves one industrial (SAES Getters) and three public research organizations: INFN - UdR Bo (National Institute of the Physics of Matter - Research Unit of Bologna) and CNR – ITAE (National Council of Research – Institute for Advanced Energy Technologies) and ENEA with three research units. Part of the activities are dedicated to study new Mg-based alloys that are able to meet the technical requirements of FCEV applications, while other activities are concentrated on the production process of mechanical alloying and on engineering and testing aspects of complete storage tanks. Samples of Mg-based alloys have already been synthesised with hydrogen adsorption of about 6% (in weight) at a working temperature of about 265 °C.

PEFC stack and system development

The project aims at R&D activities on critical subjects (components and engineering) of Proton Exchange Fuel Cells (PEFCs) and development of catalysts for fuel processing systems. Eight organizations -public research and industry- are involved. Promising results are continuous development of national fuel cell systems, which are being incorporated in some prototype vehicles.

16.3.2

Major industry projects

Nuvera Fuel Cells

Nuvera Fuel Cells -with American and Italian branches- continued its product development in collaboration with research institutes and end users. The R&D activities on automotive applications mainly focused on high power density PEFC stacks and on a gasoline fuel processor with auto thermal reforming. A new generation of FC stacks was then presented and prototypes of fuel processors were shown. Material research is underway in the FISR projects already mentioned.

In August 2005, Nuvera announced its next generation automotive fuel cell stack, which is called Andromeda™ II and which is capable of generating 125 kW of power. In December of the same year, Nuvera reached a multi-year agreement with Fiat Powertrain Technologies and the Fiat Research Centre on joint R&D of a high efficiency hydrogen fuel cell propulsion system for fuel cell vehicles.

FIAT Group

The company -through its subsidiary Fiat Research Centre- is involved in a variety of national and European R&D projects on hybrid and fuel cell electric vehicles. Achievements of these activities have been publicly presented in the form of vehicle prototypes. The second generation Fiat 600 'Hydrogen' applied a hybrid configuration (in a mode called load follower), in which a 40 kW PEFC (from Nuvera Fuel Cell) is supported by a battery pack (20 kW NiMH with an energy capacity of 0.9 kWh). The high pressure (350 bar) storage tanks (from ATK- Thiokol) can contain 1.6 kg of hydrogen, able to fuel the PEFC generator that -together with the battery- powers the 30 kW asynchronous electric motor driving the vehicle up to an urban driving range of 220 km, which is more than twice the range of the first generation. This hybrid configuration has already been transferred from concept vehicles to a road demonstration vehicle: the Panda Hydrogen. This vehicle will be used for setting up small demonstration fleets in experimental campaigns involving everyday use in practice. These demonstration fleets will contribute to a better tuning of the user and infrastructure needs.

Piaggio

This international leader in two-wheel vehicles has been involved in the development of a fuel cell electric scooter in an EU-funded project named FRESCO. The project with ECN (Netherlands), CEA (France) and Selin (Italy) aims at developing an electric scooter with a 7 kW fuel cell generator, using a composite pressurized tank for hydrogen storage. Besides that, Piaggio is involved in developing a new battery-powered electric scooter -the ZIP Electric- with various battery types and the commercialization of electric vans.

Micro-vett

This company is national leader of EV production and commercialization and is involved in some developmental projects for new products. With technical support of ENEA and the University of Pisa, Micro-vett is researching a new electric powertrain with new battery control systems as part of a special innovation public fund for enterprises. The overall energy efficiency, the battery life and the range are significantly improved by this technological innovation. In addition, Micro-vett is converting its production vehicles in order to introduce more performing batteries, such as Zebra (Na-NiCl₂). The last two research projects focus on the hybridization of an electric van (Ducato) and on the 'Ecomobility' project for the introduction of fuel cells in an electric van.



Fig. 16.1 Micro-vett hybrid van. (Photo courtesy Micro-vett S.p.A.)

16.4 Industry

This section presents the hybrid and electric vehicle related activities of two Italian companies. Research in other companies is described in section 16.3.

Arcotronics fuel cells

The company Arcotronics was created in 2003 after the incorporation of Roen Est, a small capital venture company developing -in collaboration with ENEA- its proprietary MEGA (Membrane Electrode Gasket Assembly) concept for PEFCs. This technology has been used in prototype modules for stationary and mobile applications. A production line for stacks in a power range between 500 W up to 60 kW is under construction. A vehicle development project named 'Ecomobility' is underway, in collaboration with Micro-vett, Sapio and HySyLab. An IVECO Daily 65 vehicle -already in production in a full-electric version- will be equipped with a 5kW PEFC and pressurized tanks (storing 2.5 kg of hydrogen) in order to double the average range (up to 250 km) of the electric version.

IRISBUS fuel cell urban hybrid bus (IVECO)

The first IVECO fuel cell hybrid bus -officially presented in 2001- completed test trials of about 5'000 km and was thus authorized in an official event to normal road use in public transport in the city of Turin. The complete test campaign was aimed at identifying safety and technological limits of the fuel cell (FC) and hydrogen technology. In 2003 a similar FC bus was developed and launched for a demonstration project in Madrid (Spain) -as part of the EU-funded project CityCell- that also includes demonstration of FC city buses in Berlin and Paris. IRISBUS is also leader -through its division ALTRA- of development and commercialization of hybrid and battery-powered electric buses.

16.5

On the road

The market demand of EVs and HEVs in recent years varied substantially with the availability of public subsidies. Slowing down the introduction of subsidy initiatives at local and central governments impacted the market share of these vehicles. The only constantly growing market niche considered by the various initiatives are small vehicles with limited funding.

The market introduction programmes have been mainly publicly funded because of the substantial cost difference between conventional vehicles and EVs and HEVs. Two basic market niches have been primarily addressed: service fleets and small vehicles in urban areas. The mitigation of local environmental impact has been the reason behind this choice. In addition to financial intervention, other initiatives have been supporting the introduction of these new transport means:

- networks of charging stations have been created in various cities (Rome, Milan, Florence, Naples),
- free parking spaces,
- free access to restricted areas, and
- free circulation on car-free days.

The evolution of this special market has been monitored by CIVES (the Italian Electric Road Vehicle Association) by means of special agreements with ministries and regional authorities to assist the application of funding laws. Despite of the stagnation of the car market in Italy, in Europe and in the rest of the world, the demand for EVs and HEVs is growing. The inventory of the vehicles that are offered on the Italian market -continuously updated by CIVES- demonstrates an availability of more than 100 vehicles of any type from electrically power-assisted bikes up to hybrid buses with conventional diesel engines or gas turbines. At the end of the end of the year 2003, the estimations of CIVES reached a total number of EVs and HEVs sold in Italy in excess of 95'000. By the end of 2004, this had increased to a total number of 112'700 vehicles. Figure 16.2 presents the vehicle

numbers by type for light electric vehicles and figure 16.3 shows numbers for the other hybrid and electric vehicles.

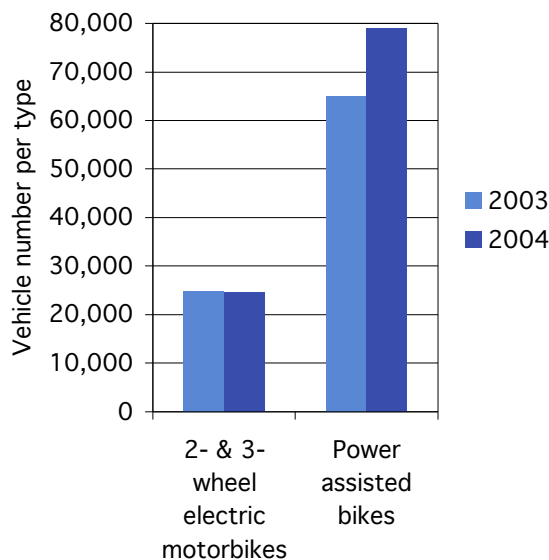


Fig. 16.2 Italian sales of light electric vehicles, as of December 2003 and as of December 2004. The numbers for 2004 are projections from a CIVES survey. (Sources: CIVES and ENEA.)

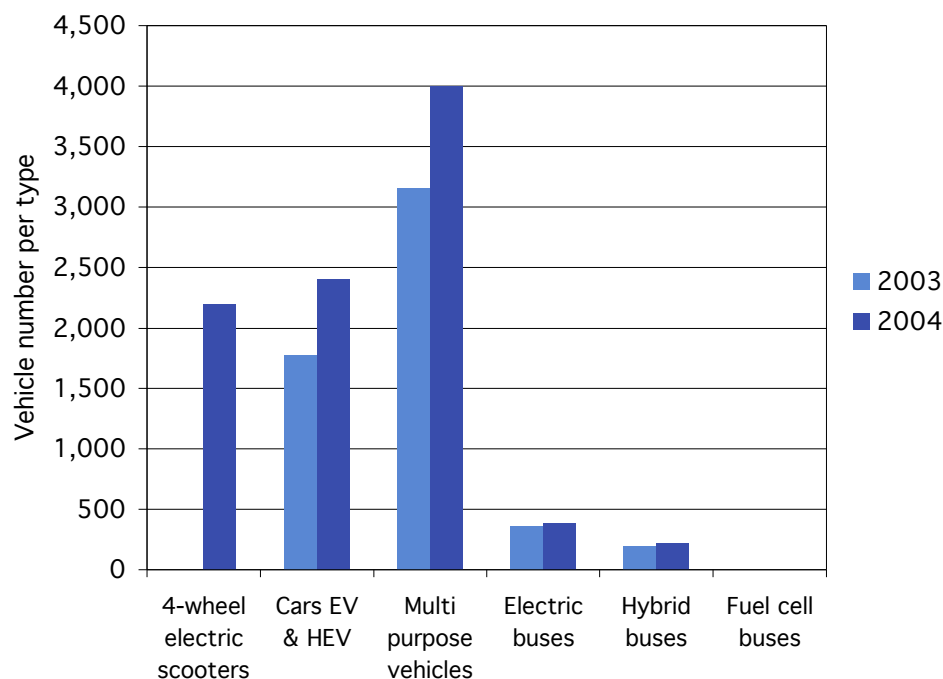


Fig. 16.3 Italian sales of hybrid (HEV) and electric (EV) vehicles, as of December 2003 and as of December 2004. The numbers for 2004 are projections from a CIVES survey. There is no data for 4-wheel electric scooters in 2003. The number for fuel cell buses is 1 for both years. (Sources: CIVES and ENEA.)

16.6

Developments

Special promotional days ‘Ecological Sundays’ and/or ‘Car-free days’ are locally set up in some cities as information and popularization days. These initiatives were integrated by temporary measures limiting private car circulation in restricted urban areas. In major cities (Milan, Rome, Florence, Naples and many others) EVs were allowed to circulate without specific permission, even during the ‘Car-free days’. Only in a few cases the introduction, demonstration and promotional initiatives have become a daily service. For example, the city of Reggio Emilia has continued its policy to electrify the public fleet by using public incentives. This worldwide awarded initiative -the ‘Global E-visionary award’ from WEVA and the IA-HEV ‘clean vehicle best practice award 2005’- is a success story for the application of EVs and HEVs. The electric fleet of the city companies has been increasing year-after-year up to the current number of over 450 vehicles.

16.7

Benefits of participation

The participation in the activities of IA-HEV has formal and informal advantages for Italy.

- The acquisition of information on relevant public R&D programmes in the transport sector is of invaluable interest, because of the possibility to better tune national programs and projects.
- The availability of R&D programs and objective results from various countries is useful to inform decision makers at government level to identify and prioritize projects.
- The comparison of experiences and case studies may result in the definition of common and standardized measures to produce comparable and neutral application data and to transfer the experiences to similar contexts.
- The informal personal contacts with experts from different countries and from various organizations are a source of new ideas, collaboration and enlarged co-operation in various scientific, technological and regulatory/standardization fields. In this way, the contacts may be easier and profitably transferred to other projects and bilateral & multilateral collaborations.

16.8

Further information

More information about EV and HEV related activities in Italy is available from the following sources.

- www.arcotronicsfuelcells.com (in English).
This web-site describes projects and products of a company producing fuel cells (PEFC).

- www.ceiuni.it/CIVES/home.htm (in Italian).
This is the official web-site of the Italian Electric Road Vehicle Association - CIVES, an internal committee of the Italian Electrotechnical Commission and the National Section of AVERE. The web-site gives a lot of information about the vehicles that are offered on the market, the status of supporting laws for electric vehicles and the major initiatives at national and local levels. It is also a source for contacts and addresses of all members of CIVES and of major Italian manufacturers, importers and research organisations and end users. An excerpt of the Italian inventory is also available online.
- www.comune.roma.it/mobilita/ (in Italian).
This is the web-site of the Rome township - General Direction Transport. The web-site contains information about initiatives for promoting the use of clean vehicles in the city.
- www.crt.unige.it (in English and Italian).
This is the web-site of an academic research centre on transport located at the University of Genova. The information contained in the web-site addresses public transport; not only electric/hybrid road vehicles. There are statistics and technical descriptions of buses.
- www.enea.it (in English and Italian).
The ENEA web-site presents programs, projects and activities in general terms, but also special reports about energy and environment.
- www.micro-vett.it (in English and Italian).
Web-site of Micro-vett, manufacturer of hybrid and electric vehicles.
- www.minambiente.it (in Italian).
The web-site of the Ministry of the Environment and the Territory contains up-to-date information about environmental legislation, initiatives and press releases. A specific area is dedicated to sustainable mobility, renewable energy, status of the environment and an on-line newsletter 'L' Ambiente Informa'.
- www.municipio.re.it/ambiente/infoambsito.nsf/mobilita?OpenForm (in Italian).
Web-site on sustainable mobility of the Community of Reggio Emilia.
- www.nuvera.com (in English).
This is the web-site of the major developer of proton exchange fuel cell and fuel processors for a variety of applications. The web-site presents products and contacts.
- www.regione.lombardia.it (in Italian).
This web-site contains information about all the initiatives of the Lombardia Region for the introduction of clean vehicles and fuels.
- White paper on electric vehicles (in Italian).
This publication has been produced by CIVES to summarize major advantages and possibilities of EVs. This publication is available directly from CIVES.

17

The Netherlands

17.1

Introduction

Hybrid electric vehicles (HEVs) became commercially available in the Netherlands in recent years, with Toyota's Prius I the first model sold. Public perception of the Prius I was very positive. The new Prius II followed in 2004, and that model has become quite a sales success. Demand is generating waiting lists for its delivery. Other manufacturers are gradually penetrating the Dutch market.

Electric vehicles (EVs) have been available for many years, but as sales have declined only a few makes remain, and so commercial availability is very limited. EVs have been used mainly in urban areas, as utility vehicles and for deliveries by local grocery sellers. Electric scooters have made their appearance in experimental markets, with limited success because the image of the vehicles is not a popular one, and because available models lack acceptable product quality. In general, the principal barrier to increased success of electric and hybrid vehicles remains the very limited availability of models.

Ongoing policies and legislation of the Dutch government for reducing CO₂ emissions and improving air quality are encouraging society and research institutes to devote greater attention to the hybridisation of vehicles and transportation systems as a CO₂ mitigation measure. Relevant automotive research and development organisations are concentrated in the southeast and interact effectively with the automotive production areas in Germany and Belgium.

17.2

Policies and legislation

Policies

The main environmental policy of the Dutch government is to implement programmes that target reduction of CO₂ emissions, improvement of air quality, and mitigation of noise levels in cities. A programme called 'CO₂ reduction in personal and goods transport' provides rebates for private investment in fuel-efficient vehicles and transportation systems. With respect to pollution from the transportation sector, air quality improvements result from reducing the emissions of particles by such diesel-powered vehicles as public transport buses, trucks and distribution vehicles. The installation of particulate filters on cars is encouraged by financial support from the government in the form of subsidies. Moreover, more sweeping efforts to improve air quality in cities could lead to the creation of

so-called 'environmental areas' in urbanized regions, to which entry by certain types of vehicles could be regulated by time of day or a fee structure.

'Eco-driving' is a focused communication programme that promotes and trains car, truck, and bus drivers in fuel-efficient and low-emission driving practices. Demonstrating knowledge of the principles of eco-driving (fuel-efficient driving behaviour) is part of the requirement for obtaining a driving licence for cars. The government is contemplating the need to mandate that fuel consumption-limiting equipment -such as speed governor and cruise control- be installed in all new vehicles. More information on this programme is available at www.ecodrive.org (see also section 17.8).

Legislation

Special tax rules apply to EVs and hybrid vehicles. Electric vehicles are already exempted from the road tax, and beginning in 2006, the purchase of a hybrid vehicle will earn a substantial rebate -up to €6'000- to encourage sales of such vehicles. Buyers of very energy efficient cars will receive a tax bonus, depending on the fuel efficiency label (energy consumption rating) for which the specific model has qualified. This tax bonus may be as high as €1'000.

Car dealers in the Netherlands are required to affix the energy consumption rating label to the new cars in their showrooms. This label -which has become very well known and accepted by the public- shows the vehicle's energy consumption in litres per 100 km and estimated CO₂ emission rate in kg per vehicle-km.

17.3

Research

In the Netherlands, there are various automotive research institutes:

- TNO Industry & Technology/Automotive,
- Technical University Eindhoven,
- Automotive Technology Centre (ATC),
- Competence Centre for Automotive Research (CARR), and
- Drive Train Innovations (DTI).

These institutes are all physically located in and about the city of Eindhoven in the southeast part of the country, with good connections to the automotive areas near Aachen in Germany and in Belgium that supply both assembled vehicles and vehicle components. Considerable co-operative work is ongoing at these research sites with research institute partners, as well as with car and truck manufacturers in the neighbouring countries.

Most car manufacturers are pursuing a change in strategy for developing components and subsystems, with component and subsystem research and development being shifted increasingly to supplier companies such that suppliers are now

developing and producing components on the basis of programmes of requirements formulated by the car and truck industry. The reality of manufacturer/supplier co-production is gaining headway.

The primary institute for advanced research on fuel cells in general applications is the Energy research Centre of the Netherlands (ECN). Additionally, universities and several smaller consultant firms have embarked on research on vehicle components and subsystems, as well as on transportation systems.

17.4

Industry

The Dutch automotive industry has:

- a truck manufacturer, DAF Trucks (a PACCAR company),
- a bus manufacturer for 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 is now fully integrated into the US-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-production have intensified during the last decade and promise to continue well into the future, Dutch automotive institutes and the component industry will have good opportunities to increase their participation in innovation with European vehicle manufacturers.

17.5

On the road

Conventional vehicle fleet populations in the Netherlands as of January 1, 2005, are shown in table 17.1. The population of approximately 7 million cars is equivalent to 1 car per 2.3 inhabitants.

Table 17.1 Approximate vehicle populations in the Netherlands as of January 1, 2005.

Vehicle category	Hybrid	Conventional
Mopeds	--	600'000
Motorcycles	--	540'000
Cars	2'000	7 million
Distribution vans	--	900'000
Trucks	--	142'000
Buses	--	11'200

Electric vehicles

Approximately 500 units are on the road, mainly cars and utility vehicles (i.e., electric vehicles with a license plate for use on public roads). Barriers to greater market penetration of EVs include purchase price, driving range, and limited availability of service support.

Sparta is a Dutch manufacturer of bicycles, including the electric bike ‘Sparta Ion’ -a very popular pedal assist bike- that is available for sales prices starting at €1’699. This electric bike is shown in figure 17.1. The Sparta web-site (see section 17.8) provides information on its features and specifications.



Fig. 17.1 The Sparta Ion electric bicycle. (Photo courtesy Sparta.)

The Netherlands is -of course- a very ‘bike-intensive’ country, with about 20 million bicycles - more than its total inhabitants.

Hybrid vehicles

Only a few car models are commercially available, including the Toyota Prius II, the Honda Civic and Honda Accord. The Lexus RX 400h will be on the market soon. To date, the Prius has been the best-selling hybrid vehicle in the country. By the end of 2005, approximately 3’000 Prius units will be on the road. To date, no hybrid goods vehicles or hybrid buses are available in the Dutch market, but some related demonstration projects are proceeding, such as the fuel cell buses in the European CUTE project that includes three buses operating in the Dutch capital city of Amsterdam.

17.6

Developments

The city of Eindhoven is demonstrating Phileas LPG electric hybrid buses in public transport. The technical goal is to successfully operate the buses on a special 15-km track - without an active driver. The bus is automatically guided by electronic controls in both the bus and the road surface. Approaches to bus stops

are also automatically guided. During this testing phase, the project has encountered some operational shortfalls as a result of difficulties with the battery pack.



Fig. 17.2 The Phileas LPG electric hybrid bus on a test track (left) and in service (right). (Photos courtesy APTS-Phileas.)

In December 2005, an automatic guided vehicle (AGV) system for public transport -the Parkshuttle- began operating near the city of Rotterdam. The vehicles transport commuters from a train station and parking area to an office complex. The AGV track is about 2 km long. The entire system is to be tested in a real-life application for an extended period. More information on the Parkshuttle system can be found on the internet (see section 17.8).



Fig. 17.3 The Parkshuttle near Rotterdam. (Photo courtesy FROG navigation systems.)

A small engineering company in the Netherlands has developed a hybrid bus with a 50 kW diesel generator set, electric wheel-hub motors on the rear axle, and a body made of lightweight materials and construction. This bus is intended for use in prototyping and testing, and the first two prototypes have been demonstrated. More information is available at the e-Traction[®] web-site (see section 17.8).



Fig. 17.4 Current (prototype) bus configuration and one of its drive wheels with electric wheel-hub motor TheWheel™. (Photos courtesy e-Traction®.)

17.7

Benefits of participation

The benefits from the perspective of the Netherlands of participating in the Implementing Agreement on Hybrid and Electric Vehicles include:

- Obtaining information on advanced transportation and automotive technologies available elsewhere around the world.
- Jointly producing studies and having opportunities to involve national research bodies in the work.
- Enabling the use of results from programmes from other countries and cultures for guidance in preparing Dutch national programmes.
- Participating in a worldwide network of experts, research institutes and government officials responsible for transportation.

17.8

Further information

Further information can be obtained from various internet web-sites, such as those listed below.

- www.atcentre.nl (in Dutch and English).
Automotive Technology Centre.
- www.ccar.nl (in English, with some articles in Dutch).
Competence Centre for Automotive Research (CCAR) in the region of Eindhoven.
- www.ecn.nl (in Dutch and English).
The Energy research Centre of the Netherlands (ECN).
- www.ecodrive.nl (in Dutch, English, French and German).
Web-site of the manufacturer of the Ecodrive rev/speed governors.
- www.ecodrive.org (in English and German).
Web-site of the European Eco-driving platform.

- www.e-traction.com (in English).
Web-site of the electric propulsion company e-Traction[®] and its self-propelled electrically powered wheel TheWheel[™].
- www.frog.nl/peoplemover.php?s=automatedpeoplemovers (in Dutch, English and German).
Information on the Parkshuttle automated people mover system.
- www.phileas.nl (in Dutch and English).
Information on the Phileas LPG electric hybrid bus.
- www.senternovem.nl/SenterNovem_English/index.asp (in Dutch and English).
The Dutch Energy Agency SenterNovem.
- www.tno.nl/industrie_en_techniek/markten/automotive_and_transporta/ (in English).
Web-site on the automotive activities of the TNO research organisation.

18 Sweden

18.1 Introduction

Something special happened in Sweden in 2005: the 'green vehicle' gained acceptance as an ordinary (i.e., non-exotic) mode of transport. This new-found acceptance is due to the political debate on the perception of ongoing climate change. Especially the evidence of change as manifested by hurricanes Katrina and Rita in the United States and in Sweden by storm Gudrun -which knocked out electricity and telecommunication systems for months in parts of the country- had an impact. Although interest in hybrid vehicle technology has increased in Sweden, the main focus has been on alternative motor fuels, particularly ethanol and biogas. There is minimal interest in all-electric vehicles, and no new vehicles of this type are available on the market.

18.2 Policies and legislation

Taxation

In December 2001, the government reduced the national taxation burden on certain green vehicles to encourage their sales. The rules have subsequently been changed a number of times, with the present rules having been set in the government's December 2003 budget bill. Under them, the taxation levy on hybrid or electric company cars is reduced by 40% relative to the closest comparable petrol model, subject to a maximum reduction of US\$ 2'000 per year. This reduction can be compared with the 20% reduction given for company cars running on E85 (a blend of 85 vol-% ethanol and 15 vol-% petrol), natural gas or biogas, subject in this case to a maximum reduction of US\$ 1'000 per year.

The following are the approximate national taxation benefits for some common green vehicles:

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

- Opel's CNG models: about US\$ 750 per year less than the corresponding petrol models.

Rules for public purchasing of vehicles

The rules governing public purchasing and leasing of vehicles have also been changed, as set out in the 'Ordinance concerning public purchasing and leasing of green vehicles'. This ordinance is intended to encourage the purchase and leasing of 'green' passenger cars to increase the proportion of green vehicles in use by public bodies. Applying to public authorities, it came into force on 1 January 2005. The first follow-up study of its effects will be carried out in March 2006. The objective is that at least 75% of the total number of cars purchased or leased by a public authority during a calendar year be green vehicles. During the year, the National Road Administration has also published a definition of the types of vehicles that qualify for definition 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, they can award grants to companies or private individuals to assist in the purchase of green vehicles costing more than equivalent petrol vehicles. Some local authorities have reduced parking charges for green vehicles, and rules can vary from one local authority to another.

A congestion charging scheme was programmed for experimental introduction in Stockholm in January 2006. The government has instructed the National Road Administration to operate the scheme, which will run until 31 July 2006. Green vehicles will be exempted from the charge and in this case, green vehicles will be those vehicles that are powered partly or wholly by electricity, alcohol or any gas other than LPG.

18.3

Research

In principle, there are three 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 synergism among them. They also share a common business intelligence monitoring and analysis element. The following paragraphs briefly describe some of the details of the programmes.

The green vehicle programme

The objective of the green vehicle programme is to develop cleaner vehicles. It is a joint programme between the automotive industry and the government. The total budget is approximately US\$ 180 million, the administrator is VINNOVA (Swedish Agency for Innovation Systems), and the programme runs from 2000 to 2005. About US\$ 10 million are budgeted for specific electric, hybrid and fuel cell vehicle research. The programme also includes a training element, in such areas as vehicle system technology for a better environment and hybrid vehicle drive systems. In 2004, the programme was extended until 2007, although without any additional funding, except for hybrid systems and internal combustion engines, for which the automotive industry and the universities have negotiated bridge funding between these programmes and the coming 'Green vehicle 2' programme. This programme will include work in the following areas, which are linked to hybrid systems: architectures for hybrid systems, drive systems, APU (auxiliary power unit) fuel cells, supercapacitors, and battery technology.

Energy systems in road vehicles

The 'Energy systems in road vehicles' programme addresses energy-related issues in vehicles. This programme has several research projects dealing with batteries, fuel cells and other components for vehicles using electricity as a means of improving energy efficiency. The total programme budget is approximately US\$ 20 million and is administered by the Swedish National Energy Agency.

The programme entered its second phase in 2004, which will continue until the end of 2006. The additional budget is about US\$ 10 million, of which 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 on a new type of hybrid driveline has been applied for. When the results of the programme were evaluated, it was decided that the programme should not attempt to spread itself over too many areas in the future, and that the work should be concentrated on hybrid vehicles. The programme covers the following areas linked to hybrid systems: the architecture of hybrid systems, drive systems, diesel reformers for fuel cells, and battery technology. This programme operates a simulation centre for merging the results of all the national programmes.

Fuel cells in a sustainable society

'Fuel cells in a sustainable society' is the second part of a programme that started in 1997. The programme was slightly modified during 2002 and it ends next year. The administrator is MISTRA -the Foundation for Strategic Environmental Research- and the total budget is approximately US\$ 10 million. The programme includes research projects on fuel cell components, materials and systems. It concentrates on investigating manufacturing methods, and on reducing the cost

and increasing the life of fuel cells. It is a joint programme with universities and industry.

18.4

Industry

Sweden is one of the world's countries that are very dependent on their automotive industry. Including those working for the thousand or so subcontractors to the industry, Sweden employs about 140'000 people in the sector.

The major manufacturers are Volvo AB, Volvo Cars, SAAB Automobile and Scania, all of which have presented electric and/or hybrid concept vehicles. As the hybrid vehicle sector -in particular- has passed into the commercial sphere and is starting to mature, it is impossible to obtain figures on R&D activities from the companies.

Subcontractors that are engaged in some way in the fields of electric vehicles, fuel cells, and/or hybrid vehicles development are shown in box 18.1.

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.
Cell Impact AB	Development and sale of bipolar plates for PEM fuel cells.

18.5

On the road

The population of green vehicles in Sweden at the end of 2004 is shown in tables 18.1 and 18.2, with the number of conventional vehicles provided for comparison. Unfortunately, sales figures can no longer be obtained from manufacturers because they now treat green vehicles as commercially and competitively

sensitive sectors, and the official statistics for 2005 will not be published until April 2006.

Table 18.1 Population of green vehicles in Sweden at the end of 2004 - Private cars and light goods vehicles.

Private cars and light goods vehicles < 3.5 tonnes	Number, December 2004	Change during 2004	Change [%]	Proportion of new registrations [%]	Proportion of total number of vehicles [%]
Conventional vehicles					
Petrol	4'037'317	+ 11'634	+ 0.3	81.4	90.1
Diesel	421'196	+ 36'431	+ 9.5	15.9	9.4
Other - not specified	14	+ 1	+ 7.7	0.0	0.0
Total conventional	4'458'527	+ 48'066	+ 1.1	97.3	99.5
Green vehicles					
Ethanol, E85	13'362	+ 5'387	+ 67	1.8	0.3
Natural gas/biogas & petrol	4'519	+ 1'080	+ 31	0.4	0.1
Low-consumption vehicles	2'080	+ 820	+ 65	0.3	0.05
Hybrid-electric vehicles	1'355	+ 736	+ 119	0.3	0.0
Electric vehicles	404	- 50	- 11	0.0	0.0
Older prod. gas, LPG, etc.	142	- 30	- 17	0.0	0.0
Methanol	1	0	0	0.0	0.0
Total green	21'863	+ 7'943	+ 57	2.7	0.5
Grand total	4'480'390	+ 56'009	+ 1.3	100	100

In total, nearly 4.5 million private cars and light goods vehicles were on the roads of Sweden at the end of 2004, which represented an increase in the number of light vehicles of 1.1% during that year. About 16% of new registrations had diesel engines and a large number of them were light goods vehicles. Eight percent of private cars were diesel models.

At the beginning of the year, there were over 19'000 light vehicles running on alternative fuels. When adding about 2'000 low-consumption petrol/diesel vehicles to this number, there were over 21'000 light vehicles in use that could be regarded as green. In total, green vehicles made up about 0.5% of the number of vehicles registered in the country and about 2.7% of new vehicle sales.

Table 18.2 Population of green vehicles in Sweden at the end of 2004 - Heavy vehicles.

Heavy vehicles > 3.5 tonnes	Number, December 2004	Change during 2004	Change [%]	Proportion of new registrations [%]	Proportion of total number of vehicles [%]
Conventional vehicles					
Heavy diesel-fuelled vehicles	84'880	+ 5	+ 0.0	97.2	96.6
Heavy petrol-fuelled vehicles	1'751	- 86	- 4.7	0.3	2.0
Other vehicles - not specified	2	0	0.0	0.0	0.0
Total conventional	86'633	- 81	- 0.1	97.5	98.6
Green vehicles					
Natural gas/biogas buses and goods vehicles	779	+ 102	+ 15	2.5	0.9
Ethanol buses	382	- 20	- 5	0.0	0.4
Older producer gas, LPG, methanol etc.	25	0	0	0.0	0.0
EVs, including fuel cells	18	+ 1	+ 6	0.0	0.0
Hybrid-electric goods vehicles	0	- 5	- 100	0.0	0.0
Total green	1'204	+ 78	+ 7	2.5	1.4
Grand total	87'837	- 3	0.0	100	100

The number of green heavy vehicles grew by about 7% in 2004. A total number of 102 heavy vehicles powered by gas were sold. Twenty ethanol-powered buses were taken out of service, as were all five hybrid-electric goods vehicles that were on the road at the beginning of the year.

18.6 Developments

During 2005, interest in hybrid vehicles has really taken off, and discussions on several R&D programmes are in progress. Whereas the state was the main driving force behind earlier discussions, it is industry that is behind them this time. As an example, the 'Green vehicle 2' project will have greater emphasis on hybrid vehicle technology than was previously the case.

During the past year, VINNOVA has unsuccessfully attempted to initiate a project to procure hybrid bus technology. This effort has been unsuccessful because bus operators have invested heavily in the introduction of alternative fuels -such as biogas and ethanol- in their fleets, and as a result they do not have enough money left to consider tackling yet another new technology.

Also during 2005, VINNOVA has evaluated results of projects undertaken to procure vehicle-related technology, including projects for electric vehicles. The most important lessons from the projects were that:

1. A support system must be kept in place for some years after delivery of the vehicles.
2. It is helpful to keep and use the same purchaser group for several procurement projects in order to reduce the start-up time.

Stockholm City Transport was involved in the Clean Urban Transport for Europe (CUTE) programme's fuel cell bus trials, with excellent results: good availability, pleased drivers and satisfied passengers. Nevertheless -during the year- the City Council decided not to take part in the planned CUTE 2 fuel cell bus project and it has now sold the buses and their hydrogen refuelling station.

18.7

Benefits of participation

The benefits of participation in IA-HEV can be summarised as follows:

- It enables the informal exchange of information and contact with organizations worldwide. As a result, participants have a cost-efficient way of learning about the research, development and application efforts undertaken by other countries. At the same time, the network provides a way of benchmarking national efforts against those of other countries in order to improve the cost benefit of our own efforts.
- It allows costs of major worldwide work to be spread among countries. Many investigations have been carried out within the framework of the group's work - investigations that would have been impossible for any one country to perform on its own at a reasonable cost. It is important that the best scientists in a particular field carry out the work, and it is easier to find out who they are when working in a group with representatives from several countries, each with its own networks.
- It provides national scientists with the opportunity to participate in international groups. As a result, researchers are able to tackle not only issues that are of interest in Sweden, but they can also take advantage of an inward flow of information from other countries - a process that strengthens the international network of scientists. It is also important that those involved bring home new thoughts and new ideas - ideas that can result in new R&D projects and/or opportunities for business.

18.8

Further information

The following web-sites publish several reports covering cleaner vehicle issues:

- www.kfb.se/publ/main.htm (in Swedish)
A good library of older reports.

- www.mtc.se (in English and Swedish).
The MTC Technical Centre of the AVL Powertrain Systems Corporation (AVL MTC AB) has issued a few reports covering test results on cleaner vehicles (reports are mainly in English).
- www.stem.se (in English and Swedish).
The Swedish Energy Agency (STEM) publishes reports, although mainly in Swedish. The main focus with respect to cleaner vehicles is on (1) energy efficiency in the transportation sector and (2) the production of alternative fuels.
- www.vinnova.se (in English and Swedish).
The Swedish Agency for Innovation Systems 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 (reports are mainly in Swedish).

A link to a demonstration project is the following:

- www.fuel-cell-bus-club.com (in English).
This site covers the CUTE project. (See section 18.6.)

A few organisations that provide regional or national information on cleaner vehicle aspects are listed below:

- www.miljofordon.org (in English and Swedish).
Site for cleaner vehicles that provides information on vehicles, infrastructure and costs.
- www.milore.nu (in Danish and Swedish).
Öresund region's information site with information on cleaner vehicles.
- www.sweva.org (in English and Swedish).
The Swedish Electric and Hybrid Vehicle Association's web-site.
- www.h2forum.org (in Swedish, an English version is under construction).
The main forum for those concerned with hydrogen in Sweden.

19 Switzerland

19.1 Introduction

Switzerland lacks car manufacturers but has a relevant automotive supplier industry. The Swiss government therefore understands that its role in this field is to facilitate the supplier industry's efforts to follow international progress and identify development gaps into which Swiss manufacturers can step. Swiss manufacturers are especially competitive in the fields of electronics, control systems, advanced storage systems and lightweight structural parts.

Although government policy promotes the use of alternative fuels -compressed natural gas (CNG), biogas, ethanol- market niches remain for special electric vehicles, e.g. lightweight vehicles for commuting and special vehicles for the 'car-free' resorts. Additionally, hybrid vehicles have recently achieved inroads in the passenger car market. Switzerland's power generation infrastructure is extremely advantageous for electric and hybrid vehicles: energy production is completely CO₂- and pollutant-emission free, with a mix of 60% hydropower and 40% nuclear power. Therefore, electric vehicles (EVs) are powered to a large extent by renewable energy.


19.2 Policies and legislation

After a 10-year period of active promotion of EVs by the Swiss government -through for example publicity programmes, purchase subsidies, direct support of the vehicle manufacturer and supplier industries- the energy law implemented in 1999 transferred the responsibility for promotion from the federal government to the local governments (cantons).

Since 1995, the Federal Office of Energy has conducted a campaign in the energy field called 'EnergieSchweiz' (or 'Swissenergy', formerly 'Energy2000') that targets to lower the overall national energy consumption. This campaign extends to the transportation field, for transportation consumes almost 40% of the total energy demand in Switzerland. Efforts to lower the energy consumption of vehicles are concentrated in the 'EcoCar' campaign. This campaign is run by the agency e'mobile, and it is summarized in box 19.1 (see next page). These measures also affect the sales of electric and especially hybrid vehicles.

Evaluations of the EcoCar approach by Swiss research institutes agree that energy efficiency is a competitive advantage only in the heavy-duty vehicle segment, and thus predict no effect on the light-duty-vehicle segment for the measures already

implemented. According to the scientists, only the ‘bonus-malus’ approach is promising - but it is exactly this measure that meets the greatest resistance from stakeholders.

Box 19.1			
Summary of the Swiss EcoCar project			
aiming to lower energy consumption of vehicles			
			
Measure	Implemen- tation	Description	Effect
Labelling	In planning	Indication that a vehicle meets/does not meet EcoCar criteria ('bonus-malus').	None to date. Start-up difficulties with respect to definitions.
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.	Categorizing too imprecise, so consumption criteria will be more stringent in a 2 nd step.
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 finance government program that will require purchase of CO ₂ certificates.	A shift to energy-saving car models is expected.

As mentioned above, the cantonal governments now have the legal authority to finance promotion measures for electric and hybrid vehicles. Until 2005, it is primarily the canton of Ticino -as the ‘heir’ of the federal promotion programme ‘VEL1’ (‘Large scale test for lightweight electric vehicles’ in Mendrisio, operated 1995-2000)- that has been active in this area. Ticino’s cantonal promotion programme ‘VEL2’ also admitted CO₂-saving conventional car models to the subsidy programme. The effect of VEL2 was that many users of electric vehicles sold the electric vehicles they bought during VEL1 and shifted to a small conventional car with low energy consumption, even though the 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 were still available in this region. A conclusion from this experience is that a highly subsidized market is not sustainable.

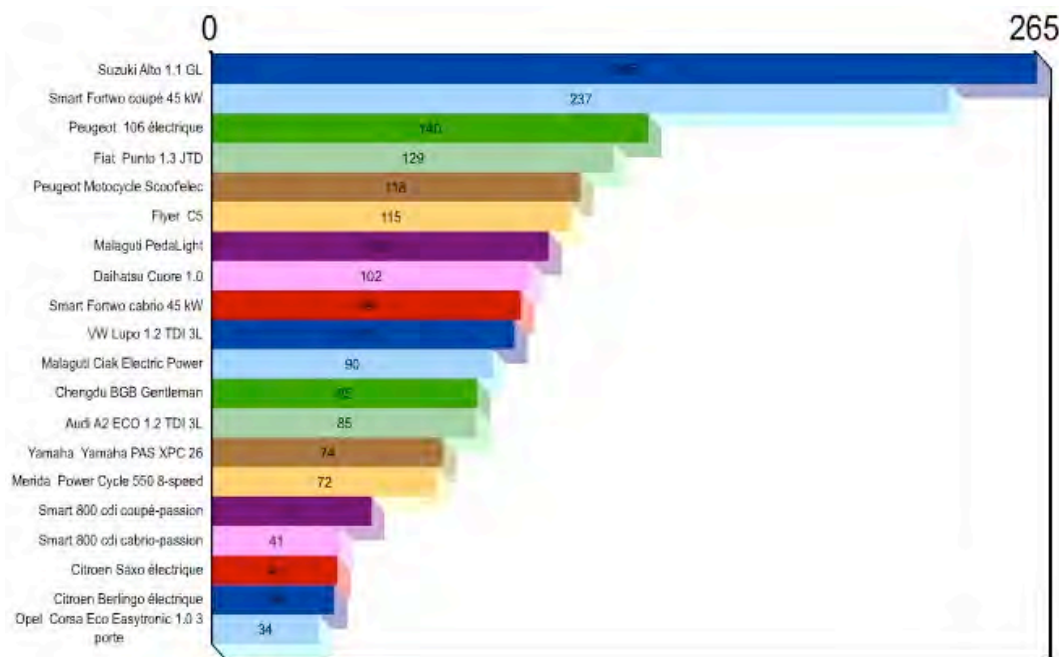


Fig. 19.1 The 20 most popular light-vehicle models in Switzerland, based on total 2005 sales. (Picture supplied by Muntwyler AG.)

The VEL2 programme ended in June 2005. In this second phase of the VEL programme, 2'785 energy efficient vehicles were subsidized, including seventy-five hybrid vehicles. Regarding electric vehicles, a total number of about 1'300 units have been subsidized within both phases (VEL1 and VEL2), including 935 electric bicycles, 280 electric scooters, 10 three-wheeled electric vehicles and 85 light-duty models such as the Peugeot 106 electric and Citroën Saxo electric.

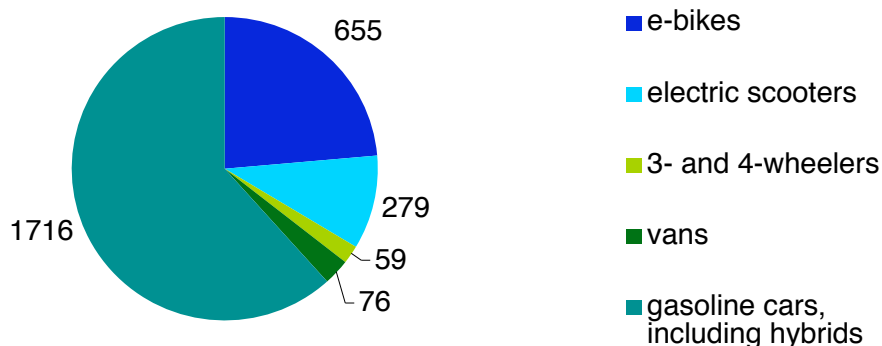


Fig. 19.2 Subsidised sales by vehicle class within the VEL2 programme in Ticino, Switzerland.

The second promotion initiative in Switzerland is concentrating on electric two-wheeler vehicles. Within a promotion programme called ‘NewRide’, municipalities in 10 cantons support the purchase and use of electric bicycles or electric scooters by a great variety of measures. In some of the cantons, purchases are subsidized (Zürich, Basel, Neuchâtel) and others support exhibitions and test-driving events or use in special application niches like hospitals or in tourism. Also, a few pilot projects in which electric bicycles were used for home delivery have been run. This promotion programme resulted in purchases of about 1’850 electric two-wheelers per year in 2003 and 2004, in addition to the sales figures realized outside the scope of NewRide.



Fig. 19.3 PR for electric bicycle use by the cantonal utility of the canton of Berne. (Picture supplied by Muntwyler AG.)

Switzerland has adopted the European guidelines to increase its population of CNG vehicles by 2020 to 10% of the total vehicle population, or about 350’000 vehicles. As of the end of 2004, about 1’250 CNG vehicles had been licensed. The use of CNG and biogas in transport is promoted in a pilot project in the city and canton of Basel called ‘Erlebnisraum Mobilität’ (‘adventure space mobility’). Within this project, the Federal Office of Energy supports taxi services using hybrid and CNG vehicles.

Switzerland is also participating in the European Community project ‘Cleaner drive’ that has developed a consistent method to value the environmental effects of vehicles with various propulsion systems. The scoring ranges from 1 to 100 points and considers emissions produced by the vehicles in operation, as well as by the production of the fuel.

Several cantons provide a tax reduction for the purchase of ‘clean’ vehicles: 16 of 26 cantons either grant reductions or exempt EVs altogether from the vehicle taxes, and eight cantons reduce the taxes for hybrid vehicles.

19.3

Research

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 Swiss Federal Laboratories for Materials Testing and Research (EMPA). The Universities of Applied Sciences (FH) in Biel and Luzern are also active. The Swiss Federal Office of Energy also supports research in private companies, emphasizing battery research. Box 19.2 (on the next page) presents an overview of Swiss research projects on automotive topics.

Research is end product oriented, given the official position that research must lead toward marketable products for Swiss manufacturers.

In addition to the projects listed in box 19.2, the Federal Office of Energy has supported several projects testing the use of alternative fuels.

19.4

Industry

The only Swiss manufacturer of electric vehicles (EVs) is BikeTech, 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'). The automotive supplier m.e.s. is converting a Renault Twingo Quickshift to an EV. Brusa Electronics -a specialist in power electronics- is developing a track-based, unmanned EV that is called the 'Coaster'.



Fig. 19.4 Flyer e-bikes (left) and swizzbee e-bike (right). (Photos supplied by Muntwyler AG.)



Fig. 19.5 From left to right: Brusa Coaster, m.e.s. Renault Twingo Quickshift Elettra, TWIKE. (Photos supplied by Muntwyler AG.)

Box 19.2			
Overview of Swiss research projects on automotive topics			
Field	Project leader	Project	Description (year of project conclusion)
Vehicles/ prototypes (+FC)		REVA EURO	Improvements of the Indian EV 'Reva'/preparation for an European homologation (2005).
	FH Luzern	TOHYCO-SAM	Test vehicle: platform for a supercapacitor storage system (2005).
	FH Biel	FC-Sam	Prototype with FC system (2005).
	ETH Zürich	'Pile à combustible' PAC-Car	Lightweight prototype for the Eco Marathon; most economic vehicle with FC system (2005).
	Hess AG	Swisstrolley	Energy-efficient, lightweight electric cable bus.
	Brusa AG	Coaster	Track-based automatic transportation system with electric propulsion.
Propulsion systems (+FC)	EMPA	Clean Engine Vehicle CEV	Monovalent CNG prototype; target: -30% CO ₂ (2005).
	FH Bern - Biel	Ultralight scooter	Propulsion system with PM motor.
	ETH Zürich	Hybrid propulsion system	2 projects in the start-up phase.
	EMPA	Hybrid prop. system with a CNG engine	1 project in the start-up phase.
Storage systems	m.e.s.	ZEBRA batteries	Improvements of cycles.
	PSI	ONEBAT	Supercapacitors for the starting-phase of SOFCs instead of batteries.
	FH Bern - Biel	Ultralight scooter	Li-battery + management system for two-wheeler EVs.
Body/ components	FH Biel	Multiple purpose mobile MUPUM	Basic module for communal vehicles (waste collection, school bus, snow plough, etc.).
	Rieter/ Horlacher	'Lightweight vision' LIVIO	Vehicle composed of composite modules with integrated functions (2007).
		CNG.H ₂ Easyconnect	
Infrastructure			

Swiss companies that developed earlier EV prototypes did not succeed in moving to series (mass) production. Notably, the touted three-wheeler 'SAM by cree' did not take this step; the 70 pre-series vehicles were sold to private users or used as a technology platform by several research institutes.

In contrast, the manufacturing of components for hybrid vehicles and EVs by the following Swiss companies has been successful: m.e.s. (ZEBRA NaNiCl batteries), Horlacher, ESORO (composite parts) and Brusa Electronics (power control systems). All of these companies are also active in research projects. The research activities on the ZEBRA batteries concentrate on lowering their operational temperature. Suitable solvents have been tested, and the feasibility of lowering the temperature has been confirmed in laboratory analyses. Nevertheless, availability of a low-temperature ZEBRA battery is likely a long way into the future.

The approach of Swiss industry is still influenced by experiences during the first worldwide solar-mobile races, the ‘Tour de sol’ (1985–1993), in which the competition was won only by maximum efficiency through highly efficient components and lightweight construction. This philosophy fortuitously comports with the tendency in the worldwide automotive industry to improve the efficiency of cars, enhancing the chances for the Swiss contributions. Thus, the approach of the LIVIO project by Rieter/Horlacher is especially promising: smart design of the integrating functions for component body parts depends on special materials and technologies, areas in which Swiss companies have substantial experience.

19.5

On the road

The Swiss electric vehicle (EV) market is small and dominated by small light-weight vehicles, such as e-bikes, e-scooters, and three-wheeled vehicles (such as TWIKE and ‘City-el’, which are licensed as motor bikes). Vehicle numbers are shown in table 19.1. Because almost no EV on a standard auto platform is still available in the Swiss market, the population of four- and three-wheeled EVs has been decreasing over the last three years. Most of the in-use EV population is

Table 19.1 Swiss vehicle population data, as of the end of 2004.

Vehicle type	Electric vehicles	Hybrid vehicles	Total vehicles
Two- and three-wheelers	licensed 1'766 + ca. 7'000 e-bikes	--	583'010 + 230'000 mopeds + 3 mio bikes
Light-duty	744	1'021	3'811'351
Buses and trucks	415	--	342'979
Others (industrial, agricultural)	+ 2'245 industrial + 31 agricultural	--	231'856
Total	ca 9'925 + 2'245 industrial + 31 agricultural	1'021	4'969'196 + 230'000 mopeds + 3 mio bikes

more than 10 years old, and it is almost impossible to replace vehicles that can no longer be repaired. A lack of new car offerings has resulted in great interest in used EVs. The market for electric two-wheelers is growing fast, with about 2'300 electric scooters and bicycles sold annually in Switzerland.

Market niches for EVs can only be stable in case the users have real advantages, or if they are forced to use EVs because of special regulations. Switzerland has two important niche market segments: commuters and car-free resorts, as described below.

- Commuters

Most of the electric vehicles are used for commuting in urban agglomerations. This results in the great success of small, lightweight EVs, especially three-wheeled and two-wheeled vehicles. They can easily be parked and recharging stations exist at privileged parking spots in the centres of most cities. Drivers of three-wheelers -like City-el, see figure 19.6- 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.



Fig. 19.6 From left to right: City-el, Electric scooter EVT, Parking spot with public recharging station. (Photos supplied by Muntwyler AG.)

- Car-free resorts

In nine resorts in the Swiss Alps, the use of conventional cars is partly or even completely forbidden. The most well-known and strictest car-free resort is Zermatt. There, no private person is allowed to own a vehicle and hotel owners must have more than 30 beds to obtain permission to own a 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.

Swiss importers are happy with developments in the hybrid vehicle market. As of September 2005, 1'658 Toyota Prius I and II, 160 Honda IMA, and 115 Lexus RX 400h had been licensed in Switzerland. For the Prius, 425 pre-orders were still pending at that time. Sales figures are suppressed to some degree by contingents of supply limitation, especially for the Toyota New Prius (II).



Fig. 19.7 Electric powered hotel taxi in car-free resort. (Photo supplied by Muntwyler AG.)

A market study by the Federal Institute of Technology Zurich comparing buyer segments for Toyota Corolla, Aventis and Prius found that the lower motor vehicle taxes in some of the cantons have resulted in a 20% increase in Prius purchases. In addition, Prius buyers had weaker brand/model loyalty than Corolla or Aventis, and buyers drove many other car models before they bought the Prius. Other significant differences between Prius buyers and Corolla/Aventis buyers could be found in the following features and circumstances: advanced propulsion technology, lower fuel consumption, and gasoline price. All were important considerations in the choice of a Prius, 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

An evaluation of cumulative sales figures for Switzerland reveals some interesting trends. At the outset of EV availability in the marketplace, the EV population increases impressively. In particular, sales rose when:

- The 'Tour de sol' was run in Switzerland (1985-1993), and the first EV models (Solec, Pinguin) could be bought.
- The subsidy programme started in Mendrisio and seven partner communes (1995).
- New vehicle models were introduced into the Swiss market each year.

Sales declined when:

- No new EV models were introduced, as in the current situation with no new model availability.
- Announced new entries to the Swiss market do not materialize, or are far too limited - as was the case with the Honda EV Plus and the electric version of the 'smart'.
- The subsidy programme for EVs was discontinued in the partner communities (2000).
- A subsidy programme -in Mendrisio- was expanded to include conventional vehicles with low CO₂ emissions (2001).

As shown in figure 19.8, EV sales figures dropped dramatically after 1991 when the promised electric ‘smart’ did not appear. In 1995, when the ‘Large scale test for lightweight electric vehicles’ commenced and the three-wheeler TWIKE entered the market, the sales curve rose again. From 1996 on, the curve of electric two-wheeler sales has risen steadily. It can be concluded that the greatest -sustainable- success lies in market niches where EVs offer advantages in use. Niches based on subsidies are not sustainable. Real advantages to EV users include faster commuting, easy access to city centres, no parking problems, lower operating costs, and -in some cases- a positive image. Image includes all ‘soft’ factors, such as the vehicles have a more futuristic look, and they symbolize (communicate) such qualities as ecology awareness and express the individuality of their owners. Lightweight three-wheelers and high-speed electric bicycles have all of these advantages in Switzerland, while four-wheeled vehicles do not. Sustainable niches can also be established by regulation, as in the case of the car-free resorts.

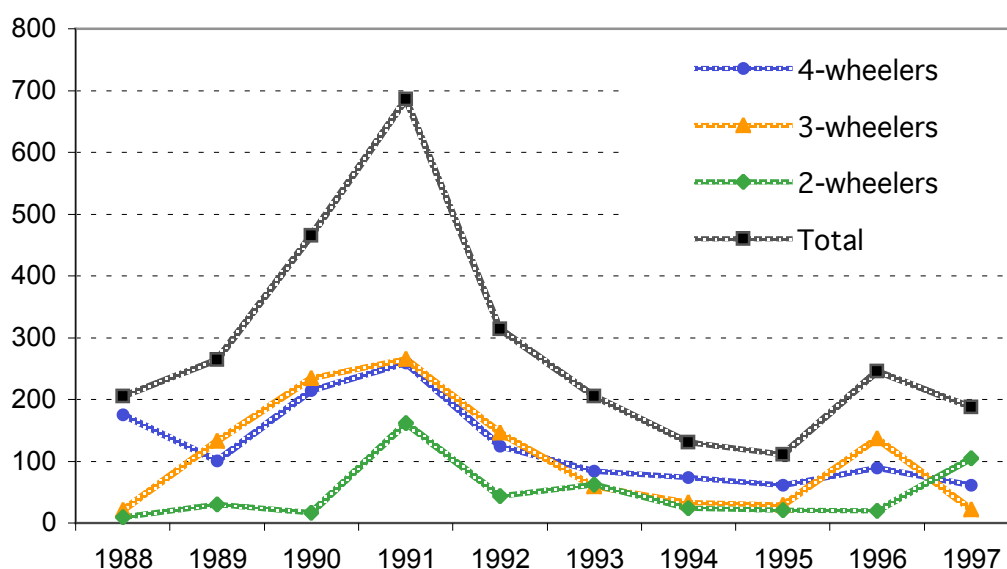


Fig. 19.8 Historical trends in EV sales in Switzerland through 1997.

The hybrid vehicle market works because of a great sensitivity toward ecology in Switzerland, a good knowledge about alternative vehicles -especially electrics, as a result of the ‘Tour de sol’ races and the promotion programme in Mendrisio- and the comparable performance of the hybrid vehicle models available in Switzerland. In addition, hybrid vehicles offer an agreeable price/performance ratio.

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

- Several small and medium companies could specialize in these fields, e.g. Brusa, ESORO.
- Large Swiss automotive suppliers see a chance to take a lead (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 the small specialized industry in Switzerland complain that:

- too much know-how is kept within research institutes,
- the step to production is difficult,
- the development of standardized products is neither supported nor existing in Switzerland at this time, and
- there is a lack of an efficient profit chain.

With respect to demonstration programmes, Switzerland assumed a leadership position in 1992 with its 'Promotion programme for light-weight vehicles'. Despite strong reservations even within the relevant Federal Office, a six-year subsidy programme was implemented in a model town (Mendrisio 1994-2000) to study the effects of the EV market under real-life conditions. The accompanying research was of high value, and the results of these special studies are still a source of valuable knowledge. The deployment of EVs suffered from an insufficient range of EV models available and in many cases a lack of professional service for all vehicles. Additionally, in the course of the programme several models were taken out of the market or did not enter, including the Honda EV Plus. The timing of such a promotion programme is crucial, with no guidance or perspective about the right moment in all instances. In several aspects of EV development such as lightweight design and model range, Switzerland jumped ahead too early. Moreover, the lack of a mass market remains a barrier for the development and successful marketing of standardized components. Nevertheless, useful feedback may emerge in unexpected and indirect ways: without the prototypes deployed in the 'Tour de sol', the 'smart' would never have been put on the market. Market influences and useful information may also be gained from other developments worldwide such as:

- Increase in onboard voltage for hybrids and accessory-intensive vehicles.
- Commercialization of mild hybrids.
- Kinetic energy recovery in conventional cars.
- New departures in design.
- New composites for lightweight car parts to reduce overall weight and increase fuel efficiency.

19.7

Benefits of participation

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

- The development of new batteries -such as those based on lithium-ion technology- and progress in component development. New batteries could precipitate a resurgence of all-electric vehicles -at least for specific market niches- and it is hoped the government will be able to identify the right moment to consider active support.
- The realization that the hybrid electric vehicle will make its way into the market without government support.
- 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 mitigating measures and the real market chances for clean vehicle technologies.

19.8

Further information

Web-sites:

- 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).
Programme 'EnergieSchweiz' of the Federal Office of Energy.
- www.erdgasfahren.ch (in French and German).
Natural gas vehicles.
- www.horlacher.ch (in English, French and German).
Horlacher Lightweight Construction.
- www.hta.fhz.ch (in German).
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, 'smart' pure elettrica, 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 ETH Zurich.
- www.psi.ch/medien/Medienmitteilungen/mm_hy_light (in German).
Fuel cell prototype HYlight.
- <http://ecl.web.psi.ch/supercap/index.html> (in English).
Supercap project of PSI.
- www.vel2.ch (in English, French German and Italian).
Project VEL2 of the canton of Ticino.

Reports:

- Project Lightweight Electric Vehicles in Mendrisio: Synthesebericht, full report on cd-rom. Order from EDMZ CH-3000 Bern.
- Programme 'EnergieSchweiz' of the Swiss Federal Office of Energy: 1st Annual Report 2001–2003. Order from BFE, CH-3003 Bern.

20

United States

20.1

Introduction

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

Energy efficiency also appears to draw broad popular support, as reflected in nationwide newspaper polls in which a significant fraction of people -when asked how to best meet the nation's energy needs- called for greater conservation efforts (including more energy-efficient cars). The scientific community in the United States shares this opinion. A panel of technical experts representing the National Academy of Sciences reported in a recently published review report that government and industry researchers should examine battery electric vehicles (EVs) as an alternative to cars and trucks powered by hydrogen fuel cells.

20.2

Policies and legislation

The United States is committed to developing alternative fuels and the infrastructure to support their commercialization. Through the FreedomCAR and Fuel Initiative, the DOE works with industry to develop and deploy advanced transportation technologies that reduce the nation's use of imported oil and improve air quality. DOE's Clean Cities Program supports public-private partnerships that deploy alternative fuel vehicles (AFVs) and build a supporting alternative fuel infrastructure. The program features:

- information about local coalitions and clean corridors,
- news and events related to alternative fuels,
- information about successful fleets,
- support and funding,
- tips for starting a coalition in individual areas, and
- information on available AFVs.

Additionally, it maintains the Alternative Fuels Data Center that includes over 3'000 documents in its database, an interactive fuel station mapping system, listings of available AFVs, vehicle purchase and assessment tools for AFV fleet managers, and more.

Provisions of the Energy Policy Act of 1992 (EPACT92), P.L.102-486, include the requirement that state and federal government fleets and the providers of alternative fuels -e.g., electric utilities, natural gas utilities and other producers/suppliers of fuels defined as alternatives to gasoline- convert an increasing percentage of their vehicle fleets to AFVs over time. Currently, 90% of new light-duty vehicles acquired by energy providers and 75% of such acquisitions by state agencies are required to be AFVs. Hybrid electric vehicle (HEV) technology was still in the developmental stage when EPACT was adopted in 1992. Consequently, HEVs 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 are those capable of running on either an alternative or conventional fuel- are eligible for credits toward EPACT mandates.

The recently signed U.S. Energy Policy Act of 2005 (EPACT05) modifies the EPACT92 purchase requirements for federal automobile fleets. It also changes the Corporate Average Fuel Economy (CAFE) program by extending the existing manufacturing incentives program for AFVs and authorizing appropriations for fiscal years 2006 through 2010 to implement and enforce CAFE standards. Also -as part of a provision in the bill- all automakers will have to label new flexible-fuel vehicles in the United States to remind buyers that they can use either gasoline or an ethanol blend. EPACT05 required the U.S. Department of Energy to study both flexible fuel hybrid vehicles and flexible fuel plug-in hybrids.

A federal tax credit -limited by a cap on the number of units- is available for light-duty HEVs placed in service after December 31, 2005, and before January 1, 2011. For medium- and heavy-duty vehicles, the expiration date is January 1, 2010. Full tax credits are available to only 60'000 vehicles per manufacturer. Above the 60'000 cap, vehicles sold during the following four calendar quarters will be eligible for only a percentage of the full tax credit: 50% of the credit for the following two quarters, 25% of the credit for the next two quarters, and none after that.

As shown in table 20.1 (see next page), at least 20 states have regulations that -in effect- promote HEVs, usually by providing incentives such as a high-occupancy-vehicle (HOV) privilege, an emissions inspection waiver, tax credits/rebates, or state fleet purchase directives. Such regulations are often actively promoted by environmental groups. Many states have considered adopting California-like clean air rules that would require automakers to reduce greenhouse gas emissions from their vehicles by 30% before 2016, and New York, New Jersey, Massachusetts, Connecticut, Rhode Island, Vermont and Maine have already adopted them. Washington -now considering adoption- would be the ninth state to do so.

Table 20.1 U.S. state-level incentives to purchase hybrid electric vehicles.
(Source: Electric Drive Transportation Association web-site 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

The U.S. National Highway Traffic Safety Administration (NHTSA) 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 25 miles per hour or less'. A Federal Motor Vehicle Safety Standard (FMVSS) -number 500- requires that such vehicles incorporate three-point restraints, safety glass, 3-mph bumpers, rear-view mirrors, horns, parking brakes, and the usual lighting and reflector equipment to appropriately address the safety of these 'low-speed' vehicles. Some states have passed laws to allow NEVs meeting certain requirements on city streets. NEVs are legal to operate only on streets with posted speed limits of 35 mph or less.

20.3

Research

20.3.1

Barriers

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

Cost

High cost is a serious barrier in almost every research area for advanced vehicle technologies, and current costs of most components for HEVs, battery EVs and fuel cell vehicles (FCVs) are higher than the target values required for cost-effectiveness. 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.
- None of the concept cars in their present forms represent an affordable set of components compatible with similar-mission vehicles.

Emissions standards

The U.S. EPA (Environmental Protection Agency) Tier 2 NO_x and particulate matter (PM) standards (now being phased in) are significantly more stringent than prior standards and may pose a barrier by precluding an early introduction and widespread use in the United States of CIDI engines for passenger cars.

Fuel issues

Successful introduction of either CIDI or spark ignition direct injection (SIDI) engines or fuel cells will be critically dependent on the 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.

The 2001 U.S. EPA regulation requiring refiners to produce highway diesel fuel with a maximum sulphur content of 15 parts per million by June 1, 2006, represents significant progress. 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 requires the energy industry to make major infrastructure changes. With a reformer onboard the car, a liquid fuel can be used. Reformers probably will require a fuel tailored for this application to achieve optimum efficiency and minimum emissions.

20.3.2

Enabling technologies

To overcome these barriers, the United States supports research efforts to enhance the state of enabling technologies for AFVs. Funding is provided for both research at the DOE national laboratories and by private industry through departmental (DOE) and government-industry partnership programs. The enabling technologies include advanced energy storage technologies, advanced power electronics, vehicle systems research, hydrogen and fuel cells, lightweight materials, and advanced combustion engine R&D - each of which is described below.

Advanced energy storage technologies

For successful commercialization of EVs, HEVs and FCVs, the battery systems must meet several requirements simultaneously. These include high energy storage capacity (for EVs), high power output (for HEVs), rechargeability, long life, safety and low cost. The three primary battery research areas -funded by DOE- include:

1. The developer program, which assesses, benchmarks and develops advanced batteries for EVs and high-power batteries for HEVs.
2. Applied battery research for providing 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.
3. Focused fundamental research for developing the next generation of battery technologies for both EV and HEV applications.

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

- A new battery system developed by A123 Systems of Watertown, Massachusetts, will be used in tools from Black and Decker's DeWalt brand. A123's battery is a lithium-ion/iron phosphate system using proprietary, nano-size materials to allow high rate discharge and charge.
- A new abuse manual was published, incorporating improvements and refinements to test descriptions presented in the Society of Automotive Engineers publication SAE J2464 (1999) Recommended Practice 'Electric vehicle battery abuse testing'.
- A Technology Life Verification Test (TLVT) manual was published at the United States Consortium for Automotive Research (USCAR) web-site.
- A thermal abuse model was developed on the basis of measured material properties to predict cell-level thermal abuse performance.
- An electrochemical cell model was developed to study low-temperature phenomena and another was developed to determine requirements for limited Li dendrite growth.

Advanced power electronics

The 'Advanced power electronics and electric machines' activity develops new technologies for power electronics and electric machinery, which include motors, inverters/converters, sensors, control systems and other interface electronics. This activity 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 included:

- During FY 2005, a 55 kW prototype Z-source inverter was developed and built. Subsequent tests and evaluations proved the viability of the technology to achieve improved efficiencies at reduced cost.
- Oak Ridge National Laboratory in Oak Ridge, Tennessee, tested a 55 kW Si-SiC hybrid traction inverter built in collaboration with Cree and Semikron, which shows up to 33.6% reduction in the energy losses.
- The National Renewable Energy Laboratory in Golden, Colorado, developed an innovative approach for building low-thermal-resistance Insulated Gate Bipolar Transistor (IGBT) structures for inverters. This technique will eliminate the need for an additional cooling loop for power electronics and thus reduce HEV cost and weight.

Vehicle systems research

The 'Vehicle systems' subprogram within the DOE FreedomCAR and Vehicle Technologies Program provides support and guidance for many cutting-edge automotive and commercial vehicle technologies under development. Research focuses on understanding and improving the way in which various new

components and systems in tomorrow's automobiles and commercial vehicles will function 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). Some recent accomplishments of DOE-funded vehicle system research included:

- Enhanced a Powertrain Systems Analysis Toolkit (PSAT) modelling and simulation tool by adding a cost modelling component, as well as the most up-to-date data for advanced vehicles, systems and components.
- Expanded the detailed benchmarking and evaluation of advanced HEVs using the Advanced Powertrain Research Facility (APRF), a four-wheel-drive, super-ultra-low emissions chassis dynamometer with hydrogen fuelling capability at Argonne National Laboratory.
- Developed the Mobile Advanced Technology Testbed (MATT), a rolling test bed for in-depth evaluations of the performance capabilities of systems and components, by using hardware-in-the-loop testing procedures and the APRF.
- Continued laboratory benchmarking and field evaluation testing of hydrogen-fuelled, internal combustion engine (ICE) powered vehicles and initiated agreements with a leading industry source to expand the hydrogen-fuelled ICE vehicles to be evaluated.

Hydrogen and fuel cells

Under the current state of the art, a polymer electrolyte membrane (PEM) fuel cell converts chemical energy into electricity and heat through the electrochemical reaction of hydrogen and oxygen. The breadth and depth of research, development and demonstration activities within the DOE's Hydrogen Program were significantly enhanced during FY 2004 and 2005 with the initiation of new competitively selected projects totalling approximately \$510 million (\$755 million with private cost share) implemented to overcome critical technology barriers and to bring hydrogen and fuel cell technology from the laboratory to the showroom. New projects span technology areas of basic science, hydrogen production and delivery, hydrogen storage, fuel cells, technology validation, and education.

The DOE Hydrogen Program supports a continuum of basic and applied research, technology development and learning demonstrations aimed at overcoming the technical, economic and institutional barriers to hydrogen and fuel cell commercialization. The program staff works with researchers from universities, national laboratories and industry through public-private partnerships to develop core technologies and address both technical and non-technical challenges to commercialization. Currently, over 286 projects are ongoing in these areas. Additional information regarding individual R&D projects is available in the 2005 Annual Progress Report, which can be found on the internet at

www.hydrogen.energy.gov/annual_progress05.html. Some recent developments include:

- The DOE Hydrogen Program:
 - Built the world's first energy station that co-produces electricity and hydrogen from natural gas in Las Vegas, Nevada.
 - Reduced the high-volume cost of automotive fuel cells from \$275/kW (2002) to \$110/kW (2005) by using innovative processes developed by national laboratories and fuel cell developers for depositing platinum catalyst.
 - Expanded a partnership with DaimlerChrysler, Ford and General Motors to include major energy companies: ExxonMobil Corporation, ConocoPhillips, Chevron Corporation, BP America and Shell.
 - Selected 65 new hydrogen production and delivery projects (\$107 million over four years).
 - Created a 'National hydrogen storage project' (\$150 million over five years) that includes three centres of excellence. These efforts involve 35 universities, 14 federal laboratories and 13 industry partners to develop high-capacity materials and low-pressure storage technologies.
 - Established a national vehicle and infrastructure learning demonstration project (\$170 million for four teams over six years) to measure progress and help guide R&D.
- External to the DOE Hydrogen Program:
 - In May 2005, the U.S. Secretary of Energy announced the selection of over \$64 million in Basic Energy Sciences (BES) research projects addressing hydrogen and fuel cell technologies in five specific technical areas.
 - A related program aims to improve coal-fired power plants, which could make coal a more acceptable 'fuel' for electric vehicles and plug-in hybrids. In FY 2005, the DOE Office of Fossil Energy announced the award of 32 clean coal research projects to advance U.S. President George W. Bush's goal to develop a coal-fired zero emissions power plant.
 - In support of the DOE Hydrogen Program, the Nuclear Hydrogen Initiative within the DOE's Office of Nuclear Energy, Science and Technology awarded three projects during FY 2005 related to the production of hydrogen via high-temperature processes (thermochemical and high-temperature electrolysis).

Lightweight materials

The reduction of vehicle mass through the use of improved design, lightweight materials and new manufacturing techniques is one of the key strategic approaches in meeting fuel economy targets for commercially viable FCVs, HEVs and EVs. The DOE Automotive Lightweight Materials (ALM) 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 such as safety, performance, recyclability and cost. The 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:

- Oak Ridge National Laboratory in Oak Ridge, Tennessee, successfully melt spun and processed into carbon fibre lignin from wood pulp - a potentially low-cost precursor for carbon fibre for automotive and other applications.
- Argonne National Laboratory in Argonne, Illinois, completed research on high-energy product neodymium iron boron permanent magnets that can reduce the size and weight of traction motors for HEVs and FCVs.
- Pacific Northwest National Laboratory in Richland, Washington, made progress in developing electromagnetic forming of aluminium sheet - a rapid, robust process that can increase the applications of sheet aluminium in cars, thereby eliminating weight and enhancing manufacturability.

Advanced combustion engine R&D

The DOE 'Advanced combustion engine R&D' activity is dedicated to removing critical technical barriers to the commercialization of higher-efficiency, advanced ICEs in light-duty, medium-duty and heavy-duty vehicles. It focuses on improving engine efficiency while meeting future federal and state emissions regulations through a combination of combustion technologies that minimize in-cylinder formation of emissions and after-treatment technologies that further reduce exhaust emissions. Work is done in collaboration with industry, national laboratories and universities. Recently, the DOE -in collaboration with industry partners- completed the development of advanced clean diesel engine technologies for pickup trucks, vans and sport utility vehicles (SUVs). The advanced technology achieves a 50% improvement in fuel economy in comparison with current gasoline-fuelled trucks and demonstrates Tier 2 Bin 5 emission certification levels for a limited duration.

20.4

Industry

In the past, various U.S. manufacturers have offered battery EVs to consumers. The battery technologies have included lead acid, nickel metal hydride, nickel cadmium and lithium-ion. Both AC and DC motors have been used. Currently, these 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 shown a greater promise of success. Other current products include hybrid buses, industrial vehicles and bike-scooters. Several companies manufacture and sell electric bicycles, including US-Prodrive and Zap. Zap also markets

motorcycles and scooters. A DaimlerChrysler subsidiary, Global Electric Motors of Fargo, North Dakota, manufactures a line of neighbourhood electric vehicles (NEVs) called GEMCars. An overview of currently available products appears in

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

(Sources: Electric Drive Transportation Association web-site www.edta.org and Ford.)

Product	List
Hybrid Electric Vehicles	<p><u>Currently on market:</u></p> <p>Ford Escape Hybrid GMC Sierra/Chevy Silverado Honda Accord Hybrid Honda Civic Hybrid Honda Insight Lexus RX 400h Mercury Mariner Hybrid Toyota Highlander Hybrid Toyota Prius</p> <p><u>Upcoming:</u></p> <p>Chevy Malibu Chevy Tahoe GMC Yukon Dodge Durango Dodge Ram TTR Ford Fusion GMC Yukon Lexus GS 450h Lexus LS 430h Mazda Tribute Mercury Mariner Nissan Altima Saturn Vue Green Line Toyota Camry Toyota Sienna</p>
Battery Electric Vehicles	<p>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.™</p>
Buses	<p>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 Gillig Diesel Hybrid RTS Hybrid Electric Bus Trolley/Shuttle Battery Electric Bus</p>
Industrial	<p>John Deere: Fuel Cell Hybrid Commercial Work Vehicle E825 Utility ECRV Postal Delivery Vehicle 4×2 Electric Gators Gorilla: e-ATV</p>
Bike-Scooters	<p>WaveCrest Labs: Tidal Force M 750 Bike Electric Transportation Solutions (EVT-168, EVT-4000e, Lashout Electric Bike and Lashout Electric Scooter) PatrolBike Electric Bicycles US ProDrive Electric Bicycles Zappy Electric Scooter ebike</p>

table 20.2. More information on each of these products is available at the Electric Drive Transportation Association (EDTA) web-site (www.electricdrive.org).

General Motors

- General Motors announced a new FCV (Sequel), which combines advanced technologies first introduced in its Autonomy and Hy-wire concept vehicles. The Sequel is said to deliver range and performance comparable to those of full function on-road vehicles legal on all highways. The technologies include fuel cells, by-wire systems and wheel-hub motors. Combined with advances in hydrogen storage, the driving range was increased to 300 miles, which is about twice that of other FCVs. Using a 25% more powerful stack also improved the Sequel's acceleration (0–60 mph in less than 10 seconds, which is about half the time for other FCVs). The by-wire system uses electrical signals and actuators instead of mechanical linkages and hydraulics.
- General Motors also announced that it will offer its 'two-mode' full hybrid 'Advanced Hybrid System 2' on light vehicles by 2007. A larger version of this system is currently used on transit buses. In this system, two electronically controlled electric motors act on a series of gears to create a variable drive system, which fits within the space typical of a conventional automatic transmission. A battery pack supplies power to the electric motors and allows for full-electric propulsion. The vehicle operates as a full hybrid with the ICE shut off at low speeds and light loads. A full-sized ICE is on tap for high-load demands. In late 2007, it will debut in two of GM's full-sized SUVs, the Chevrolet Tahoe and GMC Yukon. When combined with such technologies as cylinder deactivation, it can allow diesels and V-8 engines to deliver 25% higher fuel efficiency.



Fig. 20.1 2007 Saturn Vue Green Line hybrid. (Photo courtesy General Motors.)

- General Motors announced that it will not charge a high premium for the new Saturn Vue mild HEV, scheduled to debut as a 2007 model this summer, GM's first high-volume HEV. This will be the first hybrid in the U.S. making use of a battery pack from a U.S. manufacturer - Cobasys.
- General Motors offered hybrid versions of the Silverado and Sierra in six states -Alaska, California, Florida, Nevada, Oregon and Washington- to test the market. General Motors sold all 2'000 of the hybrid trucks it built in the initial production run.



Fig. 20.2 2006 GMC Sierra hybrid. (Photo courtesy General Motors.)

- General Motors and DaimlerChrysler AG announced that they will partner with the U.S. government in building fleets of FCVs for on-road testing over the next five years. General Motors is spending \$44 million and the DOE is contributing \$44 million to produce 40 FCVs. General Motors will operate the vehicles in Michigan, California, Washington and New York. DaimlerChrysler is spending \$70 million on the project and developing a range of FCVs, including variants of the Mercedes-Benz B-class car and Sprinter van. Other partners in the program include the U.S. Army at Fort Belvoir, Virginia, and Quantum Technologies of Lake Forest, California. Both will provide sites to store and maintain the FCVs produced by General Motors.
- General Motors and Shell are partnering on a FCV and hydrogen refuelling demonstration program in Washington, D.C., with a fleet of six of HydroGen3 FCVs and two hydrogen dispensers at a retail Shell station. The HydroGen3

FCV is based on the Opel Zafira minivan. With a fuel storage system carrying either 4.6 kg of liquid hydrogen or 3.1 kg of compressed hydrogen, it is said to achieve a range of 249 miles or 168 miles respectively, and a top speed of 99 mph.

Toyota

- Toyota announced it will assemble Camry HEVs in the United States as it further expands its hybrid line-up. The Lexus RX 400h hybrid went on sale mid-April 2005 and the Toyota Highlander hybrid went on sale in June 2005. The next generation Toyota Camry will also have a hybrid version that will be available mid 2006. Toyota will sell a six-cylinder hybrid version of the Lexus GS sedan in 2006. It plans to sell an eight-cylinder hybrid version of the Lexus LS sedan in 2007 or 2008.



Fig. 20.3 2006 Lexus RX 400h hybrid. (Photo courtesy Toyota.)

- Toyota expected to reach its U.S. sales goal of 100'000 HEVs in 2005. It saw a rise in demand for HEVs in the United States as gasoline prices peaked in the aftermath of hurricane Katrina.
- Toyota plans to develop a business partnership with Fuji Heavy Industries Ltd. to build 100'000 HEVs at Subaru of Indiana Automotive Inc.'s plant in Lafayette, Indiana.

Ford

- The Ford Corporation Mariner Hybrid Sport Utility Vehicle (SUV) went on sale in fall 2005. Mercury was expected to produce about 1'000 Mariner Hybrids in 2005. Hybrid versions of the Mazda Tribute SUV, Mercury Milan and Ford Fusion sedan were announced. Mazda will have a test fleet of Tribute Hybrids in 2006 and the vehicle will go on sale in 2007. The Milan and Fusion Hybrid sedans would go on sale in 2008, resulting in a total of five vehicle models powered by Ford Corporation hybrid powertrains at that time.



Fig. 20.4 2006 Mercury Mariner hybrid. (Photo courtesy Ford.)

- Ford held talks with Cobasys -jointly owned by Energy Conversion Devices and ChevronTexaco- to buy battery packs made in the United States for HEVs. Currently, all such batteries are manufactured in Japan.

Honda

- Honda reported that its remodelled Honda Civic has a more efficient hybrid power train than the current model and will use at least 5% less gasoline.
- Honda set an annual sales goal of 28'000 Civic hybrids in the United States. Its 2004 sales of Civic hybrids in the United States rose 17.5% over sales in 2003.
- Honda announced that it is developing a system to produce hydrogen from natural gas that will allow consumers to fill fuel cell-powering tanks at home.
- Honda leased an FCX FCV to a southern California family to collect real-world use data on fuel cells to supplement information from its own fleet and from vehicles loaned to governments. It plans to lease FCVs to other consumers over the next year.

Other automakers

- Hyundai Motor Co. and affiliate Kia Motors Corporation are expected to introduce HEVs to the United States by late 2006. The first hybrid models will be Hyundai's Accent and Kia's Rio. Hyundai will buy the batteries from Panasonic EV Energy Co., the battery supplier for the Toyota Prius hybrid. Hyundai Motor Co. also opened a hydrogen fuel cell refuelling station in Los Angeles, California.
- Volkswagen AG reported it may introduce a hybrid-powered Jetta -a mild HEV- in the United States in two years.
- Nissan Motor Co. reported it aims to sell 50'000 Altima hybrids a year in the United States, starting 2006, to be assembled it at its Smyrna, Tennessee, plant.
- Suzuki announced it may introduce a hybrid version of the Grand Vitara SUV to the United States by 2010.

Other industries

- Johnson Controls Inc. (JCI) and Yazaki Corporation reported that they are developing a variety of electrical parts for HEVs. JCI will produce battery packs and power management systems. Yazaki will make connection systems, inverters, cables and other parts. This effort may help ease the shortage of battery packs and other electric components, which is currently a major obstacle to high-volume U.S. production of HEVs. JCI also opened a lithium-ion battery-development laboratory at its battery technology centre in Milwaukee, Wisconsin. The laboratory will develop power storage technology for HEVs.
- Johnson Controls Inc. will acquire Delphi Corporation's global automotive battery business, including a long-term contract to supply batteries for General Motors. Delphi's U.S. automotive battery manufacturing locations are not included.
- Fuji Heavy Industries Ltd. -which makes Subaru- announced it aims to sell a long-lasting battery for HEVs to automakers starting in 2006. Together with NEC Corporation -a major Japanese electronics maker- Fuji Heavy has developed a manganese lithium-ion battery that it reports can last 15 years or 150'000 miles.
- Faurecia SA reported in July that it won a contract with the Chrysler group of DaimlerChrysler to make 'High integrated module' door systems in the United States by using a carrier made with an injection-moulded long-fibre thermoplastic. The module consists of a single structural plastic part with mechanical functions, including the window lift unit, internal and external handles, speakers and electrical harness.
- ArvinMeritor, Inc., introduced its highly-integrated plastic door module, which uses a thermoplastic composite to replace a steel inner structure.

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 both battery EVs and HEVs (figure 20.5). The HEVs are designed to compete with conventional on-road gasoline and diesel vehicles, while present EVs are not. Batteries for these vehicles include lead acid, nickel metal hydride, nickel cadmium and lithium-ion. Both AC and DC motors are used.

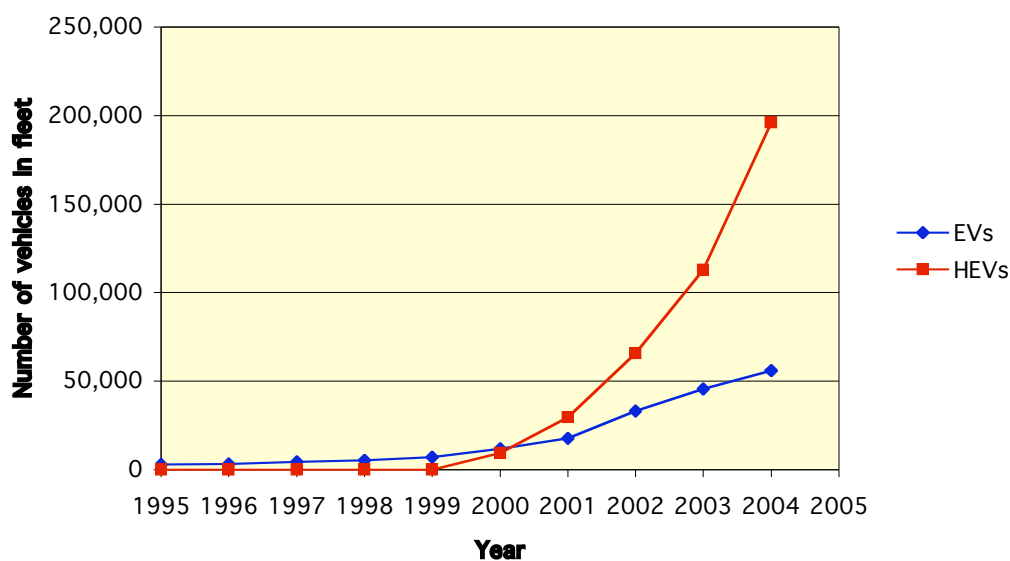


Fig. 20.5 Recent electric vehicle (EV) and hybrid electric vehicle (HEV) fleet growth in the United States.

From 1993 through 2003, ‘full function’ electric vehicles capable of top speeds of over 50 mph and meeting the strict safety standards set for U.S. light-duty vehicles were available for purchase in California and/or other states within the U.S. A separate class of electric vehicle -the Neighbourhood Electric Vehicle (NEV)- was also developed during this period. NEVs remain on the market and are slowly expanding sales, while full function electric vehicles are no longer available. Most NEVs use lead acid batteries.

Table 20.3 (next page) reports HEV sales for 2005 (through October 2005) and the numbers of U.S. registrations of HEVs in 2004. At this time, the number of EVs and HEVs combined is less than 1% of the total inventory of in-use vehicles.

Four of the 36 vehicles listed by the California Air Resources Board (CARB) as PZEVs (partial zero emission vehicles) for 2005 were hybrids, one was an electric vehicle, one was a CNG vehicle and one was a fuel cell vehicle. The others were gasoline vehicles.

Table 20.3 HEV sales and registrations in the United States.

Vehicle	2004 Registrations	2005 Sales (YTD through 10/05)
Honda Accord	653	15,269
Honda Civic	25,586	21,253
Honda Insight	587	564
Ford Escape	2,566	~15,000
Toyota Prius	53,761	90,981
Toyota Highlander	NA	13,403 ¹
Lexus RX 400h	NA	16,767 ²
Mercury Mariner	NA	NA
Lexus GS 450h ³	NA	NA

¹ June through October 2005 sales.

² April through October 2005 sales.

³ Spring 2006.

NA Not available / Not applicable

YTD Year to date

20.6

Developments

At this time, the growth of the U.S. battery EV population appears to be levelling off, primarily as a result of the lack of new personal-mobility EVs. The HEV population appears to be growing, and the trend is projected to continue. There is some difference of opinion regarding how much the U.S. HEV population can grow. 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 \$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 and oil prices 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 ride California roads by 2010 and more than one million will be on the road by 2015.

20.7

Benefits of participation

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

- Obtaining information on advanced transportation technologies that is 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:	Web-site address (all web-sites 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/consortia&teams/consortiahompages/con-usabc.htm
United States Consortium for Automotive Research (USCAR)	www.uscar.org
National Academy of Sciences. Review of the Research Program of the FreedomCAR and Fuel Partnership: First Report.	http://books.nap.edu/catalog/11406.html

21

Selected IA-HEV non-member countries

This chapter informs about hybrid and electric vehicles in eight IA-HEV non-member countries. For each country some highlights are presented.

At least 23 IA-HEV non-member countries host manufacturers of electric bicycles, scooters or three-wheelers; collectively called light electric vehicles. These countries are listed in box 21.1. In addition, commercial manufacturing of four-wheeler EVs continues in India and China (as well as the United States and Canada), whilst Japan remains the epicentre of production of hybrid electric vehicles in countries that are not a member of IA-HEV.

Box 21.1 Countries that host manufacturers of electric bicycles, scooters or three-wheelers, and that are not a member of IA-HEV. (Based on: SourceGuides.com, January 2006.)			
Australia	Germany	Korea	Spain
Barbados	Hong Kong	Malaysia	Taiwan
Bulgaria	India	New Zealand	Thailand
Canada	Ireland	Pakistan	Turkey
China	Israel	Scotland	United Kingdom
Czech Republic	Japan	Singapore	

Sales data are not uniformly available for these countries. With some exceptions, their production facilities are limited and most of their national light electric vehicle trade is based on importation. Among IA-HEV non-members, Japan is currently the only mass manufacturer of hybrid electric vehicles, with China and Korea soon to open their own production facilities. Because of either very large potential national markets (among IA-HEV non-member countries) for electric and hybrid vehicles, or an established infrastructure for serving export markets, six of the nations listed in box 21.1 are addressed in this chapter: Canada, India, Japan, the People's Republic of China, the Republic of Korea, and Taiwan. Two other countries are included here as well: Denmark because there is a lot of practical experience with electric vehicles in this country, and Norway because it is an example of how governmental regulations can create a commercial market for electric vehicles.

21.1

Canada

Thanks in part to its commitments under the Kyoto protocol and its significant hydro-electric power generating capacity, Canada was an early leader in promotion of and innovation in electric propulsion technologies. Recently, however, its lack of an established mass production infrastructure for widespread commercialisation of these technologies has redirected much of its internal effort to small-scale component manufacturing and limited niche vehicle manufacturing. Among its notable companies are Ballard Power Systems, a world leader in PEM fuel cell manufacturing; Delta-Q Technologies Corporation, a respected producer of battery chargers, converters, controllers and AC power connection equipment; Dynasty Electric Car Corporation, a niche manufacturer of low-speed light-duty vehicles available in several platforms; and Electrovaya, whose proprietary lithium super-polymer battery system appears to represent a major breakthrough in range and power and could be an industry leader within this decade. However, these companies have yet to establish firm linkages with international corporations that feature major vehicle assembly and sales divisions. Future success of this relatively low-population country (around 30 million inhabitants) for its EV component products in world markets is likely to depend on the establishment of such partnerships.

21.2

Denmark

21.2.1

Danish experiences with battery electric vehicles

In 1997, the Danish Environmental Protection Agency (EPA) issued a report on the perspectives for electric cars in Denmark, and this report demonstrated that -with the expected realistic technological development in the short term- electric cars would be an energy efficient and environmentally friendly alternative to petrol and diesel powered cars. The report recommended that the development of electric cars would have to build on practical experience with the electric cars of the time.

As a follow-up to the Danish EPA report, a collaboration between the Danish EPA, the Danish Energy Authority, the Ministry of Transport, the Technical University of Denmark and the Association of Danish Electric Utilities established a knowledge centre for electric cars at the Institut for Elteknik (Electrotechnical Institute) of the Technical University of Denmark for a three-year period, starting in April 1998.

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 during the operation of the centre 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 second reference in subsection 21.2.3.)

The study primarily builds on material currently available from the Danish EPA and the material collected by the knowledge centre for electric cars during the period in which it operated. There are also contributions from the Association of Danish Energy Companies and a number of larger municipalities that have been active with initiatives to promote electric cars.

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

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. Almost all users, however, place greater 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 because private owners use their electric car in daily commuting to and from work.

In collaboration with the municipality Hvidovre (in the greater Copenhagen area), a trial was completed in which a fleet of conventional cars was replaced by electric cars for a certain period of time. The specific fleet was used by the municipality's home-carers. This trial demonstrated that in many cases electric cars could replace petrol and diesel cars in larger fleets of service vehicles.

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 said that they are 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 with the specific problems of electric cars. An important reason for the unsatisfactory service has been that it is difficult to establish a satisfactory service organisation for a very limited number of electric cars operating throughout Denmark.

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.

A study that was published by Danish Electric Vehicle Committee in September 2003 indicates that the main reasons for the frequent battery breakdowns were problems with the material in the battery cells. These can break down after a relatively short distance, especially if the car is not used very often. The problem turned out to be related to the SAFT STM5-100 NiCd batteries produced from the mid 1990s up to 1999. In early 1999 the problem was resolved and the batteries produced later have not suffered from these breakdowns. Several private users have now driven for more than six years and a distance of more than 100'000 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.

NiCd batteries have previously been sufficiently durable and had enough energy content to be used in electric cars. However, from 2006 onwards, NiCd batteries cannot be used in new cars in the EU. Therefore the focus will be on new types of batteries, and lithium-ion batteries seem to be the most promising today. They have a high energy density and are energy efficient.

Private owners

There have been no direct purchase subsidies for electric vehicles in Denmark, and most of the new electric cars from 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 interesting as a background for an assessment of the potential of new improved technologies. They are included in the subsection ‘User experiences’ above.



Fig. 21.1 Private Danish owner of a Peugeot 106 electric vehicle. The car covered 110'000 km in 6 years with the original battery pack. (Photo supplied by Anton Bech.)

The electric vehicle (EV) that is shown in figure 21.1 was bought as a number 2 car, but turned out to be car number 1 in respect of mileage covered, mainly because of the low costs per kilometre. To compensate for the limited range of the car (100 - 120 km), the owner constructed a 3-phase 220/400 Volt charger that allows for a full charge in 2 hours (equivalent to 1 km/minute). This allows him to commute over a distance of more than 200 km (return trip) per day.

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.

21.2.2

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, by now both manufacturers have ceased production in Denmark, and the vehicles are currently produced in Germany and Norway. Recently the new Danish company Diavelo started the design and production of electric bicycles.

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 e-bikes. There are very many bicycles in Denmark (more than 1 per person, which means more than 5 million), 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 new Toyota Prius hybrid car is available on the Danish market since May 2004. About half of the Toyota dealers have a Prius for demonstration and sale, but only a very limited number has been sold until now. It is estimated that about 15 Toyota Prius have been registered in Denmark, of which a major part 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 until now a solution has been related to a total change of car taxation, which is politically difficult to achieve.

Toyota in Denmark is using unconventional methods in their marketing efforts, and also in their efforts to convince the Danish government about the need for special tax reduction for hybrid technology. A recent initiative is the ambassador program, where selected well-known people are driving a Prius for a longer period of time.

The sales of the new 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 total available stock of twenty Lexus RX 400h has already

been sold and in January 2006 the time between ordering and actual delivery of this vehicle is eight months.

21.2.3

Further Information

Further information about electric vehicles in Denmark may be obtained from the following internet web-sites:

- www.danskelbilkomite.dk (in Danish)
The site of the Danish Electric Vehicle Committee.
- www.mst.dk/udgiv/publikationer/2005/87-7614-619-7/html (in Danish, a summary in English is also provided on this web-site)
This is a report on electric vehicles in Denmark.

21.3

India

India boasts the world's largest population of gasoline (petrol) scooters and 3-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. The REVA Electric Car Company of Bangalore produces electric city cars for the domestic market and also for export markets like the UK and Malta.



Fig. 21.2 Presentation of a REVA electric car at EVS-21, April 2005. (Photos: M. van Walwijk.)

21.4

Japan

Japan continues to lead the world in production of hybrid electric automobiles, and is second only to the United States in sales. Given the strong recent surge in international sales of hybrid models by Toyota and Honda, these manufacturers have either begun or planned for near-term foreign production of these models, developing lines in strong or potential emerging markets such as the U.S., Korea (initially imported units only) and China, where Toyota is producing its Prius model jointly with China's FAW Group beginning in late 2005 (see also section 21.6). Toyota's plans call for year 2006 Prius production of 400'000 units worldwide.

Japan also leads the pack internationally in development and production of electronic accessories for 'high-tech' in-vehicle applications. Further, it retains a strong presence in the e-bike market, having introduced in 1993 the first truly modern e-bike platform (the Yamaha PAS), and still selling up to 200'000 units per year. Recently, the National Bicycle Industrial Company Ltd. has become the most important Japanese e-bike manufacturer, in part by being among the first to offer advanced Li-ion propulsion systems and by catering to specific high-demand markets by customizing configurations. E-scooters have not gained a significant foothold in Japan because, unlike the PAS-type e-bike, they are not street legal there. However, Yamaha produces several models that have found popularity in export markets. Limitation on storage and parking space for conventionally powered passenger vehicles is an important driver of the Japanese e-bike market.

21.5

Norway

In Norway, interest in electric cars has grown rapidly in recent years. The use of electric cars in Norway started later than in for example Denmark, and therefore 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. Most recently, electric cars are now permitted to use bus lanes, and this has increased demand significantly. There is now a waiting list 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 few new electric cars have been produced. A large number of second-hand electric cars has been imported, primarily from France but some originate from Denmark. The Danish KEWET El-Jet is today being produced and further developed in Norway.

The interest in electric cars has also provided the conditions necessary for specialist 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 could be achieved with today's technology.

21.5.1

The electric vehicle fleet in Norway

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.

In 2005 the company Elbilnorge is the only producer of electric cars in Norway. The company produces and has further developed the Danish KEWET El-Jet, and has recently started the production of the 6th generation model called KEWET Buddy Citi-Jet 6. In 2005 the company moved to new and larger production



Fig. 21.3 KEWET Buddy Citi-Jet 6 electric car. (Photo: Elbilnorge.)

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.

It is estimated that there are now approximately 1'500 battery electric cars running in Norway. The main models are:

- Citroën Saxo/Peugeot 106 électrique.
- Citroën Berlingo/Peugeot Partner électrique.
- Ford TH!NK City.
- KEWET Citi-Jet.

Since the production of new battery electric cars is currently very limited, the import of second-hand electric cars -mainly from France- is a major source of supply to the market.

21.5.2

Further information

Further information about electric vehicles in Norway may be obtained from the following internet web-sites:

- 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 Elbilnorge.

21.6

People's Republic of China

China (the People's Republic of China - PRC) is the world leader in e-bike and e-scooter sales and manufacturing, having sold over 10 million e-bikes and 60'000 scooters in 2005, according to Electric Bikes Worldwide Reports, following a 2004 sales year of 7.5 million and 50'000 units, respectively. The demand for powered mobility has exploded in China during its recent phenomenal economic growth, and both new and established Chinese light electric vehicle manufacturers have rushed in large numbers to meet that demand. There are as many as 170 producers in China manufacturing e-bikes, e-scooters, and/or electric motorcycles, of which the top 50 each manufacture and sell over 10'000 units per year, most for the domestic market. In addition, at least 80 enterprises manufacture components (motors, controllers, batteries) to support these bike and scooter producers. Facilitating e-bike fleet growth is the revocation, effective January 4, 2006, of a ban on electric bicycles in Beijing that was imposed in 2002 for reasons related to environmental difficulties in disposing of used bicycle batteries. A circular of the Beijing Municipal Public Security Bureau officially allows electric bikes that have met national standards and that have been entered on an approved list to take to the road after being registered with the city's traffic administration.

E-bikes are seen as an effective measure to mitigate growing congestion problems caused by automobile traffic in the capital. The PRC appears poised to surpass Taiwan (addressed in section 21.8), the current top supplier, as the principal e-bike purveyor to the world.

The PRC is also interested in becoming a significant player in the international hybrid vehicle market. Several joint ventures for producing hybrids in China have recently been announced, including agreements between Shanghai Automotive Industry and General Motors/SAIC to develop a fuel cell hybrid bus by 2007, and between Toyota and FAW Group to assemble Prius automobiles in Changchun, Jilin Province by early 2006 (*Business Day*, 1.11.04). At least one all-Chinese producer, the Maple Division of Geely Automobiles, has announced plans for joint development of a hybrid car with the engineering academy of Shanghai's Tongji University (*MixedPower.Com*, 24.8.2005). In addition, with government support, the Second Auto Works has been developing hybrid cars and buses for demonstration and commercialization. Looking to the future, the city of Beijing has been in negotiation with the French government and companies to introduce a large number of electric buses during the 2008 Olympic Games. Additionally, in October 2005 three DaimlerChrysler fuel cell buses started running in Beijing under a UNDP supported bus project that is scheduled to run up to the 2008 Olympics.

There is strong PRC governmental encouragement of eco-friendly powered vehicles, so it is likely that as the Chinese fleet of powered four-wheelers grows with increasing personal affluence and more supporting infrastructure, it will be more populated on a percentage basis than either its western or Japanese counterparts by units powered by non-petroleum fuels, especially LPG and natural gas. Thus, the opportunity for aggressive introduction and healthy market performance of gas electric hybrids (the gas might be CNG or LPG) may over the long term be most promising in the PRC.

21.7

Republic of Korea

Although not initially an active player in the light-duty hybrid area, South Korea (Republic of Korea) has begun to make inroads in this increasingly popular market, with both Hyundai -with its Click model- and Kia announcing plans to enter hybrid vehicle mass production in the next few years. Korean domestic sales of the Toyota Prius and the Honda Civic have been on the increase, which to some extent has forced the hand of the initially reluctant domestic manufacturers that have already successfully exported their economy models of conventionally fuelled passenger vehicles.

21.8

Taiwan

Partially in recognition of the importance of the light electric vehicle to its economy, Taiwan has adopted the ‘Small light electric scooter’ as a separate category of road-legal vehicle. At least 45 companies are currently active in light electric vehicle, bicycle and component manufacturing in Taiwan, which still provides the majority of e-bikes sold in the U.S. and the EU. Taiwan briefly led the world in e-scooter sales, although that demand has slackened in recent years as government incentives have been discontinued with improving air quality in Taipei and other Taiwanese cities. Some e-bike manufacturing activity has relocated to the PRC with Taiwanese engineering talent in order to take advantage of lower production costs on the mainland, but overall quality of product remains superior in Taiwan.

22

Outlook for hybrid and electric vehicles

This chapter has been prepared by Chris Saricks (Operating Agent of Annex I), Urs Muntwyler (IA-HEV chairman) and Martijn van Walwijk (IA-HEV secretary), and therefore it does not necessarily reflect the ideas and opinions of the IA-HEV Executive Committee or its members. It serves as a first contribution to establish a new Annex that will regularly produce an outlook for hybrid and electric vehicles (HEVs) that is based on the expertise of the IA-HEV participants. Anyone having comments or suggestions for this outlook is warmly invited to contact one of the authors of this chapter, whose contact details can be found in part D of this report.

22.1

Recent developments in the HEV market

The year 2005 witnessed the most dramatic growth in over 100 years of the worldwide in-use population of vehicles with electric and electric-assisted propulsion. It is now apparent that a true renaissance of the electric motor with on-board energy storage in road transportation applications is well underway, with greater vigour and in greater numbers than marked the brief ascendancy of electric automobiles and trucks in the first decade of the twentieth century.

In 2005, an alarming spike in world petroleum prices induced by a conjunction of high demand, shortfalls in refining capacity, and weather-related problems in the United States, helped to increase the demand for hybrid-electric vehicles. The

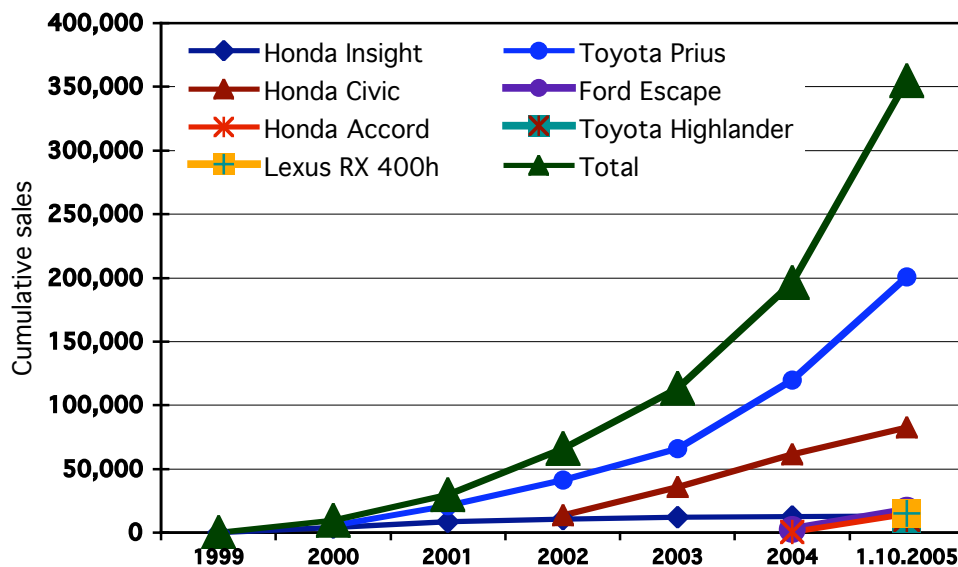


Fig. 22.1 Sales trend for light-duty hybrid vehicles in the United States (through September 2005).

worldwide market for hybrid-electric cars is currently dominated by the Toyota Corporation, with a gasoline/electric parallel full hybrid 'synergy' drive® that is offered in its model 'Prius'. Toyota has sold over 200'000 of its Prius models (the Prius I during the period 2000 - 2004, and the New Prius from 2004 onwards) in the United States, some 15'000 in Europe, and over 70'000 in Japan. In 2005 alone, over 107'000 New Priuses were sold in the U.S. The Honda Civic hybrid with Integrated Motor Assist™ mild hybrid technology is in second place, trailing the Prius with about 60'000 U.S. and 40'000 Japanese sales through mid-2005. (Table 22.1 shows 2005 U.S. sales estimates for all available hybrid models through October.) New hybrid models will enter the market -as will be shown in section 22.2- and this may increase the already steep growth rate of ownership of existing hybrids in the U.S. alone that is shown in figure 22.1.

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

Hybrid make/model	2005 Sales (10 months) ^a	1999– 2005 Cumulative sales ^a
Toyota Prius	90'981	210'836
Honda Civic	21'253	82'744
Ford Escape (SUV) ^b	15'000	17'566
Lexus RX 400h (Toyota) ^b	16'767	16'767
Honda Accord	15'269	15'922
Toyota Highlander (SUV) ^b	13'403	13'403
Honda Insight	564	13'062
Total	173'237	370'300

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

b New offering in 2004 or 2005.

Not all models shown in table 22.1 are universally available, and in some countries latent demand for imports is suppressed by tax policies unfavourable to hybrids, despite their benefit as high-efficiency vehicles. Nevertheless, both Honda and especially Toyota have made important inroads in the European auto market, with growing interest in new luxury/performance editions such as the Lexus RX 400h. 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 2004 is shown in figure 22.2 (on the next page).

The recent dramatic growth in electric-powered transport has not been limited to hybrid cars and vans, as electric bikes and scooters have over the past few years

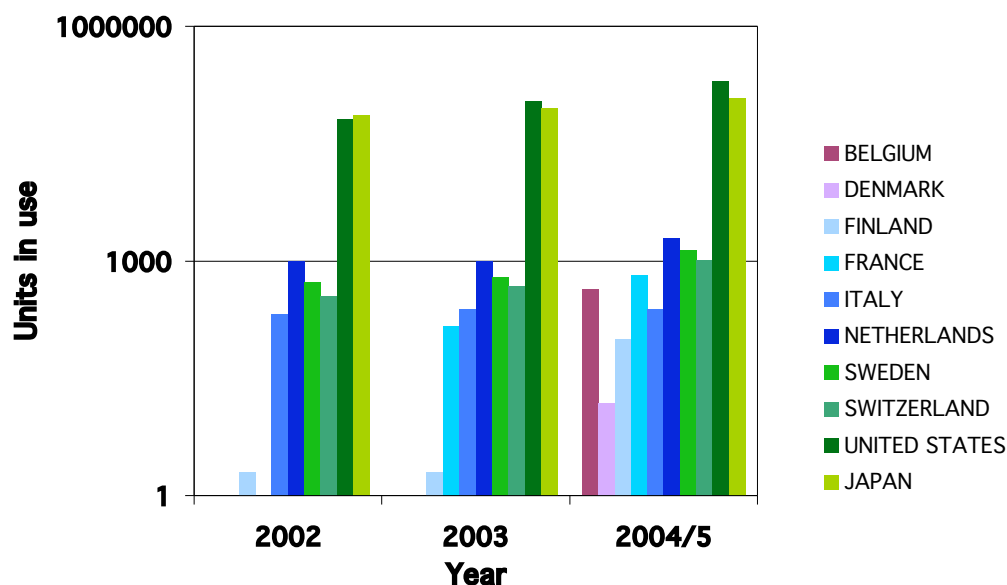


Fig. 22.2 Hybrid vehicle fleet size growth in IA-HEV countries, Denmark and Japan. (Please note the log scale on the vertical axis.)

attained enormous popularity in the People's Republic of China (PRC). By many estimates, at least 10 million e-bikes and 100'000 light and heavy electric scooters -from well over 100 domestic manufacturers- were sold in the PRC in 2005, as personal transportation shifts from almost exclusive reliance on non-motorized modes (especially outside the largest cities) to environmentally responsible and affordable electric and electric-assisted propulsion. A major spur to domestic e-bike sales over the past two years was the SARS outbreak and resulting scare that caused many to shun public transportation. However, PRC enterprises also produce relatively cheap e-bikes and scooters for the export market. Although enthusiasm for these units has cooled somewhat in the importing countries -due partly to scarcity of replacement and after-market components- the PRC remains poised to overtake Taiwan as the leading world exporter of e-bikes and has already surpassed annual production of Japan, the long-time e-bike and scooter manufacturing leader.

Meanwhile, 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) small, low-speed four wheeler 'neighbourhood electric vehicle' from DaimlerChrysler, local shuttles, jitneys and trolleys, and light utility vans.

22.2

Hybrid and electric vehicles in the coming decade

The year 2006 promises to be equally exciting as 2005, with new hybrid roll-outs promised from General Motors, Ford, Nissan, Porsche and Toyota. These manufacturers anticipate that the hybrid market will be stimulated by favourable new tax incentives in the United States, which eliminate the current US\$ 2'000 deduction (that is, reduction in taxable income) on annual income tax in favour of an actual tax credit (an amount subtracted from income tax liability). The magnitude of this credit will be based partially on a hybrid's net fuel consumption savings relative to a conventional model of the same size class, and partially on the sales volume for hybrids by manufacturer (that is, buyers cease to qualify for the credit once the manufacturer has reached the annual sales volume stipulated in the tax legislation). New platforms announced to date include SUVs from Mercury (Ford), Mazda and Porsche; light trucks from the GMC division of General Motors (GM) Corp., and new sedan models from GM, Ford/Mercury, Hyundai, Nissan, Mazda and Toyota. Table 22.2 lists the makes and models that have been announced for commercial release to international markets through 2008.

Table 22.2 Planned and announced light-duty hybrid vehicle roll-outs through 2008.

Year of introduction	Manufacturer	Model/Type
2005-06	Mercury (Ford)	Mariner (SUV)
2006	General Motors	GMC Silverado/Sierra (pick-up trucks)
	General Motors	Saturn (sedan)
	Lexus	GS 450h (luxury sedan)
	Nissan	Altima (sedan)
	Porsche	Cayenne SUV (VW/Audi hybrid drive)
2007	Daihatsu	HVS (sports car)
	Ford	Fusion (sedan)
	General Motors	Tahoe/Yukon (diesel pick-up trucks)
	Hyundai	sedan
	Mazda	Tribute (SUV)
	Toyota	Camry (sedan)
2008	Mercury (Ford)	Milan (sedan)

Compared to the North American and Japanese automotive industry, European vehicle manufacturers have been hesitant to introduce hybrid-electric vehicles on the market so far, although companies like Audi and Volkswagen have experimented with hybrid drives in the past. However, for example BMW has

presented a hybrid drive prototype of an X3 compact SUV during the Frankfurt Motor Show 2005 and Mercedes-Benz has recently presented a diesel-electric hybrid version of its 'Sprinter' van. Companies like PSA and Renault remain sceptical towards the hybrid drive concept, because they consider it not a good business case and they expect to achieve similar fuel consumption and CO₂ emission figures with diesel vehicles. For further future efficiency gains, PSA is now experimenting with a prototype diesel-electric hybrid drive. It can be concluded that also the European automotive industry will make increasing numbers of hybrid vehicles available on the market during the coming decade.

Component research and development for personal and public electric propulsion has focused increasingly on improved, lighter-weight batteries and battery materials to increase range, and on efficiency improvements to motor/controllers that enable downsizing with no loss in rated power. 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).

Although high-speed capability is not a major selling point in the all-electric propulsion marketplace, it is important for hybrids, and as the portfolio of hybrid offerings includes more 'performance and power' styled vehicles, as noted above, battery/motor power train improvements will have to keep pace. In particular, mild hybrid systems such as Honda's Integrated Motor Assist™ will need to be adapted to the duty cycles and load demands of sport utility vehicles and pickup trucks. Also, given renewed interest in and demand for non-petroleum fuels worldwide, hybrid applications will increasingly involve pairing with internal combustion engines powered by gaseous and alcohol (e.g. E85) fuels and -ultimately- hydrogen (see below). Many technical problems remain to be solved before such pairings can be wholly successful.

Lastly, the scope of hybrid research is broadening to embrace the deployment of hybrid technology in heavy-duty applications, especially transit buses and urban delivery vehicles. For most of these uses, electric drive trains will work in tandem with compression ignition (diesel) engines in both parallel and series configurations, with much of the idle and low-speed load carried by the electrical system. The great advantage for this application, beyond less diesel fuel consumption, is reduced exposure of the public to exhaust particulate matter, the emission of which has traditionally been a problem at bus stops and in congested urban street corridors.

Even as the popularity of hybrids grows, automakers have said gas-electric engines are a transitional technology that eventually will be replaced by hydrogen-powered fuel cells. But automobile manufacturers do not currently control the price and supply of the fuels their vehicles must use, and this will remain true when hydrogen emerges commercially in either direct combustion or fuel cell transport application. Deliberations in most countries that anticipate a 'hydrogen economy' future have not yet confronted the monumental challenges posed both by making adequate supplies of hydrogen fuel available to a driving public and by the need to mitigate or sequester the residuals of converting non-renewable energy sources into hydrogen or the production of hydrogen from renewable sources in sufficient quantities. A potential nearer-term 'bridge' to solving the hydrogen supply problem would be to incorporate hybrid drive in at least some of the fuel cell propulsion systems that will be commercialized. Energy storage could be obtained either as now, from excess power and regenerative braking, or from plug-in systems such as those under development in North America. Plug-in hybrids with conventionally fuelled internal combustion engines may also be discovered to be a vital component of the successful bridging solution as the hydrogen supply and distribution chain becomes adequate to meet demand. However, as the time needed to accomplish that supply goal lengthens, plug-in hybrids that use a variety of on-board fuels could come to be recognized as the best long-term solution of all.

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Abbreviations

A3	Austrian Advanced Automotive technology R&D programme
A3PS	Austrian Agency for Alternative Propulsion Systems
AC	Alternating Current
ADEME	Agency for Environment and Energy Management (France)
AFV	Alternative Fuel Vehicle
AGV	Automatic Guided Vehicle
ALM	Automotive Lightweight Materials
ANL	Argonne National Laboratory (USA)
APRF	Advanced Powertrain Research Facility, at ANL
APU	Auxiliary Power Unit
AVEM	Avenir du Véhicule Electrique Méditerranéen (France)
AVERE	European Association for Battery, Hybrid and Fuel Cell Electric Vehicles
BES	Basic Energy Sciences
BEV	Battery Electric Vehicle
BMVIT	Federal Ministry for Transport Innovation and Technology (Austria)
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
CEI	Italian Electrotechnical Commission
CERT	Committee on Energy Research and Technology of the IEA
CEU	Commission of the European Communities
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 ₂	Carbon Dioxide
CUTE	Clean Urban Transport for Europe
DC	Direct Current
DOE	Department of Energy (USA)
DPF	Diesel Particulate Filter
E85	Fuel blend of 85 vol-% ethanol and 15 vol-% gasoline
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
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 Zurich)
EU	European Union
EURO-x	European emission standard, level x
EUWP	End Use Working Party of the IEA
EV	Electric Vehicle
E.V.A.	Austrian Energy Agency
EVS	Electric Vehicle Symposium
ExCo	Executive Committee
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
gge	gallon gasoline equivalent
GHG	Greenhouse Gas
GM	General Motors
GTL	Gas-to-liquid fuel
h	hour
H ₂	Hydrogen
HEV	Hybrid Electric Vehicle
HOV	High Occupancy Vehicle
IA	Implementing Agreement of the IEA
IA-AFC	Implementing Agreement on Advanced Fuel Cells
IA-AMF	Implementing Agreement on Advanced Motor Fuels

IA-HEV	Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes
ICE	Internal Combustion Engine
IEA	International Energy Agency
IGBT	Insulated Gate Bipolar Transistor
IMA	Integrated Motor Assist™
INRETS	Institut National de Recherche sur les Transports et leur Sécurité (France)
IPHE	International Partnership for a Hydrogen Economy
ITS	Intelligent Transport System
JARI	Japan Automobile Research Institute
LCA	Life Cycle Analysis
Li	Lithium
LMP	Lithium Metal Polymer
LPG	Liquefied Petroleum Gas
MATT	Mobile Advanced Technology Testbed
MH	Metal Hydride
min	minute(s)
mph	miles per hour
NEV	Neighbourhood Electric Vehicle
NG	Natural Gas
NHTSA	National Highway Traffic Safety Administration (USA)
NiCd	Nickel Cadmium
NiMH	Nickel Metal Hydride
NL	The Netherlands
NO _x	Nitrogen Oxides
OA	Operating Agent
OECD	Organisation for Economic Co-operation and Development
P.A.	Power-Assisted
PEFC	Proton Exchange Fuel Cell
PEM	Polymer Electrolyte Membrane
PEM	Proton Exchange Membrane
PM	Particulate Matter
ppm	parts per million
PR	Public Relations
PRC	People's Republic of China
PSAT	Powertrain Systems Analysis Toolkit

PSI	Paul Scherrer Institut (Switzerland)
PZEV	Partial Zero Emission Vehicle
R&D	Research and Development
RD&D	Research, Development and Deployment
SAE	Society of Automotive Engineers
SAM	Super Accumulator Module
SCR	Selective Catalytic Reduction
SEK	Swedish Crown
SIDI	Spark Ignition Direct Injection
SOFC	Solid Oxide Fuel Cell
STEM	Swedish Energy Agency
SUV	Sport Utility Vehicle
SVE	Société des Véhicules Electriques (France)
SWEVA	Swedish Electric & Hybrid Vehicle Association
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 Consortium for Automotive Research
US\$	U.S. dollar
VAT	Value-Added Tax
VITO	Flemish Institute for Technological Research (Belgium)
WEVA	World Electric Vehicle Association
ZEV	Zero Emission Vehicle

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The web-site of the IEA Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) can be found at www.ieahev.org or at www.transportation.anl.gov/ia_hev/.

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