EARPA Position Paper

Research needs on Energy, Powertrains and Electrification

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ABOUT EARPA

Founded in 2002, EARPA is the association of automotive R&D organisations. It brings together the most prominent independent R&D providers in the automotive sector throughout Europe. At present its membership numbers 48, ranging from large and small commercial organisations to national institutes and universities.

SCOPE OF THIS DOCUMENT

The EARPA Foresight Group *Energy, Powertrains and Electrification* is supporting the continuous development and integration of clean and efficient electrified powertrains as well as powertrains working on alternative fuels with a holistic view on the EU energy system. This group aims at anticipating the forthcoming research needs that cannot be addressed by industry or academia alone but that need support from future research and innovation framework programmes.

CONTEXT

A clean and seamless passenger road transport system is requested to support the achievement of a future sustainable society in Europe. The main and urgent objective now is to reduce much faster the transport related fossil CO_2 emissions to reach a climate neutral system by 2050 and to remain confident in the achievement of a <2°C global warming scenario. In order to realize sustainable mobility in Europe, tank-to-wheel CO_2 emissions of road transport should be reduced by 69% (or even 90% according to the European Green Deal) by 2050 based on 2010 emissions[1]. This objective will be mainly achieved by a shift of energy carriers to renewable electricity, hydrogen and renewable fuels supported by vehicle optimisations (aerodynamics, weight, etc.), powertrains electrification and the continuous improvement in Internal Combustion Engines (ICE) to support the transport system with an overall minimized energy consumption.

The current focus is shifting from technologically driven innovations towards the identification of future societal needs in terms of mobility in order to link more efficiently the passenger transportation system to the different energy sources available. With the aim of reducing the Green House Gas (GHG) emissions and of achieving "near zero" impact on air quality, in-depth thinking is also required to identify the most appropriate energy carrier for each unique transport mission, and this will only be possible by adopting a holistic view of the energy system in Europe.

There is no single and ideal powertrain solving the demands of sustainable mobility, and addressing both the environmental impacts and the requirements of global markets and European competitiveness. Electric vehicles are identified as one part of the solution but the only reasonable approach is to impartially support a mix of technologies and to carefully check their progress and market success in order to leverage the cleanest and most cost effective solutions.

All powertrains must now be assessed based on Well-to-Wheel (WtW) emissions and the overall CO_2 and resources footprints of future mobility solutions must also be evaluated through Life Cycle

[1] Decarbonisation of Road Transport – A Technical CO_2 Study for 2050, Ertrac Annual Conference, 2019. The European Green Deal requires climate neutrality until 2050 (this means 50% reduction until 2030 and 90% reduction until 2050 in the transport sector).

Analyses (LCA) in order to identify the truly sustainable transport solutions. It is thus essential to adopt a comprehensive approach on powertrains optimization, by considering advanced tools, methods and standards. Additionally, it is also necessary to combine continuously developing and completely new solutions to fulfil the expectations from both regulatory bodies and the users with respect to environmental acceptance, total cost of ownership and societal investments regarding infrastructure for charging, grids, pipelines, etc.

KEY RESEARCH NEEDS AND EXPECTED IMPACTS

Some solutions are already known to make the transport system more sustainable (such as policies for fleet renewal) but they are struggling to get running because of cost effectiveness, lack of relevant energy infrastructure, or limited user acceptance. It is thus urgent to act on several fronts and considering the main challenges ahead, the EARPA Foresight Group *Energy, Powertrains and Electrification* foresees the needs for research in the following key areas.

- **Holistic view on the EU energy system**

Europe still has a long way to go to avoid fossil CO_2 emissions in its power system and several sectors such as industrial and residential heat, chemical and other industries, but also transport are far away from the target of not relying on fossil energy carriers. It is essential to analyse the future energy use scenarios in Europe to optimize the link between the energy production, storage, distribution and transport systems. The synergy between the different foreseen energy carriers (electricity, H_2, e-fuels, biogas, biofuels, etc.) and the various transport missions, but also other sectors (chemical industry, heating, etc.) will also be crucial for an efficient and clean energy use in future powertrains. The expected impact of this analysis is to reduce WtW CO_2 emissions and also to reduce the overall CO_2 emissions of Europe as such due to well-chosen synergies with other sectors and a wise usage of also imported renewable energy.

Production of renewable power stored in hydrogen, hydrocarbons or alcohols made from recycled CO_2, can help to stabilize the energy system, and to provide energy to all energy users in a similar way as today.

As it seems that renewable energy imports will play a major role on the way to sustainability, it is of very high importance to understand the energy system in Europe, the possibilities to store temporary renewable excess energy in Europe, but also to import dedicated chemical renewable energy from outside Europe, and to also understand which mixture of energy carriers in transport make sense. Transferring imported chemical energy back to power can be an option, but might be less efficient than using imported energy carriers in transport and use the European renewable electricity in heat applications or elsewhere. This discussion and a broader view on Europe's capabilities on renewable energy production is needed to avoid high efforts in electrification in areas with high additional infrastructure cost, if chemical energy carriers have to be available anyhow.

Therefore a significant research need is to understand future energy flows in Europe and to combine the possible energy availability with drivetrain development. In line with this, Europe's development efforts in drivetrain research will match better with the potential energy sources based on the total cost for the society and the fast track to fossil free mobility.

- **Transport defossilisation**

A strong contribution towards defossilisation of road transport will be achieved by increasing the share of low carbon, alternative, and renewable gaseous and liquid fuels such as 2nd generation biofuels, e-fuels, hydrogen, xME. Research needs are clearly identified to pursue the development of these future fuels with an expected impact on reduced WtW CO_2 emissions.

In 2030, these fuels should cover more than 60% of the energy demand for road transport using pure thermal powertrains, and up to 90% considering hybrid vehicles[2]. The buffering of electric energy from renewables will play a key role in a carbon-neutral future. Furthermore, renewable fuels from non-bio-based origin will be significantly required due to needed energy imports into Europe (for which bio-based fuels are critical regarding e.g. ILUC and much more difficult to control). Additionally, even the fleet in 2050 will contain significant amounts of cars being built from today until 2030 which will be required to operate on CO_2 neutral fuels.

It will be essential to keep on working towards an optimal match between these renewable fuels and future ICEs in order to reach increased efficiencies (>50%) and minimised WtW CO_2 emissions. New combustion systems should be developed to take full advantage of renewable fuels properties (high hydrogen- and carbon-to-oxygen ratios) enabling clean and efficient combustion processes (e.g. gasoline compression ignition, H_2 combustion, low temperature combustion, etc.).

Fuel flexibility is of utmost importance in times of changing infrastructures for various energy carriers. Adaptive ICEs shall bridge the time period needed for the development of the infrastructure, without requiring the customers to buy fuel-dedicated powertrains with limited operation range. Consequently, adaptive engine control for fuel flexibility has to be developed using advanced control strategies, sensors and actuators. They require intensive Hardware-in-the-Loop and Software-in-the-Loop R&D, including the integration of control to higher (infrastructure) systems. Low-carbon renewable fuels with uncompromised operation range make the ICE also very competitive for global markets and by that support European industry and growth.

- **Clean and efficient powertrains (ICE and Electrification)**

ICEs and electric components are complementary, not exclusive, and provide together maximum benefits to the customers and society. Electrified vehicles, such as HEV or EV with range extenders, set specific demands for the ICE and, as a consequence, ask for dedicated engine configurations. There is thus a need for additional research and development to optimize future ICEs specifically for electrified powertrains, with a clear focus on a limited operating range of the engine but featuring very high efficiencies (>50%) thanks to high dilution rates combined with new ignition technologies and with advanced (e.g. electrified) air charging concepts.

The relevancy of electrified regional and long haul trucks should be monitored, especially in respect of Fuel Cell Electric Vehicles (FCEV) and emerging electrification technologies, bearing in mind the ambitious CO_2 emissions reduction target and the competitiveness of European transport service providers with operations over long ranges, maximal payloads, minimal downtime, and high density energy storage.

Losses reduction is an important topic of future research activities for ICE-powered vehicles for which a significant part of the fuel energy is not used to propel the vehicle. Electrified auxiliaries will support the continuous reduction in mechanical losses and new technologies are also needed for reducing engine thermal losses. Opportunities offered by additive manufacturing will also support the reduction of both thermal and friction losses. Advanced thermal-management strategies including exhaust gas after-treatment and Heating, Ventilation and Air Conditioning (HVAC) control should also be developed for all kind of electrified powertrains. Electrified turbocharging is a potential solution for exhaust enthalpy recuperation and several other approaches are possible for heat recovery (thermo-dynamic cycles, thermo-electric or thermo-acoustic generators, etc.) but none of them is yet viable for cost-effective mass production.

ICE-powered vehicles will have to comply with strict regulations for noise and also for regulated and non-regulated emissions (NH_3, N_2O, aldehydes, PAH, etc.) that must be further investigated. Careful evidence-based consideration is required for Euro 7 and EURO VII regulations and beyond and for their impacts on vehicle requirements, test verification and monitoring technologies safeguarding

[2] EU Reference Scenario 2016 Energy, transport and GHG emissions Trends to 2050.

real-world emissions. Powertrains with a "near zero" impact on air quality must be developed in particular for vehicles (partially) operating in urban environments. Clean combustion processes, combined with enhanced catalytic after-treatment systems using less rare earth elements and electrical heating are required to achieve near zero emissions. Hence, electrified powertrains are a great opportunity to lower pollutant emissions. Different hybridisation strategies related to the target mission also lead to various approaches from urban individual vehicles to heavy duty long haul traffic which will rely for long on efficient and clean combustion engines. In order to reduce pollutant emissions in real driving conditions, advances are also required in model-based vehicle and fleet monitoring, and in model-based connected control strategies for real time optimisation and over the vehicle lifetime. Geofenced areas will also potentially require additional functionalities of these vehicles.

The large-scale deployment of electrified powertrains calls for low cost, light-weight and highly integrated components. Advanced drivetrain concepts (wheel or axle motor concepts) will open new opportunities in vehicle design. Future research activities on modular and scalable architectures for electric drivetrains will play a key role for fully EV concepts, in terms of cost reduction and potential for mass-manufacturing, and also in terms of efficiency: 90% plug-to-wheel driving efficiency over WLTC is expected, as well as a 30% efficiency improvement due to an optimized energy management and a strong reduction in parasitic losses.

The limited EVs sales so far have not yet unleashed the potential of mass production techniques applied to electric motors. In addition, powertrain modularity, scalability, and possibly standardization as well should be further enhanced. Electric motors are very efficient and it is now necessary to reduce their size and weight, and to target "rare-earth-free" high speed electric motors equipped with miniaturized power electronics modules for a better functional integration with other driveline components.

Power electronics modules using wide band-gap materials enabling the switching frequencies needed for high speed machines will have to be developed for the next generation of electrified powertrains. Future developments of power electronics modules will have to address highly efficient fast battery charging, wireless/inductive charging and regenerative braking, combined with predictive control strategies. R&D into higher voltage power electronics is a key enabler in a move towards higher voltage systems, which may be required to suit ultra-fast charging.

- **Powertrain control for optimal energy use**

Minimizing vehicle energy consumption over actual and future type approval test cycles (including real-drive conditions) is not only about optimizing the performance of sub-components, but also about the complete system through smart control. The expected impact of research activities on powertrain control and system optimization is to place European manufacturers, components and services suppliers at the leading position to increase their competitiveness.

Thermal management of the main and auxiliary powertrain components needs to be addressed as well as the various vehicle system functions with a holistic approach. The potential of shared and combined cooling circuits, the optimized use of the heat dissipated by the drivetrain, and smart energy management strategies (e.g. cabin pre-heating in cold conditions) must be exploited.

New control strategies based on continuous total optimization at a system level will be required for all types of powertrains, from hybrid powertrains using optimized ICEs with more complicated structure, to future electric vehicles featuring more flexibility and modularity. Adaptive control systems and associated sensors need to be developed to optimise the use of on-board energy and to control real driving emissions. Digitalisation and connectivity of future vehicles (V2X) will support these approaches and enable predictive and real time control based on the real operating state rather than on a traditional map-based approach. The introduction of techniques like Artificial Intelligence will also require investigations with respect to improvements and optimisation of powertrain implementations and their use in a connected environment. New virtualisation and testing methodologies will be required for the development, verification, and validation of these systems.

Contributions from on-board systems for reduction of energy consumption using online or stored traffic and situational information have significant potential for CO_2 reduction in real life conditions. As of now, these benefits cannot be proven by the VECTO tool for CO_2 values of heavy duty vehicles. To push forward technologies that contribute to real life CO_2 reductions, additional proven CO_2 benefits should be rewarded as eco-credits even before they are formally introduced in the certification tool updates[3].

The adoption of V2X connectivity and automated driving functions will also improve customer acceptance by lowering energy consumption and giving better vehicle range. Concepts for predictive control of energy management, possibly coupled with automated driving, need further emphasis to allow real-world applications and improve reliability of the prediction of range. Traffic data and big data management for transport applications will also play a role in this context.

- **Electric energy storage systems**

Electric energy storage systems are key components of electrified powertrains, directly affecting their general performance. Overall, range, cost, weight and user-friendly smart charging options for these systems are the main factors for success. The expected impacts of research activities on electric energy storage systems needs are the extension of the driving range of EVs up to 500 km, the extension of their lifetime up to 20 years calendar life, and a cost reduction below 90 €/kWh.

With the support of the European Battery Alliance and taking into account the foreseen deployment of electric vehicles, there is a clear opportunity for Europe to spearhead the development and manufacturing of future battery cells.

There are various levels of maturity in energy storage systems considering the current generations of lithium ion batteries and future post-lithium cell technologies. R&D is of utmost importance and an efficient and smooth transfer of results to the industry is a must. Research into new materials and storage technologies is needed to improve energy density and durability, keeping in mind fast charging characteristics. For this purpose, an extra effort is needed in materials development, understanding degradation phenomena at the interfaces, and in multi-scale modelling which is essential for optimizing the lifetime and safety of batteries.

Further research activities should be undertaken regarding battery management systems in order to design advanced concepts for electrical and thermal control of modules and packs. The focus should be on safety and thermal management issues, especially for vehicle operation in extreme environmental conditions. The development of advanced light-weight materials at the pack level is a must to improve the structural resistance and to anticipate the second life and re-use of battery packs. Maintenance operations should also be addressed by optimizing the packaging and modularity and by developing new software-based remote strategies or by integrating additional sensors at cell, module and pack levels. Finally, research is required into higher voltage systems compatible with ultra-fast charging, including the insulation challenges that these voltages bring.

Due to the increasing number of xEVs in Europe, LCA, second life, repair, re-use and recycling issues are of high relevance from the environmental point of view and also as a business opportunity. Several options can be considered for re-using used but valuable storage systems, but it is of utmost importance to be able first to estimate the remaining life of a used battery pack. For this purpose, multi-scale modelling tools are to be developed in combination with state of health diagnosis of such batteries to ensure the long-term sustainability of the battery market. Circular economy considerations and efficient recycling of raw materials are vital to reduce Europe's material

[3] ACEA Proposal on CO_2 standards for new HD vehicles.

dependence on less politically stable areas and markets. This includes research on recycling processes and proposals for a supporting policy.

In general terms, the various patterns of charging and discharging create the need for normalized tests to assess the impacts on the performance and lifetime of battery packs. Fast charging and grid connected vehicles (V2G) for example will require to go along with the investigation and standardization of testing methods and simulation tools for systems and components.

RELATION TO OTHER ROADMAPS AND OTHER EU INITIATIVES

EARPA sees the requirement to identify actual research topics on a European level, in close co-operation with all relevant stakeholders and European initiatives (e.g. Hydrogen Europe and European Battery Alliance). The research needs identified here by the Foresight Group *Energy, Powertrains, and Electrification* within EARPA are fully aligned with parallel initiatives and analyses originating from the European Institutions[4, 5], from EGVI[6], and from ERTRAC[7, 8, 9, 10].

Taking advantage of their expertise, EARPA members contributed to several roadmaps on a neutral basis in order to promote innovations and to maximize the impacts of research activities in the field of road transport. Strengthening the existing ties between the relevant stakeholders is a success factor for the European research and innovation area. With their research capacities and expertise, EARPA members are playing a key role in that context and contribute to raise awareness among public authorities and general public on the continuous research needs towards an affordable and sustainable road transport system.

Finally, also the relation to international programmes, e.g. those funded by the US Department of Energy or by the Japanese Cross-ministerial Strategic Innovation Promotion Program confirms the vital interest on research and innovation in the fields of *Energy, Powertrains and Electrification*.

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[4] White Paper on transport, Roadmap to a single European transport area - Towards a competitive and resource-efficient transport system, 2011.
[5] The Strategic Energy Technology Plan – at the heart of Energy Research and Innovation in Europe, 2017.
[6] EGVI 10 Years Impact Assessment, 2019.
[7] ERTRAC Strategic Research Agenda, Input to 9th Framework Programme, 2018.
[8] Long Distance Freight Transport – A roadmap for System Integration of Road Transport, 2019.
[9] European Roadmap – Electrification of Road Transport, 2017.
[10] Decarbonisation of Road Transport – A Technical CO_2 Study for 2050, ERTRAC Annual Conference, 2019.