IEA INTERNATIONAL ENERGY AGENCY
HYBRID & ELECTRIC VEHICLE IMPLEMENTING AGREEMENT

Outlook for hybrid and electric vehicles

Predicting the future is very difficult, if not impossible. Only two years ago, did you for example foresee the current worldwide economic crisis? So an outlook cannot be a prediction of the future. This outlook for hybrid and electric vehicles is a set of expectations for the future (until 2015) and factors that may influence these expectations.

Introduction and context

This outlook presents the views of a group of hybrid and electric vehicle experts (IA-HEV) collaborating under the framework of the International Energy Agency (IEA). IA-HEV is the Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes. The twelve current member countries are Austria, Belgium, Canada, Denmark, Finland, France, Italy, the Netherlands, Sweden, Switzerland, Turkey and the United States. The participants in the Agreement are governmental bodies and research institutes that are appointed by their governments. This outlook is a synthesis of inputs of IA-HEV member country delegates; it does not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

Governmental policy makers and governmental bodies are the main target audience for this outlook, but it is also meant for research institutes working in the area of road transport, energy and environment, and for the energy sector.

This outlook starts with a small recapitulation why hybrid and electric vehicles are currently in focus. Then the car market is discussed, including the role of hybrid electric vehicles (HEVs) and pure electric vehicles (EVs). Plug-in hybrid electric vehicles (PHEVs), young customers and heavy-duty hybrids as specific topics for the market are elaborated in more detail. Next, the role of costs and the impact of the economic crisis on the outlook are discussed. After briefly addressing the environmental impact of hybrid and electric vehicles, the public opinion on these vehicles is elaborated. This outlook rounds off with the role of governments in all these issues and governmental possibilities to stimulate the transition towards clean and energy-efficient vehicles such as HEVs, PHEVs and EVs.

Why hybrid and electric vehicles?

It is clear that the current road vehicle transportation system is not sustainable. It consumes fossil fuels of which reserves are not endless, and its gaseous emissions cause air pollution and contribute to climate change. Among others, hybrid and electric vehicles are options to reduce energy consumption and emissions from road vehicles compared to conventional vehicles.

So why, in spite of these advantages, are hybrid and electric vehicles not used on a larger scale? The most important reason is their higher purchase costs. A hybrid vehicle for example has at least two propulsion systems so it can use at least two different energy carriers, which makes it more expensive to manufacture than a conventional vehicle. (In this outlook, a vehicle with internal combustion engine and only a stop-start system is not considered a hybrid vehicle.) Also batteries for electric vehicles are still expensive. Other reasons are for example that a production and maintenance infrastructure is not yet in place, and for battery EVs the vehicle range is usually perceived as being too small.

In spite of the price disadvantage, the market for hybrid vehicles has started to take off. This was possible because vehicle manufacturers with a long-term vision on energy efficiency have started producing hybrids and governments have created incentives for clean and energy-efficient vehicles.

The next section presents expectations for the car market, while other vehicles are discussed in the heavy-duty applications section (on page 6).

The car market

The year 2008 showed a remarkable change in car sales. The trend of increasing sales of larger and heavier cars, including sports utility vehicles (SUVs), was broken in favour of smaller and more energy-efficient cars. During the first half of 2008 the surging oil price was driving this change, while in the second half of the year the worldwide economic crisis had its impact. The economic crisis not only led to an increasing interest in small and fuel-efficient cars, but it also caused a sharp decline in total vehicle sales. Remarkably, the share of hybrid electric vehicles in total car sales continued to grow in many countries. This trend is expected to continue because of the following reasons:

- Hybrid electric cars are more fuel-efficient than conventional cars, especially in urban traffic.
- More hybrid models will become available on the market.
- Higher production volumes may lead to lower hybrid vehicle costs and prices.
- Incentives for energy-efficient and low CO_2 emitting cars, such as tax reductions and entry rules for urban areas.

The growth of the sales share of hybrids is expected to continue in established markets (today 2-3% share in new vehicle sales) as well as in markets where hybrid sales are in their infancy. Although most car manufacturers are planning to bring new hybrid models on the market in the coming years, it is expected that total hybrid car sales will be limited because of limited supply. Especially the production volume of batteries might be a bottleneck. Box 1 presents some more detail.

Box 1
Hybrid and electric vehicle markets until 2015
Hybrid Electric Vehicles (HEVs) The worldwide HEV share in new vehicle sales is expected to continue its growth. However, the total production volume might be insufficient to meet demand, due to practical restrictions such as a limited production volume of batteries. By 2012, the global sales figure for hybrid vehicles may have tripled to 2.2 million units. The share of hybrid cars in 2015 new car sales is expected to be below 10%. **Electric Vehicles (EVs)** The share of electric cars in new car sales in 2015 is expected to be well below the share of HEVs at that time. Electric bicycles are expected to remain the dominant EV category. If current trends continue, the worldwide electric bicycle fleet will be well over 100 million units in 2015.

As mentioned earlier, it is impossible to predict the car market of 2015. Today's economic uncertainties may slow down the growth of the hybrid market share. On the other hand, a crisis offers opportunities for change and implementing new, better adapted technologies such as hybrid and electric vehicles.

Compared to hybrids, the market of pure electric cars is still very small. It appears that subsidies are not sufficient to create a sustainable electric car market. Nevertheless, electric vehicles (EVs) are a success in a number of market niches where they offer a clear advantage for the user. In countries like Norway and Switzerland, EV drivers profit from real advantages such as faster commuting, easier access to city centres, easier parking, lower operating costs, and -in some cases- a positive image. It should be noted that these advantages are not always offered by 4-wheeled electric cars, but they may be provided by lightweight three-wheelers and high-speed electric bicycles (see also box 1). The EV population may be expected to grow when new technologies that meet customers' demands are introduced on the market. Car manufacturers are developing EVs today and they are announcing the introduction of electric cars from 2010 onwards.

Plug-in hybrid electric vehicles (PHEVs)

A special category of hybrid vehicles is the plug-in hybrid electric vehicle (PHEV). Before addressing the reasons why PHEVs receive much attention lately, two different PHEV options are briefly described here. One type of PHEV is essentially a 'parallel' hybrid electric vehicle with additional batteries, giving the vehicle an all-electric drive capability in some urban driving conditions, and battery charge depletion capability in all driving conditions. A 'parallel' hybrid primarily means that both the electrical and mechanical portions of the complex

drivetrain can provide traction power to the wheels together, at the same time. Another PHEV design is the so-called 'extended-range electric vehicle' (EREV) where the vehicle only operates all-electrically while the grid-supplied battery charge is depleted. The EREV internal combustion engine comes on to drive the vehicle and extend the operating range after the battery charge is depleted. The drivetrain used is termed a 'series' powertrain. 'Series' is a form of hybrid where the internal combustion engine never provides mechanical power to the wheels, but its mechanical power is converted into electricity, which in turn is fed to batteries and/or directly used to propel the vehicle. The power to the wheels is always provided by an electric motor. Since the battery in a charge depleting series EREV must provide all needed power in all driving conditions, the EREV will have a much more powerful battery than the PHEV derived from modification of a parallel hybrid. The EREV can operate all-electrically, even on high speed limited access highways. Both types of PHEVs have a plug to connect and recharge their batteries from the electricity grid.

A major advantage of PHEVs is that they can be charged overnight, when most electric utilities have capacity available because of declining power demands. Thus, PHEVs can make use of existing generation and distribution capacity of electrical utilities, a feature considered very attractive by the utilities. PHEVs are gaining interest from utilities for other reasons as well - they offer electric storage capacity that utilities could use for their grid management.

When driving in all-electric mode, PHEVs have no tailpipe emissions. Additionally, when solar, wind or hydropower is used for electricity production, PHEVs will contribute to using renewable and clean energy in the transportation sector. Box 2 gives more information about PHEVs.

Most PHEVs are currently in the prototype phase. PHEVs modified from existing parallel HEVs are being developed by Toyota, from its Prius HEV, and by Ford, from its Escape HEV. These PHEVs will be capable of operating all-electrically in neighbourhoods and in less aggressive urban driving.

General Motors has announced that it will introduce an EREV PHEV, the Chevrolet Volt, on the market in 2010. This is a purpose-built new design, not derived from an existing vehicle body and powertrain. It will be capable of operating all-electrically in all driving conditions. Given the promise of PHEVs, other manufacturers are expected to follow. However, the share of PHEVs in new vehicle sales in 2015 will certainly be small compared to the conventional hybrid electric vehicle sales share.

Box 2

Plug-in Hybrid Electric Vehicles

A plug-in hybrid electric vehicle (PHEV) is essentially a hybrid electric vehicle (HEV) with additional batteries and a plug, giving the vehicle an ability to use electricity from the grid to move the vehicle. While the charge of the PHEV's larger battery pack is depleted, some PHEVs may operate all-electrically, while others may use both battery electric and internal combustion engine mechanical power to move the vehicle. A variety of design options for PHEVs are possible, but all will use electricity from the grid to replace liquid fuels used by internal combustion engines in vehicles.

One of the advantages of PHEVs is a potential increase in energy efficiency. This could then result in a reduction of greenhouse gas emissions, fuel consumption and dependency on fossil fuels. However, the full energy cycle result is highly dependent on the type of electricity generation capacity (solar, wind, coal, etc.), which varies greatly in IA-HEV member countries. Also, the time of charging can influence the source of the additional electricity needed to power PHEVs.

IA-HEV Annex VII's final report already mentioned that over the last decade in both the U.S. and Europe there has been a significant increase in the amount of generation of electricity by natural gas. This is a positive trend for full fuel cycle greenhouse gas emissions if the recently constructed combined cycle natural gas power plants -which are highly efficient, intermediate load plants- are used to generate electricity for PHEVs. 'Intermediate load' means that the plants increase in power output during the day and are throttled back or shut down at night. So in particular these plants are available to charge the first PHEVs that will appear on the market, when those PHEVs are charged in the evening and overnight. On the other hand, today's coal generation brings the risk that PHEVs using coal electricity emit more greenhouse gases over the full fuel cycle than conventional vehicles.

Sustainable electricity production capacity -such as wind and solar power- is increasing around the globe and will continue to grow in the coming decades. Using this kind of electricity for PHEVs is a very promising option to convert road transport to using renewable energy without greenhouse gas emissions.

These and other issues will be tackled by the newest IA-HEV task force that is collaborating on plug-in hybrid electric vehicles in Annex XV.

Young customers

Teenagers and today's young vehicle customers will form a substantial share of the people buying vehicles in 2015 and beyond. Their references may be different from the majority of today's customers. They have grown up with electronics and are used to electric powered equipment. Electric vehicles may be appealing for them, although these vehicles may offer fewer possibilities for customizing and tuning the 'engine'. It appears that young people prefer to live in cities and that makes them potential users of battery electric vehicles with limited range.

Heavy-duty applications

Besides in cars, hybrid electric drives can be used in heavy-duty applications such as trucks and buses, but also in mobile machinery such as forestry equipment, forklift trucks and wheel loaders. Hybrid drives are very well suited for stop-and-go traffic, where they can bring substantial fuel savings and emission reductions. This means that hybrid drives can be advantageously applied in vehicle categories such as city buses and goods distribution trucks. Hybrid city buses have gained a substantial fleet share in certain cities in the USA, but in Europe they are in an early development phase and only used in some demonstration projects. Hybrid goods vehicles such as delivery vans and trucks are still in the prototype phase. Today all major mobile machinery manufacturers are either developing or planning hybrid powertrains for their machines. Machines with stop-and-go use and/or with vertical load handling -such as forklift trucks, straddle carriers and wheel loaders- may especially gain in energy efficiency by using hybrid drives.

The application of hybrid powertrains in heavy-duty applications is behind in comparison with the application with cars, and consequently the worldwide market share of heavy-duty hybrids is estimated to be still small in 2015.

The role of costs

Relatively high purchase costs have already been mentioned as the most important barrier for a high share of hybrid and electric vehicles in the current vehicle fleet. This section brings more nuances and addresses other cost issues as well.

To date, owners of HEVs did not purchase these vehicles based on financial savings. A green image or just being different were more important driving forces. For a larger market share of hybrids, financial savings will have to play a much larger role in purchase decisions. The reselling price on the used car market, which to date is largely unknown, may play an important role in the total costs and savings of operating a hybrid car. When more hybrid car models will be offered on the market, total production numbers will go up and consequently production costs and purchase price may be expected to come down.

In 2008, an increasing sales share of fuel-efficient hybrid vehicles could be observed, in parallel with surging oil prices. In some countries hybrid car sales increased sharply when taxes for this kind of vehicle categories decreased. Also CO_2 emission based financial bonus/malus systems have positively affected hybrid sales. How costs of competing technologies -that meet customers demands for reduced fuel consumption and that simultaneously meet increasingly stringent emission requirements- compare to the costs of hybrid technology will play a role in the market success of hybrids. Finally, the overall economic situation will have an impact on the costs and market share of hybrid vehicles. This issue is addressed in the next section.

The impact of the economic crisis

The bad economic situation is one of the reasons why the trend of buying heavy vehicles with high fuel consumption is declining. This may be advantageous for fuel-efficient hybrid and electric vehicles when they can be offered to the customer at competitive price levels. The current economic situation makes it difficult to say how the growth of the HEV market will continue and it is almost impossible to give a reliable numerical estimation of future sales.

The economic crisis is likely to slow down or postpone hybrid vehicle development, but it is unlikely that this development work will come to a halt. The actual crisis in the car industry will also have negative effects on their suppliers. At this stage it is not clear how the automotive industry will recover from this dip. Nevertheless, some see opportunities arising from the current situation. In rare cases there might be new investments in research because companies now have labour available.

Environmental impact of hybrid and electric vehicles

Using hybrid and electric vehicles reduces CO_2 and pollutant emissions compared to conventional vehicles, where a precondition for EVs is low carbon electricity production. For example hybrid goods distribution trucks and hybrid buses will have a positive effect on air quality in cities. However, for the time being the relatively small market penetration of hybrid and electric vehicles limits their impact on the environment.

Besides hybridization, using electric vehicles or using biofuels, other energy-efficient vehicle technologies such as diesel engines and fuel cell cars are ways of reducing CO_2 emissions. When energy-efficient technologies are combined with low CO_2 fuels, these technologies become even more interesting.

Public opinion

Society in general has started moving towards more sustainable behaviour and consumption patterns, including mobility. Campaigns have raised public

awareness about the negative consequences of consumption, including petroleum based vehicle propulsion. The use of public transport is increasing, acceptance of large inefficient vehicles is declining, and sales of smaller cars are increasing, not only due to fiscal measures. The market success of hybrid vehicles by itself has contributed to change the public opinion. The popularity of HEVs is expected to further increase when more models become available. The general public has started showing interest in plug-in hybrids.

Nevertheless, there are still consumer satisfaction issues for a large-scale deployment of vehicles with an electric drive. For example, the charge depleting range of PHEVs and EVs would be sufficient for most commuter trips in North America and in Europe. However, for EVs in particular, their range using grid electricity is still perceived as being insufficient. For PHEVs initially developed from parallel HEVs, more power may later be needed to allow all-electric driving capability in more circumstances. For EREVs in early configurations, the cost of the battery to provide universal all-electric operations capability may limit the size of the market. Using EVs and PHEVs would require some lifestyle changes, particularly to refuelling and recharging habits.

Governments can play a role in raising public awareness and informing about possibilities of changing mobility related behaviour. These and other options for governments to play a role in the deployment of hybrid and electric vehicles form the subject of the next, last section of this outlook.

The role of governments in the deployment of hybrid and electric vehicles

Hybrid and electric vehicles can play a role in achieving governmental objectives to reduce CO_2 emissions, to improve air quality, to reduce energy dependency and to increase energy efficiency. These vehicles may even contribute to help countries climbing out of the economic dip by creating new business with eco-friendly technology.

Regarding vehicle development, governments can contribute to funding research projects that are aiming at advancing propulsion systems and fuels. Stringent CO_2 emission regulations can push the car industry towards developing more energy-efficient vehicles. Innovation can be promoted by funding PHEV and EV demonstration projects.

The demand for clean and fuel efficient vehicles can be encouraged by specific policies such as fiscal measures, entry rules for urban areas and free parking for clean vehicles. Dedicated tax reductions have proven to be effective to increase the demand of energy-efficient, low CO_2 emitting cars. Regulations can be used to establish sustainable market niches such as car free resorts. Directives and laws

may be used for renewing car fleets requiring improved vehicle drivetrains and fuels. Finally, it seems crucial that governments help lowering the hurdle to use clean, efficient vehicles by supporting the construction of the required refuelling/ recharging infrastructure.

Non-technical measures to support the introduction of clean and energy-efficient vehicles include public awareness campaigns and making information available that can be used when making vehicle purchase decisions.

Governments are also in a good position to help creating integrated concepts for sustainable mobility that go beyond vehicle technology. This may include for example changing the modal split, avoiding certain displacements of people and goods, combining hybrid technologies with low carbon fuels, and using PHEVs to help integrating high shares of renewable energies such as solar, wind and hydropower in electricity production. Establishing programmes that partner industry, trade organizations, universities, research institutes and the public sector, with the objective to create a joint vision and to make that vision a reality seem to be an effective way to create integrated, sustainable mobility systems.