

EARPA Position Paper

'Hybrid Powertrains and Alternative Fuels'

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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 51, ranging from large and small commercial organisations to national institutes and universities.

Boundary conditions for internal combustion engine powered vehicles in the future

In order to realize sustainable mobility in Europe, urban passenger road transport will have to be 80% more efficient by 2030, and long distance transport will have to be 40% more efficient¹. A significant part of these targets will be achieved through improving vehicle aerodynamics, reducing the vehicle weight, by influencing driving patterns and applying advanced predictive controls. At the same time, a considerable contribution will have to come from improving the energy efficiency of the vehicle powertrain itself. To some extent, this will be the result of further hybridization. However, in 2030 more than 80%² of all road transport vehicles will still be powered by powertrains which have an internal combustion engine (ICE) running on liquid fuels. Therefore, engines must become thermodynamically more efficient.

Within the same timeframe, renewable and low carbon fuels should cover more than 60% of the energy demand for road transport in pure thermal engines, and up to 90% considering hybrid vehicles³. It is expected that until then, the mainstream fuels will resemble current (diesel and gasoline) fuels as 'drop-in' solutions and will consist of blends of fossil fuel with increasing amounts of biomass-derived components or e-fuels from solar or wind energy during the transition period towards 2050. The buffering of energy from renewables will play a key role in a carbon-neutral future and the reliance on a range of liquid or gaseous energy carriers means that future engines will potentially have to be able to cope with the resulting variation in fuel quality and properties. At the same time, due to increasing traffic volumes and increasing population density, ICE-powered vehicles will have to comply with very strict regulations for noise and pollutants, for both regulated emissions and emissions requiring future regulation. In particular, the operation of vehicles within urban environments (particularly imposed from local policy) will place additional challenges requiring advanced control and monitoring regimes.

The potential philosophy of 'polluter pays', will place additional requirements on the vehicle, test verification and monitoring technologies towards safeguarding real-world emissions, with transparent openness from industry to end-user. Emission of pollutants can be limited to a desirable level if properly checked in operation, but this requires advances in both engine and aftertreatment technologies with advanced control (such as online adaptation and optimisation), combined with advances in sensors and virtual sensors in operation over the lifetime of the vehicle. Finally, the introduction of automation functionality requires careful pairing with modular powertrain energy management in a systems approach.

¹ ERTRAC Strategic research agenda (www.ertrac.org)

² ERTRAC Future Light and Heavy Duty ICE Powertrain Technologies, 2016 (www.ertrac.org)

³ EU Reference Scenario 2016 Energy, transport and GHG emissions Trends to 2050

The almost unlimited range and the fuel flexibility of ICE and hybrid powertrains will favourably keep the position of ICE powered vehicles in the market. Any future powertrain technology will need to be sustainable in terms of its demands for scarce materials, especially rare earth elements, precious metals or copper: this will be an emerging challenge.

Any new concept should be assessed based on the well-to-wheel (WTW) (not tank-to-wheel (TTW) only) efficiency and life-cycle CO₂ emissions, using a realistic approach for the energy mix available. Moreover, the energy and material consumption during the whole life cycle (Cradle to Grave) has to be considered, together with investment and depreciation costs, when comparing ICE, (plug-in or non-plug-in) hybrids, battery electric vehicles (BEV) and fuel cell (FC) vehicles, again using a WTW not only a TTW approach, i.e. including infrastructure costs. The sophisticated and cost-effective design of ICE powertrains provides a good starting position to further increase reliability, safety and durability.

New solutions of vehicles (e.g., BEV or fuel cell electric vehicles (FCEV)) are still to be proven in operation for a sufficiently long time and in large enough scale. This proof should include the robustness of the concept, durability, reliability, maintenance costs and safety, including second hand sold cars etc. Even under a shortened time to market, careful decisions considering the significant investment costs required for future infrastructure and product development are advisable. Since no clear unambiguous solution can be identified today, the only reasonable way is to continue to support all potential technology development paths and to check carefully the progress and market success achieved by these.

Advances in sophisticated control, increased functionality and increased degrees of hybridisation will require improved development and assessment methods supporting technological innovation in the automotive context. Tools for understanding and optimising Total Cost of Ownership (TCO) are required for both commercial and private vehicle users, to support any new technology introduction.

The relevance and importance of continued R&D on internal combustion engines

There is no single way to solve the demands of future powertrains for sustainable mobility, addressing the environmental impacts and the requirements of global markets and European competitiveness on a global scale. Combinations of continuously developing and completely new solutions shall be sought. Despite its long history, the potential of the ICE remains significant due to its flexibility to utilise both renewable and low-fossil-carbon fuels, its high power density combined with long operational range resulting from the energy density of chemical fuels, and the overall well-to-wheel efficiency in real-life operation.



Integrated in a hybrid powertrain, the ICE can ensure an efficient transition for targeted electrification and/or the use of chemical accumulation of electric energy for transport in the future. The electrical powertrain and IC engines are not exclusive but complementary: their combined use can provide maximum benefits to the customers and society in large.

Hybrid vehicles, as well as electric vehicles with range extension, set specific demands for the ICE and, as a consequence, ask for dedicated downsized engine configurations. The Well-To-Wheel efficiency and fossil CO₂ emissions of ICE based powertrains are good in comparison to electric vehicles, if the same vehicle operating range is considered. In particular, the gasoline engine could be made more efficient, from the nominal sub-40% thermal efficiency, to 50% and produce effectively zero emissions by combining its highly efficient aftertreatment with electrical heating. Different hybridisation strategies related to the target mission lead to various approaches in urban individual vehicles to heavy duty long haul traffic. The latter, especially, will rely on high efficiency and clean combustion engines as diesel (with different primary energy chains) will remain the

predominant fuel source for medium and heavy duty commercial vehicles through 2020, both in the triad (EU, US and JP) and emerging markets.⁴

The establishment of a leading position in powertrain control and system optimization increases the competitiveness of

1. European road vehicle manufacturers,
2. European automotive technology and component suppliers (Tier 1, Tier 2), and
3. European companies and institutes specialized in vehicle and powertrain system simulation, instrumentation and test systems.

The competitiveness of transport service providers (e.g. fleet operators) also increases through the ability to provide cleaner transport services and zero emission last mile delivery at competitive prices.

Long distance freight transport, with the demand for high power operation, the need for operation over long ranges with minimal downtime during a shift, and the need to maximise vehicle payloads, requires on board energy storage with high volume density and high mass density. This requirement is pushed further by the prospect of autonomous vehicles for long distance freight transport, since these vehicles offer the potential for 24 hour / 7 day operation where any downtime for taking energy on board is potential lost revenue. Today's on-board energy storage need is mainly covered by the use of liquid fuels and, whilst battery and fast charging technology will continue to improve, the challenges and the gap for today's alternative energy storage capabilities mean that chemical fuelled ICE powertrains are expected to provide the mainstream solution for long distance freight transport for the long term. Particularly, if operated with CO₂-neutral fuels and efficiencies as good as all-electric solutions under consideration of all electrical losses from the power plant to the wheel, the use of more expensive pure electric long haul trucks would deteriorate the competitiveness of EU industry.

Continuous research and development is needed in the areas of ultra-clean ICE solutions, improved efficiency and cost of ownership, and electrified applications to either provide the last mile delivery into urban environments via dedicated vehicles or to enable operation at urban speeds with zero impact on air quality. Fuel flexibility is of utmost importance in times of changing infrastructures for renewable and synthetic fuels, including shale NG, GTL and BTL fuels or hydrogen blends, or methanol produced from hydrogen and CO₂ using renewable energy. 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 (combustion) 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 fuels with uncompromised operation range make the ICE very competitive for global markets.

The more complicated structure of an ICE hybrid powertrain and the new role of the ICE in it, call for new design and development methods based on continuous total system level optimization and the application of Industry 4.0 approaches. Virtual product development has to be applied from the start of R&D process to ensure automated production and assembly of powertrains. The simulation and XiL tools for pre-development design, with digital twins for front loading and full model-based optimization, are of importance if almost irreversible decisions if large investment into infrastructure, vehicle development and testing are to be made.

Innovations from computer science become more important due to the digitalisation and connectivity of future vehicles. The introduction of techniques like Artificial Intelligence requires investigation with respect to improvements and optimisation of powertrain implementations and their use in a connected environment.

Hybrid powertrains offer a route of steady and managed progress towards sustainable mobility without reliance on uncertain breakthroughs and track-records in emerging technologies. Therefore, R&D support should balance a wide range of possible paths to future mobility devices.

⁴ Truck Powertrain 2020, Mastering the CO₂-Challenge, Roland Berger Strategy Consultants
http://www.rolandberger.es/publications/2010-09-21-Truck_Powertrain_2020_en.html

Research needs and suggestions for European R&D Programmes

Considering the boundary conditions described above, the EARPA Task Force for Hybrid Powertrains and Alternative Fuels sees the need for research in the following areas:

1. Optimised use of powertrain energy

Hybrid electric vehicles (HEV) are widely considered as a decisive step towards a more efficient road transport system.

Key research needs

Concerning the optimisation of a hybrid powertrain, EARPA stresses the importance of further research and development on the following elements:

1. New hybrid architectures, including the engine and the transmission, for an optimal use of the powertrain in real driving conditions
2. Ultra high efficiency gasoline engines dedicated to hybrid vehicles
3. Fully connected vehicles using V2x, for an optimal control and exploitation of the available on-board energy
4. Advanced powertrain control systems using approaches, such as real time optimisation and AI, to give an improved operating state rather than a traditional map based approach with fixed calibration
5. Energy recovery systems, such as the Rankine Cycle, thermoelectric devices, turbocompound etc. Non-battery energy storage solutions
6. Advanced thermal-management for hybrid vehicles for aftertreatment systems, thermal fatigue control and the use of waste heat for vehicle HVAC
7. WTW assessment and optimization for future hybrid powertrain concepts

2. Continuation of research on breakthrough technologies for more efficient ICE

Research on the improvement of existing internal combustion engines as well as on new solutions is a key to improve the efficiency of automotive powertrains.

Key research needs

Concerning the internal combustion engine, EARPA stresses the importance of further research and development on the following elements:

8. Optimized design of ICE to enlarge the areas of most favourable efficiency, being highly adapted to hybrid powertrains and range extender solutions
9. Ultra high efficiency medium and heavy duty engines supporting increasing powertrain electrification
10. Engine architecture with very high efficiency, such as variable compression ratio, variable engine displacement systems, intra-cycle waste heat recovery etc
11. Ultra-low emission and high efficiency gasoline compression ignition engines
12. Strong reduction of friction losses, by both mechanical and electrification means
13. Technologies for reducing in-cylinder heat transfer and improving thermal management
14. New opportunities given by additive manufacturing, especially for reducing friction losses and optimising the thermal management
15. Advanced air charging technologies, including the electrification of the air path
16. Innovative ignition system for ultra-lean combustion, for high engine efficiency over a large engine map area
17. Deepen technology for gas engines to reduce transport's CO₂ footprint

3. Increasing the share of renewable fuels used in road transport

A strong contribution towards decarbonisation of road transport will be achieved by increasing the share of low carbon alternative gaseous or renewable fuels.

Key research needs

Concerning use of alternative fuels, EARPA stresses the importance of further research and development on the following elements:

18. Improvement of material and engine components, including the aftertreatment system, for an increased biodiesel content
19. Combustion system adapted to synthetic and paraffinic fuels, in order to take full advantage of their high oxygen to carbon ratio and so low soot production
20. Combustion systems developed to be robust to and exploiting a wide range of fuel properties resulting from different feed stocks and associated adaptive control systems and the required sensors
21. New alternative fuels to allow advanced and clean combustion processes such as RCCI (reactivity Controlled Compression Ignition), Dual-Fuel, GCI (Gasoline Compression Ignition), SACI (Spark Assisted Compression Ignition), low NO_x combustion
22. New SI engines fully adapted to the Natural Gas and hydrogen mixture, alcohol fuels combustion, including the ignition and aftertreatment systems

4. Co-existence of more efficient powertrains and high standards for air quality

The research for more energy efficient technologies needs to guarantee that these technologies are equally clean - if not cleaner - in terms of conventional pollutant emissions.

Key research needs

Concerning emission control, EARPA stresses the importance of further research and development on the following elements:

23. Advanced combustion processes, such as low temperature combustion, RCCI, Dual-Fuel and GCI, including proper fuel injection systems, control strategies, sensors and aftertreatment
24. Advanced aftertreatment systems, for an optimal reduction of the pollutants in both urban and extra-urban conditions, with a lower use of rare earth elements
25. Fully flexible valve trains for an optimal control of the exhaust gas conditions with limited impact on the fuel efficiency
26. Multivariable model-based control system, including the use of external information and able to control the real driving emissions and fuel consumption, using links to autonomous driving systems

5. Maintaining the global competitiveness of European automotive industry

The research has to focus on topics needed for maintaining and safeguarding the leadership and competitiveness of the European automotive industry.

Key research needs

Concerning global competitiveness, EARPA stresses the importance of further research and development on the following elements:

27. Fast and efficient product development in a digitalized and connected industry
28. Creation of digital twins for development, production, maintenance and recycling
29. Minimization of consumption of energy and resources during entire product life cycles

Relation to other roadmaps and initiatives

EARPA sees the requirement to identify actual research topics on a European level, in close co-operation with all relevant stakeholders. In particular, ERTRAC as well as the EGVI are major instruments bringing together all relevant stakeholders.

The spirit and targets of EARPA and its Task Force HyPF are fully aligned with the recent ERTRAC roadmaps for Future Road Transport 2050 prepared by the Executive Group, and for CO₂ reduction and near zero pollutant emissions developed by the Working Group on Energy & Environment. Taking advantage of their expertise, EARPA members offered support and contribution to these roadmaps on a neutral basis.

Alongside this strategic role, EARPA wants to emphasise the importance of continuous RTD efforts to develop next generation of hybrid powertrains and to deploy the current generation. With their research capacities and expertise, EARPA members are playing a key role in that context. Strengthening the existing ties along the entire value chain is seen as a success factor for the European Research & Innovation Area.

This Position Paper is related to the following documents:

- EC-Whitepaper: COM (2011) 144 final Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system
- ERTRAC: "Energy Carriers for Powertrains – For a clean and efficient mobility", 2014
- ERTRAC: "Future Light and Heavy Duty ICE Powertrain Technologies", 2016
- EU Reference Scenario 2016 Energy, transport and GHG emissions Trends to 2050

Finally, also the relation to international research programmes, e.g. ARPA-E with several programs on electric and hybrid vehicles, combustion engines and transportation fuels confirms the vital interest on research and innovation in this field

Conclusion

All the different scenarios of future mobility suggest that the hybrid powertrain, powered by an ICE using high share of alternative fuels, will keep a significant role for quite some time.

The design and development of advanced powertrain solutions will have significant beneficial impacts on CO₂ and emission reduction, using all the different available levers, i.e. optimised and cleaner ICE, wider use of alternative fuels, high efficient and dedicated aftertreatment systems, optimal and connected ICE and energy control, thermal and energy management.

The EARPA Task Force HyPF is ready to support the identification of research topics on a European level in close co-operation with all relevant stakeholders. Taking advantage of their expertise, EARPA members can offer support to this identification process on a neutral basis. Moreover, EARPA invites all stakeholders to discuss the above research issues with the Task Force HyPF.

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