

International Energy Agency

Implementing Agreement for
Hybrid and Electric Vehicle Technologies and Programmes

Annual Report 2004

Final Report for Phase 2

Progress towards sustainable transportation

March 2005

Cover photo: In front of the Louvre museum, Paris. (Photo © M. van Walwijk)

*Implementing Agreement for
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Final report for phase 2

Progress towards sustainable transportation

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Hybrid and Electric Vehicle Technologies and Programmes

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Report structure

This report consists of four main parts. Part A ‘About the IA-HEV’ describes the Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV), its activities and its plans for the coming years. It also shows how IA-HEV is embedded in the International Energy Agency (IEA). Part B ‘Annexes’ presents the results of the work that is performed under this agreement. The outcome of the Annexes can be considered as one of the main products of IA-HEV. Part C ‘Country reports’ describes the activities on Hybrid and Electric Vehicles in IA-HEV member countries and the benefits from participation in the agreement. Part D gives practical information: a list of IA-HEV publications during phase 2, the abbreviations that are used in this report and contact information of participants in IA-HEV.

1 Chairman's message

Start of Phase 3 of the Implementing Agreement

On December 1st, 2004, the Implementing Agreement for "Hybrid and Electric Vehicle Technologies and Programmes" (IA-HEV) of the International Energy Agency (IEA) entered its third phase. In the latest IEA report on transport technologies these propulsion technologies are mentioned as the most promising ones in the short, mid- and long term up to 2050. Magazines and newspapers all over the world assert that hybrid- and fuel cell vehicles will be the future of individual mobility. When and how this can happen is the daily work of the specialists in IA-HEV. Membership and collaboration in the agreement are therefore a good and cheap investment for all countries interested in the "winning technologies" for individual mobility.

1.1 Aims and objectives of the IA "Hybrid and Electric Vehicles"

The energy objectives of IEA member countries, mainly OECD-countries, are the reduction of oil dependency and an increase in energy efficiency. The environmental objectives are the reduction of greenhouse gas emissions and an improvement of air quality.

In the transportation sector, this results in the following objectives:

- Improve the energy efficiency and reduce the environmental impacts of the national vehicle fleet,
- Use alternative fuels or energy sources for transportation.
- The objectives of the implementing agreement (ia) for hybrid and electric vehicles (please note that fuel cell vehicles are included) in the 3rd phase are:
- 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.
- To disseminate the information produced in the working groups called "annexes" to groups and organizations that have an interest.
- To collaborate on pre-competitive research projects and related topics and to investigate the need for further research in promising areas.
- To collaborate with other implementing agreements with transportation aspects in their activities (annexes, task or joint annexes).
- To collaborate with specific groups or committees with an interest in transportation, vehicles and fuels.

1.2 Strategic plan for phase 3

In the strategic plan for the 3rd phase of the agreement (details can be found at www.ieahev.org) the focus is on:

- economic and employment opportunities arising from the drivetrain revolution and the components of drive trains,
- "pushing the envelope" for hybrid vehicles (renewable fuels, plug-in hybrid vehicles),
- pre-competitive research in batteries, supercapacitors, and fuel cells,
- specific market segments for electric vehicles: two wheeled electric vehicles, cyber vehicles.

The strategy is intended to apply to both industrialized and developing countries.

1.3 Award: motivation for producers and individuals

To put a new technology on the market and to make it a market breakthrough is a very tough challenge. The public often expects the breakthrough within a short time period. This does not work with complex technologies like cars. The attention of mass media and the public turns to

disappointment, and they will look for the next "promising technology". In advanced vehicle technology progress takes place step by step. Looking back after decades one can realize how fast it was. But who has this perspective?

By means of the new "Award" we want to draw public attention to the fact that clean advanced vehicle technologies are continuously progressing. We will focus especially on non-technical aspects and on success in the market place.

In 1985 - 20 years ago - I launched the first solar car race in the world, the Swiss "Tour de Sol". This race stimulated many hundreds of competitors to build solar racing cars and lightweight electric vehicles. Among them were individuals, engineering schools, universities, high-tech companies for components such as Horlacher AG, Brusa AG, Esoro AG, Solectria, Kyocera and car companies like DaimlerChrysler. Internationally, many universities and engineering schools, individuals and car producers from Nissan, Toyota, Honda to Ford and General Motors were stimulated to compete in the transcontinental races in North America and Australia. Concepts like the GM Impact and EV1 and even the successful "Smart" car started in this framework. In 1985, small vehicle producers started to put niche products in small numbers on the market. Nevertheless, a crucial point is the number of vehicles produced. This is the main topic of the award.

Behind all these tremendous efforts were teams and individuals. Progress in technology is driven by humans. This is the reason why we dedicate a special award to those who dedicate their lives to the dream of a clean, efficient vehicle technology run by bio fuels, electricity or hydrogen produced from renewable primary energies. I will be happy to congratulate the first winner at the award ceremony at the EVS-21 in April 2005 and to thank him/her for his/her outstanding work.

1.4 The three winning technologies of the future

1.4.1 Hybrid and electric vehicles: mass market started but big potential still undeveloped

Planning for the future is good but we have to work for it in the present. That is one reason why I am so glad that we are witnessing a breakthrough for the first hybrid products in the marketplace. When our agreement started in 1993, the "Clean Air Act" with a call for the first "Zero Emission Vehicles (ZEV)" in California was a driving force. This regulation was postponed and changed many times, and the electric vehicle (EV) lost the attention of the public and the car industry. The new approach of hybrid vehicles needed some time to become a success. This technology is very attractive for consumers: no change in behaviour and no special infrastructure are needed. The customer gets a car with excellent performance and a lot of driving comfort for an acceptable price, together with low fuel consumption and very low emission levels. No wonder that customers are waiting many months for delivery of cars like the Toyota "Prius" and pay the full price and not the "feebates". I wish that more car companies all over the world would decide to put vehicles driven by this technology on the mass market. The potential of this technology is huge. Combinations with renewable energies such as bio-ethanol or biodiesel are promising ways for a powerful sustainable transport sector.

1.4.2 Electric vehicles: back in market niches preparing for the next comeback

In the past, expectations for electric vehicles were not realistic. But in many applications Electric Vehicles (EVs) are doing their job and are expanding their market niches. Their big advantage is the simple drivetrain. With the new high-energy batteries, with energy densities we could not imagine ten years ago, EVs have the potential to come back, even in the mass market.

1.4.3 Fuel cell vehicles: overestimated by the public but promising in the long term

Fuel cell vehicles (FCVs) are the hype of the moment. As specialists with long-term experience we know that there still is a long way to go. The actual overestimation by the public, politicians and mass media could lead to disappointment, if they realize how long and painful the way for the "hydrogen fuel cell" industry will be. But FCVs are very promising in the long term and could be an important part of the puzzle of the future.

1.5 How we work

An Implementing Agreement of the International Energy Agency is a platform for international collaboration and not a fixed programme. How good the "show" is, is determined by the actors who

are delegated by the member countries. This working method needs the will to collaborate, and to pay a share of the costs. Funds are needed to finance the national specialists and to contribute to the expenses of the co-ordinators, called the Operating Agents (OAs). They are responsible for leading the work programmes of the task forces, known as "Annexes" in IEA terms, because they are described in an annex to the legal text of the Implementing Agreement.

1.6 Communication will be increased in the third phase

To improve the information exchange on the work and the results of the Implementing Agreement we plan:

- several editions of our newsletter,
- the merger of our two web-sites (www.ieahev.org),
- several workshops on new planned Annexes,
- presentations at EVS-21 (Annex VII/ Annex VIII/ the work of the IA),
- a booth at EVS-21,
- press releases to announce the latest news,
- the annual report (this 2004 edition is published on the occasion of EVS-21),
- the new Award in three categories: "vehicles/ applications/ persons". The first winners of this award will be introduced on Sunday April 2nd, 2005, at EVS-21 in Monaco!
- a new one-year "guest membership" for interested new countries.

And most important: the direct communication on "special topics" among our members in Annex I "Information Exchange" during the ExCo-meetings. For the specialists we offer the Annexes as several special working platforms.

1.7 Current Annexes

As was stated in the previous section, members exchange information on special topics in Annex I meetings. Besides exchanging news on the latest developments, in each meeting one current topic is discussed in depth. All members in the agreement participate in Annex I. The other Annexes focus on one specific topic. The current Annexes -at the beginning of the third phase of the agreement- are:

- I Information exchange.
- VII Hybrid vehicles.
- VIII Deployment strategies for hybrid, electric and alternative fuel vehicles.
- IX Clean city vehicles.
- X Electrochemical systems.
- XI Electric two wheelers.

More details about each individual Annex –such as working methods and the benefits for the participants- can be found in part B of this report.

1.8 Planned new Annexes

In the coming months we are preparing new Annexes covering new subject areas. Please inform your specialists about these upcoming activities. In this phase of the new Annexes, participants can help shaping the work programme so that it best meets their requirements. The topics of the Annexes under construction are:

- HEVs & EVs for mass transportation and heavy-duty vehicles.
- Intelligent and automated transportation systems.
- HEVs & EVs powered by renewable energy.

1 Chairman's message

Have a look at section 2.2.3 for more details about these new Annexes.

Many more topics will be addressed during the third phase (2004 – 2009) of IA-HEV (see for example box 2.2 in chapter 2). Parties that are interested in co-operating on these or other new, relevant topics are invited to contact our secretary or myself so that we can set up additional new Annexes.

1.9 Member countries

The International Energy Agency was established in 1974 and has 26 member countries from the OECD (industrialized countries). Presently, the Implementing Agreement for Hybrid and Electric Vehicles has members from 9 countries. We intend to attract more members in the third phase. These could be countries with a strong position in the production of cars such as Korea, Japan, Germany, United Kingdom and Canada. They could also be countries with an expanding car production such as the Czech Republic, Poland, Romania, Spain, Portugal and Turkey. A special challenge will be encouraging the participation of countries outside the OECD but with a strong potential in the production of cars, 2-wheelers and trucks like Brazil, India and China. For such countries, where financing problems for travel and the membership fee (actually 9 500 Euros per year) could occur, we are able to negotiate special terms to lower the hurdle.

We are convinced that membership in our agreement is cost effective for all countries that are active in the promotion and research of hybrid-, electric- and fuel cell vehicles. In case you are interested in membership or if you can suggest interested persons, parties and countries please contact our secretary Mr. van Walwijk or the chair Mr. Muntwyler (please consult the address list at the end of this report for contact details).

1.10 Personnel changes in the Agreement: vote of thanks

At the end of phase 2 it was time for our secretary, Mr. Frans Koch (Canada), to say "Good bye". He managed this Agreement as its first secretary since 1993, and he will support the new secretary during the transition. He worked together with three chairs, many deputy chairs and ExCo-members. His articles in magazines and presentations at conferences all over the world opened the horizon to the real challenge of putting the new technologies on the world market. His international experience helped us to collaborate with individuals all over the world. He was the "good spirit" of the agreement.

Many countries are involved in research, development and in the production of vehicles. To reach these countries through our work and to integrate them in our Implementing Agreement is one of the two priorities for our new secretary, Mr. Martijn van Walwijk. He is an internationally known specialist and we are happy that he accepted the position after a vote by ExCo-members in November 2004. I wish Martijn van Walwijk success in his work, and I hope that I can welcome new members in 2005. At the end of 2004 the secretariat of IA-HEV was transferred from Canada to the city of Angers in France.

Changes at the head office of the International Energy Agency (IEA) are part of life at the IEA headquarters in Paris. We welcome the new desk officer, Jeppe Bjerg, and want to thank his predecessor Tom Howes for his commitment.

Last but not least I want to thank our ExCo-members that lead this Implementing Agreement and the Operating Agents that lead the work. It is always impressive to see these experts coming from all over the world and to hear how they push new technologies in their countries. I hope I can welcome them again in the 3rd phase, together with many new member countries. Attaining success in the marketplace with hybrid-, electric- and fuel cell-vehicles requires increased efforts in the future. The more individuals, institutions, companies and countries contribute, the faster and smoother we can create the transition from the old gas guzzlers to the new energy efficient and clean cars of the future.

Urs Muntwyler

Chair

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;
- to assist in the integration of environmental and energy policies.

The organisational structure of the IEA is shown in figure 2.1.

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 five active Working Parties/Committees that cover technologies for renewables, end-use technologies, fossil fuels, fusion and hydrogen. The IEA technology network is supported by three additional expert groups focusing on oil and gas, research and development strategies, and basic science and energy technologies.

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, including Hybrid and Electric Vehicles. A full list of current Implementing Agreements is available at: www.iea.org/dbtw-wpd/Textbase/techno/index.asp.

2.1.2 IEA Implementing Agreements

Introduction

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.



Fig. 2.1 Organisation chart of the International Energy Agency.

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. Almost 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 IEA also issues publications giving updates on the Implementing Agreements' major achievements over past months.

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.

<p>Box 2.1 Benefits of International Energy Technology Co-operation in IEA Implementing Agreements</p>
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- | |
|--|
| <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.

Section 2.1 is based on three IEA publications:

- *Implementing Agreements. Background and framework as of 2003. (Downloadable for free at http://www.iea.org/Textbase/publications/newfreedetail2.asp?F_PUBS_ID=593)*
- *Activities for Energy Technologies. 2002 - 2004.*
- *Implementing Agreement highlights. 2002-2003 edition.*

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, and HEVs are one of them. This means that there is a sound basis for an IEA Implementing Agreement on hybrid and electric vehicles. 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. It just completed its second five-year term of operation and entered its third term (2004 – 2009). The nine member countries at the start of this third term are Austria, Belgium, Finland, 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 HEVs.

The following subsections briefly report on previous IA-HEV activities and describe the plans for the future.

2.2.1 Achievements of phase 2, 2000 – 2004

Introduction

The second phase of the Implementing Agreement (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 vehicle, 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.

Achievement of phase 2 objectives

To see the extent to which the objectives for phase 2 were achieved, they are quoted below:

Objectives of phase 2

- 1) To provide governments, local authorities, large users and industries with objective information on electric and hybrid vehicles and their effects on energy efficiency and the environment, by means of general studies, assessment, demonstrations, comparative evaluation of various options of application, market studies, technology evaluations, and so forth.
- 2) To disseminate the information it produces to groups and organizations that have an interest in it.
- 3) To collaborate on pre-competitive research projects and related topics and to investigate the need for further research in promising areas.

Objectives a) and b) concerned producing information and disseminating it. 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 value added to information 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 level of success, it may be stated that objectives a) and b) 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 to a lot of the information produced by means of the Internet, annual reports, etc.

Objective c) was added to the statement of aims of the IA-HEV to allow for collaborative research projects in hybrid vehicles or electrochemistry if attractive projects were identified. However, no collaborative research projects were identified or implemented. Hence this objective was not actively pursued during the second phase. During phase 3, it may very well occur that an attractive project obtains the necessary amount of participation, and so the possibility of doing such projects will be retained for the future.

Work of the task forces

The strategy for phase 2 included task forces (Annexes) that would work on:

- continuation of the structured information exchange and the collection of statistics (Annex I),
- hybrid vehicles (Annex VII),
- deployment strategies for low emission vehicles (Annex VIII),
- clean city vehicles for developing countries (Annex IX),
- electrochemical systems (batteries, supercapacitors, and fuel cells) (Annex X).

The Executive Committee not only managed and co-ordinated the work of the Annexes, but was also actively involved in disseminating information, and produced the annual reports, newsletters, articles for technical journals and the web-site.

The remainder of this chapter will describe the achievements of each of the annexes, and of the Executive Committee.

Information exchange (Annex I)

During phase 2, 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 decided that all participating countries in the Implementing Agreement should automatically be participants in Annex I, and established financial arrangements to bring this about.

The hybrid vehicle task force (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 were made available to the interested public by publishing them on the IA-HEV web-site (www.ieahev.org).

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 a more expensive drive train? Convincing the customer to buy a hybrid drive train 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 drive trains 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” 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, the IA-HEV and the Advanced Motor Fuels (AMF) Implementing Agreement. 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 Deployment Strategies report provided a “menu” of recommendations to central and local governments on the market introduction of clean vehicles and fuels. The choices available and the advantages and disadvantages of each 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 could be successfully done 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 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 among the developing countries themselves. 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 Dacca. This was directly due to the workshop. The workshop concluded that some technologies that could benefit developing countries are:

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

The potential benefits of work in this area are substantive, but some barriers must still be overcome in order to make the task force operational. The main ones are that the scope of the technologies that are suitable for developing countries is much wider than the scope of the IA-HEV, and that the Ministries of Energy, which 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, the task force on electrochemical systems (Annex X) concentrated on the sharing of test methods for supercapacitors and batteries. Test procedures play a key role in moving new technologies from the laboratory to the market and developing them involves a large amount of technical work and can easily cost more than a million dollars. Consequently, the sharing of test procedures can result in large savings.

The participants in Annex X benefited mainly from the sharing of testing methods, as described above. The Annex also played a valuable role in co-ordinating the work of the Fuel Cell Implementing Agreement, the hybrid vehicle annex, and itself in the field of electrochemical technologies.

Dissemination activities

Dissemination of information is one of the main objectives of the agreement. The results of the Annexes are presented at symposia and distributed in the form of papers, books and magazine articles. The publications chapter in part D of this report presents the most important IA-HEV publications of phase 2. Many of them are available on the web-site: www.ieahev.org.

Conclusions

This section has outlined the objectives of the second phase of the IA-HEV, and the benefits that have been produced by the work of the Annexes and of the Executive Committee. There have also been some wider benefits in the three areas of: reliability of information, cost savings and of a “critical mass” for progress. These were not directly linked to individual task forces, but rather have resulted from the work as a whole.

Both the automobile market and the energy market are global markets, and governments need to know what is going on in other countries in order to make decisions for their own vehicle fleets and energy supplies. The IA-HEV is a unique channel for providing such information, because it has formed a network of government officials and of research laboratories that are on the forefront of technical developments and have a global reputation for excellence. The participants in the networks have a common interest in ensuring the information is balanced and objective, free from the influence of special interest groups. The credibility and the reliability of the information produced is the main corporate asset of the IEA as a whole and of the IA-HEV as one of its components.

Participation in the IA-HEV also represents important cost savings on technical reports, studies, and development of testing methods. By pooling resources or by sharing results, costs are shared by a number of countries, rather than needing to be incurred by each country on its own.

Finally there is the issue of the forces behind technological progress. In order to persuade large auto manufacturers or governments to change their policies, it is necessary to have a certain “critical mass” of professional and public opinion that is concerned about the problems caused by the current technology. There are many organizations throughout the world that consider hybrid and electric vehicles as an important technology improvement; the Implementing Agreement is one of them. By adding its voice to that of many others, the Implementing Agreement has contributed to the attainment of the “critical mass”, and automotive technology has seen greater changes during the present decade than during the previous 80 years.

These were the main achievements of the IA-HEV at the detailed level and at the general level during the second phase. The third phase has now started, and the participating organizations and individuals will make every effort to make the next five years even more productive and successful than the last five years. This will be the subject of the next section.

2.2.2 Strategy for phase 3, 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 about half 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 phase 3 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.

<p>Box 2.2 Topics that will be addressed during the third term of IA-HEV</p> <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 and HEVs • HEVs & EVs powered by renewable energies • HEVs & EVs in mass transportation, and heavy-duty vehicles • Electric bicycles, scooters and light weight vehicles • HEVs & EVs for power correction or decentralized power production • Market aspects of Fuel Cell Electric Vehicles (FCEVs) • Automated transportation systems including cyber cars • 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 phase 3. 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 participants of this agreement are countries from all parts of the world, from the USA via Europe to Asia. 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 cost for member countries (research by cost sharing).

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

By bringing experts from member countries together at experts meetings, knowledge is transferred among them and working relations are created or strengthened among them. 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 section 2.2.2 shows the topics to be addressed by IA-HEV during its third term of operation. Three of these topics are currently under consideration for starting new Annexes. Those three topics are HEVs & EVs for mass transportation and heavy-duty vehicles, advanced transportation systems, and HEVs & EVs powered by renewable energies.

- **HEVs & EVs for mass transportation and heavy-duty vehicles**

Most attention and R&D efforts on hybrid and electric vehicles are currently focused on passenger cars and light-duty vehicles. The goal here is to identify which role hybrid and electric vehicles can play in mass transportation and heavy-duty vehicles and which applications would be most advantageous from an energy consumption and emission reduction point of view. Urban buses with their typical stop-and-go use patterns may be the first area of attention because they seem to be a very suitable application for hybrid drivetrains.

- **Automated transportation systems**

Automated transportation systems receive increasing attention as an option to solve inner city air quality and congestion problems and they are subject of investigations at different universities and research institutes worldwide. Electric vehicles are the actual means of transportation in many of these systems. IA-HEV is investigating if it can contribute with its expertise to the development of automated transport systems.

- **HEVs & EVs powered by renewable energy**

To reduce greenhouse gas emissions from transportation, one option is to move away from fossil energy carriers towards renewable forms energy. Existing systems and systems based on renewable energy must be compared on a well-to-wheel basis (or Life Cycle Analysis, LCA), for a valid assessment of their advantages and disadvantages. For HEVs and EVs this means analysing the role of renewable electricity. For hybrid vehicles that combine an electric motor and an internal combustion engine, the (renewable) fuel for the engine must also be included in the comparison. A large amount of information on well-to-wheel comparisons is available in the public domain. The purpose of this task is to apply that information to HEVs & EVs to estimate their potential in reducing fossil energy consumption and greenhouse gas emissions.

Interested parties are invited to contact one of the IA-HEV members, the chairman or the secretariat, to discuss their possible role in these activities. Participating organisations can contribute to determine the actual content of the work, so it can be adapted to their needs.

2.2.4 IA Hybrid and Electric Vehicle Awards

Remarkable technical breakthroughs in the field of 2-4 wheeled Hybrid- and Electric Vehicles (HEVs) were achieved during the last 10 years. The challenge now is to move to large-scale application of these vehicles. To foster HEVs entering the mass market, IA-HEV will introduce three "IA Hybrid and Electric Vehicle Awards" for people and organisations that are making exceptional contributions to developing the HEV market. The award should bring the audience of decisions makers, the media and the general public up to date on the latest achievements in the field of electric, hybrid and fuel cell vehicles. Initially, the awards will be restricted to products, projects and people in IA-HEV member countries. In a later phase, the award may cover products and activities anywhere in the world.

Awards will be granted in three categories:

- **Number of cars sold**

This award is for the number of cars driven or produced in IA-HEV member countries. Four levels will be distinguished, in order of increasing volume the awards will be: bronze, silver, gold and platinum. The actual number of cars that needs to be sold for each level will be determined annually to keep up with actual market developments.

- **Good practice of fleet tests and marketing measures**

Projects and organisations that show an outstanding performance or that come up with innovative solutions in overcoming market barriers for HEVs are the candidates for this award.

- **Personal award**

This award is meant for an individual or a team that has contributed substantially to the development, acceptance or market introduction of HEVs.

The first award ceremony is scheduled in conjunction with the Electric Vehicle Symposium EVS-21 in Monaco, April 2005.

3 Information exchange (Annex I)

3.1 Goal

The task force of IA-HEV Annex I –Information exchange– collects, analyses and disseminates information from different countries as well as some other relevant markets, regarding numbers and types of EVs and HEVs, technical developments and specifications of EVs, government demonstration programmes, subsidies, and other public or private activities set up to facilitate the introduction of EVs and HEVs.

3.2 Working method

A major part of the information exchange takes place in the experts' meetings (see figure 3.1), held once or twice per year. In the meetings the participants give presentations about recent developments in their country regarding the statistical and market situation for EVs and HEVs, progress of international, central or local government programmes and initiatives in the field. Each presentation also includes a special topic that is addressed in more detail. Every meeting the participants decide on the special topic for the next meeting. In 2004 the special topic was "Hybrid-Electric Vehicle Marketing Strategies in Member Countries".



Fig. 3.1 Experts from Sweden, USA and The Netherlands at 20th Annex I Experts' Meeting held at Argonne National Laboratory (USA) in November 2004.

A major part of the information exchange in this task force is informal, received directly from the source, and as such it is not available elsewhere. The chance to share project experiences – both positive and negative – in direct communication, and to receive immediate comments, suggestions and new ideas from an international group of experts are major benefits of this network. External experts have been invited to many of the meetings, to give an overview of the local activities and to participate in the meeting as observers. It is also of high importance that the results of the work are presented in international forums, such as the Electric Vehicle Symposiums and the like.

The Operating Agent (OA) has also collected information from certain non-member countries. This work was started in the fall of 2002, as it was concluded that a lot was going on in some countries that were not members of the group, and thus there was a possibility for Annex I experts to learn from these experiences as well. The OA is responsible for collecting and reporting this information in the experts meetings, in the annual report and on the IA-HEV Annex I web-site.

3.3 Results

The countries that participate in the IEA IA-HEV have a combined fleet of about 360 million vehicles, which is about half of the world's automotive fleet. Thus the member countries are in a position to significantly influence the energy consumption of the transportation sector world wide, and the choices they make regarding the energy carriers could be used as examples for the others. The number of EVs in member countries is nearly 170 000, and the number of hybrid vehicles is ca. 190 000, making a total of almost 360 000 EVs and HEVs. The average EV & HEV penetration for all countries is 0.1 %. Statistical data related to EVs and HEVs in member countries are presented in

3 Information exchange (Annex I)

table 3.1. It shows that the increase in the number of both EVs and HEVs in the year 2004 has been very large compared to 2003.

Table 3.1 Numbers of EVs and HEVs in member countries during the period 2002-2004.

	2002			2003			2004		
	EV	HEV	Total	EV	HEV	Total	EV	HEV	Total
Austria	597	0	597	597	0	597	597	0	597
Denmark	360	0	360	360	0	360	300	15	315
Finland	450	2	452	450	2	452	460	102	562
France	10 583	0	10 583	10 921	144	11 065	11 013	650	11 663
Italy	55 262	210	55 472	55 262	210	55 472	95 161	247	95 408
Japan	4 356	70 392	74 748	4 356	70 392	74 748	4 356	70 392	74 748
Korea	0	0	0	5	0	5	5	0	5
Netherlands	100	1 000	1 100	500	1 000	1 500	500	2 000	2 500
Sweden	552	418	970	552	418	970	503	640	1 143
Switzerland	3 500	350	3 850	9 704	417	10 121	10 587	472	11 059
USA	12 346	70 090	82 436	12 346	70 090	82 436	45 650	113 857	159 507
Total	88 106	142 462	230 568	95 053	142 673	237 726	132 169	188 375	357 507

The information presented here has been provided by experts of the IEA HEV Annex I participants or has been found on the Internet. There may be some discrepancies in the data, as the methods and vehicle categories for data collection in different countries vary significantly. Furthermore, some of the data is not necessarily frequently updated –like for example Japan, where the hybrid vehicle fleet is expanding rapidly- or two sources have provided somewhat conflicting information. Thus, the data presented here is meant to be indicative rather than presenting absolute values.

Annex I has closely monitored the progress of popularization of EVs & HEVs over several years in each country. A compendium of census data providing available data on numbers of EVs by user types, vehicle types, battery types and number of charging facilities in Annex I participant countries has been collected. More recently, numbers of hybrid vehicles have also been looked into since hybrids first appeared in the market in the late 1990s. Because the statistical systems and definitions of vehicle types vary from country to country, it is very challenging to collect the number of EVs unambiguously, as for example some countries have data about numbers of nontransport industrial EVs and include that in the total, while in other countries that information is not even collected.

As an example of the variety of EVs, the UK has had the most 3-4 -wheel electric vehicles in the world, about 18 000 milk floats in late 1990's. However, the number of the milk floats has since decreased by several thousands. Moreover, Italy currently has a significant amount of 2-wheel EVs in its fleet. Due to efforts by the public sector, the number of 2-wheel EVs has increased eightfold since the year 2000 in Italy. Furthermore, small, so-called neighbourhood EVs are becoming increasingly popular in Japan and in the USA. The total combined number of EVs thus becomes fairly large, but as mentioned earlier, one must be cautious with the total numbers as there are many differences in statistical data collection and vehicle classification from country to country.

3.4 Outlook

In the future the Operating Agent will actively monitor especially the situation in non-member countries and build contact networks with those countries. The members of the IA-HEV Executive Committee will continue to play an important role in the work of this Annex by providing up-to-date information concerning their respective countries.

3.5 Conclusions

The activities in Annex I are a time and cost effective way for the experts to learn about the EV and HEV situation and experiences of other countries. The field of electric and hybrid vehicles is developing very fast now, so it is important to have the new information at one's disposal as soon as it is available. Via the experts network, the information has direct channels to the governments of the participating countries, and thus the information can be immediately utilized in decision making for new policies and regulations.

3.6 Contact details of the Operating Agent

VTT Technical Research Centre of Finland acted as the Operating Agent (OA) until the end of the second phase of the agreement in November 2004. At the time of printing, the IA-HEV members were choosing a new OA. Please contact the IA-HEV secretary for contact details of the new Annex I Operating Agent.

4 Hybrid vehicles (Annex VII)

4.1 Goal

This planned 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:

- Extreme demands for components.
- Modelling of components.
- Test procedures for components.
- Component costs.
- Electric component technologies.

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

- Components (energy storage).
- Merits.
- Costs.
- Marketability (overcoming barriers).

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.

The focus of this Annex is on vehicles with at least four 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.

4.2 Working method

TNO 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 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, on November 15 & 16, 2004.

The task force plans to do several major international studies on the subjects of components for hybrid vehicles and 'plug-in hybrid vehicles' in the new phase of Annex VII. Furthermore the Annex allows the participants to exchange information.

The current participants in Annex VII are:

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

4 Hybrid vehicles (Annex VII)

The main subtask leaders are:

- A. Austria Components for hybrid vehicles
- B. USA Plug-in hybrid vehicles
- C. NL - TNO Information exchange

The operating agent will organise three expert meetings per year. These two-day meetings (organised in co-operation with a participating country that hosts the meeting) will give the participants the opportunity to discuss and work on the three sub-tasks.

Furthermore, the Operating Agent will continue to attract new participants and sponsors. The participating countries will participate in three expert meetings per year, work on information collection and prepare presentations for the meetings.

4.3 Results

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

The automotive research organizations planning to participate in phase 3 are among the most prestigious in the world. They will 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 will give them access to research that they have not done themselves, and keep them informed on recent developments in other countries and about the state of the art of the technology.

The result of Annex VII phase 3 -being reports, papers and presentations- will be first disseminated in the countries that participate in Annex VII. Dissemination is co-ordinated by the organizations that represent their governments in this Implementing Agreement. After four months the results will be made available for a more broader public through the IEA web-site: www.ieahev.org.

4.4 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 will produce such information.

4.5 Conclusions

The final work plan, 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. Interested countries and organizations are most welcome to join the task force.

4.6 Contact

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

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5 Deployment strategies for hybrid, electric and alternative fuel vehicles (Annex VIII)

5.1 Introduction

Between 2000 and 2002 a task force, a joint effort of the Advanced Motor Fuels and the Hybrid & Electric Vehicle Implementing Agreements, collected information on 95 programmes in 18 countries. Evaluations and analyses of case studies showed that some approaches are successful, but they also identified weaknesses that are often repeated. The report elaborated by the task force provides recommendations on the basis of conclusions drawn from the analyses. It was completed in December 2002 and it is available from the Operating Agent.

5.2 Promotion policy: The importance of learning lessons

Formulating new policies involves looking into successes and failures of past experiences. This is of great importance for the introduction of clean vehicles on the market. Many of the findings resulting from promotion programmes for hybrid, electric and alternatively fuelled vehicles are transferable to another new vehicle technology. However, there are also differences depending on the specific features of the new vehicle technology and on the changes in behaviour or attitudes required from the users. It must be stressed here that only the market, i.e. only the customers, will decide on a market success of new vehicle technologies (even if the technical and environmental advantages of a new technology surpass the conventional cars).

Learning lessons is a key to success. In the case of clean vehicle promotion programmes this means learning from experiences gained from the promotion of other alternative vehicle technologies. Certainly, looking into other clean vehicle promotion programmes cannot provide recipes: each experiment has its own framework conditions, political environment and social context. Above all, guidelines for learning lessons therefore concern the overall approach rather than the specific process:

- Innovation processes involve social as well as technical change. **Learning lessons therefore happens “along the way”.**
- One single project does not provide “the lesson” – **cross-project evaluation investigating many projects with similar objectives is necessary.**
- **Learn from “failure stories”.**
- **Measures for the market introduction must address the user above all** (more so than automotive engineers, politicians etc.). Learning from marketing specialists for consumer markets is more helpful than from technology experts.
- **Information must not be kept within the programme insiders.** At present it does not reach the buyers. Lessons only can be learned if information on success as well as on pitfalls is publicly available.

5.3 Influencing vehicle markets

Introducing new technologies means that these innovations (e.g. electric vehicles) have to compete with a well-established technology (the gasoline car) already available on the market. In this case vehicle designers have to decide to which extent they should change the existing technology. At one end of the range is to adapt the existing technology to the innovative one, they “optimize” the car. At the other end of the range they completely replace the existing technology by the innovative one. This would result in a “radical change”, not only concerning the technology but also concerning the user behaviour. Such a “revolution” might appear to be a desirable process leading to “sustainable” mobility. But markets do not easily accept fundamental changes, especially in case the well-established product provides more convenience and needs no change in customer behaviour.

More than 15 years of promotion measures favouring the market introduction of clean vehicles by a great variety of stakeholders has not really changed the market. The key for this problem seems to be the conflict between “optimization” and “renewal”. “Optimization” is a step-by-step approach and hardly ever strains the acceptance of the user. “Renewal” demands examination of the new technology and a change of user behaviour. It needs protection against the existing market that allows “exploring

room for change” (see paper by Boelie Elzen, mentioned in subsection 5.7). This implies that the more changes are involved in the new technology, the more “protection” is needed (this in turn may be a strong capacity of the government to influence the market, the use of powerful instruments, large financial commitments, for example in the form of subsidies, etc.). Obviously hybrid vehicles with internal electricity generation (like the Toyota Prius) are an “optimization” that is accepted by the customers, and there are sufficient benefits for the drivers to accept that they have to pay for the added value.

Independently of the technology, one rule has to be observed: market introduction can only be successful for marketable products. In the field of clean vehicles, “marketable” was often reduced to the proper functioning of the technology. But transport relies on a network of systems, and the transport market is highly competitive. This means that clean vehicle technologies must also be introduced in the market together with the whole system making them “marketable”. This includes:

- licensing, national homologation,
- purchasing process with reasonable conditions for the customers (including the purchase price),
- the reliability and safety of the technology,
- easy access to fuels or energy needed for vehicle operation (throughout the area defined by the range of the vehicles),
- service spots in reasonable distance,
- trained staff at the service spots,
- driving lessons available if necessary,
- access to information on performance, operation, best application of the vehicles and “refuelling” infrastructure.

Working in markets always means dealing with such a great variety of framework conditions and market forces that only general guidelines can be given. The report of this Annex contains a lot of considerations and observations that result in recommendations in line with the relevant field (e.g. fleet tests, government support etc). What should be observed for every promotion activity for clean vehicles can be summarized as follows:

- **Be flexible:** Markets are complex and changing. Measures promoting market introduction must take this into consideration.
- **Evaluate:** The complexity of the market forces makes effects of deployment measures unpredictable. Only continuous evaluation ensures that the necessary adaptations can be made.
- **Learn by doing:** Market studies -however perfect they seem- mirror theoretical approaches. Only practice reveals weaknesses in technology and real effects of the market forces.
- **Learn from others:** Much experience has been gained by worldwide market introduction programmes. It is a waste of money to repeat failures that have occurred elsewhere.
- **Inform:** Learning processes can only happen if information on successes and failures is available.
- **Think markets:** The smartest technology will fail in case it is not accepted by the customers. Learning from marketing specialists may be more helpful in some stages of market deployment than to polish the technology.

5.4 Government promotion

“Success stories” for the market introduction of clean vehicles happen when the new vehicle technology offers remarkable economic advantages or specific benefits for the users – independently of the non-economic interests of other stakeholders (e.g. those of national and local governments to improve the air quality). Therefore governments that are advocating the “non-economic” interests (like clean air) take measures to push the markets into the direction that also takes these non-economic interests into account.

Measures can be manifold and can be categorized concerning their field of effects. This is shown in box 5.1.

<p>Box 5.1 Supporting measures for the market introduction of clean vehicles and fuels</p>
<p>Command and Control Instruments</p> <ul style="list-style-type: none"> • Standards • Emission-regulations • Licensing • Quality contracts • Mandates • Exemptions from certain restrictive regulations
<p>Economic Instruments</p> <ul style="list-style-type: none"> • Direct investment • Pricing policies • Subsidies • Tax incentives • Financing schemes
<p>Procurement Instruments</p> <ul style="list-style-type: none"> • Green procurement • Leadership by example • Common procurement
<p>Collaborative Instruments</p> <ul style="list-style-type: none"> • Network-management and co-ordination • Certification and labels • Voluntary agreements • Public-private partnerships • Private-private partnerships
<p>Communication and Diffusion Instruments</p> <ul style="list-style-type: none"> • External information • Marketing • Vehicle buyers' guides and vehicle labelling • Internal information • Education and training measures • Persuasion and lobbying activities

5 Deployment strategies (Annex VIII)

Success stories show that governments implemented a bundle of supporting measures in their promotion projects:

- they supported research and development,
- they set standards,
- they initiated agreements with the vehicle manufacturers on quality and warranties or on procurement,
- they supported the fuels/electricity for clean vehicles (by tax schemes etc.) – it is important that the payback period for the higher vehicle price is relatively short,
- they implemented mandates (especially for public fleets, taxis and buses of public services),
- they implemented financing schemes for private purchasers,
- they provided tax exemptions from sales tax on clean vehicles,
- they established partnerships for PR and information campaigns.

One important finding is that shaping the framework conditions seems to be more successful than direct financial incentives – although the car industry is very fond of such subsidy-programmes. A look into completed subsidy programmes for electric vehicles showed that customers did not buy them because subsidies were granted, but because the vehicles provided some extra features or benefits in the application that the conventional car could not offer.

Many of the case studies also have shown that cities and local & regional authorities play an important role when they have the authority to adapt local regulations and framework conditions (environmental zoning, parking regimes, local transport advisors, etc.). In addition, the success of market introduction programmes increases when they act within networks (for example the “Clean Cities” network in the United States). Partnerships can cover all fields in which stakeholders are active. Figure 5.1 presents an overview.

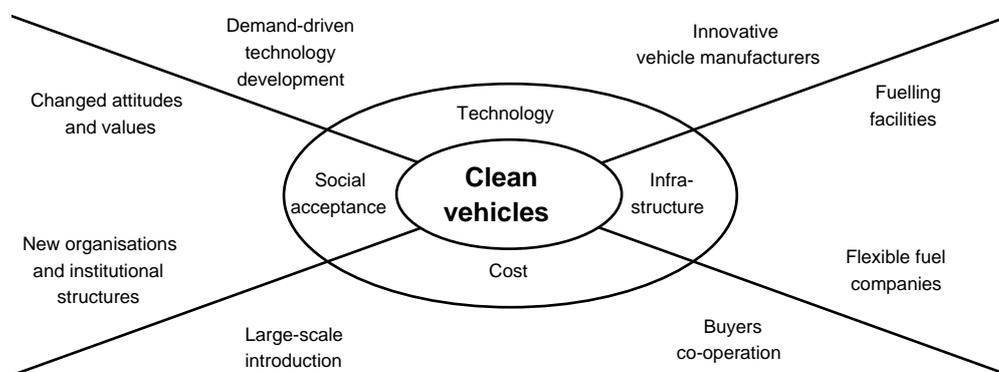


Fig. 5.1 Fields and stakeholders around clean vehicles.

Networking means that the market introduction is supported by other stakeholders in addition to governments. However, governments must take the lead in the whole process and should provide a structured co-ordination of the activities. Direct financial support by governments can then be restricted to “symbolic action” showing that governments are aware of the problem and support a special development but not requiring them to carry the whole burden of the market introduction alone.

To summarize the recommendations concerning government support the following points have resulted from the evaluation within this Annex:

- Policy instruments must re-inforce each other, their coherence must be observed.
- Realistic sufficiency of funds and time needed for effective market introduction strategies.

- International markets must be met by international efforts.
- There must be an analysis whether the transport situation calls for an approach oriented to the supply-side or to the demand-side.
- Networking approaches can cope with the complexity of vehicles markets.

5.5 How can the ‘Deployment strategies’ results be used?

The scope of the government promotion measures analysed in this Annex included the most important “clean vehicle”- technologies: electric vehicles, hybrid vehicles, CNG and LPG vehicles and vehicles using ethanol (E85). This wide approach makes it possible to use the results also for technical innovations to come. Above all fuel cell vehicles are currently a focus of interest. As soon as marketable fuel cell vehicles are available, governments will have to consider promotion activities. A short demonstration to show how to adapt the analysis of this Annex to fuel cell vehicles will give some indication of the problems.

The first question that has to be answered is: are fuel cell vehicles an optimization of the existing vehicle technology or are they a “radical change”?

The technology closest to fuel cell vehicles (from the point of view of the user) is compressed natural gas (CNG) - vehicles, at least if we assume that gaseous hydrogen (H₂) will be used in fuel cell vehicles. Specialists from the car industry claim that CNG-vehicles could be a promising intermediate step preceding the wide introduction of fuel cell vehicles.

Table 5.1 Practical and irrational issues hindering the market introduction of CNG-vehicles.

Reservations of the customers	Countermeasures
Only a few vehicle models that are optimized for CNG are available (the most are conversion vehicles or bi-powered vehicles). The gas tank needs too much space.	The car industry will increase the range of dedicated CNG vehicles with an optimized fuel tank.
The infrastructure network does not show the density needed.	In all OECD countries the national NG industries increase the NG refuelling network.
Poor conversion led to bad emission values. Converted buses cannot compete with diesel buses.	New dedicated design models do not show this problem. Emissions are highly dependent on a professional service.
The range per tank filling is not comparable to that of a gasoline car due to the lower energy content.	Increase the number of refilling stations.
Customers have an (irrational) fear of gas as a fuel.	NG has a higher ignition temperature than gasoline and a narrower range of flammability. It also does not pool on the ground or enter water systems, as it is lighter than air. NG therefore is safer than gasoline. The information problem has to be solved professionally.
Difficulties with maintenance and service.	NG vehicles need less maintenance because NG burns cleaner.

Evaluations show that the market introduction of CNG-vehicles is hindered by practical but also by irrational issues, as is shown in table 5.1. This list provides an indication why CNG vehicles are considered to be a “radical change”, at least in the view of the users. When we adapt this list for H₂ fuel cell vehicles, we get the indications as shown in table 5.2.

5 Deployment strategies (Annex VIII)

The fuel cell vehicle is favoured by policy makers for one main reason: in addition to providing a clean propulsion system, it seems that fuel cell vehicles do not demand great changes in user behaviour – in contrast to battery electric vehicles.

At the current state of vehicle development there are some issues that require a change in user behaviour:

- The range per tank filling is low.
- Safety with H₂ refuelling is a challenge.
- Safety issues of on board storage of H₂ are demanding.
- Cold weather performance is not satisfactory.

This list does not include the technical problems with the fuel cell itself (e.g. the humidity problem), but it is obvious that fuel cell vehicles are more dissimilar to conventional cars than for e.g. CNG-vehicles – even if we only look at the vehicle itself and do not include the infrastructure for refuelling. This means that the market introduction of fuel cell vehicles must be accompanied by more protection than that of CNG vehicles; protection in the form of a bundle of promotion measures that provide a reasonable opportunity to enter the market.

The next step would be to identify the network of stakeholders that has to include all important players in this field, and to allocate the fields of activity. This also has to include the level where customers find their addressees: the retailers, garages and car repair shops and the fuel stations. At the government level, the main stress should be put on favourable framework conditions. A promising bundle of measures could be:

- setting standards for on-board tanks and fuelling stations,
- agreements with the vehicle manufacturers on quality and warranties,
- support of gaseous hydrogen as fuel (by tax schemes, by taxing gasoline, etc.),
- mandates (especially for public fleets, taxis and buses of public services),
- financing schemes for private purchasers,
- tax exemptions from sales tax on fuel cell vehicles, et cetera.

Additional incentives depend on the framework conditions in the respective countries.

The key issue is that the customer only can be convinced to buy a fuel cell vehicle in case he/she gets some extra advantages that a gasoline car does not provide.

In the case of battery electric vehicles such advantages could be identified:

- the vehicle is perfect for special applications,
- the use of clean energies is possible (hydropower, photovoltaics, wind energy),
- these vehicles are the only zero emission vehicles available just now,
- electric vehicles can store electrical energy (important for electricity generated by wind generators),
- recharging of battery electric vehicles at home is possible (avoids the unpleasant stay in smelly fuel stations),
- the operating costs for EVs are low,
- personal prestige and/or PR effect for specialized companies etc.

Table 5.2 Indications for practical and irrational issues hindering the market introduction of fuel cell vehicles.

Reservations (experience with CNG-vehicles)	Hint for the market introduction of fuel cell vehicles
Currently no vehicle models available that are optimized for H ₂ (the most are conversion vehicles or bi-powered vehicles). The gas tank needs too much space.	The good news: Recently the car industry has dropped the idea to use fuels other than H ₂ (e.g. gasoline, methanol...). The bad news: With gaseous hydrogen as fuel, many problems have to be solved (cold start features, humidity problem, problems of catalysts etc.).
The infrastructure network does not show the density needed.	The hydrogen industry does not see any problem to produce the necessary amount of gaseous hydrogen; the problems are the distribution and costs for the refuelling infrastructure. The only promising way is to co-operate with conventional retail fuel providers.
Poor conversion led to bad emission values.	There only will be minimum emissions other than water vapour, due to the use of engine lubricants in case H ₂ is used in internal combustion engines.
The range per tank filling is not comparable to that of a gasoline car due to the lower energy content.	This problem is even worse with H ₂ than with NG as it requires six to ten times more storage volume than gasoline.
Customers have an (irrational) fear of gas as a fuel.	Contrary to NG, hydrogen is highly flammable – even more than gasoline- but it burns quickly. Safety is an issue in enclosed spaces.
Difficulties with maintenance and service.	Users must not be the test objects. This can never be accepted for alternative vehicles – the market would be ruined for decades. Fuel cell vehicles must not be put on the market without a dense service network with trained and well-informed staff.
The vehicle industry tends to announce market breakthroughs that create high expectations and ruin the market in case these expectations cannot be met.	Only a small pioneer segment of customers accepts testing problems. Announcements of the market entrance of fuel cell vehicles with a fixed date are not helpful.

Marketing studies show that in the vehicle market the split between rich and poor loses importance and is replaced by the individual sense of belonging to a special social group. The “visualizing of life style” fosters niche products in case they show unconventional design, convey the feeling of social security by a sympathetic vehicle make, prove the ecological and social competence of the manufacturer including a customer service that exceeds the normal efforts of vehicle distributors. All this calls for specially designed and unconventional niche products.

A comparable list of benefits and advantages must be elaborated for fuel cell (FC) vehicles. This is a real challenge for FC vehicle marketing, as it has been for EV marketing that –as we know– was not too successful at this point. But it is unavoidable that manufacturers and sales staff of fuel cell

5 Deployment strategies (Annex VIII)

vehicles must find arguments to convince customers that they gain additional benefits by using fuel cell vehicles.

5.6 Contact

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5.7 References

S. Kleindienst, M. van Walwijk et al.: *Deployment Strategies for Hybrid, Electric and Alternative Fuel Vehicles*. A report of the IEA project, December 2002.

B. Elzen: *Optimizing learning from experiments with transport innovations. A crucial step towards sustainable mobility*. Paper for the IEA Workshop "Market Deployment Strategies for Clean Vehicles", Kyoto, Japan, June 2001.

6 Clean city vehicles (Annex IX)

6.1 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 1 million population mark and even the number of cities with more than 10 million inhabitants is increasing steadily. In many of these cities air quality is a serious problem that affects the health of all their inhabitants, and traffic is often an important contributor to this pollution.

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

These are the reasons why the Implementing Agreement 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 in Paris. Important results from that workshop are included in this chapter.

6.2 Goal

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.

6.3 Working method

As a first step, Tommy Månsson (EnEN AB, Sweden) on behalf of IA-HEV 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, Indonesia, India, Kenya, Mexico, Nepal, Peru and Thailand. The workshop was highly successful and it would be fruitful to organise similar workshops in the future.

This kind of workshops would be a major constituent of this Annex. These workshops 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 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.

6.4 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’ sub-section.

An eye opener was that in many areas of the transportation sector the developing countries are in fact ahead of the industrialized ones. The ‘bus rapid transit’ systems in Bogotá and Curitiba are world leaders. Brazil is a world leader in the use of ethanol as a transportation fuel, and Argentina is leading in the conversion of vehicles to CNG. China is world leader in the use of electric bicycles. In Kathmandu over 600 electric three-wheel passenger vehicles ply the city streets, 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 the success stories of one city or country to another.

A success story of type (1) is the plan to study a “Bus Rapid Transit” system for Dacca in Bangladesh. After the Paris workshop, Annex IX arranged for city officials from Dacca 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 Dacca have now set up a task force to study the possibility of constructing a similar bus system in their city.



Fig. 6.1 People on two-wheelers suffering from smog in Ho-Chi-Minh City, Vietnam. (Photo: Gerhard Metschies; supplied by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Transport Photo CD-ROM Urban Transport, July 2002.)

An important general topic, 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.

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.

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.

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 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.

A fourth 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.

6.5 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 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 among developing countries would also be very beneficial.

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.

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.

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.

6.6 Conclusions

The exchange of information and practical experiences is a valuable tool in reducing air pollution problems from traffic in cities. This exchange is especially valuable for large and rapidly expanding cities in developing countries. Workshops appear to be an effective and efficient instrument to enable this exchange and to identify general topics that need to be solved.

A wide range of organisations is necessary to make the workshops successful and is also required to create a sufficient financial base for a sustained continuation of this Annex. Developing countries, donor organisations, multinational 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.

6.7 Contact

Organisations that are seeking further information or that are interested in participating in Annex IX are invited to contact the secretary of the HEV Implementing Agreement. Contact information can be found in part D of this report.

7 Electrochemical systems (Annex X)

7.1 Introduction

Fuel cells, batteries, and supercapacitors all fall within the scientific domain of electrochemistry, and each will have a key role to play in developing sustainable transportation technologies. Their fundamental importance is based on the fact that each can supply electricity to an electric traction motor, i.e. an electric motor that drives the wheels of a vehicle.

Electric traction motors are a superior technology for driving the wheels of a vehicle for two main reasons. The first is that they are highly energy efficient, often in excess of 90% of the electricity is converted into the mechanical energy that drives the wheels, as compared with 20 to 30% for internal combustion engines. The second is that electric motors can be used in reverse to brake the vehicle, and in doing so generate electricity that can be fed back into a battery or supercapacitor. This is called regenerative braking. In urban driving with many stops and starts, it can increase overall energy efficiency by up to 20% compared with vehicles with friction brakes, in which the braking energy is converted to heat and released into the air.

7.2 Goal

The goal of the task force in this Annex on “Electrochemical Power Sources and Energy Storage Systems for Electric and Hybrid Vehicles” is to support research, to share new information and to establish strong working relations among some of the leading electrochemical research organisations in the world, to accelerate progress on key topics in this area.

For the third phase of the HEV Implementing Agreement it is anticipated that this Annex will concentrate on research on new materials, components and systems.

7.3 Working method

The electrochemical systems task force shares information about new materials among participants in the work. By sharing the work, it is easier and less expensive to remain up-to-date on the state of the art of the technology and to monitor developments in several countries. A database was established on batteries and super capacitors, which will be continuously updated by the participants.

The following sections will briefly describe the key enabling technologies for sustainable transportation fuel cells, supercapacitors and batteries, but also hybrid vehicles, the importance of electrochemistry, test procedures and new materials. When applicable, the activities of this Annex regarding these topics are included.

Fuel cell vehicles

A fuel cell converts hydrogen fuel with oxygen from the air to produce electricity, with water as the only by product. The energy efficiency of fuel cells is around 40%. Using fuel cells to provide electricity for traction motors will likely have the advantages that a vehicle will not cause any noxious emissions while driving, and can be re-fuelled quickly once the appropriate infrastructure is in place. Prototype fuel cell vehicles have already been produced, and car manufacturers are predicting that by 2010 fuel cell vehicles will enter the mass market.

Unlike batteries, which can either provide electricity when discharging, or store electricity when charging, a fuel cell cannot be operated in reverse to store electricity. In order to take advantage of regenerative braking, and also for economic reasons, it is likely that fuel cell vehicles of the future will also have batteries or supercapacitors or both, and therefore will in fact be hybrid vehicles. Advances and cost reductions in all three of these electrochemical technologies will be necessary to make fuel cell vehicles competitive in the market.

Supercapacitors

A supercapacitor is able to provide a relatively large amount of electrical power when discharging, or store power quickly when charging. The technology is relatively new and has been initiated and developed over the past 25 years. In vehicles, supercapacitors can absorb braking energy more effectively than batteries because they can more easily store the large amount of power produced in regenerative braking. Secondly, supercapacitors can act similar to turbo-boosters, by increasing the

amount of power available when a lot of power is required, such as in acceleration, passing, or hill climbing. Supercapacitors have already been demonstrated in prototype vehicles and their costs have come down rapidly. They are also used in a variety of other applications such as digital cameras and cell phones and their manufacturing costs will continue to decrease. With continuing development, supercapacitors will be able to increase the performance and market attractiveness of hybrid, fuel cell, and battery electric vehicles.

Hybrid vehicles

Hybrid vehicles are available on the market now, and are likely to be the main sustainable vehicle technology for the coming decade. They can cut fuel consumption by 40% or more in urban driving. The key component that makes the hybrid vehicle possible is the improved battery, in most cases a nickel metal hydride battery. Battery technology has made astonishing progress over the past ten years and a decade ago few would have predicted that more than 100 000 hybrid vehicle batteries would be on the road by 2002. The progress has been marked by steady and sustained improvement over the years, rather than by dramatic breakthroughs, and has not attracted the same amount of media or stock market attention as fuel cells. Lithium ion and lithium polymer batteries may be the next steps forward. They are already used in many applications such as laptop computers and cell phones, and their development for vehicle applications is promising. They could become successors to nickel metal hydride batteries, because the cost of the materials required is lower, and consequently the potential for cost reduction is higher.

Batteries

As noted above, batteries are already a key component of hybrid vehicles, and will be a component of fuel cell vehicles as well. Technical development will be spurred by other applications such as portable electronics and improved manufacturing technologies will result from the increasing production volumes of hybrid vehicles. As batteries improve and their costs come down, they can take an increasing share of the energy needs of hybrid vehicles and increase the attractiveness of “plug-in” hybrid vehicles. If progress in battery research and development for the next ten years continues at the same rate as for the last ten years, battery electric vehicles will also become increasingly attractive because they will have acceptable range and performance at reasonable cost.

Importance of electrochemistry

Electrochemical devices can store electrical energy (batteries), provide extra power to vehicles (supercapacitors), and cleanly convert the energy in hydrogen to electricity (fuel cells). They are the key enabling technologies for sustainable transportation. Successful electrochemical research is conducted not only in the major automobile manufacturing countries such as the United States, Japan, Germany, and France, but also in many medium sized and smaller countries, such as Canada and Austria. A lot of progress has been made during the past ten years in all three areas (fuel cells, batteries, and supercapacitors), but further progress will be needed in the next decade to increase performance and reduce costs.

The task force on “Electrochemical Power Sources and Energy Storage Systems for Electric and Hybrid Vehicles” (Annex X) has identified some key activities that can contribute to accelerated progress in the areas of test procedures, new materials, and system modelling. They will be briefly explained in the following sections.

Test procedures

When a manufacturer or research laboratory has produced a new prototype or commercial battery it will, of course, test the technical specifications and publish the results. However, confusion can quickly arise if different companies use different testing methods and criteria, because the results will no longer be comparable and doubts arise about the true performance of the new product. For this reason, governments and governmental laboratories have taken a lead role in formulating test procedures that give a fair assessment of the true performance of fuel cells, batteries, and supercapacitors and that allow the products of different manufacturers to be compared on an objective basis. Developing such a test procedure involves a large amount of specialized technical work and the cost can easily exceed a million dollars. Once a satisfactory test procedure has been developed in one country, there are strong advantages to sharing it and adopting it in others. Not only will the other

countries save the cost of developing the procedure themselves, the fact that the same procedure is used in different countries will allow for fair comparisons to be made among the products of all manufacturers in all participating countries. From the manufacturers' perspective, they do not have to submit their product to different test procedures for each country in which it is sold, but can use the uniform test for all countries. This is why sharing of test procedures results in multi-million dollar savings.

A test procedure is a prerequisite step before embarking on the path to eventually adopt international technical standards. Worldwide, there are several major standardisation organizations and projects whose committees and members collaborate over a period of several years to eventually publish standards and testing methods for new products appearing on the market. Technical standards are recognized as contributing billions of dollars in savings to advanced economies by increasing the efficiency of product development and manufacturing. Before these committees can set to work, testing methods and test data have to exist on which the technical standard can be based. The task of formulating technical standards is often called "normative" work, and the work on testing methods is called "pre-normative" work.

The electrochemical systems task force has already distributed battery testing methods developed in the United States among its members, and is working to promote the international use of these methods among research organizations while the battery performance standard for battery electric vehicle application has been already established as IEC 61982. Battery performance standards for HEV batteries have to be established, which includes specific battery test cycles. Regarding fuel cells standard testing methods are still on the working group level at the different organizations and projects. During the current year, efforts are focused on testing methods for supercapacitors. Up to now only national standards are available. Therefore, the test procedures developed in Europe, the United States, Japan, Korea and China were exchanged between Annex X members and can be used to develop a harmonized test procedure.

New materials

Electrochemical devices appear deceptively simple, as they only consist of positive and negative electrodes, electrolytes, catalysts and a container. The performance of the device depends entirely on the materials from which these elements are made and there is a constant worldwide search for improved materials and new materials. The improvement can consist of better technical performance and/or lower costs and laboratories all over the world are investing large efforts in both aspects. Some of this work falls into the category of exploratory research where a better understanding of the basic properties of materials and electrochemical processes is obtained. Other work falls into the category of proprietary research where a certain company develops a specific material that performs better than others on the market.

7.4 Outlook

Within the next phase of this Implementing Agreement on Hybrid Electric Vehicles it is anticipated that this Annex will focus more on the research of new materials, components and systems. For this next phase, Austria handed over their responsibilities as Operating Agent of Annex X to the United States. After this change in Operating Agent, the participation and work will be based on task sharing. This means that there would be no common fund for this Annex, and participating countries would not be asked for annual contributions in cash because the work of the new Operating Agent will be financially supported by the U.S. Department of Energy. All participating countries and also others - research institutes and companies working in the fields of battery, super capacitance and fuel cell research- who want to become a new member of the HEV Implementing Agreement are invited to join Annex X.

7.5 Benefits of participation

Electrochemical research is being conducted in many countries, and it has been shown that countries that are not leaders in automotive research can still reap major rewards from electrochemical research. These benefits include high technology manufacturing jobs and licensing of intellectual property. The specific benefits of participation in the electrochemical systems task force include:

7 Electrochemical Systems (Annex X)

- The multi-million dollar savings resulting from the sharing and international use of testing methods for batteries and supercapacitors.
- The establishment of strong working relations among some of the leading electrochemical research organizations in the world. This network of personal contacts is particularly valuable because the members are from leading electrochemical research organizations and because the nature of the joint work establishes strong working relations, rather than a casual level of acquaintance.
- The international exchange of information which allows participants to remain up-to-date on the state of the art and good personal relations allow the exchange of verbal information -on future developments, successes and failures- that is not available in the scientific literature or in official publications.

7.6 Contacts

Until December 2004, the Operating Agent of Annex X has been:

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8 Electric two wheelers (Annex XI)

8.1 Goal

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 Executive Committee (ExCo) of the HEV Implementing Agreement decided to prepare a new Annex on electric two wheelers. The overall objective is to identify barriers that hindered the market penetration until now and to develop and to test ways to overcome them. 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.

8.2 Working method

On June 2, 2004, the interim Operating Agent organized an international workshop in the context of the ExCo meeting held in Eskilstuna (Sweden). Ten experts, both from governments and the industry, developed a first draft for a work plan.

After that workshop the interim Operating Agent established a contact group in order to constitute a strong team to define the important questions and to give corresponding answers. This group includes representatives of vehicle manufacturers, national and local authorities, research organisations and demonstration projects from a dozen countries in America, Asia and Europe.

Thirteen interested experts -including the Swiss Federal Office of Energy, the chairman of the IA-HEV, manufacturers, leaders of demonstration projects, dealers and researchers- attended a Swiss workshop at Biketec, the manufacturer of the e-bike “Swiss-Flyer”, in September 2004. They all agreed that there is a need for improving the conditions for market introduction as well as for the vehicle technology, and that an international coordination by the IEA would be very helpful.

The interim Operating Agent is organizing another workshop to be held just after the Electric Vehicle Symposium EVS-21 on April 6, 2005, in Monaco. The purpose of this workshop is to collect sufficient interest in participation, so the Annex can enter the operational phase.



Fig. 8.1 E-scooter (photo supplied by Schwegler Bureau for Transportation Planning).

8.3 Results

A draft version of a work plan including the following five subtasks has been developed:

- 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 experience and information obtained from ongoing and completed projects (extended dissemination).

8.4 Outlook

After the Monaco workshop on April 6, 2005, the interim Operating Agent will inform the ExCo on the progress. The ExCo shall decide if this new Annex can enter the approval phase, in which formal participation is solicited. The kick-off of the operational phase is scheduled for the summer of 2005.

8.5 Contact

Further information can be obtained by the interim Operating Agent:

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9 Austria

9.1 Enabling technologies

Austria is a significant player in the automotive industry. It hosts a number of automotive suppliers and there are vehicle production plants –like MagnaSteyr in Graz- producing for multinationals. The Technical Universities of Vienna and Graz and the enterprise AVL List in Graz for example are active in R&D on automotive drivetrains.

In 2002, the Austrian government through the Federal Ministry for Transport Innovation and Technology (BMVIT) started a large programme to support co-operation between the Austrian automotive industry and research organisations in projects on alternative propulsion systems. This programme is called the “A3-Technology Programme” -which stands for “Austrian Advanced Automotive Technology Programme”- and has been emphasizing the following six themes:

- New propulsion systems.
- Alternative fuels and lubricants.
- Energy efficiency for auxiliary power units (APUs).
- Innovative vehicle concepts.
- Smart vehicles.
- Low noise vehicles.



Fig. 9.1 Capsuled CDT fuel cell, a 5 kW direct hydrogen fuel cell module for vehicle drives and auxiliary vehicle systems (photo supplied by BMVIT).

At the end of 2004, a new initiative derived from the A3-Technology Programme has been announced: the “Austrian Hydrogen and Fuel Cell Initiative” (AHFI). It is based on a co-operation between research institutes, material suppliers, component manufacturers, system developers, service providers and users, and it is supported by BMVIT. The vision of the programme is threefold:

- to develop technology leadership for the key technologies “electric vehicles” via the transition path of hybrid vehicles already becoming available on the market,
- to develop ‘tank-to-wheel’ hydrogen fuelled power trains,
- to develop marketable fuel cell systems for use as APUs, in order to increase overall vehicle energy efficiency.

Examples of research projects under this programme focus on: developing a simulation tool for environmentally friendly urban bus and product delivery traffic systems, energy efficient power generation from diesel with fuel cells, hydrogen storage tanks, high-temperature membranes for fuel

cell vehicles, hydrogen as future automotive energy carrier, and integrating hydrogen and fuel cells knowledge in professional education. The scheduled budget for this programme is 15 million Euros covering the period until the end of 2006.

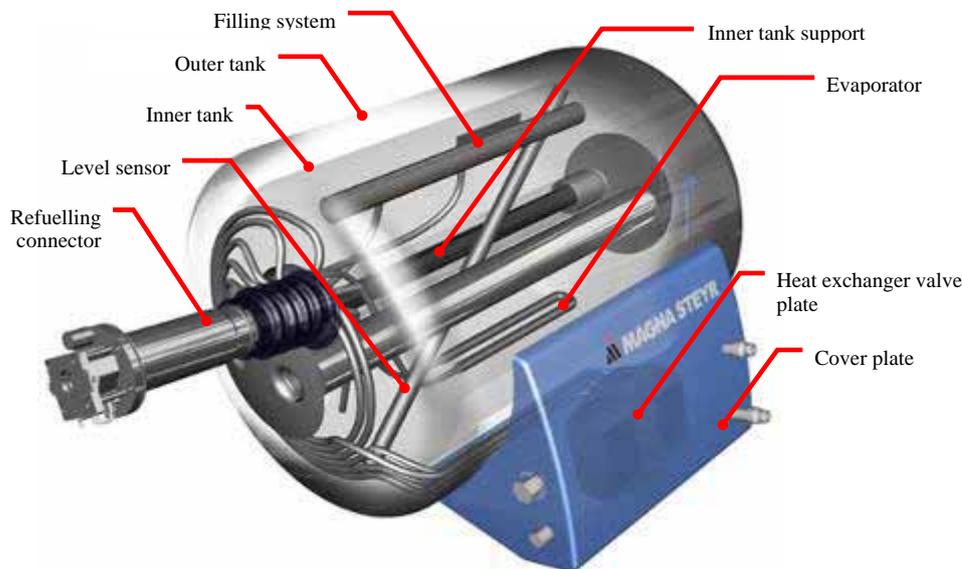


Fig. 9.2 Liquid hydrogen storage tank (picture supplied by BMVIT).

9.2 Overcoming barriers

The high purchase price for the final customer has been identified as the main barrier for the introduction of clean technology vehicles like EVs (electric vehicles), HEVs (hybrid electric vehicles) and alternative fuel vehicles. A second important barrier is the lack of infrastructure to refuel these types of vehicles. Today, building a hydrogen refuelling infrastructure is internationally recognised as an important barrier for the introduction of fuel cell vehicles.

Currently there is no governmental programme to subsidise or support the introduction of EVs and/or HEVs in Austria. However, some regional financial support programmes exist, mainly focusing on electric vehicles in tourist resorts.

9.3 Market introduction

There are no EV or HEV market introduction programmes in Austria. However, some tourist resorts and villages only allow the use of electric vehicles on their premises. Table 9.1 gives a survey of the electric vehicle fleet in Austria per end of 2003. The number of electric vehicles remains low; they are only used in niche markets. The share of electric two-wheelers is relatively high.

Under the A3-Technology Programme, AVL List is leading an international consortium developing a PEM (Proton Exchange Membrane) fuel cell hybrid vehicle. The project was extended in 2004, aiming to develop a zero emission vehicle. The technical approach is to modify an existing electric vehicle -powered by lead acid batteries- into a hydrogen fuel cell vehicle. The market introduction of such a vehicle is still some years away.

Table 9.1 Austrian vehicle fleet. Status December 31st, 2003.

Vehicle type	EV fleet	Total fleet (gasoline + diesel + EV)
Motor-assisted bicycles	213	299 924
Small motorcycles	-	1 463
Light motorcycles	2	118 511
Motorcycles	12	186 970
Cars & vans	135	4 054 308
Buses	109	9 231
Trucks	26	326 087
Tractors	15	439 637
Self-propelled machinery	21	69 796
Total	533	5 505 927

9.4 Benefits of participation

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

- Remaining informed about technology developments regarding hybrid & electric vehicles and their drivetrains in other countries, and transfer this knowledge to the local industry.
- Participating in a network of well-known automotive laboratories, research organisations and governmental officials to jointly produce studies and reports.

9.5 Further information

More information on Austrian activities regarding hybrid and electric vehicles can be found e.g. on the following web-sites:

- www.arsenal.ac.at
Austrian Research Centres Arsenal Research (in English and German).
- www.avl.com
AVL List GmbH (in English).
- www.bmvit.gv.at/tech/a3.htm
Austrian Advanced Automotive Technology Programme of the Federal Ministry for Transport Innovation and Technology (BMVIT) (in German).
- www.echem.at
Competence centre for applied electrochemistry (in German).
- www.energytech.at
Platform for innovative technologies in the area of energy efficiency and renewables (in English and German).
- www.eva.ac.at
The Austrian Energy Agency (E.V.A.) (in English and German).
- www.magnasteyr.com
Engineering and vehicle assembly company (in Chinese, English, German and Japanese).

10 Belgium

In the years 2003 and 2004 some measures were taken on different levels in Belgium to promote clean road transport.

- 1 Fiscal and technological measures.
 - Reduced registration tax on vehicles complying with future emission standards and vehicles fuelled with LPG.
 - Continuation of a measure considering electric vehicles equivalent to vehicles with lowest taxes, for registration and circulation tax.
 - Reduced taxes on low sulphur fuels (<10 ppm) making them less expensive than non low sulphur fuels.
 - Road tax for heavy-duty vehicles depending on compliance with emission standards.
 - Preparation of new measures to offer income tax reduction for people acquiring vehicles emitting low CO₂ levels.
 - Introduction of diesel particulate filters (DPF) on all EURO-II buses owned by De Lijn (the Flemish public transport, 869 buses in total).
 - A tender by the MIVB/STIB (the Brussels public transport) to equip 269 EURO-II buses with diesel particulate filters (DPFs) in 2005.
 - Promotion of public transport by the Flemish government by offering free subscription for transport by De Lijn when a car license plate has been returned.
 - Demonstration project for clean public transport by De Lijn by equipping two buses with a combined DPF + SCR (selective catalytic reduction) system to reduce all emission components.
- 2 Infrastructural measures.
 - Integration of car and train transport.
 - Reorganization of urban transport.
- 3 Research and innovation.
 - Diesel particulate filters.
 - Fuel cell systems.
 - Production of hydrogen.
 - Development of hydrogen internal combustion engine (ICE).

Due to the federal structure of Belgium policy measures related to environmentally friendly traffic can be taken at national and regional level.

10.1 Enabling technologies

Research institutes, universities and R&D-centres play an important role in the development of hybrid vehicle technology, implementing the technology with the local industry as well as prepare the niche markets for a successful vehicle implementation.

Possible users of hybrid vehicles need to be introduced in some of the technological aspects and a network. Furthermore a secure system to provide after-sales service needs to be established. This can avoid problems that have mothballed too many vehicles from past demonstration projects.

Of course, market-ready hybrid vehicles like the Toyota Prius and the Honda Civic do not require such an intensive guidance.

Hybrid vehicle development and deployment

Vito

Vito (the Flemish Institute for Technological Research) develops hybrid vehicles for niche applications as well as hybrid vehicle components. Projects typically involve industrial partners that will guarantee the servicing of the vehicles once they are in use. An example of a project in the period 2003-2004 is the technology upgrade of the three hybrid buses of the city of Luxemburg.



Fig. 10.1 Hybrid bus of the city of Luxemburg and Vito hybrid van (HEVAN project), here pictured in Ghent, Belgium. (Photo supplied by Vito.)

Vito was a main partner in a Flanders' Drive cluster project with some important industrial partners in the Flemish automotive industry. The main activities were the gathering of technological information in relevant fields as well as broadening and deepening the acquired knowledge.

Vito was also the main partner in an ESTO-project to report to the European Commission the state-of-the-art of hybrid vehicle technology. In this project the expected evolution of hybrid vehicle technology until 2020 was described and compared to the trend in conventional vehicles.

In the 2003-2004 time frame Vito also performed projects dealing with:

- batteries, battery packs and distributed battery management for different chemistries;
- a design improvement on the auxiliary power unit of a series hybrid and
- a modification of a fast charge station for grid connected hybrid vehicles.

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

Green Propulsion

Green Propulsion, a spin-off from the university of Liège, is a R&D centre for clean vehicles. In the period 2003-2004 they have developed some prototype vehicles:

- an electric kart;
- an electric bike and
- a hybrid microbus.

The hybrid minibus is actually being produced by a French partner at a rate of one vehicle per week.



Fig. 10.2 Hybrid Kangoo, developed by Green Propulsion. (Photo supplied by Vito.)

Vrije Universiteit Brussel (VUB)

Through its involvement in the European Electric Road Vehicle Association, AVERE, the international association of European cities interested in the use of electric and hybrid vehicles, CITELEC and European Power Electronics and Drives Association EPE, the VUB is involved in quite some EV and HEV activities.

Hydrogen and fuel cells in R&D projects

Vito

Vito finalised the development of its fuel cell test infrastructure in 2004. It was put to good use for testing a fuel cell with ammonia reformer developed in the ACCEPT-project (EU FP5). Because of its testing activities Vito is a partner in the EU-project FCTESTNET (FP 5). Regarding the development of an energy policy on hydrogen, Vito participates in the EU-project Hysociety (FP 5).

Vito is the Belgian representative in the IEA Implementing Agreement ‘Advanced Fuel Cells’.

Vito and major industrial players established the “Vlaams Samenwerkingsverband Brandstofcellen” (the Flemish Fuel Cell Collaboration) with financial support of the Flemish government. The collaboration aims at information sharing, networking and establishing joint development projects.

Université de Liège (ULg)

The University of Liege has tested a 200 kW_e PEM fuel cell system on its campus. The test triggered research at other universities in the Walloon region in Belgium.

Vrije Universiteit Brussel (VUB)

The Free University of Brussels participates in two EU FP6 projects related to fuel cells. The HARMONHY project aims at establishing standards and regulations for hydrogen and fuel cell technology. The partners in INTELLICON develop DC/DC converter technology to replace batteries with ultra capacitors in fuel cell vehicles.

Project-H

Project H aims at making hydrogen fuel systems available for today’s passenger cars. The project H consortium combines academic and industrial know-how to develop both the refuelling infrastructure as well as the on-board technology (fuel tank, injectors, ...).

10.2 Overcoming barriers

Technical barriers can be overcome by technology partners that help to enable the application of hybrid vehicle technology.

Non-technical barriers require promotion and financial incentives to diminish their effect. The promotion is best performed with demonstration projects and official authorities making an example.



Fig. 10.3 Water (vapour) is the only exhaust product of fuel cell vehicles. Project H. (Photo supplied by Vito.)

Technical aspects

All organisations performing research on hybrid and clean vehicles also provide guidance for possible users of these vehicles. They are good partners to overcome technical barriers in demonstration projects because of their experience with such projects and their technical know-how.

Financial incentives

Financial incentives by federal or regional governments are not based on technology but on results. The measures do not favour e.g. advanced emission control technology or hybrid propulsion but benefit the use of vehicles with low emission levels or low fuel consumption.

Reduced registration tax on vehicles complying with future emission standards and vehicles fuelled with LPG

Until the end of 2003 vehicles complying with EURO-IV and vehicles fuelled with LPG benefited from a reduced registration tax. The measure was discontinued from January 2004 because the number of EURO-IV compliant vehicles was expected to become the standard in new vehicles offered on the market. However, the Toyota Prius model year 2003 benefited from this measure.

Continuation of measure considering electric vehicles equivalent to vehicles with lowest taxes, for registration and circulation tax

Regardless of their power and size, electric vehicles are fiscally equal to the smallest vehicle available in the tax sheets. This implies the lowest registration and circulation tax. This measure is continued from before the reporting period.

Reduced taxes on low sulphur fuels (<10 ppm)

To speed up the introduction of low sulphur fuels (<10 ppm) tax levels for low and non-low sulphur fuels were differentiated to overcompensate the higher production cost and make low sulphur fuels less expensive. The switch to low sulphur fuels in Belgium was made in a period of a few weeks.

Eurovignet for heavy-duty vehicles depending on compliance with emission standard

In April 2001 the Eurovignet was introduced for heavy-duty vehicles. The Eurovignet is required to use motorways in Belgium and some other European countries. The cost is differentiated according to the EURO emission standard the vehicle complies to. Owners of newer vehicles -abiding lower emission levels- pay less.

Preparation of new measures to offer income tax reduction for people acquiring vehicles emitting low CO₂ levels

People buying a vehicle emitting low levels of CO₂ will obtain a reduction on their income tax. Depending on the CO₂ emission level, part of the acquisition cost of the vehicle (3% but not exceeding €615 for 115 gCO₂/km up to 15% but not exceeding €3280 for 105 gCO₂/km) will return to the owner when his/her income taxes will be finalised (approximately 2 years after buying the vehicle). This new ruling was prepared in 2004 to become active in 2005.

Although this measure does not benefit hybrid vehicles in particular, it goes without saying that Toyota Prius owners will obtain the highest benefit when buying their vehicle in 2005.

Promotion of public transport by the Flemish government by offering free subscription for transport by De Lijn when a car license plate has been returned

Families reducing the number of cars they operate can obtain a 3-year free subscription to travel with the services of De Lijn. When the family still has a car available -either their own vehicle or company car- one family member of choice obtains the subscription. When the family returns the licence plate of their only vehicle all family members can obtain the free subscription.

Environmental fleet screening

The Flemish Ministry of Environment (financially) encourages Flemish cities and communities to perform an environmental fleet screening. For this purpose Vito has developed a software tool implementing the Cleaner Drive environmental rating methodology. The tool provides feedback on which vehicles perform better or worse and how to improve the fleet performance.

For larger fleets Vito provides integral consultancy projects with more in-depth analysis of the fleet and its performance. The analysis is complemented with extensive feedback on measures to take and priorities to give for optimal fleet performance with balanced efforts. Due to their low fuel consumption and low emissions, the implementation of more hybrid vehicles is a substantial part of the more ambitious scenarios laid out in the consultancy report.

Demonstration projects, public and users acceptance

De Lijn

De Lijn (the Flemish public transport company) successfully concluded its demonstration project with diesel particulate filters (DPFs). Scientific and technological support was provided by Vito and funded by the Flemish Ministry of the Environment. Vito assessed the performance of the DPFs with its VOEMLow on-board high-grade emission measurement system. Following the success of the whole project the Flemish government decided to invest in DPFs for all EURO-II buses of De Lijn.

To tackle the other harmful emission component in diesel exhaust (NO_x), De Lijn started a demonstration project with a combined DPF+SCR (selective catalytic reduction) system. Two EURO-II buses are equipped with systems from different suppliers. Scientific and technological support is provided by Vito and funded by the Flemish Ministry of the Environment. Vito assesses the performance of the DPF+SCR systems with two VOEMLows in tandem, measuring pre and post aftertreatment emissions. Initial results indicate that the buses now can meet the EURO-V requirements.

De Lijn and Vito are looking into possibilities to upgrade the two hybrid Van Hool buses that are currently out of service. Vito proposes to upgrade the powertrain and battery packages.

MIVB/STIB

The MIVB/STIB (the Brussels public transport company) published a tender to acquire 269 DPFs for its EURO-II buses. The buses will be converted in 2005.

10.3 Market introduction

Fleet quota by Brussels Capital – Region

Brussels Capital – Region has decided to introduce and maintain clean vehicles in its entire fleet. The target is to have at least 20% clean vehicles. Amongst the technologies selected as being clean are hybrid power trains, fuel cell power trains and electric vehicles. The total number of clean vehicles will be a few hundred. This measure will create a market for these vehicles and facilitate the market introduction.

EcoScore by Vito and Vrije Universiteit Brussel

Vito and VUB developed a more advanced methodology to rate the environmental friendliness of vehicles. The methodology takes the well-to-wheel emissions as well as the noise level into account.

10 Belgium

A web-site presenting this rating for all vehicles that are available on the market will be established soon.

People using the web-site -when looking for a new vehicle- will be able to compare the environmental performance of the vehicles they have in mind. For those users who have question about the ratings as well as the alternative technologies of the cleaner vehicles, information will be provided.

Due to the good environmental rating of hybrid vehicles, some people may be convinced by the EcoScore to opt for these vehicles.

The project is funded by the Flemish Ministry of the Environment.

10.4 Benefits of participation

The participation to the activities of the IEA Implementing Agreement HEV has several advantages.

- 1) The exchange of information from and experience with relevant public R&D programs in the transport sector from various countries allows a better preparation of national programs and projects.
- 2) The informal personal contacts with experts from different countries and from various organizations may be sources of new ideas, collaboration and enlarged co-operation in various scientific, technological and regulatory/standardization fields.
- 3) The contacts between researchers and specialists bring synergies.

10.5 Further information

The following web-sites give further information on the activities in Belgium.

- www.vito.be
Vito, the Flemish Institute for Technological Research.
- www.vub.ac.be
Vrije Universiteit Brussel (VUB).
- www.ulg.ac.be
Université de Liège (ULg).
- www.greenpropulsion.be
GreenPropulsion.
- www.project-h.org
Project H.

11 Finland

11.1 Enabling technologies

In Finland there are no passenger vehicle manufacturers, and thus R&D in the automotive sector is mostly related to vehicle components rather than complete vehicles. However, some manufacturing of specialty vehicles, heavy-duty trucks and busses takes place, but none of the vehicles produced specifically utilise electric traction or hybrid technology. Even though it is on a small scale, Electric Vehicle (EV) component R&D is done in Finland by a company called AC Electric Vehicles, which develops e.g. controllers, motors and battery management systems (see figure 11.1). However, currently most of their customers are not related to the EV industry.

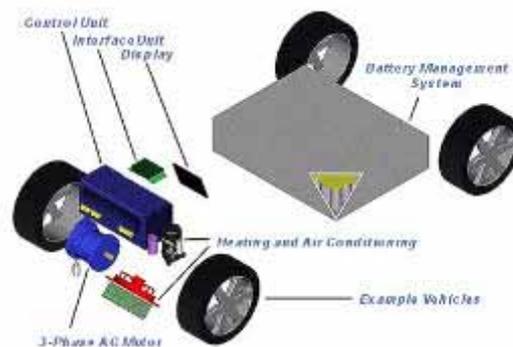


Fig. 11.1 AC drive system components provided by AC Electric Vehicles (photo by ACEV Ltd).

Beginning in 2003, Finnish Electric Vehicle Technologies Ltd (FEVT) together with Elcat Ltd, a former manufacturing company of EVs, started importing to Europe a new type of lithium batteries produced in China and that are meant to be used in EVs. This is partly intended to benefit the refurbishing of the pre-owned postal vehicles, withdrawn from the active service because their lead-acid battery packs became degraded. This way the number of private EV drivers could be increasing, because with a fresh and very active battery, people might be more interested in buying such vehicles.



Fig. 11.2 EnergyPack – a new type of lithium battery manufactured in China (photo by FEVT Ltd).

Hydrocell Ltd continues its research and development on fuel cell batteries (fuel cell + metal hydride reservoir). Previously their fuel cell batteries have been demonstrated in small applications, such as portable electric tools. Later on their R&D focused more on larger fuel cells and the launch of a fuel cell battery took place in 2004. It has a power of 25 W, tubular solid-state construction and it can be coupled to their metal hydride hydrogen storage device that can store 200 (MH200) or 1200 litres (MH1200) of hydrogen. The application range is recently widened to demonstrate its use in an e-scooter and an e-bike (see figure 11.3). They have also started negotiations with hydrogen retail companies to supply the hydrogen for the fuel cells of these vehicles, using a system in which an empty metal hydride vehicle storage device is replaced by a full one.



Fig. 11.3 Fuel cell HC-100 by Hydrocell Ltd combines metal hydride hydrogen storage and fuel cell to produce 14,4 V (DC) at 1,6 A current level. Hydrogen capacity of the smaller hydride storage MH200 is 36 Ah, and the larger unit MH1200 equals 220 Ah. These are used to power an e-bike and an e-scooter (photos by Hydrocell Ltd).

11.2 Overcoming barriers

The Finnish automotive market volume is quite modest (about 150 000 units are sold annually) and this small volume combined with a high vehicle purchase tax (relative to the vehicle price) leads to the fact that Finland does not attract foreign EV or HEV manufacturers very much to enter the market. Previously, the only EVs available on the market were Elcat EVs. The limited product range of Elcat EVs (mainly small vans) has not been appealing to all potential customers. Since the changes of the past few years in Elcat ownership and strategy, the company has now become an EV importer instead of an EV manufacturer. This widened the available product range significantly, making electric 2-3 wheelers, scooters, bicycles, golf carts and even an electric light truck commercially available in Finland.

At present, there is no governmental programme to stimulate the production, purchase or use of EVs or HEVs in Finland.

QualTron™ and a
TM (unregistered) designator
are needed to use the picture.

Fig. 11.4 Melex light utility EV, now imported to Finland by Elcat. Price starts at 12 500 € (photo by J. Laurikko).

11.3 Market introduction

Although bicycles in general are not very popular for transportation in Finland due to the cold climate, Elcat and Helkama have sold a couple of hundred e-bikes. Furthermore, Elcat has sold a fair amount of electric scooters and the amount is expected to increase, because the prices for electric scooters are very similar to the prices of conventional scooters. Special scooters for elderly and disabled people have been promoted in Finland also during the year 2004. In addition, by the end of 2004 there were several different models of e-bikes on the market, as well as two different kinds of e-scooters, and electric kick-boards. Several companies have started to import electric scooters and kick-boards to Finland (figure 11.5 gives some examples). The price range starts at about 200 € and goes up to 500 €.



Fig. 11.5 Selection of light 2-3 wheel electric scooters and kick-boards offered for sale in Finland (picture by KoneGlans Ltd).

The target market segments for these electric 2-3 wheelers are for example golf courses, hospitals, airports and factory personnel, who need fast and silent transportation both indoors and outdoors, as well as the elderly, physically disabled, and the year-round commuter cyclists.

The biggest e-bike user is Finland Post Ltd, which has used custom-made Helkama bicycles for post delivery since the year 2000. The postal fleet also still includes some Elcat E-Vans and one Citroën Berlingo in daily use. The electric Berlingo has been tested in different locations and routes in the daily postal delivery, and building on the collected experience the Finnish Post now has plans to purchase more of these vehicles.

The year 2004 marks the market-entry of HEVs in Finland. The Toyota Prius II was launched in the spring and -in spite of the steep price (ca. 40 000 €) and no tax relief programmes or other benefits- the cumulated sales figures reached almost 100 by the end of the year. This is a vast increase in market acceptance, since the first-generation Prius did not even pass the initial criterion of a fixed order for 20 cars to make it available on the Finnish market.

11.4 Benefits of participation

The participation to IA-HEV has provided an opportunity to closely follow the worldwide evolution of EV and HEV technology and make that information available to interested parties in Finland. It has also provided an opportunity to make the developments in Finland regarding EV and HEV technology and market known to international experts. Furthermore, the direct link to participants in the agreement provides possibilities to bi-lateral or multilateral communication regarding initiatives towards market-success and wide deployment of EVs and HEVs.

11.5 Further information

More information about the Finnish companies that are mentioned in this chapter can be found on their respective Internet web-sites.

- www.acev.fi
Web-site of AC Electric Vehicles Ltd, which is performing EV component R&D.
- www.elcat.fi
Web-site of Elcat Ltd, a former manufacturing company of EVs.
- www.fevt.com
Web-site of Finnish Electric Vehicle Technologies Ltd (FEVT).
- www.hydrocell.fi/en/index.html
Web-site of Hydrocell Ltd, doing research and development on fuel cell batteries (fuel cell + metal hydride reservoir).

12 France

12.1 Enabling technologies

In addition to the already existing production of electric vehicles by the major French automakers Citroën, Peugeot and Renault, a new company specifically dedicated to electric vehicles has been created. The company SVE (Société des Véhicules Electriques) is on its way to commercialize a new electric vehicle.

12.2 Overcoming barriers

12.2.1 Incentive program for electric vehicles

On the 31st of December 2004 finished the previous incentive program for the purchase of EVs (electric vehicles). The ADEME (Agency for Environment and Energy Management) has decided to continue to support the development of the EV market by a new incentive program. The structure of the program has been simplified so that communities and other users will receive the same premium for the purchase of an EV. Furthermore the amounts of the premiums have been increased with a special bonus for very small companies, shops and artisans.

12.2.2 Program for environmental friendly vehicles

In September 2003, the French Prime Minister Mr. Jean-Pierre Raffarin announced the new governmental program for Environmental Friendly Vehicles (EFV). The plan was conceived in partnership with the French manufacturers. It consists of an additional support of almost 40 million Euros, dedicated to research and development. The program is now operating by means of the French National Program for Research on Transportation (PREDIT III) in which ADEME plays a paramount role.

Among the priority topics selected one notes:

- Management and storage of the electric power aboard the vehicles (8 M€), in order to overcome the obstacles to the development of the electric and hybrid vehicles.
- Development of the fuel cell (6 M€). Used as main or auxiliary energy source, this system will constitute a real technological rupture compared to the combustion engine. This financial support will complement European and world scale fuel cell programs in which France participates.

12.3 Market introduction

12.3.1 Electric vehicles

During the year 2004, 106 electric scooters, 134 light-duty vehicles or passenger cars and 67 specific electric vehicles have been registered. In comparison to the previous year, one observes a sales decrease of 26 % for specific EVs, 40 % for light duty vehicles or passenger cars. The market of two wheelers is stable.

The new electric truck based on the Renault Midlum chassis is now commercially available. Developed with financial support of the ADEME, the 10 tons electric truck can do all the urban missions usually done with diesel trucks. It has a maximum driving range of 80 km in pure electric mode with a maximum speed of 70 km/h. Optionally, a 15 kW range extender can add 10 km of driving range per functioning hour. So equipped the truck has a driving range of 100 km in urban conditions and meet the goal of reducing air pollution in towns.

Tested by several companies all over the nation, the product has been well accepted. The manufacturer plans to sell ten to twenty vehicles next year. ADEME and the French utility EDF (Electricité de France) joined in a Framework agreement will give their financial support to the first delivery operations using this vehicle.

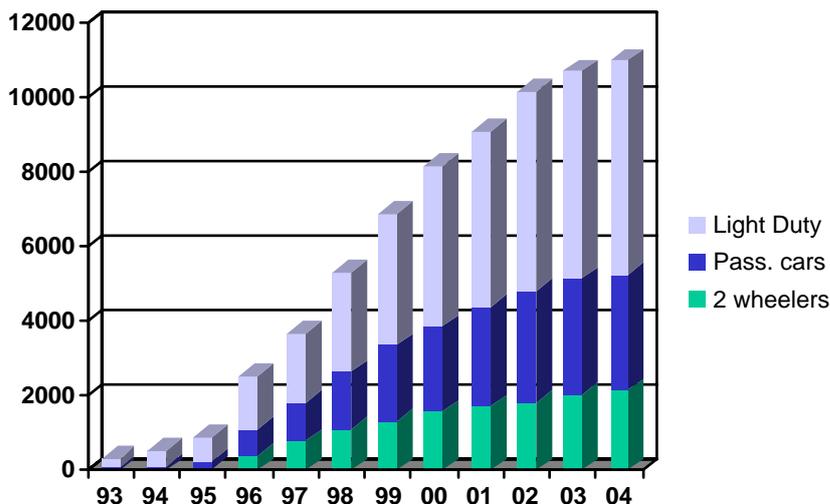


Fig.12.1 Electric vehicles in France over time (picture supplied by ADEME).

With a definite and regular service, urban buses constitute a sector offering a strong potential for the development of the electric traction. With the aim of promoting EVs in the equipment of the communities and operators of transport, ADEME, EDF, the GART (Group of Transport Authorities) and UTP (Union of Public Transportation) launched in February 2002 a call for projects entitled "100 Electric buses". By the end of the time that was scheduled for the call, 20 projects had been presented and selected, representing a fleet of 92 buses. The market of electric buses starts its development in France, so the costs of investment are still rather high. They are between 120 000 € and 160 000 € for a small bus for 20/25 passengers and between 270 000 € and 305 000 € for a bigger vehicle offering a capacity of 40/60 passengers.

Nevertheless, the program has stimulated manufacturers and importers, so it is possible for customers to find a product that fits their needs.

Average energy consumption from the grid is between 0.6 and 0.756 kWh/km for a small bus for 22 passengers and 1.04 to 1.4 kWh/km for a medium size bus for 55 passengers. Thanks to the very low CO₂ emissions of the French electric kilowatt-hour (74 gCO₂/kWh) an electric bus with 20/25 seats (0.6 kWh/km) having a annual mileage of 30 000 km allows to avoid the emission of 11.8 tons CO₂ compared to an equivalent ICE (Internal Combustion Engine) bus (14 l/100 km). For the same mileage, but with a higher fuel consumption (50 l/100 km), this benefit increases to 44.7 tons for a vehicle with a capacity of 50/60 passengers (1.22 kWh/km).

Concerning light electric vehicles, the recently created company SVE (Société des Véhicules Electriques) as unveiled during the "Mondial de l'Automobile 2004" its prototype vehicle based on Renault Kangoo and equipped with a lithium-ion battery. At the same time, the French business man Vincent Bolloré announced that Matra and the battery company Batscap will present a new pure EV equipped with a Lithium Metal Polymer battery pack at the 2005 Geneva auto show.

12.3.2 Hybrid vehicles

In November 2004 the hybrid car Toyota Prius 2 has been elected "voiture de l'année 2005" (car of the year 2005) by the French automotive press. The Prius 1 was the first hybrid car launched in France in 2000, but this model has been sold in very small numbers (15 sold in 2003; 150 during the whole period from 2000 to 2003). For the second version, which is more comfortable and less expensive, the 500 units planned for the French market for 2004 had already been sold in September.

During the same period, the French automaker Citroën presented its C3 stop and start model. The automatic transmission "SensoDrive" combined with the "Stop and Start" function allows a major reduction of CO₂ emissions. In urban driving, CO₂ emissions and fuel consumption are reduced by almost 10%, and by approximately 6% in a mixed driving cycle.

12.4 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.

12.5 Further information

More information about HEVs in France can be found on the following web-sites:

- <http://assoc.wanadoo.fr/avem/>
Description: "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. Language: French.
- <http://transports.edf.fr/>
Description: 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. Language: French and English.
- <http://www.gart.org/>
Description: "Groupement des Autorités Organisatrices de Transport" (Group of Transportation Authorities). Content: Information about clean transport, public transportation and goods delivery. Language: French.
- <http://www.ademe.fr/>
Description: Site of the French Agency for Environment and Energy Management. Content: A lot of information about environment plus special pages for transport and financial incentives. Language: French.
- <http://www.clean-auto.com/>
Description: Site of the clean@uto magazine. Content: Very riche site about all the clean solutions for transportation (EV, HEV, FCEV...). Language: French.

13 Italy

In the past two years the national transport policy was further focused on clean vehicles in order to minimize the greenhouse gas emissions (GHG) and to improve the air quality in major cities as a consequence of repeated environmental emergencies. This policy was also a significant part of the National Plan for the CO₂ reductions in the period 2003-2010, aiming at meeting the overall Kyoto Protocol targets. The main efforts in the transport sector are in fact 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 CO₂ average emissions not more than 120 g/km (European and national voluntary agreements).
 - Introduction of more efficient and cleaner heavy-duty vehicles by accelerating the use of new European Union 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 the 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.

In addition, the efforts of the central government on 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.

13.1 Enabling technologies

In recent years a 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 Union and national level: the VI Framework Programme of the Commission of the European Communities (CEU) and the Italian National Plan for Research.

These programmes have been able to streamline the running projects on fuel cells (FCs), batteries and drive trains, 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 recently been approved and are now under a final revision process. 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 M€ of which about 70% is public funding. The projects on hydrogen involve ENEA, FIAT Research Center, 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, 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 (see figure 13.1) 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.

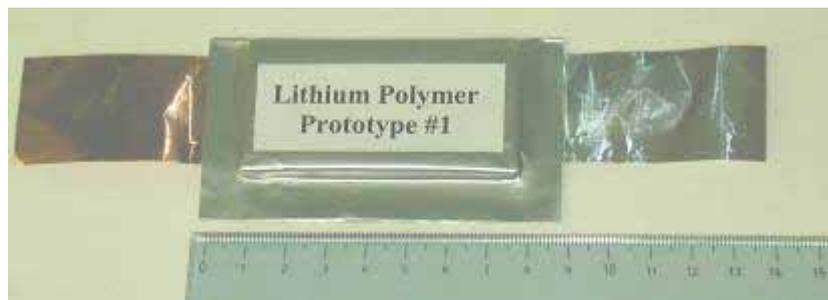


Fig. 13.1 ENEA Lithium metal softpack (710 mAh – 167 Wh/kg) prototype for EV applications. (Photo supplied by ENEA.)

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 (PEFC) and development of catalysts for fuel processing systems. Eight organizations (public research and industry) are involved. Promising results are continuous development of national FC systems, which are being incorporated in some prototype vehicles.

Major industry projects

Nuvera Fuel Cells

Nuvera (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 autothermal reforming). A new generation of FC stacks was then presented (illustrated in figure 13.2) and prototypes of fuel processors were shown. Material research is underway in the FISR projects already mentioned.



Fig. 13.2 75 kW PEFC stack ANDROMEDATM by Nuvera Fuel Cell. (Photo supplied by ENEA.)

Arcotronics Fuel Cells

The company 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 5 kW 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. A recent version of the 5 kW PEFC is shown in figure 13.3.



Fig. 13.3 Arcotronics FC 5 kW PEM FC Stack. (Photo supplied by ENEA.)

IRISBUS FC Urban Hybrid Bus (IVECO)

The first IVECO FC Hybrid Bus, officially presented in 2001, completed test trials (about 5000 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 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, which 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.

FIAT Group

The company -through its subsidiary FIAT Research Centre- is involved in a variety of national and European R&D projects on hybrid (such as the SUVA Project) and FC electric vehicles. Recent 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 Ni-MH with an energy capacity of 0.9 kWh). Figure 13.4 shows this new FC EV.



Fig. 13.4 FIAT 600 “Hydrogen” (2003) (courtesy Fiat Group).

The high pressure (350 bar) storage tanks (from ATK- Thiokol) can contain 1.6 kg of hydrogen, able to fuel the PEFC generator, which together with the battery, powers the 30 kW asynchronous electric motor driving the vehicle up to an urban driving range of 220 km (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 (figure 13.5). 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.



Fig. 13.5 FIAT Panda Hydrogen (courtesy Fiat Group).

Piaggio

This international leader in two-wheel vehicles -besides developing of a new battery-powered electric scooter (the ZIP Electric) with various battery types and the commercialization of electric vans- has been involved in the development of a FC 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 FC generator, using a composite pressurized tank for hydrogen storage.

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 fuel economy, 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.

13.2 Overcoming barriers

Technical and non-technical barriers (financial, regulatory, social) have all been tackled as part of the public initiatives to favour a wider introduction of cleaner vehicles. Central and local authorities have proposed and enacted special laws for addressing (mainly environmental) problems.

Technical aspects

The use of power-assisted bikes has been difficult in Italy for years because of the lack of clear definition of the specific category. After the approval of a European Union 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 (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 EVs (and even 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 Euros 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 3000 vehicles. The rules that have been published recently 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”, 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, 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. Table 13.1 gives the subsidy scheme applied in Modena, as an example of such measures.

Table 13.1 Subsidy scheme for EVs and HEVs in Modena.

EVs + HEVs	Subsidy in Euros (max. 35%)
Power-assisted (P.A.) bike	361.52
Electric kit for P.A. bike	129.11
2-w-scooters	774.69
3-w-scooters	2 582.28
Passenger cars	5 164.57
Hybrid cars	2 582.28
Commercial vans	5 164.57
Batteries, EM & chargers	77.47

More recently, the Lombardy Region approved two new funding instruments for funding the introduction of clean vehicles in the region.

Demonstration projects; public and users acceptance

Special promotional days “Ecological Sundays and/or Car Free Days” are currently 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, using public incentives. This worldwide awarded initiative (Global E-visionary Award from WEVA) turned into 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. Figure 13.6 shows the small fleet for a new project for renting the EVs to commercial companies.



Fig. 13.6 EV commercial fleet in the city of Reggio Emilia. (Photo supplied by ENEA.)

13.3 Market introduction

The market demand of EVs and HEVs in recent years varied substantially with the availability of public subsidy. Slowing down the introduction of subsidy initiatives at local and central governments impacted the market share for such 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 CEI-CIVES (the Italian EV 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 EVs and HEVs demand is growing. The inventory of the vehicles that are offered on the Italian market -continuously updated by CEI-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 2003, the estimations of CEI-CIVES reached a total number of EVs and HEVs sold in Italy in excess of 95 000. Figure 13.7 presents the market distribution by type in 2003.

Preliminary market monitoring for 2004 shows a significant increase of small EV sales: more than 12 500 power-assisted bikes and more than 1500 electric scooters. Toyota Prius hybrid vehicle (second generation) sales have been supported by a company promotional campaign but the market results are not yet available.

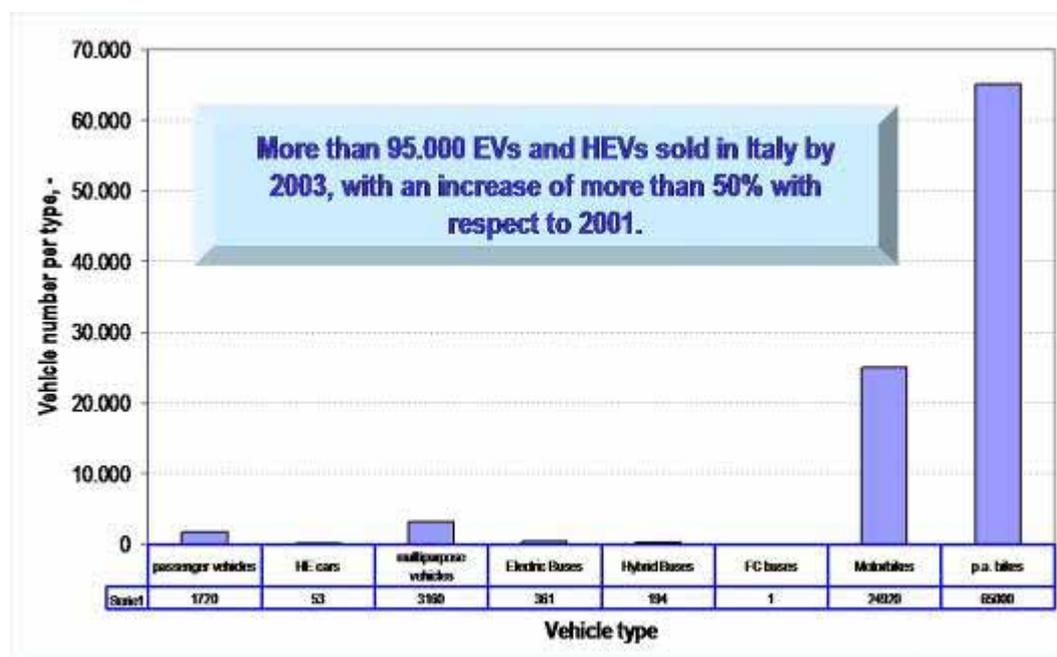


Fig. 13.7 EV and HEV sold in Italy as of December 2003. (Picture supplied by ENEA.)

13.4 Benefits of participation

The participation to the activities of the IEA Implementing Agreement 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 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 and multilateral collaborations.

13.5 Further information

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

- www.ceiuni.it/cives.htm
This is the official web-site of the Italian Electric Road Vehicle Association - CIVES, an internal committee of the Italian Electrotechnical Commission and National Section of the European Electric Road Association – AVERE. The web-site is in Italian and 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, updated in 2003, is also available online.
- www.minambiente.it
The web-site of the Ministry of the Environment and the Territory is in Italian and 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 “AmbienteInforma”.
- www.enea.it
The ENEA web-site is in Italian and in English. It normally presents programs, projects and activities in general terms, but also special report about Energy and Environment. It is worth to mention under the title “publication” a Survey Report (in Italian) -in pdf format and downloadable- on the status of fuel cell technology, updated in February 2002.
- www.crt.unige.it
This is the web-site of an academic research centre on transport located at the University of Genova. The web-site has an English version, which can be easily used. 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.regione.lombardia.it
This web-site (in Italian) contains information about all the initiatives of the Lombardia Region for the introduction of clean vehicles and fuels.
- www.comune.roma.it/mobilita/
This is the web-site of the Rome Township – General Direction Transport. The web-site is mainly in Italian and contains information about initiatives for promoting the use of clean vehicles in the city.
- www.nuvera.com
This is the web-site (in English) 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.arcotronicsfuelcells.com
This web-site (in English) describes projects and products of a company producing fuel cells (PEFC).

- White paper on EVs.
This publication in Italian has been produced by CEI-CIVES to summarize major advantages and possibilities of EVs. This publication is available directly from CIVES.

14 The Netherlands

14.1 Enabling technologies

The Netherlands has a few manufacturers of automotive vehicles for road transportation: an assembly plant for cars (NedCar), a truck manufacturer (DAF Trucks, part of the US based Paccar company) and an assembly plant for trucks (Scania, a Swedish truck manufacturer). Since 2003 there is one bus manufacturer for public transport busses and touring busses on the market (VDL Group). This company has three locations for manufacturing the vehicles. In the Netherlands there are a lot of small companies that are producing truck bodies, trailers and semi-trailers, and manufacturers for automotive components and automotive materials.

To support these manufacturers the Netherlands has research institutes with specific automotive knowledge, like TNO Automotive, Energy Centre Netherlands (ECN) and universities/colleges with specific automotive departments and laboratories. These institutes are internationally known. TNO Automotive has recently opened a test and demonstration facility for automatic guided vehicles.

In 2003 an Automotive Technology Centre was founded in Eindhoven, the home city of a technical university with a strong automotive department. Automotive companies and R&D institutes are participating in this Centre. The city of Eindhoven is located in the Southeast of the Netherlands, and therefore geographically close to the automotive centres in Aachen/Germany and the automotive companies in the North of Belgium.

In the field of hybrid and electric vehicle technologies the research institutes are taking the lead, and are providing the manufacturers with automotive knowledge and testing facilities. The technologies concerned are: hybrid drive systems, batteries, lightweight materials and technologies for automated transportation systems.

All the models of hybrid and electric cars are coming from manufacturers that are based outside the country. They are imported by the national importers of the manufacturers, either from Europe (PSA, Renault and FIAT) or from Japan (Toyota and Honda).

At this moment there are only a few types of electric vans available on the market.

The Toyota Prius II (car of the year 2005) and the Honda Civic IMA are the hybrid vehicles that are commercially available on the market, and they are well accepted by the public. The sales of the Prius II in 2004 were rapidly growing.

The Netherlands is one of the European countries that has more bicycles than inhabitants, and historically the country has some bicycle manufacturers. Nowadays electric bicycles are commercially available. Some models are fully electrically driven while others are equipped with electrical assistance. An electric bicycle made by a Dutch manufacturer is chosen as the bicycle of the year 2004.

The Netherlands has some manufacturers of automotive LPG (Liquefied Petroleum Gas) systems. The availability of LPG is very good; almost every fuel station along the main roads provides LPG. By the end of 2004, approximately 4 % of the car fleet is using LPG as the main fuel. (All LPG-cars are of a dual-fuel type; gasoline and LPG.) Sales of new LPG-cars are declining rapidly because of currently low economical advantages.

The share of diesel cars in new car sales has increased in 2004, compared to earlier years.

CNG (Compressed Natural Gas) is hardly used as a motor fuel in the Netherlands. Only some small-scale operations are ongoing. Most demonstration projects are subsidised by the government.

14.2 Overcoming barriers

The most common barrier for the introduction of hybrid and electric vehicles is the purchase price for the customer, which is still higher compared to vehicles with internal combustion propulsion systems. For electric scooters there is the problem of customers' acceptance. The governmental policy is to support the introduction of such vehicles and therefore some supporting programmes are operating. Most of the programmes are based on the principle of subsidising market introduction projects (as investment support). For this purpose a programme called Demonstration projects Mobile Sources

(DEMO) was in operation until the end of the year 2003. The programme was financed by the Ministry of Environment and it was executed by the Netherlands Agency of Energy and the Environment (SenterNovem). The programme was terminated in 2004.

The Dutch government is now changing the direction of the intentions of the programmes from a supply orientation towards a demand orientation.

To stimulate the introduction of electric vehicles, the government has exempted these vehicles from the annual road tax. The number of electric vehicles on the road is rather low, a few hundred vehicles.

14.3 Market introduction

Until 2004, the Dutch government operated the DEMO programme to stimulate the market introduction of vehicles with new technologies.

The government is now setting up policy measures to stimulate market demand. Influencing vehicle end users (the drivers) will also stimulate vehicle manufacturers to develop products with low energy consumption and low emissions (such as NOx and particulates).

In 2003 the city of Amsterdam became a partner in the CUTE-project. This project is set up to collect field experience with 30 fuel cell busses in operation for public transport in 10 cities throughout Europe. The fuel cell busses are manufactured by DaimlerChrysler in Germany. The project in Amsterdam is running very well and the city public transport company is satisfied with the experiment.

14.4 Other measures to reduce vehicular energy consumption

The governmental objective for road vehicles is mainly focussed on the use of different fuels for various vehicle categories. The total energy consumption by transportation is about 18 % of the total national energy consumption, so reducing this part of the energy consumption is quite important. Car dealers in the Netherlands put an energy consumption label on new cars in their showrooms. This label is providing data on the energy consumption in litres per 100 vehicle-km and it also mentions the CO₂ emissions in kg per vehicle-km. This label is very well accepted and known by the public.

In the Netherlands two other important programmes are executed for the reduction of energy consumption in transportation.

One programme is called "The new way of driving". This programme is seeking to change driving behaviour of car drivers. By teaching them the rules for energy efficient driving, some 5 to 10 % reduction of fuel consumption can be achieved.

The other programme is called "CO₂ reduction in person transport and in goods transport". Within this programme rebates are given for investments in fuel efficient vehicles and transportation systems.

14.5 Benefits of participation

The benefits from participating in the Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes are from the perspective of the Netherlands:

- Obtaining information on advanced transportation and automotive technologies that is available in other countries form around the world.
- Jointly producing studies and having opportunities to get national research bodies involved in the work.
- To be able to use results from programmes from other countries and cultures for guidance in preparing national programmes.
- Participating in a network of transportation experts, research institutes and government officials responsible for transportation.

14.6 Further information

More information can be found on the Internet, on the following web-sites:

- www.senternovem.org (in English)
The web-site of the Dutch Agency for Energy and Environment, an agency of the ministry of economic affairs. The agency executes governmental programmes for energy efficiency and emissions reduction.
- www.automotive.tno.nl (in English)
The automotive section of the TNO research institute.
- www.ecn.nl (in English)
ECN is a Dutch research institute for energy technologies. Within ECN operates an unit for research on fuel cells for mobile applications.
- www.innas.com (in English)
Innas is an engineering consultancy bureau. Innas operates an automotive fuels database for the IEA Implementing Agreement on Advanced Motor Fuels.
- www.atcentre.nl (in Dutch)
The automotive research centre at the Technical University of Eindhoven.
- www.schonevoertuigen.nl & www.platformschonevoertuigen.nl (both in Dutch)
Information sites for clean vehicles.

15 Sweden

15.1 Enabling technologies

Research programmes

There are, in principle, five national research programmes dealing with issues related to cleaner vehicles:

- **The Green Vehicle Programme** is a joint programme between the automotive industry and the government. The total budget is approximately USD 180 million, the administrator is VINNOVA and the programme runs from 2000 to 2005. The objective is to develop cleaner vehicles. About USD 10 million are budgeted for specific electric, hybrid and fuel cell vehicle research. In 2004, the programme was extended until 2007, although without any additional funding.
- **Energy Systems in Road Vehicles** addresses energy-related issues in vehicles. It 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 USD 20 million, and the Swedish National Energy Agency administers it. The programme entered its third phase in 2004, running until the end of 2006 with an additional budget of about USD 17 million.
- **Fuel Cells for a Better Environment** is the second part of a programme that started in 1997, was slightly modified during 2002 and that ends in 2006. The administrator is MISTRA and the programme includes research projects on fuel cell system components, materials and systems. The total budget is approximately USD 10 million.
- **Emissions Research Programme, EMFO.** EMFO is a joint programme between the automotive industry and the government. The first projects in the programme started mid 2004 and address emissions research from road transport. The programme budget is approximately USD 4 million per year during 6 years.
- **Innovative Vehicles, Vessels and Systems** is a research programme that started during 2003. It addresses environment, safety and ITS (Intelligent Transport Systems) and emphasises the innovative character of the projects as well as the importance of an improved innovation system. All modes of transport are covered. Administrator is VINNOVA and the programme budget is approximately USD 5 million annually during 5 years.

Important technologies

Fuel cells. Research focus in Sweden has shifted from traction towards APU (Auxiliary Power Unit) applications and reformer technology.

Energy-efficient vehicles. Energy-efficient engines and propulsion systems are a must and a priority, both for the vehicle industry and the government. With two manufacturers of heavy vehicles based in Sweden, there is particular importance in improving the design of diesel engines.

Biofuels. Production methods for different biofuels are being investigated and tested. Cellulose-based ethanol production is one of the main areas of interest. Ethanol is used as a fuel in two different forms: as E85 (85 percent ethanol, 15 percent gasoline) and as an admixture in gasoline of up to five percent. Other important areas of interest are biogas and synthetic fuels.

15.2 Overcoming barriers

Hybrid and electric vehicle market

Only one hybrid or electric vehicle model is sold in Sweden, the Toyota Prius. Toyota introduced its latest model of the car (Prius II) on the Swedish market early in 2004. No other electric or hybrid electric vehicle is scheduled to enter the Swedish market in 2005.

Demonstration vehicles fuelled by hydrogen are being sought; in order to start demonstration projects and make the best use of available hydrogen production and distribution facilities.

Infrastructure development

The existing infrastructure of normal and fast charging stations for battery electric vehicles is still operating to a large extent, although no further installations are planned.

Hydrogen refuelling stations have opened in Stockholm and Malmö. The Stockholm station serves three Citaro buses from DaimlerChrysler's Evobus. In Malmö, hydrogen is mixed with natural gas for use in buses. A pure hydrogen refuelling station (350 bar) is also available.

Demonstration projects

One demonstration project involving electric and hybrid vehicles is CUTE (Clean Urban Transport for Europe). It is an EC-funded project introducing fuel cell buses. Stockholm is one of nine European cities that are involved in testing and evaluating the new technology. About half of the SEK 40 million for the Swedish project is in the form of EU grants; the rest has come from various parties. The buses have been operating in regular traffic since the beginning of 2004. DaimlerChrysler is the co-ordinator for the entire EU project.



Fig. 15.1 The fuel cell version of an Evobus Citaro bus in service in Stockholm. (Photo supplied by STEM.)

Saab has developed a prototype four-wheel drive hybrid car. It is a concept vehicle meant to learn about the technology. This car will not be available on the commercial market.



Fig. 15.2 Sweden's King Carl XVI Gustav tested a four-wheel drive Saab hybrid in November 2003. (Photo supplied by STEM.)

Volvo exhibited a concept study for a battery electric vehicle (named 3CC) at a motor show in China in 2004. Some facts about this vehicle are:

- • Maximum speed, 135 km/h.
- • Maximum driving distance, 300 km with lithium battery technology.
- • Acceleration from 0 to 100 km/h in 10 seconds.

15.3 Market introduction

Clean vehicles and fuels 2004

A symposium and exhibition was held in Stockholm in June 2004 (see www.cleanvehicles.net) with the aim of accelerating the introduction of cleaner vehicles and fuels in Europe. The target audience was European buyers and sellers of cleaner vehicles and fuels at all levels, from policy makers to fleet managers. The event attracted a large number of exhibitors and visitors. A similar conference, Clean Vehicles and Fuel 2005, is being planned and will probably be held in the autumn.

Table 15.1 On-road electric and hybrid electric vehicles in Sweden, including fuel cell vehicles.

Registered as:	Jan-03	Jan-04
Passenger car or light truck	980	1100
Heavy truck	5	5
Bus	11	17
Totals	996	1122

The table above shows the development in terms of the total number of registered on-road electric and hybrid vehicles in Sweden. Fuel cell vehicles are also included. As stated above, the electric and hybrid vehicle market is now limited almost entirely to the Toyota Prius, with a reported total sales figure of 619 units. Ten new battery electric vehicles were sold in 2003.

Other cleaner vehicles are mainly ethanol flexible fuel vehicles (about 9 300 on the road) and methane vehicles (approximately 4 100 on the road).

15.4 Special topics

Which vehicles are replaced by EV/HEV use?

HEV use

With only the Toyota Prius available on the market, there are several restrictions in terms of realistic market segments to attract. But unlike almost all other vehicles, the Prius has managed to attract buyers normally looking for a vehicle in another segment. The main reason for this is probably an interest in new technology and environmental aspects. This was confirmed by an interview with a Toyota dealer in Berkeley, California, in the summer of 2003. Toyota's Berkeley dealership has sold the largest number of hybrid cars throughout the USA, and probably also the most anywhere in the world outside Japan.

Sweden provides a number of incentives at national and local levels to increase the number of hybrids in Sweden. The tax on car benefit for company car users is reduced by more than 40 percent, and some local administrations give direct subsidies to buyers of new HEVs. Consequently, Toyota aims its marketing efforts mainly at companies: only a few private users have bought a Prius.

EV use

First of all, there are no BEVs (Battery Electric Vehicles) on the Swedish market, and so all analyses relate to historical data. In addition, even when they were available on the Swedish market, almost all BEVs were sold for special purposes, such as demonstration projects or as a result of technology procurement. This affects the analysis, as most programmes were directed towards certain target groups on the market.

Another important fact is that even if the BEVs were (are) quite well accepted by some of the users, the users are predominantly using them for test purposes, with test vehicles often being added to a fleet without actually replacing another vehicle.

Box 15.1

Evaluation of a battery electric vehicle project

The companies participating in the demonstration project undertook continuous evaluation of the electrical vehicles and of the project itself. One part of the evaluation was an attitude survey among the users, based on interviews with the decision makers/buyers and a questionnaire sent to the drivers. About 20 interviews were held and 70 questionnaires were answered.

Expectations

To the question: "Has the BEV fulfilled your expectations?", 74% of the drivers answered "Yes, in all respects", while the rest (26%) said "Yes, it has partly fulfilled my expectations". Users had a very positive opinion about the battery electric vehicle they drove. They were proud of driving an environmentally friendly vehicle, and said that the vehicle was easy to drive, silent and ideal for city use. Disappointments that were mentioned included the slow acceleration, the reduced maximum speed and the presence of / necessity for a petrol heater in the car.

The main difference in driving a BEV compared to a petrol car is the lack of engine braking. 47% of the drivers said that they had changed their driving because of the lack of an engine brake: they think ahead more, drive more gently and more calmly. Most of them saw these changes as positive. For example:

"I drive more carefully and take more responsibility in the traffic",

"I drive more gently and in a calmer way",
 "I drive more economically from an energy point of view, compared to driving a petrol car."

Some negative aspects mentioned were that the car was too slow when driving on highways and that the absence of engine noise was dangerous for cyclists and pedestrians. Drivers had to be more observant of the surrounding traffic.

One public authority, for example, had a few vehicles in a pool for its employees. Among the vehicles was a Renault Clio Electricque. It was not used very much until the booking system for vehicles was changed to make the user book the BEV if it was free (and had the needed capacity in terms of range and carrying capacity). This increased its use considerably, and one lesson learnt is that using BEVs in a car pool is a very good way to replace conventional vehicle use.

In a study made a few years ago in one of the BEV demonstration projects, the participating companies monitored the attitude of the vehicle users. The results are shown in box 15.1.

Benefits of using electric vehicles in urban areas

The general benefits of using BEVs are well-known and do not need to be repeated. Some policy tools used in Sweden to give extra benefits for BEV owners and/or users are:

- Free parking.
- Free recharging.
- Reserved parking places.
- Road tax exemption for new vehicles.
- Reduced benefit in kind for company cars (more than 40 percent reduction).
- Subsidies to reduce the initial purchase cost.
- Driving in bus lanes.
- Reduced congestion charges (not implemented yet, therefore not definitive).

There are also benefits related to image and profile. A market study made a few years ago in Malmö gives some important information to consider when introducing BEVs to new company users.

Theoretical study

An enquiry was sent to 2 002 vehicle owners, randomly selected from a complete list of vehicle-owning companies in Malmö. Drivers were asked to keep as exact a record as possible of a typical working day, in terms of where and when they drove, the distances covered, the number of passengers and the weight of any load.

The reference vehicle used was a Renault BEV, with an assumed range per charge of 65 km in city traffic and requiring eight hours for a complete recharge. It was also assumed that the batteries were charged during all stops in the working day that lasted for more than 30 minutes. No restrictions regarding load capacity were considered and only working days were studied.

Of the vehicles in use on the selected day, almost four out of five could have been replaced by electric vehicles. However, a large number of vehicles was not in use on the specified day. Assuming that none of these vehicles could be replaced by battery electric vehicles, which is an extremely pessimistic estimation, the percentage of possible battery electric vehicles is reduced to 27%. The actual amount of traffic work in kilometres during the studied week exceeded 25 000 km for the vehicles in the study. From the results of the study, half of this work (46%) could have been performed by battery electric vehicles.

Applied study

An invitation to a lunch meeting was sent to all those companies having vehicles that, according to the theoretical study, could be replaced by electric ones. The invitation included information on BEVs and a favourable offer for the supply of a BEV: there was also an opportunity at the meeting to test-drive a BEV. The offer was of a three-year full service leasing contract for a Peugeot 106 or a Renault Express, at a price comparable to, or slightly higher than, what an equivalent petrol-driven vehicle would cost.

Three such meetings were held, and attended by a total of 60 persons from 35 companies. In addition, almost all other companies were contacted by phone to get views on the offer.

Out of 167 companies, we arranged a complete interview with 77, and of which 35 came to the meetings. One company signed spontaneously for an EV. Two more signed after long consideration. The others did not feel able to accept our offer, due to various factors. We identified two categories: "Not able to" and "Not willing to". The "Not able to" arguments are such as limited range, limited carrying capacity and lack of flexibility, by which is meant the need for back-up vehicles if one vehicle in the fleet is unavailable. The "Not willing to" group did not accept the price or felt that it was a bad timing (fixed contracts), or some other arguments.

According to the theoretical study, a high percentage of the companies could use a BEV. In the follow-up applied study we realized that only very few actually wanted to substitute a conventional vehicle by an EV. Why this difference?

- Only one working day was considered in the theoretical study. Even if the vehicle very seldom has to exceed the range limits of a BEV, it might be enough to make the use of a BEV unfeasible.
- The range is not the only important factor. 70% of the arguments against the use of a BEV in the applied study were not directly related to the range.
- New technology is not adopted immediately by everybody. Since BEVs are quite new on the market, a lot of companies prefer to wait for a broader acceptance before acting themselves.

Who is the buyer?

An interesting question regarding how to market BEVs to companies is: who is the buyer? Traditionally, every large company has a person responsible for the company's vehicles. He -it is usually a male- keeps an eye on the market and tries to minimize the costs for vehicles and the associated repairs and service. If you present a BEV to him, there is a clear tendency for cost to dominate the decision. Other factors such as environment, fuel economy or marketing possibilities are more or less ignored.

Today, a BEV is not merely a vehicle to fulfil transport needs: it is also a tool for marketing and an effective way to demonstrate environmental awareness. We found out that this message is easiest to communicate to the manager of the company, followed by the person responsible for environmental matters (if there is one), and then the marketing manager.

BEV development

Increased load capacity is important. Some users, such as plumbers or other tradesmen, use the vehicle as a toolbox, always carrying approximately 500 kg load. The actual daily driven distances, on the other hand, are very short.

Competitive prices are necessary. Even a price comparable to a conventional vehicle is too high for many potential buyers, as shown in the applied study.

15.5 Benefits of participation

The benefits for Sweden of participating in the Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes are the following:

- To be updated on the latest technologies regarding battery electric vehicles, hybrid electric vehicles and fuel cell electric vehicles in a relevant network.

- It is cost effective and also time wise it is an efficient way of working. Performing cost and task sharing projects together with international partners with high competence both saves money and brings a higher quality to the results of the work.
- It creates new knowledge in Sweden resulting from both networking and new combinations of existing knowledge.

15.6 Further information

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

- www.stem.se
The National Swedish Energy Agency publishes reports, although mainly in Swedish. The main cleaner vehicle focus is on energy efficiency in the transportation sector and the production of alternative fuels.
- www.vv.se
The National Swedish Road Administration publishes several reports covering emissions and safety issues, mainly in Swedish.
- www.vinnova.se
The Swedish Agency for Innovation Systems provides a wide range of reports regarding cleaner transportation. A good library of older reports is also available at www.kfb.se.
- www.mtc.se
The AVL MTC AB has a few reports covering test results on cleaner vehicles, mainly in English.

Links to demonstration projects

www.fuel-cell-bus-club.com covers the CUTE project described above.

A few organisations that provide regional or national information on certain cleaner vehicle aspects are listed below. Most of the material is in Swedish:

- www.miljofordon.org
Gothenburg's main information site for cleaner vehicles, with much information on vehicles, infrastructure and costs.
- www.milore.nu
The Öresund region's information site covering cleaner vehicles.
- www.miljobilar.stockholm.se/index.asp
Stockholm's web-site, with information on all environmental vehicle activities being carried out in the region.
- www.sveva.org
The Swedish Electric and Hybrid Vehicle Association's web-site.
- www.h2forum.org
The main forum for those concerned with hydrogen in Sweden.

16 Switzerland

The interest of Switzerland in clean vehicle technology is on one hand driven by the need of reducing the energy consumption in transportation, on the other hand by the commitment to reduce the CO₂ emissions. Government activities are pooled in the campaign “EnergieSCHWEIZ”. The main focus in the transport sector of this campaign is to establish the legal framework that favours clean vehicle technologies, and to ensure the commitment of the car importers.

16.1 Enabling technologies

Vehicles

Switzerland has no car industry but many important component suppliers. The interest of the Swiss activities in the transport field is twofold. On one hand the Swiss research institutes are trying to find their place in closing the transfer gap between research and application. On the other hand Swiss companies want to keep a strong position as suppliers of components in this high-tech field.

All over the world electric vehicles seem to be no longer in the focus of interest. Also in Switzerland the political discussion concerning transportation concentrates on CO₂ reduction and lowering energy consumption. Governmental activities have shifted to consumption labelling and voluntary agreements with the vehicle importers to lower the average fuel consumption of new car fleets. Legislation allows the implementation of CO₂ taxes from 2004 onwards in case no decrease in fuel consumption is achieved.

Meanwhile there are only two small companies left producing electric bicycles (Biketec and Velocity). Velocity E-bikes are produced under the brand name “swizzbee” by a licensee in Southern Germany. The Biketec model ‘Flyer C’ now is also exported to Germany (it is the only Flyer-model that is in line with the speed limit regulation for E-bikes in Germany). The producer of the three-wheeler “TWIKE” went bankrupt in 2002 and sold the production line of the “classic” version to the main German importer where the production of 200 to 300 items per year is announced. The licence for producing the new prototype “TWIKE.ME” has been bought by an engineering company in Berlin with links to Volkswagen. According to reliable sources the company is only interested in the steering joystick.

In fall 2004, the Swiss company m.e.s., well known as the producer of the “ZEBRA” batteries, has started the conversion of the Renault Twingo and Smart pure to electric vehicles. The first vehicles will be delivered for the promotion programme VEL2 in the Canton of Ticino.

A few other vehicle prototypes have been developed in Switzerland. The Federal Institute of Technology Zürich (ETHZ) has built a prototype hybrid vehicle on the base of a VW Bora. An electric moped called “Mobilec” with a maximum speed of 30 km/h and a range of 30 km (with lead-acid batteries) or 60 km (with NiMH-batteries) is designed to replace conventional mopeds. Within a students’ project a recumbent bike called “EVA” has been electrified, with a range of 100 km (with Li-ion batteries) and a consumption of 0.7 kWh/100 km.

In addition some fun-vehicles have been developed, among others an electric trotinette called “easy-glider” for the use in cities. It offers a tiny platform on which users can stand, and it also can be used for dragging inline-skaters.

The Biel Institute of Technology is involved in a project developing an electric rickshaw for the use in Indian urban centres.

Propulsion systems

The developments of smart driving systems for small electric vehicles have been continued. The chainless propulsion system “Autork” developed within a project of the Institute of Technology Berne is commercially available. Its transmission system is based on a CAN bus and power bus system. This allows the control of every possible combination of electric motors and storage systems (batteries, flywheels, fuel cells, supercapacitors etc.), but also of all-wheel drive, anti slip braking and electronic traction control. Each application can be monitored and enables easy service. This system is planned to be tested in a lightweight electric scooter in 2005.

Fuel cell vehicles

Just like in the rest of the world, also in Switzerland the fuel cell (FC) technology is regarded as the future propulsion system. R&D in the field of fuel cell development is concentrated at the Paul Scherrer Institute PSI (an energy research institute connected with the Swiss Federal Institute of Technology, ETH Zürich). Within the framework of the FC research programme above, all membranes for PM-fuel cells have been developed and a stack has been built (called “PowerPac”). The values in the laboratory show a lifespan of 4000 hours at 80°C; this corresponds roughly to 200 000 km driven at 50 km/h. For automotive applications the membranes must still become more reliable, especially for winter conditions, and above all cheaper. The PSI-stack has been distributed among Swiss institutes of technology for their own research projects. At the Federal Institute of Technology Zürich the stack has been improved by integrating the humidifier into the cells, also the bi-polar plates became thinner and the hydrogen drains have been optimized to lower the amount of hydrogen that has to be pumped through the plates. A prototype vehicle called “HYlight” -developed by the Paul Scherrer Institute together with the Michelin Research Center- participated in the Show Challenge Bibendum in Shanghai. The vehicle was fitted with two 15 kW in-wheel electric motors, a chassis and suspension by Michelin. The consumption was equivalent to 2 l gasoline / 100 km.



Fig. 16.1 HYlight fuel cell prototype vehicle by the Paul Scherrer Institute together with Michelin (photo supplied by Muntwyler Energietechnik AG).

The Institute of Technology Biel has used this laboratory stack for the development of a test bench for testing FC applications (stationary and mobile) operating with hydrogen, up to a performance of 10 kW. In addition, this institute has fitted a “SAM” vehicle with a fuel cell hybrid propulsion system. The many electronic devices (e.g. the components to control the fuel cell like pressure regulation and humidification, a resonance boost converter to adapt the voltage of the fuel cell to that of the batteries, a control board with integrated CAN bus for the communication with the vehicle electronics etc.) have been developed by the Institute. The vehicle is now used as a platform for further research, especially for optimization (e.g. an improvement of the ratio of power density and weight of the fuel cell stack). The intention is to fit another “SAM” with a fuel cell with a smaller lithium polymer battery in favour of bigger hydrogen storage.

The Swiss company ESORO developed a prototype (HyCar) using a 6.4 kW FC running on gaseous hydrogen (80 kWh) in a hybrid configuration with a 35 kW asynchronous electric motor. The hybrid configuration combines the advantages of an electric drive train – especially the possibility of recuperative braking – with the most efficient fuel cell system using gaseous hydrogen. The HyCar proves that the use of fuel cells as “range extender” – resulting in 360 km maximum range - in an electric vehicle is a feasible and promising solution. The ESORO company also designed the first hydrogen filling station (“HyStation”) in Switzerland, together with a chemical engineering company (Sauerstoffwerk Lenzburg). Currently the hydrogen is produced from natural gas by a steam reforming process.

Electrochemical storage systems

The Na NiCl- battery type “ZEBRA” is still being improved. During the last two years the work concentrated on reducing the amount of materials and weight, and eliminating sulphur as stabilizer. At

the moment the ZEBRA batteries are predominantly used in stationary telecommunication facilities. Also the conversion Twingo and SMART are fitted with ZEBRA batteries. Contracts to fit prototypes of an E-bus project and a hybrid vehicle project are signed.

The former Swiss company Montena, now Maxwell Switzerland, is one of the main suppliers of supercapacitors. Maxwell sees great advantages in the use in hybrid vehicles. Supercapacitors provide high power at initial acceleration and by that relieve peak load stress on batteries and extend the battery life. The “boostcaps” of the company are also used in several Swiss prototype vehicles.

The Institute of Technology Lucerne is engaged in the development of a supercapacitor package based on the Maxwell technology for the use in electric vehicles. This “Super Accumulator Module” SAM can be used as power circuitry or in a charge-equalizing circuitry, in combination with other storage systems (batteries, fuel cells). Since August 2004 a shuttle bus equipped with the SAM system operates regularly on a 3.5 km-track between the Lucerne main station and the famous transport museum ‘Verkehrshaus Luzern’. At the stops the SAM-system is recharged within 3 minutes by an inductive charging system developed by Wampfler.



Fig. 16.2 TOHYCO Rider shuttle bus at inductive charging station (photo supplied by Muntwyler Energietechnik AG).

Also the Paul Scherrer Institute is working on a supercapacitor project (“Integrated Micro Supercap”) for the use in vehicles.

The Institute of Technology Biel has developed a charging method to increase the lifespan of lead acid batteries (BALADUM). The aim of the project was to develop a cheap on-board charger that results in higher cycle numbers. The charging method consists of a sequence of individual partial charging of each single 12 V battery block at a rather high charging current. So each battery block reaches approximately the same state of charge within the same charging period. Tests promise an increase in cycle life. On the basis of these tests cheap on-board chargers will be developed, and tests on charging methods are continued.

Lightweight materials

Swiss developing companies concentrate on the design of lightweight bodies and components. The project “MODULTEC” of the Swiss company Horlacher entered its 3rd phase. The goal is to develop modules made from composites that can be adapted to the demands of the customers. For the prototypes 12 main parts and their interfaces have been defined. In the 1st and 2nd phase of the project a roof and a bottom module have been developed that save about 30% weight. Especially the bottom module is extremely flexible to serve the needs of different propulsion systems. There are deepening in which components like fuel tank, propulsion aggregates, electric systems etc. can be integrated. In the 3rd phase the bottom module shall be improved, also with respect to fuel cell vehicles, and additional modules for the sides with sliding doors (which would increase the passengers safety) and variable trunks will be developed. In addition, technologies for pressing lacquer foils shall be tested which would result in high quality surfaces. Also the behaviour of the composite material at fire will be investigated.

Automated transportation systems

The project of the people mover system “cybermove” (former “Serpentine”), an automatically operated transport system, is continued. A prototype is tested on a short test track.

The company Brusa Elektronik is developing a people mover system called “Downhill-Coaster”. It is designed to replace private cars in alpine regions with great gradients and slopes. The vehicles run on tracks comparable with those of roller coasters, the vehicles can drive individually but are controlled by distance-keeping and automatic emergency systems. The advantage is that the infrastructure is cheaper than roads and much less space is needed. A test track is installed and a vehicle prototype has been tested in 2004.

16.2 Overcoming barriers

The acceptance of electric and hybrid vehicles is relatively high in Switzerland. Nevertheless, the market for electric four-wheeled vehicles has collapsed as there are hardly any models available. There is a very small second hand market left, especially in the Canton of Ticino.

Since 1999 the new "Energy Law" shifts the responsibility for promotion measures to the local states (Cantons). Subsidies for vehicle purchases (as they have been granted within the national project "Large Scale Test with Lightweight Electric Vehicles" in Mendrisio finished since June 2001) therefore are no longer granted on national level.

The strategy of the national government concentrates on the support of research and development and on implementing legal (and cheap) measures like the implementation of CO₂ taxes. The voluntary agreement between the government and the car importers to lower the average consumption of new vehicles fleets does not achieve the target values (2001: - 1,3%; 2002: - 2,3 %; 2003: - 1,35% - instead of - 3%/year). Consequently the taxes on CO₂-emissions will be introduced in 2008 at the latest. Currently four taxation models are being discussed:

- 10 Euro cents/l on all fuels, increasing by 10 c in a 2nd phase,
- 10 c/l fuels for transport (return is used for CO₂ certificates), other fuels: lower taxes,
- “climate rappen” on fuels for transport: 0.7 c/l fuel, other fuels: CO₂ taxes,
- “climate rappen” on fuels for transport, other fuels: no CO₂ taxes.

The parliament will decide on the model. The “climate rappen”-models have been launched by the right-wing parties to avoid the at least 10 times higher tax charge of the governmental models.

The Canton of Ticino continued the promotion programme of the "Large Scale Test with Light-weight Electric Vehicles" run between 1996-2001 in Mendrisio. This successor programme called “VEL2” also includes hybrid and internal combustion engine vehicles, grading the amounts of the subsidy according to the output of CO₂. By the end of November 2004 the total stock was 2205 vehicles: 844 with battery electric propulsion, 761 gasoline, 562 diesel and 38 hybrid cars. The electric vehicles included 527 E-bikes, 174 E-scooters, 15 electric three-wheelers, 48 Peugeot 106 electric, 15 Peugeot Partner electric, 34 Citroën Saxo electric, 27 Citroën Berlingo electric and 3 Renault Kangoo electric; 27 Toyota Prius (inclusive of the New Prius) and 15 Honda Civic IMA (available since late 2003). Interesting are the shrinking numbers of the Peugeot 106: in 2002 still 104 have been licensed. Best-sellers in this programme are internal combustion engine vehicles with low energy consumption: SMART with a total of 509 models, followed by Suzuki Alto with 232 models sold. The overall goal is to achieve 4000 vehicles with less than 120 g/km CO₂ emissions by the year 2005. The decision on a third phase of the project, “VEL3” will be taken in 2005.

The “New Ride” project concentrates on the promotion of electric two-wheelers (bicycles, scooters). Meanwhile 20 Swiss municipalities are partners of this programme. Their commitment includes the organisation of test driving events, exhibitions and the use of electric two-wheelers within the city administration. A few partner-cities also provide subsidies (e.g. the cities of Zürich, Basel and Neuchâtel). The amounts are between about 600 and 800 US\$. A positive aspect of this project is the close co-operation with the vehicle suppliers and retailers. An award for the “retailers of the year” stimulates the competition. All in all there are 24 models by 10 E-bike manufacturers and 4 models by 3 E-scooter manufacturers available in Switzerland. In 2003 about 40% more electric 2-wheelers

(1800 items) have been sold compared with the sales figures of 2002. Studies show that each E-bike saves average 900 car kilometres per year. "New Ride" participated in the European E-TOUR-project.

16.3 Market introduction

Speaking about the Swiss hybrid- and electric-vehicle-market is speaking about a private market. There are practically no fleet owners interested or willing to use these vehicle types.

Table 16.1 Swiss hybrid and electric vehicle fleet (per December 2003).

	Electric Vehicles	Hybrid Vehicles
Passenger / small vans	760	472
2&3 wheelers	1 644 licensed 5 000 e-bikes	
Buses, trucks	435 (above all car free resorts)	
Others	30 agricultural 2 817 industrial	
Total	7 750	472

The market for the Peugeot 106-like sized EVs has practically faded away (with the exception of the subsidy programme in the Canton of Ticino). The market for small vehicles suffers from a lack of new models that could replace the 'city-els' that are getting old. Only the E-bikes- and E-scooters-segment is still growing strongly.

There are altogether about 7600 electric vehicles running on the Swiss roads, including about 5000 electric bicycles, about 1600 electric scooters or three-wheelers and about 700 passenger vehicles or small vans (like the Peugeot Partner electric or the Citroën Berlingo électrique).

The Toyota Prius has been introduced on the Swiss market in October 2000. Until the end of 2003 about 470 of these vehicles have been sold. In Ascona a taxi enterprise called Ecotaxi (in Italian a play on words with the meaning ecotaxi=yes) uses 3 Toyota Prius'. Since late 2003 also the New Prius and the Honda Civic IMA are available. The sales figures of the New Prius are promising (334 sold, 464 on the waiting list in October 2004). The PR efforts, especially by Toyota, are remarkable. Nevertheless, the high price for the New Prius may be a barrier (it is about 10 000 US\$ higher than in the USA). Honda is far less present in the media and only about 20 Honda IMAs have been sold by the end of 2004.

An interesting but limited application niche are the 9 "car-free" resorts (most famous are Zermatt and Saas Fee) where about 750 special electric vehicles are in use. They cannot be counted as road vehicles because they are designed for a maximum speed of 20 km/h and therefore are not used outside the resort areas. This segment will not grow as the resorts are determined to limit the number of these vehicles. In spite of the efforts of the association of the car-free resorts no additional resorts made the step to free their village from ICE (Internal Combustion Engine) transport.

The Swiss AVERE section e'mobile is in charge of the "EcoCar" campaign of the "EnergieSchweiz"-programme that is started by the Swiss Federal Office of Energy. Its aims are to promote the dissemination and to support the marketing efforts for energy efficient cars (independent from the propulsion system). In addition to the consumption label that is obligatory for all cars under 3.5 t, an "EcoCar"-label will be created to award energy efficient cars. The introduction is planned for 2005. The organisation of test driving events, exhibitions (e.g. at the Autosalon in Geneva) and the dissemination of information are the main activities. A close co-operation with car associations in Switzerland is necessary (e.g. the Association of Swiss Car Importers), but no great commitment can be expected from this side. The efforts more and more shift to the promotion of natural gas vehicles (also in combination of "compost gas") and the use of bio- gas made from liquid manure.

In 2003 an award for “sustainable mobility” has been created by EnergieSchweiz to enhance the awareness of energy consumption by transportation. The award of 2003 has been given to a group of medicines in Basel that propagates walking instead of driving. In 2004, the winner was “Swiss Farmer Power”, an initiative to produce biogas from liquid manure for the use in transport (the motto: “1 cow/year = 3000 km car trips”). From 2005 on, biodiesel made from biomass (especially rape and wood) will be used as diesel blending.

16.4 Primary energy for transportation

The Kyoto protocol forces the Swiss government to take measures in the transport field to reduce the fuel consumption and to promote alternative fuels.

One initiative in this field is the use of waste gas for transportation. Since 1988 the Federal Office of Energy has supported the installation of pilot plants that transform compost into biogas. In 2002, seven plants converted compost into biogas. The major share of this gas is fed into the natural gas (NG) grid, but there are also 10 vehicle refuelling stations in the area of Zurich and 1 in the city of Lucerne for bifuel vehicles (in addition to 43 NG filling stations in all Switzerland). One of the local distribution centres of the largest Swiss grocery chain runs 9 delivery trucks with “Compost-gas” produced by the bio-waste of the shops in this area. This project called “salad in the tank” got the 2nd prize of the Energy Globe Award 2002. “Compost gas” is exempted from the “mineral oil taxes” and therefore cheaper than natural gas and clearly cheaper than gasoline (minus 41%). In 2004 the stock of bi-fuel vehicles was about 550. The Swiss NG industry announced a goal of 50 000 NG vehicles by 2010 and 100 filling stations for NG as well as “compost gas”. A precondition is a wide range of vehicle models for all customer segments. The ambitious expectations are based on the announcement of new bi- and monovalent vehicles (like the NG Opel Astra, Golf Variant bi-fuel and a mono- and bi-valent Smart).

16.5 Further information

Web-sites

- www.e-mobile.ch
Project EcoCar / Swiss Programme “EnergieSchweiz” of the Federal Office of Energy (in German, French, English).
- www.energie-schweiz.ch
Programme “EnergieSchweiz” of the Federal Office of Energy (in German, French, Italian, English).
- www.vel2.ch
Project VEL2 of the Canton of Ticino (in Italian, English).
- www.newride.ch
Project NewRide (electric two wheelers) (in German, French).
- www.hycar.ch
Fuel cell-prototype ESORO Hycar (in English).
- www.psi.ch/medien/Medienmitteilungen/mm_hy_light
Fuel cell prototype HYLIGHT (in German).
- www.maxwell.com
Web-site including supercapacitors.
- www.hta.fhz.ch
Tohyco Rider mini bus.
- www.erdgasfahren.ch
NG-vehicles (in German).
- www.horlacher.ch
Horlacher Lightweight Construction (in German, English).

- www.imrt.ethz.ch/research/projects/_details/index.cfm?id=22
Supercap-Project of the ETHZ (in English).
- www.mes-dea.ch
Twingo Quickshift Elettrica/Smart pure elettrica/ZEBRA batteries.

Reports

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

17 United States

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. It supports the development of fuel cells and advanced technologies for batteries, power electronics, direct injection engines, vehicle systems, lightweight materials, and fuels.

17.1 Enabling technologies

Hydrogen and fuel cells

A polymer electrolyte membrane (PEM) fuel cell converts chemical energy into electricity and heat through the electrochemical reaction of hydrogen and oxygen. Because of its high power density and other potential benefits, worldwide interest in fuel cell technology is very strong for a broad range of transportation and other applications. DOE plans to spend a total of \$1.2 billion in this research over 2004-2008, focusing on accelerated, parallel track R&D of fuel cell and hydrogen infrastructure technologies to enable an industry commercialization decision by 2015. 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 mission of this program is to research, develop, and validate fuel cells and hydrogen production, delivery, and storage technologies for transportation and stationary applications.

The program works with universities, national laboratories and industry partners through public-private partnerships to develop core technologies and address both technical and non-technical challenges to commercialization. Fuel cell R&D activities are aimed at reducing PEM fuel cell component cost and improving the performance and durability of fuel cell systems for transportation, small-stationary, and portable applications. Areas of emphasis include improved catalyst and membrane designs; improved air, thermal, and water management systems; and fuel processing (reforming) technologies. Hydrogen R&D is focused on hydrogen production and delivery technologies, hydrogen storage, vehicle and infrastructure learning demonstrations, safety and codes & standards, education and analysis. Currently, as shown in table 17.1, over 180 projects are ongoing in these areas. Additional information regarding individual R&D projects is available in the 2004 Annual Progress Report at the web-site for this program.

Some recent accomplishments of the program include:

- 1) Initiated over \$425 M in new projects (\$675 M with private cost share) to overcome critical technology barriers and to bring hydrogen and fuel cell technology from the laboratory to the showroom. These new projects include the Hydrogen Storage Centers of Excellence, which address a critical technical challenge.
- 2) Reduced the high-volume cost of automotive fuel cells from \$275/kW (2002) to \$200/kW (2004) using innovative processes developed by national labs and fuel cell developers for depositing platinum catalyst. Additional research is needed for fuel cells to achieve the cost competitive target of less than \$50/kW.
- 3) Demonstrated an improved electrolyte for PEM cells (proton conductivity of over 0.1 Siemens/cm at less than 25% relative humidity at 120°C).
- 4) Developed protective, high-conductivity chromium nitride layers on stainless steel for use on cost-effective metallic bipolar plate.
- 5) Completed a 5-year project, resulting in the demonstration of a multipurpose refuelling station with:
 - 1) on-site H₂ production by reforming natural gas;
 - 2) operation of a 50 kW PEM fuel cell to generate electricity; and
 - 3) dispensing of compressed hydrogen for vehicles and buses.

Table 17.1 2004 R&D projects in the Hydrogen, Fuel Cells, and Infrastructure Technologies Program (detailed project descriptions are available at http://www.eere.energy.gov/hydrogenandfuelcells/annual_report04.html).

Subprogram	Research areas	Projects
Hydrogen production and delivery	Distributed production technologies, separations, biomass gasification/pyrolysis, photobiological production, photo-electrochemical production, electrolysis, high-temperature thermo-chemical processes, hydrogen delivery, and analysis	36
Hydrogen storage	Compressed/liquid H ₂ tanks, chemical hydrides, metal hydrides, carbon materials, testing and analysis, and new "grand challenge" projects	19
Fuel cells	MEAs and catalysts, membranes and MEAs, catalysts, bipolar plates, platinum recycling, fuel processing, stationary power systems, transportation systems and balance of plant components, fuel cell characterization, and DMFC and SOFC	71
Technology validation	Power parks analysis, hydrogen and fuel cell demonstration/analysis, system analysis, refuelling technology development and demonstration, and vehicle demonstrations	27
Safety and codes & standards		10
Education		11
Cross-cutting		10
Total		184

- Reduced the cost of natural gas-based hydrogen production from \$5.00 per gallon gasoline equivalent (gge) in 2003 to \$3.60 per gge using innovative reforming and purification technologies. Further research is needed to achieve \$1.50 per gge (untaxed) to be cost-competitive with gasoline.
- Met 2005 efficiency (82%) and cost (\$0.11/kg) targets for refuelling station hydrogen purification (PSA).
- Exceeded DOE 2005 targets for fast filling hydrogen tanks (1 kg H₂/min) by successfully filling a 10 000-psi tank in 3 minutes.
- Prepared metal hydrides that have improved hydrogen discharge kinetics.
- Operated stationary PEM fuel cell over 1440 hours with no degradation. (The predicted lifetime is 8000 hours.)
- Expanded the FreedomCAR Partnership to include energy companies to focus on hydrogen infrastructure challenges.
- Developed long-term plan for hydrogen technology education.
- Developed world-wide collaboration on hydrogen technology. Fifteen nations and the European Commission have joined a U.S.-led initiative, the International Partnership for a Hydrogen Economy (IPHE).

In addition, recent significant fuel cell-related industry events included:

- General Motors (GM)

- GM and Shell announced a partnership and intent to open the nation's first retail hydrogen fuelling station in the Washington DC area. The station officially opened for business in November 2004.
 - GM and BMW agreed to jointly develop refuelling devices for liquid hydrogen vehicles.
 - GM launched its Washington DC-based fleet of hydrogen-powered vehicles.
 - Dow Chemical and GM officially powered up a stationery fuel cell power module at the Dow Chemical Freeport Texas plant, the world's largest fuel cell application at a chemical manufacturing site, where by-product hydrogen is used to generate electricity.
 - The U.S. Postal Service and GM announced that a GM HydroGen3 vehicle would be leased by the Postal Service and assigned to a postal delivery route in the Washington DC area.
 - The state of Maryland announced plans to lease a GM HydroGen3 vehicle for use as part of the state's fleet representing a significant step toward the foundation for a hydrogen economy.
 - GM and Dow Chemical announced Phase II of a project to test stationery fuel cells at Dow's Freeport Texas plant, expanding from a single cell to a multi-cell pilot plant.
 - Sandia National Lab and GM announced a 4-year, \$10 million partnership for designing and testing advanced methods for storing hydrogen onboard.
 - GM's Sequel was unveiled in Detroit. It includes advanced materials, electronic controls, computer software and advanced propulsion (fuel cell propulsion) in a thin skateboard chassis.
- Honda Motor Company announced that it had developed a more efficient, cheaper fuel cell that can operate in temperatures as low as -4°F. It conducted a successful cold weather demonstration of its fuel cell vehicle (FCV).
 - Ford Motor Company tested the 'Model U' concept car, a "green" car powered by hydrogen.
 - California, Michigan, and Ohio announced their intention to work as a partnership on the development of fuel cell infrastructure.



Fig. 17.1 GM Sequel prototype vehicle, including advanced materials, electronic controls and fuel cell propulsion in a thin skateboard chassis (courtesy General Motors).

Advanced energy storage technologies

For successful commercialization of electric vehicles (EVs) and hybrid electric vehicles (HEVs), their battery systems must meet the combined requirements of high energy (for EVs), high power output (for HEVs), recharge-ability, long life, safety, and low cost. The three primary battery research areas, funded by DOE, include the developer program which assesses, benchmarks, and develops advanced batteries for EVs and high-power batteries for HEVs; applied battery research for providing near-term assistance to high-power battery developers to overcome the calendar life, abuse tolerance, low temperature performance and cost barriers associated with lithium-ion batteries for light and heavy-duty vehicles; and 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:

- Showed that existing high-power cells meet or exceed most technical requirements set forth by the Energy Storage Technical Team, including a lifetime exceeding 300 000 cycles and excellent energy and power density. Abuse tolerance and cost issues are being actively addressed and recent results show promise that these requirements are within reach.
- Measured the thermal characteristics of Saft Li-ion cells at 0°C, 30°C, and 50°C, demonstrating that the cells avoided thermal runaway and were 58% efficient at -30°C, thus addressing one of the major ongoing concerns associated with Li-ion batteries, thermal stability.
- Conducted screening tests on advanced materials and oversaw the development of a more optimal form of natural graphite which exhibits improved performance and abuse tolerance in high power cells.
- Showed that electro active polymers whose conductivity depends on their state of charge can provide excellent overcharge protection in Li batteries. The result is a reversible, self-actuating, low-resistance internal shunt that allows overcharge currents to pass through a cell without damaging the components, maintaining the discharge capacity and allowing the rest of the cell stack to operate normally.
- Surface sensitive diagnostics showed that the battery charging and discharging processes are not homogeneous, leading to insights on how one might control capacity and power fade in high power batteries.

In addition, recent significant battery-related events in the industry included:

- Texaco Ovonic completed construction of the first North American plant for high-volume production of nickel-metal hydride batteries in Springboro, Ohio. When the plant reaches full production, it is expected to produce 1.2 million 12-volt battery modules annually for transportation and stationary power storage.
- Honda Motor Company released an ultracapacitor design for its FCX vehicle.
- Johnson Controls Inc. (JCI) displayed its Powerwatch system (expected on some 2005 vehicles) which communicates with a battery and tracks engine inputs to manage the way electricity is distributed throughout the car. According to JCI, it can reduce emissions by 1-2 percent by switching off the charging load of the alternator when the battery does not need more electricity.

Vehicle systems research

The Vehicle Systems subprogram within the FreedomCAR and Vehicle Technologies Program provides support and guidance for many cutting-edge automotive and commercial vehicle technologies under development. Research is focused on understanding and improving the way the various new components and systems of tomorrow's automobiles and commercial vehicles will function in a vehicle to improve fuel efficiency. It also supports development of advanced automotive accessories and the reduction of parasitic losses (e.g., aerodynamic drag, thermal management, friction and wear, and rolling resistance). It utilizes advanced vehicle modelling, benchmarking, and validation to enable the development of such technologies.

Some recent accomplishments of DOE-funded vehicle system research included:

- Enhanced advanced vehicle, systems, and component modelling capabilities by integrating latest fuel cell, hydrogen, energy storage, energy management, and HEV data into the Powertrain Systems Analysis Toolkit (PSAT) modelling and simulation tool.
- Opened the Advanced Powertrain Research Facility, a four-wheel drive super ultra low emissions chassis dynamometer with hydrogen fuelling capability, at Argonne National Laboratory.
- Developed the Emulated Fuel Cell Vehicle; drive- and brake-by-wire electric vehicle test fixture.
- Initiated laboratory benchmarking and field evaluation testing of hydrogen-fuelled internal combustion engine vehicles.

Advanced combustion engine R&D

The DOE Advanced Combustion Engine R&D activity is focused on removing critical technical barriers to commercialization of higher-efficiency, advanced internal combustion engines (ICEs) in light-duty, medium-duty, and heavy-duty vehicles. It is focused 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 aftertreatment technologies that further reduce exhaust emissions. Work is done in collaboration with industry, national laboratories, and universities and in conjunction with the FreedomCAR partnership and the 21st Century Truck Partnership. The advanced engine technologies being researched and developed will allow the use of hydrogen as a fuel in ICEs, providing an energy-efficient interim hydrogen-based powertrain technology in the ultimate transition to hydrogen-/fuel-cell-powered transportation vehicles. Recently, in collaboration with industry partners, this activity completed development of advanced clean diesel engine technologies for pickup trucks, vans, and SUVs (sport utility vehicles), achieving a 50% fuel economy improvement, relative to current gasoline-fuelled trucks, while demonstrating Tier 2 Bin 5 emission levels for a limited duration.

Lightweight materials

The reduction of vehicle mass through improved design, lightweight materials, and new manufacturing techniques, is one of the key strategic approaches in meeting fuel economy targets for commercially viable fuel cell, hybrid, and electric vehicles. 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. 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 composites (such as metal-matrix materials and glass- and carbon-fiber- reinforced thermosets and thermoplastics).

Recent significant accomplishments in this area included the following:

- Researchers at the Pacific Northwest National Laboratory (PNNL) developed a new low cost aluminium metal matrix composite and a cost model for the material showing that \$1/lb is achievable at pilot scale volumes. A novel brake rotor with enhanced heat dissipation has also been cast from the new material.
- An engine cradle for the 2005 Chevrolet Corvette was successfully cast from magnesium, achieving a 35% mass saving over the same aluminium part.
- Researchers completed the design, build, and installation of Test Machine for Automotive Crashworthiness (TMAC) at National Transportation Research Center (NTRC) in Oak Ridge, TN, demonstrating the capability to conduct controlled, progressive crush experiments at constant velocity ($\pm 10\%$), high forces (0-267 kN) and intermediate rates (0-8 m/s).
- A pilot recycling plant was commissioned at Argonne National Laboratory (ANL) in 2004, in collaboration with the vehicle recycling partnership. The facility will support research into rapid, cost effective recycling of end-of-life vehicles.

In addition, recent significant events in the industry included:

- BMW claimed that it substantially cut the cost of producing body panels from carbon-fiber reinforced plastic. By automating the process of layering the carbon-fiber textile, BMW cut the time needed to make panels by a factor of five. BMW rolled out an M3 CSL with a carbon-fiber roof module.
- Dana Corporation in Toledo, Ohio, announced developing thermoplastic oil pans. It also designed a reduced weight rear suspension axle for light trucks, by using aluminium in several key parts.
- Toyota announced that its next generation Tacoma pick-up truck, arriving in 2006, will use an all-composite box.

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. It is divided into power electronics, electric motors/generators, and power management and integration sub-activities. A primary research focus is on the thermal management of inverters and motors with two phase cooling technologies. Advanced component modelling, fabrication, and manufacturing techniques are being investigated. Work is underway on integration of emerging power electronic technologies in order to manage and control high-power components, which will provide rapid, bidirectional energy flow to improve performance and lower costs.

Recent significant accomplishments in this area included:

- Completed a detailed cost study and analysis of potential processes and packaging methods meeting the technical requirements for a System on a Chip (SoC) motor controller, for use in a broad range of applications including HEVs and FCVs.
- Semikron, Inc. developed a 42 volt DC Bus power inverter for lower battery voltage in light hybrid applications and a 600/1200 volt module for full size HEV applications.

17.2 Overcoming barriers

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

Cost

FCVs, EVs, and HEVs face critical cost barriers. High cost is a serious barrier in almost every research area and the current costs of most components are higher than the target values required to meet cost-effectiveness goals. For example:

- Lightweight body construction, compression ignition direct injection (CIDI) engines, batteries, and electronic control systems all increase the vehicle cost.
- Emission control systems for high efficiency direct injection gasoline and diesel engines, when developed, would be more expensive than current systems.
- 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 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 U.S. 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 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 (ppm) 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 major infrastructure changes by the energy industry. 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.

17.3 Market introduction

Electric vehicles

Compared to its total inventory of vehicles (over 230 million), the U.S. has a relatively small, growing population of pure electric vehicles designed to compete with conventional on-road gasoline and diesel vehicles. Table 17.2 lists available EV models in the U.S. in the recent past (1999-2002). Table 17.3 lists a summary of light-duty and heavy-duty electric vehicle numbers in the U.S. Batteries for current EVs include lead acid, nickel metal hydride, nickel cadmium, and lithium-ion. Both AC and DC motors are being used. Since 1998, special safety standards for Neighbourhood Electric Vehicles (NEVs) have existed. The Federal Motor Vehicle Safety Standard 500 requires that such vehicles incorporate safety devices such as 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 certain NEVs on city streets.

Recent significant EV-related events included:

- In April 2003, the California Air Resources Board (CARB) voted to make modifications and upgrades to the state's zero emission vehicle (ZEV) regulation. It created provisions giving manufacturers a choice of meeting ZEV standards as in 2001, or by a new alternative compliance strategy.
- In August 2004, CARB proposed new greenhouse gas emission standards requiring a 30 percent cut in vehicle emissions, required by the 2016 model year.
- In August 2004, a panel created by the California Governor proposed eliminating CARB. No decision has been taken in this regard.

Table 17.2 EV models introduced in the U.S. in the recent past (1999 - 2002).

Model year	Company	Name	Body type	Battery type	Motor type	kWh/100 miles		Rated range (miles)	Top speed (mph)
						City	Highway		
1999	Ford	Ranger	Truck	PbA	AC	38	44	72	75
	Ford	Ranger	Truck	NiMH	AC	NA	NA	NA	75
	Chrysler	EPIC	Minivan	NiMH	AC	67	73	96	80
	Nissan	Altra	St. wagon	Li-ion	AC	NA	NA	NA	75
	Hyundai	Accent-EV	car	NiMH	DC	NA	NA	87	NA
	Honda	EV Plus	Comp Car	NiMH	DC	49	51	115	80+
	GM	EV1	2 seat car	PbA	AC	NA	NA	65-95	80
	GM	EV1	2 seat car	NiMH	AC	NA	NA	75-140	80
	Bombard.	NV	NEV	PbA	NA	NA	NA	30	25
2000	Toyota	RAV4	SUV	NiMH	DC	29	37	126	NA
	Ford	Ranger	Truck	PbA	AC	38	44	72	NA
	Ford	Explorer	SUV	PbA	AC	54	72	53	NA
	Ford	Th!nk City	2 seat car	NiMH	AC	32	41	42	NA
	Solectria	Flash	Truck	PbA	AC	NA	NA	45	45
	Solectria	Force	Car	NiCd	NA	NA	NA	85	70
2001	Ford	Ranger EV	Pickup Truck	PbA/ NiMH	AC	38	44	50-85	72
	Ford	Th!nk Neighbour	LSV	PbA	DC	NA	NA	30	25
	Nissan	Hyper-mini	Urban EV	Li-Ion	AC	NA	NA	40	62
	Daimler Chrysler	GEM	LSV	PbA	DC	NA	NA	25	30-35
2002	Ford	Th!nk City	City EV	NiCd	DC	NA	NA	40/34	53
	Daimler Chrysler	GEM	LSV	PbA	DC	NA	NA	25	30-35
	Solectria	Force	Car	NiCd	NA	NA	NA	85	70
	Club Car	Pathway	LSV	PbA	DC	NA	NA	33	21
	Columbia Car Park	Commuter	NEV	PbA	DC	NA	NA	40	25

Source: Electric Drive Transportation Association (EDTA) http://www.electricdrive.org/edtech/ele_product_info.htm;
DOE Fuel Economy Guides <http://www.fueleconomy.gov/feg/>;
California Air Resources Board (CARB) <http://www.arb.ca.gov/html/databases.htm>.

Table 17.3 Number of EVs in the U.S.

	1995	1996	1997	1998	1999	2000	2001	2002	2003*	2004*
LD	2 715	3 126	4 257	4 996	6 684	11 198	17 056	31 926	44 334	54 252
M&HD	109	154	196	247	280	636	791	1 121	1 322	1 600
Total	2 860	3 280	4 453	5 243	6 964	11 834	17 847	33 047	45 656	55 852

LD Light Duty

M&HD Medium & Heavy Duty

* estimates

Source: Energy Information Administration (EIA). http://www.eia.doe.gov/cneaf/alternate/page/datatables/afvtable1_03.xls

Hybrid vehicles

Recent significant HEV-related events included:

- **Toyota Motor Corporation**

- Toyota produced a redesigned Prius, a five-door liftback, reaching 60 mph speed in about ten seconds and a highway fuel economy of 55 mpg.
- Toyota displayed hybrid versions of its Highlander and Lexus RX 400 sports wagons, using a 3.3 litre V-6 engine. Production is expected to begin in 2005, and U.S. sales in April 2005.
- Toyota predicted selling 100 000 hybrid vehicles in U.S. starting in 2005 (50 000 Priuses, 30 000 Highlanders, and 20 000 RX 400H's). In June 2004, Toyota reported robust Prius sales, with a waiting list of over 20 000 and was considering increasing its U.S. allocation of Priuses.
- The Prius won an award as the 2004 car of the year, voted by a panel of 49 automotive journalists, at the 2004 Detroit Auto Show.
- Toyota indicated intentions to develop a hybrid version of its every vehicle, including a hybrid Camry (2006), a hybrid Lexus LS (2007) and a hybrid Corolla (2008). It also announced plans to assemble certain hybrid vehicle models in U.S.
- It was announced that Porsche may build a hybrid version of its Cayenne SUV using a Toyota powertrain.



Fig. 17.2 Toyota Prius hybrid car, model 2005 (courtesy Toyota Motor Company).

- **General Motors**

- GM announced that it will offer hybrid technology on a dozen models by 2007, with potential annual sales of over a million units.
- GM launched a hybrid propulsion program focused on highest fuel consuming vehicles (e.g., buses, full size trucks and SUVs). It began its hybrid strategy with the hybrid powered bus, which uses its patented two-mode full hybrid diesel-electric drive system. Since 2001, it has delivered a total of 335 hybrid powered buses to 18 U.S. cities.
- GM announced that it will co-develop a two-mode full hybrid with DaimlerChrysler. Both companies were independently working on a two-mode full hybrid system to be launched in 2007 in the Chevrolet Tahoe and GMC Yukon SUVs. Chrysler Group will introduce this system shortly following its introduction in the GM SUVs. The two-mode full hybrid will be offered in GM's full size trucks in late 2008. In the SUVs, the fuel economy gain is estimated to be 25 percent. For the two-mode full hybrid system, the addition of a second hybrid mode to the drive system improves efficiency and reduces the need for large electric motors of current single-mode systems. The compact size of the two-mode system enables it to be packaged within the automatic transmission envelope. The system is scalable, making it more versatile and cost effective to adapt for various vehicle configurations.
- GM has developed mild hybrid-electric powertrain system applicable to a wide range of cars, trucks and SUVs. The belt alternator starter hybrid system is scheduled to debut in 2006 on the Saturn VUE and in 2007 on the Chevrolet Malibu. It is expected to increase fuel economy by 10 percent.
- GM began offering a mild hybrid flywheel alternator starter system to its retail customers in May of 2004 on the Chevrolet Silverado and GMC Sierra pickup trucks, providing fuel economy savings of 10 percent.



Fig. 17.3 GMC Sierra hybrid pick up truck (courtesy General Motors).

- **Ford Motor Company**

- Ford launched the all-new Escape Hybrid in August 2004, the first hybrid sport utility vehicle (SUV) in North America. During 2004, the distribution would be limited to 15 states along the east and west coasts, but would subsequently become nationwide. An annual output of 20 000 vehicles is planned.
- Ford announced plans to expand its hybrid line-up with Ford Mercury getting a hybrid version of its Mariner, coming out in October 2005. It also announced plans for a hybrid

engine in the Fusion (a sedan based on Ford's global midsize car automobile platform architecture entitled "CD3"), to start selling in 2007 and a Mazda Tribute Hybrid in two years.



Fig. 17.4 Ford Escape hybrid (courtesy Ford Motor Company).

- **Others**

- Honda expanded an Accord sedan hybrid in U.S. in 2004, the world's first V-6 hybrid.
- Mazda indicated it may offer a hybrid version of its Tribute SUV in the U.S.
- Mercedes-Benz announced plans to test hybrid powertrains in its Sprinter van.
- Hyundai Motor Co. announced plans to offer a hybrid vehicle in the U.S. by 2006, initially to U.S. fleet buyers (by the end of 2004). The expected hybrid vehicle will be derived from its Getz model.

17.4 Benefits of participation

The numerous benefits of DOE's participation in various IEA Annexes include:

- obtaining information on advanced transportation technologies (not available from other sources) as well as being a source for such information;
- producing joint studies and reports for mutual benefits;
- remaining informed about technology developments in other countries; and
- participating in a network of well known automotive research entities (while providing information regarding work at U.S. national laboratories) and government officials responsible for advanced transportation issues.

17.5 Further information

Further information may be obtained from the following Internet web-sites:

- www.eere.energy.gov/vehiclesandfuels/
DOE FreedomCAR and Vehicle Technologies Program.
- www.eere.energy.gov/hydrogenandfuelcells/resources.html
DOE Hydrogen and Fuel Cells Program.

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- www.electricdrive.org/
Electric Drive Transportation Association.
- www.eia.doe.gov/
Energy Information Administration.

Publications

Major IA-HEV publications during the second term, 2000 - 2004

- IEA Hybrid and Electric Vehicle Implementing Agreement, *Progress Towards Sustainable Transportation - Report by the IEA Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes for the year 2000*, Ottawa, Canada, 2001.
- IEA Hybrid and Electric Vehicle Implementing Agreement, *Progress Towards Sustainable Transportation - Report by the IEA Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes for the year 2001*, Ottawa, Canada, 2002.
- IEA Hybrid and Electric Vehicle Implementing Agreement, *Progress Towards Sustainable Transportation - Report by the IEA Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes for the year 2002*, Ottawa, Canada, 2003.
- Frans Koch, *The IEA Agreement - Lessons Learned about Hybrid and Electric Vehicles*, Proceedings of EVS-17, Montreal, October 2000.
- Victor Hacker, *Start-up of a New Annex "Electrochemical Power Sources and Energy Storage Systems" in the Implementing Agreement Hybrid & Electric Vehicles of the International Energy Agency*, Proceedings of EVS-17, Montreal, October 2000.
- Frans Koch, Urs Muntwyler, Stephane Biscaglia, *Renewable Primary Energy for Hybrid, Fuel Cell and Electric Vehicles*, Proceedings of EVS-18, Berlin, October 2001.
- Urs Muntwyler, Sigrid Kleindienst, *Some Observations Concerning the Energy Consumption of Electric Vehicles in Real Traffic Conditions*, Proceedings of EVS-18, Berlin, October 2001.
- Tomohiko Ikeya, Ken-ichi Takahashi, Kojiro Miyake, *International Cooperation for Information Exchange on Electric Vehicle Technologies and Programmes at Annex I of Implementing Agreement for Hybrid and Electric Vehicles in IEA*, Proceedings of EVS-18, Berlin, October 2001.
- Sigrid Kleindienst Muntwyler, *Annex VIII "Deployment Strategies for Hybrid, Electric and Alternative Fuel Vehicles" of the IEA Implementing Agreement "Hybrid & Electric Vehicles"*, Proceedings of EVS-18, Berlin, October 2001.
- Urs Muntwyler, Frans Koch, *Sustainable Transport - RE Supply Options and Resource Potential for Transportation*, RE Focus, Kidlington, UK, July/August 2002.
- Sigrid Kleindienst Muntwyler, *Government Deployment Strategies for Hybrid, Electric and Alternative Vehicles Examined*, Proceedings of EVS-19, Busan, Korea, October 2002.
- Rob Winkel, Richard Smokers, Robert Kost, Terry Penney, Kenji Morita, Peter Coenen, David Bauner, François Badin, *Annex VII "Hybrid Vehicles" of the IEA Implementing Agreement "Hybrid & Electric Vehicles"*, Proceedings of EVS-19, Busan, Korea, October 2002.
- Nils Stelzer, *IEA HEV Implementing Agreement Annex X Electrochemical Power Sources and Energy Storage Systems for Electric and Hybrid Vehicles*, Proceedings of EVS-19, Busan, Korea, October 2002.
- Toru Nakatsu, Tomohiko Ikeya, Sari Nobell, *International Cooperation for Information Exchange on Electric Vehicle Technologies and Programmes of Annex I of IEA Implementing Agreement for Hybrid and Electric Vehicles*,

Major IA-HEV publications during the second term, 2000 - 2004

Proceedings of EVS-19, Busan, Korea, October 2002.

- Sigrid Kleindienst Muntwyler, *Market Introduction Policy for Clean Vehicle Technologies*, Proceedings of EVS-20, Long Beach, CA, USA, November 2003.
- Sigrid Kleindienst Muntwyler, *Learning from Successful Market Introduction Programs for Clean City Vehicles*, Proceedings of the European Electric-Drive Transportation Conference, Estoril, Portugal, March 2004.
- Urs Muntwyler, Frans Koch, *International Energy Agency prepares third phase of its Hybrid and Electric Vehicle Agreement*, Proceedings of the European Electric-Drive Transportation Conference, Estoril, Portugal, March 2004.
- Frans Koch, *The IEA Hybrid and Electric Vehicle Agreement*, Windsor Workshop, Toronto, Canada, June 2004.
- Frans Koch, *Deployment Strategies for Clean Vehicles and Fuels (Annex 8)*, Windsor Workshop, Toronto, Canada, June 2004.
- IA-HEV *Newsletter*, 2000 – 2003.
- IA-HEV *web-site*: www.ieahev.org

Abbreviations

AC	Alternating Current
ADEME	Agency for Environment and Energy Management (France)
ANL	Argonne National Laboratory (USA)
APU	Auxiliary Power Unit
BEV	Battery Electric Vehicle
BMVIT	Federal Ministry for Transport Innovation and Technology (Austria)
CARB	California Air Resources Board
CERT	Committee on Energy Research and Technology of the IEA
CEU	Commission of the European Communities
CIDI	Compression Ignition Direct Injection
CNG	Compressed Natural Gas
CNR	National Research Council (Italy)
CO ₂	Carbon Dioxide
DC	Direct Current
DOE	Department of Energy (USA)
DPF	Diesel Particulate Filter
EM	Electric Motor
ENEA	Italian National Agency for New Technology, Energy and the Environment
EPA	Environmental Protection Agency
EURO-x	European emission standard, level x
EV	Electric Vehicle
EVS	Electric Vehicle Symposium
ExCo	Executive Committee
FC	Fuel Cell
FCEV	Fuel Cell Electric Vehicle
FCV	Fuel Cell Vehicle
gge	gallon gasoline equivalent
GHG	Greenhouse Gas
GM	General Motors
H ₂	Hydrogen
HEV	Hybrid Electric Vehicle
IA	Implementing Agreement of the IEA
IA-HEV	Implementing Agreement for Hybrid and Electric Vehicle Technologies and Programmes
ICE	Internal Combustion Engine
IEA	International Energy Agency
IPHE	International Partnership for a Hydrogen Economy
ITS	Intelligent Transport System

LCA	Life Cycle Analysis
Li	Lithium
LPG	Liquefied Petroleum Gas
MH	Metal Hydride
NEV	Neighbourhood Electric Vehicle
NG	Natural Gas
NiMH	Nickel Metal Hydride
NOx	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
R&D	Research and Development
RD&D	Research, Development and Deployment
SAM	Super Accumulator Module
SCR	Selective Catalytic Reduction
SEK	Swedish Crown
SIDI	Spark Ignition Direct Injection
SOFC	Solide Oxide Fuel Cell
SUV	Sport Utility Vehicle
USD	US dollar
Vito	Flemish Institute for Technological Research (Belgium)
ZEV	Zero Emission Vehicle

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The web-site of the IEA Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes can be found at www.ieahev.org.

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