The Electrification of the Vehicle and the Urban Transport System

Recommendations on key R&D
by the European Automotive Manufacturers
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1. PURPOSE OF THIS DOCUMENT

Through the European Green Car Initiative (EGCI), the European Commission announces its focus on Electrification of Road Transport in a coordinated manner. As a way to support the European Commission on such a long-term objective, the European Automotive Manufacturers in EUCAR have seen the need to formulate and agree on the R&D issues that are of common concern and of key importance for the wide dissemination of electric vehicles. For this purpose, EUCAR established a Task Force of experts from the vehicle manufacturers in early 2009 to analyse and formulate the R&D needs in a short, medium and long term perspective. The aim of the task force work has been to gather the automotive industry around the primary R&D topics, to engage related stakeholders for collaboration and to guide the EU R&D program for support on these issues. This document reports the findings of the Task Force.

NB: this document is focused on pure Electric Vehicles. That means that topics specific to Fuel Cell Electric Vehicles or Hybrid Electric Vehicles are not addressed in this document.

2. INTRODUCTION/VISION

Limitation of fossil energy resources and climate change are the major challenges that society is facing today and which will gain in importance. A growing demand for mobility and energy in emerging regions makes these problems even more severe. The automotive industry has to find and realize sustainable solutions for the mobility and transport systems of the future. These solutions will be exposed to even stricter requirements than those of today. Low environmental impact regarding noise and emissions, based on a secure source of energy and clean fuels, and efficient use of this energy are just a few boundary conditions.

Another fact is that urban areas continue to attract an even larger part of the population - the forecast is that as much as 70% of the population will live in urban areas. This implies that a large portion of the population limits their daily travel to short / medium distances of less than 100 kilometres, often within urban agglomerations. Also, a large amount of goods transport will take place in urban areas, increasing the need for clean and energy efficient distribution vehicles.

Still, an easy answer to the challenges of future traffic cannot be given. Electrification of both the mobility and transport system is one possible answer. Consequently, new concepts and new technologies need to be developed to realize efficient electric vehicles suited for both individual and public mobility and for goods distribution in urban areas. Figure 1 indicates the pathway of increasing electrification, ending up with pure electric vehicles powered by batteries or hydrogen fuel cells. Both fuel cell and battery electric vehicles use similar technologies in the drivetrain and thus there are many synergies in component development for the drivetrain, such as high voltage systems, E-Drives and battery technology. In contrast to the hydrogen fuel cell vehicle, all plug-in electric vehicles can build on an existing infrastructure for distributing electric energy, which however needs to be adapted and extended.

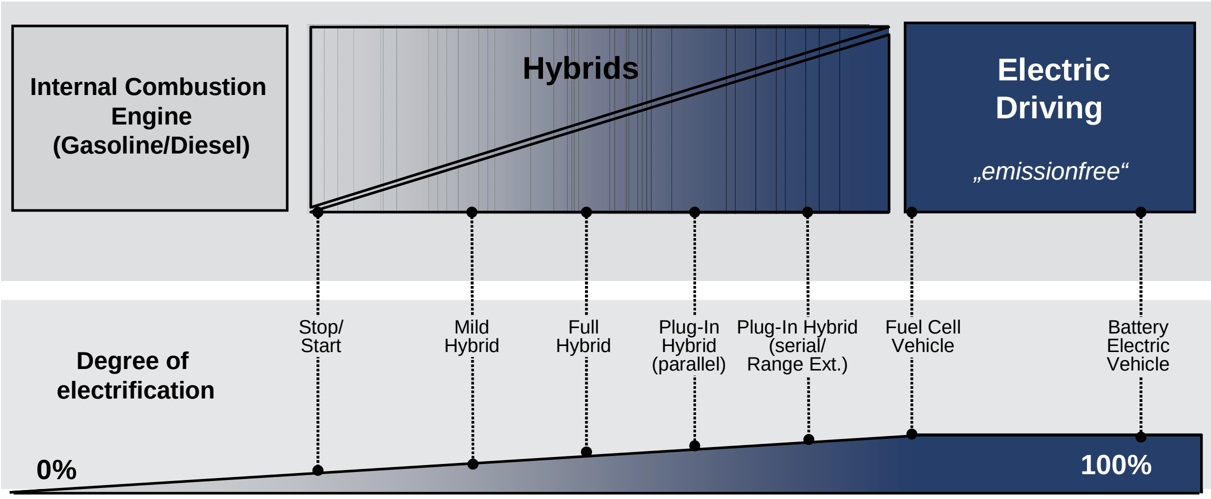

Figure 1: Electrification of the powertrain

Besides the specific mobility needs in urban areas, where travel is often done in congested conditions and with limited range, other transport needs covering larger daily driving distances at higher speeds will continue to remain. All these diverse transportation needs will lead to further diversification of future vehicle types and their propulsion, and electrified drivetrains will cover a large area in the application map. Figure 2 shows how the different vehicle types populate the appropriate application fields, and the areas indicate preferred application of the different technologies.

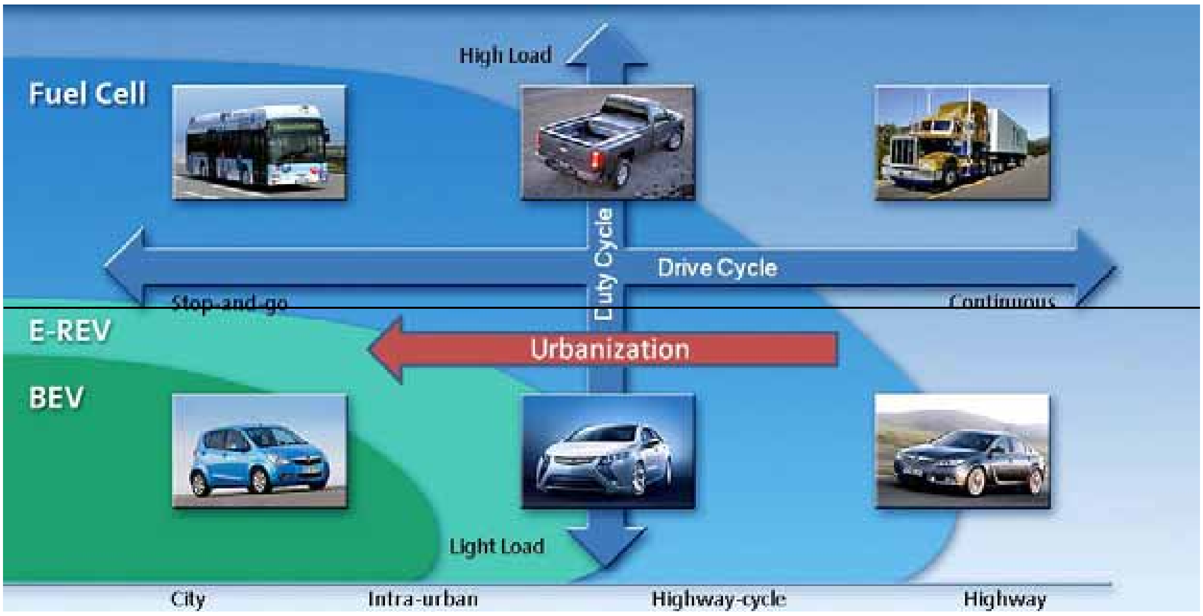

Figure 2: Application map for Battery (BEV), Extended-Range (E-REV), and Fuel Cell Electric Vehicle

3. NEED FOR AN INTEGRATED, “EVOLUTIONARY” APPROACH

Success of the electrification of the transport system is built on, and requires, the coordinated collaboration of the key stakeholders and contributors such as:

- Automotive industry for developing efficient and affordable electric vehicles (vehicle manufacturers together with components suppliers mainly for the new electric devices)
- Energy suppliers and distributors for deploying the needed infrastructure, including charging spots, related information and communication systems,
- Authorities for deployment and mass market creation of the electric vehicle

To achieve this, it is necessary to act with a coordinated approach and in a consistent direction from short term (based on today's technologies), to long term solutions where adapted and new technologies will enable the electric vehicle to be affordable and dominant in the urban regions. Standards and common interfaces (e.g. vehicle-to-infrastructure) need to be agreed upon quickly for Europe as a whole to avoid a fragmented pattern of local competing and incompatible solutions. This is a unique opportunity for European industry to establish themselves as world leaders in electric vehicles and related transport systems. In this scenario to reach this leadership position, the battery technology at cell, module and system level will surely have a key role, while transversally impacting other application fields (distributed generation systems, CHP units…).

Regarding cruising range, affordability and space provided in the vehicle, today’s electric vehicles fulfil customer requirements only to a limited extent. Considering the expected limited vehicle volumes of the early market, these EVs have to be derived from existing vehicle designs, using current “electric” technologies (adapted in some cases from other applications outside the automotive market), which will lead to expensive solutions with limited durability and performance. Hence, in order to achieve a large scale replacement of the conventional fossil-based ICE vehicle by EV, there is a need to support an accelerated evolution (but not revolution) of today's EV technologies. For future electric vehicles it seems to be appropriate to progressively introduce more and more dedicated design solutions for the vehicle in order to be able to use optimised component technologies.

Given the limitations of the electric vehicle, its intelligent integration into the existing urban transport infrastructure is essential, as is the application of intelligent ICT solutions allowing optimised traffic management and intermodality between different types of transport solutions.

The following section outlines a number of technological improvements that need to be introduced for the vehicle and its sub-systems.

4. R&D PRIORITIES FOR THE VEHICLE AND ITS INTERFACE

R&D needs to address the following major areas:

- An affordable and safe battery system with improved performance and lifetime
- An efficient vehicle and energy management system
- A dedicated vehicle-to-infrastructure interface

Corresponding requirements are explained briefly in the following description. Required R&D activities are listed in the appendix.

An affordable and safe battery system with improved performance

The market introduction and convenient use of vehicles with an electric powertrain depend mainly on the costs and performance of these vehicles. Safe operation certainly has to be secured for all automobile applications. The key component for both performance and costs of an electric vehicle is the energy storage system. Today it is expected that the energy storage system will be a lithium based battery system.

It has to be taken into account that a battery system includes, besides the battery cells, components for interconnections and packaging as well as electrical and thermal management equipment. All these additional components have a significant influence on the overall volume, weight and cost of a battery system.

Even if a lot of progress has occurred in terms of energy content related to volume and weight of a modern battery, these characteristics remain about hundred times lower than that of fuels for combustion engines. This fact is one of the main challenges for electric mobility, as it influences both costs and usability. For this reason, the Battery Electric Vehicle (BEV) will mainly be used for urban and near-urban transportation. The required range of BEV under everyday conditions (including energy for comfort functions such as heating, air conditioning, etc.) in 2015 will be 150 km (250 km under ideal conditions). Targeted R&D will lead to 200 km (300 km under ideal conditions) in 2020.

The corresponding quantified targets that need to be met for passenger car Li-ion battery systems are:

- **Performance:**
  Energy density has to be improved at least to 200 Wh/kg in 2020 (150 Wh/kg in 2015). Current technologies achieve below 100 Wh/kg.
- **Durability:**
  Calendar and cycle life targets have to meet the expected lifetime for the vehicle. Batteries must last 15 years lifetime or 5000 deep charge/discharge cycles by 2020 in order to operate the vehicle without replacement over vehicle life.
- **Costs:**
  A cost less than 150 €/kWh has to be achieved in 2020 (300 €/kWh in 2015) for a widespread dissemination of EVs.

To overcome, in the long term, the performance hurdles of Li-ion technologies, it is necessary to investigate already today post Lithium-ion technologies for further improvement of the overall comfort and performance of electric powered vehicles (see appendix, section 1, 2 and 11 for more details on related R&D activities)

An efficient vehicle and energy management system

Today, the ICE powers the electric safety and comfort features, like brake force booster, power steering, air conditioning and heating. The electric vehicle has to take the energy for these systems from the battery. In addition, the battery has to be thermally managed to avoid damage and quick aging. Therefore, it is essential to minimize the energy consumption of on-board safety and comfort systems to limit the negative impact on the range of the electric vehicle.

From a customer point of view, the main difference between an ICE and an EV vehicle is the significantly lower autonomy of EV and, at least up to now, the longer recharging / refuelling time. In order to limit over-dimensioning the battery capacity and added vehicle cost, R&D is required for:

- Electric powertrain cost reduction and efficiency improvement
- Efficient solutions for electrification of vehicle auxiliaries, for example for heating (which today uses waste heat from the combustion process), cooling, steering and integrated passive and regenerative braking (braking split)
- System architecture (e.g. redundant concepts in order to ensure the function of safety critical systems) and integration, including novel range extender concepts.

Referring to this last point, in the short to mid term it will require the development of new small, lower cost and highly efficient ICE designed considering not just the constraints, but also the advantages of the range extender application usage. This will be necessary in order to reach the extremely ambitious targets of noxious, CO_2 and acoustic emissions, while at the same time maintaining the required range and/or power requirements for certain applications, such as heavy goods transportation (see appendix, section 3, 4, 5, 6, 7 and 8 for more details on related R&D activities).

Connection to infrastructure

The two following R&D needs deal with connection to infrastructure and must promote the usage of EV (these topics are explained in more details in the appendix, section 9):

- Charging : development of fast charging and contact-free charging systems, easy-to-use interface to infrastructure
- Dedicated information system for charging management: localization of free spots, invoicing …

In addition to these R&D topics which are related to the vehicle, its components and its interface to the grid, some accompanying activities have been identified (see appendix, sections 10, 12 and 13) concerning high voltage usage, market creation road-map and field tests and demonstration in order to acquire experience and feedback from first customers. This will allow the design of the next generation EV, optimised for electric mobility.

5. IMPLEMENTING THE R&D RECOMMENDATIONS

This document formulates the view of vehicle manufacturers for R&D directions and priorities for the successful development and deployment of EV. It is recommended that these R&D priorities are implemented in remaining calls of FP7 under the European Green Car Initiative.

R&D topics to be addressed for the Electric Vehicle

TOPIC	RELEVANCE	WHAT	WHERE WITH WHOM	WHEN
1. Energy storage technology	High	▪ Improvement of materials, cost, availability, manufacturing, cell design, cell packaging, recycling and life cycle analysis	▪ OEM/Suppliers/ materials suppliers ▪ European coordination of involvement of R&D suppliers ▪ European rules for Li-Ion (and others) battery recycling	▪ Immediately ▪ Short Term ▪ Immediately
2. Post Lithium-ion battery cells and chemistry	High	▪ Basic cell research for high power, high energy density ▪ Low cost technologies compared to Li-Ion ▪ Recycling & life cycle	▪ European establishment of centre of excellence in academic R&D for industrial application	▪ Long term 2020
3. Electric machines	High	▪ Materials: permanent magnets, iron core, alternative for magnetic and/or scarce materials ▪ Design to cost / quality for high volume production ▪ Both for drivetrain and auxiliaries (electric compressors), both for motors and generators	▪ OEM: specification and initiation ▪ Suppliers: development	▪ Immediately ▪ Medium term 2015

TOPIC	RELEVANCE	WHAT	WHERE WITH WHOM	WHEN
4. Power electronics	High	▪ New materials, cooling, packaging and manufacturing technologies for automotive semi conductor applications ▪ Modular / standardised components for cost reduction ▪ Passive components (e.g. capacitors for high compact integration) ▪ Power electronics control and supervision. ▪ Redundancy concepts.	▪ OEM: specification ▪ Suppliers: development	▪ Immediately ▪ Medium term 2015
5. Heating, cooling and other auxiliaries	High	▪ Energy efficiency ▪ Alternative technologies: Seebeck, Rankine, heat pump …	▪ OEM: specification ▪ Suppliers: development ▪ Academic labs	▪ Immediately ▪ Short and medium term
6. Range Extender	High	▪ Optimisation and integration of ICE ▪ Novel concepts of Range extender (both devices itself & integration)	▪ OEM: specification and initiation and specific development areas ▪ Innovative solutions supported by EC	▪ Immediately ▪ Short and Medium term
7. System Architecture	High	▪ Functional architecture / position of interfaces and standardisation of defined interfaces ▪ Communication for power and energy management ▪ AUTOSAR integration (does electrified vehicles put any additional requirements to the AUTOSAR requirements?).	▪ OEM: specification ▪ Suppliers: development	▪ Short term

TOPIC	RELEVANCE	WHAT	WHERE WITH WHOM	WHEN
8. System Integration	High	▪ Integration of mechanical and electric functions / components to complete drivetrain ▪ Simulation methodology for electrical aspects. ▪ Energy management ▪ Interfaces to add-on equipment (i.e. Body builder interfaces)	▪ OEM	▪ Medium
9. Intelligent charging system	High	▪ Vehicle on-board charging system including fast charging and contact-less technologies	▪ OEM ▪ Suppliers	▪ Immediately ▪ Short & Medium Term
		▪ Interface to infrastructure ▪ HD vehicles interface from vehicle to trailer, HV interfacing	▪ OEM ▪ Suppliers ▪ Energy companies ▪ EU standardisation	
		▪ Standards	▪ OEM ▪ Suppliers ▪ Standardisation bodies	
		▪ Information systems on charging systems	▪ OEM ▪ Authorities	

TOPIC	RELEVANCE	WHAT	WHERE WITH WHOM	WHEN
10. Road-Map for market creation	High	▪ Identify and formulate possible scenarios for needed support actions for EV market creation, and establishment: economical aspects, business models, vehicle & battery residual value ▪ New concept for heavy duty commercial vehicle taking into account electrification ▪ Identify market possibilities through the availability of additional electrical energy devices and smart auxiliary units	▪ OEM ▪ Suppliers ▪ Energy companies ▪ Authorities	▪ Immediately ▪ Medium term

Related Topics and needed accompanying activities

TOPIC	RELEVANCE	WHAT	WHERE WITH WHOM	WHEN
11. **Energy storage systems for vehicle applications**	High	▪ Cell integration ▪ Management, cell-balancing and supervision ▪ Cooling ▪ Safety ▪ Commercial vehicles: common specifications and standards (also for personal cars) ▪ Modular / standardised components for cost reduction ▪ Including mass production technologies	▪ OEM: specification and initiation and specific development areas ▪ Suppliers: development	▪ Now: gather experience ▪ Soon: formulate basis for standards of components and interfaces
12. **High voltage**	High	▪ Safety and security at handling / maintenance ▪ High voltage indication (badge)	▪ Not R&D ▪ Covering in existing programmes ▪ EU : Standardisation of HV badge on vehicle (damaging, crashes, safety)	
13. **Field tests / Demonstrations**	High	▪ Customers' acceptance and experience / feedbacks ▪ Cars, Busses, Light & Medium Vehicles ▪ Heavy duty with range extender ▪ Urban area including infrastructure aspects ▪ Market understanding ▪ Feedback on Key issues from previous table's topics	▪ European level: OEM, energy companies ▪ Local authorities ▪ Customers	