EVS24
Stavanger, Norway, May 13-16, 2009

EV and Hybrid Developments at MAGNA STEYR

(Subtitle: Will Alternative Powertrains become a Commercial Success for OEMs and Suppliers in the Next Future?)

Wolfgang Kriegler, Othmar Peier, Friedrich Quissek
MAGNA STEYR AG & Co KG, Liebenauer Hauptstraße 317, 8041 Graz; Email: wolfgang.kriegler@magnasteyr.com
Austria

Abstract

In the beginning of the paper a bridge will be built from historic developments to current MAGNA STEYR (MSF) vehicle projects in the field of alternative powertrains. An overview about the ongoing development activities such as HySUV™, Hi-CEPS and MILA™ EV will be given. Especially the development of the MAGNA Innovative Lightweight Electric Vehicle (MILA™ EV) will be highlighted. The MILA™ EV is an independent electric vehicle platform which is intended to serve as a base for OEM developments. Some technical details are opened to the public.

Based on the ongoing activities the commercial aspects of electric vehicles in general will be addressed and compared with conventional vehicles. Current market considerations, technological boundaries especially regarding batteries and the end customer view will be discussed. A life time cost comparison has been performed concluding that from legal side as well as from industry special effort is required to overcome the cost gap with EVs.

Finally the remaining technical risks of electric vehicles which could affect the business situation are investigated, and key success factors identified.

MAGNA's unique position by being a skilled HEV and EV engineering partner as well as a component supplier in the upcoming industrialisation of alternative power trains will be presented.

Keywords: demonstration, BEV (battery electric vehicle), HEV (hybrid electric vehicle), powertrain, lithium battery

1 Introduction

1.1 Drivers for alternative power-trains

Environment:

The major driver for the development of alternative powertrain is the fact that global warming is becoming a real threat to the human race. Although the CO_2 increase in atmosphere correlates with the increasing world population about 20% derives from traffic. Therefore getting out of conventional hydrocarbon fuels is a must on the longer term.

Resources:

Furthermore the fuel resources are limited and the end of worldwide oil production is coming closer. The limited hydrocarbon based energy reserve leads to the requirement to develop alternatives such as bio fuels, synthetic fuels but also using electric energy produced by renewable energy.

Legislation:
Legislation has already reacted to these two major challenges and is continuously tightening up on CO_2, exhaust gas and noise emissions limits. We are at the dawn of more and more strict CO_2 or fuel consumption based taxation all over the world.

Economic considerations:
Most governments wish to reduce the dependency on oil producing countries as the price dictate is a permanent annoyance and threat to stable economies. The step out from oil will reduce import costs.
The development of alternatives does create new industries and job possibilities, a target which is gaining significant importance in the current financial crisis.
Public opinion and legislation is asking for a structural change of the automotive industry – there is hope that the development and production of alternative powertrains such as hybrid and electrical vehicles represent a start in the right direction.

End customer attraction:
Customers are attracted by the promise for low operating and maintenance costs of electric cars. Electric motors have the reputation to be very robust and maintenance free. Buying incentives, no congestion charges, free parking lots, low insurance premiums are seen as the major motivator for the purchase decision.

The question to be answered is whether these vehicles really can improve the CO_2 situation considerably.
Many studies have been performed and the results – as seen by EUCAR/Concave/JRC are shown in Figure 1.

As can be seen from Figure 1 hybrid vehicles have the possibility to reduce fuel consumption in urban driving conditions from 20 to 35 % (diesel hybrids). Bio fuels by closing the CO_2 circuit, and fuel cell vehicles show high reduction potential, pure EVs charged by the electricity produced on the European energy mix “emit” around 80 g CO_2 per km. This also shows that EVs – introduced in countries with a high portion of coal energy plants like China –will not improve their CO_2 situation. There the introduction can only be motivated by other reasons such as energy autarky, and big city traffic conditions.
Nevertheless it can be concluded that it is worth to develop hybrid and electric vehicles and the impact to environment will be considerably but depends on how the electric energy will be produced in future. The trend to electric power could also lead to a revival of nuclear energy – as some announcements of different countries indicate.

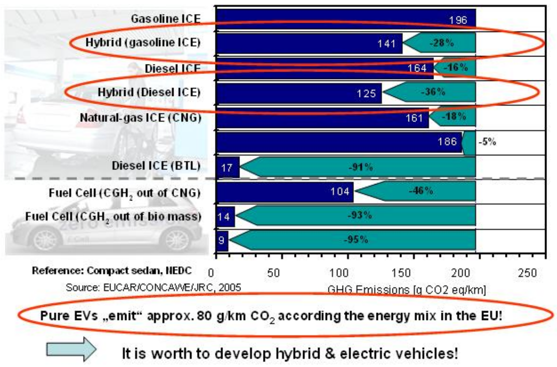

Figure 1: GH gas reduction potential of several technologies

1.2 MAGNA STEYR history in alternatives power trains

Following the above mentioned driving forces, within the last 20 years MAGNA STEYR, well established as contract car developer and manufacturer, has started several approaches for development and production in the field of alternative power trains in it’s history.

Figure 2: MAGNA STEYR “Alternative” Developments in twenty years

So the first attempt in the development of electric cars dates back to the year 1989. A Fiat Panda electric car has been developed and led to a small serial production. The technology at that time was rather archaic, lead acid batteries and DC motors.

Later more sophisticated components like the integrated 2 speed automated transmission E2G, based on newer technologies, were developed and introduced in a Taxi fleet test (1996).
Over the years several attempts in the development and production for alternative powertrains especially in the field of fuel cell and H2 storage tanks were done until mid of this decade.
Unfortunately all those approaches produced high technical interest and had some indirect positive effect on the reputation and business development, but big commercial successes could not be achieved.

In the recent five years the public interest in alternatives to the conventional powertrains increased dramatically. Reasons are the environmental concerns mentioned, especially the CO_2 debate and the political will and further measures to protect urban environments, e.g London congestion charge.

Recent advances especially in the area of batteries make it possible now to develop new hybrid and electric vehicles, which better fulfil customer expectations. The expected long-term increase in fuel prices contributes as well to the new acceptance.

2 Magna Demo-Vehicle-Projects

Figure 3 shows the step by step roadmap of powertrain electrification, starting from first generation hybrids such as Toyota Prius or Lexus 400h, continuing with the upcoming plug-in hybrids, then flexible e-drive platforms, EVs with range extender until finally pure electric vehicles will dominate the market. The speed of this development cannot exactly be predicted but will certainly depend on the quality and speed of the future battery development. So the periods for these vehicles can be much longer as shown and it is also most likely that by the end of the day all these versions may exist in parallel.

MAGNA STEYR R&D activities are focused on the development of hybrids such as the full hybrid sport utility vehicle named HySUV™ and the mild hybrid version of the Fiat Panda in an European Research Program called Hi-CEPS [1].

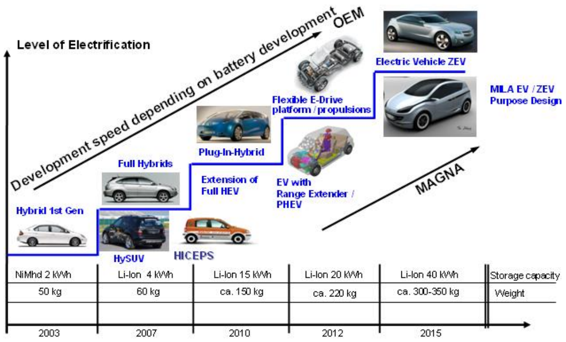

Figure 3: Roadmap of powertrain electrification and MAGNA STEYR demo vehicles

Latest, still ongoing development is the MILA™ EV, a completely new electric vehicle development based on an innovative chassis concept (IMC).

In the following the three demo vehicles will be discussed in more detail:

- Full hybrid "HySUV™" demo vehicle
- Mild hybrid "HiCEPS" vehicle
- E-Vehicle: "MILA™ EV"

2.1 HySUV™ (<u>Hy</u>brid <u>S</u>port <u>U</u>tility <u>V</u>ehicle)

HySUV™, Figure 4, is a full hybrid vehicle based on the Daimler M class [2]. In it's core is the so called and patented "electric four wheel drive module, E-4WD-Module" and consists of a parallel hybrid arrangement and an electric front axle, see Figure 5.

Figure 4: Hybrid SUV ("HySUV") Vehicle based on Daimler M-Class

This vehicle has a longitudinal powertrain which has been modified by introducing the hybrid module between ICE-engine and transmission. The standard AT transmission has been changed to an

AMT transmission which is hydraulically actuated. The corresponding controller had to be re-programmed.
The E-4WD module is placed between the ICE-engine and an automated manual transmission and allows to individually lead the additional electric torque to the front or rear axle, see Figure 5. A limited electric range is possible with this vehicle. The flexible architecture allows to optimise the operating strategies which resulted in considerable fuel consumption reduction up to 24% (measured!) in combined city driving.

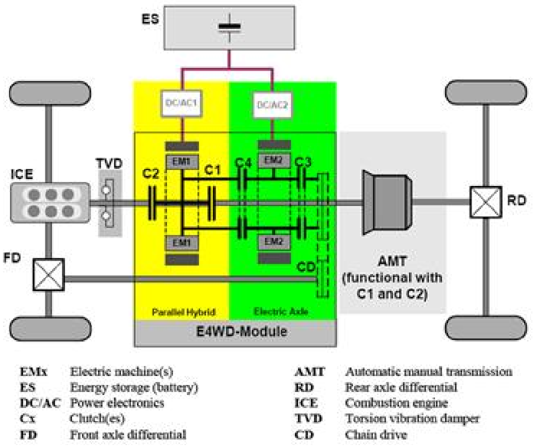

Figure 5: HySUV™ Architecture

Figure 6 shows the vehicle integration of the new electric components, also some technical details of the vehicle are given in the description of the components.

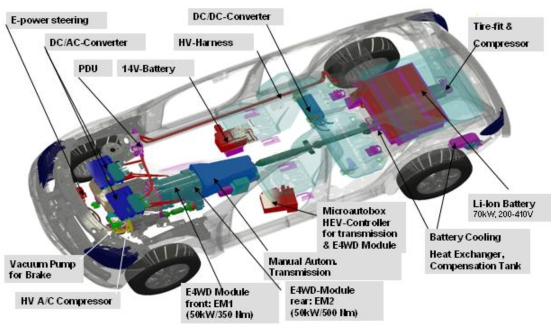

Figure 6: HySUV™ Integration of electric components

2.2 Hi-CEPS

MAGNA STEYR is participating in the Hi-CEPS program (<u>H</u>ighly <u>I</u>ntegrated <u>C</u>ombustion <u>E</u>lectric <u>P</u>ropulsion <u>S</u>ystem), funded by the European Commission within the 6th research framework program. As one of the sub project leaders MSF is working on a hybridisation of an A-segment mass production vehicle.

The idea is to integrate the hybrid components without significant changes to a base vehicle to achieve a low cost hybrid solution. For this purpose a modular concept has been developed, which can be easily adapted to different vehicle architectures and customer (OEM) requirements.

The demonstrator is based on a standard FIAT Panda 1,2l gasoline as available on the market. This vehicle is hybridised by a distributed power split electric four wheel drive powertrain and equipped with an electric rear axle.

For integration the internal combustion engine is left completely unchanged. A 6 kW belt-driven high voltage starter-alternator (12 kW peak) is added to the front drive unit to realize start-stop functionality and charge the battery (load shifting to higher bmep for better specific fuel consumption).

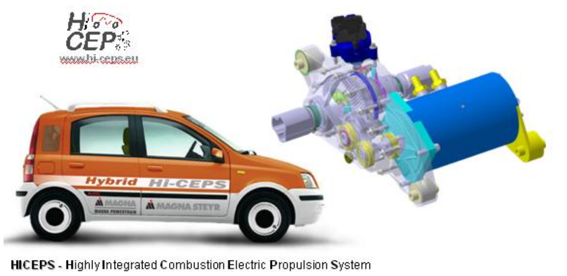

Figure 7: Hi-CEPS Panda and core electric drive module

The rear axle module consists of a 12 kW electric motor (23 kW peak) coupled with a gear box with a fixed transmission ratio. With a maximum speed of 12,000 rpm the gear ratio can be set to 8 or 12 in the same housing and is optimized with respect to weight, efficiency and NVH aspects. The rear axle module is used for boosting and recuperation (“through the road”) without mechanical coupling to the rest of the powertrain. The electronic coupling which uses a MSF powertrain control system allows four wheel drive functionality for vehicle start situations and wet/snow traction improvement.

As the electric motors in front and in the rear have the same outer diameter, the power is scalable depending on it’s length. The power electronic unit includes all converters in a single water cooled housing (2 x DC/AC, 12 V DC/DC, step-up-DC/DC) and is adaptable to the different requirements of the three hybrid vehicles of the Hi-CEPS project.

The energy storage unit, a MSF Li-Ion power battery with 1.2 kWh, is highly integrated in the FIAT Panda. The package was a challenging task: the battery housing is part of the vehicle body.
As part of the Hi-CEPS project the FIAT Panda hybrid is based on a very flexible concept.

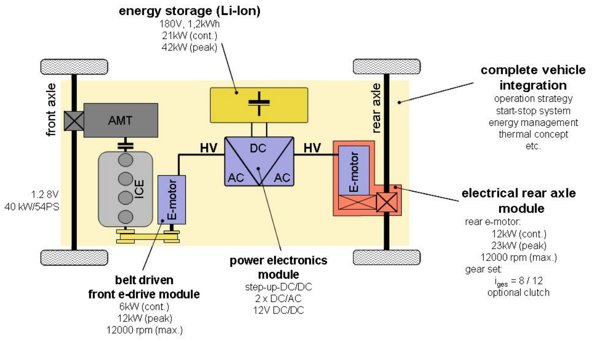

Figure 8: Hi-CEPS Powertrain Configuration

Technical details and specifications can be seen from Figure 8. For charging of the batteries a HV generator is placed on the ICE engine. For this the standard belt drive had to be changed.

Because of the modular structure of the powertrain control system, including energy management, thermal management etc, and the scalable hardware components the electric rear axle concept can be used in all vehicles of the A and B segment.

The vehicle is currently being built. The target is a CO_2 reduction of 35% without active downsizing and enhanced dynamic performance. Additional advantage of the concept is the all wheel drive functionality and limited pure electric driving for short distances. The demonstrator will show very innovative and cost optimized solutions for A class cars.

2.3 MILA EV

The third activity highlighted is the development of a small electric city car. It is the so called MILA EV (MAGNA Innovative Lightweight Automobile, Electric Vehicle). The technology used in this car is on the leading edge of current available technologies.

The vehicle is being developed as a pure electric vehicle version and as a version which could be best described as an "electric dominant plug-in hybrid" (PHEV). In the last mentioned version a range extender assures higher customer value and security. Built up with newest prismatic Li-Ion energy cells the battery system provides the vehicle a range of more than 80 km.

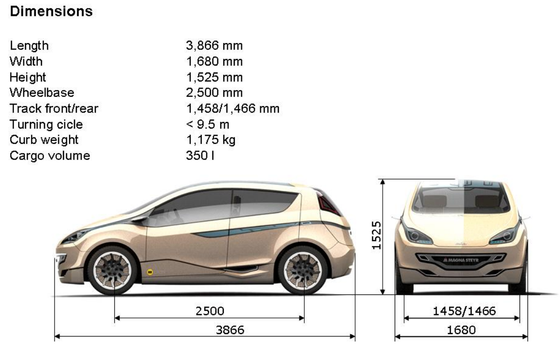

Figure 9: The MILA EV – Styling & Dimensions

MILA EV Vehicle specification:

- Four passenger EV sedan, B segment
- 35 (50_{peak}) kW PM electric motor; 120 Nm @ 0 – 4000 rpm
- 15 kWh battery (SOC range 70%)
- 80 km EV range (A/C off)
- Performance of 0 – 100 kph in < 15 s
- Energy cons. : 13,2 kWh/100 km in the FTP72 cycle
- Mass 1175 kg

EV features:

- Driver information center
- High voltage air conditioning
- High voltage electric heater
- Air cooled lithium ion battery
- Liquid cooled traction motor and inverter
- On-board charger
- Power steering and power brakes maintained
- Regenerative braking

Figure 10 shows the electric drive axle consisting of the electric motor and the reduction gear.

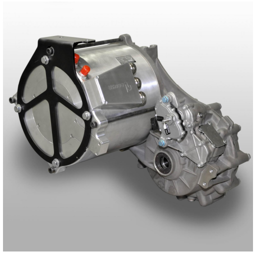

Figure 10 : MILA EV Electric drive axle

Figure 11 gives an overview of the electric powertrain system and shows all required components and systems in an electric vehicle.

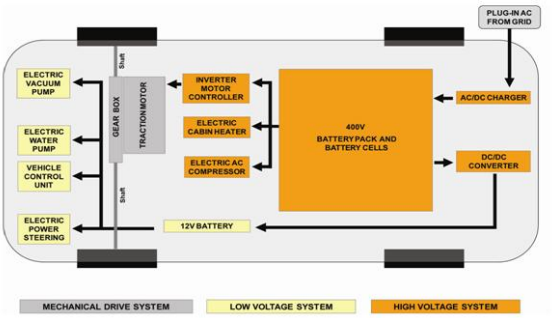

Figure 11 : MILA EV Powertrain, HV and LV system and electric auxiliaries

The picture shows how many electric systems –mechanical, high voltage and low voltage are required. The number of new systems needed on different voltage levels explains why electric vehicles are complex and relatively expensive today.

Figure 12 outlines the basic electric and electronic architecture of an electric vehicle. Core is the DC/AC Converter (inverter) which controls the e-motor and provides the interface to the battery management system. A DC/DC converter is needed to supply the low voltage (12V) system.

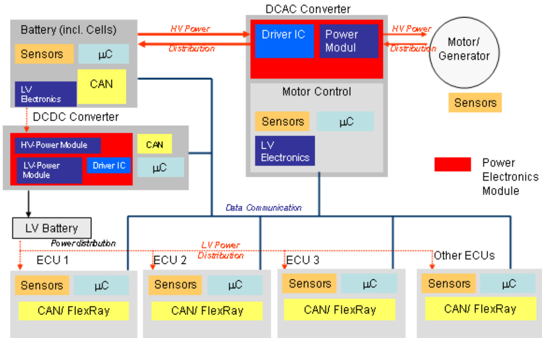

Figure 12: MILA EV EE Architecture

For the chassis a new idea called Innovative Module Concept (IMC) has been invented. The basic idea is that an electric powertrain does not allow much brand differentiation and therefore there is not necessary for the OEMs to develop the complete vehicle by themselves. A common platform could also serve the same purpose; the differentiation would be made only by the upper body.

- More than one OEM shares the same common platform for vehicles with alternative drive systems, i.e. a rolling EV chassis, see Figure 13
- All non-brand-specific (non-visible) parts can be identical (IMC scope)
- Brand-typical upper body allows differentiation
- A considerable cost advantage can be generated due to volume effect and can assure economical success for various vehicles

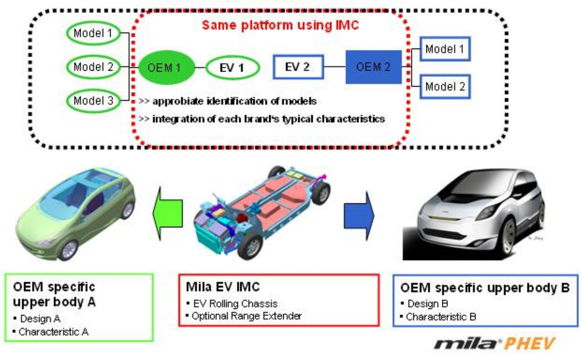

Figure 13: IMC Body Concept

The MILA EV is currently being tested in three different powertrain configurations:
Version

A Pure electric vehicle: electric front axle in "offset" design
B Serial hybrid: stand alone range extender combined with above electric axle
C Serial / parallel plug-in hybrid with range extender with direct drive possibility at higher speeds (weight added 110 Kg)

For testing MSF has set up a MULE vehicle which can be equipped with all above mentioned variants. Extensive tests on test tracks, chassis dyno and in public traffic are planned and will be reported in future papers.

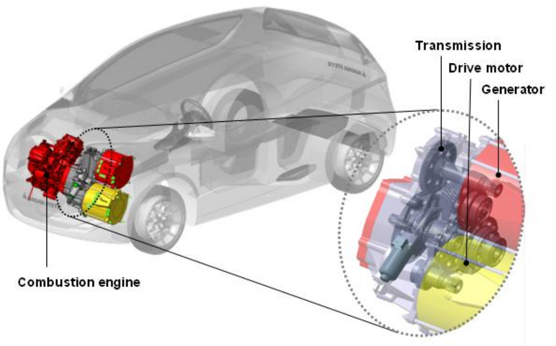

Figure 14: MILA EV- Plug-In Hybrid Architecture

Figure 14 shows version C with integrated transmission and attached range extender, Figure 15 provides a closer look to the complete powertrain module:

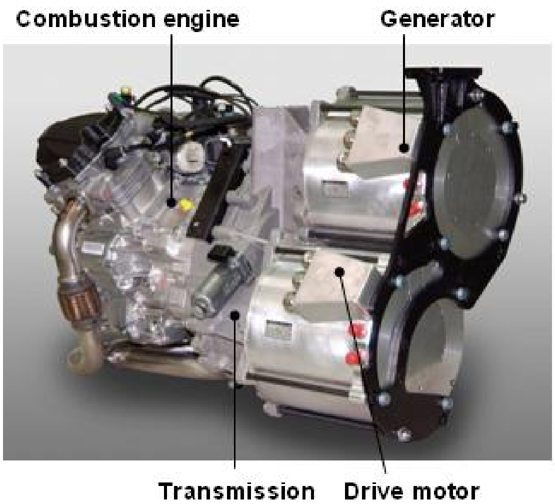

Figure 15: MILA EV Combined Powertrain Module

Figure 16 shows the set-up of the powertrain modules in the mule vehicle.

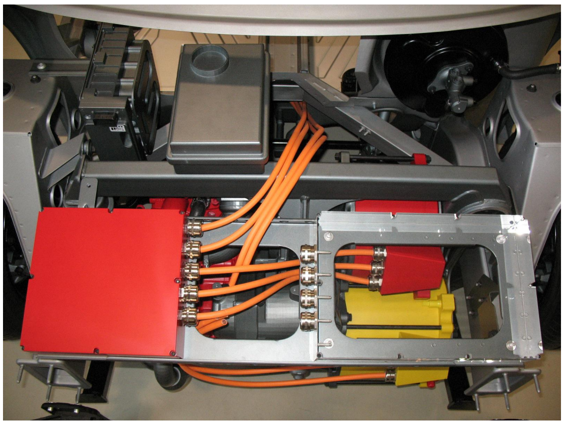

Figure 16: MILA EV Set-up MULE Vehicle

The expectation of these efforts is to get answers on the following questions:

- Which powertrain configuration is suitable for which vehicle mission?
- What will be the most appropriate operating strategies for different applications?
- What is the customer acceptance for the versions?
- What will be the initial production cost differences?
- What will be the operational costs?

3 Commercial aspects of EVs & PHEV compared with conventional vehicles

Not always in the history of inventions and technologies the breakthrough can be achieved immediately. Most of the breakthroughs are delayed by many years when not all technical, economic and social prerequisites can be fulfilled. Especially the automotive industry has proven to be always conservative and changes are coming slowly. This behavior is also a result of being quality-oriented, reliable and robust with their products. Even small quality problems can result in call-back actions and can almost ruin the company or at least damage the reputation significantly.

When a company like MAGNA steps into the development of hybrid and electric vehicles, the following questions need to be answered:

- Will there be a market for hybrids & EVs?
- How have the boundary conditions such as legislation changed since last electric vehicle hype in the 1990s?

- What are the technology breakthroughs since then?
- Will customers bear the additional costs?
- And finally is it now the right time for business in alternative powertrains?

In the following answers to above questions are outlined.

3.1 Market considerations

Starting from the market prediction (averaged from several studies), see Figure 17 it can be concluded that there will be a significant market by the end of the next decade.

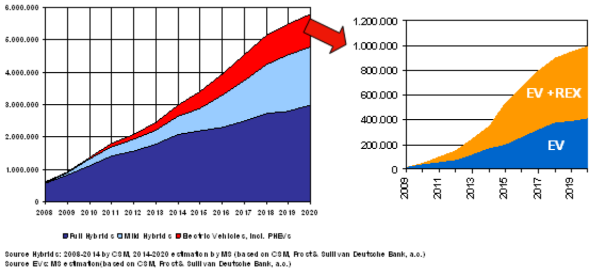

Figure 17: Global markets for hybrids and EVs [5]

As can be seen from the graph there is a market of about 6 million "alternative powertrain" vehicles, one million could be electric vehicles. It is also remarkable to note that the majority of the electric vehicles will have a range extender ("REX") – a small combustion engine which allows to charge the battery on board and to come home safely when the battery should be empty or fail.

Boundary conditions have certainly changed since the mid of 1990. Technically, the Japanese manufacturers have shown that hybrid vehicles can be commercially attractive and bring good reputation in the market place. The global warming and the oil price situation in recent years have made people sensitive to these topics and is changing the perception of people regarding alternative propulsion systems.
Also the political will in general and of city administrations on the other hand has changed too as some examples in big cities show.

3.2 Technological breakthrough – the battery!

The key component for success of the electrified powertrains is the battery. NiMH batteries have proven that they can be reliable and robust in the market place, but LiIon batteries promise even better performance and further improvement potential.

Initiated by and as a prerequisite for the development of the HySUV vehicle MSF started five years ago the development of Li-Ion battery systems and has been already awarded for a series production program. Details about the battery development at MSF will be given in the this conference by [3].

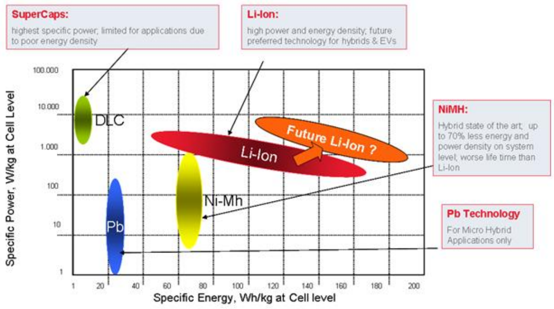

Figure 18: Battery technologies in comparison (Ragone Diagram)

3.3 End consumer cost comparison

Consumers are ready to buy electric vehicles, but need to know more about boundary conditions. An interesting question is - and also business decisive – whether end consumer can afford to buy those electric vehicles.
A relief on the cost side can be expected by incentives and privileges for such vehicles.

Figure 19 gives an overview about the European wide incentive landscape.

A life time cost comparison of a standard A class vehicle and an EV has been performed, Figure 20.

Unfortunately the base price of an electric vehicle is still much higher compared to conventional A class vehicles equipped with ICE engine which can be bought for a price around 10.000.- €.

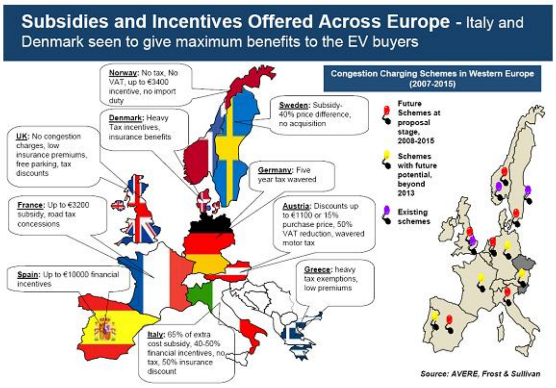

Figure 19: Overview taxation and incentives for alternative vehicles in Europe

Electric vehicle require different chassis concepts, lightweight materials which based on the initial production volumes create a relative high base price. One further reason is that all auxiliaries in an electric vehicle need to be electrified too, and currently small production numbers of high voltage equipment are expensive.
But the worst item is – of course – the battery price, if the customer has to pay the full price.

Batteries will have expected to cost from €10.000 - €15.000 for a lifecycle of 70,000km-100,000 km and these capacity result in a driving distance of around 150km with an average electric vehicle.

In our example (Figure 20) we have used a leasing model which could be one of the most reasonable scenarios.

Figure 20 highlights that the end customer cost of total ownership is still not favourable for the electric vehicle. (In our investigation the resell value was not considered in both cases.)

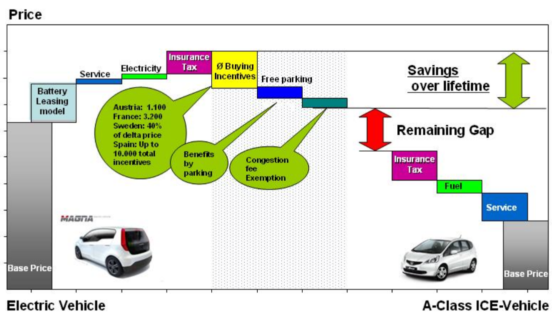

Figure 20: Life time (100.000 km) cost comparison: conventional vehicle vs. EV

The base price plus the battery leasing model for electric vehicles is still much higher and cannot be compensated by cheaper service, "fuel" (electricity), insurance and the other benefits coming from buying incentives, free parking and congestion fee exemptions. There is still a considerable remaining gap in the comparison which needs to be compensated.

So finally it can be concluded that the prerequisites for a business success are basically here today and good prospects from political, economic and social boundaries encourage supplier companies to enter into this field.

So the remaining task is on one hand to solve the cost issue especially the battery price situation. On the other hand to increase the benefits for the owner of environmental friendly vehicles. Only if industry and governments work from both sides to remove the cost gap, the consumers can be satisfied and the offer would be attractive.

4 Risks and key success factors

Investing in such ambitious programs in the field of alternative powertrains incorporates always a big risk regarding commercial success, especially for contract development and manufacturing companies and component suppliers. But also OEMs are careful and step slowly into new concepts as the Daimler example with the Smart vehicles shows.

4.1 Technical risks

In first glance it seems that we have a good control of the technical risks, but looking closer some items still have a question mark.
The powertrain consisting of electric motor and inverter seems technically solved, the remaining risks are:

<u>High voltage levels in the vehicle</u>

The high electric power loads on board requires voltage levels higher than 60V. Electrical safety issue for the HV power net and components integration becomes dominant from the vehicle point of view. There are no consistent global electric safety standards and regulations which make the development more complicated.

Nevertheless the complete development process has to be adapted to comply relevant requirements for testing and production. Special trainings for development and production staff, service people and has to be taken also into account. A skilled HV distribution concept and clustering of HV components can improve the packaging, the electrical safety, the EMC and the crash situation. For conversion HEVs this is a huge challenge. In principle, EVs allow more freedom, especially for new platforms e.g. IMC. Plug-in capability (battery charging from outside) makes the situation more sophisticated, because of the additional installed HV connectors to the outside [4].

<u>Battery safety, reliability and life time</u>
Society need to build up thrust in batteries (reliability) and need to get familiar with their handling. Life time worries need to be addressed by exchange models or rental/leasing models. Recycling processes need to be developed and introduced.

<u>Battery material resources</u>
Especially Lithium is a rare metal and only available in a few countries, especially in South America. Production boundaries are difficult. This situation could bring a new dependency and a considerable hold-up.

<u>Production capabilities of cell suppliers</u>
Capabilities are limited and is case of an electric vehicle hype most likely not sufficient. This might raise price again and result in a delay.

<u>Infrastructure (private and public)</u>
Authorities are too slow to provide sufficient charging stations in public areas. Refitting in home garages as well too slowly. This could be a big problem especially in the beginning of the electric era.

<u>Dimensioning of the battery :</u>
Battery over-dimensioning is not recommended. Result would be too heavy and too expensive vehicles.
Studies have shown that the daily routine travels have a probability peak around 20 to 30 km therefore it might be smart not to dimension the battery for a desirable EV range of 300 km, but just for the average of daily routine electric travels.

4.2 Acceptance risk by consumer

Vehicle owners enjoyed "unlimited" range and high transport capabilities. Now customers will face new challenges and need to rethink their habits.
So key market restraints and critical questions from customer side could be:

- Will customers accept limited electric vehicle range?
- Will be electric vehicles seen as a second or even third car in the family (single or multi car households?) – something only for rich people?
- Missing electric infrastructure – too little places to recharge the batteries?
- 6-8 hours domestic charging, lack of private garages to charge?
- Batteries limited lifecycle (defined through numbers of charging / discharging cycles).
- Too short calendar life time of the battery – how about the resell value of the battery or the complete car after some years?

It can be assumed that a lot of work is needed to change customer mindsets to accept the limited range and it can be understood that they keep skeptical and careful.
Polls have shown that the majority of customer would accept electric vehicles when the range is higher than 200 km?! Such demands would lead to absurd big and expensive battery packs.
If a customer can accept the limited range for daily routine travels, a pure electric vehicle would serve his purpose. If customers cannot, they can choose a variant with range extender. Such considerations will lead to production of PHEVs, which would give a better driving distance compared to EVs.

Most likely the solution for this problem – at least in mid term - will be to provide more flexible vehicles to the mass of the customer such as plug-in hybrids with small range extender ICE which provide the possibility to use the vehicle in a more used and flexible way.

4.3 Key success factors

Key success factors to make hybrids and especially electric car a market success will be:

- Create modern distinctive designs for EVs, compare MILA EV

- Cost-effective shared lightweight vehicle chassis designs (i.e IMC), to achieve scaling effects
- Affordable component technologies (especially battery and power electronics) and /or establish special financial solutions such as rental or leasing for the battery. Make use of co-operations to get high production numbers to reduce component prices.
- Using the available components, ice and electric propulsion in a complementary way that the benefits and advantages of both systems can be used for a greener and more acceptable mobility.
- Allow an evolutionary change to electric propulsion with hybrids and plug-in hybrids as an intermediate steps, including EV with range extender option.
- Political commitments to maintain individual mobility and support of the introduction of alternative solutions (buying incentives, tax relaxation, additional benefits for the user such as free lanes, free parking etc)
- Make potential customers proud to buy an electric vehicle!

5 Summary / Conclusions

MAGNA STEYR's recent developments in hybrid and electric vehicles have been presented in detail.
It was shown that the development of hybrid and electric vehicles means not only replacement of the conventional powertrain but complete new concepts regarding chassis, auxiliaries, air condition, battery packaging and energy management. Especially safety aspects need to be addressed.

Essential technical and commercial questions regarding the development, production and introduction of those vehicles have been discussed, risks and key success factors have been addressed. The mind set of consumers is changing by the media campaign for the new vehicle concepts and the financial crisis is helping too in the acceptance.

The remaining task for the automotive industry is to overcome the remaining technical challenges, present more lightweight vehicles, and to solve the cost issue (especially battery, electrified components).

Remaining task for the society and legislation is to provide the required infrastructure and to increase incentives and benefits in terms of favour those vehicles, especially in big cities.

MAGNA STEYR and its sister companies MAGNA ELECTRONICS, MAGNA POWERTRAIN have decided to become a complete supplier for the development and big scale industrialisation of hybrid and electric vehicles and corresponding components. The presented prototype vehicles prove that Magna is also a skilled partner in the development of such power trains and vehicles. Magna and it's partners can support OEMs with development know-how and components such as electric motors, inverters, transmission solutions, battery systems and vehicle integration engineering as well as comprehensive testing. This unique combination of skills and components offers good possibilities and prospects for a mutual success in the upcoming "electrical" future.

The current economic and political situation offers an unique chance for the implementation of environmental sensible vehicles – Just help to do it!...

Acknowledgments

Thanks to all contributors, especially to the development teams of the presented demonstration vehicles.

References

[1] Ravello V.: Hi-CEPS: Highly Integrated Combustion Electric Propulsion System (EC - FP6), ECPE-HOPE Symposium Automotive Power Electronics, Stuttgart- Sindelfingen, October 7-8, 2008; CD Proceedings.

[2] Schmidhofer A., Zoehrer F., Starzinger J., Erjawetz K.: Powertrain Hybridization of a Full Size SUV – A Multifunction Electric 4WD Traction Module, EVS23 Conference and Exhibition, Anaheim, California, December 2-5, 2007

[3] Pichler Peter, Kapaun Margarita: Lithium-Ion for hybrid and electrical vehicles: Ready for mass market production!? EVS24 Conference and Exhibition, Stavanger, Norway, May 13-16, 2009

[4] Schmidhofer A., Bouvier S., Lanzenberger H., Schluder M., Schruth R.: Power Net Topologies for HEVs and EV – Aspects on

Vehicle Integration for Different Powertrain Configurations on System and Components Level. EVS24 Conference and Exhibition, Stavanger, Norway, May 13-16, 2009

[5] Data Sources: MS estimation based on Frost & Sullivan Database Q2/2009 and CSM Engine Database Q1/2009

Authors

Wolfgang Kriegler studied mechanical engineering with special focus on ICE engine technology at the Vienna technical university. In his former job he gained comprehensive experience in the development of internal combustion engines and he is now employed at MAGNA STEYR in the field of hybrid and electric powertrain. In his current occupation he is responsible for product management and he is leader of the skill area “Hybrids and EV Powertrain” in the MAGNA Project House, a foundation of MAGNA STEYR, MAGNA ELECTRONICS and MAGNA POWERTRAIN for the development of new innovative hybrid and electric powertrain components.

Othmar Peier studied Mechanical Engineering with special attention to automotive technology at the Technical University of Graz. Since the beginning of 2006 Othmar Peier is head of MAGNA STEYR’s worldwide advanced development activities. The main emphasis of his work is on guaranteeing MAGNA STEYR’s competitiveness by focussing on innovative, new products in the fields of complete vehicle concepts, vehicle safety, alternative propulsion systems and by further developing the possibilities of virtual product development..

Friedrich Quissek born in Vienna, Austria, studied mechanical engineering at the Vienna technical university. Gained comprehensive experience in the development of ICE`s and alternative powertrain vehicles development and production. Current occupation is technical expert for new technologies, supporting advanced engineering and the MAGNA Project House, a foundation of MAGNA STEYR, MAGNA ELECTRONICS and MAGNA POWERTRAIN, for the development of innovative components for HEV and EV vehicles.