

International Energy Agency

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

## **Hybrid and electric vehicles**

**The electric drive gains momentum**

**March 2008**

**Progress towards sustainable transportation**

The IA-HEV, also known as the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes, functions within a framework created by the International Energy Agency (IEA). Views, findings and publications of IA-HEV do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

Cover photo:

By charging their batteries with renewable electricity, plug-in hybrid electric vehicles (PHEVs, subject of new Annex XV) contribute to using renewable energy in transportation.

PHEVs may also play a role as enablers for the introduction of intermittent renewable energy -such as wind power- into the electricity grid.

(Photo © M. van Walwijk)

## International Energy Agency

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

Annual report of the Executive Committee and Annex I  
over 2007

## Hybrid and electric vehicles

### The electric drive gains momentum

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## ***Report structure***

This report consists of five main parts. Part A ‘About IA-HEV’ describes the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV), its activities and its plans for the coming years. The Chairman’s message in chapter 1 can be read as a summary of this report. Chapter 2 shows the relationship between IA-HEV and the International Energy Agency (IEA) and it describes the IA-HEV history and strategy. This year it also includes some essentials of the IEA activities on technology learning and deployment. Chapter 3 presents the IA-HEV clean vehicle awards.

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

A general picture of hybrid and electric vehicles (HEVs) around the globe is painted in part C ‘hybrid and electric vehicles worldwide’. The first chapter (13) in this section gives worldwide HEV statistical information and developments in 2007. It also includes a synopsis of governmental programmes in IA-HEV countries, which serves as a guide to quickly find in which IA-HEV member countries certain programmes are running. More detailed information can then be found in the IA-HEV member country chapters (14-24) that describe activities on hybrid and electric vehicles in each country. Chapter 25 highlights HEV issues in selected IA-HEV non-member countries.

Part D is dedicated to an outlook for the future of hybrid and electric vehicles, by the IA-HEV Executive Committee.

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

# 1

## ***Chairman's message***

**Successful year of the Implementing Agreement Hybrid and Electric Vehicles, with another new Annex and the new member countries Canada, Denmark and Turkey - the electric drive takes off**

### **1.1**

#### ***Introduction***

##### **1.1.1**

###### ***Good progress in 2007***

After a successful 2006, we could hold this level in 2007 and we moved forward in different working fields that are also open for more member countries:

- We started the Annex 'Market deployment of hybrid and electric vehicles: Lessons learned'. The Operating Agent is the Institute of Transportation Studies, University of California at Davis (USA).
- Already in 2006 Turkey announced its interest in membership, which could be settled in 2007. Turkey is represented by the Scientific and Technical Research Council of Turkey, TÜBITAK Marmara Research Center.
- Denmark rejoined the Implementing Agreement and the Danish Energy Authority is the Contracting Party.
- Canada (through Natural Resources Canada) decided to return to our Implementing Agreement. Canada took the lead for the new plug-in hybrid electric vehicles (PHEV) Annex that already started early in 2008.
- The first results of the work on the 'Outlook' were presented at the EET-2007 conference in Brussels.
- We started planning the preparation of the 4<sup>th</sup> phase of the Implementing Agreement, which is scheduled to run from 2009 to 2014.
- Our specialists collaborated in several workshops organized by the International Energy Agency (IEA) headquarters in conjunction with the G8+5 initiative of the IEA.
- We started a constructive collaboration with the AVERE organization.
- At the electric vehicle symposium EVS-23 in Anaheim we could present the winners of the 'IA-HEV clean vehicle awards 2007' in three categories.

The producers of hybrid vehicles had another year of strong demand for their car models. The total number of vehicles in use is now more than 1 million. The new plug-in hybrid vehicle concept will fill the consumers with enthusiasm. We expect that in 2008 the first hybrid vehicle model will exceed the one million sales figure.

### 1.1.2

#### ***The benefit for member countries***

Decision makers are highly dependent on the information they get before they decide. It is not only the independency but also the completeness and the global view that is crucial, but hard to attain. To put objective information on electric and hybrid vehicles and their effects on energy efficiency and the environment at disposal of governments, local and city authorities, fleet users and industries is one goal of our work. Participation in the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) provides a unique access to insider information and task forces. This saves time, money and accelerates the process of technical transition towards sustainable mobility. The call for co-ordinated action is one thing. This makes information for decision makers and politicians a necessity. But there is a need of closer investigation of a lot of questions concerning the technologies, applications, markets and environmental issues that are also covered by this Implementing Agreement and elaborated by the various task forces, the so called Annexes.

### 1.1.3

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

Actually eleven countries actively participate in IA-HEV (Austria, Belgium, Canada, Denmark, France, Italy, the Netherlands, Sweden, Switzerland, Turkey and the United States of America) and co-ordinate their research and pilot- and demonstrations efforts in the field of hybrid and electric vehicles. They have a better access to reliable information and therefore lower transaction costs. IA-HEV tries to expand these benefits to new member countries. Additionally, sponsors from industry (e.g. Tokyo R&D) and other organizations (e.g. AVERE) are involved in this Implementing Agreement and some of the task forces (Annexes).

### 1.1.4

#### ***Good opportunity to join our international working group***

In 2008-2009 we are preparing the work plan for the 4<sup>th</sup> phase (December 2009-November 2014) of this Implementing Agreement. This is a good opportunity for interested countries to share their experience and to join the group. Our secretary Mr. Martijn van Walwijk and I are eager to inform and to help you.

## 1.2

#### ***The three winning technologies of the future***

In the future, several technical solutions will provide the energy for the propulsion of mass transportation. This is reflected by the various Implementing Agreements of the International Energy Agency (IEA), e.g. the Agreement on Advanced Motor Fuels. But finally the electric drive will be the dominant propulsion system.

It is the most efficient technology, and the electricity can be produced by renewable energies in many different ways.

In our field, actually three different drivetrain solutions are to the fore. In all of them the electric motor plays an important role. By its advantages concerning the energy efficiency, it will be the winning technology of the future.

### 1.2.1

#### ***Hybrid vehicles: first EV technology for the mass market***

Hybrid vehicles that are partially powered by an electric traction motor can be highly energy efficient, can recover their braking energy and have major environmental advantages. They allow a great flexibility in technology choice, so a lot of combinations are possible. The plug-in hybrid technology has still to be developed and optimized, but it is the most promising technology regarding environmental aspects in the short term.

### 1.2.2

#### ***Electric vehicles***

Vehicles entirely powered by an electric traction motor are unbeatable in view of energy efficiency. Due to advanced technologies, their range is satisfying for the majority of all trips; they are smaller and lighter, therefore save space and material. Electricity is no exotic fuel, and recharging at home during the night is not only convenient but it also saves time and it is cheap.

### 1.2.3

#### ***Fuel cell vehicles***

Fuel cell vehicles allow a great variety of technologies and therefore the pathway is not yet clear. A lot of uncertainties concerning the technology and the infrastructure will cause delays in the market introduction. Range and efficiency are still weak points. Nevertheless, it is clear that the fuel cell vehicle has a great potential to replace the ICE (internal combustion engine) vehicle as soon as all the uncertainties are clarified.

## 1.3

### ***Objective information***

Currently vehicles with hybrid drivetrains are not the only option for designing 'clean' vehicles. At the moment biofuels dominate the discussion. The European Commission, for example, intends to increase the share of biofuel consumption up to 10%. The ethanol hype already caused a price increase for corn and wheat.

Such a situation makes information for decision makers and politicians a necessity. In the case of biofuels, an objective comparison of the energy efficiency shows that biofuels can only be an option in special and local environments. A

calculation of the magazine Photon compared the range achieved by the energy produced on one hectare of land: on one hand energy plants, on the other hand a freeland photovoltaic installation. The result is striking: the plug-in hybrid electric vehicle using solar energy drives more than 150 times further than cars using biodiesel or bio-ethanol (the bar of the plug-in hybrid vehicle in figure 1.1 has a length of an additional 6 pages).

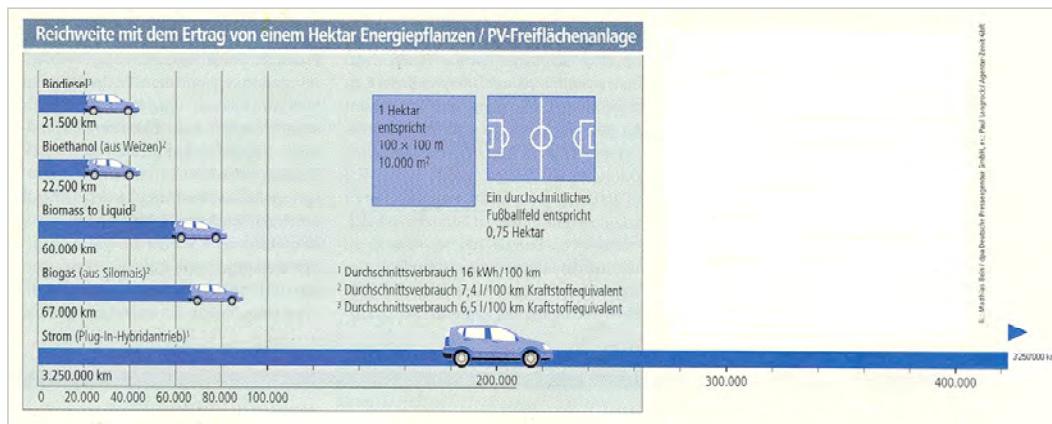


Fig. 1.1 Range achieved by the energy produced on one ha land (energy plants vs. photovoltaic installation). (Source: Photon magazine. Picture supplied by Muntwyler.)

The fact that public attention always follows the latest novelties has the effect that the novelty of yesterday escapes the awareness. Political decisions are highly influenced by this ‘mainstreaming’. Electric vehicles as the topic of yesterday are now in the shadow of the (plug-in) hybrid and alternatively fuelled vehicles, and therefore decision makers hardly include them in their clean car strategies. Mostly, they do not realize the progress and increased options of battery electric vehicles and their potential role in future transportation. Objective information on future clean cars must not follow this mainstreaming but has to evaluate all the options.

The objective of the Implementing Agreement on Hybrid and Electric Vehicles of the International Energy Agency is to put objective information on electric and hybrid vehicles and their effects on energy efficiency and the environment at disposal of governments, local authorities, fleet users and industries. In addition, there is a need of closer investigation of a lot of questions concerning technologies, applications, markets and environmental issues. Consequently, detailed studies or workshops on specific urgent questions are set up in special working groups called Annexes. The topics and the method of the investigation are discussed and decided by the Executive Committee, and the Annex itself is run by those countries that finally participate in it. These participating countries nominate the experts in the working groups, which ensures that the real specialists for the relevant topic join in and increase the experts’ network in the Implementing

Agreement. This provides a lot of flexibility: in the IA-HEV history paper studies have been published as well as conference papers and workshop protocols. Also the topics exceed the technical focus and cover issues of markets, marketing, economics and political aspects like promotion and governmental support.

## 1.4

### ***The plug-in hybrid electric vehicle (PHEV) is the EV for the consumer of today***

#### 1.4.1

##### ***Consumer problems with EVs***

Electric vehicles (EVs) are still successful in market niches but they could not convince the consumers as a replacement for the conventional car. The short range is perceived as the main problem. Drivers of electric vehicles have to manage their battery systems to reach the next electric outlet for a recharge. This is less important in commuter applications. But watching what kind of vehicles commuters use we see the illogicality: it is not the best-suited vehicle. Especially men drive big SUVs (USA) or over-powered cars (Europe) for the daily ride. Smaller, lighter and cheaper vehicles would be smarter. Car buyers choose their vehicle for the most extreme application of the year - a long distance holiday trip with a lot of luggage. This takes pure battery electric vehicles off the game. The other problem is a psychological one. It is not everyone's matter to deal always with the short range. Car users do not like such stress.

#### 1.4.2

##### ***Glider pilot's problem and the solution***

Glider pilots deal with a similar problem. After the launch by a winch or a towing plane, they search upcurrents for their flight. Their energy reserve is the altitude of the plane above the ground. Experienced glider pilots can glide long distances if the weather conditions are good. Sometimes the upcurrents are not sufficient; then gliders have to land in fields and must be transported to the airstrip with a trailer. This is a risk - no wonder that glider pilots are a minority, similar to EV-drivers!

In the last years a new type of glider has attracted the glider pilots: a glider with a retractable motor. Now the glider pilot can launch the retractable motor when the upcurrents are missed or the altitude is not sufficient. This lowers the stress for the pilot. Even more than that: the glider pilot can try cross-country flights and can avoid off-field landings. In practice the glider pilots are ambitious enough to avoid the use of the motor.

### 1.4.3

#### ***EV drivers solution: the plug-in hybrid electric vehicle (PHEV)***

The plug-in hybrid electric vehicle provides the same possibility: to drive without stress because of the long range capability. At the same time PHEVs have high energy efficiency and can be driven mainly by electricity.

### 1.5

#### ***The plug-in hybrid electric vehicle is the flexible link to the consumer***

##### 1.5.1

##### ***Plug-in hybrid electric vehicle: the EV-solution with many advantages***

The plug-in hybrid electric vehicle possesses a propulsion configuration with many advantages:

- The user does not have to fear running out of energy.
- Car companies can still integrate a combustion engine.
- This technology is a smooth transition to the pure battery electric vehicle.
- The energy consumption of the vehicle can be similar to that of pure battery EVs.
- The battery of the plug-in hybrid can be used as storage system for electricity (vehicle-to-grid concept).

It is obvious that the plug-in hybrid electric vehicle concept is a good compromise between the conventional (internal combustion engine) vehicle and the pure electric vehicle.

##### 1.5.2

##### ***Technical obstacles to be tackled***

The plug-in hybrid electric vehicle technology is more complex than that of electric or hybrid vehicles:

- The battery will be discharged lower than in a hybrid vehicle.
- The battery will be faster charged and discharged than in an electric vehicle.
- The charger must be bi-directional for vehicle-to-grid application (such as energy storage).
- The charger must be integrated in the vehicle.
- The battery must have more capacity than for a hybrid vehicle.
- The ICE must be integrated in the vehicle.

These and many optimization problems have to be carefully studied and solved. No doubt that co-ordinated research and a well-organized information exchange will speed up the process. This will be part of our new Annex on plug-in hybrid electric vehicles.

**1.5.3*****Challenge: batteries and their battery management systems***

Especially the battery and the battery management system must be adapted to this new application. This will be a task of the specialized Annex X - Electrochemical systems.

The energy exchange with the grid has to be optimized in the vehicle-to-grid mode as part of the battery management system. This could be a part of our pending Annex 'Renewable energies for hybrid and electric vehicles'.

**1.6*****Where are all the EVs gone?***

Electric vehicles are known for more than hundred years. In the last two decades many EVs have been introduced on the market. Many of them were not mature, but some of them could survive in market niches or are still in use by drivers who know that their electric vehicle will phase out. What happened with all these EV models? Were there weaknesses they all had in common? How can we be sure that mistakes will not be repeated by new projects of hybrid, plug-in hybrid or fuel cell vehicles? But we have seen the success of hybrid models, especially from Toyota, Lexus, Honda and recently Ford.

Our Implementing Agreement will investigate the stories behind the successful projects and behind the failures. A very active research group (Annex XIV) evaluates the situation in the U.S., European and Japanese markets. To be entitled to obtain all the results of this evaluation, membership in Annex XIV is required. After the first workshops of this Annex we expect very interesting results that can avoid wrong-guided investments in the future. This will help to increase the rate of success of future projects.

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

After the successful launch of a new Annex in 2007, today seven Annexes are simultaneously active - more at the same time than ever before. Our next effort is to increase the number of member countries.

**1.7.1*****Running Annexes******Information exchange (Annex I)***

This working group plays a key role in the programme. It establishes a regular information exchange on hybrid, electric and fuel cell vehicle developments and promotion measures in the member countries as well as the most interesting non-

member countries. The working group also works as a ‘turntable’ by publishing the figures and basic information on the Agreement’s website. The informal information that is the specific benefit of the participation is only available for the member countries. Participation in this Annex is included in the membership fee of the Implementing Agreement.

#### **Hybrid vehicles (Annex VII)**

This group of specialists from the USA and Europe worked on new trends concerning components and vehicles. Members of this group have been the first promoters of the current trend to plug-in hybrid electric vehicles. This has already been discussed in 2001, on the occasion of the IA-HEV Executive Committee meeting in Long Beach. The knowledge of this group enables the governments to influence the model policy of automakers of their country. The working group has published the final report and by that officially finished its work at the end of 2007.

#### **Electrochemical systems (Annex X)**

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

#### **Electric cycles (Annex XI)**

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

#### **Heavy-duty hybrid vehicles (Annex XII)**

This working group aims at structuring the information about heavy-duty hybrid vehicle components and configurations. An important aspect of this task is to gain insight in existing and possible applications of hybrid vehicle technologies. Besides the obvious vehicle types like buses and trucks, other applications of conventional heavy-duty vehicle technology -like dedicated and off-road vehicles- may be candidates for hybridization. Additionally to this study of the application area of hybrid technology, the Annex also studies the current situation of existing hybrid prototypes and standard vehicles. The information gathering will focus on the applied technology, the costs and the merits. This Annex -which had its kick-

off workshop in February 2007- will broaden the insights in these applications and provide essential information for future heavy-duty hybrid vehicle projects. The Operating Agent is the Belgian research institute VITO.

#### **Fuel cells for vehicles (Annex XIII)**

Fuel cells as electrochemical systems are not limited by thermodynamic restrictions of combustion processes. Therefore they offer unique advantages concerning energy efficiency and the reduction of noise and exhaust emissions. Considered by many scientists as optimal long-term solution for clean and efficient energy conversion for mobile and stationary applications, the transport industry, energy utilities and producers of portable consumer products invest strongly in the development of this technology. Nevertheless, limited lifetime as well as high production costs due to noble metal catalysts have impeded until now the broad market introduction of fuel cells beyond specialised niches like space applications. But in the last years cheaper and more stable materials for separators and electrodes have contributed to achieving major improvements for fuel cell technologies. Rising costs for after-treatment of internal combustion engine emissions due to tightening emissions standards will bring fuel cell vehicles nearer to competitiveness. This Annex concentrates its activities not on the development of fuel cells but on tuning their properties as well as using their high potential for their successful application in vehicles. The main focus is on road vehicles but other means of transport will be considered as well if their specific needs could play an interesting intermediate step for the market introduction of fuel cell road vehicles. In this respect boats, aeroplanes and mining vehicles could be an interesting niche preparing the market introduction of fuel cell, electric and hybrid road vehicles. The Operating Agent is Mr. Andreas Dorda from the Austrian Agency for Alternative Propulsion Systems (A3PS).

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

IA-HEV Annex VIII 'Deployment strategies for hybrid, electric and alternative fuel vehicles' (finished in 2002) investigated 95 promotion measures run by governments or other public and private organizations to enable the market deployment of clean vehicle technologies. The evaluation did not include success or failure stories of clean vehicles themselves. This is now the task of the new Annex XIV working group (see chapter 11).

The research group started the work with two workshops in 2007 that highlighted the situation in California and the United States. In 2008 they will study the situation in Europe (at the Geneva car show) and Japan. Being a member of this group can save wrong-guided investments in new vehicle projects. To know what happened during the market deployment of these vehicles is a pre-condition to learn from these stories and to avoid the repetition of mistakes.

**Plug-in hybrid electric vehicles (PHEVs) (Annex XV)**

The new member country Canada launched the idea for a new Annex focussing on plug-in hybrid electric vehicles. The idea was immediately accepted, and the Executive Committee agreed to a first draft work plan at the end of 2007. The Operating Agent, Mr. Charles Thibodeau from Natural Resources Canada (NRCan), has started this Annex by a kick-off workshop in February 2008. I expect that this Annex will attract new member countries. PHEVs have been the top item of this year. The group will build on the basis of the Annex VII 'Hybrid vehicles' working group. Research institutes, private companies (sponsors) and countries interested in this work please contact the Operating Agent (see chapter 12) or the secretary of the Implementing Agreement, Mr. Martijn van Walwijk.

**1.7.2****New Annexes in planning**

Two topics are candidates to become new Annexes:

**Clean city vehicles (Annex IX - pending)**

This is a proposal for energy-efficient transportation in developing countries. This scope demands a close co-operation with development agencies and raising of additional funds. After a first successful workshop in Paris in 2002, the benefit of such a co-ordination was clear. But financing a task with developing countries involved is challenging and has not yet been settled.

**Renewable energies for hybrid and electric vehicles**

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

**1.8****New participants are welcome**

Annexes finance their work by contributions of the member countries to the Annex fund. But the benefit of participation exceeds the costs by far. Research institutes or companies can collaborate as sponsor or subtask leader. Please contact the Operating Agent (OA) of the relevant Annex or the IA-HEV secretary in case you are interested. It is also possible to participate in a workshop free of charge, if an interest in further participation is expressed.

## 1.9

### ***Dissemination activities***

Because more and more decision makers in governments, states and communities are interested and want to get more information on hybrid and electric vehicles, we updated or started activities to meet this demand:

- Annual report.

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

- Newsletter via e-mail

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

- Website.

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

- Insight newsletter.

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

- IA-HEV clean vehicle awards.

Since 2005, this is a medium to point out to the necessity of a great clean vehicle share in transportation and the commitment of the automotive industry in clean vehicle production. There is not only the pressure of air quality standards or energy efficiency issues, but it is also a prospective market. The example of Toyota (first IA-HEV award winner in 2005) shows that commitment results in increased market shares and value of the brand. Three awards are annually granted:

- for more than 25'000, 50'000, 100'000 or 250'000 vehicles sold,
- for the best application of HEV and fuel cell vehicles,
- for a dedicated person in the field of HEV and fuel cell vehicles.

- The Executive Committee increases the value of the Implementing Agreement by elaborating an 'Outlook' chapter in the annual report (since 2006). This Outlook shows trends in vehicle technologies and market shares in the most relevant countries. Here you learn what a board of specialists expects of future clean vehicle developments and markets.
- Presentations at conferences like the Electric Vehicle Symposia (EVS) or the European Ele-Drive Transportation (EET) conferences.

## Workshops

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

- Annex I - Information exchange: 1-2 workshops per year.
- Annex X - Electrochemical systems: about 2 workshops per year.
- Annex XI - Electric cycles: about 2 workshops per year (for members).
- Annex XII - Heavy-duty hybrid vehicles: about 2 workshops per year.
- Annex XIII - Fuel cells for vehicles: about 2 workshops per year.
- Annex XIV - Lessons Learned: 2-4 workshops per year.
- New Annex XV - Plug-in hybrid electric vehicles: about 2 workshops per year.
- Several planned Annexes are preparing workshops for 2008!

In 2007 the Annexes of this Implementing Agreement have organized more than 10 workshops. All these workshops are open for participants from member countries. If you are interested to visit them as an observer please ask our secretary or the Operating Agent of the Annex.

## 1.10

### ***Participation in the IEA Implementing Agreement on Hybrid and Electric Vehicles***

#### **1.10.1**

##### ***How member countries profit by their membership***

The goals in the third IA-HEV phase of operation (until the end of 2009) are:

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

In 2008-2009, members will decide on the new objectives of the 4<sup>th</sup> IA-HEV working phase, which will start December 2009.

### **1.10.2**

#### **New countries and parties are welcome**

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

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

### **1.10.3**

#### **Support for specialists from developing countries**

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

### **1.10.4**

#### **Outlook: Can you see a future world without HEVs?**

The rhythm of working in 5-year phases caused a wave-like change in the intensity of our work. At the end of a phase, our activities declined, and after the 'green light' from the members and the IEA End Use Working Party that an additional 5-year phase was justified, we ramped up our activities again. By this process we used to loose a lot of momentum. After the breakthrough of hybrid vehicles, the success for small EVs in market niches and the renaissance of new EV-concepts, the approach should be changed. In the future, vehicle concepts like hybrid or plug-in hybrid electric vehicles will gain a bigger share in many fleets. This should be reflected by the working method of our Implementing Agreement. This will be discussed during the preparation of the 4<sup>th</sup> phase, which will start on the 1<sup>st</sup> of December 2009! For interested countries, 2008 is the right moment to 'jump on the train' and to participate in the discussion on the future course of the Implementing Agreement on hybrid and electric vehicles. I hope to welcome one or two new countries in 2008, which support our activities in this great time for hybrid and electric vehicles.

### **1.11**

#### **Final remarks: words of thanks**

For 2007, I have to say "thank you" to many of our specialists. Many members of the Executive Committee and subtask leaders have been very active. Especially the efforts of our new Operating Agents were impressive. It is always very difficult to bring a new working group together.

A special word of thanks is owed to our new member countries, first of them Turkey, represented by the Scientific and Technical Research Council of Turkey, TÜBITAK Marmara Research Center. I am personally very eager to learn about the Turkish research efforts in the field of HEV. Secondly Denmark, one of the pioneering countries in light-duty electric vehicles in the eighties. Today, through a high share of wind power in its electricity production, Denmark is in a position to base its mobility on EVs and PHEVs that are running on renewable energy. Canada, thirdly, is a well-known country for us. It influenced our Implementing Agreement in the first two phases. Natural Resources Canada already suggested a new Annex on plug-in hybrid electric vehicles, which has just started. I recommend this Annex for all countries that are involved in the research in this field.

The fruitful collaboration with other organizations like AVERE, EDTA, WEVA and e-Mobile went further in 2007. But first to mention is the support of the International Energy Agency with whom we had a closer collaboration than ever. The chairman of the IEA End Use Working Party (EUWP) Peter Cunz participated in one of our ExCo meetings, and I am looking forward to the co-operation with the new EUWP vice chairman for transport Mr. Nils-Olof Nylund.

A special thank goes to the deputy chairman of our Agreement, Arie Brouwer, who represented our Implementing Agreement in several meetings and workshops. Special efforts were made by our secretary Martijn van Walwijk and by the staff in my office.

Finally I have to thank the member countries and their representatives in the Executive Committee. They support our Implementing Agreement by the needed funds and by their expertise.

February 2008  
Urs Muntwyler  
IA-HEV chairman

**2**

## **The IEA and its Implementing Agreement on Hybrid and Electric Vehicles**

This chapter introduces the International Energy Agency (IEA) and its Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV). 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. Additionally, section 2.3 presents the outcome of two IEA workshops on technology learning and deployment that were held in 2007, and it shows how these results can be applied to road vehicles.

### **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. Current IEA member countries are shown in box 2.1. The basic aims of the IEA are:

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

**Box 2.1**  
**IEA member countries**

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

Fostering energy technology innovation is a central part of the IEA's work. Development and deployment of safer, cleaner, more efficient technologies is imperative for energy security, environmental protection and economic growth. IEA experience has shown that international collaboration on these activities avoids duplication of effort, cuts costs and speeds progress. The IEA 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 include fossil fuels, renewable energy, efficient energy use -in buildings, energy and transport-, fusion power, electric power technologies and technology assessment methodologies. Implementing Agreement participants undertake collaborative research, the benefits of which include pooled resources and shared costs, harmonization of standards and hedging of technical risks. (See also section 2.1.2.)

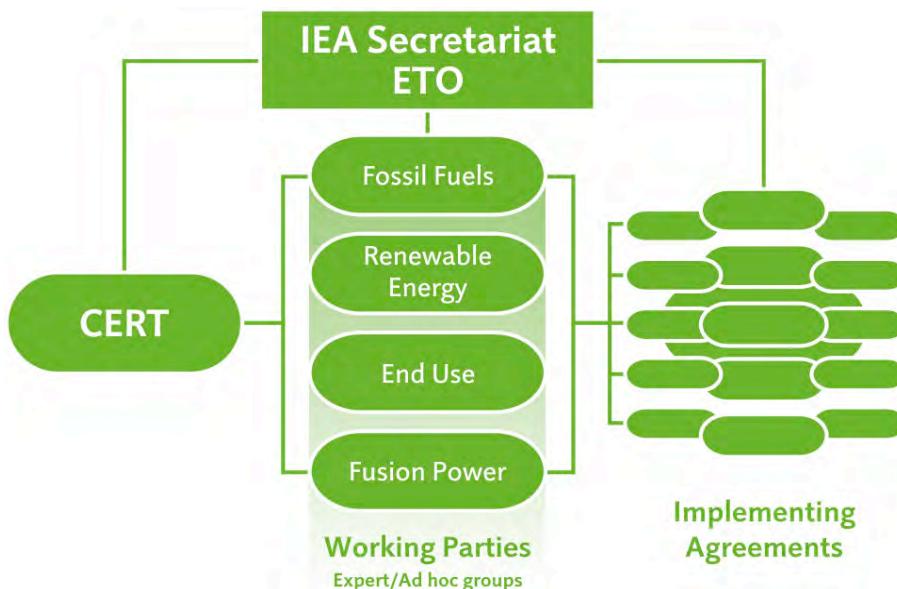


Fig. 2.1 IEA energy technology collaboration programme structure.

The IEA Office of Energy Technology and R&D (ETO) focuses on how energy technology and appropriate policies for its development and deployment -notably through international collaboration- can help underpin energy security, economic growth and sustainability. Under guidance from the Committee on Energy Research and Technology (CERT), the ETO provides authoritative information and analysis on how energy technology can make a difference. It plays a strong role in IEA work under the 2005 Gleneagles Summit mandate from G8 leaders to

‘advise on alternative energy scenarios and strategies aimed at a clean, clever and competitive energy future’. (Section 2.1.3 gives more information about the collaboration between the G8 and the IEA.)

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

### 2.1.2

#### ***IEA Implementing Agreements***

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

Since its creation in 1974, the International Energy Agency (IEA) has provided a structure for international co-operation in energy technology research, development and deployment. Its purpose is to bring together experts in specific technologies who wish to address common challenges jointly and share the fruit of their efforts. Within this structure, there are currently more than 40 active programmes, known as the IEA Implementing Agreements. Over three decades of experience have shown that these Agreements are contributing significantly to achieving faster technological progress and innovation at lower cost. Such international co-operation helps to eliminate technological risks and duplication of effort, while facilitating processes like harmonization of standards. Special provisions are applied to protect intellectual property rights.

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

In April 2003, the IEA’s Governing Board approved the new ‘IEA Framework for International Energy Technology Co-operation’. The Framework provides uncomplicated, common rules for participation in Implementing Agreements. It is a legal structure that actually simplifies international co-operation between

national entities, business and industry. Participants are welcomed from OECD member and OECD non-member countries, from the private sector and from international organizations.

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

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

The rights or benefits of a Sponsor cannot exceed those of Contracting Parties designated by governments of OECD non-member countries, and a Sponsor may not become a Chair or Vice-chair of an Implementing Agreement.

Participation by Contracting Parties from OECD non-member countries or international organizations or by Sponsors must be approved by the IEA Committee on Energy Research and Technology (CERT).

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

<b>Box 2.2</b>
<b>Benefits of International Energy Technology Co-operation in IEA Implementing Agreements</b>
<ul style="list-style-type: none"> <li>• Shared costs and pooled technical resources</li> <li>• Avoided duplication of effort and repetition of errors</li> <li>• Harmonised technical standards</li> <li>• A network of researchers</li> <li>• Stronger national R&amp;D capabilities</li> <li>• Accelerated technology development and deployment</li> <li>• Better dissemination of information</li> <li>• Easier technical consensus</li> <li>• Boosted trade and exports</li> </ul>

performance, and on to final market deployment. Some Implementing Agreements focus solely on information exchange and dissemination. The benefits of international co-operation on energy technologies in Implementing Agreements are shown in box 2.2.

Financing arrangements for international co-operation through Implementing Agreements fall into two broad categories:

- Cost sharing, in which participants contribute to a common fund to finance the work.
- Task sharing, in which participants assign specific resources and personnel to carrying out their share of the work.

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

Effective dissemination of results and findings is an essential part of the mandate of each Implementing Agreement. Wide-ranging products and results are communicated by various means to those who can use them in their daily work. For its part, the IEA Secretariat circulates the on-line OPEN Energy Technology Bulletin, which reports on activities of the Implementing Agreements. The OPEN Bulletin regularly highlights -among others- the activities of IA-HEV. The IEA also bi-annually issues a publication ‘Energy Technologies at the Cutting Edge - International energy technology collaboration IEA Implementing Agreements’ that presents updates on the Implementing Agreements’ major achievements. These reports are available at the IEA headquarters in Paris or can be downloaded free of charge from the internet website:  
[www.iea.org/Textbase/publications/free\\_all.asp](http://www.iea.org/Textbase/publications/free_all.asp).

### **2.1.3**

#### ***IEA’s G8 Programme***

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

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

G8 leaders invited the IEA to help activate dynamic worldwide networks for energy technology research and development. Building on its existing Implementing Agreement programmes, the IEA is linking with the international business community, with policy makers, researchers and other stakeholders in many countries. It is working to enhance awareness of existing research, development and deployment networks and to facilitate broader participation. For this purpose the IEA has created the NEET initiative (Networks of Expertise in Energy Technology). As part of the dialogue, the NEET team is planning workshops and high-profile presence at major international events between mid-2006 and 2008.

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

Section 2.3 of this report highlights the ‘Technology learning and deployment’ issue from the IEA Plan of Action deliverables.

## **2.2**

### ***The Implementing Agreement on Hybrid and Electric Vehicles***

Very few IEA countries do not have problems with urban air quality, and a few others are self-sufficient in oil, but all IEA countries have problems with greenhouse gas emissions from automobiles. There is a range of technologies available to address these problems, including hybrid and electric vehicles (HEVs). This means that there is a sound basis for an IEA Implementing Agreement (IA) on HEVs. The IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) was created to collaborate on pre-competitive research and to produce and disseminate information. IA-HEV is now in its third five-year term of operation that runs from December 2004 until November 2009. The eleven active Contracting Parties (member countries) per January 2008 are Austria, Belgium, Canada, Denmark, France, Italy, the Netherlands, Sweden, Switzerland, Turkey and the USA. Finland formally is a member, but it is currently not active.

Compared to the automotive industry and some research institutes, IA-HEV is a relatively small player in the field. By focusing on a target group of central & local governments and government supported research organizations, and by co-operating between different countries in joint research and information exchange activities, IA-HEV can play its role. More countries are invited to join the Agreement and to benefit from this international co-operation on hybrid and electric vehicles.

The work of IA-HEV is controlled by the Executive Committee (ExCo), which consists of one member designated by each Contracting Party. Contracting Parties are either governments of IEA countries or parties designated by their respective governments. The IA-HEV ExCo meets twice a year to discuss and plan the

working programme. The actual work on hybrid and electric vehicles is being done by different task forces that work on specific topics. Each topic is addressed in an Annex, which is managed by an Operating Agent (OA). The work plan of a new Annex is prepared by an interim Operating Agent -either on its own initiative or on request of the ExCo- before it is submitted for approval to the IA-HEV Executive Committee. The Annexes that are currently active are described in part B (chapters 4 through 12) of this report. The activities regarding hybrid and electric vehicles in IA-HEV member countries can be found in part C, chapters 13 through 24.

The next subsection (2.2.1) briefly reports on IA-HEV activities and results in its second term of operation (phase 2), and the strategy for the current term of operation (phase 3) can be found in subsection 2.2.2. Chapter 3 presents the IA-HEV clean vehicles awards.

### **2.2.1**

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

The second phase of the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) started in November 1999 at a time when hybrid vehicles had just been introduced on the market, and battery electric vehicles were considered suitable for some market niches such as neighbourhood electric vehicles, small trucks for local deliveries, or two- or three-wheel vehicles. Although good progress had been made in battery technology, low cost, high performance traction batteries were not yet commercially available. The first hybrid car -the Toyota Prius- had just appeared on the market. Progress with fuel cell technology led to optimism about a 'hydrogen economy' and car manufacturers switched their attention to fuel cells and away from battery electric vehicles.

Against this background, the most important objective of IA-HEV for phase 2 was the production and dissemination of objective information on hybrid & electric vehicles and their effects on energy efficiency and the environment. The principal way in which information was produced was by collecting it from participating countries and organizations and bringing it together into one report or database. The main ways in which information was disseminated was through technical reports, the annual report, articles in technical journals, newsletters, the internet, and through verbal presentations at meetings. The added value of the work in IA-HEV came from:

- Bringing together information from many different countries and thereby presenting a global overview on hybrid and electric vehicle technologies. The value added resulted from collecting individual pieces of a puzzle and putting them together to provide the overall picture.

- Collecting the most recent developments and the latest news, often months before it was officially published. The value added resulted from the ‘freshness’ of the information.
- Sharing information at meetings on successes and failures of government programmes and personal opinions on prospects of certain technologies that would never appear in print. The value added resulted from the uniqueness of the information; it was not available from other sources or by other means.

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

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

- Structured information exchange and the collection of statistics (Annex I).
- Hybrid vehicles (Annex VII).
- Deployment strategies for hybrid, electric and alternative fuel vehicles (Annex VIII).
- Clean city vehicles (Annex IX).
- Electrochemical systems (Annex X).

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

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

#### ***Information exchange (Annex I)***

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

Agreement should automatically be participants in Annex I, and the ExCo established financial arrangements to bring this about.

#### ***Hybrid vehicles (Annex VII)***

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

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

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

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

Annex VII was at the forefront of hybrid vehicle technology and produced valuable reports for the participating automotive research organizations and their governments. It shared test results on hybrid vehicles that were introduced on the market, and explored some of the issues that governments will have to address in

their automotive and environmental regulations. It also created and sustained a network of highly reputable automotive research laboratories throughout the world, and encouraged the sharing of information both within the scope of the task force and on other subjects.

#### ***Deployment strategies (Annex VIII)***

The task force on ‘Deployment strategies for hybrid, electric and alternative fuel vehicles’ considered 95 government programmes in 18 countries that were aimed at introducing clean vehicles and fuels. The scope of the work included both vehicles and fuels, and for this reason the task force was a joint effort between two Implementing Agreements, IA-HEV and the Implementing Agreement on Advanced Motor Fuels (IA-AMF). The objectives of the task force were to analyze how governments can accelerate the deployment of advanced automotive technologies in the market place and to make recommendations that will enhance the effectiveness of policies, regulations and programmes.

#### **Report of the deployment strategies task force**

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

#### **Benefits to participants**

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

force involving two Agreements demonstrated that co-ordination among IEA Implementing Agreements can be successful if there are common interests and objectives.

#### ***Clean city vehicles (Annex IX)***

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

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

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

The potential benefits of work in this area are substantive, but some barriers must still be overcome in order to make the task force operational. The main ones are that the scope of the technologies that are suitable for developing countries is much wider than the scope of the IA-HEV, and that the Ministries of Energy that participate in the IEA do not have a mandate for development assistance. Consequently, obtaining financial support for this work is complex. Efforts 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 (super-capacitors), and cleanly convert the energy in hydrogen to electricity (fuel cells). These are key enabling technologies for sustainable transportation.

During phase 2, this task force concentrated on the sharing of test methods for supercapacitors and batteries. Test procedures play a key role in moving new technologies from the laboratory to the market, and developing them involves a large amount of technical work and can easily cost more than a million dollars. Consequently, the sharing of test procedures can result in large savings.

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

#### **2.2.2**

##### ***Strategy for the third term of operation, 2004-2009***

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

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

Urban air pollution is still a source of public concern during the 21<sup>st</sup> 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 co-operation on Hybrid and Electric Vehicle Technologies and

Programmes (IA-HEV) started. Governmental programmes aiming at developing technologies to achieve these objectives have been remarkably successful during the past decade and have now brought us to a point where advanced vehicles are starting to enter the market. During the coming decade, the introduction of hybrid electric vehicles and in a later stage the introduction of fuel cell vehicles will cause unprecedented changes to the automobile market and this will have major economic, environmental, and energy implications for all IEA member countries.

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

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

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

The emphasis during the third term of the Agreement is on collecting objective general information on hybrid, electric and fuel cell vehicles. More specific information is collected in the subject area of each Annex. Priorities for topics to be addressed during the third term are shown in box 2.3.

<b>Box 2.3</b>
<b>Topics to be addressed in the third term of IA-HEV</b>
<ul style="list-style-type: none"> <li>• Information Exchange (Annex I). The work includes: country reports, census data, technical data, behavioural data, information on non-IEA countries</li> <li>• Electrochemical systems for EVs &amp; HEVs (Annex X)</li> <li>• Renewable energies for HEVs &amp; EVs</li> <li>• HEVs &amp; EVs in mass transportation, and heavy-duty vehicles (Annex XII)</li> <li>• Electric bicycles, scooters and light weight vehicles (Annex XI)</li> <li>• HEVs &amp; EVs for power correction or decentralized power production</li> <li>• Market aspects of Fuel Cell Electric Vehicles (Annex XIII)</li> <li>• HEVs &amp; EVs for special applications</li> <li>• HEVs &amp; EVs in developing countries</li> <li>• Recycling HEVs &amp; EVs at the end of their operational life</li> <li>• Testing standards and new vehicle concepts</li> <li>• User acceptance of HEVs; barriers for implementation</li> <li>• Impacts of HEVs &amp; EVs on industry and the economy</li> </ul>

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

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

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

- **Knowledge transfer by networking meetings**

Almost all Annexes of the Implementing Agreement (IA) organise expert meetings to exchange information. There is also an interaction between different IAs of the International Energy Agency, especially between IAs with transportation as an item in their work programme. Within the IA-framework there are seven IAs with such a transportation aspect. Again, value is added by bringing together information from several areas of expertise and exchanging it in a meeting or in written reports.

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

Automotive research is done by vehicle manufacturers as proprietary research, and by laboratories and research organizations that are often partially government supported. The work of the Implementing Agreement is done by the most reputable and best known public sector institutes and laboratories in the member countries. These institutes usually have research contracts with

industry as well as with the government. Their research services related to EV, HEV and fuel cell technologies are at the forefront of developments. By collaborating in international research studies, national governments can avoid national research of a smaller scope, and can have a cost reduction through pooling of resources. The added value of this working method lies both in the high quality of research studies, and in the lower costs for member countries (research by cost and/or task sharing).

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

By bringing experts from member countries together at expert meetings, knowledge is transferred among them and working relations are created or strengthened. By co-operating in joint studies, a high powered and effective network is formed among the (national) experts. This enables them to follow the evolution of technology and market developments for the purpose of assessing the market maturity and possibilities for implementation of EVs and HEVs.

Possibilities are available for exchange of personnel amongst laboratories, sharing of testing methods and protocols, and also improved access to e.g. testing equipment.

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

The delegates of the participating countries of the IA are (national) experts in the field of EVs and HEVs, or specialist on specific areas of automotive technologies. By meeting regularly and making joint decisions on the priorities and activities of the IA, they also exchange knowledge and form a network. This enables them to provide their governments with advice based on in-depth knowledge of international developments and on the state-of-the-art of the technology.

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

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

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

## 2.3

### ***Technology learning and deployment***

#### 2.3.1

##### ***Introduction and background***

The International Energy Agency (IEA) has committed itself to a Plan of Work as a response to the Gleneagles G8+5 summit in 2005, in which the countries agreed to act with resolve and urgency against climate change and its origins. (See also section 2.1.3.) A first result of this Plan of Work was the publication of the IEA report ‘Energy technology perspectives 2006 - Scenarios and strategies to 2050’ [2.1]. This report will be re-edited in 2008 and will then include a chapter on ‘Technology learning and deployment’.

The IEA energy technology perspectives report shows that only accelerated technology (ACT) scenarios will lead to a reduction of greenhouse gases. The basic ACT scenario is called ACT Map and demands the deployment of already existing CO<sub>2</sub> reducing technologies. Most of the perspectives are based on the ACT Map scenario (see also figure 2.2). After the publication of the 4<sup>th</sup> ‘Global climate change assessment report’ by the Intergovernmental Panel on Climate Change (IPCC) in 2007, the more demanding ‘Blue’ scenario (45 Gt instead of 32 Gt CO<sub>2</sub> reduction) has been added for some of the energy technologies.

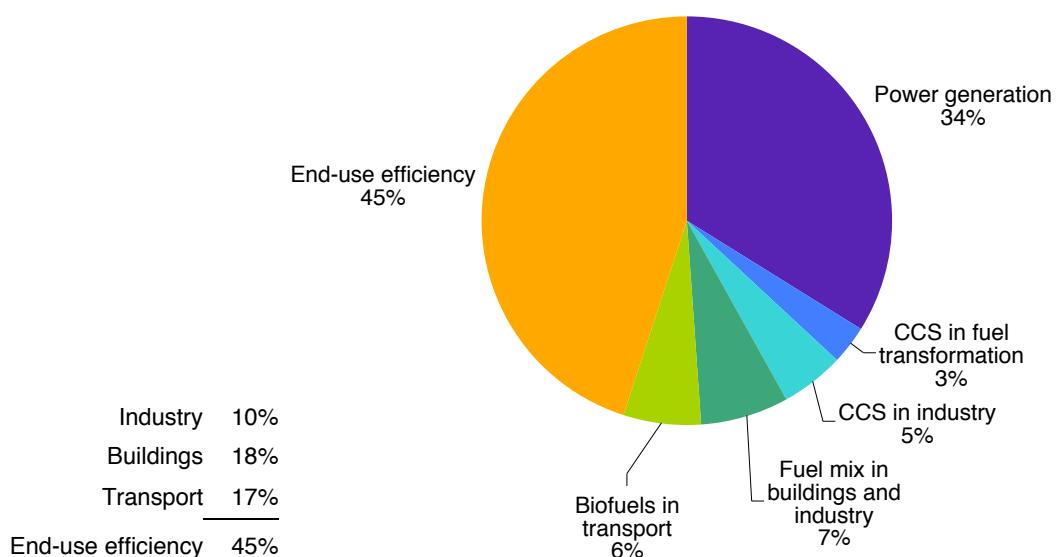


Fig. 2.2 Share of different sectors in CO<sub>2</sub> emission reduction target for 2050, according to the IEA ACT Map scenario. For a reduction target of 32 Gt CO<sub>2</sub> by 2050, the transport sector has to contribute 17% of the savings. (Sources: IEA estimates and [2.1].)

For the deployment of advanced energy technologies, market growth and capital stock are considered to be the key constraints. Technology learning has been

identified as a key issue to get to accelerated technology scenarios. In this context two topics have been discussed:

- The use of experience curves as an analysis tool. Experience curves help clarify the potential benefits of deployment programmes and provide policy decision makers with a tool to explore technology and policy options that can support the transformation of energy systems.
- The importance of early deployment of advanced technologies saving green-house gas emissions.

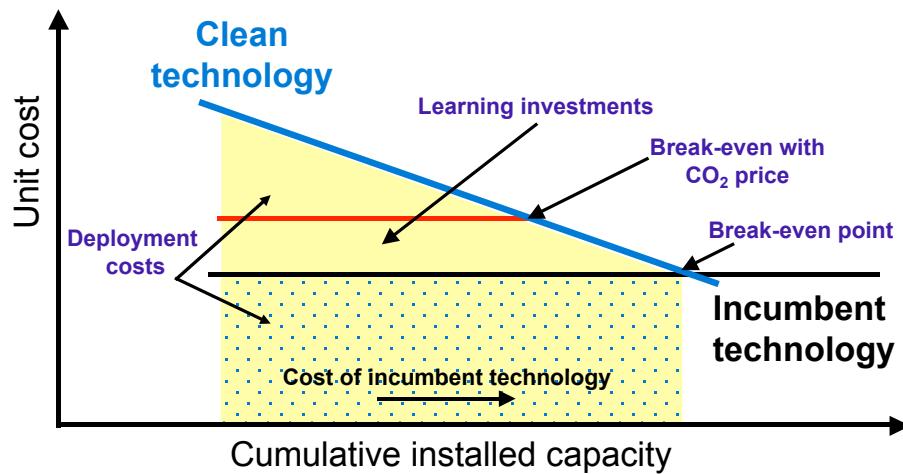


Fig. 2.3 Learning / experience curves show the price reduction at increasing production capacity. The field under the curve indicates the incremental costs until the break-even point with conventional (incumbent) technologies. (Source: IEA.)

For this reason, the IEA organized two workshops to share experiences and provide inputs to these two topics. The first workshop concentrated on supply technologies and the second workshop focused on demand side technologies. Inputs for transport related technologies came from the two Implementing Agreements Hybrid and Electric Vehicles (IA-HEV) and Advanced Motor Fuels (IA-AMF), completed by contributions on battery technologies for cars by the Japanese National Institute of Advanced Industrial Science and Technology (AIST), on the improvements of vehicle and fuel economy by the IEA, and on biofuels in Germany by the meo Consulting Team.

Two important results of these workshops can be summarized as follows:

- Experience curves should be handled with greatest care. They hardly show the framework conditions in which the increase of production and price decrease take place, and therefore they can more serve as an evaluation tool (showing whether the development is on the right track) than as a reliable tool to assess the market success and deployment costs of promising advanced technologies.
- Deployment as the first step into real markets is highly dependent on the price structure in which the advanced technology has to compete. There has been

unanimity that only a price for CO<sub>2</sub> emissions for all competitors in the market can push the deployment of advanced CO<sub>2</sub> saving technologies within the short period of time needed to get early results.

### 2.3.2

#### **Learning rates applied to transportation technologies**

The IEA experts extrapolated incremental costs by applying learning rates to energy technologies (partly based on data of the World Business Council for Sustainable Development) that also include three advanced vehicle technologies. The outcome for vehicles is shown in table 2.1.

Table 2.1 Estimates of incremental costs for three advanced vehicle technologies, by applying learning rates. (Source: IEA estimates.)

	Unit	Boundary	Current costs [US\$]	Learning rate	Cost target to reach commercialization*
<b>Fuel cell vehicles (millions of cars)</b>	US\$/kW	FCV drive system cost	1'875	22%	50
<b>Hybrid electric vehicles (millions of cars)</b>	car	ICE + electric + battery	2'500	20%	1'000
<b>Plug-in hybrid electric vehicles (millions of cars)</b>	car	Batteries for plug-ins	10'000	20%	3'000

*\*) A discount rate of 10% was applied to calculate the annualized cost of the incumbent technology and an import fuel cost of US\$ 6.5-7 per GJ (7 was assumed for the energy saved).*

In the ACT Map scenario, hybrid electric vehicles are estimated as the advanced vehicle technology in a phase from 2005 to 2030, whereas plug-in hybrid electric vehicles and fuel cell vehicles will be deployed only after 2030. In the more demanding Blue scenario based on a CO<sub>2</sub> reduction of 45 Gt by 2050, plug-in hybrid electric vehicles have to be introduced earlier. The deployment costs for hybrid electric vehicles under the ACT Map scenario are estimated at 500 billion US\$, whereas in the Blue scenario hybrid and plug-in hybrid electric vehicles have to replace a greater segment in the vehicle market and therefore show deployment costs of about 450 billion US\$ each. (See figure 2.4.)

It is remarkable that fuel cell vehicles are not shown in the chart of figure 2.4. The IEA experts think that they will play a role in the phase from 2030 to 2050, but their marketability cannot yet be assessed.

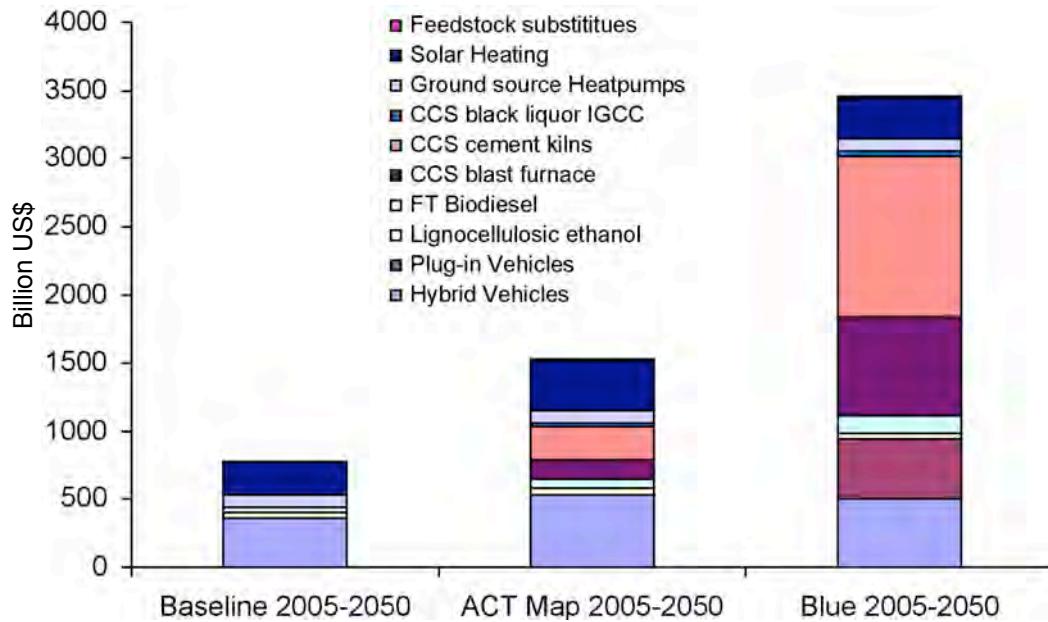


Fig. 2.4 Breakdown of deployment costs for demand side technologies. (Source: IEA estimates.)  
*This figure does not include investments for fuel cell vehicles under the Blue scenario, which total US\$ 15 billion from 2005-2030 and US\$ 3.56 trillion from 2030-2050.*  
*Note: Figures are not discounted.*

### 2.3.3

#### **Barriers for diffusion of advanced technology**

Scenarios shall help governments to decide what level of investments in certain technologies help to achieve the targets for CO<sub>2</sub> reduction. The focus on economic

Table 2.2 Barriers to technology diffusion. (Source: IEA, 2003.)

Barrier	Key characteristic
Information	Availability and nature of a product must be understood at the time of investment.
Transaction costs	Costs of administering a decision to purchase and use equipment.
Buyer's risk	Perception of risk may differ from actual risk.
Finance	Initial cost may be high threshold. Imperfections in market access to funds.
Capital stock turnover rates	Sunk costs, tax rules that require long depreciation and inertia.
Excessive / inefficient regulation	Regulation based on industry tradition laid down in standards and codes not in pace with development.
Uncompetitive market price	Economies of scale and learning benefits have not yet been realised.

barriers as shown above surely does not cover the whole problem of deploying advanced energy technologies, including vehicle technologies. Therefore also other barriers are mentioned (see table 2.2), as well as the potential of niche markets.

The authors of the ‘Technology learning and deployment’ chapter in the 2008 version of the ‘Energy technology perspectives: Scenarios & strategies to 2050’ report know very well that markets are more complex than to be depicted only in learning rates that do not specify boundary conditions, but governments need simple tools to justify their energy policies.

### 2.3.4

#### References

- [2.1] IEA. *Energy technology perspectives 2006 - Scenarios & strategies to 2050*. International Energy Agency. Paris, France, 2006. A summary is available on the internet at [www.iea.org/textbase/npsum/etp.pdf](http://www.iea.org/textbase/npsum/etp.pdf)
- [2.2] IEA. *Proceedings of the 1<sup>st</sup> workshop on ‘Technology learning and deployment’, 11-12 June 2007*. Paris, France. Available on the internet at [www.iea.org/textbase/work/2007/learning/proceedings.pdf](http://www.iea.org/textbase/work/2007/learning/proceedings.pdf)

**3*****IA-HEV clean vehicle awards*****3.1*****Introduction and background***

To put a new technology on the market and to create a market breakthrough is a very ambitious goal. The quickly changing society expects market breakthroughs within a very short time. With complex technologies -like cars- this often does not work; the attention of public and mass media turns into disappointment, and people look for the next ‘promising technology’.

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

- The ‘Clean vehicle award’ is granted to manufacturers with outstanding sales figures. There are four categories, based on the number of vehicles sold: bronze for 25’000, silver for 50’000, gold for 100’000, or platinum for more than 250’000.
- The ‘Best practice award’ is granted to the organizers of an outstanding promotion project.
- The ‘Personal award’ is granted to a person that has dedicated her or his work to the development or promotion of clean vehicles in an outstanding way.

**3.2*****The procedure***

Each specialist in the field of hybrid, electric or fuel cell vehicles worldwide is invited to nominate one or more candidates in the three categories mentioned above:

1<sup>st</sup> category: clean vehicle (according to sales figures),

2<sup>nd</sup> category: best practice,

3<sup>rd</sup> category: personal.

For the nominations of the 2<sup>nd</sup> and 3<sup>rd</sup> categories, candidates of that region are preferred in which the WEVA Electric Vehicle Symposium is held (Europe in 2005, Asia in 2006, the Americas in 2007, and Europe again in 2009). In the nomination process the AVERE section of the relevant region is contacted for co-operation. In the years without a WEVA Electric Vehicle Symposium (EVS), no regional restriction is made. An IA-HEV committee ranks the nominations.

### 3.3

#### The winners

##### 3.3.1

###### Awards 2007

The 2007 awardees are:

- Ford Motor Co. (USA), achieving sales of more than 50'000 hybrid models worldwide.
- The Plug-In Partners National Campaign (USA), for its outstanding promotion of plug-in hybrid vehicles.
- Paul MacCready (USA, posthumous), for decades of commitment to enable progress in electric vehicles by proving the potential of lightweight materials in body structures.

###### - **Clean vehicle award - Ford Motor Co. (USA)**

The Ford Motor Company played an important role as a clean vehicle innovator in the early 1990s, especially with the development of the electric vehicle Ecostar. The purchase and transformation by Ford of the Th!nk electric car proved an important experiment to explore market acceptance. By developing and marketing the hybrid Ford Escape, the company has been a pioneer among U.S. manufacturers to introduce a sports utility vehicle to the marketplace, and this has rewarded the company with well-earned market success.

In 2006 the HEV Implementing Agreement had the pleasure to recognize Ford for passing the 25'000 milestone in clean vehicle sales. In 2007 IA-HEV was glad to reward continuing commitment by designating Ford Motor Company as recipient of the ‘Clean vehicle award’ in acknowledgement of more than 50'000 hybrid models sold worldwide.



Fig. 3.1 From left to right: Ford Ecostar, Ford Th!nk, Ford Escape hybrid. (Photos: courtesy Ford Motor Co.)

###### - **Best practice award - Plug-In Partners National Campaign (USA)**

To develop a new vehicle technology is one thing. To introduce it into a market that is dominated by one technology -the gasoline vehicle- is more demanding. But to demonstrate the marketability of a propulsion system that no automaker has yet produced is a real challenge.

In 2006, the Plug-In Partners National Campaign was launched in the U.S. Employing the instruments of a grassroots movement, it collected signatures for a petition to show automakers that many customers would buy a plug-in hybrid if such a vehicle was produced. It convinced state and business fleet owners to order plug-in hybrid vehicles in advance. It encouraged governments, city administrations, environmental, consumer, civil and other organizations to demonstrate their support for plug-in hybrid vehicles. It looked for partners to join the campaign, and found them. Now about 550 organizations are participants, from cities to local government administrations, from utilities to other energy and transport related businesses. Some 30'000 people have confirmed by their signature that they would buy a plug-in hybrid car, and 10'000 advance orders originated from government and business fleets.



Fig. 3.2     Plug-In Partners National Campaign logo. (Courtesy Plug-In Partners National Campaign.)

The success of this campaign -as desired- won full attention of the automotive industry and at the same time it prepared the awareness of tens of thousands of people and made them think about ‘cleaning-up’ their mobility.

IA-HEV recognizes this outstanding commitment of the Plug-In Partners National Campaign to prove the marketability of plug-in hybrid vehicles, and therefore take great satisfaction in acknowledging this commitment with the ‘Best practice award’.

- **Personal award - Paul MacCready (†) (USA)**

A great loss was suffered when Paul MacCready passed away in his sleep on August 28, 2007. Those of us who knew him were so much looking forward to seeing him again at the award ceremony where we could demonstrate how much the electric and hybrid vehicle world owes him.

Being a glider pilot -winning the national soaring championship in 1948, 1949 and 1953- he was always fascinated how far one can get by just striving for the highest efficiency. He learned of the ‘Kremer prize’ for the first sustained human powered flight over a distance of one mile and he took up the challenge. The result was the Gossamer Condor, a glider powered only by human energy, and it won him the prize. This was the starting point for his thinking about

transportation. The limited capacity of aircraft to carry fuel on board made lightweight design necessary in aircraft engineering, and the technologies were well-known, with no questioning of the need for or cost of lightweight materials. So, why not enhance the efficiency of cars (and trains or other means of transportation) by learning from aircraft technology? Why not improve aerodynamics, drag and rolling resistance by using lightweight materials and shaping the body? This would enhance fuel economy, save resources, and ease impacts on the environment. ‘Doing more with less’ became his motto. In 1971, MacCready founded AeroVironment, a company specialized and well known in developing high efficient electric energy systems.

Paul’s masterpiece in automotive technology resulted from the entrance of GM in the first World Solar Challenge 1987. AeroVironment and Caltech formed the development team under his direction. The GM Sunraycer had a weight of 390 pounds (175 kg), consumed only 1.8 Wh/100 km, and was supreme winner of the first World Solar Challenge. GM thought this was a unique chance to establish itself as top in class in advanced electric drive technology. In response, MacCready and AeroVironment developed the Impact electric vehicle for the Los Angeles Motor Show in January 1990, later improving it as the EV1. This purpose-design electric vehicle of one of the Big Three had more ‘impact’ than expected: convinced by its performance, the California Air Resources Board implemented the Zero Emission Vehicle Mandate, demanding a 2% share of EVs in the sales of seven car producers. MacCready did not only think in terms of technology. He thought in systems, having nothing less in mind than the future of civilization.

The IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes honours Paul MacCready posthumously for his vision of and practical contribution to future clean transportation by presenting the 2007 ‘Personal award’ to his family.



Fig. 3.3 Left: Paul MacCready in the Solar Challenger crossing the Channel (1981). Right: Paul MacCready (right) with the GM Sunraycer (1987). Opposite of him Alec Brooks and Peter Lissaman (AeroVironment). (Photos supplied by Muntwyler.)

### 3.3.2

#### **Picture gallery**



Photo: Muntwyler.

#### **2005**

The 'IA-HEV clean vehicle award' winners, from left to right:

Masitami Takimoto, Toyota, Japan: platinum 'Clean vehicle award' for more than 250'000 Prius models sold.

René Jeanneret, Switzerland: 'Personal award'.

Alberto Santel and Paolo Rodiglione, Reggio Emilia, Italy: 'Best practice award'.

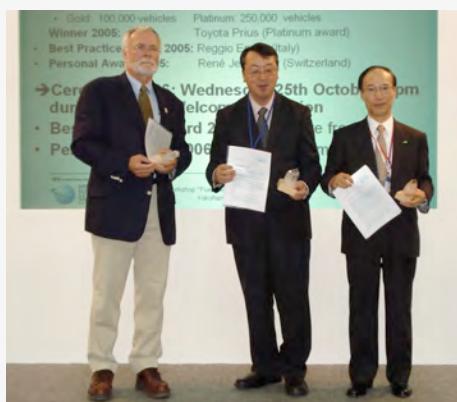


Photo: M. van Walwijk.

#### **2006**

Three of the 'IA-HEV clean vehicle award' winners, from left to right:

Hans Tholstrup, Australia: 'Personal award'.

Akira Fujimura, Honda, Japan: silver 'Clean vehicle award' for more than 50'000 hybrid models sold.

Masitami Takimoto, Toyota, Japan: silver 'Clean vehicle award' for more than 50'000 hybrid Lexus models sold.



Photo: M. van Walwijk.

#### **2007**

The 'IA-HEV clean vehicle award' winners, from left to right:

Tyler MacCready, USA, on behalf of his father Paul MacCready: 'Personal award'.

Greg Frenette, Ford, USA: silver 'Clean vehicle award' for more than 50'000 hybrid Escape models sold.

Roger Duncan, The Plug-In Partners National Campaign, USA: 'Best practice award'.



## **4**

### **Information exchange**

#### **(Annex I)**

##### **4.1**

##### **Introduction**

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

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

##### **4.2**

##### **Objectives**

The function and objective of the information exchange task force (Annex) is to collect, analyze and disseminate information from both member and non-member countries regarding research, concept development, commercialization, marketing, sales and fleet penetration of two- to four-wheel electric (EV) and hybrid electric vehicles (HEVs) and their components. Vehicles in this context are generally classified as electric and electric-assist bicycles, electric scooters, three- and four-wheel light-duty electric vehicles (including small trucks and delivery vans), hybrid gasoline-electric automobiles and light trucks, and hybrid diesel-electric heavier trucks and buses (which could also include mobile off-road equipment). In future years, it is expected that a subset of one or more of these categories will be a plug-in hybrid form able to obtain at least twenty percent of its operation range from purely electric power delivered from charging off of the grid. To qualify as a hybrid, a vehicle's electric motor must be able to contribute to propulsion through the drivetrain, not merely to provide engine-off and restart capability in idle.

## 4.3

### **Working method**

The work of collecting and analyzing this HEV information is carried out by the respective country experts, who then make it available to other members at both experts' meetings, held up to twice annually in conjunction with meetings of the IA-HEV Executive Committee, and through the IA-HEV website ([www.ieahhev.org](http://www.ieahhev.org)), on which data may be updated more frequently. The Operating Agent (OA) is responsible for co-ordinating these activities, maintaining the IA-HEV website, and contributing to the production of the Executive Committee (ExCo) annual report. The OA also acts as liaison to the OAs for other Annexes and, through the Executive Committee Secretary, to the ExCo chair and the cognizant IEA Desk Officer.



Fig. 4.1 Annex I experts and guests convene in Brussels, Belgium, May 2007 ... and in Santa Ana, California, USA, December 2007. (Photos: C. Saricks.)

A major part of the information exchange for the Annex occurs at the experts' meetings, in which participants who have spent time compiling the relevant reports, facts and statistics from their home countries brief the other attendees. These presentations generally cover developments since the previous meeting in the respective statistical and market situations for EVs and HEVs (national sales and fleet penetration, by vehicle type); the progress of international, governmental, or local programmes and incentives in the field; and new initiatives in vehicle and component development arising from both the private sector and public-private partnerships. Often, a special topic will have been identified for specific consideration and coverage during that year, to be discussed in depth at the autumn meeting, possibly to include separate country presentations. The special topic for Annex I in 2007, the third full year of phase 3 of the Agreement, was 'National and regional taxation policies that either promote or militate against EVs and HEVs, and the outlook for HEV technologies'. When it was approved at the spring 2007 meeting of the Annex experts in Brussels, Belgium, the purpose of this topic was to examine the taxation basis for commitment of member countries in expanding and diversifying the hybrid vehicle market. Experts were

to collect data on taxation policies of both national and regional governmental authorities in their home countries to better define the extent to which the mass market for these vehicles was being either helped or hindered. Experts were also asked to weigh in with their own judgments about the outlook for HEV and components production and markets in their home countries. At the autumn 2007 meeting of Annex I in Santa Ana, California, USA, it was reported that a white paper on taxation policies was in development and scheduled for pre-release review by March 2008.

An ongoing role of this Annex is the collection of less technical data and news to inform the preparation and dissemination of (up to) three newsletters per year. Timely information updates, comments and new ideas may also be obtained for posting on the website from country experts and Operating Agents of other Annexes, a benefit much more difficult to offer in the absence of such a well-informed international network as that of the IA-HEV. Participation in Annex I experts' meetings is not limited to members, but has frequently included experts on local activities invited to discuss these programmes and sit in as observers. For example, guests from Indian and Canadian institutions focused on vehicular technologies attended the spring 2007 meeting.

#### **4.4**

#### **Results**

Twenty-six experts' meetings have been conducted since the inception of the IA-HEV. As many as eleven nations have participated in Annex I and sent experts to these meetings during the three phases of the Implementing Agreement. Through 2004, the Annex published an annual report separate from that of the Executive Committee; this report was primarily a digest of EV and HEV statistics for the preceding year and a compendium of country presentations from that year's experts' meetings. Beginning in 2005, the Annex I and ExCo annual reports were combined. This joint annual report is expected to be issued for the duration of phase 3 and eliminates much prior redundancy of statistical and topical coverage between the two reports. Similarly, the consolidation of the Annex I and Executive Committee (IA-HEV) internet sites under the administration of the Annex I Operating Agent eliminates considerable duplication between the two predecessor sites. It also facilitates the presentation of HEV information to a broader audience spanning the various Annexes, the Executive Committee and interested persons within the International Energy Agency. A product of this broader outreach effort is the 'Expanding HEV universe' feature on the news page of the website which -on a monthly basis- recapitulates for a lay audience recent developments of interest in the area of electric and hybrid vehicle technologies and policy.

## 4.5

### ***Further work***

The objective of assuring that the information and data posted on the IA-HEV / Annex I combined internet site are as timely and accurate as possible will continue during 2008. Access to proprietary data and other 'late breaking' information will be limited to participating members as an inducement to non-member countries to join. Items from both member and non-member nations may be posted. In addition, the Annex I Operating Agent expects to be able to continue to employ the wide spectrum of international contacts to which it has access, to facilitate incorporation into website content the views and insights of experts from non-member countries in Asia and North America. Because the world has entered an unprecedented period of growth in the fleet of HEVs worldwide, it will be important to ensure that key developments in technologies, vehicle configurations and markets are highlighted and up to date.

## 4.6

### ***Contact details of the Operating Agent***

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

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## 5

### **Hybrid vehicles (Annex VII)**

#### **5.1**

##### ***Introduction***

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

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

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

Experts from Austria, Belgium, France, the Netherlands, Sweden and the United States participated in Annex VII. Canada and Turkey have been attending expert meetings as guests. TNO | Science & Industry in the Netherlands was the Operating Agent of this Annex. Annex VII was formally closed during the IA-HEV Executive Committee meeting in December 2007.

#### **5.2**

##### ***Objectives***

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

- Fuel converters for HEVs.
- Drive technologies for HEVs.
- Auxiliaries for HEVs.
- Energy storage for HEVs.

The second goal was to exchange information and to prepare reports on the following topics related to plug-in hybrid electric vehicles (PHEVs):

- Modelling and simulation of PHEVs.
- External benefits of PHEVs.

- Marketability of PHEVs (including infrastructure).

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

The focus of this Annex was on (hybrid) vehicles with four (or more) wheels. At first both light-duty vehicles (e.g. passenger cars) and heavy-duty vehicles (e.g. busses and trucks) were included. However, after the start of IA-HEV Annex XII 'Heavy-duty hybrid vehicles', Annex VII only considered light-duty vehicles.

The overall objectives of the task force in the third phase of this Annex were 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.

### **5.3**

#### ***Working method***

TNO | Science & Industry, part of the Netherlands Organization for Applied Scientific Research, acted as Operating Agent of this Annex. The Annex revived with an initial workshop in Eskilstuna, Sweden, in June 2004. This was the start of the third phase of this Annex. In Sweden the task force agreed on a three-year basic work plan. The work plan was finalised at the first expert meeting of the task force in Mol, Belgium, in November 2004. In 2005, 2006 and 2007 the progress was discussed in three expert meeting per year.

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

The participants in Annex VII were:

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

Furthermore, observers in this Annex were:

- Canada (National Resources Canada - NRCan),
- Turkey (TÜBITAK Marmara Research Center).

The work in this Annex was split in three subtasks that are directly related to the three goals of this Annex. The subtask leaders are shown in box 5.1.

<b>Box 5.1</b>			
<b>Subtasks and subtask leaders in Annex VII</b>			
<b>Subtask</b>	<b>Country</b>	<b>Company</b>	
A Components for hybrid vehicles	Austria	Arsenal Research	
B Plug-in hybrid vehicles	USA	Argonne National Laboratory	
C Information exchange	NL	TNO I Science & Industry	

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

The Operating Agent organised two or three expert meetings per year. These two-day meetings (organised in co-operation with a participating country that hosts the meeting) gave the participants the opportunity to discuss and work on the three subtasks. Furthermore a technical visit, often to the facilities of the organization that hosted the meeting, was included. Box 5.2 shows the expert meetings that have taken place.

<b>Box 5.2</b>			
<b>Expert meetings of Annex VII</b>			
<b>#</b>	<b>Date</b>	<b>Place</b>	<b>Country</b>
1	November 15 <sup>th</sup> - 16 <sup>th</sup> , 2004	Mol	Belgium
2	March 31 <sup>st</sup> - April 1 <sup>st</sup> , 2005	Lyon	France
3	September 22 <sup>nd</sup> - 23 <sup>rd</sup> , 2005	Chicago	USA
4	January 19 <sup>th</sup> - 20 <sup>th</sup> , 2006	Vienna	Austria
5	April 27 <sup>th</sup> - 28 <sup>th</sup> , 2006	Palo Alto	USA
6	September 6 <sup>th</sup> - 7 <sup>th</sup> , 2006	Delft	The Netherlands
7	February 5 <sup>th</sup> - 6 <sup>th</sup> , 2007	San Diego	USA
8	May 24 <sup>th</sup> - 25 <sup>th</sup> 2007	Paris	France
9	September 20 <sup>th</sup> - 21 <sup>st</sup> 2007	Istanbul	Turkey

## 5.4

### Results

In 2007, the following papers have been presented:

- *Trends in energy storage systems* at the European Ele-Drive Transportation Conference (EET-2007) in Brussels, Belgium. This paper gives an overview of the advantages, disadvantages and practical aspects of energy storage technologies that can be used in hybrid electric vehicle applications.
- *The IEA Annex VII Hybrid Vehicle phase III experience* at EVS-23 in Anaheim, USA. This paper gives an overview of current state of the art of components for hybrid and electric vehicles.

Previous publications are:

- *Components for Hybrid Vehicles: Results of the IEA Annex VII 'Hybrid Vehicle' Phase III* in WEVA journal 2006-038.
- *Energy Storage* at the Global Powertrain Congress. This paper gives an overview of the advantages, disadvantages and practical aspects of battery technologies and ultra capacitors that can be used in hybrid electric vehicle applications.
- *Global Prospects of Plug-in Hybrids* at EVS-22 in Yokohama. The topics that are addressed are the potentials of PHEVs and their ability to use charge depletion in conjunction with hybrid mode operation to displace gasoline use. Multiple charge depletion strategies are considered.
- *Components for Hybrid Vehicles* at EVS-22 in Yokohama. The paper describes the international collaboration in modelling validation and testing between the Annex VII participants, considering the complex characteristics and internal non-linear interactions of HEV components.

All papers were prepared and presented by Annex VII participants.

The main deliverables for phase I and II were the 'Overview report 2000' and its update, the 'Overview report 2002'. The results of phase III are presented in the report 'Status overview of hybrid and electric vehicle technology 2007'. The final report is available on the internet at [www.ieahhev.org/pdfs/annex\\_7/annex7\\_hev\\_final\\_rpt\\_110108.pdf](http://www.ieahhev.org/pdfs/annex_7/annex7_hev_final_rpt_110108.pdf). Below is a summary of the conclusions of the report.

#### ***Conclusions regarding components for hybrid and electric vehicles***

##### **Fuel converters**

In a hybrid powertrain, inefficient phases of combustion can be (mostly) avoided. In an optimized hybrid powertrain, the internal combustion engine working conditions (or operating point) are similar for use in urban areas and on motorways, thus independent of the vehicle usage. As a consequence, the benefits will

be bigger in urban use. Most improvements are similar to improvements for conventional engine technologies, including improvements of air circuit (valves, charger(s), exhaust gas recirculation, de-throttling for gasoline engines), injection (direct injection, multi-injection, very high pressure), combustion (variable compression ratio, Atkinson cycle, new types like compressed auto-ignition, HCCI, ...), after-treatment (diesel particulate filters, selective catalyst reduction, ...) or engine (low friction, electrified auxiliaries).

It is important to look at the total energy management of the vehicle. Great care will have to be taken in the future to choose the optimal engine (and drivetrain) technology with respect to its overall costs for different applications (regarding vehicle use, country, energy paths schemes, ...).

### Drive technology

Currently most HEV applications on the market use permanent magnet synchronous motors (PMSM). Their main advantage is their high power density, so they can be smaller than other motors, no power losses associated to the excitation field production (as it is provided by permanent magnets) and a wide (basic) usage speed range. The main disadvantages are slightly higher production cost, limited thermal robustness (both due to the expensive permanent magnets) and safety issues in case of failures at high speed of the vehicle (as magnets and thus power are permanent).



Fig. 5.1 Components of a hybrid drivetrain. The example shown here is for the Porsche Cayenne hybrid. Left are the internal combustion engine, gearbox, power electronics and electric motor/generator. Right is the battery pack with cooling system. Components of the electric system are shown in red. (Photos: M. van Walwijk.)

Another drive technology suited for hybrid applications is the asynchronous induction machine (AIM). Currently the squirrel cage rotor AIM (SQAIM) is used on the market in EV applications. The main advantage of the SQAIM is its simple and cheap construction. This results in lower costs, high durability and minimal maintenance. Other advantages are: speed range extension by so-called flux weakening (possible due to field oriented control), high thermal robustness

(maximum operation temperature is limited by the insulation material in the stator windings) and easy to implement safe operation measures (as there is little voltage without excitation).

Although PMSMs will be used most often in the next generation of HEV applications, it is likely that in a few years both AIM and PMSM will be used in HEV applications. In the future, power electronics controlling the electrical share (of power distributed to the drivetrain) will also become more important.

### **Auxiliaries**

The electrification of auxiliaries has a great potential for improving vehicle fuel consumption. An example is the electrification of door openers, suspension, parking brake and steering system for a bus (driving an urban cycle) with possible reduction of the energy consumption of these systems by 80%.

Up to now only few applications are ready for mass production. The main issues for an intensive electrification of the auxiliaries in passenger cars and heavy-duty vehicles are the costs and the complex optimization of the energy management.

By means of advanced design tools like simulation software it is possible to design well optimized auxiliaries with a suited efficient management. This optimized design can make the switch from a mechanical or thermal system to an electrical system affordable.

In the near future it will be likely to have electric air conditioning units and electric power steering. Even if these new components are introduced firstly on upper class vehicles, small and medium cars (which most of the time run in cities) might take the biggest advantage in terms of fuel consumption reduction.

### **Energy storage**

The electric energy storage technologies relevant for hybrid electric vehicle applications are lead acid batteries, used in many heavy-duty hybrid electric vehicles up to today and suited for soft/mild hybrid applications, and nickel metal hydride (NiMH) batteries. NiMH is the current choice of passenger car OEMs for power assist/full hybrid applications. Li-ion is a very promising battery technology, mainly for full hybrid applications. Ultra capacitor technology is a possible valuable alternative for batteries for soft/mild hybrid applications. The combination of ultra capacitors and batteries may have some applications in mild HEVs or even in full HEVs, but further development is needed. Dependent on the electric energy storage system, there might be a requisite to implement battery management and/or thermal management systems.

Other energy storage systems like flywheels and hydraulic vessels might be valuable alternatives, but their technology stills needs to be proven.

***Conclusions regarding plug-in hybrid electric vehicles (PHEVs)*****External benefits of PHEVs**

Due to an anticipated mix of natural gas and (in the U.S.) coal fired power, leavened with a small amount of wind power, plug-in hybrid electric vehicles operating in charge depletion mode will very sharply reduce oil use per kilometre and also very consistently reduce greenhouse gas (GHG) emissions.

For all fuels evaluated other than oil, use of the fuel to serve a PHEV in charge depleting mode would provide more kilometres of service than competing options evaluated and provide the greatest GHG reduction.

Once any feedstock has been converted to electricity, use of that electricity will result in more than double the kilometres of service, if used in a PHEV in charge depleting mode rather than in a near term (~ 2015) fuel cell vehicle.

When comparing Europe to the U.S., two factors have to be considered: the less stringent emissions controls (for light-duty) on the conventional diesel powertrain compared to the U.S., as well as the far less frequent use of coal in the power generation mix in the EU. If these two factors are considered together it appears that PHEV technology has even more potential to reduce GHGs and improve air quality (particulates and NO<sub>x</sub>) in Europe than in the U.S.

The estimates presented and sources investigated in the report imply that there are no effects of criteria pollutant (such as particulates and NO<sub>x</sub>) that cannot be successfully addressed. More optimistically, valuable air quality and human exposure benefits seem attainable.

It appears that if PHEVs succeed technically and economically, they will not have to overcome any negative external effects. Instead, they are likely to garner support because of their broad ability to consistently reduce negative externalities with respect to energy imports, GHGs and air quality.

**Marketability of PHEVs**

HEVs, PHEVs and diesels will split the advanced powertrain market in comparison to gasoline vehicles. HEVs will be most advantageous in the most congested conditions, realizing the highest fuel savings per hour there. Diesels will be most advantageous to those customers driving long distances per day, far in excess of the range of available PHEVs. PHEVs will fit in the middle of these two markets. We expect this market to be on the outside of the most dense centre cities, in residential areas where higher income residents are found, and where the highest percentage of single family detached dwelling units are found.

The early PHEV market is seen as a spin-off of the HEV market. We have essentially argued, for Europe, that the development of a HEV market would have to precede the development of a PHEV market.

Considering driving behaviour, income level, climate sensitivity of batteries, and availability of plugs, the early target market is households with garages with plugs.

## 5.5

### **Further work**

Because of their potential to reduce fuel consumption and emissions, hybrid vehicles are at the centre of interest for government officials and automotive research organizations. The increasing popularity is also shown by record braking sales numbers for several successive years. Recently the next step in electrification of road transport has become clear: the application of plug-in hybrid electric vehicles. This new generation of hybrids is getting most attention in California, but also in Europe and Japan the interest is increasing. With most of the major car manufacturers announcing development of models in this area, the momentum is growing. To retain this growing success the focus should be on efficiency - in both costs and components of hybrid vehicles. This is necessary in order to get hybrid vehicles to a greater public, because only if they become an important share of a country's car fleet, they can make a significant impact on reducing oil imports and on greenhouse and noxious gas emissions.

For these reasons it is important for government officials and automotive research organizations to obtain reliable, objective information on hybrid vehicles. Now Annex VII is closed, the topic of plug-in hybrid electric vehicles is addressed in a new IA-HEV Annex (Annex XV).

## 5.6

### **Contact details of the Operating Agent**

Mr. Gerben Passier was the Operating Agent of Annex VII. Please feel free to contact him with your questions regarding this Annex.

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## 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 and India are striking examples spurred by their rapid economic growth. More and more cities around the world are passing the 1 million population mark and even the number of cities with more than 10 million inhabitants is increasing steadily. In many of these cities air quality is a serious problem that affects the health of all their inhabitants, and traffic is often an important contributor to this pollution.

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

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

#### **6.2**

##### ***Objectives***

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

## 6.3

### ***Working method***

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

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

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

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

## 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 unexpected outcomes may emerge, and to illustrate both types of activities that are mentioned above in the 'working method' section.

An eye opener was that in many areas of the transportation sector the developing countries are in fact ahead of the industrialized ones. The 'Bus rapid transit' systems in Bogotá and Curitiba are world leaders. Brazil is a world leader in the use of ethanol as a transportation fuel, and Argentina is leading in the conversion of vehicles to CNG. China is world leader in the use of electric bicycles. Over 600

electric three-wheel passenger vehicles ply the city streets in Kathmandu, Nepal, mainly as taxis. Many cities in developing countries have a system of communal taxis or small vans that is highly energy efficient and low cost. There is a large potential for replicating this kind of success stories of one city or country to another.

A success story of a type (1) activity (see section 6.3) is the plan to study a ‘Bus rapid transit’ system for Dhaka in Bangladesh. After the Paris workshop, Annex IX arranged for city officials from Dhaka to visit the TransMilenio bus rapid transit system in Bogotá, Columbia, with the financial support of the Swedish International Development Agency (Sida). Because of this visit, the officials from Dhaka have now set up a task force to study the possibility of constructing a similar bus system in their city.

An important general topic (see (2) in section 6.3), which was recognised by the participants in the Paris workshop to be a challenge for everyone, is how to bring the necessary changes about. Many types of clean vehicles are available on the market, but it appears to be difficult to actually get a significant number of these vehicles on the road. The workshop came up with a four-step approach to solve this problem:

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

implementation. Projects need to be financially viable even after the completion of eventual donor involvement. An exchange of information among cities with pilot projects can also be very useful, because it allows for success stories to be replicated and for failures to be avoided.

4. A last step is to do evaluation studies of projects and programmes and to disseminate the results widely. For example, the TransMilenio project in Bogotá or the ethanol industry in Brazil are highly beneficial for those countries and by making a video available or by maintaining a website hundreds of other cities in dozens of other countries can become aware of these opportunities and they can use some of the ideas themselves.

## **6.5**

### ***Further work***

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

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

During its third phase of operation, IA-HEV will continue its efforts assisting developing countries with their mobility and air quality problems. The scope for technology transfer to non-IEA member countries is very large, but at present efforts in this direction are limited by a lack of financial resources. More parties need to be involved, both inside and outside the IEA. Work for the International Energy Agency (IEA) is usually financed by Ministries of Industry and Energy. These ministries generally do not have a mandate to finance development assistance. Obtaining financial support of government development agencies is one option to create a broad basis for the continuation of Annex IX.

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

## **6.6**

### ***Contact details***

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

## 7

# ***Electrochemical systems (Annex X)***

### **7.1**

#### ***Introduction***

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

### **7.2**

#### ***Objectives***

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

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

### **7.3**

#### ***Working method***

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

The Annex addresses selected topics in the form of focused working groups. Each working group will meet one or two times to discuss a specific topic. Products from the working groups vary depending upon the nature of the discussions and might include items such as publications in the open literature or restricted meeting notes. Once a country has joined the Annex, the decision to participate in a working group may be based upon the level of interest in the particular subject matter. Therefore each working group will have its own unique members, and a country or organization may participate in one working group without making a

multiyear commitment to every meeting of the Annex. The Annex was represented at several major technical meetings during 2007, but no working group meetings were held this year.

## 7.4

### Results

This section presents an overview of the current status on vehicle batteries, written by the Operating Agent of this Annex. As such, it is not the outcome of an Annex working group.

**The importance of batteries** to the successful development and production of HEVs, PHEVs and EVs has been confirmed in a variety of ways. For example, news articles on vehicle development programs at General Motors, Toyota and Th!nk have all identified the battery as being the most critical or challenging component. Meetings related to vehicular batteries set attendance records in 2007 and promise to do the same in 2008. In the United States and Japan, the governments' budgets for battery research and development (R&D) have been increasing. In the United States, members of Congress sent letters to the Secretary of Energy stressing the importance of battery R&D.

**The requirements for a battery** in an HEV, PHEV and EV are not identical. As is shown in figure 7.1, the battery in an HEV experiences short, high power charge and discharge pulses, but its state of charge stays relatively constant. The battery in a PHEV would start fully charged and after a period of discharge would switch to behaving in a manner similar to an HEV battery. In an EV, the battery starts

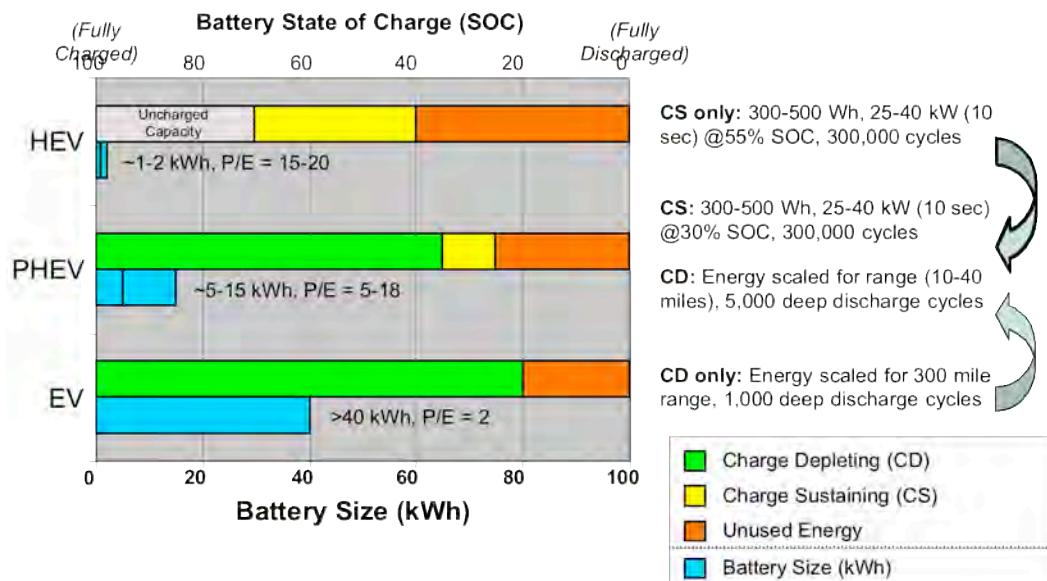


Fig. 7.1 Relative battery operation for HEVs, PHEVs and EVs. (Courtesy of the U.S. Department of Energy.)

fully charged and is discharged before being recharged. Thus, PHEV and EV batteries experience a much wider change in their state of charge than do HEV batteries. Generally, the energy stored in an HEV battery is less than that in a PHEV battery, which is less than an EV battery.

In 2007, the United States Advanced Battery Consortium (USABC) published performance goals for two versions of a PHEV battery. One battery was designed to provide 10 miles of all-electric range (or its equivalent) for a mid-sized sport utility vehicle. The other set of goals was for a battery that would allow a compact size sedan to have a 40 mile all-electric range. These goals are given in table 7.1.

Table 7.1 USABC goals for two versions of PHEV battery.

Characteristic (end of life)	--	High power/energy ratio	High energy/power ratio
Reference equivalent electric range	miles	10	40
<b>Power and energy</b>			
Peak pulse discharge power - 2 sec / 10 sec	kW	50 / 45	46 / 38
Peak regenerative pulse power (10 sec)	kW	30	25
Available energy: charge depleting mode at 10 kW	kWh	3.4	11.6
<b>Battery life</b>			
Charge depleting life / Discharge throughput profile	cycles / MWh	5'000 / 17	5'000 / 58
Charge sustaining (HEV) cycle life, 50 Wh	cycles	300'000	300'000
Calendar life, 35°C	year	15	15
<b>Weight, volume and cost</b>			
Maximum system weight	kg	60	120
Maximum system volume	litre	40	80
Battery cost	US\$	1'700	3'400

### Batteries in vehicles

Almost all HEVs now being built in large quantities by major manufacturers use nickel metal hydride batteries (NiMH). The largest single supplier of these batteries is Panasonic Electric Vehicle Energy (PEVE), a joint venture between Toyota and Panasonic. Other major suppliers for vehicles in production include Sanyo and Cobasys. The design of the individual cells used in these batteries varies and includes wound cylindrical cells in metal cans and flat-plate prismatic

cells in both metal and plastic containers. It is expected that as the number and type of HEVs on the market increases, that several different energy storage systems will be used. For example, lead acid batteries and ultracapacitors have both been suggested for micro and mild hybrids, NiMH has already proven successful in moderate and full hybrids, and lithium-ion systems are being proposed for use in similar vehicles.

### Lithium-ion batteries

The term ‘lithium-ion battery’ is applied to a wide range of electrochemical systems and cell designs. In all of them, lithium ions move from the negative electrode (often called the anode) to the positive electrode (often called the cathode) during discharge and in the reverse direction during charge. About three billion lithium-ion cells are produced each year; most of these are used in consumer electronics such as cell phones and portable computers, but larger cells -optimized for vehicular applications- are now under development by over a dozen companies. The lithium-ion batteries on the market today include systems with negative electrodes composed of a variety of materials including graphite, hard (also called amorphous) carbon, lithium titanate and metal alloys. The active materials in the positive electrodes include layered materials such as  $\text{LiCoO}_2$  and  $\text{LiNi}_{0.8}\text{Co}_{0.15}\text{Al}_{0.05}\text{O}_2$ , spinels such as  $\text{LiMn}_2\text{O}_4$  and olivines such as  $\text{LiFePO}_4$ . To make matters more complex, some batteries contain mixtures of these materials in their electrodes. Several different versions of microporous separators are in commercial use. Although most commercial batteries use the same organic solvents and salts in their electrolytes, the proportion of the various components is often different, and every manufacturer has its own set of electrolyte additives to improve performance. As with NiMH cells, lithium-ion cells can be built in several ways. The most common forms are wound cells in cylindrical metal cans and flat plate or flat wound cells in rectangular packages (often called prismatic packages). Prismatic cells can be packaged either in a metal can or in a pouch made of a multilayer laminate of polymers and metal foil.



Fig. 7.2 A cell from Johnson Controls / Saft. (Courtesy JCS.)

The range and complexity of lithium-ion cells is illustrated by some of the systems now under development in contracts between the USABC and battery companies. Several of these examples are illustrated and described below.

A joint venture between Johnson Controls, Inc. and Saft (JCS joint venture) is developing cells using a layered material in the cathode and a spirally wound design in metal cans such as shown in figure 7.2. This cell has a relatively high voltage when fully charged. During discharge the voltage decreases steadily from about 4.1 to about 3.0 Volts.

A123 Systems is manufacturing a cell with a similar design, but it incorporates a nanophase olivine material in its cathode. An example of this product is shown in figure 7.3. The use of the olivine material means that the cell operates at a lower voltage than the JCS cell, but the cell's voltage changes very little during most of the discharge process.



Fig. 7.3 A cell from A123 Systems. (Courtesy A123 Systems.)

LG Chemical and its American subsidiary -Compact Power, Inc.- are developing cells using a modified spinel cathode and a hard carbon anode for application to HEVs. Their flat plate cells are sealed in a laminate package. Figure 7.4 shows typical cells of this design and battery packs that the company has developed.



Fig. 7.4 Cells and two packs from LG Chemical and Compact Power, Inc. (Courtesy LG Chemical.)

Cells under development by EnerDel also incorporate a flat plate design in a laminate package, but they are using a titanate anode with a spinel cathode. Examples of their products are shown in figure 7.5.



Fig. 7.5 EnerDel cell (left) and complete battery (right). (Courtesy EnerDel.)

### Lithium-ion batteries in vehicles

As of the end of 2007, lithium-ion batteries are not being used in many production vehicles. They are found in small numbers in hybrid buses and in many after-market PHEV conversions. Toyota has used them in one mild hybrid. The industry expects that the next generation of HEVs and PHEVs will find many more examples of these batteries. In late 2007, Daimler announced that they would use a lithium-ion battery from JCS in a hybrid version of the Mercedes S class. Production of the batteries for this vehicle will begin in early 2008 in a facility in Nersac, France. General Motors has announced that it will use lithium-ion batteries in several HEVs and in its PHEV, the Volt. These vehicles are scheduled to reach the market between now and 2010. At present, GM is in negotiation with several manufacturers for these batteries. Th!nk has announced that their EVs will use batteries from A123 Systems or EnerDel. Tesla Motors expects to deliver several hundred of their EV roadsters in 2008. These vehicles will use a battery built of several thousand small lithium-ion cells of the type often used in laptop computers.

### Summary of trends in vehicle batteries

For the near-term, most HEVs on the road will contain NiMH batteries. The next generation of HEVs will incorporate a wide range of energy storage technologies including ultracapacitors and lead acid, NiMH and lithium-ion batteries. The range of energy storage systems will reflect the range of types of HEVs being developed. Most PHEVs will probably use some form of lithium-ion battery.

*Note: The Annex thanks the represented companies for providing pictures of their products for this report.*

## 7.5

### **Further work**

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

Recent interest in plug-in hybrid electric vehicles reveals a need for advanced battery technology dedicated to this kind of vehicles. The load cycle for batteries in PHEV applications puts specific requirements on battery chemistry. Therefore the topic for the next working group will be batteries for PHEVs, and this topic would best be addressed in co-operation with Annex XV on plug-in hybrid electric vehicles. The Operating Agents of the two Annexes are currently discussing a joint meeting on the availability of the basic lithium compounds necessary for the synthesis of many of the active materials used in a lithium-ion battery. Anyone who might be interested in participating in this working group is invited to contact the Operating Agent of Annex X.

## 7.6

### **Contact details of the Operating Agent**

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

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**8*****Electric cycles  
(Annex XI)*****8.1*****Introduction***

City governments see it as an important part of their responsibilities to improve mobility in their urban areas. Their constraints are more than just reducing emissions or oil consumption. The limited space that is available per vehicle, traffic safety and noise reduction make urban mobility become a key issue. City governments have to take a wide range of measures, including the improvement of public transport, facilitation of non-motorised transport like walking or cycling, and improvement of roads and parking facilities for vehicles. Many solutions have to be implemented and the interface among these solutions has to be convenient and smooth, so inhabitants are not affected and they can still enjoy a good quality of life.

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



Fig. 8.1 Vectrix zero emission electric two-wheeler. (Photo: M. van Walwijk.)

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

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



Fig. 8.2 Electric drive and battery of a Flyer foldable electric bicycle. (Photo: M. van Walwijk.)

## **8.2**

### **Objectives**

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

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

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

### **8.3**

#### ***Working method***

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

##### **Subtask 1: Energy saving and market potentials**

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

##### **Subtask 2: Market introduction**

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

##### **Subtask 3: Technology improvements**

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

##### **Subtask 4: Infrastructure**

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

##### **Subtask 5: Sharing experiences**

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

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

- Kick-off meeting, Taiwan, March 10-11, 2006, in conjunction with the LEV conference.
- 1<sup>st</sup> progress meeting, Paris, France, June 13, 2006, in conjunction with the Challenge Bibendum.
- 2<sup>nd</sup> progress meeting, Tokyo, Japan, October 24, 2006, in conjunction with EVS-22.
- 3<sup>rd</sup> progress meeting, Hsinchu, Taiwan, March 24, 2007, again in conjunction with the LEV conference.
- 4<sup>th</sup> progress meeting, Chiasso, Switzerland, November 7, 2007, in conjunction with the EICMA exhibition.

A workshop took place on the occasion of the IAMF/EET-2008 congress, on March 11, 2008, in Geneva. During this workshop the findings of phase I of this Annex as well as the basis for the second phase -that is scheduled to start in April 2008- were discussed.

## **8.4**

### **Results**

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

- the need for clear explanations why governments should support both electric bicycles and scooters,
- safety aspects in manufacturing batteries, and in particular the social responsibility,
- ‘adaptation sets’ to convert conventional bicycles into electric ones,
- the issue of poor quality products, inducing a very negative publicity,
- homologation or labelling to ensure that existing regulations are respected.

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

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

- E-bike product overview.
- Manufacturer’s profiles.

- Battery price and safety.
- Product affordability (price, quality, design, ...).
- Views on policies and context.
- Key recommendations for governments to support electric two-wheeler.
- Life cycle analysis (LCA).
- Hints to remove barriers for development and foster the market to take off, including:
  - harmonization of connectors for charging,
  - leasing systems of the batteries,
  - battery swap systems,
  - safety issues,
  - developing countries,
  - creating a need for electric cycles,
  - minimal requirements for product quality and after sales.
- Standardization and the link with relevant bodies at local, European and ISO levels.
- Role of the dealers and -in particular- helping them to make the link between R&D efforts and market requirements.



Fig. 8.3 Informing the dealers. Dealer workshop in Mendrisio in conjunction with the EICMA exhibition (left) ... and getting first hand information ... (right). (Photos supplied by AVERE.)

- Education of consumers, dealers and authorities.
- Study tours.
- Identification of highest leverage between manufacturer's investments and consumer requirements.

## 8.5

### **Further work**

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

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

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

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

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

## **8.6**

### **Contact details of the Operating Agent**

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**9****Heavy-duty hybrid vehicles  
(Annex XII)****9.1****Introduction**

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

This Annex was approved at the IA-HEV Executive Committee meeting in October 2006. The work of Annex XII has formally started on January 1<sup>st</sup>, 2007 and is scheduled to end on November 30<sup>th</sup>, 2009, which is at the end of the third operating phase of the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV).

**9.2****Objectives**

In its first phase, this Annex aims to report the current status of the heavy-duty hybrid vehicles ‘playing field’. Next to a general description of the heavy-duty hybrid vehicle situation, the status report will focus on the available as well as emerging hybrid vehicle technologies, and on the market situation and trends. To collect and organise the required information, three subtasks have been defined.

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

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

In the third subtask, this Annex studies the application area of hybrid technology for heavy-duty vehicles. First the current situation of existing hybrid prototypes

and standard vehicles is investigated. The information gathering focuses on the applied technology, as well as the costs and the merits in a broad sense. In this way it complements the first subtask.



Fig. 9.1 Hybrid refuse lorry. (Photo © VITO.)

The third subtask also aims at increasing the insights in these applications and provides essential information for future hybrid vehicle deployment projects. The lessons learned will not only focus on the technical barriers to overcome, but also on the required framework (training, support, ...) for successful project implementations. To address the potential of heavy-duty hybrid vehicles it is useful to identify niche applications that may benefit to a great extent from hybridization. Today in many heavy-duty applications the gearbox PTO (power take off) of the powertrain is used to provide power for auxiliary systems. In most cases, this is a cheap but energy inefficient solution. Here hybrid vehicle technology may provide a solution that is more energy efficient. When considering other benefits like lower emissions and noise levels, the advantage of choosing a hybrid version becomes more apparent. In this way the barrier to switch to hybrid vehicles for these applications can be lowered.

### **9.3**

#### ***Working method***

After the kick-off meeting, the Operating Agent organizes two expert meetings per year in participating countries. Each meeting includes a technical visit to the participant's facilities and/or other interesting projects or events. This allows the local participant to illustrate its capabilities and infrastructure in the field of heavy-duty hybrid vehicle technology. The Operating Agent chairs the meetings, prepares agendas and minutes, and reports to the Executive Committee of the Implementing Agreement. The Operating Agent provides project management and co-ordination, to ensure that activities are implemented and objectives are achieved.

To increase the attractiveness of participating in the Annex, the Operating Agent prepares papers and presentations dealing with the contents and the results from this Annex to be presented at relevant conferences. The preparation of papers

summarizing the whole topic or highlighting certain aspects is on a voluntary basis, but should be encouraged. By publication in international journals and presentation at conferences, the Annex as well as the Implementing Agreement gain exposure to a wider professional public.

A subtask leader is designated for each of the three main objectives. The Operating Agent is best placed for leading the topic of information exchange in the third subtask. The subtask leaders for the other two topics have been assigned. They co-ordinate the progress of their subtask and complete the respective reports.

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

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

The papers and presentations are public matter once published in proceedings and presented at conferences. From that moment on, the document management system can make them publicly available. The reports have a more proprietary nature. Therefore they are initially only made available to member countries. A timing as well an approval system to make these reports publicly available will be established.

## **9.4**

### **Results**

Three expert meetings have been organized and successfully executed in 2007. They are shown in box 9.1. The first expert meeting in San Diego was combined with a heavy-duty hybrid vehicle workshop.

<b>Box 9.1</b>			
<b>Expert meetings of Annex XII in 2007</b>			
#	Date	Place	Country
1	February 9	San Diego	USA
2	May 10	Mol	Belgium
3	September 19	Istanbul	Turkey

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

#### Subtask I: Heavy-duty hybrid vehicle technologies.

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



Fig. 9.2 Nissan hybrid truck with supercapacitors. (Photo: M. van Walwijk.)

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

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

### Subtask III: General information gathering and dissemination.

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

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

## **9.5**

### ***Further work***

The following expert meetings (EM) are scheduled for 2008:

- Vancouver, Canada, on February 6<sup>th</sup>-7<sup>th</sup> (4<sup>th</sup> EM), in conjunction with the kick-off workshop of the new IA-HEV Annex on plug-in hybrid electric vehicles (Annex XV).
- Denver, USA, on October 2<sup>nd</sup> (5<sup>th</sup> EM).

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

## **9.6**

### ***Contact details of the Operating Agent***

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## 10

### **Fuel cells for vehicles (Annex XIII)**

#### **10.1**

##### ***Introduction***

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

Fuel cells offer a number of interesting options for the vehicle design. Fuel cells are not limited by thermodynamic restrictions of combustion processes. Therefore they offer unique advantages concerning energy efficiency, possible driving distance and the reduction of noise and exhaust emissions. Many scientists see them as optimal long-term solution for clean and efficient energy conversion for mobile and stationary applications. The transport industry, energy utilities and producers of portable consumer products invest strongly in the development of this technology.

Nevertheless, limited lifetime as well as high production costs due to noble metal catalysts have impeded until now the broad market introduction of fuel cells beyond specialized niches like space applications. In recent years cheaper and more stable materials for separators and electrodes have achieved major improvements for fuel cell technologies. On the other side, more restrictive emission standards will raise costs for after treatment of internal combustion engine emissions. This will bring fuel cell vehicles nearer to competitiveness.

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

#### **10.2**

##### ***Objectives***

The different types of fuel cells actually under development dispose of an extreme variety of technical properties. Therefore a thorough analysis of all kind of fuel cells regarding their capability to fulfil propulsion requirements of different vehicles is the first task in this new Annex. The strong expertise on electric

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

The specific demands for power, cost, lifetime and range of vehicles powered by fuel cells, batteries and all kind of hybrid solutions are the main reason why the Executive Committee (ExCo) of the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) decided in fall 2005 to expand its activities and to prepare a new Annex on ‘Fuel cells for vehicles’. Nevertheless, IA-HEV aims for strong ties and co-operation with the IEA Implementing Agreement on Advanced Fuel Cells (IA-AFC).

The HEV Implementing Agreement concentrates its activities in this Annex on tuning fuel cell properties as well as using their high potential for their successful application in vehicles. The main focus is on road vehicles, but other means of transport are considered as well if their specific needs could be an interesting intermediate step for the market introduction of fuel cell road vehicles. In this respect boats, airplanes and mining vehicles could be interesting niches preparing the market introduction of fuel cell, electric and hybrid road vehicles.



Fig. 10.1 CEA - PSA Peugeot Citroën fuel cell. (Photo: M. van Walwijk.)

This Annex does not only concentrate on polymer electrolyte membrane (PEM) fuel cells as dominating technology for fuel cell research for vehicles today, but it analyzes the potential of other fuel cell types as well. Because many scientists

believe that auxiliary power units (APUs) might be the first economically viable niche for the market introduction of fuel cells in vehicles, this Annex studies the potential of fuel cells for this market segment, after the preliminary investigation of all fuel cells mentioned above.

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

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

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

### **10.3**

#### ***Working method***

The activities in this Annex predominantly exist of foresight studies and technology assessments. The cost for these activities is strongly reduced compared to independent investigations by each country, due to shared costs and broader data records. The danger to overlook regional technological trends or results in the global development process is much lower in this international co-operation than in single country investigations.

This shared activity allows combining the strengths of different partners in a co-ordinated R&D process. The huge task of changing the transport system surpasses the resources of even the biggest countries or companies. Therefore the international split of labour not only saves large amounts of money to the participants, but it also saves a lot of time by developing tasks in parallel and by assigning responsibilities to partners with the highest expertise related to a specific problem. IA-HEV and this Annex have direct access to national, industrial and scientific representatives. The results of this Annex will therefore guide their R&D activities and initiate coverage of missing research areas. Internal information

available for participants facilitates their decisions on how to organise their fuel cell research in the most efficient way and how to embed it in international research co-operation.

Close co-operation with the IEA Implementing Agreement on Advanced Fuel Cells (IA-AFC) is planned. The co-operation on one hand ensures that information and knowledge from fuel cell experts is integrated into this Annex and on the other hand it avoids duplication of work on topics that are relevant for both Implementing Agreements.

In parallel to this Annex, some IA-HEV member states strongly support fuel cell research in their national R&D programs and participate in regional multilateral activities like the technology platform ‘Hydrogen and fuel cells’ of the European Union.

## **10.4**

### **Results**

In November 2006, the IA-HEV ExCo decided officially to start Annex XIII of the Implementing Agreement. The Annex started its operative work at a kick-off meeting in Graz (Austria) in September 2007. Experts from six countries presented their work at this meeting. The detailed work plan was discussed intensively. Resources of each partner in this Annex are limited and therefore a focused work plan with a limited number of topics was established. Four topics have been chosen:

- Hybridization.
- System integration and behaviour.
- Sustainability of fuel cell hybrid vehicles.
- Cross cutting issues (especially with Annex XX of IA-AFC).

There was common interest on these topics among all participants of the kick-off meeting. In a fruitful discussion it was pointed out that not only the fuel of a future vehicle has to be sustainable but also the car and its parts should be to a large amount sustainable.

A deeper look into these questions might also bring a new and comprehensive understanding of commercial scenarios for HEV vehicles when entering the mass market. The objective is to provide updates and assessment reviews of the technical and commercial status. It will be important to have a look on components of the vehicle -such as the fuel cell and the whole system- in order to guarantee a broad coverage of sustainability issues.

## **10.5**

### ***Further work***

After the kick-off meeting in September 2007, the next expert meeting is scheduled in March 2008. The meeting is held in parallel to the Geneva motor show. For this expert meeting a workshop on cold start behaviour of fuel cell vehicles is planned as well.

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

## **10.6**

### ***Contact details of the Operating Agent***

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## 11

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

#### **11.1**

##### ***Introduction***

At the turn of the 20<sup>th</sup> century, electric vehicles were a popular choice for personal transport, and there was a range of choices for consumers made by craft producers. However, as gasoline supplies expanded and the power, range and reliability of gasoline engine vehicles improved, electric vehicles (EVs) never made it into the age of mass-produced vehicles.

During the past three decades, there have been several attempts to redesign and reintroduce electric vehicles to the market. These efforts have been motivated primarily by concern with dwindling oil resources, world oil politics, air pollution, and more recently with greenhouse gas emissions. The world oil crisis of the 1970s and increasing concern for the environment initiated a number of design and manufacturing efforts worldwide, including innovative lightweight designs that were outcomes of solar car competitions, and more conventional vehicle designs aimed to displace oil consumption.

A regulatory process -begun in 1990 by California- aimed to force automakers to make zero tailpipe emission vehicles (ZEV Mandate). This process spurred EV efforts worldwide in the 1990s, encouraging the formation of small companies and design efforts in the major OEMs (Original Equipment Manufacturers). A wide range of EVs was deployed in several nations by several automakers, including some new start-up firms. Some of these efforts were well-organized 'city' projects, involving local governments and utilities, notably the cities of La Rochelle in France, Mendrisio in Switzerland and Göteborg in Sweden. California proposed to force the sale of up to 10% ZEVs of annual vehicle sales. Eventually, regulators and OEMs agreed to a 'test' with several thousand EVs, many of which were excellent designs.

Ultimately, these efforts in the 1990s failed to create a sustained market and manufacturing base for electric vehicles. OEMs were not enthusiastic, citing lack of profit, regulators in California backed down, most small firms disappeared and OEMs ended their programs. Many observers of this period agreed that batteries were not sufficiently reliable and were too expensive to compete, but others hope for a sustained effort that would eventually bring down costs and improve batteries.

Despite the ending of OEM efforts to build EVs, battery development continued and in the years after 2000 hybrid vehicles using NiMH batteries did successfully enter the market in Japan, the U.S. and select markets in Europe such as Sweden and Switzerland. Higher energy density lithium batteries found their way into consumer electronics in the millions, setting up a potential reconsideration of EVs. Additionally, some EV enthusiasts refocused their efforts on plug-in hybrid electric vehicles (PHEVs), some of them able to convert OEM hybrids into reliable PHEVs. Moreover, the climate crisis and rising oil prices during the past decade have shifted attention back to electricity as a solution. While batteries for EVs are not yet a normal product, they are much closer than in the 90s, and several OEMs have recently announced renewed efforts in this area. EVs are getting renewed attention worldwide.

## 11.2

### **Objectives**

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

## 11.3

### **Working method**

The work of this Annex -which was formed in October 2007- will rely upon at least three research components:

- Workshops in former deployment areas (California, Japan, Sweden, Switzerland) that bring together experts from these regions with a range of experiences and perspectives on the lessons they have learned so far in the deployment of electric and hybrid vehicles. These will include those with experience in manufacturing, distribution, sales, charging infrastructure and market support from the utilities and governments. This approach will yield a useful comparative project across these regions.
- Additional interviews with important experts who cannot attend workshops.
- Review of literature and historical material from all deployment regions, including other sources of interest will be evaluated, e.g. surveys among EV and HEV users in fleet tests, etc.

## 11.4

### **Results**

This Annex was begun late in 2007 and did hold two workshops in California to initiate the work. The first workshop -held in Santa Cruz- on October 3 and 4, included Tom Cackette and Annalisa Bevins, two central persons from the Air Resources Board, who presided over the ZEV process in the 1990s, John Dabbs, former head of marketing for the GM EV1 program, Chelsea Sexton, a front lines

EV1 sales person for GM, Tom Turrentine (Operating Agent for this Annex) and Ken Kurani, who conducted several years of market research projects for the State of California, and Annex country experts, Urs and Sigrid Muntwyler from Switzerland, Kanehira Maruo from Sweden, and James Barnes and Dan Santini representing the U.S. Department of Energy.

A second workshop was held in conjunction with EVS-23 in December 2007, with attendance by the Annex country experts, Tien Duong of the U.S. Department of Energy, Craig Childers, another veteran of the California ZEV regulatory process, Edward Kjaer and Dean Taylor, EV deployment veterans from Southern California Edison, a utility heavily involved in EVs during and continuing since the 1990s, as well as Chelsea Sexton from the GM EV1 program.

The results of these workshops are still being compiled and prepared for use in the future workshops planned for 2008. However, the workshops have already resulted in the development of practical lessons for future deployments in the area of how regulators can work best with OEMs, how local governments and utilities can best develop infrastructure and incentives for future EV deployments, and how state and OEM marketing can best introduce EVs to the public. In particular, these small workshops result in candid and in-depth discussions.

## **11.5**

### ***Further work***

Additional workshops have been already planned; one in Geneva, March 10, 2008, one in Japan in May 2008, and another one in Sweden in September 2008. Additionally, expert interviews are being planned with former auto executives in the U.S. and Japan.

## **11.6**

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## 12

### **Plug-in hybrid electric vehicles (Annex XV)**

#### **12.1**

##### ***Introduction***

Oil security has become a major concern in recent years. Nations around the world are concerned with issues surrounding the consumption, availability, transportation, dependency, cost, environmental effects, etc. of oil extraction and use. To combat these issues and the harmful emissions associated with the consumption of oil in our respective transportation systems, consideration of more secure and environmentally friendly forms of transportation are being pursued.

Advanced technology options such as vehicles equipped with varying degrees of hybrid powertrain systems are growing and seem to be the advanced vehicle technology of choice by many, as evidenced by consumer demand and their recent popularity. Automotive manufacturers around the world are also showing a rising interest in pursuing related technologies, such as plug-in hybrid electric vehicles (fig. 12.1). Furthermore, government RD&D funds are increasingly dedicating their efforts towards these and other related technologies.



Fig. 12.1 Fisker Karma, plug-in hybrid electric car. Start of production is announced for the fourth quarter of 2009. (Photo: M. van Walwijk.)

If consumer acceptance and product availability of these technologies continues to expand over time as is expected, these technologies will undoubtedly make significant contributions in diminishing carbon dioxide levels and possibly extend our dependence on petroleum with a much more sustainable approach.

## 12.2

### ***Objectives***

The goals and objectives of this Annex are to provide essential information for member countries to better understand the current situation related to plug-in hybrid electric vehicles (PHEVs) and their related prospects.

Five subtasks have been identified and will be the basis of work for this Annex.

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

The automotive research organizations participating in this work are among the most prestigious in the world. Other organizations and partners are welcomed to participate. Automotive R&D departments and government policy developers interested in joining this Annex would not only benefit from participating, but will also broaden and deepen their own expertise in PHEVs and related technologies and will help strengthen working relationships and international collaborations.

The results of this Annex will be beneficial to all organizations mentioned above as well as to the general public in helping them understand the benefits of PHEVs and their potential in reducing oil consumption.

## 12.3

### ***Working method***

Participating organizations will be expected to set aside a certain amount of professional service time to participate in the technical work and the meetings of this Annex. This amount of time required will vary depending on the participants' interest and capacities but is estimated as a minimum of at least one month per year per meeting. In addition, participants will be expected to finance their own travel and accommodation cost for the participation of at least two expert meetings per year. Finally, each participant will be expected to host an expert meeting in turn. This is collectively known as task sharing.

Tasks and duties will be distributed on a voluntary basis during the expert meetings and progress reported to the group on a regular basis. Each member will be expected to participate in the work of the group.

## 12.4

### **Results**

After presenting the final draft version the proposed work plan, the Executive Committee of the IA-HEV voted on March 14, 2008, to proceed to the operational phase of this Annex. Given this early stage of the Annex, there are no specific results to be reported yet.

## 12.5

### **Further work**

In conjunction with the Electric Power Research Institute (EPRI), Annex XV will host its first official meeting during the ‘Plug-in 2008’ conference in San Jose, California, in July 2008. With the results of the February 2008 workshop that was organized to prepare this Annex, members will finalize its work plan for phase I and will begin creating subtask action plans, identifying specific tasks, as well as roles and responsibilities.

It is the Operating Agents’ opinion that there remains a multitude of other issues needed to be addressed by an expert group on PHEVs and members of the IEA HEV Implementing Agreement, as well as the IEA would be well served if it would continue with this Annex after its initial proposed 3-year phase I.

It is not too late to join the group, provide your input, and help mould the first phase of its existence. Be an integral part of this exciting technology development area and join us in the PHEV Annex.

## 12.6

### **Contact details of the Operating Agent**

The Canadian Federal Government through its Department of Natural Resources (NRCan) acts as Operating Agent for this Annex. For more information on joining this Annex or this Implementing Agreement, please contact its secretariat, your countries representative, or the Operating Agent directly.

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## 13

### **Overview of hybrid and electric vehicles in 2007**

This chapter presents data and developments for hybrid and electric vehicle fleets around the world, in section 13.1. Section 13.2 summarizes measures to support the development and deployment of clean vehicles in IA-HEV member countries and serves as a guide to find detailed information about these measures in the individual country chapters of this report.

#### 13.1

##### **Statistical information and fleets**

The year 2007 was something of a watershed for electric and hybrid propulsion, one in which the commercial maturity and success of the technology both flowered with increased propulsion applications and began to encounter realities of a cyclical vehicular market. The hybrid electric light-duty vehicle continued its impressive rate of increase of units in service, with more new configurations in the midsize and luxury sedan and sport utility vehicle (SUV) segments in the largest hybrid electric vehicle (HEV) market - the United States (see figures 13.1 and 13.2). All manufacturers were stimulated by a continuation of the tax credits for hybrid purchase made available in the United States by the Energy Policy Act

Table 13.1 Actual or estimated (*estimates in italic*) electric vehicle (EV) and hybrid electric vehicle (HEV) populations of IA-HEV member countries, per December 31<sup>st</sup> of each year that is shown. Data for Canada and Turkey are not yet available.

Vehicle type	2004		2005		2006		2007	
	EV <sup>1</sup>	HEV						
<b>Austria</b>	515	0	517	75	565	481	n.a.	n.a.
<b>Belgium<sup>2</sup></b>	1'053	131	1'058	602	990	1'560	1'030	2'900
<b>Denmark</b>	300	15	650	35	650	50	650	76
<b>France</b>	11'013	650	11'000	n.a.	11'000	> 7'000	n.a.	n.a.
<b>Italy</b>	112'481	1'695	131'381	2'415	153'695	4'285	n.a.	6'878
<b>Netherlands</b>	n.a.	2'000	n.a.	3'000	20'450	5'003	30'450	7'005
<b>Sweden</b>	418	1'350	373	3'300	> 335	6'100	3'320	9'400
<b>Switzerland<sup>3</sup></b>	10'780	1'057	13'140	2'469	17'590	4'722	23'400	7'762
<b>USA</b>	49'536	197'000	51'398	403'000	53'071	655'000	54'555	1'006'000
<b>Total IA-HEV</b>	186'096	203'898	209'517	414'896	258'346	684'201	300'000	1'040'021

n.a. not available

1 Includes e-bikes and e-scooters.

2 EV data for Belgium are per August 1<sup>st</sup> of each year.

3 Swiss EV data does not include industrial and agricultural vehicles.

of 2005. Table 13.1 shows the recent growth of electric vehicle (EV) and HEV fleets in IA-HEV member countries.

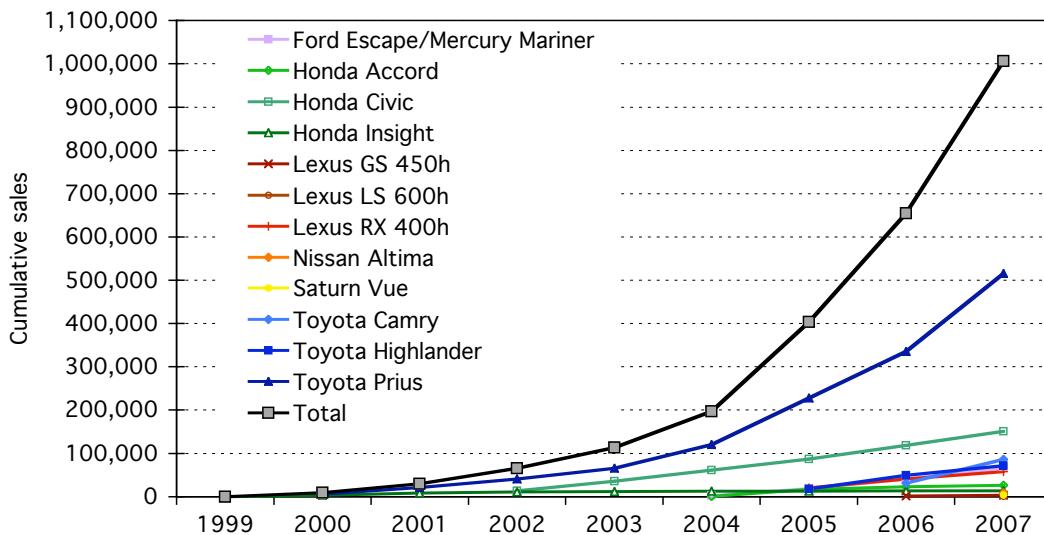


Fig. 13.1 Cumulative sales for light-duty hybrid electric vehicles in the United States (to December 31, 2007).

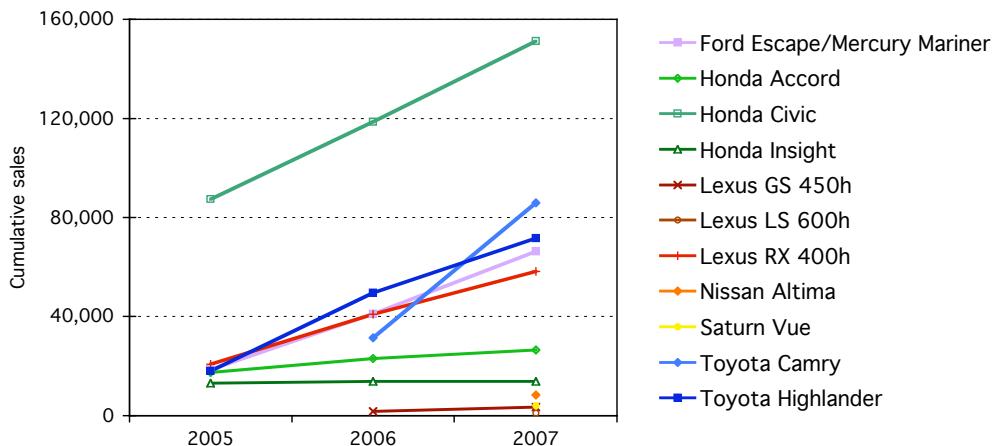


Fig. 13.2 Detail of fig. 13.1. Cumulative sales for light-duty hybrid electric vehicles in the United States 2005-2007 (Toyota Prius and total sales are not shown).

Figures 13.1 and 13.2 report the actual sales values of light-duty hybrid electric vehicles in the United States, for 2007 and previous years. Not all models shown in this figure are universally available, and in some countries latent demand for imports continues to be suppressed by tax policies unfavourable to hybrids despite their benefit as high-efficiency vehicles. Sustained interest in new luxury/performance editions such as the Lexus RX 400h and Lexus GS 450h kept sales through mid 2007 relatively robust among up-market purchasers, for whom the tax burden

is less of an impediment. Worldwide, light-duty hybrid fleet growth has exceeded 40 percent per year over the past four years.

The year 2008 promises further sales gains, but an economic slowdown that appeared to commence early in 2008 may retard the rate of increase relative to past years. Of note during 2007 was the slowing of USA sales growth by hybrids in the SUV and luxury categories. New platforms announced for introduction within the present decade include additional SUVs and/or light trucks from GMC and Porsche, and new sedan models from Ford, Hyundai and Nissan. Toyota's Kentucky plant is targeted to produce 48'000 Camry hybrids each year, about 10 percent of its total production capacity of 500'000 units. Table 13.2 lists the makes and models that have been announced for commercial release through approximately the end of the current decade.

Table 13.2 Planned and announced light-duty hybrid vehicle rollouts.

<b>Year of introduction</b>	<b>Manufacturer</b>	<b>Model/Type</b>
<b>2008</b>	Ford/Mercury	Fusion/Milan (sedan)
	General Motors	Chevrolet Silverado/GMC Sierra (pick-up trucks)
	Hyundai	Accent (sedan)
<b>2009</b>	Porsche	Cayenne SUV (VW/Audi hybrid drive)
<b>Unspecified</b>	Daihatsu	HVS (sports car)
	General Motors	Cadillac Escalade
	General Motors	Chevrolet Malibu (luxury sedan)
	General Motors	Chevrolet Volt (multi-fuel EREV)
	General Motors	Tahoe/Yukon (SUVs)

Whilst all-electric propulsion advanced in niche markets through 2007, as both Mexico City (with a municipal car fleet conversion programme) and Israel (with a new public-private partnership creating incentives for personal EV acquisition) were amongst public entities announcing major new initiatives in specific applications, the crescendo of interest in electricity-intensive plug-in hybrid electric vehicles (PHEVs) continued to swell. The year saw introduction of the world's first PHEV aerial lift truck - a PHEV delivery van introduced into courier service in Toronto- and continued market readiness testing of personal PHEVs in California. Also, diversification of already commercialised hybrid technologies continued apace, with General Electric unveiling a 4'400 hp (3'280 kW) diesel-electric locomotive with energy-storage capability, Mack Truck delivering a diesel hybrid dump truck to a U.S. Air Force installation, the onset of mass production of medium-duty diesel hybrid trucks (from Navistar), a diesel tugboat with hybrid electric assist slated for launch into the Ports of Los Angeles and

Long Beach, California in 2008, and diesel hybrid double-decker buses preparing to enter service in London and Dublin. Countries such as Sweden with strong commitment to renewable fuels are ramping up development of ethanol/battery hybrid buses from Scania Corp., whilst Ford and VeraSun Energy continue their joint development of an E85 Escape (small SUV) hybrid. As remains the case from recent years, significant challenges must still be met with respect to light-weight, long-range battery development before the full promise of PHEVs (and significant improvement to conventional HEV technologies) can be realized.

### **13.2**

#### **Synopsis of governmental programmes in IA-HEV member countries**

This section presents an overview of governmental incentives and programmes to stimulate the development and deployment of clean, energy-efficient vehicles such as hybrids and EVs. It is meant as a complement to the other (country) chapters that follow in this report section (C: H&EVs worldwide), in which the individual incentives and programmes for each country are described in more detail. This section is structured on the basis of measures; one can find the countries in which a certain measure is applied. For example: if one wants to know more about allowance for clean vehicles to circulate in restricted zones, it shows in box 13.3 that more information on this topic can be found in the Austria, Italy, the Netherlands, Sweden and Switzerland chapters, because these countries have implemented this type of measure.

After summarizing the background of measures for clean vehicles, this section is split in measures to support research, support of market introduction, and tax incentives.

#### **Background**

Incentives, green vehicle programmes, technology developments and clean vehicle deployment programmes are predominantly driven by environmental

<b>Box 13.1</b> <b>Governmental environmental objectives for clean vehicle technologies in IA-HEV member countries</b>	
<b>Objective</b>	<b>Country</b>
Reduction of CO <sub>2</sub> emissions	Belgium, Denmark, France, Italy, the Netherlands, Sweden, Switzerland, Turkey
Reduction of energy consumption	Austria, Denmark, United States
Improving local air quality	Austria, Canada, Italy, the Netherlands, Turkey
Increase in the use of renewable energy	Denmark, France, Italy, the Netherlands, Sweden, Turkey, United States

objectives. Box 13.1 shows the objectives of such programmes and lists IA-HEV countries in which these types of programmes are running.

### ***Support for research***

If clean vehicle technologies to meet governmental objectives are not yet available, governments may decide to support research to develop such technologies. The research institutes and automotive industry that are present in a certain

<b>Box 13.2</b> <b>Governmental programmes to support research on clean vehicle technologies in IA-HEV member countries</b>	
<b>Topic</b>	<b>Country and programme</b>
Advanced (clean/efficient) automotive (propulsion) technology	Austria (IV2Splus - A3plus) Belgium Canada (PERD) France The Netherlands (HTAS) Sweden (Green Vehicle Programme, Energy Systems in Road Vehicles, SHV, Environment Vehicle Development Programme) Switzerland Turkey United States
Batteries	Austria (A3plus) Canada (PERD) Italy Sweden (Energy Systems in Road Vehicles) Turkey United States
Fuel cells	Austria (A3plus) Canada (PERD) Denmark Italy (National R&D programme) Sweden (Fuel Cells in a Sustainable Society) Turkey United States
Hydrogen	Austria (A3plus) Canada (PERD) Denmark Italy (National R&D programme) Turkey United States

country may influence the research topics that the government of that country decides to support. Box 13.2 gives an overview of research topics and support programmes related to clean vehicle technologies in IA-HEV member countries.

#### ***Support for market introduction***

Desired clean vehicle technologies may be available but hurdles including lack of knowledge or a cost penalty relative to conventional vehicles prevent them from gaining substantial market share. Governments may choose to put measures into place that facilitate deployment of these clean vehicles. Justification for doing so may include such objectives as improving local air quality. Box 13.3 lists non-fiscal support measures currently operative in IA-HEV member countries.

<b>Box 13.3</b> <b>Non-fiscal measures to stimulate the market introduction of clean vehicle technologies in IA-HEV member countries</b>	
<b>Measure</b>	<b>Country</b>
Agreements	Belgium, Switzerland, United States
Allowance to circulate in restricted zones	Austria, Italy, the Netherlands, Sweden, Switzerland
Establish codes and standards	Canada
Pilot and demonstration projects	Austria (Lighthouse projects), Italy, the Netherlands
Raise public awareness	Canada, the Netherlands (ecodriving), Turkey, United States
Stimulate co-operation	Austria, France, Turkey
Subsidies and/or incentives	France, Italy, Sweden, Switzerland, United States

#### ***Tax incentives***

In many countries, tax incentives are in place to stimulate the use of clean and energy-efficient vehicles. Box 13.4 presents an overview of different kinds of tax incentives in IA-HEV member countries. A trend is apparent that governments do not stimulate specific technologies but reward specific results, such as low vehicular emissions. It is then up to players in the market how to achieve the desired results in the most efficient manner.

<b>Box 13.4</b>	
<b>Tax measures to stimulate the use of clean and energy efficient vehicle technologies in IA-HEV member countries</b>	
CO <sub>2</sub> tax on fossil fuels	Switzerland
Reduced circulation/road tax	Belgium, Denmark, the Netherlands
Reduced circulation/road tax for low CO <sub>2</sub> emitting vehicles	The Netherlands
Reduced registration/property tax	Belgium, Sweden
Reduced registration/property tax for energy-efficient vehicles	Denmark
Reduced sales tax for energy-efficient vehicles	The Netherlands, United States
Reduced sales tax for low CO <sub>2</sub> emitting vehicles	Belgium, France
Reduced tax on 'green' vehicles	Canada, Sweden, Switzerland

The use of the (European) vehicle energy label for tax differentiation has been instituted in the Netherlands, with Switzerland expected to follow in 2009. Table 13.3 shows the applicable tax reductions and additions per energy consumption category for these two countries.

Table 13.3 Vehicle energy label and sales tax reductions/additions.

	A	B	C	D	E	F	G
<b>The Netherlands</b>	Effective February 1, 2008						
General [Euros]	-1'400	-700	0	+400	+800	+1'200	+1'600
Hybrid [Euros]	-6'400	-3'200	0	+400	+800	+1'200	+1'600
<b>Switzerland</b>	Proposal for a system to be introduced in 2009						
[Swiss Francs]	-2'000	-1'000	tbd	tbd	tbd	tbd	tbd

*tbd to be decided*

Although policies are -as mentioned- generally designed to reward results, there are a few tax incentives that either are or have been in place that stimulate the use of specific vehicle technologies:

- **Belgium.** Irrespective of their size, pure EVs are subject to the lowest category of registration and circulation taxes.
- **Denmark.** BEVs and FCVs are exempted from registration tax and annual tax. Special tax rules for PHEVs are scheduled to be in place before the end of 2009.
- **France.** A programme that granted financial support for the purchase of electric vehicles terminated December 31, 2007.

- **The Netherlands.** EVs are exempted from the yearly road tax. HEVs qualify for an additional sales tax reduction (see table 13.3).
- **Sweden.** Annual notional taxation burden is reduced for hybrid or electric cars owned by a company.
- **Switzerland.** Several cantons provide vehicle tax reductions for clean vehicles. 16 of 26 cantons grant vehicle tax reductions or full tax exemptions specifically to electric vehicles, whilst eight cantons reduce taxes for hybrids.
- **United States.** A limited federal tax credit is made available for light-duty HEVs, a credit that expires for a given manufacturer when a specific sales threshold for that manufacturer's hybrid models is reached.

## **14**

### **Austria**

#### **14.1**

##### **Introduction**

Austria is a significant player in the automotive industry. It hosts a number of automotive suppliers and vehicle production plants, an example of which is Magna Steyr in Graz. More than 175'000 people work in over 700 enterprises in the Austrian automotive industry.

Although hybrid electric vehicles (HEVs) and electric vehicles (EVs) play a subsidiary role in the Austrian vehicular market, researchers at the Technical Universities of Vienna and Graz and in such enterprises as AVL-List in Graz are active in the field of alternative automotive drivetrains. The Universities in Vienna and Graz, as well as extramural research institutes like ECHEM (Competence Centre for Applied Electrochemistry) or the Christian Doppler Laboratory for Fuel Cell Systems, conduct research in the field of batteries and fuel cells. As hybrid vehicles come to play a more significant role in the vehicular market -as shown by the success of the Toyota Prius- Austrian interest in this technology is expected to grow.

#### **14.2**

##### **Policies and legislation**

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

#### **14.2.1**

##### **Governmental programmes**

Mobility plays a key role within a modern society. Therefore, the BMVIT has launched the strategy programme ‘Intelligent Transport Systems and Services’ (IV2S). In the course of the IV2S, a variety of both short- and longer-term initiatives in strategically important topics and topic areas concerning traffic are pursued. The two IV2S programmes ‘A3’ and its follow up programme ‘A3plus’ are highly relevant for EVs and HEVs in Austria.

##### **The strategy programme IV2S**

The strategy programme IV2S ‘Intelligent Transport Systems and Services’ selected certain strategic core themes and technologies in the transport sector that take into account the strengths of Austrian industrial, research and innovation

stakeholders. From 2002 to 2006, this research funding programme aimed also to increase industrial competitiveness, as well as the environmental and social acceptability of transport. First, it was determined that research and technological development should create jobs in a key industry and raise competitiveness through opening innovative potentials, and second, that innovative solutions should contribute to a more sustainable transport system.

The following aspects were supported:

- Achieving technological breakthroughs.
- Gaining synergies by pooling complementary know-how from universities, research centres and industry.
- International networking.
- Demonstrating and implementing new technological solutions.

Project selection followed a public call for proposals and an evaluation procedure conducted by a panel of international experts.

Strategy Programme 2002-2006		
<b>IV2S</b>		
Intelligent Transport Systems and Services		
Impulse Programme <b>A3</b> Austrian Advanced Automotive Technology	Impulse Programme <b>I2</b> Intelligent Infrastructure Transport Telematics	Impulse Programme <b>ISB</b> Innovative Rail System

Fig.14.1 Intelligent Transport Systems and Services (IV2S) strategy programme.

Figure 14.1 gives an overview of the IV2S programme. Most relevant here is the impulse programme A3 ‘Austrian Advanced Automotive Technology’. Therefore, this programme line is described in detail in the following subsection.

#### ***The A3 programme ‘Austrian Advanced Automotive Technology’***

The Austrian Ministry for Transport, Innovation and Technology (BMVIT) is strongly committed to promoting technological breakthroughs in the fields of transport, environmental and energy technologies. The automotive industry is a particularly successful segment of the Austria’s economy, employing more than 175’000 people and one of the most important economic sectors in the world.

In recognition of this, BMVIT launched in 2001 the R&D programme ‘A3 - Austrian Advanced Automotive Technology’ to concentrate a support framework for highly innovative research projects with increased development risk. A3-sponsored work covers the entire innovation cycle, from basic research to

demonstration projects. Another pillar of the programme supports international networking, mobility and co-operation among researchers. Consortia consisting of a minimum of three partners may submit project proposals. Through 2005, four calls for R&D proposals were executed for projects developing alternative propulsion systems, as well as vehicle electronics, material research and production technologies. Among the 152 proposals submitted, 79 projects with a government funding budget of 20.6 million Euros and total budget of 40 million Euros were short-listed for funding and approved after evaluation. Because of the dramatically increased importance of alternative propulsion systems and the success of hybrid vehicles, the BMVIT augmented A3 in 2004 with an ‘Austrian hydrogen and fuel cell initiative’. One BMVIT principle that has been ingrained and observed throughout the life of this programme is that politics must not make a choice between different technological options but should provide optimum framework conditions for R&D. This principle enables the BMVIT to stimulate the development of all kind of alternative engine and fuel technologies (including hybrids, CNG and biofuels).

#### ***Lighthouse projects***

Lighthouse projects are an instrument of the BMVIT to support the market introduction of alternative propulsion systems and fuels. Complementary to the A3 proposal calls, the BMVIT supports -through the lighthouse scheme- a portfolio of large pilot and demonstration projects to prove the successful operation of new technologies and prepare the public for technological change. Between 2005 and 2006, 25 proposals were submitted within the rubric of the lighthouse projects, and eight projects were accepted in a two-step evaluation process. The total budget was 7.4 million Euros, with BMVIT funding of 3.3 million Euros. A second call for lighthouse projects was opened in 2007 through October 4, when preliminary evaluation approval of a subset of the proposal drafts to submit full project proposals by March 2008 completed the first round of the two-step evaluation process.

#### ***Follow-up programme IV2Splus - Intelligent Transport Systems and Services plus***

IV2Splus ‘Intelligent Transport Systems and Services plus’ operates as a continuation of the successful forerunner programme IV2S (2002–2006), but it transcends IV2S in some significant aspects and establishes new emphases and core areas of content. The programme focuses on expanding excellence in research and development through stronger international embedding of successfully established Austrian R&D competencies and has a goal of increased integration of these competencies into international industrial value-creation chains. Through this programme, Austria expects to make a significant contribution to the development of future transport and mobility solutions at the European level.

Within the innovation cycle, the IV2Splus strategy programme diagrammed in figure 14.2 spans the arc from problem-oriented basic research through demonstration projects and pilot projects, with core areas differing, depending on the particular programme line. Whilst the ‘A3plus’ impulse programme operates mainly in the areas of applied research and experimental development, the core focus of the ‘I2V’ impulse programme rests principally in experimental development because of the already advanced development of the technologies in this area. The action lines ‘ways2go’ and ‘impuls’ primarily address problem-oriented basic research with a future-oriented focus.



Fig. 14.2 Intelligent Transport Systems and Services plus (IV2Splus) strategy programme overview. (Logos copyright BMVIT.)

#### **Programme line A3plus**

In 2007, the BMVIT continued its funding of the new programme A3plus that supports R&D projects in the field of alternative propulsion systems and fuels. A3plus is striving to make the transport of the future significantly more energy-efficient and more environmentally friendly by promoting research and development in the field of innovative propulsion technologies and alternative fuels. Groundbreaking key innovations should trigger technological leaps that pave the way to entirely new propulsion concepts that yield previously unachievable reductions in energy consumption and emissions of surface transport.

In the first A3plus call for proposals, 5 million Euros were available for funding co-operative R&D projects. This call was open from the end of July to mid October 2007, and 23 proposals were submitted. After an evaluation process through an international jury, 18 projects involving 42 partners were accepted. This call was transnational and open to foreign partners. Within the European

Research Area Network ERA-NET TRANSPORT, the A3plus call was tuned to funding activities in Germany and Switzerland, in order to match technology promotion programmes in these countries and provide funding for foreign partners in A3plus projects.

#### ***Goals of the programme line A3plus***

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

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

According to the scenarios set out by the automotive industry, future sustainable production of hydrogen will be achieved either from methane -by means of biomass recycling- or by electrolysis of water using electricity from renewable energy sources. Before this point is reached, however, a series of technological barriers must be overcome. For that reason, the A3plus programme line is focusing on alternative propulsion systems and fuels. Beyond the automotive sector, the programme is also aiming to develop alternative propulsion systems for rail transport and inland waterway transport.

The A3plus programme line is intended to support co-operative research proposals involving industrial, university and non-university research across the entire R&D cycle, in order to strengthen the innovation capability and competitiveness of the Austrian industry in the field of propulsion technology. Beyond this, promotion of technological innovation is meant to help increase the social and ecological sustainability of surface transport. Technology and knowledge transfer operating across the different transport modes is intended to strengthen the development of interdisciplinary know-how in the field of alternative propulsion technologies in Austria. Supplementing the European research programmes and harmonizing with the European Commission's transport and energy policy, system solutions and genuine advances in technology are to be supported in the Austrian engine-construction and automotive-supplier industries. This also

contributes to meeting the Austrian federal government's targets regarding the future use of alternative fuels and propulsion systems in the transport sector.

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

#### ***Core areas of the programme line A3plus***

Alternative propulsion systems and their components.

- Scope: drive systems/drivetrains for road transport, rail transport and inland waterway transport, including electronic management of such drives.
- Examples: highly specialized monovalent or highly flexible multivalent combustion engines with alternative combustion processes and fuels or in innovative hybrid solutions, electric motors and fuel cells.
- Objectives: increase motor efficiency/energy efficiency (including energy recuperation), reduce energy consumption/emissions.

Alternative fuels.

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

Innovative storage concepts.

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

Development and support for the necessary supply infrastructures for refuelling and operating alternative propulsion systems.

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

Concepts for embedding alternative drivetrains in overall vehicle design.

- Scope: optimizing the spatial arrangement of alternative drive systems.
- Objectives: reduce weight, volume and energy consumption, by matching the drive, bodywork and other components; develop (full) hybridization concepts; increase overall vehicle efficiency (energy management/emissions), safety standards, and standards of comfort.

### ***Programme line I2V***

I2V is the Austrian impulse programme to promote co-operative research and development projects in the area of intermodality and interoperability of transport systems. The goal is to increase the efficiency of the overall transport system by improving the smooth interoperation of different modes of transport, increasing integration of environmentally sustainable modes of transport, and making more efficient use of the existing infrastructure. New technologies and system solutions are to be developed and tested, both for goods transport and for passenger transport.

### ***Action line ‘ways2go’***

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

### ***Action line ‘impuls’***

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

#### **14.2.2**

#### **A3PS - Austrian Agency for Alternative Propulsion Systems**

Following the principles of modern technology policy the Austrian Ministry for Transport, Innovation and Technology (BMVIT) is convinced that public authorities can facilitate the development of new technologies far beyond their financial contributions.

Therefore, the BMVIT decided to establish a new institution called the Austrian Agency for Alternative Propulsion Systems (A3PS). The A3PS is a public-private partnership between the BMVIT and partners from industry, small and medium enterprises (SMEs), and academic research and research facilities in Austria. The agency has 19 stakeholders at present, with further expansion planned. The new agency started its work in autumn 2006 and has the following scope of activities:

- Build up interdisciplinary research co-operation and comprehensive and trans-sectoral demonstration projects.
- Stimulate the co-operation of complementary partners to overcome the ‘chicken and egg problem’.
- Adopt supportive legal framework conditions -like fuel taxation, privileged access to sensitive areas, and emission or technical standards- to avoid barriers for innovation.
- Discuss topics and organization of programme calls with all relevant stakeholders to optimise the funding instruments.
- Inform extensively and in detail about all national and international funding opportunities.
- Analyse technological trends and evaluate technology foresight and assessment studies.
- Support the definition of interesting niches for Austrian research institutions within the technological development.
- Facilitate the integration in national and international networks, as well as participation in FP6 projects and other research activities.
- Represent Austria’s position on FP7, EU technology platforms, ERA-NET, IEA and other activities.
- Co-ordinate regional research activities to avoid duplication of efforts and to achieve a critical mass in the international perception.
- Give Austrian research institutions a long-term security in planning and investments because of a clear public commitment beyond election terms.

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

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

### **14.3** ***Research***

Research on electric vehicles, batteries and fuel cells takes place mostly at Austria’s universities and research centres: Vienna University of Technology, Graz University of Technology, University of Leoben, Joanneum Research Forschungsgesellschaft mbH, ARC Seibersdorf research GmbH, Arsenal Research, HyCentA Research GmbH and ECHEM (Competence Centre for Applied Electrochemistry). These research centres work co-operatively with automotive industry companies such as Plansee, AVL-List, BMW and Magna Steyr.

Principal research topics include:

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

## 14.4

### **Industry**

Austria has more than 700 automotive and automotive component companies. The main field of the industry relating to hybrid and electric vehicles is onboard hydrogen storage and fuel cell propulsion systems. A few companies, such as Banner, are active in the field of lead acid batteries. Magna Steyr is deeply involved in the development of a lithium-ion battery system for automotive applications (figure 14.3) and in the development of a hybrid SUV vehicle.



Fig. 14.3    Lithium-ion battery system from Magna Steyr. (Photo: M. van Walwijk.)

## 14.5

### **On the road**

Although no formal market introduction or inducement programmes for EVs or HEVs have been attempted in Austria, some tourist resorts and villages only allow the use of electric vehicles on their premises. Table 14.1 profiles the motorised vehicle fleet in Austria.

Table 14.1 Characteristics and population of the Austrian motorised vehicle fleet per December 31, 2003-2006.

Vehicle type	2003	2004	2005	December 31, 2006		
	EV fleet	EV fleet	EV fleet	EV fleet	HEV fleet	Total fleet
Bicycles (no driver licence)	215	201	206	246	0	439'189
Motorbikes	12	19	21	22	0	206'124
Passenger vehicle	135	128	127	127	481	4'204'969
Multipurpose pass. vehicle	0	0	0	0	0	0
Bus	109	108	108	110	0	9'297
Truck	26	22	17	21	0	364'323
Industrial vehicles	36	37	38	39	0	498'722
<b>Total</b>	<b>533</b>	<b>515</b>	<b>517</b>	<b>565</b>	<b>481</b>	<b>5'722'624</b>

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

Statistics show that the total number of vehicles in Austria is increasing. The number of electric vehicles appears to be more or less constant during 2003-2006. Motor assisted bicycles -which can be operated legally on streets without the need for a driving licence- comprise the largest share of the Austrian EV fleet. The number of HEVs (bivalent gasoline/electric cars) is increasing as well.

## 14.6

### **Outlook**

As already mentioned, the government is funding research projects aimed at advancing alternative propulsion systems and fuels. In the course of discussions on such topics as global warming and the related energy security, energy costs and sustainability areas, EVs and HEVs gain ever more importance worldwide.

Industry and research facilities are active also in developments for EV, HEV and fuel cell cars. The Austrian government actively supports these research areas with funding and cross-linking activities. As high gasoline prices and advertising campaigns raise the public's awareness of alternatives to pure petroleum propulsion, the market for EVs and HEVs -now very limited in Austria- should certainly continue to increase.

## 14.7

### **Benefits of participation**

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

- Remaining informed about technology developments in other countries regarding EVs and HEVs and their drivetrains, with the objective of transferring this knowledge to the local industry.

- Participating in a network of well-known automotive laboratories, research organizations and governmental agency representatives to produce joint studies and reports.

## 14.8

### ***Further information***

More information on Austrian activities regarding hybrid and electric vehicles can be found on the following websites:

- [www.arsenal.ac.at](http://www.arsenal.ac.at) (in English and German).  
Austrian Research Centres - Arsenal Research. Arsenal works on research questions in the areas mobility and energy.
- [www.avl.com](http://www.avl.com) (in English).  
AVL-List GmbH is the world's largest privately owned and independent company for the development of powertrain systems with internal combustion engines, as well as instrumentation and test systems.
- [www.a3ps.at](http://www.a3ps.at) (in English and German).  
Austrian Agency for Alternative Propulsion Systems (A3PS). A3PS is a public-private partnership between the BMVIT and Austrian industry and research institutes. It is the Austrian platform for all alternative propulsion systems and fuels, including hybrid and electric vehicles.
- [www.banner.at](http://www.banner.at) (in English and German).  
Lead acid batteries and traction battery systems.
- [www.bmvit.gv.at/en/innovation/mobility/a3plus.html](http://www.bmvit.gv.at/en/innovation/mobility/a3plus.html) (in English and German).  
A3plus Alternative Propulsion Systems and Fuels programme of the Federal Ministry for Transport Innovation and Technology (BMVIT).
- [www.echem.at](http://www.echem.at) (in German).  
Competence Centre for Applied Electrochemistry.
- [www.energyagency.at](http://www.energyagency.at) (in English and German).  
The Austrian Energy Agency.
- [www.energytech.at](http://www.energytech.at) (in English and German).  
Platform for innovative technologies in the area of energy efficiency and renewables.
- [www.magnasteyr.com](http://www.magnasteyr.com) (in English and German).  
Engineering and vehicle assembly company.

# 15

## Belgium

### 15.1

#### **Introduction**

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

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

In 2006, the energy consumption of the transportation sector in Flanders amounted to 212 PJ (peta Joules). This corresponds to 13% of the total energy consumption of Flanders. The majority of this energy consumption was the result of road traffic: 57% passenger transport and 40% goods transport. Since 2000, the energy consumption of passenger transport on the road has increased by only 0.6%, while for goods transport this figure was 5.6%. An increased share of diesel vehicles and the greater availability and acquisition of more fuel-efficient vehicles explain the low figure for passenger transport, as shown in tables 15.1 and 15.2.

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

Belgium							
		2002	2003	2004	2005	2006	2007
<b>Number of vehicles (x 10<sup>3</sup>)</b>	Gasoline	154	135	143	128	133	94
	Diesel	288	303	342	351	392	430
	Total	442	438	485	479	525	524
<b>Average fuel consumption [l/100km]</b>	Gasoline	7.1	7.0	6.9	6.7	6.6	6.6
	Diesel	5.8	5.8	5.7	5.6	5.6	5.6
	Total	6.3	6.2	6.0	5.9	5.8	5.8

Table 15.2 Percentage of new car sales by CO<sub>2</sub> class in Belgium. (Data © VITO.)

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

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

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

## 15.2

### **Policies and legislation**

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

#### **Individual consumers**

Buyers of vehicles that emit low levels of CO<sub>2</sub> receive a tax reduction at purchase. This reduction is 15% of the purchase price for vehicles with CO<sub>2</sub> emissions equal to or lower than 105 g/km (e.g., Toyota Prius with 104 g/km) and a 3% reduction for vehicles with CO<sub>2</sub> emissions between 105 and 115 g/km (e.g., Honda Civic with 109 g/km). These amounts are maximised to, respectively, 4'270 Euros and

800 Euros for the 15% and 3% price reductions. Effective since July 2007, this sum is now directly applied at the moment of purchase and is no longer returned to the owner only when income taxes are finalized, which is approximately two years after the acquisition of the vehicle.

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

#### ***Belgium company car taxation***

When an employer gives an employee a company car that is subsequently used for private transport, this usage is taxed in two ways. The employee must state the net benefit-in-kind received from the employer, which is a value calculated on the basis of the average mileage and the fiscal horsepower of the car. For the employer, the benefit-in-kind is treated as a form of salary on which social security contributions must be paid. Since January 2005, the social security contribution is calculated on the basis of the CO<sub>2</sub> emissions of the car, rather than on fiscal horsepower [15.2]. The calculation of the annual social security contribution is as follows (in Euros):

Gasoline cars: (CO<sub>2</sub>-emission \* 9€) - 768€

Diesel cars: (CO<sub>2</sub>-emission \* 9€) - 600€

LPG cars: (CO<sub>2</sub>-emission \* 9€) - 990€

As of April 2007, the percentage of costs for the purchase of a company car that the company can deduct from its taxable income also depends on the CO<sub>2</sub> emissions of the car - a calculation that replaces the overall tariff of 75%. The percentages per CO<sub>2</sub> category and fuel type are given in table 15.3.

Table 15.3 Deductible percentage of costs of company cars, as a function of CO<sub>2</sub> emission level.

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

Beginning in April 2008, the percentages that can be deducted will be applied to the total costs of the company fleet [15.1]. (Note that this legislation does not

favour the larger hybrid vehicles on the market, such as the Lexus RX 400h, Lexus GS 450h and Lexus LS 600h.)

### ***Other***

Currently, there are several systems to define the environmental friendliness of vehicles, including fuel type, CO<sub>2</sub> emission level or homologation legislation (e.g., EURO-4). However, these approaches are not sufficient to describe the complete impact on the environment. For this reason, VITO and other partners -including the Vrije Universiteit Brussel- have developed the Ecoscore methodology. With this methodology, climate change counts for 50% in the final score, health effects for 20%, impact on ecosystems for 20%, and noise for 10%. The pollutants considered are CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, CO, NMVOS, PM<sub>10</sub>, NO<sub>x</sub>, and SO<sub>2</sub>. The environmental evaluation permits the combination of different effects in one indicator. The methodology is based on a well-to-wheel analysis. The Belgian government is evaluating how this methodology can be incorporated in the regulations.

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

## **15.3**

### ***Research***

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

#### ***VITO***

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

In past years, VITO has participated in the Flanders’ DRIVE project ‘Development of a knowledge platform for hybrid vehicles’, supported by the Flemish Government. The main objective of the project is the development of a Flemish

knowledge platform for the design and development of vehicles with hybrid powertrains (including the long-term relevant fuel cells) and the subsystems/components for such hybrid powertrains. The general objective is to initiate, enrol and technically support the development of hybrid vehicles and components for the industry. Currently, the covered fields are system engineering, energy management, battery management, vehicle management, vehicle integration components and subsystems, simulation and testing.

Some of the recent technological projects are concerned with the development of hybrid heavy-duty vehicles. VITO -with its industrial partners- is preparing hybrid vehicle development projects to produce demonstration fleets of hybrid vehicles. Each fleet will be backed by an industrial consortium that provides full service to vehicle users. Two announced projects are the hybrid refuse lorry (figure 9.1 in the Annex XII chapter) and a hybrid distribution truck that allows transportation in the inner city in all-electric mode (figure 15.1).



Fig. 15.1 Hybrid distribution truck by VITO. (Photo supplied by VITO.)

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

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

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

#### ***Vrije Universiteit Brussel***

VUB (Vrije Universiteit Brussel) is a full (Dutch-language) university located in the Brussels capital region. It was created in 1969 as a partition of the (French-language) Université Libre de Bruxelles. It counts more than 9'000 students and 2'000 personnel.

In the Department of Electrical Engineering and Energy Technology (ETEC) of the VUB Faculty of Engineering Sciences, professor G. Maggetto has led a long tradition (since 1974) of R&D on electric, hybrid and fuel cell vehicles. The ETEC's work mainly emphasizes the characterization, testing and demonstration of electric, hybrid and fuel cell vehicles and their components, such as electric drives and batteries.

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

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

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

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

### ***Green Propulsion***

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

With Metropol software -developed in-house- the simulation and optimization of a tailored vehicle saves time and money before any development occurs. Green Propulsion consequently offers homemade complete vehicle integration, including mechanical design, thermal management, electric wiring, electronic cards development, vehicle tuning and monitoring.

Recent projects include the development of an electric superkart with an acceleration of 0-100 km/h in 2.5 seconds, a prototype parallel hybrid VW Lupo, an electric/series-hybrid Microbus, a prototype combined series/parallel hybrid Renault Kangoo, an Imperia revival sport concept car and a hybrid bus (figure 15.2).



Fig. 15.2 Hybrid 12m bus project for the Walloon transport company. (Photo © Green Propulsion.)

## **15.4**

### ***Industry***

The Belgian light-duty automotive industry consists principally of assembly plants (Ford Genk, Volkswagen Vorst, Opel Antwerpen and Volvo Gent) and components suppliers. In heavy-duty vehicle markets, Belgium has two bus- and coachbuilders. One builder -Van Hool- specializes in bodies and chassis. Since building three A308H 9-meter hybrid public transport buses in the mid 1990s, Van Hool has recently developed a fuel cell bus for the U.S. market and introduced that model also into the European market (figure 15.3).

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

Punch Powertrain will modify its existing CVTs to become the core of this new parallel hybrid powertrain. The first development project aims at powering B-segment passenger cars and small vans. Punch Powertrain is partnering with



Fig. 15.3 Van Hool fuel cell bus, operational in Belgium. (Photo supplied by VITO.)

battery and electric motor technology providers to combine good performance and improved fuel consumption with a low cost premium. The market introduction is scheduled for early 2009.

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

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

## 15.5

### ***On the road***

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

The income tax benefit for vehicles with low CO<sub>2</sub> emissions partially compensates for the price premium of the Toyota Prius. Also, the new Prius II seems to appeal to a broader spectrum of car buyers than its predecessor. Consequently, sales figures for the Prius have risen substantially.

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

Currently, no electric cars (passenger vehicle category in table 15.5) are sold in Belgium, although a total number of almost 80 EVs has been sold during the years 1995-2003. The number of electric cars in the Belgian vehicle fleet is diminishing over the years.

Table 15.4 provides an overview of the different hybrids sold in Belgium for the period 2004-2007. Thus, the number of hybrids sold is increasing, but it remains marginal compared with the total car market (i.e., 0.26% in 2007).

Table 15.4 Hybrid car sales in Belgium for the period 2004-2007. (Data © Febiac.)

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

Table 15.5 Characteristics and population of the Belgian motorised vehicle fleet per August 1, 2003-2007. (Source: FOD Economie - Algemene Directie Statistiek en FOD Mobiliteit en Vervoer.)

<b>Vehicle type</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>August 1, 2007</b>	
	<b>EV fleet</b>	<b>Total fleet</b>				
Bicycles (no driver licence)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Motorbikes	6	6	5	8	10	374'743
Passenger vehicle	51	30	22	13	8	5'048'723
Multipurpose pass. vehicle	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bus	2	2	n.a.	21	19	15'479
Truck	84	78	66	62	51	690'747
Industrial vehicles	925	937	965	886	942	232'469
<b>Total</b>		<b>1'068</b>	<b>1'053</b>	<b>1'058</b>	<b>990</b>	<b>6'362'161</b>

*n.a. not available*

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

Motorised vehicle fleet data for Belgium is presented in table 15.5. Separate data for hybrid electric vehicles was not available at the time of writing.

## **15.6**

### ***Outlook***

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

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

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

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

## **15.7**

### ***Benefits of participation***

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

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

## 15.8

### **Further information**

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

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

### **AVERE**

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

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

### **CITELEC**

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

- Informing the cities on the characteristics of battery electric, hybrid electric and fuel cell vehicles (referred to henceforth as 'electric vehicles').
- Accompanying the deployment of electric vehicles in the cities and training the users.
- Contributing to the realization of the needed infrastructures.

- Organizing test demonstrations for electric vehicles: '12 Electric Hours' and 'Transeuropean' ([www.transeuropean.org](http://www.transeuropean.org)).
- Submitting electric vehicles to test programs.
- Performing studies concerning the influence of electric vehicles on traffic and environment in the city.
- Taking part in international standardization concerning electric vehicles and their infrastructure.

More information is available at [www.citelec.org](http://www.citelec.org) (in Dutch, English and French).

### **EPE**

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

More information is available at [www.epe-association.org](http://www.epe-association.org) (in English).

### **Flanders' DRIVE**

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

More information is available at [www.flandersdrive.be](http://www.flandersdrive.be) (in English).

### **VSWB - Flemish Cooperative on Hydrogen and Fuels Cells**

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

More information is available at [www.vswb.be](http://www.vswb.be) (in Dutch).

## **15.9**

### **References**

- [15.1] Envirodesk. *Milieumaatregelen beslist op federale top te Leuven.* Newsflash, March 20, 2007.
- [15.2] Willems, M. *Het nieuwe stelsel van CO<sub>2</sub>-bijdragen.* Magazine Fleet, January 2005.

## 16 Canada

### 16.1 *Introduction*

With the rising price of oil and gas, many Canadian consumers are pondering the purchase of a hybrid car as way to save money at gasoline stations. However, cost is not the only reason that people are considering hybrid vehicles. It is also good for the environment, since driving hybrid vehicles results in reduced emissions and less dependence on oil.

Hybrid vehicles in Canada cost anywhere from \$5'000 to \$8'000 more than their conventional counterparts, and fuel savings do not easily outweigh the operating costs of hybrids in the long run. Canadians are also concerned about higher insurance rates, taxes and regulatory charges, simply on the basis of the higher price point of the hybrid. However, some provinces offer sales tax rebates to environmentally conscious car owners. This being said, the cost of technology will decrease over time, which means hybrids may sell at lower prices in the future. As a result, savings at the pump may eventually offset their initial purchase price.

One of the selling points of hybrid electric vehicles (HEVs) is their fuel economy, but the amount of fuel saved depends on the speed at which the vehicle is driven. It is widely known to technicians and engineers that HEVs have excellent fuel economy when cruising in residential neighbourhoods and slow city traffic, but they are not necessarily fuel efficient when it comes to highway driving.

The Canadian consumers' knowledge of HEV technologies is at a point where they now realize that one never has to recharge the car by plugging the batteries into an electrical outlet. However, the next evolution of HEVs may require this to happen. The plug-in hybrid electric vehicles (PHEVs) will offer more electric-only operability and reduce fuel consumption even further. This consumer education continues to be a priority for several Canadian federal government programmes.

### 16.2 *Policies and legislation*

New vehicles sold in Canada are required to meet the safety standards enforced by Transport Canada, as laid out in the Canadian Motor Vehicle Safety Act. Emission regulations are established under the authority of the Canadian Environmental Protection Act and enforced by Environment Canada.

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

### **16.3** ***Research***

The Program of Energy Research and Development (PERD) is a federal, inter-departmental programme operated by Natural Resources Canada (NRCan). The PERD funds research and development (R&D) designed to ensure a sustainable energy future for Canada in the best interests of both the economy and environment. It directly supports energy R&D conducted in Canada by the federal government and is concerned with all aspects of energy supply and use.

The PERD and other such programmes administered by NRCan will fund research, development and demonstration (RD&D) endeavours in a wide array of energy portfolios. Its efforts in the Clean Transportation Systems Portfolio are meant to support the development of hydrogen and fuel cell technologies, electric vehicles, emission reduction technologies, and advanced fuels and materials needed to break through to a clean transportation system. It also strives to generate the new scientific knowledge essential to support the proposed regulatory approach to the Clean Air Agenda, and this includes providing the sound scientific and technical background for establishing meaningful codes and standards.

The electric vehicle technology area will conduct RD&D activities that concentrate on PHEVs and will focus its efforts on the range of opportunities and challenges that they present. As with the other advanced vehicle technology explored in this portfolio, the PHEV concept holds great promise to significantly reduce air pollutants, greenhouse gas emissions and oil consumption.

Led by the National Research Council of Canada (NRC), the RD&D activities of the PERD will focus mainly on four areas: energy storage systems, electric drive components, powertrain optimization, and development of regulations for emissions and fuel efficiency.

### **16.4** ***Industry***

Electric vehicles in Canada have a large potential market for a wide range of component suppliers who are actively pushing the market via the rising interest in the PHEV technology area. For some time, Canada has been included in the top 10 list of worldwide countries that produce motor vehicles. The auto sector is

Canada's biggest manufacturing contributor to the gross domestic product and this is in no doubt due to its parts suppliers and manufacturers. With already well-established manufacturers in the electric vehicle industry, Canada is well positioned to benefit from the continued growth of HEVs and future PHEVs.

## **16.5**

### ***On the road***

On-road population data for HEVs are not yet available for publication, as Canada only rejoined the IA-HEV in late 2007.

## **16.6**

### ***Outlook***

A Canadian outlook was not yet available at the time of printing.

## **16.7**

### ***Benefits of participation***

The principal reason why NRCan has joined this international research community is to encourage the development and commercialization of hybrid and electric vehicles. More specifically, the reasons can be enumerated as follows:

- A renaissance in electric transportation applications.
- Recent interest in plug-in hybrid electric vehicles (PHEVs).
- The popularity of hybrid electric vehicles.
- An increase in world petroleum prices induced by high demand.
- Shortfalls in refining capacity.
- The creation of a new program on electric mobility focusing on PHEVs.

## **16.8**

### ***Further information***

The following internet websites may be consulted for further information:

- <http://cfs.nrcan.gc.ca/subsite/ecoleap/perd> (in English and French).  
Program of Energy Research and Development (PERD).
- [www.ec.gc.ca](http://www.ec.gc.ca) (in English and French).  
Homepage of Environment Canada's website. Environment Canada's work includes: to preserve and enhance the quality of the natural environment; and to co-ordinate environmental policies and programs for the federal government.
- [www.nrc-cnrc.gc.ca](http://www.nrc-cnrc.gc.ca) (in English and French).  
The National Research Council (NRC) is the government of Canada's premier organization for research and development, active since 1916.
- [www.nrcan-rncan.gc.ca/com](http://www.nrcan-rncan.gc.ca/com) (in English and French).  
Natural Resources Canada homepage.

- [www2.nrcan.gc.ca/es/oerd](http://www2.nrcan.gc.ca/es/oerd) (in English and French).

The Office of Energy Research and Development (OERD) is the government of Canada's co-ordinator of energy research and development activities.

## 17 **Denmark**

### 17.1 **Introduction**

In January 2007, the Danish government announced a new energy strategy, which is aimed at ensuring that a higher share of energy consumed in Denmark is renewable. The strategy is consistent with the long-term vision to win independence from fossil fuels such as coal, oil and natural gas.

The specific goal of the government is to at least double to 30% by 2025 the current 15% share of energy utilisation accounted for by renewables. As of 2007, biomass accounted for almost half of the use of renewable energy and wind turbines are generating about 20% of total electricity.

In 2025, it is possible that up to 50% of electricity will be produced by wind turbines through expansion of the total wind power generation capacity from 3'000 MW to about 6'000 MW. However, achieving this objective requires that several challenges be overcome. A major challenge is to adapt the electricity system to manage the intermittent electricity production that will result from much greater reliance on wind turbines. Flexibility in electricity consumption will be an important factor and in this context battery-, plug-in hybrid and fuel cell electric vehicles could play a very important role.

### 17.2 **Policies and legislation**

#### **Policies**

The new energy strategy that took effect as of January 2007 incorporates measures for the transport sector. To reduce oil dependency and CO<sub>2</sub> emissions from the transport sector, the emphasis is on more energy-efficient vehicles and use of biofuels. The Danish government has decided to give priority to the development of second-generation biofuels produced mainly from the waste products of agriculture.

In August 2007, the Danish Energy Authority published a report on alternative fuels in the transport sector. One of the conclusions in the report is that over the longer perspective, battery electric vehicles have the potential to deliver the highest energy efficiency while providing important environmental advantages for the areas in which they operate, such as no local emissions and a very low noise level. The electricity storage capabilities of the batteries embody interesting

potential means to optimise the integration of intermittent renewable energy -such as wind power- into the electricity system.

To support development and demonstration of new energy technologies to realize the energy strategy, the government has initiated a new Energy Technology Development and Demonstration Programme (EUDP), starting in 2008.

During 2007, hybrid and electric vehicles have frequently been identified in political and public discussions as an optimal and realistic answer to many of the challenges of the transport sector. In particular, the energy generation sector has shown considerable interest in plug-in hybrids and electric vehicles as an important means to meet the future challenge of integrating 50% wind power into the electricity system. The energy sector is an important advocate of demonstration programmes for advanced technology electric propulsion.

In February 2008, a new Climate and Energy Agreement was reached that includes almost all political parties in the Danish Parliament. As an element of this agreement, the parties decided to allocate 30 million DKK (4 million Euros) to the promotion of electric vehicles.

### ***Legislation***

The Danish registration tax for passenger cars is very high (180%) and is indexed to the value of the car. In August 2007, the tax rules for light vehicles (passenger cars and vans) were changed to promote the sale of more energy-efficient vehicles. The new rules reduce the registration tax for gasoline cars more energy efficient than 16 km/l (for diesels 18 km/l) and impose a higher tax for less energy-efficient cars. This change in the rules will complement the already implemented annual vehicle tax structure that rewards lower energy consumption and reduced CO<sub>2</sub> emissions generally to promote the sales of energy-efficient cars. The new reduction is 4'000 DKK for each km/l higher than 16, and the extra tax is 1'000 DKK for each km/l less than 16. These changes have considerably affected sales of passenger cars in Denmark in that the share of small cars sold -especially diesel cars- has increased considerably.

There are no special incentives for hybrid cars. Of course, the Toyota Prius will benefit from the new changes in registrations tax and a low annual tax, but the price for the passenger version is still considered to be too high. A new possibility to register the Prius as a van -with front seats only- reduces the price considerably because of the favourable tax situation for vans, and so sales of this modified version are expected to increase.

Battery electric vehicles and fuel cell vehicles are exempted from registration tax and annual tax, but no such vehicles are currently on the market.



Fig. 17.1 From the start of 2008, the Toyota Prius may be sold in Denmark as a van (yellow number plates) with only front seats. This reduces the price by almost 40%, and Toyota expects sales of the Prius -very limited until now- to increase considerably. (Photo courtesy Toyota Denmark.)

No tax rules have been passed to cover plug-in hybrid electric vehicles. The new Climate and Energy Agreement includes a commitment to instate tax rules before the end of 2009 to promote plug-in hybrid electric vehicles.

### **17.3 Research**

The main focus in Danish research related to transportation technologies has been on biofuels, hydrogen and fuel cells.

Denmark has two world leading companies -Novozymes and Danisco- involved in development and production of enzymes to produce biofuels. In 2007, with support from the EUDP programme that is mentioned above, construction of a full-scale production plant broke ground for second-generation process conversion of agricultural waste products to bio-ethanol.

The Danish Energy Authority has, over several years, conducted a Hydrogen and Fuel Cell Programme, the focus of which has been on research and development of SOFC and PEM fuel cells. The use of SOFC fuel cells has been demonstrated and tested as micro CHP (Combined Heat and Power) units running on natural gas, and the use of PEM fuel cells has been demonstrated and tested as micro CHP running on hydrogen produced from off-peak wind power.

The company H2 Logic is working on a project with Th!nk in Norway to develop a hybrid storage system with batteries and PEM fuel cells for the new Th!nk electric car. The aim is to combine the high energy efficiency of batteries with the

possibility of fast refuelling with hydrogen. To demonstrate this solution, the Danish Hydrogen Link network is working to establish a hydrogen infrastructure. This work is a part of the Scandinavian Hydrogen Highway Partnership (SHHP), which is aiming to establish an early hydrogen refuelling infrastructure.

In 2007, several activities and research projects -which are expected to expand considerably in coming years- were initiated to analyze the potential of vehicle-to-grid (V2G) services from plug-in hybrid and battery electric vehicles. The immediate aim is to prepare demonstration projects to analyze under realistic conditions how such vehicles can support and benefit from an electricity system with a large share of wind power.

## 17.4

### ***Industry***

Denmark has no conventional car industry but hosts many component suppliers, but Denmark was one of the first countries to produce and market electric vehicles. Production of the small 'Ellert' -that became the most sold electric vehicle in the world- started in 1987, and in 1991 production of the Kewet El-Jet commenced. To facilitate their sales, electric vehicles were exempted in Denmark from registration tax and the annual car tax based on weight. However, by now both EV manufacturers have ceased production in Denmark, with improved versions of the original vehicles currently being produced in Germany and Norway.

## 17.5

### ***On the road***

The total count of passenger cars in Denmark has just passed 2 million and is slightly increasing. The population of electric cars is estimated at about 300. These cars are mainly the French Citroën models Saxo- and Berlingo Électrique and the Danish Kewet El-jet. Additionally, there are about 350 City-el (three-wheeler) vehicles and a few electric scooters and e-bikes. There are many bicycles in Denmark (more than 1 per person, for a total of more than 5 million), but e-bikes are still not selling in large numbers.

The number of electric cars on the road in Denmark has been decreasing because there has been no opportunity to purchase new vehicles and some existing cars are taken out of service as a result of technical problems (for example, failed batteries or malfunctioning electric equipment). Many electric cars originally bought and owned by companies and public authorities have been sold for private use or have been exported.

Only Toyota is currently marketing hybrid vehicles in Denmark. The Toyota Prius II hybrid has been available on the Danish market since May 2004, but only a very limited number have been sold so far. As of the end of 2007, only 25 Toyota

Priuses have been registered in Denmark. The most important barrier to consumers is the high price of the Prius, as well as a lack of special incentives (such as a reduced registration tax). Because of the high registration tax, the price of the Prius is about 60'000 Euros (about US\$ 90'000), which is considered too high by almost all potential customers. The recent changes in the registration tax giving reductions to energy-efficient cars on an absolute scale has reduced the price, but this is not yet reflected in the sales figures.

Sales of the Lexus RX 400h hybrid sports wagon started in September 2005. Because of the Danish registration taxation rules, this car in a configuration as a van with only front seats can be sold at a lower price than the Toyota Prius passenger car. As of the end of 2007, 34 vans and 8 passenger cars are registered on the road.

In 2006, the Lexus GS 450h became available for sale in Denmark. It is priced at more than US\$ 200'000, but its luxury-car segment seems to be less sensitive to higher cost if associated with new advanced technology. As of the end of 2007, six GS 450h are on the road. Similarly, in 2007, the Lexus LS 600h was introduced to the Danish market. Sales in this high power, high-end market segment are very limited in Denmark. As of the end of 2007, three LS 600h models had been sold.

Table 17.1 Hybrid cars on the road in Denmark, as of December 31, 2007.

<b>Make</b>	<b>Model</b>	<b>2007</b>
Lexus	GS 450h	6
Lexus	LS 600h	3
Lexus	RX 400h	42
Toyota	Prius	25
	<b>Total</b>	<b>76</b>

#### **Danish experiences with battery electric vehicles**

In 2005, the Danish Environmental Protection Agency (Ministry of Environment) published the report ‘Experience with electric cars in Denmark’. The report collates and assesses the practical experience of electric cars in Denmark from 1998 through 2001, but it also includes user experience from later years. The report emphasized user experience with the new generation of Citroën and Th!nk electric cars, which have been marketed in Denmark since 1997. (See also the [www.mst.dk](http://www.mst.dk) website that is mentioned in subsection 17.8.)

### ***User experiences***

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

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

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

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

### ***Battery problems***

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

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

***Private owners***

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

These experiences could be an indication of the potential of the possible share of the electrically driven mileage of plug-in hybrid electric vehicles (PHEVs) with a similar electric range of 70-100 km.

**17.6*****Outlook***

As a result of the introduction of battery electric vehicles from French car manufacturers in 1995, there was a considerable interest in electric vehicles in Denmark over the following five-year period. However, after 2-3 years, massive battery problems with the first generation of the NiCd-batteries from Saft started to appear and the confidence in electric cars declined dramatically, especially in the public sector. Private owners who had the batteries changed within the guarantee period have remained satisfied with the electric cars.

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

In the coming years, the focus will be on a demonstration project with plug-in hybrid electric vehicles and the development of vehicle-to-grid technologies.

**17.7*****Benefits of participation***

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

- It provides opportunities to exchange information on the latest developments in hybrid and electric vehicles and technologies.
- It provides a source of new ideas that goes beyond the information that is available through written communication, through personal contacts with experts from different countries and organizations.

- It provides opportunities -through possible informal contacts with experts from other countries- to discuss and evaluate new information on the numerous findings in the field of hybrid and electric vehicles, as well as a possibility of informal contacts with experts in other countries to discuss new issues that come up in the member country.

## **17.8**

### ***Further information***

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

- [www.danskbilbilkomite.dk](http://www.danskbilbilkomite.dk) (in Danish).  
The site of the Danish Electric Vehicle Committee.
- [www.danskenergi.dk](http://www.danskenergi.dk) (in Danish and English).  
The site of the Danish Energy Association.
- [www.hydrogennet.dk](http://www.hydrogennet.dk) (in Danish).  
This website includes information on hydrogen, fuel cells and transport.
- [www.mst.dk/udgiv/publikationer/2005/87-7614-619-7/html](http://www.mst.dk/udgiv/publikationer/2005/87-7614-619-7/html) (in Danish, a summary in English is also provided on this website).  
This is a report on electric vehicles in Denmark.
- [www.scandinavianhydrogen.org](http://www.scandinavianhydrogen.org) (in English).  
The site of the Scandinavian Hydrogen Highway Partnership (SHHP).

## **18**

### **France**

#### **18.1**

#### **Introduction**

Regarding industrial and R&D activities that were under way as the year 2006 drew to a close, a promising picture emerged for the development of electric vehicle (EV) and hybrid electric vehicle (HEV) markets in France and Europe. Through 2007, carmakers and their suppliers were involved in industrial projects with the goal of marketing EVs and HEVs on a large scale by 2010. However, 2007 was also a transition year for France, with the election of a new president and a ‘new deal’ on environment embodied in the ‘Grenelle de l’Environnement’.

#### **18.2**

#### **Policies and legislation**

##### ***Le Grenelle de l’Environnement***

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

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

- Reducing the average CO<sub>2</sub> emissions from the total fleet from 176 gCO<sub>2</sub>/km (today) to 130 gCO<sub>2</sub>/km in 2020.
- Encouraging the strengthening of European new vehicle limits on CO<sub>2</sub> emissions from 130 gCO<sub>2</sub>/km to 120 gCO<sub>2</sub>/km.
- Developing ‘new technologies of clean vehicles’ EV/HEV plug-in.

- Promulgating incentives for the purchase of low emission vehicles (see Bonus/Malus, below).

Table 18.1 shows the details of the Bonus/Malus system put into force on January 1, 2008. This new incentive system based on CO<sub>2</sub> emissions replaces the previous tax credit for the purchase of clean vehicles. The purchase tax relief (green) or penalty (orange) shown in table 18.1 is a function of CO<sub>2</sub> emission rate per kilometre. An extra 300 Euro bonus is offered for the destruction of a vehicle older than 15 years.

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

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

Table 18.2 reviews the 2007 ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie) incentive programme for the purchase of electric vehicles (EVs).

Table 18.2 Characteristics of the ADEME electric vehicle (EV) support programme.

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

### 18.3 *Research*

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

The Comop 8 has defined five main axes of work:

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

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

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

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

## **18.4**

### ***Industry***

#### ***Johnson Controls-Saft***

Johnson Controls-Saft Advanced Power Solutions announced the official opening of its new lithium-ion automotive battery manufacturing facility as of January 2008. The plant, based in Nersac, France, and dedicated to the manufacture of advanced lithium-ion batteries for hybrid, plug-in, fuel cell and electric vehicles, is the first of its kind in the world.

Johnson Controls-Saft initially invested 15 million Euros in the facility, which produces batteries for global automotive customers. It has been built to be

scaleable, so that as customer and market demands increase it can increase production capacity to meet them.

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

### **BatScap**

After having bought AVESTOR (its only competitor in lithium metal polymer (LMP) battery production) in 2006, BatScap announced in December 2007 the creation of a 50/50 joint venture with Pininfarina to build a fully electric vehicle. The vehicle will be a four-seater powered by a LMP battery developed by Bolloré, and it will have a range of 250 km (155 miles) in an urban environment. The Pininfarina electric vehicle will be marketed simultaneously in Europe, the United States and Japan in 2009. The production capacities -which depend on the number of batteries produced by Bolloré- will allow the delivery of 1'000 vehicles by mid 2009. Total capital investment in the Bolloré-Pininfarina project is about 150 million Euros (US\$ 216 million).

Table 18.3 Characteristics of the BatScap 2600 F supercapacitor cell. (Supplied by ADEME.)

Capacitance (25°C, 100 A)	2'600 F
Nominal voltage	2.7 V
Serial resistance DC (25°C, 100 A)	0.35 mOhm
Serial resistance AC (25°C, 100 A)	0.2 mOhm
Maximum peak current	600 A
Weight	500 g
Specific energy (2.7 V, 25°C)	5.3 Wh/kg
Maximum specific power (2.7 V, 25°C)	20 kW/kg
Time constant $R_{SDC}C$ (25°C, 100 A)	0.9 s
Operating temperature	-30 to +60°C
Storage temperature	-30 to +70°C



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

With a nominal rating of 2.7 V and designed to achieve ultra-low resistance values, BatScap's supercapacitors show remarkable performance with regard to energy density (up to 6 Wh/kg) and lifecycle (several million charge/discharge cycles). BatScap is commercialising its supercapacitors as single cells, as well as multi-cell modules with voltage balancing electronics included. Two cells with capacitances of 2'600 F and 5'000 F are commercially available (see also table 18.3).

### Valeo

Valeo's LOwCO2MOTION programme aims to improve vehicle gasoline engine efficiency on the one hand and the proper management of the energy used by the vehicle on the other hand, especially during the slowing down and stopping phases. This programme will contribute in the long run to reducing CO<sub>2</sub> emissions and diesel engine pollutants.

This programme focuses on two new products:

- 1) The camless valve actuation system enables control of the valves of the internal combustion engine -thanks to electromagnetic actuators- and it replaces the camshaft. It also optimizes combustion for all gasoline engine speeds, as it will for the diesel engine in a subsequent version (figure 18.1).



Fig. 18.1 Valeo camless valve actuation system. (Picture supplied by ADEME.)

- 2) The mild hybrid system, conceived on the basis of an alternating current car starter, enables management of the energy used by the vehicle and applies to all types of motorizations and fuels (figure 18.2). This stop-start system features a regenerative braking function; energy generated during braking is recovered and is used again when the car starts to move. The system suppresses all fuel consumption when the car is at a standstill. This programme integrates the development of a new high efficiency, high power alternator technology. The partnership for this mild hybrid system includes PCA (PSA

Peugeot Citroën group), BatScap (Bolloré Group) for electricity storage by ultracapacitors, and TNO (the Netherlands).



Fig. 18.2 Valeo first-generation stop-start system. (Picture supplied by ADEME.)

The LOWCO2MOTION programme represents a 211.6 million Euros global investment in research and development that will extend over the 2007-2011 period.

#### ***Peugeot Citroën Automobiles (PCA)***

In mid 2006, the French carmaker PCA launched an industrial development programme in order to pave the way to commercialization of diesel hybrids by 2010. Originally, its hybrid HDi target was intended to be a mid-class vehicle combining a 1.6-litre HDi diesel engine, a particulate filter (DPF) and a new generation stop-start system, together with an electric motor, a power converter, high-voltage batteries and an electronic control unit, with emission goals of 90 gCO<sub>2</sub>/km. However, early in 2008, the manufacturer announced the reduction of the mid-class development programme and its intent to re-focus on a top class vehicle that would be better able to accept the extra cost of the hybrid powertrain.

#### ***Renault***

In March 2007, Renault announced plans to develop an electric vehicle by 2010. The development -part of Renault's efforts to reduce greenhouse gas emissions-falls under their Renault Commitment 2009 environmental plan. The electric vehicle is being jointly developed with Nissan as part of their corporate alliance. Research has focused on looking into a solution that will emit zero CO<sub>2</sub> emissions in use and will be ideally suited to city driving.

The project has reached an advanced stage, with the company already working on all the future vehicle's components. Renault and Nissan are also working together on lithium-ion battery technology and packaging, the electric motor and the software needed to manage the solution. As to commercialization, the joint company's wide variety of markets offers the potential for high sales volumes,

says Renault. The fleet market in France and Europe will be the main focus for the vehicle in 2010.

## 18.5

### ***On the road***

#### ***La Poste***

In April 2007, La Poste (the French mail service) invited electric vehicle manufacturers to bid for a contract to supply the first 500 vans, with a view to ordering a further 9'500 over the next five years. As well as the electric vans, the organization plans to purchase 600 electric bicycles and 250 electrically assisted handcarts to help it achieve its ambition of becoming the biggest user of clean vehicles in the world.

This whole scale backing of electric vans follows successful trials of the vehicles in Paris and Bordeaux in the rubric of the Société des Véhicules Electriques (SVE) project funded by ADEME. The trials showed that the vehicles were well suited to the role, particularly in built-up areas where restrictions on polluting diesel and gasoline vehicles are in place.

Unfortunately, due to the lack of industrial production it has been impossible to conclude the bid in 2007, so that negotiations are still under way.

#### ***EDF and Toyota***

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

The vehicles use Toyota's hybrid technology, but with the added benefit that their batteries can be recharged using a standard electrical plug. EDF and Toyota have also developed an innovative charging and invoicing system, equipped in each of the test vehicles. This system is compatible with a new generation of public charging stations, which aims to make electric power more accessible on public roads and car parks while reducing the cost to the customer.

## **18.6**

### **Outlook**

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

## **18.7**

### **Benefits of participation**

Keeping in touch with the latest developments in HEV technology and demonstration projects is an important benefit of participation in IA-HEV. Participation also enables the exchange of experiences in the French automotive industry and achievements related to demonstration projects with representatives from other countries that are active in the same field. Parties working on HEVs in France also receive practical information based on experiences in other countries. The personal contacts enable an exchange of experiences that goes beyond the information that is available through simple written communication.

## **18.8**

### **Further information**

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

- [www.avem.fr](http://www.avem.fr) (in French).  
‘Avenir du Véhicule Electrique Méditerranéen’ (AVEM) is an association based in the South of France that aims to promote the usage of EVs. Content: local info, EV events, EV links.
- [www.batscap.com](http://www.batscap.com) (in English and French).  
BatScap is developing and producing energy storage components that are intended for applications related to electric or hybrid transportation and backup power supply.
- [www.clean-auto.com](http://www.clean-auto.com) (in French).  
Site of the clean@uto magazine. Very rich site about clean solutions for transportation (EV, HEV, FCEV, etc.).
- <http://transports.edf.fr> (in French).  
EV pages of the French utility ‘Électricité de France’ (EDF). Content: all activities of EDF in the EV domain, plus some technical and economical information.
- [www.predit.prd.fr/predit3/homePage.fo](http://www.predit.prd.fr/predit3/homePage.fo) (in French, with summaries in English and German).  
PREDIT is a program of research, experimentation and innovation in land transport.
- [www.psa-peugeot-citroen.com](http://www.psa-peugeot-citroen.com) (in English, French and Spanish).  
The site of the French carmaker PSA Peugeot Citroën, with many documents on clean vehicles, EVs and HEVs.

- [www.venturi.fr](http://www.venturi.fr) (in English and French).

The site of the carmaker Venturi contains all technical specifications of Eclectic and Fétilsh models, plus a vision of future clean vehicles.

## 19 **Italy**

### 19.1 **Introduction**

The Italian overall vehicle market is constantly growing, in excess of 70% in the last 20 years, reaching a record of over 46 million vehicles (excluding mopeds) on the roads in 2007. This is about one passenger car per 1.7 inhabitants, one of the highest car densities in the world. This large fleet has been analysed -by various public bodies, authorities and research organizations- in terms of fuels, age, consumption and emissions in order to evaluate and minimise potential impacts. The most evident trends in the car fleet structure are the increasing introduction of less polluting and more efficient fuels, and the substitution of older vehicles (often without exhaust catalyst) with cleaner and more efficient ones. New European emission standards that have been introduced over the years are one of the driving forces behind this car fleet renewal.

In 2007, some initiatives and a large public consensus have continued to favourably affect the perception about most advanced cleaner vehicles, such as electric vehicles (EVs) and hybrid electric vehicles (HEVs). To maintain the level of attention for emission and air quality control, central and local authorities have established financial, regulatory and practical measures to promote the purchase and introduction of cleaner transport means, mainly in urban areas. The results of these initiatives are evident. There is a larger use of diesel and gas propelled vehicles and there is an increased interest for HEVs (which has more than tripled in two years) and for special hybrid and electric vehicle applications such as goods distribution and delivery, taxi services, large public utility fleets and personal mobility with 2-wheelers. In addition, for most advanced technologies (including hydrogen fuelled vehicles and fuel cell vehicles) emphasis has been put on applied research and industrial development, and on large introductory activities from the industry sectors and local authorities by dedicated national programs, such as Industry 2015 and the National Fund for Sustainable Mobility. Industry, academia and research organizations are seconding these initiatives by increasing the offer of qualified research and development (R&D) and dedicated innovative vehicles, including HEVs and EVs.

### 19.2 **Policies and legislation**

The Italian participation in the European Union (EU) legislation and regulations in the field of transport, energy and environment is a straightforward policy making process, based on a concerted action by the EU member countries. Recently established EU targets for 2020 are aiming at a 20% reduction of

greenhouse gas emissions, a 20% reduction of primary energy consumption and 20% increase of renewable energy sources. Consequently, in 2007 the Italian government continued to define and started key initiatives to meet the EU targets, including the CO<sub>2</sub> emission targets for vehicles. As part of these initiatives, there were actions having positive effects on the development and introduction of cleaner vehicles. The implementation measures are a combination of financial, technical and non-technical actions aiming at removing practical, psychological and economical barriers.

1. Car fleet renewal with financial incentives to accelerate the destruction of older cars and the introduction of more severe emission standards.
2. Large renewal of public and service fleets.
3. Definition and introduction of new regulatory standards for tailpipe emissions, such as EURO-5 and EURO-6.
4. Structural plans and agreements in urban areas to favour the use of sustainable mobility projects (National Fund for Sustainable Mobility).
5. Better integration of private and public transport by means of new parking infrastructures for clean vehicles.
6. New routes for cleaner fuels, including hydrogen blends and biofuels.
7. Increase of 'clean days' initiatives in urban areas, with free access for low-emission vehicles, particularly HEVs and EVs.

In 2007, the Italian government has continued to subsidise the purchase or retrofitting of vehicles by private users, by offering an incentive up to 2'000 Euros for passenger cars emitting less than 120 gCO<sub>2</sub>/km. HEVs and EVs were entitled to receive the maximum funding. Also a similar funding scheme was approved by the Ministry of Environment for replacing old 2- and 3-wheel mopeds and motorcycles by electric ones and power-assisted (p.a.) bikes: 2.5 million Euros were available with a maximum incentive of 1'000 Euros per vehicle, while not exceeding 30-35% of the retail price.

A National Fund for Sustainable Mobility has been approved, with the creation of a National Committee for Sustainable Mobility, to support projects of local authorities, including the use of cleaner transport means. The initial funding budget is 270 million Euros in 3 years. This is a new funding scheme in addition to the Call for Proposals from Regions and Provinces for defining specific Air Quality Plans in specific areas (with another 210 million Euros funding availability).

Regional and local authorities have been using or integrating central government funds by promoting local initiatives to assist the introduction of low emission vehicles:

- Creation of new recharging stations for natural gas and even for electrical energy (see figure 19.1).

- Restricted access zones limited to clean vehicles.
- No-circulation days, only open to cleaner vehicles.
- Toll-free parking lots for cleaner vehicles.
- Direct financial incentives to private users and companies for purchasing EVs and HEVs (up to 35% of the retail price with a maximum funding per vehicle type).



Fig. 19.1 A new electric charging station in Rome. (Photo supplied by ENEA.)

### 19.3 Research

The research activities in the transport sector are carried out in various universities and research centres, as well as in industry laboratories. Major projects are part of some national and regional programmes as well as EU Framework Programmes (FP6 and FP7).

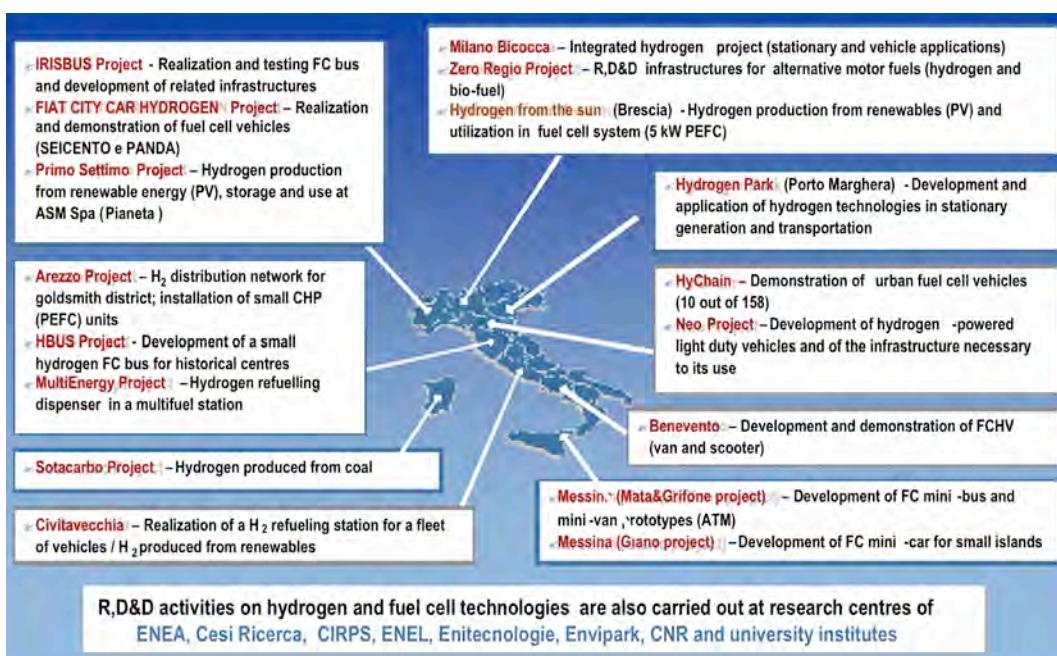


Fig. 19.2 Update of Italian projects on hydrogen and fuel cells. (Picture supplied by ENEA.)

Fuel cells (FC) and hydrogen projects received less attention, mainly because there was a delay in the start of the EU programmes. However, the large national R&D programme on ‘Hydrogen and fuel cells’ continued. This programme started in 2005 and is promoted by the Ministry of Education, University and Research and by the Ministry of Environment, through the Special Integrative Fund for Research (FISR). Figure 19.2 sketches an update of the most recent projects on hydrogen and fuel cells, including FC vehicle applications.

### **ENEA**

The Italian National Agency for New Technologies, Energy and the Environment (ENEA) is working on various projects related to the development of electrically driven vehicles. Within the two EU projects ILHYPOS (Ionic Liquid-based Hybrid Power Supercapacitors) and ILLIBATT (Ionic Liquid-based Lithium Batteries), ENEA is contributing in developing advanced supercapacitors (at higher energy and power densities of up to 15 Wh/kg and 7 kW/kg respectively, and working at FC temperatures) and safer and better performing lithium batteries (that make use of solid-state electrolytes, with specific energy higher than 180 Wh/kg based on the overall weight of the cell, with an average coulombic efficiency higher than 99% during cycling, and with a life of 1'000 cycles with maximum 20% loss of capacity). ENEA is also involved in the EU project HYSYS by testing Li-ion batteries for application in FC vehicles.

Additionally, in collaboration with the University of Rome, ENEA is developing a lightweight hybrid quadri-cycle that is using supercapacitors together with a small diesel engine. Figure 19.3 shows the layout of the small hybrid car.

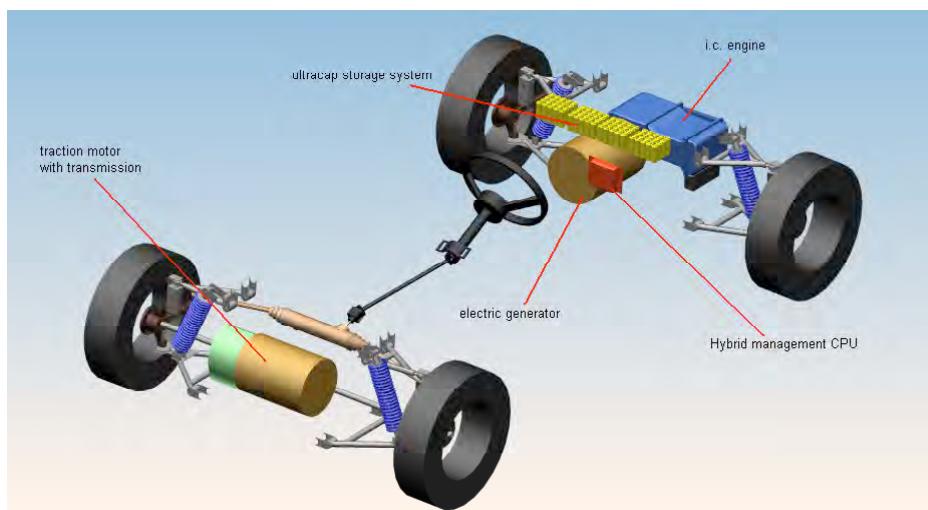


Fig. 19.3 ENEA small hybrid quadri-cycle. (Picture courtesy ENEA.)

ENEA is also working on hydrogen and fuel cell technologies, covering FC basic research, hydrogen storage, infrastructure and applications. In 2007, a demonstra-

tion hydrogen refuelling station with a capacity of 28 Nm<sup>3</sup> at 350 bar has been showcased at Brasimone Research Center (figure 19.4).



Fig. 19.4 ENEA Brasimone H<sub>2</sub> refuelling station for testing components. (Photo courtesy ENEA.)

### Fiat Research Center

Fiat Research Center (CRF) is involved in various EU projects for developing fuel cell vehicles (FCVs) and hybrid vehicles. Among others, CRF is involved in HYSYS, a research programme that aims to develop low-cost components for fuel cell systems and electric drive systems that can be used in future hybridised FCVs and internal combustion engine vehicles, and to test developed components in two FCV platforms with different concepts. The activities of CRF are mainly concentrated on electric drive development (see figure 19.5).



Fig. 19.5 HYSYS electric motor. (Photo supplied by ENEA.)

Furthermore, CRF is co-ordinating another large EU project, HI-CEPS (Highly Integrated Combustion Electric Propulsion System), aimed at developing three different, innovative, integrated series-parallel full hybrid thermal-electric powertrains utilising low-cost and standardised electric devices (electric motors, power electronics and batteries) and vehicle auxiliaries, and using dedicated

gasoline, diesel and natural gas engines with specific exhaust after-treatment systems. The adaptation to future fuels and combustion systems will also be taken into account. CRF is looking at a new hybrid powertrain (shown in figure 19.6) to achieve -at vehicle level- both the environmentally friendly requirements (fuel consumption, CO<sub>2</sub> and regulated noxious emission reduction) and fun-to-drive characteristics (enhanced transient performance, driveability and comfort) at an acceptable purchasing/operation cost (perceived value).

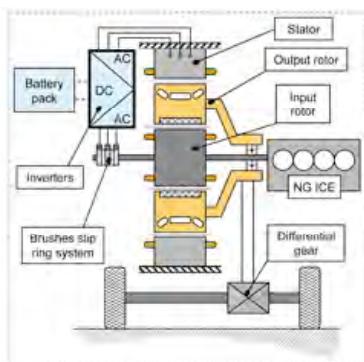


Fig.19.6 HI-CEPS electro-magnetic split hybrid powertrain. (Picture supplied by ENEA.)

CRF is also participating in the EU project Zero Regio (Development and demonstration of hydrogen infrastructure for FC passenger cars) supplying FC cars: in September 2007 a H<sub>2</sub> fuelling station was opened in Mantova -with the support of ENI (an Italian Oil company)- where hydrogen will be produced on-site from natural gas (figure 19.7). Three Fiat Panda Hydrogen fuel cell cars will be used for the demonstration.



Fig. 19.7 Fiat Panda Hydrogen fuel cell car at the service station in Mantova (Zero Regio Project). (Photo supplied by ENEA.)

Besides the large organizations, various small and medium enterprises are developing and producing innovative EVs, HEVs and FCVs. In 2007 the main objective was to improve the vehicle range. Chief changes are the use of most advanced batteries (mainly lithium-ion) and fuel cells in substitution of lead acid and also sodium nickel chloride batteries. Some examples are given below.

### **Piaggio**

In July 2007, Piaggio -world leader in scooters and motorcycles production-revealed its MP3 HYS, a plug-in hybrid electric motorcycle with lithium-ion batteries and able to travel 60 km on 1 litre of gasoline. The MP3 HYS is scheduled to be commercially available in 2008. Figure 19.8 shows the official presentation of the MP3 HYS.



Fig. 19.8 Presentation of the Piaggio MP3 HYS plug-in hybrid electric motorcycle. (Photo supplied by ENEA.)

### **Arcotronics Fuel Cells**

Arcotronics Fuel Cells was sold to Morphic (a Swedish company) in the second half of 2007 and is renamed Exergy Fuel Cells. It continued to apply FC systems in various vehicle prototypes and -under the aegis of the province of Benevento-



Fig. 19.9 Prototype fuel cell motorcycle with Arcotronics fuel cell. (Photo supplied by ENEA.)

presented in 2007 a commercial van and the motorcycle that is shown in figure 19.9. The FC motorcycle is powered by a 4 kW fuel cell stack and can carry up to 140 g of hydrogen fuel at a pressure of 200 bar in its tank.

### VEM

Veicoli Eco Metropolitani (VEM) is involved in the EU HYCHAIN MINI-TRANS project that aims at deploying several fleets of innovative fuel cell vehicles that operate with hydrogen as fuel, in four regions of Europe (in France, Spain, Germany and Italy). The fleets are based on similar modular technology platforms in a variety of applications, with the main objective to achieve a large enough volume of vehicles (up to 158) to justify an industrial approach to vehicle production to lower vehicle costs and to overcome major cross sectional barriers. VEM -in collaboration with Axane and Air Liquide- completed in 2007 a FC utility van with a 2.5 kW FC system and onboard storage of 80 litres of hydrogen at 300 bar, which enables a range of 120 km (figure 19.10).



Fig. 19.10 VEM fuel cell hybrid utility van in the HY-CHAIN project. (Photo supplied by ENEA.)

### Micro-Vett

The largest Italian EV and HEV manufacturer Micro-Vett has been producing electric vehicles with a new type of batteries and is participating in a large introductory project. A large fleet of about 85 passenger EVs is under preparation in Rome, with EVs supplied by Micro-Vett and Veicoli. In addition, the successful public demonstration of an all-electric Fiat Doblo was announced in Norway in October 2007. The vehicle, a regular size 5-seat medium-duty van powered by a custom 18 kWh Altairnano high performance NanoSafe® battery pack, travelled 300 kilometres in an urban delivery circuit. The custom battery pack was three times fully recharged in less than ten minutes, using a high voltage rapid charging system rated at 125 kW. The vehicle will be driven an estimated total of 7'500 kilometres during the 60-day demonstration period, which translates to an annual equivalent use of 45'000 kilometres.

## **19.4**

### ***Industry***

The most recent EV and HEV industry and product survey carried out by CIVES (the Italian EV, HEV and FCV association), which was updated in 2006, shows the presence of about 50 producers, assemblers and importers. Only a few large manufacturers are in the list (BredaMenarini, Piaggio, Cacciamali), which means that most of the companies in the list are small and medium enterprises. The products on offer range from power-assisted bikes, scooters (with 2, 3 or 4 wheels) up to light- and heavy-duty pure electric and hybrid buses, and also electric boats. The number of EVs and HEVs is well beyond 100 types, covering almost all vehicle categories for road and even off-road use. The possibility to significantly vary the configurations makes the list of available vehicles on the market very large, with retail prices ranging from a few hundred Euros for p.a. bikes to some hundred thousands of Euros for hybrid buses. The model flexibility entails all the possible applications from passenger cars up to goods delivery and garbage vans.

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

## **19.5**

### ***On the road***

The total fleet of EVs and HEVs is still negligible compared to the overall vehicle park, but during the last three years it is gradually increasing, with a significant growth in the number of HEVs. The market for EVs and HEVs is still connected to a system of financial support, which is strongly dependent on central and local public subsidies. The fluctuation in vehicle sales over the years is linearly related to the variation of funding initiatives. The park renewal policy and greater emotional appeal of cleaner vehicle use in urban areas -even though not strictly directed towards the introduction of large EVs and HEVs- are having a positive impact on EV and HEV niche markets.

The CIVES estimations at the end of 2006 show a substantial increase in the total number of EVs and HEVs on Italian roads compared to the 2005 figure (158'000 versus 132'000 vehicles). Big and expensive EVs and HEVs were mostly purchased by fleet users, mainly public service utilities. Private users were more interested in buying scooters and p.a. bikes, which are substantially supported by public authorities to make them cost competitive with conventional vehicles, by cutting down the difference in purchase costs.

The market share of HEV passenger cars is really small in Italy, but as a result of more aggressive introduction campaigns by major worldwide manufacturers

(Toyota and Honda) and thanks to the municipal measures to favour the introduction and circulation of cleaner vehicles, it has more than tripled in two years - from 0.05% in 2005 to 0.14% in 2007. For passenger HEVs, this niche market opened in 2005 with 1'100 vehicles sold, while in 2007 this figure arrived at 3'400.

The air quality control initiatives have not only affected the EV/HEV market but all the alternative fuel markets: the number of natural gas service stations for example increased in 2006 to about 620 while a few years before their number was approximately 200, and there are about 1'800 service stations where LPG is available. The growth of refuelling stations for alternative fuels -including some for hydrogen- is related to the increase of bi-fuel and dedicated gas-powered vehicle market, which is the main target of vehicle substitution policy: in 2005 more than 21'400 passenger natural gas vehicles (NGVs) were sold, while in 2007 this number exceeded 60'000. For LPG vehicles, the number increased from 1'700 in 2005 to 19'300 in 2007. In Italy biofuels are mainly used in the transport sector in large urban buses, but in 2007 the first six gasoline-ethanol passenger cars appeared on the road. A few converted vehicles running on pure hydrogen or hydrogen-methane mixtures were demonstrated in 2007.

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

Vehicle type	December 31, 2006		
	EV fleet	HEV fleet	Total fleet
Bicycles (no driver licence)	113'000	0	--
Motorbikes*	32'300	0	10'238'818
Passenger vehicle	2'085	4'065	35'297'282
Multipurpose passenger vehicle	5'700	0	568'654
Bus	610	220	96'099
Truck	0	0	3'763'093
Industrial vehicles	0	0	1'315'198
<b>Total</b>	<b>153'695</b>	<b>4'285</b>	<b>51'279'144</b>

\* The total fleet number for motorbikes includes 4'950'000 mopeds.

For information: 70 electric boats have also been sold.

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

Some potential interest was also derived by particular demonstrations of clean vehicles in urban areas for specific applications. In 2007, two European projects demonstrated the positive impact of clean vehicles for good delivery: CEDM (Centre For Eco-Friendly City Freight Distribution) in Lucca and C-Dispatch

(Clean-Distribution of goods in Specimen Areas at the last mile of the intermodal Transport Chain) in Frosinone, both using EVs and/or NGVs. Figure 19.11 depicts the structure of the CEDM organization, while figure 19.12 shows the electric van used in C-Dispatch.

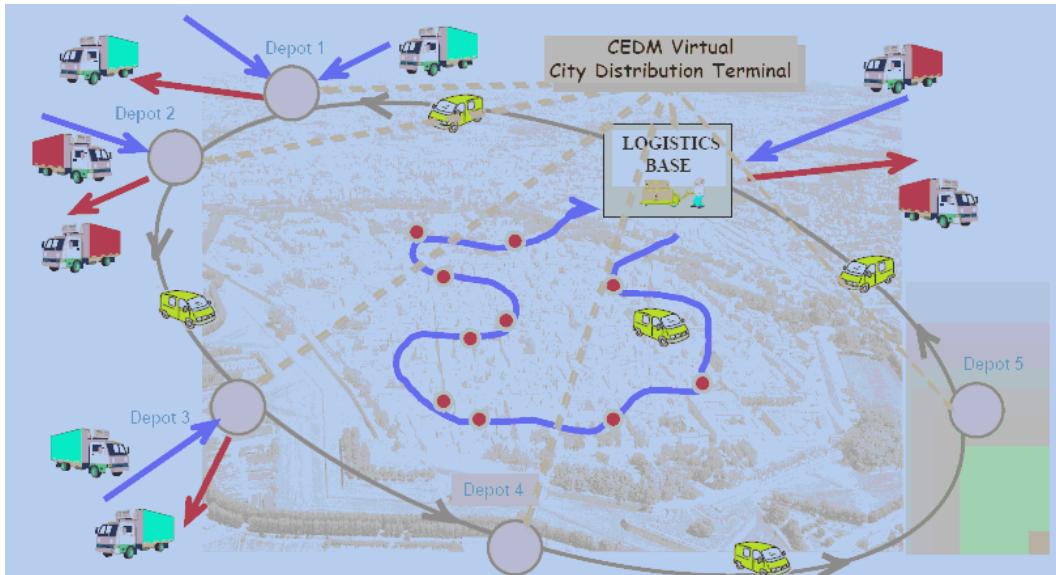


Fig. 19.11 CEDM goods distribution in urban areas with EVs. (Picture supplied by ENEA.)



Fig. 19.12 Micro-Vett Porter electric van used in C-Dispatch for goods delivery. (Photo supplied by ENEA.)

## 19.6 Outlook

The interest in electrically driven vehicles is growing in Italy: local and central authorities are supporting the development and introduction of these vehicles with dedicated research programmes, subsidies and non technical measures; the industry (even the large ones) are recently modifying their strategy in the sector with increasing resources and production; and the research organizations -and also the end users- are significantly increasing efforts and consciousness on the possibility to develop and introduce such vehicles. Italian policies are related to those of the EU, with significant commitment for the long term on the sustainability of the

transport sector. The short-term vision is: significant growth of the vehicles in the market place and in the research area.

## 19.7

### ***Benefits of participation***

There are various Italian organizations potentially interested in the activities of IA-HEV, which may benefit from the feedback from participation in the Agreement.

1. Government and ministries, for the possibility to define policy and supporting measures of cleaner transport technologies and related research and deployment programmes, by appraising the level of knowledge and the initiatives that are already in place in other countries.
2. Industry, by collaboration on aspects facilitating the development and commercialization of their products (common standards, common lower cost components, easy access to a variety of suppliers, identification of market opportunities).
3. Research organizations interested in collaborating at international level on basic and applied research (components, infrastructure, impact evaluation, usability constraints, safety).
4. End users and local authorities, willing to know more about the status of the technology and the possible applications.

Until now, the participation of the interested parties only occurred occasionally due to different hurdles:

- The government has delegated participation to ENEA, industry and end users, due to budget limitations.
- For organizational reasons, local authorities were so far unable to contribute.

## 19.8

### ***Further information***

Additional information on hybrid and electric vehicles in Italy may be found on the following websites.

- [www.c-dispatch-frosinone.it](http://www.c-dispatch-frosinone.it) (in English and Italian).  
This is the official website of the C-Dispatch project, describing the complete project and the major results, with miscellaneous news about the progress of the work, and photos.
- [www.ceiweb.it/cives/home.htm](http://www.ceiweb.it/cives/home.htm) (in Italian).  
This is the official website of the Italian Electric Road Vehicle Association (CIVES), an internal committee of the Italian Electrotechnical Commission (CEI) and the national section of the European Association for Battery, Hybrid and Fuel Cell Electric Vehicles (AVERE). The website gives a lot of information about vehicles that are offered on the market, the status of laws and the major initiatives at national and local levels. It is also a source for contacts and

addresses of all members of CIVES, major Italian manufacturers, importers, research organizations and users.

- [www.crt.unige.it](http://www.crt.unige.it) (in English and Italian).  
This is the website of an academic research centre on transport, located at the University of Genova. The information on the website addresses public transport in general, not only electric/hybrid road vehicles. There are statistics and technical descriptions of buses.
- [www.enea.it](http://www.enea.it) (in English and Italian).  
The ENEA website presents programs, projects and activities in general terms, but also a special report about Energy and Environment.
- [www.minambiente.it](http://www.minambiente.it) (in Italian).  
The website of the Ministry of the Environment and Territory Safeguard contains up-to-date information about environmental legislation, initiatives and press releases. A specific area is dedicated to sustainable mobility, renewable energy and the status of the environment.
- [www.regione.lombardia.it](http://www.regione.lombardia.it) (in Italian).  
This is the website of the Lombardia Region. The website is mainly in Italian and contains information about the use of main initiatives for a sustainable mobility, including funding initiatives.
- [www.sph2.org](http://www.sph2.org) (in English and Italian).  
This is the website of the ‘Sistema Piemonte Idrogeno’, an initiative of the Piemonte Region to create a network of stakeholders working on hydrogen in the region. It contains information about projects, programmes and events.
- <http://srvweb01.softeco.it/LIFE-CEDM/> (in English and Italian).  
This is the website of LIFE CEDM, a pilot project running in Lucca, Italy, aiming at the realization of innovative e-logistics solutions for the start of the Centre for Eco-Friendly City Freight Distribution and efficient, sustainable goods delivery in the historic centre of Lucca.

The websites of major EVs and HEVs producers that are mentioned in this chapter may be consulted for additional information.

## 20

### The Netherlands

#### 20.1

##### ***Introduction***

Hybrid vehicles have been commercially available in the Netherlands since the 2004 introduction of the Toyota Prius II, now a major sales success. Lexus and Honda have also introduced hybrid car models into the Dutch market. The principal barrier to increased sales of hybrid vehicles remains limited availability of vehicle models. By contrast, sales of pure battery electric vehicles have declined to nil, with commercial availability of such vehicles only for very special (niche) applications that do not require a registration plate, such as utility vehicles in the cities and local grocery delivery vans in urban areas. Marketing of electric scooters has failed to achieve much success because of a negative consumer image resulting from lack of availability of units with acceptable product quality.

Ongoing policies and legislation of the Dutch government for reducing CO<sub>2</sub> emissions and improving air quality will encourage society and research institutes to devote more attention to transportation systems and the hybridization of vehicles. Automotive research and development (R&D) organizations are currently concentrated in the southeast part of the country, a location that provides these organizations with good access to and beneficial collaboration with counterparts in the automotive production areas of Germany and Belgium.

#### 20.2

##### ***Policies and legislation***

###### ***Policies***

The main environmental policy of the Dutch government is to reduce CO<sub>2</sub> emissions and improve air quality. There are also initiatives for reducing noise levels in cities and urban areas. Improving air quality by actions in the transportation sector means reduction of emissions, with special focus on emissions of particles by diesel powered vehicles such as public transport buses, trucks and distribution vehicles. The government provides financial support by subsidy for retrofitting diesel vehicles with particle filters. In the broader context of reducing CO<sub>2</sub> emissions, a programme called ‘CO<sub>2</sub> reduction in personal transport and in goods transport’ is now in operation. Within this programme, rebates are given for investments in fuel-efficient vehicles and transportation systems. A programme for supporting the production of biofuels for transportation is operational and investments in alternative fuel refuelling stations are also supported.

Concentrated communication programmes sponsored by the government promote the concept of ecodriving for car drivers, as well as for truck and bus drivers. Demonstrating the principles of ecodriving (fuel-efficient driving behaviour) is part of the course requirement for earning a car operator's license. More information on this programme may be obtained from the internet website [www.ecodrive.org/What-is-ecodriving.228.0.html](http://www.ecodrive.org/What-is-ecodriving.228.0.html). The basic principles are shown in box 20.1.

<b>Box 20.1</b>	
<b>Golden rules of ecodriving</b>	
<b>1. Shift up as soon as possible</b>	Shift up between 2'000 and 2'500 revolutions.
<b>2. Maintain a steady speed</b>	Use the highest gear possible and drive with low engine RPM.
<b>3. Anticipate traffic flow</b>	Look ahead as far as possible and anticipate to surrounding traffic.
<b>4. Decelerate smoothly</b>	When you have to slow down or to stop, decelerate smoothly by releasing the accelerator in time, leaving the car in gear.
<b>5. Check the tyre pressure frequently</b>	25% too low tyre pressure increases rolling resistance by 10% and your fuel consumption by 2%.

### **Legislation**

Special tax rules are in place for both electric and hybrid vehicles. Electric vehicles are exempted from the yearly road tax. Since mid 2006, hybrid vehicles have qualified for a substantial bonus/tax reduction (as high as 6'400 Euros in 2008) to encourage sales. Very energy-efficient cars also get a tax bonus, depending on the fuel efficiency label (reductions by efficiency class are shown in table 20.1). The tax bonus can go up to 1'400 Euros (as of February 1, 2008). Less fuel efficient vehicles are subject to an extra tax as high as 1'600 (also as of February 1, 2008).

Table 20.1 Energy label and Dutch sales tax reductions/additions, effective February 1, 2008.

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

Car dealers in the Netherlands must display the energy consumption label/class (A-G) on all new cars in their showrooms. The class is based on both the vehicle's

rated energy consumption in litres per 100 vehicle kilometres and CO<sub>2</sub> emission rate in grams per vehicle kilometre (g/km).

As of February 1, 2008, buyers have to pay an additional sales tax of 110 Euros per gram CO<sub>2</sub> emitted above a specific level (in g/km) that differs by fuel type (gasoline or diesel) of the vehicle. Also under new regulations, vehicles meeting a specific CO<sub>2</sub> emission rate target (below 110 g/km for gasoline; 95 g/km for diesel) earn a 50% reduction of the yearly road tax.

Improving air quality in cities has led to the introduction of so-called environmental zones in certain urban areas; these have specific entry rules more stringent for vehicles not classified as 'environment friendly'.

## 20.3

### ***Research***

The Netherlands boasts several significant automotive research institutes:

- TNO Industry and Technology - Automotive.
- Technical University Eindhoven.
- Technical College, Automotive division, Arnhem.
- Automotive Technology Centre (ATC).
- Competence Centre for Automotive Research (CCAR).
- Drive Train Innovations (DTI).

These institutes are all spatially concentrated around Eindhoven -in the southeast part of the Netherlands- with good connections to the areas of automotive production, component supply and research in Belgium and near Aachen in Germany.

This geographic proximity facilitates co-operative efforts among research institute partners, as well as with car and truck manufacturing entities in all three countries.

Most car manufacturers are changing their strategies for developing components and subsystems, with R&D shifted (outsourced) to supplier companies. Suppliers now develop and produce components on the basis of programmes of requirements formulated by the car industry. This -in turn- strengthens the concept (and incidence) of co-production, with each partner sharing in the credit for a proven concept or product.

Research at the institutes covers not only components and vehicle systems, but also transportation systems. Some universities -as well as several small consultant firms- are also involved in transport systems R&D.

Among governmental entities, the Energy research Centre of the Netherlands (ECN) is performing research on fuel cells and its applications. Various demonstration projects for the production and use of biogas in transportation are under

way. Waste biomass is converted into biogas, upgraded to natural gas specifications and then used to fuel vehicles with CNG engines.

### ***High Tech Automotive Systems programme (HTAS)***

HTAS is a market-driven innovation programme set up and steered by the Dutch automotive industry to focus automotive innovation on areas that match the strengths and ambitions of the Dutch automotive sector, as well as on future opportunities and challenges of the international automotive industry. For specific facets of the automotive industry, the Netherlands plays a significant role, together with leading innovative companies involved in automotive activities worldwide. Such focus on areas of important Dutch innovation -specifically vehicle efficiency and vehicle guidance- will contribute to both the international competitiveness and the economic position of the Dutch automotive sector.

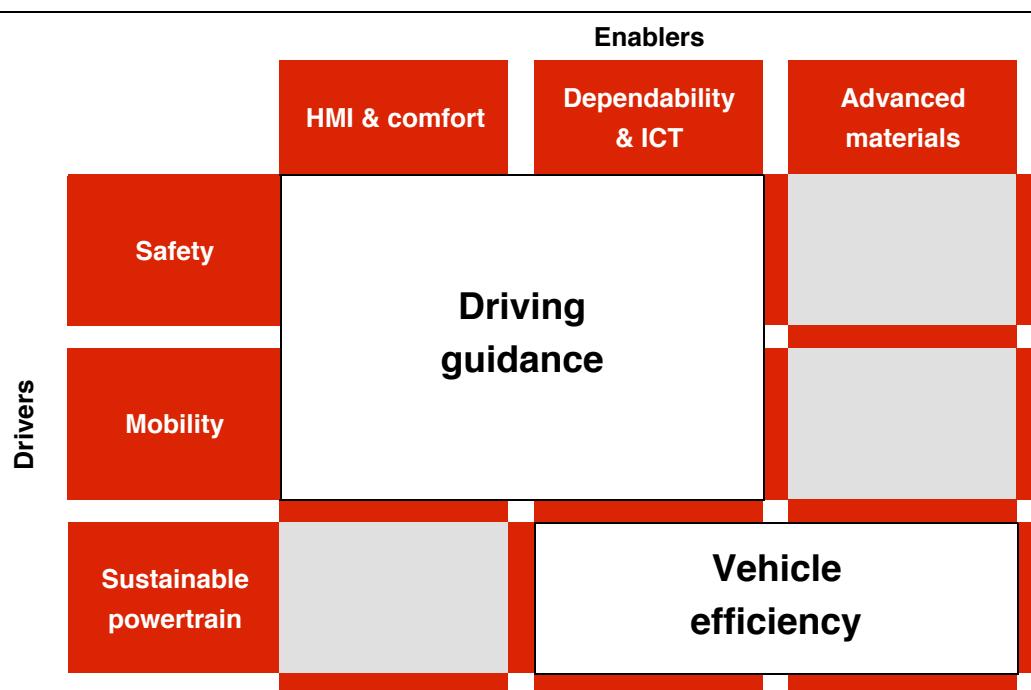


Fig. 20.1 Focus areas of HTAS. (Source: HTAS, Focus document 2007.)

The programme started in 2007 and will run through 2012. More information may be obtained from the internet website [www.htas.nl](http://www.htas.nl).

## **20.4**

### ***Industry***

The automotive industry consists of:

- A truck manufacturer, DAF Trucks (a PACCAR company).
- A bus manufacturer for public transport buses and touring cars.
- An assembly factory for cars.

- Various manufacturers of semi trailers, trailers and truck bodies.
- Various automotive component manufacturers.

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



Fig. 20.2 Example of a DAF Trucks product. (Photo supplied by SenterNovem.)

Co-development and co-production intensified during the last decade and should continue to do so in the future, which will afford the Dutch automotive institutes and component industry good opportunities to make important contributions in the larger European arena of vehicle manufacture.

## 20.5

### ***On the road***

Vehicle park sizes (fleet populations) in the Netherlands as of January 1, 2007, were as follows:

- Cars (LDV up to maximum 8 passengers): 7.1 million (1 car per 2.3 inhabitants).
- Distribution vans (goods vehicles up to 3.5 t GVW): approx. 850'000 units.
- Trucks (goods vehicles above 6 t GVW): 142'000 units.
- Buses (public transport and touring cars, above 8 passengers): 11'000 units.
- Motorcycles (two-wheelers with engine above 50 cc): 570'000 units.
- Mopeds (two-wheelers with engine under 50 cc): 500'000 units.

The park sizes at the end of the year 2007 were at approximately the same levels as at the beginning of the year because of very limited growth.

Because MPVs and SUVs are basically constructed as passenger vehicles, they are included as passenger vehicles in table 20.2. Light-duty trucks constructed on a separate chassis (for example, a pick-up like the Ford F-150) are almost unknown in the Netherlands and therefore the number in the multipurpose passenger vehicle category is about zero.

Table 20.2 Characteristics and population of the Dutch motorised vehicle fleet per December 31, 2006-2007. (Numbers for 2007 are estimates.)

Vehicle type	December 31, 2006			December 31, 2007		
	EV fleet	HEV fleet	Total fleet	EV fleet	HEV fleet	Total fleet
Bicycles (no driver licence)	20'000	0	520'000	30'000	0	530'000
Motorbikes	0	0	570'000	0	0	570'000
Passenger vehicle	50	5'000	7'100'000	50	7'000	7'200'000
Multipurpose pass. vehicle	0	0	0	0	0	0
Bus	0	3	11'000	0	5	11'000
Truck <sup>(a)</sup>	0	0	992'000	0	0	992'000
Industrial vehicles	400	n.a.	n.a.	400	n.a.	n.a.
<b>Total</b>	<b>20'450</b>	<b>5'003</b>	<b>9'193'000</b>	<b>30'450</b>	<b>7'005</b>	<b>9'303'000</b>

(a) Includes vans and minibuses. Minibuses are vehicles for up to 9 persons, with a GVW up to 3.5 tons. This category cannot be separated from vans up to 3.5 tons in Dutch statistics.

n.a. not available

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

There are still approximately 450 battery electric (four-wheeled) vehicles, mainly cars and utility vehicles (from a prior market era in which electric vehicles were for use on public roads with a license plate) on the road. Barriers to greater sale and use of electric cars include purchase price, driving range and availability of service support.

The Netherlands is a bike-intensive country with about 20 million bicycles - more than the nation's inhabitants. Various makes and models of electric bicycles of the power-assist type (electric assistance only when pedalling) are available on the



Fig. 20.3 Bicycle parking (photo: M. van Walwijk) and bicycle use (photo supplied by SenterNovem) in the Netherlands.

market. These electric bicycles, which enjoy about a 5% market share, are allowed a maximum speed of 25 km/h.

Only a few models of hybrid cars are commercially available today. Toyota Prius II, Honda Civic hybrid, and Lexus RX 400h and GS 450h are available for purchase, with the Toyota Prius enjoying the highest sales of any hybrid in the country (in 2007 approximately 2'250 units).



Fig. 20.4 Toyota Prius II on a Dutch dyke. (Photo supplied by SenterNovem.)

Hybrid goods vehicles or hybrid buses are not commercially available in the Netherlands, so no such hybrid vehicles are on the road in the current truck and bus stock. Demonstration projects involving these units are under way, such as the fuel cell buses in the European CUTE project, of which three were in operation in Amsterdam (Netherlands' capital city) until the project's termination early in 2008. DAF Trucks have recently demonstrated a prototype hybrid distribution truck.

## **20.6 Outlook**

### ***Current trends***

Although most of the car manufacturers in the world are doing intensive product development work on hybrid vehicles, the supply of those vehicles to the Dutch market is very limited. Only Toyota, Lexus and Honda currently offer hybrid car models. However, by 2015 the number of available models is expected to grow dramatically. Hybrid goods vehicles (vans and trucks) remain in the prototype (functional proto) stage, while hybrid buses are also in a very early development phase.

### ***HEVs and EVs fit into country objectives***

At the end of 2007, the Dutch government issued a policy paper addressing policies for clean environment and energy efficiency within all sectors of the society. For the transportation sector, policies are addressing the issue of regulatory consistency with the European Union, the issue of how and how actively to encourage demand for clean and fuel-efficient vehicles, and the issue

of promoting innovation by demonstration projects. Hybrid and electric vehicles of both personal and goods type (light-duty goods distribution vans, heavy-duty distribution trucks and buses) will fit these policies very well.

#### ***Public opinion***

Society in general is moving toward 'greening' its behaviour and consumption patterns. This is also the case with the mobility of persons. The use of public transport is increasing, as are the sales of smaller cars - and not only because of the government's fiscal measures. These developments will have a positive effect on the future picture for HEVs and EVs.

#### ***Present plans***

As mentioned above, the active market in hybrid and electric vehicles in the Netherlands mainly depends on supply from manufacturers outside the country, but the market can be influenced by specific policies of the government, such as fiscal measures and entry rules for urban areas (environmental zones in cities). Research, development and demonstration plans are made and the above-mentioned research projects are under way, with plans for the time period 2009-2015 worked out.

#### ***Core technologies***

The Netherlands does not have a national car manufacturer. DAF Trucks (a PACCAR company) is the only truck manufacturer with its own product development and production capacities for components and vehicle assembly. R&D capabilities exist within the universities and a few research institutes. This resource is used by the vehicle manufacturers all over the world, and the HTAS program will play a major role in the future development of core technologies.

#### ***Market developments***

The average annual sales of cars in the Netherlands during the last 5 years was approximately 500'000 units. In 2007, the sales share of hybrids was below 1%. Through 2015 this segment is expected to increase, but remaining within the single digits. The share is substantially dependent on supply from manufacturers outside the country.

#### ***Plug-in hybrid electric vehicles (PHEVs)***

The technical possibility for hybrid vehicles to be plugged into the electrical grid (PHEV) is a welcome enhancement for hybrid technology. Some technical barriers must still be overcome, including provision of sufficient/appropriate battery capacity, depending on the required all-electric range (AER), the possibilities for the car user connecting to the grid, the safety issue of connections, and the ability of utilities to identify and meet associated electricity demand when

required. Also, special attention should be devoted to finding ways of recycling of all the components of PHEVs. The recyclability goal should be 95% of car mass.

Because the mean commuting distance in the Netherlands is under 20 km (one way), the PHEV represents a good fit for Dutch transportation, for under such circumstances a PHEV with all an AER of about 20 km (12 miles) could run most of the time without using the internal combustion engine. Everyday, 2.5 million cars commute with an average occupancy rate of 1.15 persons per car.

#### ***Energy and environmental impact***

Although fuel prices for the car user have risen dramatically over the last three years, the average yearly total of vehicle kilometres continues to increase (for a gasoline private car it is currently about 10'500 km per year; average for all private cars is 13'800 km per year). The average curb weight of cars has increased over the last 20 years to 1'110 kg in 2007. Although the drivetrains of cars are ever more efficient, the average fuel consumption per 100 vehicle kilometres stays almost at the same level (8.4 litres per 100 vehicle kilometres = 28 U.S.-mpg). Penetration of hybrid cars into the total market over the next five years will be slow, limiting their salutary effect on energy and environment. Nevertheless, HEVs and PHEVs will ultimately have a substantial and positive impact on the local air quality in urban areas.

The hybridization of goods vehicles (distribution vans and distribution trucks) and of public transport buses will also have a positive effect on air quality in cities, assuming success in the strides needed in product development and development in production machinery.

## **20.7**

#### ***Benefits of participation***

The benefits of participating in the HEV Implementing Agreement from the perspective of the Netherlands include:

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

The dimension of having an international perspective is important.

## 20.8

### ***Further information***

Further information can be obtained from various websites, as listed below.

- [www.atcentre.nl](http://www.atcentre.nl) (in Dutch and English).  
Automotive Technology Centre.
- [www.ccar.nl](http://www.ccar.nl) (in English).  
Competence Centre for Automotive Research.
- [www.ecn.nl](http://www.ecn.nl) (in Dutch and English).  
Energy research Centre of the Netherlands.
- [www.ecodrive.org/What-is-ecodriving.228.0.html](http://www.ecodrive.org/What-is-ecodriving.228.0.html)
- [www.han.nl](http://www.han.nl) (in Dutch with some pages in English and German).  
HAN University of applied sciences.
- [www.htas.nl](http://www.htas.nl) (in English).  
HTAS (High Tech Automotive Systems) is the innovation programme of the Dutch automotive industry in which industry, knowledge institutes and government participate.
- [www.senternovem.nl](http://www.senternovem.nl) (in Dutch and English).  
Dutch Energy Agency SenterNovem.
- [www.tno.nl](http://www.tno.nl) (in Dutch and English).  
Website of the Netherlands Organisation for Applied Scientific Research TNO, including automotive activities.

## 21

# Sweden

### 21.1

#### **Introduction**

In 2007, ‘green’ vehicles became more popular in Sweden. The market share of green (high-efficiency, low-petroleum) private cars increased from 12.9% to 17.8%. Great interest in and concern about climate change could account for some of this growth, but high oil prices and legislation financially promoting green vehicles also played a key role. Ethanol (E85) vehicles comprised the greatest share of green vehicles sold, but sales of hybrid vehicles also increased. Relative market shares for green vehicles in 2007 are shown in table 21.1.

Table 21.1 Relative market shares for ‘green’ vehicles in Sweden, 2007.

Category	Percent of ‘green’ vehicles	Percent of total cars
E85 (ethanol)	64.9	11.6
Max 120 gCO <sub>2</sub> /km, gasoline	13.7	2.4
Max 120 gCO <sub>2</sub> /km, diesel	12.1	2.2
Hybrids	6.2	1.1
Gas	3.1	0.6
Total	100.0	17.8

Two centres for the development of hybrid vehicles were established in 2006. The centre operated by Volvo Cars is responsible for developing hybrid platforms to serve Ford Europe, while the other endeavour is a joint operation of the Swedish



Fig. 21.1 Hybrid prototype bus, manufactured by Volvo Buses. (Photo supplied by the Swedish Energy Agency.)

vehicle industry and three universities to build a competitive centre of excellence for hybrid electrical vehicle technology.

During the past year, both Volvo and Scania began development and demonstration projects for hybrid buses and hybrid garbage trucks, assisted by grants from the Swedish Energy Agency (figure 21.1). The first vehicles (garbage trucks) from these projects will be rolled out in spring 2008.

## **21.2**

### **Policies and legislation**

#### **Taxation**

In December 2001, the Swedish government reduced the national taxation burden for certain green vehicles in order to encourage their sales. These rules have subsequently undergone several changes, with the present rules having been set in the government's December 2003 Budget Bill. The annual notional taxation burden of hybrid or electric cars owned by a company is reduced by 40% relative to the closest comparable gasoline model, subject to a maximum reduction of US\$ 2'000 per year. This reduction can be compared with the 20% reduction given for company cars running on E85 ethanol, natural gas or biogas; such vehicles are subject to a maximum reduction of US\$ 1'000 per year.

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

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

#### **Rules for public purchasing of vehicles**

The rules governing public purchasing and leasing of vehicles have also been changed, as set out in the Ordinance Concerning Public Purchasing and Leasing of Green Vehicles. This change -which came into force on January 1, 2005- is intended to encourage the purchase and leasing of green passenger cars by public authority fleets. The objective is that at least 75% of the total car purchases or

leases by a public authority during a calendar year should be green vehicles. The National Road Administration published in 2006 a definition of the types of vehicles that qualify as green vehicles in accordance with the requirements of the Ordinance.

#### ***Grants for green vehicles***

Any private individual who buys a new green car between April 1, 2007 and December 31, 2009 will receive an ‘eco car subsidy’ of SEK 10'000 = US\$ 1'500.

The criteria for an eco car subsidy are:

- An alternative fuel vehicle (flexible fuel, bi-fuel and/or electric) must have fuel consumption below the energy equivalent of:
  - 9.2 litres of gasoline,
  - 9.7 m<sup>3</sup> natural gas (CNG), or
  - 37 kWh electric energy per 100 km.
- An alternative fuel vehicle must also run predominantly on alternative fuels as opposed to fossil fuels.
- A vehicle run on fossil fuels may be called an eco car if the carbon dioxide emissions are below 120 g/km. To meet this requirement, the fuel consumption must be below 4.5 litres of diesel or 5.0 litres of gasoline per 100 km.  
(Note that this is due to the requirement concerning carbon dioxide.)
- For vehicles with diesel engines, emissions of particulate matter must be below 5 mg/km. In practice, this means that vehicles that run on diesel fuel must be equipped with a particulate filter to be classified as an eco car.

Some local authorities have reduced parking charges for green vehicles, although rules vary from one local authority to another.

A congestion-charging scheme was tested in Stockholm from January 1 to July 31, 2006. The scheme has been evaluated and it was decided that it would continue from summer 2007. The congestion tax is imposed upon Swedish-registered vehicles driving into and out of the Stockholm inner city zone between 6:30 a.m. and 6:29 p.m. on weekdays (Monday to Friday). Each passage into or out of the inner city zone costs SEK 10, 15, or 20 (= US\$ 1.5 to 3), depending on the time of day. Vehicles equipped with technology for running (1) completely or partially on electricity or a gas other than LPG or (2) on a fuel blend that predominantly consists of alcohol are exempted from the charge.

### **21.3**

#### ***Research***

There are -in principle- five national research programmes dealing with issues related to electric, hybrid or fuel cell vehicles. The programmes are closely linked

in order to benefit from common tasks and overall synergies among them. They also share monitoring and analysis of business intelligence. In brief, they are:

**The Green Vehicle Programme** (the objective of which is to develop cleaner vehicles) is a joint initiative of the automotive industry and the government. The total budget of the current (second) phase is approximately US\$ 120 million, the administrator is VINNOVA (Swedish Governmental Agency for Innovation Systems), and the programme runs from 2006 to 2008. About US\$ 35 million are budgeted for specific electric, hybrid and fuel cell vehicle research, which will include work on hybrid systems architectures, drive systems and energy storage technology.

**Energy Systems in Road Vehicles** -administered by the Swedish Energy Agency- addresses energy related issues in vehicles. It has several research projects dealing with batteries, fuel cells and other components for vehicles that use electricity as a means of improving energy efficiency.

The programme entered its third phase in 2007 -to run until the end of 2010- with an additional budget of about US\$ 15 million. Of the total budget, US\$ 8 million is devoted to hybrid vehicles and fuel cells. To date, several PhD students in the field of hybrid vehicles and fuel cells have been trained, and a number of patents have been issued for a new type of hybrid driveline.

When the results of earlier phases were evaluated, it was decided that the programme should not attempt to spread itself over so many areas, but that its work should be concentrated on hybrid vehicles. The programme covers the following areas linked to hybrid systems: architecture of hybrid systems, drive systems, diesel reformers for fuel cells, and battery technology. In co-operation with other efforts, the programme operates a simulation centre for collating the results of all the national programmes.

**Fuel Cells in a Sustainable Society** -a joint programme of universities and industry- is the third phase of a programme that started in 1997, was slightly modified during 2002 and is to end 2009. The administrator is MISTRA (Sweden's Foundation for Strategic Environmental Research) and the programme includes research projects on fuel cell system components, materials and systems. The total budget is approximately US\$ 18 million, and -in addition to investigating manufacturing methods- the programme emphasises reducing the cost and increasing the life of fuel cells.

**The Swedish Hybrid Vehicle Centre (SHC)** aims to establish an internationally competitive centre of excellence for hybrid electrical vehicle technology. It will facilitate education and research to meet industrial and societal needs in the area

and form a natural framework for co-operation between industry and academia. Participating in the centre are AB Volvo, Scania CV AB, Saab Automobile AB, GM Powertrain Sweden AB, Volvo Car Corporation, BAE Systems Hägglunds AB, Chalmers University of Technology, Lund University and the Royal Institute of Technology. The centre started operation in July 2006, and the budget for the first phase (2007-2010) is approximately US\$ 14 million.

**The Environment Vehicle Development Programme** started in June 2007. The total budget from the government is approximately US\$ 37 million, the administrator is the Swedish Energy Agency and the programme runs from 2007 to 2010. The programme covers hybrids, engines for alternate fuels, and lightweight and fuel-efficient engines. The programme includes co-operative projects between U.S. (Department of Energy, Mack Trucks) and Swedish (Swedish Energy Agency, AB Volvo) entities.

## 21.4

### **Industry**

Sweden's economy is very dependent on its automotive industry. About 140'000 are employed in its automotive sector, including employees of the about 1'000 subcontractors to the industry.

<b>Box 21.1</b> <b>Subcontractors in the fields of electric vehicles, fuel cells and/or hybrid vehicles development</b>	
<b>Company</b>	<b>Activity</b>
ETC, Battery and Fuel Cells AB	Development and sale of batteries for hybrid vehicles: primarily nickel metal hydride. Various activities in the fuel cell sector.
Morphic Technology AB	Development of production technology for PEM fuel cells.
Cellkraft AB	Development of systems for PEM fuel cells.
Opcon Autorotor AB	Air supply systems for PEM fuel cells.
Woxna Graphite AB	Graphite for fuel cells.
Outocumpo Stainless AB	Stainless steels for fuel cells.
Actia Nordic AB	Power electronics for electric and hybrid vehicles.
LiFeSiZE AB	Up-scaled production and sale of low-cost Fe-based cathode materials for EV/HEV Li-ion batteries (especially $\text{Li}_2\text{FeSiO}_4$ ).
Transic	Development of silicon carbide power electronics.
Powercell	Development and commercialization of fuel cell auxiliary power unit (APU) for heavy-duty applications.
Cell Impact AB	Development and sale of bipolar plates for PEM fuel cells.

The major manufacturers are AB Volvo, Volvo Cars, SAAB Automobile AB and Scania, all of which have developed electric and/or hybrid concept vehicles. As the hybrid vehicle sector -in particular- has moved into the commercial sphere and approaches its maturity phase, it is not possible to obtain reliable data on specific R&D activities from the companies, as all of this is now proprietary.

Subcontractors who are engaged in some way in the fields of electric vehicles, fuel cells and/or hybrid vehicles development are listed in box 21.1.

## 21.5

### ***On the road***

The registered year-end population totals of green vehicles in Sweden from 2001 to 2007 are shown in table 21.2.

Table 21.2 Numbers of green vehicles in Sweden at December 31 of the years 2001 to 2007.

	2001	2002	2003	2004	2005	2006	2007
<b>Private cars</b>							
Electric vehicles	-	500	450	400	360	325	310
Hybrid electric vehicles	350	530	620	1'350	3'300	6'100	9'400
Low consumption vehicles, max 120 g CO <sub>2</sub> /km	840	970	1'260	2'080	2'300	7'000	21'000
Natural gas/biogas vehicles	1'640	2'500	3'440	4'500	6'500	9'900	12'900
Ethanol vehicles, E85	890	3'500	7'980	13'300	21'400	47'000	81'000
<b>Heavy vehicles</b>							
Ethanol buses	-	-	400	380	370	490	490
Natural gas/biogas buses and trucks	-	-	680	780	900	1'100	1'166
Electric and fuel cell buses and trucks	-	-	17	18	13	10	10

At the end of 2007, there were over 4.8 million private cars and heavy vehicles on the roads of Sweden. About 35% of newly registered private cars had diesel engines.

The total of newly registered green vehicles reached a record in 2007 with 54'555 private cars, which is an increase of 49% over 2006. The market share of green cars increased in that period from 12.9% to 17.8%.

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

Vehicle type	December 31, 2007		
	EV fleet	HEV fleet	Total fleet
Bicycles (no driver licence)	3'000	0	220'000
Motorbikes	0	0	430'000
Passenger vehicle	310	9'400	4'300'000
Multipurpose passenger vehicle	n.a.	n.a.	n.a.
Bus	9	0	13'000
Truck	1	0	510'000
Industrial vehicles	n.a.	0	500'000
<b>Total</b>	<b>3'320</b>	<b>9'400</b>	<b>5'973'000</b>

*n.a. not available*

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

### **Development**

During 2007, interest in hybrid vehicles remained high. Discussions to inaugurate several R&D programmes are now in progress with a difference that, whereas the State was the main driving force behind earlier discussions, industry now most actively supports them. As a case in point, the ‘Green Vehicle 2’ project, thanks to industrial priorities, will emphasize hybrid vehicle technology more than was previously the case, and industry has been the most vocal champion of the Swedish Hybrid Vehicle Centre (SHC).

## **21.6**

### **Outlook**

The trends for eco cars in Sweden are divided. The market share of green private cars has increased to 17.8%, and most of them are ethanol (E85) cars (65%). However, there is not yet a public consensus that ethanol cars are the best or even the right way to reduce emissions of carbon dioxide from the transport sector. Concerns include fuel production methods and comparative advantages of similar fuels, such as methanol, dimethyl ether (DME) and hydrogen. Higher vehicle fuel efficiency in such technologies as diesel, hybrid, electric and fuel cell cars is also a way to reduce the carbon dioxide emission from the transport sector. In addition, hybridization with low carbon dioxide emission fuels (e.g., biofuels) is feasible.

In recognition of these options, the technology for energy-efficient cars has become ever more interesting. The European Union has proposed directives for ever-more stringent reductions of carbon dioxide emissions, which puts greater pressure on the role that vehicles must play to achieve them. The Swedish vehicle

industries have become very focused on hybrid technology to manage this emission reduction role until through 2015. Beyond 2015, plug-in hybrids (PHEVs), all-electric cars and trucks with superior driving range and perhaps fuel cell vehicles may become feasible alternatives. Beginning in 2007, Volvo Cars, Saab Automobile AB, ETC Battery and Fuel Cells AB and Vattenfall (an electricity power producer) entered into a PHEV project designed to demonstrate 10 such vehicles in practical use.

## **21.7**

### ***Benefits of participation***

The benefits of participation in the IEA's HEV Implementing Agreement include the following:

- The Agreement enables an informal exchange of information and worldwide contacts, thereby providing a means of finding out what other countries are doing (or not doing) -and how they are doing it- in a cost-efficient manner. At the same time, the network of national and technology Annex experts provides a way of benchmarking national efforts against other countries to improve the cost benefit of Swedish efforts.
- The Agreement also enables the costs of major worldwide work to be shared. Many investigations have been carried out within the framework of the group's work - investigations that would have been impossible for any one country to perform on its own for anything like a reasonable cost. It is also important that any work should be carried out by the best scientists in the particular field, and it is a lot easier to find out who they are when working in a group of representatives from several countries, each with its own networks.
- Giving national scientists the opportunity to participate in international groups -tackling issues that are of interest not only in Sweden- creates an inward flow of information and strengthens the international network of scientists. It is also important that those involved bring home new thoughts and ideas - ideas that can suggest new R&D projects and/or opportunities for business.

## **21.8**

### ***Further information***

The following websites publish several reports covering cleaner vehicle issues:

- [www.avl.com](http://www.avl.com) (in English).  
This website includes the AVL MTC Motortestcenter AB in Haninge. AVL MTC Motortestcenter AB has a few reports covering test results on cleaner vehicles, mainly in English.
- [www.energimyndigheten.se](http://www.energimyndigheten.se) (in English and Swedish).  
The Swedish Energy Agency publishes reports, although mainly in Swedish. The primary cleaner vehicle focus is on energy efficiency in the transportation sector and the production of alternative fuels.

- [www.vinnova.se](http://www.vinnova.se) (in English and Swedish).  
The Swedish Governmental Agency for Innovation Systems (VINNOVA) provides a wide range of reports regarding cleaner transportation.
- [www.vv.se](http://www.vv.se) (in English and Swedish).  
The Swedish Road Administration publishes several reports covering emissions and safety issues, mainly in Swedish.

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

- [www.fuel-cell-bus-club.com](http://www.fuel-cell-bus-club.com) (in English).

A few organizations that provide regional or national information on certain cleaner vehicle aspects are listed below.

- [www.chalmers.se/shc](http://www.chalmers.se/shc) (in English and Swedish).  
Website of the Swedish Hybrid Vehicle Centre (SHC).
- [www.miljofordon.org](http://www.miljofordon.org) (in English and Swedish).  
This website shows a collaboration between the three largest cities in Sweden: Stockholm, Göteborg and Malmö. It is a website for cleaner vehicles that provides considerable information on vehicles, infrastructure and costs.
- [www.stockholmresilience.org/mistra](http://www.stockholmresilience.org/mistra) (in English and Swedish).  
MISTRA is Sweden's Foundation for Strategic Environmental Research.
- [www.sweva.org](http://www.sweva.org) (in English and Swedish).  
The Swedish Electric and Hybrid Vehicle Association website.

## 22

# Switzerland

### 22.1

#### **Introduction**

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

Switzerland's power generation is completely CO<sub>2</sub>- and air pollutant-emission free, with a mix of 60% hydropower and 40% nuclear power. The share of transportation in total national CO<sub>2</sub> emissions is therefore rather high: 34% in 2007. Government measures have resulted in a 4.6% reduction of CO<sub>2</sub> emissions in the household, service and industry sectors, while emissions in the transportation sector have been increasing (see figure 22.2).

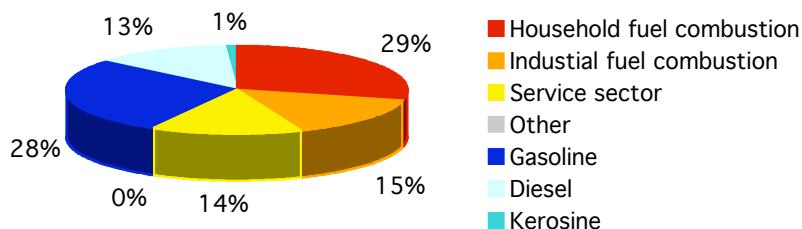


Fig. 22.1 CO<sub>2</sub> emissions from fuel combustion in Switzerland (2005). Gasoline and diesel together contributed 41% to the CO<sub>2</sub> emissions that were emitted by burning fuels. In a general examination (including agriculture etc.) the transport sector contributed 34% of the CO<sub>2</sub> emissions in 2007. (Data source: Federal Office of Environment BAFU).

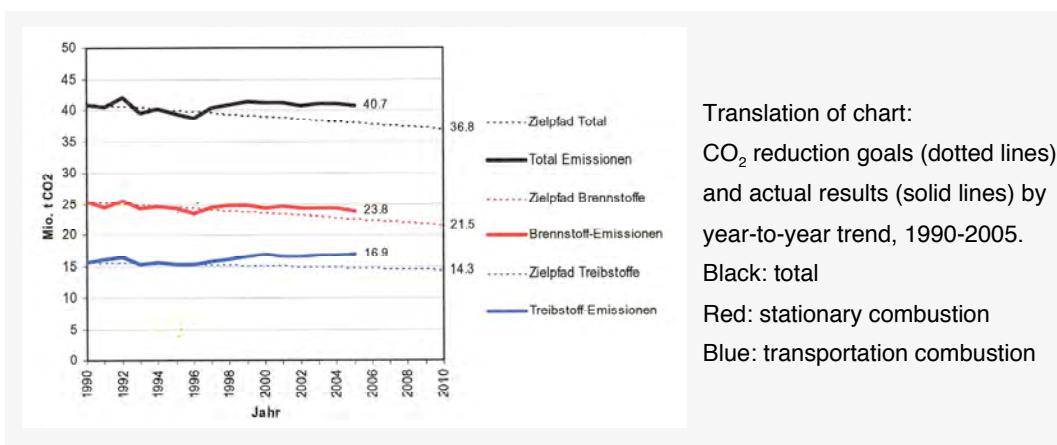


Fig. 22.2 CO<sub>2</sub> emissions in Switzerland from 1990 to 2005, and goals until 2010. (Graph supplied by Muntwyler AG.)

The trend to large, heavy cars results in a higher average of CO<sub>2</sub> emissions compared with EU member countries. In the last 10 years, the vehicle weight increased from an average 1'300 to 1'500 kg. The average fuel consumption of a Swiss car is 7.6 l/100 km, while that of a car in EU countries is 6.7 l/100 km. The average CO<sub>2</sub> emission rate of the car fleet is 161 g/km in the EU countries, while that of the car fleet in Switzerland is 187 g/km.

Government policy pursues two strategies: in the first strategy, the government concludes voluntary agreements with the car importers (Decree on the Lowering of the Average Fuel Consumption, ‘Climate Rappen’), and in the second strategy, the federal car import taxes are switching to a bonus/malus system on the basis of the CO<sub>2</sub> emissions of the relevant car model. This approach is completed by the information campaign EcoCar (see section 22.2). This includes propagating the use of alternative fuels (compressed natural gas, biogas, ethanol) and the trend to ‘slow traffic’ (walking, cycling) that creates market niches for electric vehicles (small, lightweight vehicles for commuting and special vehicles for ‘car-free resorts’ such as Zermatt).

Vehicle taxes and promotion measures are the responsibility of the cantons. Some of them have changed the taxation criterion for motor vehicles from unit mass to CO<sub>2</sub> emissions. This transformation becomes apparent first in cities and towns. Some have exchanged diesels for biogas buses in their public transport services or have acquired small electric-powered utility vehicles for street cleaning and waste collection.

The private user segment has accepted hybrid vehicles as a viable alternative. With more than 7'700 hybrid vehicles on its roads, Switzerland leads Europe in per-capita hybrid ownership (in absolute figures, the United Kingdom is on top, with more than 20'000 hybrid vehicles in use).

## 22.2

### **Policies and legislation**

The effects of climate change on the Swiss environment have stimulated discussion on effective measures to lower the CO<sub>2</sub> emissions caused by transportation. The measures of the EcoCar campaign starting in 2001 failed to reduce fuel consumption, and CO<sub>2</sub> emissions caused by transportation actually increased by 9.1% instead of decreasing by 8%, as stipulated under the Kyoto agreement.

At the beginning of the EcoCar campaign, the government set goals: by the year 2010, 20'000 hybrid and 30'000 CNG (compressed natural gas) vehicles were to be circulating on Swiss roads. These goals will not be achieved and in 2004 the political emphasis shifted to CO<sub>2</sub> taxes (in force since January 2008), CO<sub>2</sub> emission certificate trading, and ‘green taxation’ of vehicle imports in the form of

<b>Box 22.1</b> <b>Summary of the Swiss EcoCar project</b>			
			
<b>Measure</b>	<b>Implemen-</b> <b>tation</b>	<b>Description</b>	<b>Effect</b>
<b>EcoCar labelling</b>	In planning	Inclusion of a bonus-malus (incentive-penalty) system is intended.	Difficulties with scoring and implementation.
<b>Declaration of goods</b>	2003	The energy consumption of each light-duty vehicle model must be declared on the basis of 7 consumption categories in 8 weight categories. Pure EVs excluded.	Since 2006 weight criteria are tightened. Label A hardly attainable by heavy vehicles.
<b>Target values</b>	2002	Voluntary agreement with car importers to reduce fuel consumption in new-vehicle fleets by 3% per year (= -24% by 2008). CO <sub>2</sub> taxes to be imposed on fuels if 2008 target not met.	Actual achieved values: 2002: - 2.3% 2003: - 1.35% 2004: - 1.3% 2005: - 0.9% 2006: - 0.65% Targets have not been met in any year.
<b>Regulations</b>	Climate Rappen: 1 Oct. 2005	Tax of 1 ¢/l on petroleum fuels, to feed a fund of € 67 million for projects to reduce CO <sub>2</sub> and the purchase of CO <sub>2</sub> certificates. Reduction target: 1.6 million t CO <sub>2</sub> /year.	Almost all projects are in the building sector; hardly any effect in the transportation sector.

a bonus-malus system that depends on the fuel consumption label for light-duty vehicles. Consumption ratings run from A (most fuel efficient) through G. The green tax will rise for cars in the label categories C to G, while cars of category A will get a bonus of CHF 2'000 (1'350 Euros) and cars of category B CHF 1'000 (675 Euros). This tax scheme will be introduced in 2009.

Since 2000, the government has been authorized by law to raise duties on the basis of CO<sub>2</sub> emissions, and regulations have been adopted beginning in 2004. Starting in 2008, the duty per litre oil or kilogram of gas is 0.18 Euros; this amount will double in 2009 and triple in 2010. The duty is returned directly to the Swiss population (about 9.5 Euros per person). Because of heavy resistance from the automotive sector, another voluntary agreement replaces the CO<sub>2</sub> duty on fuels for transportation: the Climate Rappen (a duty of about 0.01 Euro/l on petroleum fuels) is used for projects to reduce CO<sub>2</sub> emissions. Although the goals of the Climate Rappen agreement will be achieved overall, the effect in the transport

sector is minimal, as most of the projects apply to the construction sector. There is great temptation to include CO<sub>2</sub> reduction among achievements of the Climate Rappen, although other reasons are responsible and there are no additional CO<sub>2</sub> savings from the Climate Rappen itself.

Beginning in 2000, the cantonal governments have the legal authority to finance promotion measures for electric and hybrid vehicles. Until 2005, primarily the canton of Ticino was active in this area, consistent with its role as successor to the federal promotion programme VEL1 (Large Scale Test for Lightweight Electric Vehicles, conducted in Mendrisio from 1995 to 2000). The cantonal promotion programme VEL2 (2001-2005) also qualified for subsidizing conventional car models that have lower CO<sub>2</sub> emissions. In this second phase, 2'785 efficient vehicles have been subsidized, including 75 hybrid vehicles. For VEL1 and VEL2 combined, about 1'300 electric vehicles were subsidized: 935 electric bicycles, 280 electric scooters, 10 three-wheeled electric vehicles, and 85 light-duty models (like the Peugeot 106 electric and Citroën Saxo electric). Meanwhile, most of the electric vehicles converted by the company MES DEA are sold in Ticino, such as the Fiat Panda Elettrica or the Twingo Quickshift Elettrica.

Switzerland has adopted the European guidelines to increase to 10% by 2020 its population of vehicles powered by compressed natural gas (CNG), which is about 350'000 vehicles. The official targets are more modest: the agency EcoCar cites a goal of 30'000 natural and biogas vehicles by 2010. As of the end of 2007, almost 6'000 gas vehicles had been licensed and 100 gas stations were available. Several city authorities have substituted CNG for diesel in their public transport bus fleets and in their communal service vehicles (like garbage trucks). Ethanol is being promoted as a biofuel option, with the first ethanol filling stations now in operation. The eco-balance of ethanol is highly disputed, especially from traditional European feedstocks. Home production is based on whey and waste products of slaughtering, which brings a 60% reduction of the overall ecological damage and a minimum of CO<sub>2</sub> emission compared with gasoline, but production output is limited. For imported ethanol, the Institute of Material Sciences and Technology Development EMPA has published an eco-balance that will inform future government policy regarding biofuels.

Several cantons provide vehicle tax reductions for clean vehicles: 16 of 26 cantons grant tax reductions to electric vehicles or exempt them altogether from vehicle taxes, and eight cantons reduce taxes for hybrids.

## 22.3

### **Research**

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

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

The Office sponsors research and development that will contribute to the reduction of fuel consumption and CO<sub>2</sub> emissions in personal transportation by means of:

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

Benefits should include:

- enhanced safety,
- reduced space requirements for transport infrastructure,
- strengthened initiative for Swiss-located industries, and
- strengthened initiative to locate new industrial production in Switzerland.

Research in transport-related projects is centred at the Swiss Federal Institute of Technology (ETH Zürich) and its research institutes: the Paul Scherrer Institute (PSI) and the Federal Laboratories for Material Sciences and Technology Development EMPA. The Universities of Applied Sciences (FH) in Biel, Luzern and Rapperswil also participate in transport related research.

Projects have been or will be initiated to develop a ‘1.5 l/100km equivalent’ fuel cell prototype. The Michelin Research Centre has developed the fuel cell prototype Hy-Light (2004) of the Paul Scherrer Institute to an advanced fuel cell vehicle (Hy-Light II) and a pure battery electric vehicle (EV-Light). Both have a



Fig. 22.3 Hy-Light II, prototype vehicle from the Michelin Research Centre, based on Hy-Light I developed by PSI. (Photo supplied by Muntwyler AG.)

removable Li-ion battery that -in the case of the fuel cell vehicle- stores braking energy (in the Hy-Light I, prototype supercapacitors served this purpose). Completely new is the ‘active wheel’, in which the electric motor and suspension are integrated into the combined propulsion and braking system. A second electric motor controls the motion of the wheel. This ‘active wheel’ makes shock absorbers, components for the power transmission, complex suspension parts and ABS unnecessary. Two ‘active wheels’ drive the two front wheels of the two prototypes. As a result, the weight of the original vehicle could be reduced (Hy-Light II: 790 kg).

In another project efforts continue to achieve a mass reduction of 30% (project LIVIO). Storage technology work includes ultracapacitor applications being matched with ‘intelligent’ batteries that have adequate charging procedures, combined battery-supercapacitor systems, and basic research on conductive materials and nanostructures for advanced batteries.



Fig. 22.4 ‘e-motion’ by the IWK of the Institute of Technology Rapperswil. (Photo: courtesy IWK Rapperswil.)

A project of the Institute of Synthetic Materials IWK (Institute of Technology Rapperswil) also targets reduction in mass. Its lightweight electric vehicle prototype is based on an aluminium space frame, a body made from a steel resin+glass fibre compound and windshields of polycarbonate, resulting in a mass of 200 kg unloaded and without batteries (figure 22.4). The vehicle is driven by two in-wheel electric motors of 3.5 kW each. The institute intends to develop this vehicle to a marketable product.

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

## 22.4

### **Industry**

Electric cycles (pedelecs) are already a consumer mass product. Their Swiss sales figures rise annually, with more than 6'000 e-cycles sold in 2007. Products originally developed in Switzerland but now manufactured by licensees in Germany include the TWIKE three-wheeler and ‘swizzbee’ e-bike (formerly the Dolphin).

The automotive supplier MES DEA is converting the Renault Twingo and the Fiat Panda to an electric vehicle platform and is seeking a manufacturer. A Swiss energy supplier operating one of the largest pumped storage power stations began small-scale production of the Renault Twingo Quickshift Elettra, together with the University of Applied Sciences Biel. They will be operated by Swiss utilities as service vehicles. In addition, the close connections of this Swiss utility to Brazil have been used to establish a co-operation of Fiat Brazil with Th!nk Norway. Switzerland expects the first Th!nk deliveries in 2009.

The company HESS AG, which specializes in bodywork for buses, has developed a hybrid bus (also in a trolley version), together with the German propulsion specialist Vossloh Kiepe. The drivetrain features two electric asynchronous motors: 160 kW on axles 2 and 3 each, and a biodiesel engine rated at 250 kW in the rear, with supercapacitors as the electrical storage system (figure 22.5). In January 2008, this commitment was awarded the Watt d’Or 2008 by the Swiss Federal Office for Energy in the category ‘Energy efficient mobility’.



Fig. 22.5 LighTram by HESS AG (left) and Coaster in Arosa (right). (Photos supplied by Muntwyler AG.)

Brusa Electronics -a specialist in the development of control systems for electric vehicles- has developed a track-based unmanned electric vehicle system named Coaster, which is now marketed by a licensee. The first commercial application was installed in Arosa in spring 2007 (figure 22.5).

Development and manufacturing of components for hybrid and electric vehicles are concentrated within the Swiss companies MES DEA (ZEBRA NaNiCl batteries and PEM fuel cells in the range of 500 W to 3 kW), Horlacher, ESORO

(composite parts) and Brusa Electronics (control systems). All of these companies are active in research projects. Research on the improvement of ZEBRA batteries concentrates on lowering the operational temperature. Suitable solvents have been tested, and the feasibility of lowering the temperature has been confirmed in the laboratory. Nevertheless, near-term availability of a low-temperature ZEBRA product remains unlikely. The high-temperature ZEBRA-battery is already used successfully in various electric and hybrid vehicles, especially in buses (e.g., Irisbus, Gruau Microbus).

Regarding fuel cell propulsion, the Swiss industry is interested in the development of components like electronics, control systems and system management. Fuel cell systems are not only developed and tested by research institutes but also by private companies. As long ago as 2002, ESORO demonstrated a fuel cell vehicle in hybrid configuration, and the prototype is still used as a company car. ESORO is one of the renowned specialists in lightweight materials and processing. The lightweight rear door of the new ‘smart’ car is produced by a method developed by ESORO.

Swiss industry is still influenced in its approach to propulsion research by experiences during the worldwide first solarmobile races -the Tour de Sol (1985-1993)- which could be won only by achieving maximum efficiency through highly efficient components and lightweight construction. The current tendency in the worldwide automotive industry to improve the efficiency of cars plays well into Swiss industrial strengths.

Thus, the approach of the LIVIO (lightweight vision) project by Rieter/Horlacher is especially promising (see figure 22.6). The target is to assemble a vehicle from few parts, each of which also integrates more than structural function. For example, instead of adding acoustical and thermal insulation and the interior surface to the body-in-white structure and thus assembling three components for one function, one ‘intelligent’ and lightweight component integrates all of these features. In addition, some parts can be easily interchanged to meet specific customer needs.



Fig. 22.6 LIVIO by Rieter/Horlacher. (Photo: e'mobile.)

Another spin-off of the ‘Tour de Sol’ philosophy of lightweight efficient design is Walter Janach’s ultra light vehicle, which is assembled from a sandwich platform and has a cabin that is constructed like a cyclist’s helmet and is made of a foam material laminated by carbon fibre (see figure 22.7). An electric hub motor of 3 kW and a small battery package should enable speeds of up to 50 km/h with a 50-km range, which is sufficient for commuting. The target publics are developing countries with rapid economic growth, dense population, and limited reserves of oil (like China and India). Janach is looking for industrial partners in China to launch small-scale production.



Fig. 22.7 Ultra light vehicle concept by Walter Janach. (Photo supplied by Muntwyler AG.)

## 22.5

### ***On the road***

Vehicle density is rather high in Switzerland. By September 2007, almost 4.4 million light-duty vehicles were licensed, thus a density of 586 cars per 1'000 inhabitants. In 2007, 32.5% of all new cars had a diesel drive (85% of them with particle filter). The Swiss electric vehicle market is small and dominated by small lightweight vehicles, such as e-bikes, e-scooters and three-wheeled vehicles (such as TWIKE and City-el, which are licensed as motor bikes). Table 22.1 reports the data on the Swiss car park as of December 2007.

#### ***Development of the EV and HEV deployment in Switzerland***

Because almost no commercially produced EV model is available in the Swiss market, the population of four- and three-wheeled EVs has been decreasing over the last five years. Most of the in-use EV population is more than 10 years old, and it is almost impossible to replace vehicles that can no longer be repaired. However, the lack of new EV offerings has still resulted in great interest in used electric vehicles, and the market for electric two-wheelers is growing fast. As noted above, more than 6'000 e-bikes and scooters were sold in 2007.

The hybrid vehicle market is developing satisfactorily to retain importer interest. By December 2007, about 7'700 hybrid cars had been licensed (models: Toyota Prius I and II, Honda Civic IMA and all hybrid Lexus models). Importers expect a steadily growing market for the next years.

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

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

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

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

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

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

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

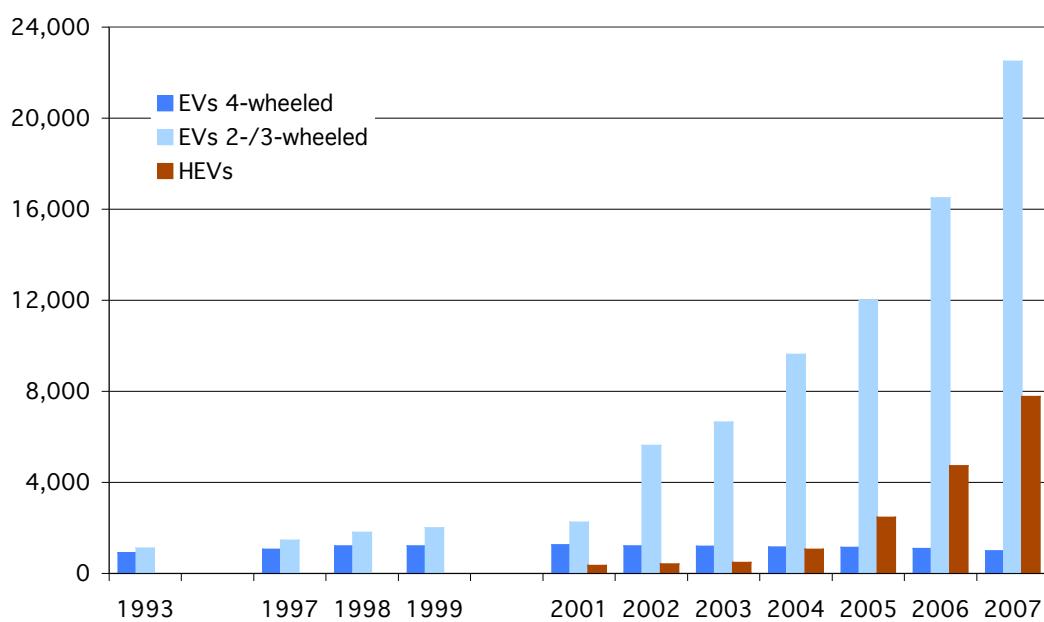


Fig. 22.8 Swiss EV and HEV fleet numbers.

### ***Electric vehicles in Switzerland: mostly electric cycles and scooters***

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

#### **1. Commuters**

Most of the electric vehicles in Switzerland are used for commuting in urban agglomerations. This fact results in the great success of small lightweight EVs, especially three-wheeled and two-wheeled vehicles that can easily be parked and for which recharging stations exist at privileged parking spots in the centres of several cities and towns. Drivers of three-wheelers (like the City-e1) are even allowed to park in bicycle parking spaces. In a few cases, drivers of small lightweight electric vehicles are permitted to use roads that are closed to conventional cars.

#### **2. Car-free resorts**

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



Fig. 22.9 Electric-powered hotel taxis in car-free resort Zermatt. (Photos: M. van Walwijk.)

## **22.6**

### ***Outlook***

In general, government policy in Switzerland -as well as in the European Union- has shifted toward implementation of stringent pollutant emission standards and the taxation of CO<sub>2</sub> emissions. In this context, clean vehicle technologies find opportunities, but they must also find the most promising market segments to achieve sales figures that actually do reduce pollutants and CO<sub>2</sub> emissions. Indeed, the greatest success in sustaining market niches for EVs has been achieved where they offer clear advantages in use. Niches based on subsidies only are not

sustainable. Real advantages to EV users include faster commuting, easier access to city centres, easier parking, lower operating costs and -in some cases- a positive image. Here, image includes all ‘soft’ factors, such as the more ‘futuristic’ look of the vehicles, their symbolization of ‘ecology’, and the ‘individuality’ of the user, among others. In Switzerland, these advantages are provided by lightweight three-wheelers and high-speed electric bicycles. Four-wheeled vehicles do not possess these same advantages with respect to access to congested city centres or parking lots or in their design. Sustainable niches can also be established by regulations (for example, in Switzerland’s ‘car-free’ resorts). The great increase in sales figures of electric vehicles in Switzerland can be attributed to the success of electric two-wheelers. Advanced electric purpose design vehicles -such as the new Th!nk- will find a ‘prepared’ market in Switzerland.

The hybrid vehicle market is a success thanks to great sensitivity to ecology in Switzerland; a good knowledge about alternative vehicles (especially electrics, as a result of the Tour de Sol races and the promotion programmes VEL1 and VEL2 in Mendrisio); and the performance of the hybrid vehicle models available in Switzerland, which rivals that of conventional cars. Hybrid vehicles also feature an agreeable price/performance ratio.

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

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

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

- Too much know-how is kept within research institutes.
- The step to production is difficult.
- The development of standardized products is neither supported nor existing.
- There is a lack of an efficient profit chain.

## 22.7

### **Benefits of participation**

Switzerland has participated in the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes since its inception in 1993 and -in ensuing years- has been one of the member countries most active in the promotion of electric vehicles. As most electric vehicle manufacturers have ceased production -resulting in decreasing EV activities in Switzerland- the

information exchange with experts from other countries has become more important in providing insight into many key issues, including:

- The development of new batteries (such as those based on lithium technology) and progress in component development. New batteries could precipitate a resurgence of all-electric vehicles -at least for specific market niches- so the ability of the government to identify the right moment to consider active support will be enhanced.
- The realization that hybrid vehicles succeed in the market without government support.
- Recognition of political realities (CO<sub>2</sub>, oil price) that will demand a shift to clean vehicle technologies in the relatively short term. The activities of other member countries -as well as the information provided by the International Energy Agency itself- provide insight into possible CO<sub>2</sub> mitigating measures and real market opportunities for clean vehicle technologies.

## **22.8**

### ***Further information***

#### ***Websites***

- [www.e-mobile.ch](http://www.e-mobile.ch) (in English, French and German).  
Swiss association for electric and efficient vehicles. Project EcoCar/Swiss Programme ‘EnergieSchweiz’ of the Federal Office of Energy.
- [www.energie-schweiz.ch](http://www.energie-schweiz.ch) (in English, French German and Italian).  
Programme ‘EnergieSchweiz’ of the Federal Office of Energy.
- [www.erdgasfahren.ch](http://www.erdgasfahren.ch) (in French, German and Italian).  
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- [www.hslu.ch/t-fei\\_tohyco\\_rider\\_en.pdf](http://www.hslu.ch/t-fei_tohyco_rider_en.pdf) (in English).  
Tohyco Rider mini bus.
- [www.hycar.ch](http://www.hycar.ch) (in English and German).  
Fuel cell-prototype ESORO HyCar.
- [www.maxwell.com](http://www.maxwell.com) (in English).  
Supercapacitors.
- [www.mes-dea.ch](http://www.mes-dea.ch) (in English).  
Twingo Quickshift Elettrica, plug-in hybrid Fiat Idea, ZEBRA batteries.
- [www.newride.ch](http://www.newride.ch) (in English, French and German).  
Project NewRide (electric two-wheelers).
- [www.paccar.ethz.ch](http://www.paccar.ethz.ch) (in English and German).  
PAC-Car II energy-efficient fuel cell vehicle project of the ETH Zürich.
- [www.psi.ch/medien/Medienmitteilungen/mm\\_hy\\_light](http://www.psi.ch/medien/Medienmitteilungen/mm_hy_light) (in English).  
Fuel cell prototype Hy-Light.

- [www.vel2.ch](http://www.vel2.ch) (in English, French, German and Italian).  
Project VEL2 of the canton of Ticino.

### **Reports**

- *Project Lightweight Electric Vehicles in Mendrisio: Synthesebericht.* Full report on CD-rom. Order at: EDMZ CH-3000 Bern.
- Martin Pulfer. *Konzept 2004-2007, Technologiebereich Verkehr & Technologiebereich Akkumulatoren.* Bundesamt für Energie 2006.
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## 23

# Turkey

### 23.1

#### ***Introduction***

Turkey has introduced several prototype hybrid electric vehicles (HEVs) throughout its years of involvement in alternative automotive technology development. The first HEV prototype ELIT-1 was a series hybrid developed in 2003 by TÜBITAK and Tofas Automotive Factory (figure 23.1). In 2006, Ford Otosan presented a split-drive light-duty truck FOHEV-1 that was exhibited in 2007 at the Hannover Messe (Fair) in Germany. In November 2007, Otokar exhibited the Doruk 160LE Hibra hybrid electric urban bus prototype at the International Commercial Vehicle Exhibition in Istanbul.



Fig. 23.1 ELIT-1 series hybrid electric vehicle design and development project. (Photo supplied by TÜBITAK MRC.)

The hybrid vehicle market in Turkey is in its beginning phase, with the Honda Civic hybrid being the first commercial hybrid offered for sale. Toyota recently announced tentative plans to sell its hybrids in Turkey. Turkey's hybrid sales figures for 2007 are unknown at the time of writing. Sales of electric two-wheelers have recently begun, but these have not achieved significant market penetration.

### 23.2

#### ***Policies and legislation***

Within the last decade, the financial resources allocated for research and development (R&D) in Turkey have been significantly increased by the government. The importance of transport as an industrial sector prioritises automotive related research for government support. Turkey has several institutional instruments for the greening of transportation.

The vision of the Ninth Development Plan -prepared to be consistent with international developments and basic trends during 2007-2013, while considering past developments in the Turkish economy as well as existing economic and social conditions- was articulated as: ‘Turkey, a country of the information society, growing in stability, sharing more equitably, globally competitive and fully devoted to coherence with the European Union’.

Law No. 5346 -which pertains to the use of renewable energy resources for electricity production purposes- was enacted during the period of the new Development Plan, with the aim of increasing the share of renewable energy resources in electricity production.

During the prior eighth Plan period, the share of highways in domestic freight transport rose from 88.7% in 2000 to 90% in 2005. Meanwhile, the already small share of maritime transportation in freight transportation decreased even more, to 2.8% in 2005. Railway and pipeline transportation maintained their shares. During this period, 95.2% of domestic passenger transportation occurred over highways. While freight transportation to destinations abroad was dominated by maritime transportation, international passenger transportation continued to be dominated by airways.

The share of R&D expenditures in gross domestic product (GDP) -which was 0.67% as of 2002- is quite low when compared with leading countries in the fields of science and technology. Even though public resources allocated to science and technology in Turkey have significantly increased since 2005, R&D expenditures as a share of GDP still account for less than 1%.

During the eighth Plan period, centres of excellence in strategic areas were created at several universities. In addition -since 2002- projects to produce scientists and -since 2004- multilateral projects with interdisciplinary characteristics have enjoyed new support. The support previously provided for work in technology development zones, technology centres, technology incubators without walls and university-industry joint research centres has continued. Companies in technology development zones are exempt from corporate and value-added taxes until the end of 2013, and an exemption from all taxes is also provided for researchers working in these zones. For companies that remain outside this region, 40% of R&D expenditures are deducted from their income and corporate tax bases.

Within the scope of the Turkish Research Area Programme (TARAL) that was implemented by TÜBITAK in 2005, the initiatives of ‘Academic and applied R&D support’, ‘Public R&D support’, ‘Industry R&D support’, ‘Defence and space R&D support’, ‘Increasing science and technology awareness’ and ‘Scientist raising and improving’ were inaugurated.

Even though Turkey has fully participated in the sixth framework programme (FP6) of the European Union (EU) in the field of science and technology, the share of overall programme support for projects has remained quite low. The primary reasons for this situation are the weak relationship with the EU research network and inadequacies in the R&D infrastructure and number of researchers.

#### ***Targets and projects for the period 2007-2013***

Substantial increases in private sector R&D expenditures -as well as ever greater investment and support in the state budget for R&D- have been important in setting national targets for economic growth. As of 2002, 64.3% of total government R&D expenditures were directed to higher education institutions, while 7% and 28.7% respectively went to other public institutions and the private sector. By 2013, the private sector is projected to account for at least 60% of total R&D expenditures, with continuing public sector R&D investment and activity designed to be complementary to and supportive of the R&D activities of the private sector. However, to increase R&D expenditures at this scale will be meaningful only if a sufficient number of adequately qualified researchers is available to capably and efficiently use the created resources. As of 2002, 73.1% of total researchers were employed at universities, while 11.5% and 15.4% respectively were employed at other public institutions and in the private sector. It is a national objective to implement education and training policies to ensure an increase in the number of researchers and direct the majority of these researchers to employment in the private sector.

#### ***Main objectives: development axes***

A comprehensive national urban transportation strategy is in development, which will seek to implement measures sustainable and consistent with energy, environment, economics, housing and land-use policies. This strategy will be binding for the public sector and indicative for the private sector. Diversity and integration in urban transportation modes will be assured in a manner consistent with the original structure, dynamics and potentials of each city. In particular, pedestrian and bicycle transportation and public transportation modes will be prioritized and use of these modes will be encouraged to reflect the sustainability paradigm for urban transportation systems within the EU's harmonization process.

To increase national productivity and competitiveness, it will be ensured that R&D programmes are designed in a way to produce innovations and target relevant markets. The share of R&D expenditures in GDP and the share of the private sector in expenditures will be increased to support this goal, such that the basic objective of science and technology policy will be to increase the capability of the private sector to create innovation.

The R&D activities supported in universities will be designed such that they will contribute to the economic, social and cultural development of the country.

Patents granted and scientific articles published will carry much weight in academic promotion. Support will be given to improving the university-industry collaboration and the private sector's access to the human resources and infrastructure of R&D in universities. Infrastructures of technology development regions that bring universities and the private sector together will be completed and their specialization in the areas of priority will be encouraged.

Looking to the future, research into nanotechnology, biotechnology, new generation nuclear technologies, and hydrogen and fuel cell technologies will be given greater priority in industrial policy. The R&D activities that aim to transform local resources into value-added product, research in the field of health (primarily vaccination and anti-serums to enhance the quality of life), information and communication technologies, and defence and space technologies will also be supported as priority fields. International co-operative research activities in information and technology transfer will be undertaken, primarily with EU countries that have demonstrated competence in the relevant science and technologies.

Turkey aims to ensure that it becomes one of the important production centres in the medium and high technology sectors of automotive components, white goods, machinery and electronics. In the automotive industry, it is envisaged to create an industrial structure producing high value-added output with sustainable competitiveness, targeting exports primarily to developed markets and having a developed R&D capacity. In order to maintain sustainability of competitiveness in the automotive industry, competence achieved in the area of production will be extended, capabilities in the technology development and R&D areas will be improved and collaboration among the main and supplier industries -starting from the concept and design stage- will be developed. Moreover, participation of Turkish industry in co-operative EU programmes will be increased.

#### **Taxation**

The recent taxation measures imposed on vehicles in Turkey are of two types. The tax on an initial new vehicle sale is about 62% of the actual cost for a passenger vehicle and 24% for light-duty and heavy-duty commercial vehicles. The second tax -the engine vehicle tax- is paid yearly according to the engine cylinder volume and the vehicle age (i.e., lower than 1300 cm<sup>3</sup>, 1301-1600 cm<sup>3</sup>, 1601-1800 cm<sup>3</sup>, etc.; and vehicle age of 1-3 years, 4-6 years, etc.). The tax is lower for smaller engines and older vehicles. For buses and minibuses, the tax is independent of engine type or size; rather, the amount is dependent on seating capacity and vehicle age. Studies are under way to guide the preparation of new tax regulations that will be based on vehicular emission rates.

## 23.3

### **Research**

Research topics relevant to HEV technology are naturally a part of automotive R&D. With the growth of the HEV market, it was inevitable that scientific interest and industrial interest would become synergistic, developing joint projects over the years. Some of the major R&D players in the hybrid and electric vehicle arena are the Energy Institute of TÜBITAK MRC, OTAM, MEKAR and Mekatro.

#### **TÜBITAK MRC Energy Institute**

The Scientific and Technological Research Council of Turkey (TÜBITAK) was founded in Ankara in 1963 with the aim of developing, promoting, planning and co-ordinating R&D activities in the field of positive sciences consistent with priorities for Turkey's development.

Scientific research and technological development activities of TÜBITAK are conducted through its research institutes. Of these, Marmara Research Center in Gebze -founded 1972- is the oldest and largest research organization under TÜBITAK.

TÜBITAK MRC Energy Institute's vehicular technology research efforts emphasize:

- Advanced energy technologies: fuel cell technologies such as PEM and DSBHFC (Direct Sodium Borohydride Fuel Cell), hydrogen production and storage, combustion, gasification and gas cleaning and absorption cooling systems.
- Fuel technologies: analyses of solid fuels such as lignite, coke and pet coke; analyses of liquid fuels -especially gasoline, diesel, biodiesel and fuel oil- according to international standards; production of biodiesel.
- Vehicle technologies: system integration of HEV powertrains, modelling and simulation of electric vehicle or HEV technologies, HEV control systems,



Fig. 23.2 FOHEV light commercial hybrid electric vehicle development project. (Photo supplied by TÜBITAK MRC.)

rapid prototyping of control systems, electrical energy storage systems and battery technologies, and electric machines and drives for traction applications.

- Power electronics technologies: power electronics circuit design; programming, control, and signal processing; power system simulation and analysis; network analysis.

TÜBITAK MRC Energy Institute has several completed and ongoing projects on topics related to electric and hybrid vehicles and subcomponents. Some of these projects are: ELIT-1 series hybrid electric vehicle design and development project, FOHEV light commercial hybrid electric vehicle development project (figure 23.2), electric motor driver design and development project (figure 23.3),



Fig. 23.3 Prototype of electric motor and driver developed by TÜBITAK MRC Energy Institute.  
(Photos supplied by TÜBITAK MRC.)

battery development for hybrid electric vehicles, and emission reduction in transportation project. The Energy Institute is a centre of excellence for the hybrid electric vehicle and is supported in that capacity by the State Planning Organization. The Energy Institute hosts test facilities, including a chassis dynamometer, electric motor, battery and engine stands (figure 23.4).



Fig. 23.4 TÜBITAK MRC Energy Institute vehicle test laboratory. (Photos supplied by TÜBITAK MRC.)

### **OTAM**

The Automotive Technology Research and Development Center (OTAM) was established as a collaboration of the Automotive Manufacturers Organization (OSD), the Scientific and Technical Research Council of Turkey (TÜBITAK) and Istanbul Technical University (ITU). Its mission is to carry out pre-production R&D and product testing for the automotive industry and its suppliers in co-operation with Istanbul Technical University, and to institutionalise this co-operation. OTAM has been providing these services since September 2004, following completion of the first phase of upgrading of the automotive laboratories in the Automotive Division of Faculty of Mechanical Engineering at the university. OTAM has several test systems online, including a semi-anechoic acoustic test chamber, a chassis dynamometer for light-duty vehicles (figure 23.5), an engine dynamometer test system and an emission test system serving the automotive industry.



Fig. 23.5 Chassis dynamometer (left) and semi-anechoic acoustic test chamber (right) of the OTAM vehicle test laboratories. (Photos supplied by TÜBITAK MRC.)

### **MEKAR**

MEKAR is a mechatronics research group in the Department of Mechanical Engineering at Istanbul Technical University that consists of post-doctoral students and graduate students. It operates two research laboratories. The research at MEKAR -funded through governmental agencies and automotive companies- concentrates on automotive control and mechatronics, active safety control systems, internal combustion engine control, hardware-in-the-loop simulation and HEV modelling and control (figure 23.6).

### **Mekatro**

Mekatro is a R&D company that aims to marshal academic backgrounds into industrial efforts to produce innovative commercial products in the field of automotive mechatronics. This field includes: design of electromechanical actuators; design capability on rotary and linear brushless electric motors;



Fig. 23.6 Driving simulators developed by MEKAR. (Photos supplied by TÜBITAK MRC.)

development of control systems, including actuators, power electronic drives, control hardware, and software; real-time control system operation through a software/hardware interface, such as a digital signal processing; employment of rapid control prototyping methods to achieve flexible control system design capability; and design and prototyping of mechatronic systems. Some of their projects have included the ELIT-2 hybrid electric vehicle, a vehicle power seat and a sliding vehicle door.

## 23.4

### *Industry*

Turkey's automotive industry was established before the 1960s for the purpose of import substitution and its existence was maintained by primarily focusing on agricultural vehicles. The industry gained momentum with the establishment of Tofas A.S. and Oyak Renault A.S. in 1970. An automotive supply industry also began to develop in conjunction with the establishment of the main automotive industry. In the 1990s, it first qualified as an export-oriented competitive industry. Intense integration of global companies brought increased collaboration with Turkish partners to produce more vehicles in Turkey. This in turn improved process and quality to the extent that the manufacturing methods and technologies implemented in the domestic automotive industry are now equivalent to those seen at the international level as employed by the major companies. This is especially true as a result of the recent improvements in Turkey's R&D facilities and the increased capacity to support production methods and product development efforts in the automotive industry.

The Automotive Manufacturers Association (OSD) represents 18 manufacturers in Turkey (Anadolu Isuzu, Askam, B.M.C., Ford Otosan, Hattat, Honda Türkiye, Hyundai Assan, Karsan, M.A.N. Türkiye, M. Benz Türk, Otokar, Otoyol, Oyak Renault, Temsa, Tofas, Toyota, Türk Traktör and Uzel). All OSD members are in the list of 'Turkey's top 500 industrial enterprises 2006' in the annual report of the

Istanbul Chamber of Industry. The automotive industry accounted for 27.8% of Turkey's exports and 15.4% of its production-based sales in 2006.

The current situation of the Turkish automotive industry may be summarized thus: an annual manufacturing capacity of 1.2 million units; the largest bus manufacturer in the EU; the third largest light commercial vehicle manufacturer in the EU; the third largest truck market in the EU; the world's seventeenth largest automotive manufacturer; the world's twentieth largest economy, with the world's fifteenth largest population; and a light commercial vehicle market larger than that of eight EU member states (Czech Republic, Romania, Slovenia, Poland, Hungary, Slovak Republic, Estonia, Latvia and Lithuania).

The short-term target of Turkey's automotive industry is to reach an annual manufacturing capacity of 2 million vehicles and to become the world's tenth largest (and EU's third largest) vehicle manufacturer, while also being ranked in the EU's top five with respect to R&D expenditures.

Turkey considers the following to be among its strengths:

- Competitive power of the automotive sector.
- Strength of the automotive industry.
- Unsaturated domestic vehicle market.
- Compliance with EU customs union and technical legislation.
- Flexible production capacity with competitive costs.
- Competitive supplier industry.
- High quality standards in production.
- Well-trained, youthful, dynamic, enthusiastic and qualified labour force.
- Flexible and extended-time working possibilities.
- High level of technical and commercial skills.
- Prevalence of international management systems (quality, environment and security).
- Ability to comply with changing standards and conjuncture arrangements.
- Flexibility in production and delivery (even in small quantities).
- Foreign company partners.
- Advanced know-how level in the supplier industry.
- Existence of entrepreneurial teams.
- Relatively low costs (with respect to EU).
- Co-operative design work with the supplier industry on new vehicle projects.

Opportunities presented to the Turkish automotive industry include:

- Greater domestic demand due to positive economic indicators.
- New export markets in neighbouring countries and global markets.
- Studies for harmonization with EU legislation (e.g., block exemption provides opportunities for increased market share and strength in the EU aftermarket).

- Increased attractiveness for investors.

TAYSAD (the Association of Automotive Parts & Components Manufacturers) was established in 1978 and is the sole and most competent representative of the Turkish automotive supplier industry. With 239 members, TAYSAD represents 65% of the output of the automotive supplier industry and 70% of the industry's exports. Of TAYSAD's members, 85% operate in the Marmara region, 10% in the Aegean region and 5% in other regions of Turkey. The total of 239 TAYSAD members employ 55'000 people, but when including suppliers to TAYSAD members the total employed by this industry reaches approximately 120'000. The product range of TAYSAD members covers most kinds of automotive parts and is sufficiently diversified to support an 85-90% local parts ratio in domestically produced motor vehicles. The main product groups manufactured by TAYSAD members can be classified as follows:

- Complete engines and engine parts.
- Powertrains.
- Brake systems and parts.
- Hydraulic and pneumatic spare parts.
- Suspension parts.
- Safety spare parts.
- Foam and rubber parts.
- Chassis parts and spare parts.
- Forged and cast parts.
- Electrical equipment and illumination systems.
- Batteries.
- Automobile glass.
- Seats.

The Turkish automotive and supply industry has become an integrated part of the global automotive industry. Today, the Turkish automotive supply industry sells 90% of its production to the spare part market or for vehicles manufactured for the global markets. To complement the domestic manufacturing companies of an automotive supply industry with 35 years of experience, well known car brands also invest in Turkey. Automotive supply industry manufacturers have not only won the approval of their customer vehicle manufacturers, but have also won international technology and quality awards signalling their attainment of the ultimate level in quality and standards. The major factor in reaching this level has been the adaptation to a global competitive environment where collaborative activities, supportive investments and educational programmes have all proven effective.

The automotive supply industry manufactures parts and pieces for vehicles manufactured in Turkey and the global market, both for the original equipment and

after markets. Complying with international standards, the automotive supply industry performs manufacturing and sales processes in congruence with the terms of quality, price target, delivery details and so forth, as specified by its customers - the main industry companies.

Some of the automotive supply industry companies that function as co-designer for the vehicles manufactured in Turkey also earned the chance to become co-designers for the global production of the main industry companies, and thus have reached an important stage in know-how generation with their long years of expertise and knowledge.

## 23.5

### ***On the road***

The number of vehicles on the road is increasing in Turkey. Although the total vehicle fleet on the road numbers about 12 million units, only a few HEVs (Honda Civic hybrids) are among them. The number of road vehicles presented in table 23.1 is based on figures published by the Turkish Statistical Institute for the period of 2001-2006. Most passenger cars in Turkey are fuelled by gasoline, but

Table 23.1 Number of vehicles on the road in Turkey for the period 2001-2006.

	2001	2002	2003	2004	2005	2006
Passenger vehicle	4'534'624	4'600'141	4'700'343	5'400'440	5'772'745	6'140'992
Minibus	239'375	241'700	245'394	318'954	338'539	357'523
Bus	119'305	120'097	123'500	152'712	163'390	175'949
Light-duty truck	833'130	875'381	973'457	1'259'867	1'475'057	1'695'624
Truck	396'463	399'025	405'034	647'420	676'929	709'535
Motorbike	1'031'208	1'046'907	1'073'415	1'218'677	1'441'066	1'822'831
Tractor	n.a.	n.a.	n.a.	1'210'283	1'247'767	1'290'679
Others	188'508	191'793	198'444	28'004	30'333	34'260
<b>Total</b>	<b>7'342'613</b>	<b>7'475'044</b>	<b>7'719'587</b>	<b>10'236'357</b>	<b>11'145'826</b>	<b>12'227'393</b>

*Passenger vehicle: Vehicle with a designated seating capacity of 8 or less.*

*Minibus: Vehicle with a designated seating capacity of 9 to 15.*

*Bus: Vehicle with a designated seating capacity greater than 16.*

*Light-duty truck: Vehicle designated for the transportation of equipment with a maximum gross vehicle mass of 3'500 kg.*

*Truck: Vehicle designated for the transportation of equipment with a gross vehicle mass of more than 3'500 kg.*

*Motorbike: Vehicles designated to travel with no more than three wheels contacting the ground.*

*Tractor: Agricultural vehicle not used for commercial transportation.*

*Others: Vehicles designated for the transportation of passengers or equipment, such as an ambulance, fire fighting vehicle, towing truck and hearse.*

*n.a.: not available*

the proportion of diesel passenger vehicles is increasing. Road vehicle populations by fuel type are presented in table 23.2. Sales of electric two-wheelers have recently begun, but these have not yet lead to significant numbers of these vehicles on the road.

Table 23.2 Road motor vehicles\* in Turkey by type of fuel used, for the period 2001-2006. (Source: Turkish Statistical Institute.)

	2001	2002	2003	2004	2005	2006
Gasoline vehicle	4'981'422	5'044'259	5'130'400	4'366'622	4'175'709	4'122'134
Diesel vehicle	1'141'736	1'192'084	1'317'328	2'198'490	2'635'509	3'121'797
LPG vehicle	n.a.	n.a.	n.a.	818'127	1'297'542	1'568'158
Other	n.a.	n.a.	n.a.	396'154	317'900	267'534
<b>Total</b>	<b>6'123'158</b>	<b>6'236'343</b>	<b>6'447'728</b>	<b>7'779'393</b>	<b>8'426'660</b>	<b>9'079'623</b>

\* Motorcycles, special purpose vehicles and road construction and work machinery and trucks are excluded.

n.a.: not available

## 23.6 Outlook

In the last decade, Turkey introduced several prototype HEVs. The first HEV prototype ELIT-1 was a series hybrid developed by the TÜBITAK and Tofas Automotive Factory in 2003. Ford Otosan presented a split-drive light-duty truck FOHEV-1 in 2006. This prototype was presented at the Hannover Fair in 2007. At the International Commercial Vehicle Exhibition -held in November 2007 in Istanbul- Otokar exhibited its Doruk 160LE Hibra hybrid electric urban bus prototype.

The hybrid vehicle market in Turkey is in its beginning phase. The Honda Civic hybrid is the first commercial hybrid offered for sale in the Turkish automotive market. Toyota recently announced that they are considering selling hybrids in Turkey, but market trends and sales figures are not clear for 2007. Sales of electric two-wheelers have recently begun, but these have not yet achieved significant market penetration.

Public financial resources allocated for R&D have been significantly increased within the last decade. Because of its importance as a sector, automotive research is a key element of the government-supported R&D programme. The greening of transportation is being realized in Turkey by means of several supporting instruments.

Within the scope of the Turkish Research Area Programme (TARAL) that was implemented by TÜBITAK in 2005, the programmes of 'Academic and applied

R&D support’, ‘Public R&D support’, ‘Industry R&D support’, ‘Defence and space R&D support’, ‘Increasing science and technology awareness’ and ‘Scientist raising and improving’ have been started.

TÜBITAK’s major endeavour in the coming years will involve the National Automotive Technology Platform, a new programme to support the foundation of technology platforms in Turkey, for which the Council will support half the expenses. It will partner industry, trade organizations, universities, research institutions and the public sector, with the objective of jointly determining a vision for the Turkish automotive industry and establishing the means for the strategic research areas (SRAs) to achieve this vision. Pre-competitive R&D projects at both the national and Europe-wide scale will be awarded based on these SRAs, and activities will seek to create awareness of Turkey’s vision and goals across all European technology platforms. The vision and the SRAs will be reviewed and possibly realigned on an annual basis.

As of 2002, 64.3% of total R&D expenditures were directed to higher education institutions, while 7% and 28.7% were made by other public institutions and the private sector, respectively. As of 2013, the private sector is projected to realize at least 60% of total R&D expenditures. In this framework, supports to be provided by the public sector will be designed in a way to increase the R&D activities of the private sector.

Toward creating a sustainable urban transportation system within the EU harmonization process, pedestrian and bicycle transportation and public transportation modes will be prioritized and the use of these modes will be encouraged.

Turkey will ensure that it becomes one of the important production centres in the medium and high technology sectors of automotive development. In the automotive industry, it is envisaged to create an industrial structure producing high value-added goods with sustainable competitiveness, targeting exportation primarily to developed markets and having a developed R&D capacity. In order to maintain sustainability of competitiveness in the automotive industry, competence achieved in the area of production will be continued, capabilities in technology development and R&D areas will be improved, and collaboration among the main and supplier industries -starting from the concept and design stage- will be further developed.

According to the current situation and the presented short-term policies, an increase is expected in the number of R&D projects related to electric vehicles, hybrid vehicles, fuel cells, energy storage and alternative fuels. Also -with the increased awareness about clean vehicles and the environment- it is expected that more hybrids will be seen at the market and on the roads.

## 23.7

### ***Benefits of participation***

Turkey is a new member of the IEA Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV).

Participation in IA-HEV activities offers Turkey the following advantages:

- Exchanging information among international-level experts to provide an international insight and enable better planning of national R&D programmes.
- Evaluating a member country's governmental implementation plans in order to check/organise national standardization and regulatory actions on HEV technologies.
- Obtaining information on the latest developments in member countries, which enables sharing of experiences based on ongoing and completed programme results.
- Engaging in informal personal contacts to create options for potential collaborations in the fields of joint projects.
- Building scientific networks for new ideas and projects among international experts.

## 23.8

### ***Further information***

Further information regarding the above topics can be obtained from the following websites:

- [www.dpt.gov.tr/ing/](http://www.dpt.gov.tr/ing/) (in English and Turkish).  
Turkish Republic Prime Ministry State Planning Organization.
- [www.mam.gov.tr/eng/institutes/ee/index.html](http://www.mam.gov.tr/eng/institutes/ee/index.html) (in English and Turkish).  
TÜBITAK Marmara Research Centre Energy Institute.
- <http://mekar.itu.edu.tr> (in English and Turkish).  
Mechatronics research group at Istanbul Technical University.
- [www.mekatrol.com](http://www.mekatrol.com) (in Turkish).  
Research and development company in the field of automotive mechatronics.
- [www.osd.org.tr/index-english.htm](http://www.osd.org.tr/index-english.htm) (in English and Turkish).  
Automotive Manufacturers Association.
- [www.otam.itu.edu.tr/Eindex.php](http://www.otam.itu.edu.tr/Eindex.php) (in English and Turkish).  
Automotive Technologies Research & Development Company.
- [www.taysad.org.tr](http://www.taysad.org.tr) (in English and Turkish).  
Association of Automotive Parts & Components Manufacturers.
- [www.turkstat.gov.tr](http://www.turkstat.gov.tr) (in English and Turkish).  
Turkish Statistical Institute.
- [www.ubak.gov.tr/ubak/en/index.php](http://www.ubak.gov.tr/ubak/en/index.php) (in English and Turkish).  
Republic of Turkey, Ministry of Transport.

## 24

### ***United States***

#### **24.1**

##### ***Introduction***

The United States -through the U.S. Department of Energy (DOE)- actively supports research and development (R&D) on innovative vehicle technologies. Government-industry partnerships for the advancement of high efficiency vehicles envision affordable full-function cars and trucks, reduced import of oil and fewer harmful emissions. Energy efficiency appears to draw broad popular support in the United States.

#### **24.2**

##### ***Policies and legislation***

###### **24.2.1**

###### ***Federal***

The United States is committed to developing alternative fuels and the infrastructure for their commercialization. The DOE works with industry to develop and deploy advanced transportation technologies accordingly. For example, DOE's Clean Cities Program supports public-private partnerships that would deploy alternative fuel vehicles (AFVs) and build supporting infrastructure. The provisions of the Energy Policy Act of 1992 (EPACT) included a requirement that state and federal government fleets and the providers of alternative fuels (including electric utilities, natural gas utilities and other producers/suppliers) convert an increasing percentage of their vehicle fleets to AFVs over time. A 2005 amendment to EPACT included changes to the Corporate Average Fuel Economy (CAFE) program by extending the existing manufacturing incentives program for AFVs and by authorizing appropriations for fiscal years 2006 through 2010 to implement and enforce the CAFE standards. Also, automakers now have to label new flexible fuel vehicles in the United States to remind buyers that they can use either gasoline or an ethanol blend. A limited federal tax credit was made available for light-duty HEVs placed in service between December 31, 2005, and January 1, 2011. The tax credits -to expire on January 1, 2010- for medium- and heavy-duty vehicles are capped at 60'000 vehicles per manufacturer, beyond which -over the next four calendar quarters- the vehicles only qualify for a decreasing percentage of the full tax credit. Toyota had already reached its cap in 2006 and by October 1, 2007, there was no more tax credit available for Toyota. However, differing amounts of tax credits were still available for other manufacturers in October 2007.

The U.S. National Highway Traffic Safety Administration (NHTSA) has developed special safety standards for Neighbourhood Electric Vehicles (NEVs), which are defined as electric powered motor vehicles with three or more wheels in contact with the ground, a fully enclosed passenger compartment, a vehicle curb weight of less than 2'000 pounds and a top operating speed of 40 miles per hour or less. A Federal Motor Vehicle Safety Standard (FMVSS) -number 500- requires such vehicles to incorporate certain devices (e.g., three-point restraints, safety glass, 3-mph bumpers, rearview mirrors, horns, parking brakes and lighting, and reflector equipment) to appropriately address safety issues. Some of the states have laws that allow certain NEVs on their city streets.

Additional impetus for vehicle energy efficiency improvements comes from the Advanced Energy Initiative (AEI) announced by President Bush in 2006, which provides for a 22% increase in funding for clean energy technology research. It outlines the future U.S. vision for the fuelling of vehicles and the powering of homes and businesses. The near-term solutions are primarily regulatory (e.g., Corporate Average Fuel Economy standards, tax incentives and a switch to alternative fuels like ethanol), with emphasis on cellulosic production from agricultural waste and purpose-grown biomass (and -later on- hydrogen). The long-term solutions require accelerating efforts to develop radically improved technologies for plug-in hybrid electric vehicles (PHEVs).

In December 2007, an energy bill raising fuel economy standards by about 40% was signed into law. Besides requiring cars and light trucks to average 35 mpg by 2020, the energy bill would allow automakers to trade fuel economy credits among fleets (and with others), extend fuel economy credits for some automakers, and direct regulators to devise separate standards for 'work trucks' and for medium and heavy trucks. The fuel economy provisions would start in 2011.

A new Environmental Protection Administration (EPA) methodology of estimating fuel economy for cars and trucks was implemented in 2007. Under it, most vehicles would rate a lower miles per gallon (mpg) estimate, but gasoline electric hybrids can rate less by up to 30%. The city mileage rating for the Toyota Prius drops from 60 mpg to 45 mpg.

A federal court in California halted the state's effort to limit greenhouse gas emissions from new cars and trucks, ruling that under the Clean Air Act, California cannot enforce its rules without federal approval. The U.S. Supreme Court later ruled that the EPA could regulate auto emissions of gases -such as carbon dioxide- that potentially cause global warming. The EPA is writing up broad new rules to limit fuel consumption to implement the '20-in-10' plan to reduce gasoline consumption by 20% in 10 years.

EPA adopted regulations in February 2007, requiring automakers to meet new limits on emissions of toxic compounds (for 2010-2015 model years). It also issued guidelines to warn drivers regarding the care of diesel emissions systems that inject urea (an ammonia based chemical) into the exhaust system.

Under a rule change, automakers would have to re-label some of their vehicles - currently called trucks- as cars for fuel economy purposes. The objective is to close the so-called 'SUV loophole' in the CAFE program, from 1975.

#### **24.2.2**

##### ***State***

As shown in table 24.1 (on the next page), at least 24 U.S. states maintain regulations that provide for HEV incentives - including offering a high occupancy vehicle (HOV) privilege, waiving emissions inspection, providing tax credits/ rebates, or offering purchase directives. Some attempts have been made to bring about state-level adoptions of California-like clean air standards, which would require automakers to reduce greenhouse gas emissions from their vehicles by 30% before 2016. Currently, there are 13 such states - Connecticut, Florida, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont and Washington.

Table 24.1 2007 status of U.S. state-level incentives to purchase hybrid electric vehicles.  
 (Source: Table developed from information at the Electric Drive Transportation Association website [www.electricdrive.org](http://www.electricdrive.org).)

State	Law/Date	Waived			State-level purchase directive
		HOV privilege	emissions inspection	Tax/ Rebates	
Arizona	SB 1429 (6/01)	X			
California	Chapter 737 (10/03)		X		
Colorado	SB 91 (4/03), HB 1067 (5/00)	X		X	
Connecticut	Public Act 04-231 (10/04)			X	
Delaware	SB 17 (04/07)		X		
Florida	Chapter 2003-45 (5/04)	X			
Georgia	HB 719 (5/03)	X			
Maine	MRSA Title 36 §1752 and §1760-79			X	
Maryland	HB 61 (5/03), HB 20 (5/00), Chapter 111 (04/07)		X	X	
Michigan	HB 5443 (6/00)			X	
Minnesota	SB 2675 (4/02)			X	
Nevada	Chapter 231 (5/07)	X			
New Jersey	HB 2351 (1/04), SB 16/HB 2586 (5/00)		X		
New Mexico	SB 86 (3/04), SB 18 (3/02)			X	
New York	AB 11749 (7/02), EO 111 (6/01), Chapter 413 (11/96)			X	
Oklahoma	HB 1085 (5/03)		X		
Oregon	HB 2041 (7/03)		X		
Pennsylvania	Act 178 of 2004			X	
Tennessee	Chapter 532 (6/07)			X	
Texas	HB 2293, HB 3319 (06/07)		X	X	
Utah	Utah state tax form TC-40V		X		
Virginia	HB 887 (4/04)	X			
Washington	Chapter 285 (4/02), Chapter 24 (3/02)		X		X
Wisconsin	HB 155 (Act 183) (4/04)			X	

## 24.3

### ***Research***

#### 24.3.1

##### ***Barriers***

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

##### **Cost**

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

- Lightweight body construction, compression ignition direct injection (CIDI) engines, batteries and electronic control systems all increase vehicle cost.
- Emission control systems for high efficiency direct injection gasoline and diesel engines -when developed- would be more expensive than current systems.
- None of the concept cars in their present forms represent an affordable set of components compatible with similar mission vehicles, although the prices could come down for large-scale manufacturing.

##### **Emissions standards**

The U.S. EPA Tier 2 NO<sub>x</sub> and particulate matter standards (being phased in) are significantly more stringent than prior standards and may pose a barrier by precluding an early introduction and widespread use in the United States of certain advanced engine technologies for passenger cars.

##### **Fuel issues**

Successful introduction of either CIDI engines, spark ignition direct injection (SIDI) engines or fuel cells will be critically dependent on widespread availability of suitable fuels. The large capital expenditures and long lead times required to manufacture and distribute a significantly modified fuel 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 be cost-effective for the petroleum companies or mandated by regulation. A 2001 U.S. EPA regulation required refiners to produce highway diesel fuel with a maximum sulphur content of 15 parts per million by June 1, 2006, and represented significant progress. However, the development of cost-competitive combustion and emission control systems to perform and endure at Tier 2 levels -even with 15 ppm sulphur fuel- remains a challenge. For automotive fuel cell power plants,

the most efficient and lowest emission system involves direct hydrogen storage on board of the vehicle, which requires major infrastructure changes for the energy industry.

#### 24.3.2

##### ***Enabling technologies***

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

##### **Hydrogen and fuel cells**

A polymer electrolyte membrane (PEM) fuel cell converts chemical energy into electricity and heat through the electrochemical reaction of hydrogen and oxygen. The DOE Hydrogen Program conducts basic and applied research, technology development and learning demonstrations, and education/outreach activities; focuses on addressing key technical challenges for fuel cells and hydrogen production, delivery and storage, as well as institutional barriers; works with public- and private-sector partners, including automotive and energy companies, manufacturers, utilities, government agencies, universities, laboratories and other stakeholders; and integrates hydrogen activities for various federal agencies.

In fiscal year (FY) 2008, Congress appropriated US\$ 280 million for the Hydrogen Fuel Initiative, representing an increase of US\$ 12 million over FY 2007. The program works with industry through such partnerships as the FreedomCAR and Fuel Partnership, which includes DOE, the U.S. Council for Automotive Research (whose members are Ford Motor Company, General Motors Corporation and Chrysler LLC) and five major energy companies (BP America, Chevron, ConocoPhillips, ExxonMobil and Shell). The partnership examines the pre-competitive, high-risk research needed to develop the technologies for deploying vehicles and infrastructure that will reduce the nation's dependence on imported oil and minimise harmful emissions. Additional information on the program appears in the 2007 annual progress report (available at [www.hydrogen.energy.gov/annual\\_progress07.html](http://www.hydrogen.energy.gov/annual_progress07.html)). Some recent highlights include:

- The fuel cell sub-program has made significant advances in increasing the durability of membranes and catalysts. DuPont has developed a membrane that operates for almost 5'000 hours (equivalent to 150'000 miles of vehicle operation) with combined humidity and voltage cycling.

- Considerable progress was made toward further reducing the cost of hydrogen produced on-site from natural gas. H2Gen completed the fabrication of its first distributed (565 kg/day) hydrogen generator. The projected cost of hydrogen from this system at a refuelling site -at large production volumes (500 units/year)- approaches the 2010 target of US\$ 2.50 per gallon gasoline equivalent of hydrogen.
- Progress was made in physical storage systems with the successful demonstration of a 'cryo-compressed' tank concept aboard a hydrogen fuelled vehicle. The cryo-compressed tank system capacity surpassed the 2007 gravimetric target of 4.5 wt-% and was within 20% of the volumetric target of 36 g/l.
- 14 new patents were issued for discoveries or technologies developed in DOE Hydrogen Program projects; 54 applications were filed or were being awarded.
- In addition:
  - Toyota Motor Corp. announced it obtained a 25% higher fuel efficiency from its latest generation of hydrogen powered fuel cell vehicles from before. It doubled the hydrogen compression in the four storage tanks, used denser fuel cell stacks and used a better power management scheme.
  - DOE is partnering with carmakers and energy companies in a program to evaluate the technical data from fuel cell vehicle validation projects, which indicate significantly improved fuel cell durability.

### **Advanced energy storage technologies**

For successful commercialization of EVs, HEVs, PHEVs and extended-range electric vehicles (EREVs), the battery system must meet several requirements simultaneously. For EVs, these include high energy; for HEVs, high power; for PHEVs (and EREVs), both high energy and high power; and for all, rechargeability, long life, safety and low cost. To cover all of those, the three primary battery research areas funded by DOE include (1) the developer program (performed in close collaboration with the industry through the United States Advanced Battery Consortium - USABC), which assesses, benchmarks and develops advanced batteries for vehicles, (2) applied battery research, which provides near-term assistance to high-power battery developers to overcome the barriers (calendar life, abuse tolerance, low-temperature performance and cost) associated with lithium-ion batteries for light- and heavy-duty vehicles, and (3) focused fundamental research, which involves research into the next generation of battery technologies for vehicle applications. Recent significant accomplishments of DOE-funded energy storage research included:

- Battery energy, power, life and cost targets for short- and long-term commercialization of plug-in hybrid electric vehicles were defined by the Freedom-CAR Electrochemical Energy Storage Tech Team, with analysis support from National Renewable Energy Laboratory (NREL) and Argonne National Laboratory (ANL). Subsequently, DOE announced putting US\$ 30 million

- into the effort to bring plug-in hybrid vehicles to market, through matching grants for projects aimed at improving battery performance to those levels.
- Advanced lithium-ion battery materials developed at ANL -under the DOE's Advanced Technology Development program- are now being licensed for use in commercial lithium-ion cells.
  - Scientists at Idaho National Laboratory (INL) successfully completed stage 2 of a large study to characterise the long-term performance of lithium-ion cells that have undergone cell formation under various conditions.
  - Research results are providing the fundamental understanding necessary to design thermally stable lithium-nickel-manganese oxide electrodes for advanced lithium-ion batteries for HEVs.
  - In addition:
    - The Electric Power Research Institute (EPRI), Chrysler and Southern California Edison (SCE) are partnering in an accelerated testing program of advanced battery technologies in PHEV applications. Its primary objective is to determine PHEV Sprinter environmental benefits and lifecycle operating costs. It would be conducted in two phases: a battery evaluation phase to assess the performance and cycle life of selected batteries under Sprinter PHEV test profiles and a vehicle testing phase. EPRI currently has all four phase 1 prototype vehicles in operation - two in California, one in Kansas City (at the Kansas City Transit Authority) and one in New York City (at the New York Times). As part of the accelerated bench testing, two battery types are being field-tested. The first -using the Varta NiMH chemistry- reached a cycle equivalent to 125'000 PHEV miles but underwent power degradation before reaching the desired life. The second - a Saft lithium-ion battery- reached equivalent to 130'000 miles, has similar capacity and power degradation, and is expected to meet the life cycle requirements.
    - Nissan Motor Co., NEC Corp. and a NEC affiliate will set up a venture (Automotive Energy Supply Corp.) to make lithium-ion batteries for electric and hybrid vehicles, starting in 2009.
    - In early May, Mitsubishi Motors Corp., trading house Mitsubishi Corp. and battery maker GS Yuasa Corp. agreed to create a company to make large-capacity lithium-ion batteries specifically for EVs. Production is targeted to begin in 2009.
    - General Motors awarded four advanced-development lithium-ion battery contracts for PHEV and EREV applications, both tentatively scheduled for production in 2010.
    - The U.S. Council for Automotive Research (USCAR) awarded a contract to OnTo Technology LLC of Bend, Oregon, for R&D into methods of recycling NiMH and lithium-ion batteries.

- Firefly Energy, Inc., of Peoria, Illinois, said it has developed lead acid batteries using lightweight and porous carbon-graphite foam instead of lead metallic grid plates, thus reducing weight, increasing capacity and prolonging battery life.
- Ener1 -an alternative energy development company owned partly by Delphi- said that it will bring its automotive lithium-ion battery to market by the end of 2008. The United States Advanced Battery Consortium awarded Ener1's subsidiary EnerDel a US\$ 6.5 million contract to conduct battery life testing.
- Mercedes awarded Maxwell Technology a contract to design and produce ultracapacitors for an HEV drivetrain program incorporating a regeneration system that enables it to increase fuel efficiency.

### **Vehicle systems research**

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

### **Advanced combustion engines R&D**

This activity is focused on removing critical technical barriers to the commercialization of high efficiency, advanced internal combustion engines 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 minimise in-cylinder formation of emissions and after-treatment technologies that further reduce exhaust emissions and convert engine waste heat to electricity by using solid state devices. Work is done in collaboration with industry, national laboratories and universities.

- Lawrence Livermore National Laboratory (LLNL) has demonstrated engine analysis tools that can predict Homogeneous Charge Compression Ignition (HCCI) and Premixed Charge Compression Ignition (PCCI) (i.e., partially stratified) combustion and emissions with unequalled accuracy, within a reasonable computational time.
- Researchers at Sandia National Laboratories have completed a comprehensive investigation into the effects of increased intake boost pressure (through turbo charging) on emissions and combustion performance for two promising

advanced engine combustion systems. The information is critical to developing high efficiency, clean engine technologies with full load range capabilities.

- A peak thermal efficiency of 42% was demonstrated at Oak Ridge National Laboratory (ORNL) on a GM 1.9-litre diesel engine and a modified Mercedes 1.7-litre diesel engine.
- Pacific Northwest National Laboratory improved the performance for barium oxide (BaO) -based lean NO<sub>x</sub> trap catalyst materials via the use of ceria as a support material instead of alumina.
- In addition:
  - GM demonstrated a 15% improvement in fuel efficiency in a Saturn Aura and Opel Vectra equipped with the HCCI technology.
  - In collaboration with the DOE, Cummins developed a clean and efficient light-duty diesel engine that will be used in a 2010 Chrysler vehicle.
  - Cummins analytically characterized dual-combustion modes with an advanced fuel injection system, demonstrating a 12% improvement in efficiency, a 96% reduction in NO<sub>x</sub> and a 54% reduction in soot compared to a baseline engine.
  - Starting in late 2009, most diesel engines in mid-sized cars, heavy-duty pickups, SUVs and heavy-duty trucks will use urea. Injecting urea -by a process also called Selective Catalytic Reduction- can reduce NO<sub>x</sub> by up to 90%.
  - BSST LLC and GM started developing thermo-electric generators to directly convert engine waste heat to electricity.

#### **Lightweight materials**

The reduction of vehicle mass through the use of improved design, lightweight materials and new manufacturing techniques is key to meeting fuel economy targets for commercially viable FCVs, EVs, HEVs, PHEVs and EREVs. The DOE lightweight materials technology area focuses on the development and validation of advanced lightweight material technologies to significantly reduce automotive vehicle body and chassis weight without compromising other attributes (e.g., safety, performance, recyclability and cost). It pursues research in areas of cost reduction, manufacturability, design data and test methodologies, joining, and recycling and repair. Priority lightweight materials include aluminium, magnesium, titanium and carbon fibre composites.

Recent significant accomplishments in this area included the following:

- ORNL developed the baseline technology necessary to use lignin (a by-product of the paper-making process) as a very low-cost feedstock for carbon-fibre precursors. MeadWestvaco Corporation applied solvent-extraction techniques to purify hardwood lignin and provided ORNL with a 1 kg sample.

ORNL successfully melt-spun and wound the organic-purified lignin as a 12-filament tow without the need for any additives.

- The High-Integrity Magnesium Automotive Castings (HI-MAC) project investigated low-pressure permanent mould, squeeze casting and emerging casting processes (Ablation and T-Mag), and developed technologies critical to increased cast-magnesium (Mg) automotive applications, including microstructure control, porosity and hot-tearing computer models, thermal treatments and controlled mould filling. The new casting processes provide industry with higher-integrity Mg automotive castings for such applications as control arms, knuckles and wheels that may enable weight savings of 35-60%. They reduce Mg-component processing and facility costs and enable the production of high-integrity Mg castings.

#### **Advanced power electronics and electrical machines**

This activity develops new technologies for power electronics and electric machinery, which includes motors, inverters/converters, sensors, control systems and other interface electronics. It is divided into power electronics, electric motors/generators, and thermal control and integration sub-activities. A primary research focus is on the thermal control of inverters and motors with two-phase cooling technologies. Recent significant accomplishments included:

- ORNL engineers developed and tested a ‘floating loop’ integrated cooling system for advanced vehicle applications -integrating the passenger air conditioning system- to cool the power electronics and electric motors, independently of the air conditioning compressor - and needing minimal power to operate.
- A team of Penn State researchers integrated commercial flat-panel-display glass and glass-ceramic materials into high-energy-density capacitors for the DC electric bus on HEVs. These new capacitors have excellent performance characteristics at and above 200°C, which is almost double the temperature limit of current capacitors in traction drive inverters.

## **24.4**

### ***Industry***

In the past, various U.S. manufacturers have made battery EVs available to consumers, as summarized in prior IEA reports. (Other current products include hybrid buses, industrial vehicles and bike-scooters. Several companies manufacture and sell electric bicycles, including U.S.-Prodrive and Zap. More information on each of these products is available at the Electric Drive Transportation Association EDTA website.) The battery technologies have included lead acid, nickel metal hydride, nickel cadmium and lithium-ion. More recently, only HEVs have entered the market in significant numbers, just reaching a cumulative figure of one million. An overview of currently available HEV products appears in table 24.2.

Table 24.2 2007 overview of HEVs, PHEVs and EREVs in the United States.  
 (Source: Electric Drive Transportation Association, website [www.electricdrive.org](http://www.electricdrive.org).)

<b>Manufacturer</b>	<b>On the market in 2007</b>	<b>Upcoming</b>
Chrysler	--	Dodge Durango Dodge Ram TTR
Ford	Escape hybrid Mariner hybrid	Fusion hybrid Milan hybrid
General Motors	Chevrolet Malibu hybrid Chevrolet Tahoe hybrid GMC Yukon hybrid Saturn Aura Green Line Saturn Vue Green Line	Cadillac Escalade Chevrolet Volt (EREV) GMC Sierra hybrid GMC Silverado hybrid Saturn Vue hybrid Saturn Vue PHEV
Honda	Accord hybrid Civic hybrid	--
Lexus	GS 450h LS 600h RX 400h	--
Mazda	Tribute hybrid	--
Mercury	Mariner hybrid	--
Toyota	Highlander hybrid Prius	--



Fig. 24.1 2008 Toyota Highlander hybrid. (Photo courtesy Toyota.)

The following summarizes 2007 industry highlights related to EVs and HEVs.

### **General Motors**

Fuel cell vehicles:

- The General Motors (GM) fuel cell stack, currently being readied for production, is said to fit in the space of a four-cylinder engine. GM transferred the work of more than 500 fuel cell experts from advanced development laboratories to core engineering functions to prepare this technology for future production.
- GM initiated its 'Project Driveaway' to obtain data on durability/performance of 100 fuel cell powered Equinox crossovers, equipped with its fourth-generation fuel cell system. The program would begin in early 2008 in New York, Washington and Los Angeles. The fuel cell and batteries together deliver a power of 120 kW and have a range of 150 miles. The vehicle can run at a temperature as low as 5°F.

Electric vehicles:

- At the 2007 Detroit auto show, GM unveiled the Chevrolet Volt EREV. The Volt is the first vehicle to be built on GM's E-Flex electric vehicle architecture. GM's E-Flex system is an all-electric vehicle architecture that consists of a common drivetrain system that uses electricity created and stored aboard the vehicle in several ways. Production engineering has been initiated for two variants of the E-Flex system.
- The Volt EREV variant uses electricity stored in a lithium-ion battery pack with 40 miles of electric drive range to power the wheels at all speeds. For longer trips, the Volt's onboard engine-generator set (range-extender) -powered by E85- generates additional electricity to power the car beyond the 300-mile range. GM's internal target for production is 2010, dependent upon the availability of the lithium-ion battery.



Fig. 24.2 Chevrolet Volt concept electric vehicle. (Photo courtesy General Motors.)

- The fuel cell electric vehicle (FCEV) variant is built on the same architecture as the EREV variant and uses many of the same components. It couples GM's next generation fuel cell system with a smaller lithium-ion battery that enables up to 300 miles of electric driving range. GM awarded contracts for the advanced development of lithium-ion batteries for the E-Flex system to Compact Power, Inc. (a wholly owned subsidiary of Korea-based LG Chem), Berlin-based Continental Automotive Systems and A123Systems of Boston, Massachusetts.

#### Plug-in hybrid electric vehicles:

- GM has also begun work on a Saturn Vue plug-in hybrid production vehicle. The 2008 Saturn Vue crossover will be its first front wheel drive vehicle with a two-mode hybrid transmission. It can be driven at low speeds on electric power alone. A mild hybrid version will also be available, delivering about a 20% improvement in fuel economy.

#### Hybrid electric vehicles:

- The Chevrolet Malibu hybrid sedan, which uses a nickel-metal battery pack from Cobasys LLC, in partnership with A123Systems, has become commercially available.
- GM announced that its 2008 Chevrolet Tahoe and GMC Yukon hybrids, powered by its two-mode hybrid system, will deliver up to 30% gain in overall fuel economy over conventional models - mostly from the two-mode transmission. These hybrids have a four-speed automatic transmission with two electric motors and two electrically variable modes of operation. In the first mode, they can run on electric power alone at speeds of up to 30 mph, and then the V-8 gasoline engine takes over. In the second mode -at highway speeds- the electric motors assist the gasoline engine. Both vehicles use GM's active fuel management system, which shuts down four of the eight cylinders.



Fig. 24.3 2008 GMC Sierra hybrid. (Photo courtesy General Motors.)

- Orders were placed for 1'732 GM-Allison hybrid buses from public transportation systems in Washington, D.C.; Philadelphia, Pennsylvania; and Minneapolis-St. Paul, Minnesota.

### **Ford**

Fuel cell vehicles:

- Ford Motor Co. announced it has a fleet of about 30 fuel cell powered Focus FCEVs with a range of about 200 miles operating in the United States, Canada and Germany. Some have logged close to 50'000 miles, twice that of the earlier generation FCVs. Ford stated it intends to raise fuel cell performance with the demonstration of the HySeries Edge, which combines a hydrogen fuel cell with lithium-ion batteries. It would deliver the equivalent of 41 mpg and a range of 225 miles.
- Ford announced it has been testing a Ford Edge powered by a fuel cell. It generates electricity to power a motor and recharge its battery pack. This powertrain could be in limited production within a decade.

Fuel cell vehicle/Plug-in hybrid electric vehicle:

- At the 2007 Detroit auto show, Ford unveiled the Airstream PHEV, its compact concept crossover vehicle. Its hydrogen fuel cell generated electricity goes into a lithium-ion battery pack -instead of the electric motor- enabling it to operate at very cold temperatures, when a regular fuel cell vehicle could encounter difficulty.
- Ford announced it plans a plug-in Escape hybrid powered by lithium-ion batteries. Both the mild hybrid and the plug-in system could be ready for sale within three years.



Fig. 24.4 2008 Ford Escape hybrid. (Picture courtesy Ford.)

### Hybrid electric vehicles:

- Ford announced it expects its hybrid vehicle program to become profitable by the end of 2008. It plans to double its hybrid offerings to four models. The Ford Fusion and Mercury Milan cars will join the hybrid Escape and Mercury Mariner crossovers. The Fusion and Milan hybrids are expected to go into production in late 2008.

### ***Others***

#### Hybrid electric vehicles:

- Toyota Motor Corp. said it has sold more than 1 million hybrid vehicles since 2000, more than half of them in the United States. In 2007, Toyota offered the first incentives on its Prius hatchback.
- Honda Motor Co. announced it is aiming for annual sales of 100'000 units in North America for its next generation hybrid, which will be priced below the Honda Civic hybrid. The car will enter the market in 2009 and will be a dedicated hybrid with no gasoline version. Honda plans worldwide sales of 200'000 units for the new hybrid.
- Nissan announced it will launch an Altima hybrid in the United States in 2008, using technology licensed from Toyota. It said it will sell a hybrid car using its own technology in the United States and Japan in 2010.
- Daimler AG and BMW AG have collaborated on a mild hybrid powertrain with an electric motor placed between the engine and transmission. The vehicle is expected to cost less than the two-mode hybrid.

#### Electric vehicles:

- Tesla Motors opened its Michigan Technical Center in Rochester Hills, Michigan, the company's second U.S. facility. The first project scheduled is the WhiteStar, a four-door, five-passenger sedan planned for production around 2009. It also announced it will sell its vehicles through factory-owned stores rather than franchised dealerships.
- Mitsubishi Motors Corp. announced it may launch the i-MiEV -an EV powered by a lithium-ion battery- in Japan as early as 2009, then in Europe and possibly the United States. The i-MiEV would travel about 100 miles on a single charge. The top speeds will be about 80 mph in Japan and 90-95 mph in Europe and the United States.

#### Fuel cell vehicles:

- Honda Motor Co. launched its next generation FCX hydrogen powered fuel cell vehicle - its first FCV to meet all applicable federal motor vehicle safety standards. The car will be available in low volumes in 2008 to customers in the United States and Japan. It uses lithium-ion batteries in tandem with Honda's V-Flow fuel cell stack. Its power plant is 40% smaller and 400 pounds

lighter than that in the previous FCX concept vehicle. Honda says it also provides significantly improved cold-temperature performance.

## 24.5

### **On the road**

Compared to its total inventory of vehicles (over 230 million), the United States has a relatively small -but growing- number of HEVs (while PHEVs and EREVs are in the process of entering the market). These are designed to compete with conventional on-road gasoline and diesel vehicles. Batteries for these vehicles include nickel metal hydride and lithium-ion. Both AC and DC motors are being used. U.S. HEV sales for 2005-2007 appear in table 24.3. Figure 24.5 shows the number of EVs and HEVs in the United States over the past few years.

Table 24.3 HEV sales in the United States.

<b>Vehicle</b>	<b>Sales</b>		
	<b>2005</b>	<b>2006</b>	<b>2007<sup>1</sup></b>
Ford Escape / Mercury Mariner <sup>2</sup>	15'960	22'549	25'108
Honda Accord	16'826	5'598	3'405
Honda Civic	25'864	31'253	32'575
Honda Insight	666	722	3
Lexus GS 450h <sup>2</sup>	--	1'784	1'645
Lexus LS 600h	--	--	937
Lexus RX 400h <sup>2</sup>	20'674	20'161	17'291
Nissan Altima	--	--	8'388
Saturn Vue <sup>3</sup>	--	--	3'969
Toyota Camry <sup>2</sup>	--	31'341	54'477
Toyota Highlander <sup>2</sup>	17'989	31'485	22'052
Toyota Prius	107'897	106'971	181'221
<b>Total U.S. HEV sales</b>	<b>205'876</b>	<b>251'864</b>	<b>351'071</b>
Total U.S. light vehicle sales	16'946'611	16'518'686	16'114'815
Total U.S. HEV sales percent	1.2%	1.5%	2.2%

<sup>1</sup> Through December 2007. Insight and Prius sales data are from J.D. Power. Other data from EDTA and Green Car Congress.

<sup>2</sup> The Escape, GS 450h, RX 400h, Camry and Highlander hybrid sales represent registrations from EDTA through 2006. The 2007 sales of Escape and GS 450h are from Green Car Congress.

<sup>3</sup> January-May 2007 sales from EDTA.

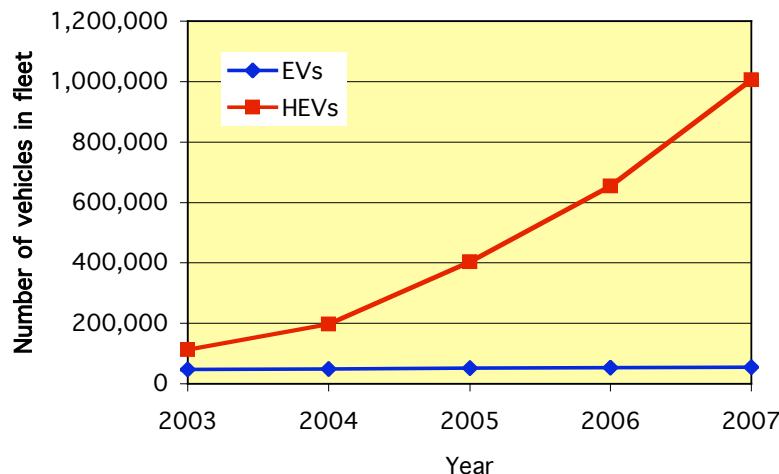


Fig. 24.5 Number of EVs and HEVs present in the United States.

*EV data from Energy Information Administration (EIA)  
([www.eia.doe.gov/cneaf/alternate/page/attables/afvtrans\\_v1.xls](http://www.eia.doe.gov/cneaf/alternate/page/attables/afvtrans_v1.xls)).  
2006 and 2007 data for EVs are extrapolated.*

*HEV data from Electric Drive Transportation Association website  
([www.electricdrive.org](http://www.electricdrive.org)) and other sources. Cumulative numbers estimated from annual sales.*

## 24.6

### Outlook

At present, the U.S. population of battery electric vehicles appears to be stable because of the lack of new personal mobility electric vehicles. The population of vehicles with some form of electric drive is growing and is projected to grow more as new technologies (such as PHEVs and EREVs) are introduced. The forecasting firm of J.D. Power-LMC Automotive has projected that vehicles partially or completely powered by electricity will account for 3% of the U.S. light-vehicle market by 2010 (about a half-million annual sales), but the hybrid market share will plateau, mostly because of the expected US\$ 3'000-4'000 premium that hybrids command over standard vehicles. Other projections -based on a lower premium- have indicated a larger market share. Regulatory steps can also affect the eventual number of such vehicles.

According to an outlook statement from Japan's Nomura Research Institute, the global market for hybrid vehicles could more than triple by 2012, while the value of its worldwide parts business will double to US\$ 7 billion. It was said that the demand for hybrid vehicles will surge as automakers feel increased pressure to cut carbon dioxide emissions. Lower cost and the expansion of hybrid offerings also will fuel the market increase. By 2012, the global market for hybrid vehicles is expected to reach 2.19 million units, up from an estimated 619'000 in 2007. The United States is seen as leading this demand, with 1.68 million units.

## 24.7

### ***Benefits of participation***

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

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

## 24.8

### ***Further information***

<b>Further information for:</b>	<b>Website address</b>
(all websites are in English)	
DOE Vehicle Technologies Program	<a href="http://www.eere.energy.gov/vehiclesandfuels/">www.eere.energy.gov/vehiclesandfuels/</a>
DOE Hydrogen and Fuel Cells Program	<a href="http://www1.eere.energy.gov/hydrogenandfuelcells/resources.html">www1.eere.energy.gov/hydrogenandfuelcells/resources.html</a>
Electric Drive Transportation Association (EDTA)	<a href="http://www.electricdrive.org">www.electricdrive.org</a>
Energy Information Administration (EIA)	<a href="http://www.eia.doe.gov">www.eia.doe.gov</a>
United States Advanced Battery Consortium (USABC)	<a href="http://www.uscar.org/guest/view_team.php?teams_id=12">www.uscar.org/guest/view_team.php?teams_id=12</a>
United States Consortium for Automotive Research (USCAR)	<a href="http://www.uscar.org">www.uscar.org</a>

## 25

### ***Developments in selected IA-HEV non-member countries***

As of the end of 2007, at least 29 IA-HEV non-member countries hosted manufacturers of electric cars, electric bicycles, electric scooters or three-wheelers, electric motorcycles (collectively, light electric vehicles - LEVs) and/or hybrid electric vehicles, according to SourceGuides.com. These countries are listed in box 25.1.

<b>Box 25.1</b>				
<b>IA-HEV non-member countries that host manufacturers of electric cars, electric bicycles, electric scooters or three-wheelers, electric motorcycles and/or hybrid electric vehicles</b>				
Australia	Germany	Japan	New Zealand	South Africa
Bangladesh	Greece	Jordan	Pakistan	Spain
Bulgaria	Hungary	Korea	Panama	Taiwan
China	India	Lebanon	Philippines	Thailand
Cyprus	Ireland	Malaysia	Saudi Arabia	United Kingdom
Czech Republic	Israel	Nepal	Singapore	

Sales data are not uniformly available for these countries. With some exceptions, their production facilities are limited, and most of their actual LEV trade may be based on importation. Among IA-HEV non-members, Japan is currently the only non-member mass producing hybrid electric vehicles (HEVs), but China is beginning to ramp up domestic production (initially for export) with international partnerships, and Korea is opening its own production facility. However, Australia, Bulgaria, Cyprus, the Czech Republic, Hungary and India -among others- all claim small specialty manufacturers of (possibly not road-legal) hybrid electric vehicles and/or hybrid auxiliaries. The last IA-HEV annual report profiled China, Denmark, Japan, Norway and Taiwan, plus three other non-member nations boasting e-vehicle production and marketing activities. With Denmark having rejoined the Agreement, and policy developments in some non-member countries coming to the fore during 2007, we profile this year Germany, Israel, Korea, New Zealand, Singapore and the United Kingdom.

#### **25.1**

##### ***Germany***

A country long known for excellence in petroleum-powered automotive engineering and design -especially in the application of diesel engine technology- Germany has begun to take the first tentative steps to participate in the new paradigm of electric drive. This is not to imply that e-drive manufacturing has not heretofore been present in the German economy. As an example, for many years Heinzmann GmbH & Co. KG of Schönaeu (Schwarzwald) has produced a variety

of e-bikes and pedelecs (power-assist bikes) under its Estelle brand, with battery-pack options that include 36 V NiCd and NiMH capacities delivering 250-500 W of power. For 2008, the company has announced that it will be offering lithium-ion battery systems in all of its two-wheel products at no reduction in power, with a range increase of up to 25% on a full charge. Cost increases from 2007 to 2008 are expected to be nominal (generally less than 2%) across the line.

Germany's major light-duty vehicle manufacturers have entered the HEV ring, with production plans largely contingent on international demand that emerges this year. Audi has introduced -at several car shows- its Q7 hybrid SUV concept in which a 4.2-litre V8 engine is paired with a power-assist electric motor that will enable the vehicle to operate at up to 641.4 Nm (473 lb-ft) of torque, reducing both 0-100 km/h acceleration time and fuel consumption (the latter by about 15%). A decision for 2009 market introduction of this model is deferred, pending U.S. sales results for comparable Toyota and Lexus vehicles.



Fig. 25.1 Audi Q7 SUV hybrid concept slated for possible 2009 introduction. (Source: Automobile Magazine. Photo supplied by ANL.)

BMW appears to be nearing a decision on a rollout date for its X5 hybrid 'sport activity vehicle'. This vehicle, pairing a 4.4-litre V8 engine and an electric motor integrated with the transmission, will incorporate supercapacitors into its power boost package to enable a torque increase to 1'000 Nm (737 lb-ft) together with a 15% improvement in fuel efficiency relative to the standard X5.

DaimlerChrysler is pushing forward to introduce its 'smart fortwo' hybrid into the USA market, pending crash test and emissions certification. This micro-compact, some 8.8 ft (2.70 m) in length and 1'600 lb (725 kg) in weight, is expected to be rated at about 60 mpg (25.5 km/l) over its full certification driving cycle. The power plant is a 61 hp (45 kW) three-cylinder rear-mounted Otto cycle engine coupled as a mild hybrid with a 20 kW electric motor connected to a NiMH

battery pack (no regenerative braking). Novel among recent hybrid introductions is the toggled operating system, which allows the driver to select one of two modes: one that computer-optimizes the propulsion source participation for maximum fuel efficiency, and the other that permits the electric motor to perform strictly in power-assist mode (similar to Honda's IMA system).

## 25.2

### *Israel*

Israel is a country for which a reliable petroleum supply chain is a more tenuous proposition than for many nations, and thus it is not surprising that electric drive has begun to play a more prominent role in its strategic energy planning. Israel is home to several commercial entities involved in the light electric vehicle (LEV) market, including the e-bike and e-scooter system designer and converter Bikit International (2000) Ltd. of Netanya and Dr. Brushless, e-vehicle component manufacturer (power inverters) of Zichron Yaakov.

Desiring to move to the next level of electric vehicle commitment, the Israeli government has announced support for a broad effort to promote the use of electric cars, which will rely heavily on a joint venture between an American-Israeli lithium-ion battery entrepreneur and Renault/Nissan Motors. The effort will apply principles of cell phone purchase/leasing to electric vehicles (EVs) in that the EV buyer will obtain an Israeli government purchase subsidy (for the Renault/Nissan-made vehicles) and pay a monthly fee for expected total distance travelled - similar to cell phone minutes. Such a plan anticipates significant operating and long-run cost savings relative to running a vehicle on gasoline, which currently retails at well over US\$ 6.00/gallon in Israel. Meanwhile, the government will significantly increase the availability of public recharging infrastructure across the country. Spent battery packs may be swapped out at service stations. The private principals behind the plan are looking to Israel as the test bed from which similar programmes can be launched in congested cities and comparably sized entities, such as Denmark and Singapore. Even China and India -for which petroleum demand has become an economic issue- could be eventual targets for this concept.

## 25.3

### *Korea*

Like Germany, the Republic of Korea has begun to test the waters of the hybrid car market. Mass producer Kia is adding a mild hybrid version of its compact Rio sedan that uses a 90 horsepower 1.4-litre gasoline engine together with a 16 hp electric motor and continuously variable transmission (CVT). Four thousand Rio hybrids -co-sponsored by the Korean Ministry of the Environment- are to participate this year in a real-world test program over Korean roads. Consumer models of this Rio should arrive in the United States in late 2008.

Hyundai has said it plans to begin mass production of hybrid vehicles in 2009, beginning with a gas/electric version of the Accent model sedan and hatchback. Meanwhile, Hyundai will introduce an Avante hybrid in its Korean home market in 2009. The Avante (known as the Elantra in the United States) will recharge its battery pack with LPG power in order to take advantage of LPG's current price advantage over gasoline, and because Korea already has a workable LPG infrastructure in place. The automaker will follow up with a gasoline-electric hybrid by 2010. It is anticipated that the LPG/electric system will pay off with fuel economy between 44 and 47 mpg (18.7-20 km/l).

At the close of 2007, LG Chem -South Korea's largest chemical company and a major international force in small consumer electronics (such as cell phones)- announced it won an order as the exclusive supplier of rechargeable lithium-ion polymer hybrid car batteries for Hyundai Motor and its affiliate Kia Motors, in conjunction with the Hyundai-Kia Automotive Group's mass production of hybrid motor vehicles from 2009 (source: Korea Times 12/16/07).

## 25.4

### New Zealand

Another country with a generous endowment of renewable energy and the commitment to use it in transportation applications is New Zealand. In October 2007, New Zealand published -through its Ministry of Economic Development- a formal energy plan through year 2050 that will -among other goals- work toward positioning the country to be a world leader in new vehicle technologies, including EVs and plug-in hybrid electric vehicles (PHEVs). The government has decided in principle that New Zealand will be one of the first countries to deploy EVs of all types (buses, trains, BEVs, PHEVs) widely into the fleet. The rate of deployment will be contingent on advances in battery capability and technology.

At least one New Zealand-based manufacturer -Watkin Technology- produces foldable pedelecs, including a 200 W, 35 V AC model (the WTEB-04) capable at full-charge of a 30 km range at up to 25 km/h. However, it is not currently legal to operate unregistered powered two-wheelers on the country's roads. More market-ready from an international perspective is the MK 'EcoSaver' IV hybrid bus, produced by the Charlotte, North Carolina, -based DesignLine International company's principal manufacturing facility in Ashburton, New Zealand. This vehicle appears to be one of the most advanced hybrid buses in the world, using an LPG-fuelled turbine as an auxiliary power unit to keep the battery pack charged while operating 100% on electric power, and thus generating substantially fewer emissions than other (diesel) hybrid models. The unit is also said to incorporate the latest technology for both system control and driver interface systems, with a fully automatic battery management system, drive control system and APU controller. System readouts display all information required by service staff.

## 25.5

### **Singapore**

As its prominence as both a hub and crossroads of Asian commerce and international transport grows, Singapore is adding its name to those nations actively engaged in e-bike and pedelec manufacturing and distribution. Most prominent is the eZee company, producer of many internationally popular models, including the gearless motor road hybrid TORQ (now available with NiMH battery) that -in pedelec mode- provides an assistance rate of 60% on hills. While receiving favourable reviews for styling and performance from many users, the TORQ appears to have limitations that emerge once it operates in topography and climate dissimilar to Singapore's. Company engineers advise against full-speed operation all the time, 'jackrabbit' starting, frequent hill climbing, battery depletion (i.e., users should keep it charged over the winter), and operation in very hot weather.



Fig. 25.2 eZee TORQ road hybrid two-wheeler. (Source: eZeebike.com. Photo supplied by ANL.)

## 25.6

### **United Kingdom**

In general, there is a high awareness of, and positive attitude toward, hybrid electric vehicles (HEVs) in the United Kingdom (UK) of Great Britain and Northern Ireland. The adoption of HEVs by high-profile politicians has further fuelled an active media debate about the true environmental benefits of HEVs. Local government policy -which leads to fiscal benefits for HEV owners- continues to maintain public awareness. There is also a high awareness of electric vehicles (EVs) in the UK's capital, London. Neighbourhood EVs are growing in popularity as a result of free parking and free recharging in some boroughs, along with the creation and expansion of London's Congestion Charging zone, which EVs can currently enter without incurring a fee.

However, despite zero road tax for EVs and good publicity -such as for the smart fortwo EV, NICE city vehicle, Smith Edison and Modec van- a similar level of awareness is yet to be seen across the rest of the UK.



Fig. 25.3 smart fortwo EV. (Photo supplied by AVL UK.)

#### **Policies and legislation**

The UK national CO<sub>2</sub> (carbon dioxide) emissions regulations and legislation adopt the European Commission (EC) voluntary agreements on new car fuel efficiency - which expire in 2008/9- and the national government is working with the EC on developing legislative proposals for the successor arrangements. The forthcoming recommendations of the King Review of low-carbon cars are also likely to be adopted as policy. In 2007, the UK government released an Energy White Paper that included setting a fleet average car procurement target of 130 g CO<sub>2</sub>/km for 2010/11 for new cars purchased by UK central government and used for administrative operations. This Low Carbon Vehicle Procurement Programme involves an initial £20 million, using the public sector's purchasing power to accelerate market introduction of lower-carbon-vehicle technologies. These government policies are expected to lead to the wider adoption of HEVs.

The London metropolitan area has two controlled areas in which vehicle operation is monitored. A Congestion Charge zone exists in central London, and a Low Emission zone extends to the main orbital route.

Transport for London has currently set a zero fee for driving into the Congestion Charge zone in an EV or HEV. Similarly, during 2008/9 Transport for London is phasing in the Low Emission zone for heavy-duty vehicles, with fees for vehicles that do not meet current Euro emission levels.

#### **Research**

The UK Technology Strategy Board has created a new Innovation Platform, providing up to £30m of support from 2008/9 onwards for UK research into lower-carbon-vehicle technologies, heavily focused on HEVs and EVs. A further £5m per year investment is made by the Department for Transport through the Energy Technologies Institute into low-carbon-transport technology research, which also covers alternative fuels, including hydrogen.

Large-scale UK OEM activity on HEV development is concentrated in Jaguar/Land Rover and Ford Motor Company. Jaguar/Land Rover is a leading developer of HEV technology for premium vehicles and has announced activity on full hybrid and partial hybrid programmes. The Land\_e is Land Rover's e-Terrain Technology Concept using integrated electric rear and starter-generator systems to improve both urban emissions and off-road ability. Ford Motor Company is a leading developer of stop-start and micro-hybrid technology and has demonstrated small passenger cars and commercial vehicles with high cost-benefit systems. These vehicles are expected to be market-ready shortly. Furthermore, there are niche vehicle manufacturers in the commercial vehicle, passenger transit bus, taxicab and sports car sectors also undertaking HEV and EV development programmes.

A notable research achievement has been the development of the world's first hydrogen fuel cell motorbike -the ENV- by the UK fuel cell company, Intelligent Energy. The 100-mile range and 50 mph top speed is achieved with a 1 kW PEM fuel cell. Intelligent Energy has strategic relationships with Suzuki and PSA Peugeot Citroën on bike and automotive systems, respectively.

The strong engineering consultancy sector -which includes Ricardo, Ztek, AVL, Lotus, Prodrive, MIRA, Millbrook, Mahle, TRW Conekt and Pi Technology, among others- supports both vehicle and component manufacturers in the UK by providing much of the expertise in EV and HEV technology.

The UK academic community has a strong presence in the field of automotive electric component technologies or systems. There are researchers at more than 20 universities undertaking a number of projects in this area, many of them funded through the research council EPSRC.

### **Industry**

Passenger transit bus manufacturers currently make good sales progress with HEV products. Wrightbus and Alexander Dennis offer single-deck vehicles with series HEV architectures. The current development activity in this sector is toward double-deck vehicles -a common sight in UK towns- and Transport for London has recently commenced operation of series-hybrid double-deck buses built by Wrightbus.

Commercial EVs (such as the range manufactured by Smith and the van offered by Modec) are also available, with Smith making good sales progress. These are suited to operation where maximum daily mileage is around 150 miles, such as urban deliveries.



Fig. 25.4 Modec Box Van. (Photo supplied by AVL UK.)

Four EVs in (or near) production in the UK are:

1. Smith electric vans (in production). Range is 150 miles, recharge time is 8 hours.
2. Modec van (in production). Range is 100 miles, recharge time us 8 hours.
3. G-Wiz (available today). Range is 48 miles, recharge time is 2.5-8 hours.
4. smart fortwo EV (100 in operation). Range is 50-70 miles, recharge time is 3.5-8 hours.

#### ***On the road***

Various supportive mechanisms to achieve wide acceptance of HEVs and EVs are under consideration in the UK. The Centre of Excellence for Low Carbon and Fuel Cell Technologies ‘Cenex’ is pioneering forward procurement activities that are aimed at ensuring the market for manufacturers that must invest heavily to develop promising products ready for market. One such programme involves lower-carbon delivery vans, together with the retailer John Lewis Partnership.

As of 30 May 2007, there were 6568 new registrations for passenger HEVs; by comparison, in 2006, there were 3117.

#### ***Outlook***

Local government fiscal incentives -most notably in London- are a key driver to encouraging the wide acceptance of HEVs and EVs. National government policy plays a stronger role in ensuring that HEV and EV vehicles are brought to market, ready for wider demand.

Only the passenger transit bus market has a clear outlook, with predictions that by 2012 all new vehicles will be HEVs.

In summary, the HEV and EV activity in the UK is progressing, and impact on the composition of the national vehicle fleet is beginning to take effect. Several organizations and government-funded mechanisms have been established in the last five years. Therefore, there is growing interest in joining international energy organizations -certainly including the IA-HEV- the goals of which are consistent with these initiatives.

#### ***Further information***

Websites with additional information on UK activities are listed below. (All websites are in English.)

- [www.cenex.co.uk/default.asp](http://www.cenex.co.uk/default.asp)  
Low Carbon and Fuel Cell Technologies Centre of Excellence 'Cenex'.
- [www.dft.gov.uk/pgr/scienceresearch/technology/lowcarbonvehicleprocurementprog](http://www.dft.gov.uk/pgr/scienceresearch/technology/lowcarbonvehicleprocurementprog)  
Low Carbon Vehicle Procurement Programme.
- [www.dft.gov.uk/pgr/scienceresearch/technology/transportewp](http://www.dft.gov.uk/pgr/scienceresearch/technology/transportewp)  
UK Government White Paper on Energy 'Meeting the Energy Challenge', May 2007.
- [http://fcf.globalwatchonline.com/epicentric\\_portal/site/FuelCellsForum/menutem.9f8800ce7b28f0b924a5def32b97c53c/?mode=0](http://fcf.globalwatchonline.com/epicentric_portal/site/FuelCellsForum/menutem.9f8800ce7b28f0b924a5def32b97c53c/?mode=0)  
Knowledge transfer network on low carbon and fuel cell technology.
- [www.foresightvehicle.org.uk/index\\_heafv.asp](http://www.foresightvehicle.org.uk/index_heafv.asp)  
HEV thematic area in Foresight Vehicle R&D programme on vehicles and vehicle technologies.
- [www.hm-treasury.gov.uk./independent\\_reviews/king\\_review/king\\_review\\_index.cfm](http://www.hm-treasury.gov.uk./independent_reviews/king_review/king_review_index.cfm)  
Government-commissioned King Review of low-carbon cars.
- [http://media.ford.com/newsroom/feature\\_display.cfm?release=22615](http://media.ford.com/newsroom/feature_display.cfm?release=22615)  
Land\_e, Land Rover's e-Terrain Technology Concept.
- [www.tfl.gov.uk/roadusers/default.aspx](http://www.tfl.gov.uk/roadusers/default.aspx)  
Transport for London, driving information.

## 26

### ***Outlook for hybrid and electric vehicles***

#### **26.1**

##### ***Introduction and context***

Hybrid and electric vehicles can contribute to meeting the challenges in road transport regarding CO<sub>2</sub> and pollutant emissions, energy efficiency, noise and even congestion. This outlook presents the expectations for the future of hybrid and electric road vehicles of a group of experts (IA-HEV) collaborating under the framework of the International Energy Agency (IEA).

IA-HEV is the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes of the IEA. Current member countries are Austria, Belgium, Canada, Denmark, France, Italy, the Netherlands, Sweden, Switzerland, Turkey and the United States. The participants in the Agreement are governmental bodies and research institutes that are appointed by their governments. This outlook is a synthesis of inputs of IA-HEV member country delegates; it does not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

The target audience for this outlook are predominantly governmental policy makers and governmental bodies, but it is also meant for research institutes working in the area of road transport, energy and environment, and the energy sector. This is the first joint outlook of IA-HEV members, and to avoid being too speculative the time period under consideration is until the year 2015.

This outlook is structured as follows. First, it presents a brief overview of the characteristics that distinguish hybrid and electric vehicles from conventional vehicles, and how they can contribute to achieving objectives regarding energy security, CO<sub>2</sub> emissions and pollutants. Next are the barriers for their deployment and the options for governments to help overcoming these barriers. Based on this information and building on the expertise of the IA-HEV members, expectations for hybrid and electric vehicle deployment are formulated in the final section of this outlook.

#### **26.2**

##### ***Hybrid and electric vehicles***

Hybrid and electric vehicle have certain characteristics that may contribute to achieving governmental objectives regarding energy, environment and road transportation. In this section the vehicle characteristics are presented first, followed by how these vehicles can contribute to achieving governmental objectives.

### ***Vehicle characteristics***

Three types of hybrid and electric vehicles are distinguished here: hybrid electric vehicles, battery electric vehicles and fuel cell vehicles.

Hybrid electric vehicles (HEVs) show improved fuel economy compared to conventional vehicles, especially in stop-and-go traffic. They may also be designed to offer improved performance. Additionally, a limited range of silent operation with zero tailpipe emissions is possible when HEVs drive in electric mode. The operating range in electric mode may be extended by mounting larger batteries and/or by plugging into the electricity grid when the vehicle is parked (plug-in hybrid electric vehicle - PHEV). PHEVs can also be perceived as battery electric vehicles that have a range extender in the form of an internal combustion engine.

Battery electric vehicles (BEV) operate with zero vehicular emissions and very low noise. Their range is smaller than for conventional vehicles, although it is for example sufficient for about most of the commuter trips in Europe and North America.

Fuel cell vehicles only emit water vapour and they have the potential to be energy efficient. However, they are in an early stage of development and before the year 2015 fuel cell vehicles are not expected to gain a significant share in the road vehicle fleet, so they are not discussed in detail in this outlook. Box 26.1 gives an example of factors that play a role in reaching an answer to the question of whether battery electric cars or fuel cell vehicles are closest to lasting success in the commercial market.

### ***Application of hybrid and electric vehicles***

Because of their characteristics, hybrid and electric vehicles can contribute to achieving country objectives for energy independency, reducing CO<sub>2</sub> emissions and a clean environment. Important examples are:

- For hybrid vehicles running on gasoline or diesel, improved fuel efficiency reduces oil demand and reduces CO<sub>2</sub> emissions.
- Hybridization of vehicle drivetrains can also be combined with low CO<sub>2</sub> emission fuels such as biofuels, to further reduce CO<sub>2</sub> emissions from road transport and to become independent from fossil oil.
- When electricity is produced with renewable sources such as solar, hydro and wind power, hybrid (PHEV) and electric (BEV) vehicles that are recharged from the electricity grid will run on renewable and clean energy.

### **Box 26.1**

**Q: Which zero emission vehicle is closer to successful introduction in the commercial market: the pure battery electric vehicle or the hydrogen fuel cell vehicle?**

**Background**

A pure battery electric vehicle is an electric vehicle with batteries as the only form of onboard energy storage and no propulsion system other than the electric motor. This kind of vehicle has been on the market for decades, but has never been able to gain a substantial share of the road vehicle market against conventional offerings.

Hydrogen fuel cell vehicles have for over a decade been considered a promising option to eliminate road vehicle pollution, but their expected market introduction date keeps moving back.

**Common vehicle technology issues**

The battery is a key component that needs further improvement in energy density and costs.

Vehicle manufacturing and maintenance infrastructures need to be established.

**Battery electric vehicle technology**

Limited range is a handicap that needs improvement and/or user acceptance.

**Fuel cell vehicle technology**

The fuel cell needs further development, especially to reduce its costs.

Hydrogen onboard storage needs improvement of energy density and costs.

**Energy infrastructure**

In large parts of the world, an electricity distribution grid is already in place.

A hydrogen distribution and refuelling infrastructure needs to be constructed.

**Energy and environment**

It should be kept in mind that vehicle energy and environmental issues are most appropriately compared on a well-to-wheel basis. Pure battery electric vehicles and fuel cell vehicles make most sense when electricity and hydrogen are produced in a renewable manner with near-zero pollutant emissions.

**Vehicle manufacturers**

Manufacturers need to be dedicated and willing to invest resources to make new vehicle technologies a success.

**Vehicle users**

It seems difficult for users to accept a shorter driving range and longer refuelling times compared to conventional vehicles. The option that comes closest to conventional vehicles regarding these attributes will most easily gain market acceptance. Additionally, costs of use will have to be competitive with other energy carriers on the market.

**A: The answer is dependent on how the issues mentioned above develop. However, advanced, pure battery electric vehicles (BEVs) seem to be closer to becoming a significant player in the commercial vehicle market than do hydrogen fuel cell vehicles. The first generation of advanced BEVs might still be small, limited range vehicles for use in urban areas.**

- PHEVs and BEVs can even serve as enablers for high shares of renewable energy in electric power production. This can be explained as follows. The electric energy that is produced by renewable sources such as solar and wind power is intermittent and the amount varies over time. In general, these variations are not synchronous with the variations in electricity demand. To overcome this mismatch in time between production and demand, electricity temporarily needs to be stored. The batteries of (a large number of) PHEVs and BEVs that are plugged into the electricity grid may serve as such a storage buffer.
- Given their low vehicular emissions and low noise production, hybrid and electric vehicles can advantageously be applied in sensitive areas such as inner city centres. When driving in electric mode, distribution trucks may even be allowed to operate during the night for example, and thus contribute to reducing congestion during daytime.

To achieve hybrid and electric vehicle sales figures that are large enough to contribute significantly to energy independency and reducing pollutants and CO<sub>2</sub> emissions, market segments must be found in which they offer clear advantages for their users. This is the subject of the following sections.

### **26.3**

#### ***Barriers for the deployment of hybrid and electric vehicles***

In spite of the advantages that hybrid and electric vehicles can bring to their users and the possible contributions to achieve governmental objectives, their market share is still small. This section highlights some of the barriers for the deployment of hybrid and electric vehicles, seen from three different angles: the general public (vehicle users), vehicle manufacturers and utilities.

There still is a lack of public awareness regarding alternatives to conventional gasoline and diesel cars. Three major hurdles exist for vehicle buyers:

- For a large proportion of the vehicle-buying public, purchase price is the most important criterion when choosing a vehicle. The general public is not aware of the vehicle life cycle costs and how these costs compare among different propulsion alternatives. Because of the higher price of hybrid and electric vehicles, most buyers choose a conventional vehicle.
- The range of electric vehicles is perceived as being too small, even though it would be sufficient for the majority of vehicle trips.
- In certain markets there is a lack of confidence in electric powered vehicles that is the result of battery problems in the past, and despite the fact that these problems have been successfully eliminated.

Hybrid and electric vehicles are significantly different from conventional vehicles. This means that vehicle manufacturers have to break new ground regarding

vehicle components, drivetrain systems, production facilities, safety issues and vehicle maintenance infrastructure.

- As for any new technology, standardization of hybrid and electric vehicle components and test methods are not as mature as for conventional vehicles. This is a barrier for industry to build up an efficient profit chain.
- Because it takes time to develop new vehicles and to build up the production and maintenance infrastructure, manufacturers are not yet always able to supply sufficient numbers of vehicles to meet the demand of surging markets.

Utilities are among the parties displaying significant recent interest in plug-in hybrid electric vehicles (PHEVs), because these vehicles may serve as enablers for high shares of renewable energy in the grid (see section 26.2) and because they are a substantial potential electricity market. However, before large numbers of PHEVs can be used some technical problems must still be overcome, such as the possibilities and safety issues of connecting the vehicle to the electricity grid, and the ability of utilities to meet electricity needs on demand.

## **26.4**

### ***The role of governments in the deployment of hybrid and electric vehicles***

The previous sections have shown that governmental objectives may differ from vehicle buyers' interest and that hurdles may need to be overcome to achieve the objectives. However, governments have means -such as awareness campaigns, legislative power, taxation schemes and supporting research- to influence activities in society, so they can play an important role in overcoming the barriers for the deployment of hybrid and electric vehicles. Important governmental options are given below.

Technical developments may help in reduce the price premium for hybrid and electric vehicles. Governments can support technical developments by funding research projects that aim at advancing propulsion systems and components. Research and development (R&D) can also be stimulated by supporting cross-linking activities as well as supporting the foundation of technology platforms.

Governments have many different options to encourage the demand and deployment for clean and fuel efficient vehicles. Examples are:

- Demonstration projects to promote innovation.
- Fiscal measures such as tax incentives for clean vehicles, or taxation of CO<sub>2</sub> emissions.
- Subsidies that may help overcome the price premium of hybrid and electric vehicles. (Although it should be kept in mind that market niches based on subsidies alone are not sustainable. Niches where these vehicles offer clear advantages for their users must be found and/or created.)

- Non-monetary measures such as parking lots with free recharge for electric vehicles, or entry rules for certain areas such as ‘car free’ zones that are accessible only for zero emission vehicles.
- Heightening of public awareness and sensitivity to environmental issues, for example through promotion programmes.
- Stimulation of fleet renewal programmes to remove polluting older vehicles from the in-use population.
- Directives for ever more stringent emission levels.

Different measures may be combined and can reinforce each other. For example, parking privileges for electric vehicles also contribute to raising awareness by the public.

Consistency among different countries with respect to regulations creates larger vehicle markets with similar requirements, and this helps vehicle manufacturers develop products that meet all regulatory requirements. In a complementary manner, local governments are in a position to enforce regulations -such as entry rules for urban zones- in smaller geographical areas.

## **26.5**

### ***Expectations for hybrid and electric vehicle deployment until 2015***

Based on the elements that are presented in the previous sections and enriched by their expertise, the IA-HEV members formulate the following expectations for hybrid and electric vehicle deployment.

Environmental awareness is increasing in society, including awareness of the impact of road transport on the environment, but this has not yet resulted in a large fleet share of hybrid and electric vehicles. However, some regulations that stimulate the use of clean and energy efficient vehicles are already in place and -combined with surging oil prices- have caused the hybrid electric vehicle market to take off (see figure 26.1). Independent from that, also the use of public transport and sales of smaller cars are both increasing. In this generally positive climate, it is expected that the markets for hybrid and electric vehicles will develop towards self-sustaining markets.

#### ***Hybrid electric vehicles***

Today, the share of hybrid electric vehicles (HEVs) in car sales is small. It is below 1% in for example Austria, Belgium, Denmark and the Netherlands, about 1.1% in Sweden and 2.2% in the United States. The number of HEV car models available on the market is expected to grow substantially until 2015 and this will boost the HEV sales. The global market for hybrid vehicles could more than triple by 2012, compared to 2007 sales. Important factors expected to influence the eventual 2015 HEV market share are:

- Regulatory and other governmental measures to overcome the barriers for large deployment of hybrid and electric vehicles.
  - The difference in purchase price between HEVs and standard vehicles (HEVs are likely to remain more expensive).
  - The quantity of HEVs that manufacturers will be able to supply.
- Although the impact of these factors is not yet known, the HEV percentage share of the 2015 car market is expected to remain within the single digits.

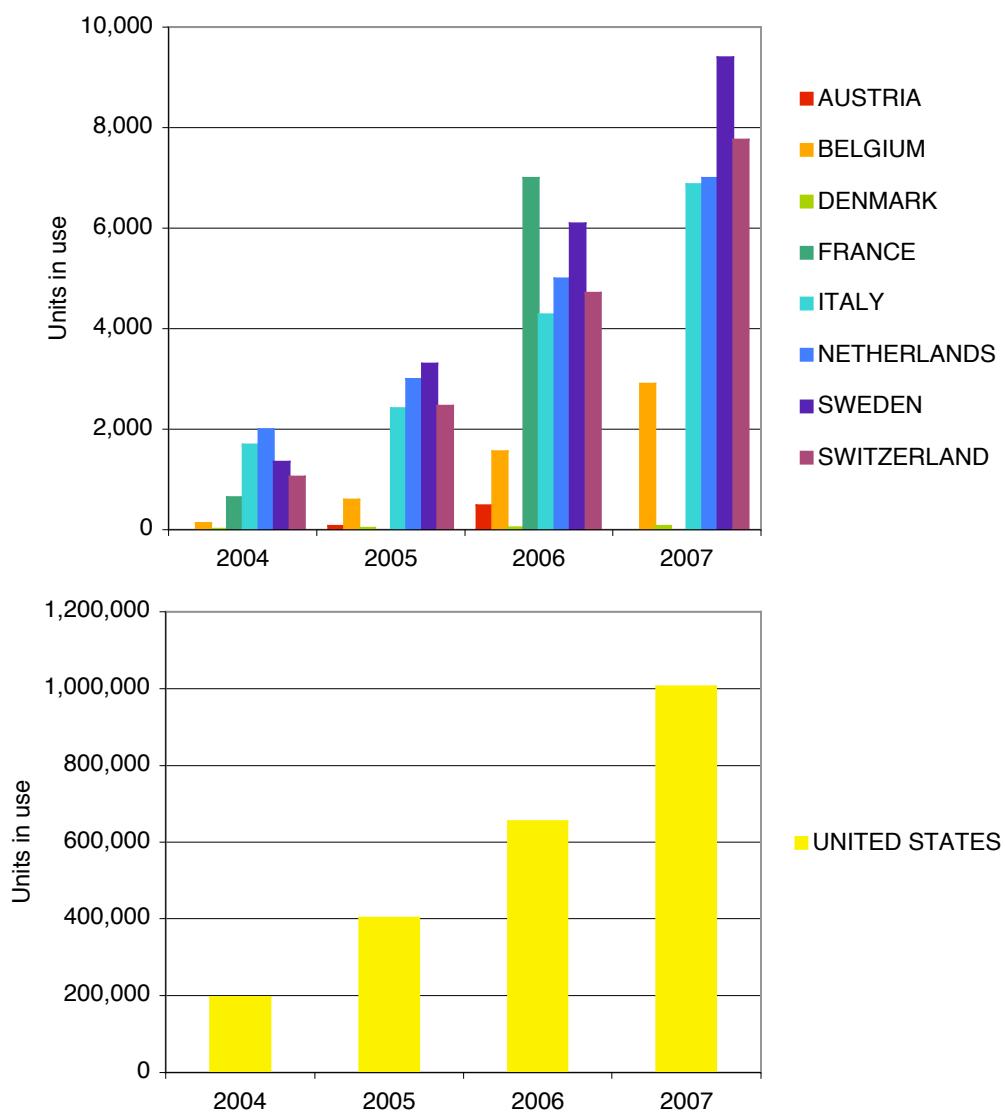


Fig. 26.1 Hybrid vehicle fleet size growth in IA-HEV member countries. Data for Canada and Turkey are not yet available.

Given the small market share, it can be concluded that the share of hybrid cars in the total vehicle fleet in both Europe and North America will remain low over the next five years, thus limiting their salutary effect on energy and environment.

Nevertheless, by 2015 they may be expected to have a quantifiable positive impact on the local air quality in urban areas.

The development and deployment of heavy-duty hybrid electric vehicles is lagging behind those of the light-duty sector. Trucks and buses -with a few commercial exceptions- are in the prototype and demonstration phase today and their fleet share in 2015 is expected to be small.

Increased interest in plug-in hybrid electric vehicles has recently emerged. In the coming years, work on PHEVs will focus on demonstration of these vehicles in practical use, and on the development of vehicle-to-grid technologies.

#### ***Battery electric vehicles***

The market for battery electric cars and battery electric heavy-duty vehicles is small. However, sales of e-bikes, e-scooters and electric power-assisted bicycles are surging and this trend might continue. Acceptance of electric vehicles in the two-wheeler market might prepare the market for advanced electric purpose designed vehicles such as the Th!nk.

#### ***Final remark***

Hybrid electric vehicles and battery electric two-wheelers have gained a firm position in the road vehicle market and are expected to continue increasing their share in the vehicle fleet. This outlook has shown that the actual growth rate is dependent on many different factors, often interrelated. These factors give hints for the focus of governmental policies that are aiming to increase the deployment of clean and energy efficient vehicles.

## ***IA-HEV publications***

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## **Vehicle categories**

In the ‘on the road’ sections of the country chapters on Austria, Belgium, Italy, the Netherlands, Sweden and Switzerland, fleet numbers of motorised road vehicles are as much as possible presented in a standardized table. The definitions of the vehicle categories that are used in these tables are given below.

Vehicle	Description
Bicycle (no driver licence)	Two-wheeled vehicle with an appearance similar to a conventional bicycle or moped.
Motorbike	Vehicle designated to travel with not more than three wheels contacting with the ground.
Passenger vehicle	Vehicle with a designated seating capacity of 10 or less, except Multipurpose passenger vehicle.
Multipurpose passenger vehicle	Vehicle with a designated seating capacity of 10 or less that is constructed either on a truck chassis or with special features for occasional off-road operation.
Bus	Vehicle with a designated seating capacity greater than 10.
Truck	Vehicle designed primarily for the transportation of property or equipment.
Industrial vehicle	Garbage truck, concrete mixer, etc., including mobile machinery like forklift trucks, wheel loaders and agricultural equipment.

## Conversion factors

This chapter presents conversion factors for quantities that are relevant for hybrid and electric road vehicles, such as kilometres per hour and miles per hour for vehicle speed, and miles per gallon and litres per 100 km for fuel consumption. The International System of Units (SI - Système International) gives the base units for these quantities, and therefore the relevant SI units are presented first. The actual conversion factors can be found in the second section of this chapter.

## Base units

Table 1 Selection of SI base units.

Quantity	Unit	Symbol
Length	Metre	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A

Table 2 Selection of SI prefixes.

Prefix	Symbol	Value	
Kilo	k	1 000	Thousand
Mega	M	1 000 000	Million
Giga	G	1 000 000 000	Billion

Table 3 Selection of derived units.

Quantity	Unit	Symbol	
Energy	Joule	J	$1 \text{ J} = \text{N}\cdot\text{m}$
Force	Newton	N	$1 \text{ N} = 1 \text{ kg}\cdot\text{m/s}^2$
Power	Watt	W	$1 \text{ W} = 1 \text{ J/s}$
Pressure	bar	bar	$1 \text{ bar} = 10^5 \text{ N/m}^2$
Time	hour	h	$1 \text{ hour} = 3600 \text{ s}$
Volume	litre	l	$1 \text{ litre} = 0.001 \text{ m}^3$

## Selected conversion factors

Table 4 Mass, dimensions and speed.

Quantity	Unit	Symbol	Conversion	Reverse conversion
Mass	pound (US)	lb	1 lb = 0.45359 kg	1 kg = 2.2046 lb
Length	inch	in	1 inch = 0.0254 m	1 m = 39.3701 inch
Length	foot	ft	1 ft = 0.3048 m	1 m = 3.2808 ft
Length	mile	mile	1 mile = 1.60934 km	1 km = 0.62137 mile
Volume	barrel (petroleum)	bbl	1 bbl = 159 l	--
Volume	gallon	gal (UK)	1 gal (UK) = 4.54609 l	1 l = 0.21997 gal (UK)
Volume	gallon	gal (US)	1 gal (US) = 3.78541 l	1 l = 0.26417 gal (US)
Speed	miles per hour	mph	1 mph = 1.609 km/h	1 km/h = 0.621 mph

Table 5 Energy and power.

Quantity	Unit	Symbol	Conversion	Reverse conversion
Energy	British thermal unit	Btu	1 Btu = 1055.06 J	1 J = 0.0009478 Btu
Energy	kilowatt-hour	kWh	1 kWh = 3.6·10 <sup>6</sup> J	1 J = 277.8·10 <sup>-6</sup> kWh
Power	horse power	hp	1 hp = 745.70 W	1 W = 0.001341 hp
Pressure	pound-force per square inch	psi	1 psi = 0.0689 bar	1 bar = 14.5037 psi
Torque	foot pounds	lb-ft	1 lb-ft = 1.35582 Nm	1 Nm = 0.73756 lb-ft

Table 6 Fuel consumption.

x mile/gal (UK)	↔	282.48/x l/100 km
x l/100 km	↔	282.48/x mile/gal (UK)
x mile/gal (US)	↔	235.21/x l/100 km
x l/100 km	↔	235.21/x mile/gal (US)

Table 7 Comparison of energy carriers.

<b>Energy carrier</b>	<b>Unit</b>	<b>Energy content</b>
Battery	Stored energy, expressed in kWh	1 kWh = 3.6 MJ
Diesel fuel	Calorific value, based on volume	34.9 - 36.1 MJ/l
Gasoline (petrol)	Calorific value, based on volume	30.7 - 33.7 MJ/l

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## **Glossary**

This glossary of terms related to hybrid and electric vehicles also includes information on the ‘competition’ to the electric drive, because now that plug-in hybrid electric vehicles get major attention, there are many ways to mix and match electric and conventional drive, including multiple fuel possibilities for the conventional drive.

### **Advanced Technology Partial Zero Emission Vehicle (AT-PZEV)**

As defined by the California Air Resources Board in a regulatory incentive system, a vehicle that uses electric drive components that should ultimately help industry introduce ZEVs such as EVs or FCVs.

### **All-electric Range (AER)**

This is a term used by CARB which has legal meaning related to a requirement that a PHEV be able to operate electrically until a specified set of conditions is no longer met. Within CARB regulations as of 2007, a credit system within their LEV regulations existed for PHEVs with 10 (16) or more miles (km) of AER.

### **Ampere**

The Ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to  $2 \times 10^{-7}$  Newton per metre of length. Ampere is symbolised by ‘A’.

### **Ampere-hour capacity**

The quantity of electricity measured in Ampere-hours (Ah) that may be delivered by a cell or battery under specified conditions. Typical conditions for EV applications are ambient temperature and a discharge time of 1- or 3-hours: in these cases the capacity is expressed as  $C_1$  or  $C_3$  (see also Rated Capacity, Installed Capacity, Energy Capacity).

### **Ampere-hour efficiency**

The ratio of the output of a secondary cell or battery, measured in Ampere-hours, to the input required to restore the initial state of charge, under specified conditions (also coulombic efficiency). It is not dependent on the change of voltage during charge and discharge.

### **Battery cell**

A primary cell delivers electric current as the result of an electrochemical reaction that is not efficiently reversible, so the cell cannot be recharged efficiently.

A secondary cell is an electrolytic cell for generating electric energy, in which the cell, after being discharged, may be restored to a charged condition by sending a current through it in the direction opposite to that of the discharging current.

**Battery module**

A group of interconnected electrochemical cells in a series and/or parallel arrangement, physically contained in an enclosure as a single unit, constituting a direct-current voltage source used to store electrical energy as chemical energy (charge) and to later convert chemical energy directly into electric energy (discharge). Electrochemical cells are electrically interconnected in an appropriate series/parallel arrangement to provide the module's required operating voltage and current levels.

In common usage, the term 'battery' is often also applied to a single cell. However, use of 'battery cell' is recommended when discussing a single cell.

**Battery pack**

Completely functional system, including battery modules, battery support systems and battery specific controls. A combination of one or more battery modules, possibly with an added cooling system, very likely with an added control system. A battery pack is the final assembly used to store and discharge electrical energy in a HEV, PHEV or EV.

**Battery round trip efficiency**

The ratio of the electrical output of a secondary cell, battery module, or battery pack on discharge to the electrical input required to restore it to the initial state of charge under specified conditions.

**Battery State Of Charge (SOC)**

The available capacity in a battery expressed as a percentage of rated nominal capacity.

**C rate**

Discharge or charge current, in Amperes, expressed in multiples of the rated capacity.

For example, the  $C_{5/20}$  discharge current for a battery rated at the 5-h discharge rate is:  $C_5$  (in Ah) divided by 20 gives the current (in A).

As a cell's capacity is not the same at all discharge rates and usually increases with decreasing rate, a cell which discharges at the  $C_{5/20}$  rate will run longer than 20 h.

**Capacitance**

The ratio of the charge on one of the conductors of a capacitor (there being an equal and opposite charge on the other conductor) to the potential difference between the conductors. Capacitance is symbolised by 'C'.

**Capacitor**

A device which consists essentially of two conductors (such as parallel metal plates) insulated from each other by a dielectric and which introduces capacitance into a circuit, stores electrical energy, blocks the flow of direct current, and permits the flow of alternating current to a degree dependent on the capacitor's capacitance and the current frequency.

**Certification fuel economy or fuel consumption**

An estimate of fuel economy (or the inverse, consumption) developed for official purposes by means of specified test procedures including particular driving cycles. These estimates usually result in fuel economy values that exceed what consumers actually realize 'in-use'. Fuel economy and fuel consumption may for example be expressed in l/100km (litres per 100 km), km/l, or mpg (miles per gallon).

**Charge / charging**

The conversion of electrical energy, provided in the form of current from an external source, into chemical energy within a cell or battery. The (electrical) charge is also a basic property of elementary particles of matter.

**Charge / charging factor**

The factor by which the amount of electricity delivered during discharge is multiplied to determine the minimum amount required by the battery to recover its fully charged state. Normally, it is higher than 1.0 for most batteries, for accounting for the losses in discharging and charging processes.

**Charge rate**

The current at which a battery is charged (see C rate).

**Charger**

An energy converter for the electrical charging of a battery consisting of galvanic secondary elements.

**Charge depletion (CD)**

When a RESS on a PHEV, EV or extended-range EV is discharged.

**Charge depletion (CDB)**

When an RESS on a PHEV or extended-range EV is discharged, but it is not the only power source moving the vehicle forward (blended mode). A separate fuel and energy conversion system works in tandem with the RESS to provide power and energy to move the vehicle as charge of the RESS is depleted. This mode of operation allows use of a much less powerful RESS than does CDE operation.

**Charge depletion (CDE)**

When an RESS on a PHEV, EV or extended-range EV is discharged, and

continuously provides the only means of moving the vehicle forward (all-electric operation).

**Charging equalizer**

Device that equalises the battery state of charge of all the modules in an EV during charging. With this measure the voltage of all the batteries will rise equally and the battery with the smallest capacity is not overcharged.

**Coal-to-liquids (CTL)**

Conversion of coal to a diesel like fuel low in sulphur suitable for use in CIDI ICEs. The process used for conversion is called Fischer-Tropsch chemistry.

**Compression ignition (CI)**

Ignition of a mixture of air and fuel in a cylinder of an ICE via heating by compression of the mixture. A name consistently used for ICEs that use this method of ignition is ‘diesel’.

**Controller**

An element that restricts the flow of electric power to or from an electric motor or battery pack (module, cell). One purpose is for controlling torque and/or power output. Another may be maintenance of battery life, and/or temperature control.

**Controller, Three phase**

An electronic circuit for controlling the output frequency and power from a 3-phase inverter.

**Conventional mechanical drivetrain**

A mechanical system between the vehicle energy source and the road including engine, transmission, driveshaft, differential, axle shafts, final gearing and wheels. The engine is operated by internal combustion (ICE).

**Conventional vehicle**

A vehicle powered by a conventional mechanical drivetrain.

**Current**

The rate of transfer of electricity. The unit of measure is the Ampere.

**Cut-off voltage**

The cell or battery voltage at which the discharge is terminated. The cut-off voltage is specified by the cell manufacturer and is generally intended to limit the discharge rate.

**Cycle**

A sequence of a discharge followed by a charge or a charge followed by a discharge of a battery under specified conditions.

**Cycle life**

The number of cycles under specified conditions that are available from a

secondary battery before it fails to meet specified criteria regarding performance.

**Diesel fuel - conventional and low-sulphur**

Diesel fuel is a refined petroleum product suitable for use in CIDI engines. In recent years there has been a worldwide movement to reduce sulphur content of diesel fuel in order to improve the reliability of required emissions aftertreatment for vehicles using CIDI engines. The sulphur reduction also reduces emissions of SO<sub>x</sub>, which in turn reduces sulphate particle matter in the atmosphere. Costs of diesel fuel have been driven up by the need to remove sulphur from a mix of crude oil that is increasing in average percent of sulphur.

**Depth Of Discharge (DOD)**

The percentage of electricity (usually in Ampere-hours) that has been discharged from a secondary cell or battery relative to its rated nominal fully charged capacity (see also Ampere-hour efficiency, Voltage efficiency, Watt-hour efficiency).

**Direct-current motor**

An electric motor that is energised by direct current to provide torque. There are several classes of direct-current motors.

**Discharge**

The direct conversion of the chemical energy of a cell or battery into electrical energy and withdrawal of the electrical energy into a load.

**Discharge rate**

The rate, usually expressed in Amperes, at which electrical current is taken from a battery cell, module or pack (see C rate).

**Driving range**

See 'Range'.

**E-bike**

With an e-bike, cycling is possible without pedaling. The motor output of an e-bike is activated and controlled by using a throttle or button. Human power and the electric motor are independent systems. This means that throttle and pedals can be used at the same time but -in contrast to a pedelec- they don't have to. This also means that an e-bike is more or less used in the same way as a scooter or motorcycle rather than a bicycle. Swiss and Italian regulations define the maximum power that can be used for an e-bike. More power makes it an electric scooter.

**Electric assist bike**

See 'E-bike'.

**Electric bike**

See ‘E-bike’.

**Electric drive system**

The electric equipment that serves to drive the vehicle. This includes (a) driving motor(s), final control element(s), and controllers and software (control strategy).

**Electric drivetrain (including electric drive system)**

The electromechanical system between the vehicle energy source and the road. It includes controllers, motors, transmission, driveshaft, differential, axle shafts, final gearing and wheels.

**Electric motor cycle**

An electric vehicle usually with two wheels, designed to operate all electrically, and capable of high speed, including ability to travel on high speed limited access highways and motorways. Usually capable of carrying up to two passengers. Such vehicles have a relatively high power to weight ratio. In addition to greater capability on highways, these vehicles are also more capable of travel off road on undulating terrain with steep slopes, than are electric scooters.

**Electric scooter**

See ‘E-scooter’.

**Electric Vehicle (EV)**

EV is defined as ‘any autonomous road vehicle exclusively with an electric drive, and without any onboard electric generation capability’ in this Agreement.

**Electrochemical cell**

The basic unit able to convert chemical energy directly into electric energy.

**Energy capacity**

The total number of Watt-hours that can be withdrawn from a new cell or battery. The energy capacity of a given cell varies with temperature, rate, age and cut-off voltage. This term is more common to system engineers than the battery industry, where Ampere-hours is usually referred.

**Energy consumption**

See ‘Fuel consumption’.

**Energy density**

The ratio of energy available from a cell or battery to its volume in litre (Wh/l). The mass energy density in battery and EV industry is normally called specific energy (see ‘Specific energy’).

**Equalizing charge**

An extended charge to ensure complete charging of all the cells in a battery.

**Equivalent All-Electric Range (EAER)**

A legal term defined by CARB, in which a formula is used to translate blended-mode charge-depleting (CDB) operations distance of a PHEV into a lesser ‘equivalent’ all-electric range.

**E-scooter**

Small electric sit-down or stand-up vehicles ranging from motorised kick boards to electric mini motorcycles.

Differences between the two types of small electric scooters:

Stand-up scooters. Instead of pushing the scooter forward with one leg you simply turn the throttle on the handlebar and ride electrically. A typical stand-up scooter is a little more than one meter long and weights 12-25 kg.

Sit-down scooters. Small electric vehicles with a seat are used much the same way as gasoline powered scooters. A throttle on the handlebar regulates the acceleration. Sit-down e-scooters are usually bigger and heavier than the stand-up types. The appearance and accessories vary from trendy and stylish products to ones with large seats and a big shopping basket.

**Ethanol (EtOH)**

A chemical that may be used as a motor fuel, either ‘neat’ (pure) or blended into refined petroleum products such as gasoline. When used as a fuel, it requires multiple revisions of engine controls and of materials used in the engine and emissions aftertreatment system. Generally, the higher the percentage of ethanol blended into gasoline, the more changes have to be made to the engine and exhaust system. It is possible to design a vehicle to use varying blends of gasoline and ethanol. Such vehicles are called ‘flexibly fuelled vehicles’ or ‘fuel flexible vehicles’ (FFVs). Brazil, the United States and Sweden produce significant quantities of FFVs. The leading producers of ethanol in the world are the U.S. -which produces it from corn- and Brazil, which produces it from sugar cane. In the future, the U.S. intends to expand production of ethanol by use of biomass other than corn. Production of vehicles capable of using ethanol costs hundreds of dollars per vehicle, in contrast to PHEVs and EVs, where the costs of conversion to electric drive are in the thousands.

**Extended-range electric vehicle**

An ‘autonomous road vehicle’ primarily using electric drive provided by a RESS, but with an auxiliary onboard electrical energy generation unit and fuel supply used to extend the range of the vehicle once RESS electrical charge has been depleted. A more brief term for such a vehicle is ‘series PHEV’.

**E85, E20**

Ethanol blended into gasoline is generally labelled according to the volume percentage of ethanol in the mixed fuel. Thus, E85 contains 85% ethanol by volume; E20 contains 20% and so forth. Generally the lowest percentage of

gasoline in gasoline-ethanol blends is 15% (i.e. E85). In E85 the gasoline-like hydrocarbons contribute to improved vehicle cold starting, flame luminosity to help fire-fighters if the fuel catches fire, and also acts as a denaturant (prevents human consumption of the ethanol).

#### **Federal Test Procedure (FTP)**

By FTP here we mean the federal test procedure used to measure emissions, from which an estimate of ‘city’ fuel economy is also constructed. The FTP involves running a complete urban dynamometer driving schedule (UDDS), starting with a cold start, turning the engine off for ten minutes, restarting warm and running the first 505 seconds of the UDDS again. The running time for the UDDS is 1372 seconds. The running time for the FTP is 1877 seconds (ignoring the ten minutes with engine off). The average weighted speed of the FTP is 34 km/h, while the average speed for the UDDS is 31 km/h. This test is conducted at ~ 24 degrees centigrade. For purposes of developing estimates of ‘on-road’ fuel economy, accounting for starting in cold temperatures, the U.S. Environmental Protection Agency has recently developed the ‘Cold FTP’, which is conducted at ~ - 6.7 degrees centigrade.

#### **Fuel cell**

An electrochemical cell that converts chemical energy directly into electric energy, as the result of an electrochemical reaction between reactants continuously supplied, while the reaction products are continuously removed. The most common reactants are hydrogen (fuel) and oxygen (also from the air).

#### **Fuel Cell Vehicle (FCV)**

A vehicle with an electric powertrain that uses the fuel cell as a source of the electricity to provide electric drive. FCVs may also include an electric storage system (ESS) and be HEVs or PHEVs. However, an ESS is not technically necessary in a FCV.

#### **Fuel consumption**

It is the energy consumed by a vehicle per unit distance (in km) and, sometimes, also per unit weight (in ton). It may be expressed as kWh/km and also kWh/(km·ton). For EVs and PHEVs the electrical energy counted, expressed in AC kWh, is from the plug (charger input). Usually developed from tests of vehicles when driven over a ‘driving cycle’ (a speed versus time requirement), with a specified passenger and/or luggage load. Standardized methods of estimating fuel consumption of PHEVs have not yet been developed.

#### **Fuel economy**

Also referred to as fuel efficiency. For an EV it is the distance (in km) travelled per unit energy from the plug, in kWh. For an internal combustion engine vehicle it represents the distance travelled per litre of fuel. It is the reciprocal of the energy per unit distance (the reciprocal of fuel consumption). Usually developed from tests of vehicles when driven over a ‘driving cycle’

(a speed versus time requirement), with a specified passenger and/or luggage load. Standardized methods of estimating fuel economy of PHEVs have not yet been developed.

**Full HEV**

A full HEV has the ability to operate all electrically, generally at low average speeds. At high steady speeds such a HEV uses only the engine and mechanical drivetrain, with no electric assist. At intermediate average speeds with intermittent loads, both electric and mechanical drives frequently operate together. A PHEV can be developed based on a full HEV powertrain.

**Gasoline (reformulated - RFG, and conventional)**

Gasoline is a refined petroleum product burned in spark ignition (SI) internal combustion engines. It comes in many types and grades, with formulations varying for purposes of octane rating and to influence evaporative and tailpipe emissions. In the U.S. two very broad categories are ‘reformulated’, which is a minority grade used in areas that need low emissions to improve air quality. The majority of gasoline in the U.S. is ‘conventional’.

**Gas-to-hydrogen (G2H)**

Conversion of (natural) gas to a synthesis gas containing hydrogen ( $H_2$ ) and carbon monoxide (CO), followed by clean-up of the gas to produce pure  $H_2$ . The common process used is steam reforming.

**Hourly (hour) battery rate**

The discharge rate of a cell or battery expressed in terms of time a fully charged cell or battery can be discharged at a specific current before reaching a specified cut-off voltage: hour-rate =  $C/i$ , where C is the rated capacity and i is the specified discharge current. For EVs, a 3-hour or a 1-hour discharge is preferred.

**Hybrid road vehicle**

A hybrid road vehicle is one in which propulsion energy during specified operational missions is available from two or more kinds or types of energy stores, sources or converters. At least one store or converter must be onboard.

**Hybrid Electric Vehicle (HEV)**

The 1990s definition of IA-HEV Annex I was ‘a hybrid electric vehicle (HEV) is a hybrid road vehicle in which at least one of the energy stores, sources or converters delivers electric energy’. The International Society of Automotive Engineers (SAE) defines a hybrid as ‘a vehicle with two or more energy storage systems, both of which provide propulsion power - either together or independently’. Normally, the energy converters in a HEV are a battery pack, an electric machine or machines, and internal combustion engine. However, fuel cells may be used instead of an internal combustion engine. In a hybrid, only one fuel ultimately provides motive power.

**Hybrid Electric Vehicle (HEV) - Parallel configuration**

A parallel hybrid is a HEV in which both an electric machine and engine can provide final propulsion power together or independently.

**Hybrid Electric Vehicle (HEV) - Series configuration**

A series hybrid is a HEV in which only the electric machine can provide final propulsion power.

**Induction motor**

An alternating-current motor in which the primary winding on one member (usually the stator) is connected to the power source, and the secondary winding on the other member (usually the rotor), carries only current induced by the magnetic field of the primary. The magnetic fields react against each other to produce a torque. One of the simplest, reliable, and cheapest motors made.

**Inductive charging**

The use of magnetic coupling devices instead of standard plugs in charging stations. This technology was actively pursued for EVs in the 1990s in the U.S.

**Infrastructure**

Everything except the vehicle itself that is necessary for its use. For PHEVs or EVs the infrastructure is including: available fuel (electricity), power plants, transmission lines, distribution lines, access to parts, maintenance and service facilities, acceptable trade-in and resale market.

**Installed capacity**

The total number of Ampere-hours that can be withdrawn from a new battery cell, module or pack when discharged to the system specified cut-off voltage at the HEV, PHEV or EV design rate and temperature (i.e. discharge at the specified maximum DOD).

**Internal Combustion Engine (ICE)**

The historically most common means of converting fuel energy to mechanical power in conventional road vehicles. Air and fuel are compressed in cylinders and ignited intermittently. The resulting expansion of hot gases in the cylinders creates a reciprocal motion that is transferred to wheels via a driveshaft or shafts.

**Kilowatt-hour (kWh)**

1000 Watt-hours of energy. Equals to 1.341 horsepower-hours (or 1.35962 CVh).

**Lithium ion (Li-ion)**

Lithium ion is actually a family of battery chemistries. Currently used Li-ion chemistries have come down significantly in cost and have increased gravimetric and volumetric energy density over the last 15 years, accelerating

in the last seven. Li-ion has nearly completely supplanted NiMH in consumer electronics. NiMH remains the chemistry of choice in HEVs, but is anticipated to be replaced by emerging Li-ion chemistries. Because it has already attained significantly higher gravimetric and volumetric energy density than NiMH in consumer cells and is improving further with new chemistries, Li-ion is seen as the coming enabling technology for PHEVs, in addition to being a solid competitor to replace NiMH in HEVs. NiMH does also continue to slowly improve.

#### **Low Emissions Vehicle (LEV)**

A vehicle with tailpipe emissions below a specified level, as determined by regulations and test procedures specified by CARB.

#### **Maintenance-free battery**

A secondary battery, which during its service needs no maintenance, provided specified operating conditions are fulfilled.

#### **Mild HEV**

A HEV that has a less powerful electric machine and battery pack than a full hybrid. According to TNO, a mild HEV cannot operate all electrically. Electric assist always works together with the internal combustion engine.

#### **Motor, electric machine, generator**

A motor is a label for an electric machine that most frequently converts electric energy into mechanical energy by utilising forces produced by magnetic fields on current-carrying conductors. Most electric machines can operate either as a motor or generator. When operating as a generator, the electric machine converts mechanical energy into electrical energy. In HEVs, PHEVs and EVs electric machines operate both in motoring and generating modes.

#### **Neighbourhood Electric Vehicle (NEV)**

A vehicle defined in U.S. Federal Regulations. NEVs are low speed electric vehicles that have a maximum speed of 25 mph and can only be driven on roads with a maximum speed of 35 mph. Such vehicles have a much less stringent set of safety requirements than do other U.S. light-duty vehicles.

#### **Nickel Cadmium (NiCd)**

Nickel Cadmium was a common battery chemistry used in many EVs of the 1990s, and in consumer electronics. It is no longer common in use.

#### **Nickel Metal Hydride (NiMH)**

Nickel metal hydride was a common commercial battery chemistry in the 1990s for consumer electronics. In the late 1990s it became the battery of choice for HEVs. It has higher gravimetric and volumetric energy density than NiCd.

**Nitrogen Oxides (NO<sub>x</sub>)**

NO<sub>2</sub> and/or NO - ‘criteria pollutants’ whose emissions from the tailpipe and concentration in the air is regulated. NO<sub>x</sub> reacts in sunlight and high temperatures with ROG to form ozone, a regulated pollutant of general concern. NO<sub>x</sub> also reacts with ammonia to form the particulate matter (PM) ammonium nitrate. Total PM, by mass per unit volume of air, is also regulated.

**Nominal capacity**

The total number of Ampere-hours that can be withdrawn from a new cell or battery for a specified set of operating conditions including discharge rate (for EV usually C<sub>1</sub> or C<sub>3</sub>), temperature, initial state of charge, age and cut-off voltage.

**Nominal voltage**

The characteristic operating voltage or rated voltage of a cell or battery or connecting device.

**Normal charging**

Also called slow or standard charge. The most common type and location for charging of a PHEV or EV battery pack necessary to attain the state of maximum charge of electric energy.

**On-road (or ‘in use’) fuel economy (or consumption)**

Official certification test fuel economy (consumption) values typically exceed (underestimate) actual values experienced by vehicle drivers. To varying degrees, nations that have been involved with the IA have conducted research to determine actual ‘on-road’ fuel economy (consumption). At this time, the U.S. has adopted a method to estimate, and publish for consumers, estimates of on-road fuel consumption that use five different driving cycles. The official U.S. certification fuel economy rating system uses only two different driving cycles. Europe has conducted studies on this topic, but has not yet developed an ‘on-road’ rating system for consumers.

**Opportunity charging**

The use of a charger during periods of EV or PHEV inactivity to increase the charge of a partially discharged battery pack.

**Overcharge**

The forcing of current through a cell after all the active material has been converted to the charged state. In other words, charging is continued after 100% state of charge (SOC) is achieved.

**Parallel battery pack**

Term used to describe the interconnection of battery cells and/or modules in which all the like terminals are connected together.

**Parallel HEV**

A HEV in which the engine can provide mechanical power and the battery electrical power simultaneously to drive the wheels.

**Partial Zero Emission Vehicle (PZEV)**

A category defined in the regulatory structure of the California Air Resources Board (CARB). From CARB's perspective the vehicle has some of the desirable emissions characteristics of a ZEV, but not all.

**Particulate matter (PM)**

A mix of chemicals in particulate form, emerging from the tailpipe of a vehicle or within air. Both tailpipe PM and PM concentrations in ambient air are regulated in most advanced nations. PM emissions historically have consistently been far higher from diesel (compression ignition) engines than from gasoline (spark ignition) engines.

**Peak power (in kW)**

Peak power attainable from a battery, electric machine, engine (or other part) in the drive system used to accelerate a vehicle. For a battery this is based on short current pulse (per 10 seconds or less) at no less than a specified voltage at a given DOD. For an electric machine the limiting factor is heating of insulation of copper windings. Peak power of an engine is generally related to mechanical capabilities of metal parts at peak allowable revolutions per minute, also affected by heat. Generally continuous power ratings are well below peak power ratings.

**Pedelec**

Pedelec stands for 'pedal electric cycle'. While pedaling the rider gets additional power from the electric drive system. The control of the motor output of a pedelec is linked to the riders pedaling contribution by means of a movement or power sensor. In other words: the electric motor is activated as soon as the rider starts to pedaling and deactivated as soon as the rider stops pedaling.

**Plug-in Hybrid Electric Vehicle (PHEV)**

A HEV with a battery pack with a relatively large amount of kWh of storage capability, with an ability to charge the battery by plugging a vehicle cable into the electricity grid. This allows more than two fuels to be used to provide the propulsion energy.

**PHEV<sub>xk</sub>**

A plug-in hybrid electric vehicle with 'x' miles or kilometres of estimated CDE range (AER). In this glossary, we suggest adding a small letter 'k' to denote when the 'x' values are in kilometres, or an 'm' to denote when those values are in miles.

**Power**

The rate at which energy is released. For an EV, it determines acceleration capability. Power is generally measured in kilowatts.

**Power density (volumetric)**

The ratio of the power available from a battery to its volume in litres (W/l). The mass power density in battery and EV industry is normally called specific power (see Specific power), or gravimetric power density.

**Range**

The maximum distance travelled by a vehicle, under specified conditions, before the ‘fuel tanks’ need to be recharged. For a pure EV, it is the maximum distance travelled by a vehicle -under specified conditions- before the batteries need to be recharged. For a PHEV it will be the maximum distance achievable after emptying both the battery pack and fuel tank. For a conventional vehicle or HEV it will be the maximum distance achievable after emptying the fuel tank.

**Rated capacity**

The battery cell manufacturer's estimate of the total number of Ampere-hours that can be withdrawn from a new cell for a specified discharge rate (for EV cells usually C<sub>1</sub> or C<sub>3</sub>), temperature and cut-off voltage.

**Reactive Organic Gases (ROG)**

These are emissions from the tailpipe and or evaporation of fuel from vehicles. Consistent with the name, they are problematic because they react in air with other gases (NO<sub>x</sub> in particular) to form ambient air pollution, primarily ozone. Generally both the emissions of ROG from vehicles and ozone in the air are regulated.

**Rechargeable electric energy storage system (RESS)**

Battery packs, flywheels and ultracapacitors are examples of ‘systems’ that could be repeatedly charged from the grid, with the charge later discharged in order to power an electric machine to move a vehicle.

**Regenerative braking**

A means of recharging the battery by using energy produced by braking the EV. With normal friction brakes, a certain amount of energy is lost in the form of heat created by friction from braking. With regenerative braking, the electric machines act as generators. They reduce the braking energy lost by returning it to the battery, resulting in improved range.

**Self-discharge**

The loss of useful electricity previously stored in a battery cell due to internal chemical action (local action).

**Series HEV**

A series hybrid is a HEV in which only the electric machine can provide final propulsion power.

**Smart charging**

The use of computerised charging devices that constantly monitor the battery so that charging is at the optimum rate and the battery life is prolonged.

**Spark ignition (SI)**

Ignition of a mixture of air and fuel in the cylinders of an internal combustion engine via an electric spark.

**Specific energy, or gravimetric energy density (of a battery)**

The energy density of a battery expressed in Watt-hours per kilogram.

**Specific power, or gravimetric power density (of a battery)**

The rate at which a battery can dispense power measured in Watts per kilogram.

**Start-stop**

The lowest level of electrification of a powertrain, involving a slightly larger (higher kW) electric machine and battery than for starting alone, providing an ability to stop the engine when the vehicle is stopped and save fuel that would have been consumed at engine idle.

**Start-stop + regeneration (and electric launch)**

This technology package can also be called ‘minimal’ hybridization or ‘soft’ hybridization. According to the International Society of Automotive Engineers (SAE), a hybrid must provide propulsion power. If a start-stop system includes regeneration and electric launch, it is a hybrid, according to the SAE definition. If it does not, it is not a hybrid.

**State Of Charge (SOC)**

See ‘Battery state of charge’.

**Sulphur Oxides ( $\text{SO}_x$ )**

Sulphur oxides - a ‘criteria pollutant’ whose concentration in the air is regulated. Sulphur content of fuel is usually regulated; both in order to reduce conversion of fuel sulphur to  $\text{SO}_x$  from the tailpipe, and also to increase the reliability and functionality of vehicle emissions control systems.  $\text{SO}_x$  mass per unit volume concentrations is regulated.  $\text{SO}_x$  also reacts with ammonia to form the particulate matter (PM) ammonium sulphate. Total PM, by mass per unit volume of air, is also regulated.

**Super Ultra Low Emissions Vehicle (SULEV)**

For a given type of vehicle, the lowest ‘non zero’ emissions rating under the CARB LEV emissions regulations.

**Type 0 (as defined by CARB)**

Utility EV, less than 50 mile range.

**Type I (as defined by CARB)**

City EV, range of 50 miles to 75 miles.

**Type I.5 (as defined by CARB)**

City EV, range of 75 miles to less than 100 miles.

**Type II (as defined by CARB)**

Full function EV, range of 100 or more miles.

**Type III (as defined by CARB)**

ZEV, range of 100 or more miles plus fast refuelling.

**Type IV (as defined by CARB)**

ZEV, range of 200 or more miles plus fast refuelling.

**ULEV II**

Ultra Low Emissions Vehicle after 1998 CARB regulation revisions.

**Useable capacity**

The number of Ampere-hours (or kilowatt-hours) that can be withdrawn from a battery pack installed in a PHEV, taking into account decisions on control strategy designed to extend battery pack life or achieve vehicle performance goals (refers to a minimum power level). Useable capacity < nominal capacity.

**Volt**

A unit of potential difference or electromotive force in the International System units, equal to the potential difference between two points for which 1 Coulomb of electricity will do 1 Joule of work in going from one point to the other. Volt is symbolised by 'V'.

**Voltage efficiency**

The ratio of the average voltage during discharge to the average voltage during recharge under specified conditions of charge and discharge.

**Watt-hour efficiency**

The ratio of the Watt-hours delivered on discharge of a battery to the Watt-hours needed to restore it to its original state under specified conditions of charge and discharge.

**Watt-hours per kilometre**

Energy consumption per kilometre at a particular speed and condition of driving. A convenient overall measure of a vehicle's energy efficiency. Watt-hour efficiency = Ampere-hour efficiency x voltage efficiency.

**Zero Emission Vehicle (ZEV)**

A vehicle that has no regulated emissions from the tailpipe. Under California

Air Resources Board (CARB) regulations, either an EV or a FCV is also a ZEV.

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## Abbreviations

A	Ampere
AC	Alternating Current
ACEA	European Automobile Manufacturers Association
ACT	Accelerated Technology (IEA)
ADEME	Agency for Environment and Energy Management (France)
AEI	Advanced Energy Initiative (USA)
AER	All-Electric Range
AFV	Alternative Fuel Vehicle
AGV	Automatic Guided Vehicle
Ah	Ampere-hour
AHFI	Austrian Hydrogen and Fuel cell Initiative
AIM	Asynchronous Induction Machine
AIST	National Institute of Advanced Industrial Science and Technology (Japan)
ALABC	Advanced Lead Acid Battery Consortium
ALM	Automotive Lightweight Materials
ANL	Argonne National Laboratory (USA)
ANR	Agence Nationale de la Recherche (France)
ANVAR	Agence Nationale de Valorisation de la Recherche (France)
APRF	Advanced Powertrain Research Facility (at ANL)
APSC	Austrian Alternative Propulsion Systems Council
APU	Auxiliary Power Unit
ASBE	Belgian Electric Vehicles Association
AT-PZEV	Advanced Technology Partial Zero Emission Vehicle
AVEM	Avenir du Véhicule Electrique Méditerranéen (France)
AVERE	European Association for Battery, Hybrid and Fuel Cell Electric Vehicles
A3	Austrian Advanced Automotive technology R&D programme
A3PS	Austrian Agency for Alternative Propulsion Systems
BES	Basic Energy Sciences
BEV	Battery Electric Vehicle
BMVIT	Federal Ministry for Transport, Innovation and Technology (Austria)
BTL	Biomass-to-liquid (fuel)
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
cc	cubic centimetre
CCS	CO <sub>2</sub> Capture and Storage
CD	Charge Depletion

CDB	Charge Depletion - Blended mode
CDE	Charge Depletion - all Electric operation
CEI	Italian Electrotechnical Commission
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CERT	Committee on Energy Research and Technology (IEA)
CHF	Swiss Franc
CHP	Combined Heat and Power (generation)
CH <sub>4</sub>	Methane
CIDI	Compression Ignition Direct Injection
CITELEC	Association of European Cities interested in Electric Vehicles
CIVES	Italian Electric Road Vehicle Association
CNG	Compressed Natural Gas
CNR	National Research Council (Italy)
CO	Carbon monoxide
Co.	Company
Corp.	Corporation
CO <sub>2</sub>	Carbon dioxide
CRF	Fiat Research Center (Italy)
CTL	Coal-to-liquid (fuel)
CUTE	Clean Urban Transport for Europe
CVT	Continuous Variable Transmission
DC	Direct Current
DKK	Danish Crown
DME	Dimethyl ether
DOD	Depth Of Discharge
DOE	Department of Energy (USA)
DOT	Department of Transportation (USA)
DPF	Diesel Particulate Filter
DSBHFC	Direct Sodium Borohydride Fuel Cell
EAER	Equivalent All-Electric Range
EC	European Commission
ECN	Energy research Centre of the Netherlands
ECU	Electronic Control Unit
EDF	Électricité de France
EDTA	Electric Drive Transportation Association
EET	European Ele-Drive Transportation Conference
EEV	Enhanced Environmentally friendly Vehicle (Europe)
EIA	Energy Information Administration (USA)
EM	Electric Motor
EM	Expert Meeting

EMPA	Swiss Federal Laboratories for Material Sciences and Technology Development
EMU	Electrified Motive Unit
ENEA	Italian National Agency for New Technologies, Energy and the Environment
EPA	Environmental Protection Agency
EPACT	Energy Policy Act (USA)
EPE	European Power Electronics and Drives Association
EPRI	Electric Power Research Institute (USA)
EREV	Extended-Range Electric Vehicle
ESS	Electric Storage System
ESS	Energy Storage System
ETEC	Department of Electrical Engineering and Energy Technology (VUB)
ETH	Eidgenössische Technische Hochschule Zürich (Swiss Federal Institute of Technology Zürich)
ETO	Office of Energy Technology and R&D (IEA)
EtOH	Ethanol
EU	European Union
EUDP	Energy Technology Development and Demonstration Programme (Denmark)
EURO-x	European emission standard, level x
EUWP	End Use Working Party (IEA)
EV	Electric Vehicle
E.V.A.	Austrian Energy Agency
EVS	Electric Vehicle Symposium
ExCo	Executive Committee
E85	Fuel blend of 85 vol-% ethanol and 15 vol-% gasoline
F	Farad
FC	Fuel Cell
FCEV	Fuel Cell Electric Vehicle
FCV	Fuel Cell Vehicle
FFV	Flexibly Fueled Vehicle or Fuel Flexible Vehicle
FH	Fachhochschule (University of applied sciences - Germany, Switzerland)
FISR	Special Integrative Fund for Research (Italy)
FMVSS	Federal Motor Vehicle Safety Standard (USA)
FP	European Framework Programme for research and technological development
FT	Fischer Tropsch
FTP	Federal Test Procedure (USA)
FY	Fiscal Year

GDP	Gross Domestic Product
GEM	Global Electric Motorcars
gge	gallon gasoline equivalent
GHG	Greenhouse Gas
GM	General Motors
GMC	General Motors Corporation
Gt	Giga ton ( $10^9$ tons)
GTL	Gas-to-liquid (fuel)
GVW	Gross Vehicle Weight
G2V	Grid-to-Vehicle
h	hour
HCCI	Homogeneous Charge Compression Ignition
HEV	Hybrid Electric Vehicle
HMI	Human Machine Interaction
HOV	High Occupancy Vehicle
hp	horsepower
HTAS	High Tech Automotive Systems (The Netherlands)
H <sub>2</sub>	Hydrogen
H&EVs	Hybrid and Electric Vehicles
IA	Implementing Agreement (of the IEA)
IA-AFC	Implementing Agreement on Advanced Fuel Cells
IA-AMF	Implementing Agreement on Advanced Motor Fuels
IA-HEV	Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes
ICE	Internal Combustion Engine
ICT	Information- and Communication Technology
IEC	International Electrotechnical Commission
IEA	International Energy Agency
IGBT	Insulated Gate Bipolar Transistor
IMA	Integrated Motor Assist™ (by Honda)
Inc.	Incorporated
INL	Idaho National Laboratory
INRETS	Institut National de Recherche sur les Transports et leur Sécurité (France)
IPCC	Intergovernmental Panel on Climate Change
IPHE	International Partnership for a Hydrogen Economy
IRS	Internal Revenue Service (USA)
ISO	International Organization for Standardization
ITRI	Industrial Technology Research Institute (Taiwan)
ITS	Intelligent Transport System
ITU	Istanbul Technical University (Turkey)

IV2S	Intelligent Traffic Systems and Services research programme (Austria)
JARI	Japan Automobile Research Institute
JCS	Johnson Controls, Inc. and Saft joint venture
kWh	Kilowatt-hour
LCA	Life Cycle Analysis
LDV	Light-Duty Vehicle
LEV	Light Electric Vehicle
LEV	Low Emissions Vehicle
Li	Lithium
LiP	Lithium Phosphate
LiP	Lithium Polymer
LLNL	Lawrence Livermore National Laboratory
LMP	Lithium Metal Polymer
LNG	Liquefied Natural Gas
LNT	Lean NO <sub>x</sub> Trap
LPG	Liquefied Petroleum Gas
MATT	Mobile Advanced Technology Testbed
MCFC	Molten Carbonate Fuel Cell
Mg	Magnesium
MH	Metal Hydride
min	minute(s)
mpg	miles per gallon
mph	miles per hour
MPV	Multi Purpose Vehicle
MRC	Marmara Research Center (TÜBITAK, Turkey)
NEET	Networks of Expertise in Energy Technology (IEA initiative)
NEV	Neighbourhood Electric Vehicle
NGV	Natural Gas Vehicle
NHTSA	National Highway Traffic Safety Administration (USA)
NiCd	Nickel Cadmium
NiMH	Nickel Metal Hydride
NL	The Netherlands
NMVOS	Non-Methane Volatile Organic Substances
NO <sub>x</sub>	Nitrogen Oxides
NRC	National Research Council of Canada
NRCan	Natural Resources Canada
NREL	National Renewable Energy Laboratory (USA)
N <sub>2</sub> O	Nitrous Oxide (not considered a NO <sub>x</sub> compound)

OA	Operating Agent
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OERD	Office of Energy Research and Development (NRCan)
ORNL	Oak Ridge National Laboratory (USA)
OSD	Automotive Manufacturers Association (Turkey)
OTAM	Automotive Technologies Research & Development Company (Turkey)
P.A.	Power-Assisted
PCA	Peugeot Citroën Automobiles (France)
PCCI	Premixed Charge Compression Ignition
PEFC	Polymer Electrolyte Fuel Cell
PEFC	Proton Exchange Fuel Cell
PEM	Polymer Electrolyte Membrane
PEM	Proton Exchange Membrane
PERD	Program of Energy Research and Development (NRCan)
PHEV	Plug-in Hybrid Electric Vehicle
PHEVx	Plug-in Hybrid Electric Vehicle that has the ability to travel x miles on electric-only mode
PM	Particulate Matter
PMSM	Permanent Magnet Synchronous Motor
PM <sub>10</sub>	Particulate Matter, size < 10 µm (10 <sup>-6</sup> m)
ppm	parts per million
PR	Public Relations
PRC	People's Republic of China
PSAT	Powertrain Systems Analysis Toolkit (ANL)
psi	pound-force per square inch
PSI	Paul Scherrer Institut (Switzerland)
PTO	Power Take Off
PV	Photovoltaic
PZEV	Partial Zero Emission Vehicle
RD&D	Research, Development and Deployment
RESS	Rechargeable (electric) Energy Storage System
RFG	Reformulated Gasoline
ROG	Reactive Organic Gases
R&D	Research and Development
SAE	Society of Automotive Engineers
SAM	Super Accumulator Module
SC	Sub-Committee
SCE	Southern California Edison
SCR	Selective Catalytic Reduction

SEK	Swedish Crown
SHC	Swedish Hybrid Vehicle Centre
SHHP	Scandinavian Hydrogen Highway Partnership
SI	Spark Ignition
SI	Système International (International System of Units)
SIDI	Spark Ignition Direct Injection
SMEs	Small and Medium Enterprises
SOC	State Of Charge (battery)
SOFC	Solid Oxide Fuel Cell
SOH	State Of Health (battery)
SO <sub>x</sub>	Sulphur Oxides
SO <sub>2</sub>	Sulphur dioxide
SQAIM	Squirrel cage rotor Asynchronous Induction Machine
SRA	Strategic Research Area
SULEV	Super Ultra Low Emissions Vehicle
SUV	Sport Utility Vehicle
S.V.E.	Société des Véhicules Electriques (France)
SWEVA	Swedish Electric & Hybrid Vehicle Association
t	Ton(s) (1 t = 1'000 kg)
TC	Technical Committee
TLVT	Technology Life Verification Test
TNO	The Netherlands Organisation for Applied Scientific Research TNO
UDDS	Urban Dynamometer Driving Schedule (USA)
UK	United Kingdom
ULEV	Ultra Low Emissions Vehicle
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
U.S.	United States (of America)
USA	United States of America
USABC	United States Advanced Battery Consortium
USCAR	United States Council for Automotive Research
US\$	U.S. dollar
V	Volt
VAT	Value-Added Tax
VITO	Flemish Institute for Technological Research (Belgium)
vol-%	Percentage based on volume
VRLA	Valve Regulated Lead Acid (battery)
VSP	Vehicle Simulation Programme (ETEC, VUB)
VSWB	Flemish Cooperative on Hydrogen and Fuels Cells (Belgium)
VTT	Programme Véhicules pour les Transports Terrestres (ANR, France)

VUB	Vrije Universiteit Brussel (Belgium)
VW	Volkswagen
V2G	Vehicle-to-Grid
WEVA	World Electric Vehicle Association
Wh	Watt-hour
WSC	World Solar Challenge (race for solar powered vehicles)
wt-%	Percentage based on weight
ZEV	Zero Emission Vehicle

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The website of the IEA Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV) can be found at [www.ieahhev.org](http://www.ieahhev.org).

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