R&D CHALLENGES: HYBRIDS AND FUELS 2021+

TRENDS ON TECHNOLOGY DEVELOPMENT AND RESEARCH DEMAND

Hybrid powertrains fueled **with CO_2-neutral liquid and gaseous fuels incl. hydrogen** are highly efficient and very well suited for applications where long ranges and short refueling times are of major importance. Small batteries and largely mechanical components of hybrid powertrains lead to a low environmental impact during production and recycling. Thus, hybrid powertrains can very effectively and in short term contribute to the achievement of a CO_2-neutral mobility.

Therefore, research must focus on further **hybrid powertrain and vehicle efficiency** and at the same time on **fuels with low pollutant emissions and low (fossil) carbon intensity** (based on LCA methods). Improvements in these directly contribute to the reduction of CO_2 and pollutant emissions in the short and medium term. Today, the best chemical energy carriers (renewable liquid and gaseous fuels and hydrogen) achieve as low GHG emissions as the best electric vehicles with current national carbon intensity of electric power generation. Another important aspect of such climate-neutral fuels is that they can be used in existing vehicles as part of the existing fuel supply infrastructure and the use of these fuels immediately has a positive impact on the GHG balance. Further, the use of hydrogen also in combustion engines (incl. turbines) can help to increase the demand for hydrogen as a transport fuel in nearer future. Thus, a hydrogen network and hydrogen refilling stations could be operated economically much earlier.

Studies by the European technology platform ERTRAC show further potential for efficiency increases or GHG reductions for hybrid drives with combustion engines - also by means of engine measures (increase in peak efficiency in the range of 50% for cars and 55% for commercial vehicles - without fuel effects). These figures underline the great importance of further research efforts to improve the efficiency of powertrains.

At the same time, fuel-side measures have an equally high potential for reducing GHG emissions. On the one hand, synthetic fuels in the form of sustainable advanced biofuels can be based on a broader biological raw material basis and, unlike sugar, starch, oils and fats, are not in competition with food and feedstock production. Residues from agriculture and forestry, industrial residues and waste can be considered as raw materials. However, the corresponding production technologies still have to be developed to market maturity through appropriate R&D activities. In addition, these fuel paths open up new regional value creation potential. On the other hand, hydrogen as well as synthetic fuels in the form of e-fuels from renewable (climate-neutral) electricity and renewable carbon sources can also be made available as high-quality and almost climate-neutral energy carriers for engines. Whereas these technologies are already quite developed, they are currently not commercially produced.

In summary, the following specific research needs can be stated for the years 2021+:

1) Efficiency improvement of the powertrain system by hybridization, optimal and predictive thermal and energy management, waste heat utilization (e.g., on-board fuel reforming from waste heat recovery) and loss reduction through electrification of auxiliary units.
2) Continuous development of CO_2-neutral synthetic fuels - including the efficient production of hydrogen from local surplus renewable energy in a sustainable and economical combination with international renewable energy - and their manufacturing processes and improvement of combustion properties to reduce local pollutants and GHG emissions.
3) Technology research and development on hybrid and single transmissions to achieve highest powertrain operation efficiency.

4) Overall efficiency improvement of thermodynamic cycle and innovative adaptation of the internal combustion engine to hybrid powertrains in combination with CO_2-neutral liquid and gaseous fuels including hydrogen and with exhaust gas aftertreatment systems to finally achieve zero impact pollutant emissions.

ESSENTIAL LEGAL FRAMEWORK

- Creation of an EU-wide legislative framework and/with directives for rapid implementation of an efficient and climate neutral mobility allowing EU-industry the introduction of new technologies resulting from R&D activities described in this position paper.
- Adapting legislation and powertrain requirements to allow for higher blending of biofuels.
- Provide incentives for production or supply of advanced renewable fuels
- Adapting the (EU-wide) CO_2-regulation to include well to wheel GHG emission benefits using renewable energy carriers (hydrogen, biofuels and synthetic fuels) would allow the automotive industry to factor in renewable fuels into their targets and would thus encourage the adaptation of ICEs to higher blends of renewable fuels.

These framework conditions (i.e., legislation and regulations) must be long-term and based on the actual GHG reduction, without favoring specific technologies. This actual GHG reduction depends on the carbon intensity of the energy carriers (fuels and electricity) used and the actual use of these energy carriers in the related vehicles; e.g., plug-in hybrid vehicles that are never charged but always run on fossil fuels do not provide actual GHG emission reductions. Without such a long-term framework, great uncertainty exists for customers and especially for industry and companies which are basically prepared for innovative long-term but also very costly investments. Obviously, such investments can only be made on a sound basis.

LIFE CYCLE ASSESSMENT

Key factor in Life Cycle Assessment (LCA) of hybrid vehicle architectures is the change in energy demand and efficiency during operation. While research focuses on increasing system efficiency, the impact of the additional weight of the specific components of hybrid vehicles on energy demand also depends on real world driving. LCA of drop-in biofuels and so-called e-fuels based on carbon capture and utilization involves a wide range of supply chains of different types of biomass, biomass conversion processes, renewable electricity, hydrogen production, CO_2-sources and separation technologies. LCA-results are therefore highly influenced by the CO_2 source, the degree of process integration and system efficiency, by the allocation of double used fossil CO_2-emissions between emitter and receiver and the long-term availability of fossil based CO_2-sources.

RESEARCH REQUIREMENTS

1. HYBRID SYSTEM

- New hybrid topologies
    - Increase of efficiency (and thus reduce GHG emission)
    - Solutions at optimal costs
- Electrified and on-demand-driven auxiliary units
    - Efficient air conditioning compressor, coolant / oil pump, power steering pump, components of the charging system
    - Electric machines for electric auxiliary units including control - especially powerful units for commercial vehicle applications
    - Electrified units for 48V electrical systems
- Energy management (including thermal management)
    - Avoiding cold start losses (heat storage, heat encapsulation)
    - Thermal conditioning of the exhaust gas after-treatment system
    - Optimizing electric energy management
    - Thermodynamic recuperation including waste heat recovery (WHR)
    - Rankine cycle
    - Thermo-chemical waste heat recovery (e.g., fuel reforming)
    - Thermo-electric waste heat recovery
    - Optimal predictive thermal control (e.g., predictive cooling)
    - Combined control of heat and power flux
- Control of the hybrid system
    - Optimal operating strategy and control of hybrids using connectivity Car2X - X2Car (e.g., hybrid system on navigation system); Monitoring and service optimization
    - Software for component control and system control
    - Fast modeling methods and fast, automated control and diagnosis system parameterization
    - Combined physical-mathematical / phenomenological modeling
    - Efficient validation of complex drive systems
    - Automated operating and cutting-edge control strategies
    - Development tools & methodologies (e.g., "simulation on molecular level")

2. FUELS

- Efficient and "green" (i.e., low carbon) fuel production and on-board storage
    - Drop-in fuels for energy supply for existing vehicle technologies (and in the current legacy fleet)
    - Production of synthetic fuels, i.e., biofuels, e-fuels and other non-fossil fuels
        - Production processes of e-fuels (e.g., produced from hydrogen from renewable electricity sources and CO_2 from air or industrial sources or carbon from biomass) in view of efficiency and cost-per-unit impact between regional primary energy availability and imported e-fuels / H_2
        - Processes for utilization of regenerative carbon sources from exhaust gases, flue gases, or other fossil sources
        - Gasification technologies and other thermal processes to produce biofuels (e.g., gasification of biomass followed by synthesis to liquid or gaseous fuels etc.)
        - Integration of biofuel production into refineries through co-processing and upgrading of biobased intermediate energy carriers such as pyrolysis oils, bio-oils and FT-liquids
    - Application of higher blends of synthetic fuels in combustion engines (e.g., E20, B10, ED95)
    - Efficient energy storage for liquid and gaseous fuels (e.g., CNG / LNG, H_2)

    - Measurement and analysis techniques for increased quality requirements as well as for online analysis of the gas constituents for optimal setting of the ICE
- Material technology for advanced / new fuels
    - Tank / pipe / sealing materials and fuel metering materials
    - Fuel sensors (on and off board)

3. HYBRID POWERTRAIN

- Transmission and clutch technology for hybrid vehicles
    - Variable gear systems
    - Transmissions for high-speed e-machines (including noise reduction)
    - Sinter and coating technologies
    - Lightweight technologies
    - Fast actuators
    - Transmission for highly efficient hybrid topologies
    - Optimal and predictive gear shift control/operation

4. THERMODYNAMICS OF THE INTERNAL COMBUSTION ENGINE INCLUDING EXHAUST GAS TREATMENT

- Combustion technologies for CO_2-neutral fuels incl. hydrogen and new legal requirements (RDE, ...)
    - Development and use of "Fully Flexible Direct Injection Systems" for liquid and gaseous fuels
    - New variabilities for efficiency improvements of the engine system
    - Ultimately highly efficient combustion systems aiming at 50% efficiency (including multi-fuel capability) incl. HCCI, long expansion, thermal insulation/swing
    - Optimal adaptation of engines to hybrid systems
    - Further NVH reduction of hybrid systems
- Enhanced exhaust gas aftertreatment for future fuels and future legislative requirements (RDE…)
    - Identification and elimination of other pollutants
    - Elimination of ultra-fine particle emissions
    - Sensors and control systems for RDE exhaust gas monitoring (OBD)
    - Direct emission control
- Material technology for engine improvements
    - Improvement of thermal insulation / adiabatic operation
    - Lightweight construction plus the use of new materials
    - Use of sintered components (also for actuators)
    - Reduction of friction and wear (including new bearing technologies especially for future / gaseous fuels …)
    - Fully recyclable materials

REQUESTED NATIONAL FUNDING INSTRUMENTS

- Low TRL research
- Co-operative industrial research and experimental development
- Flagship projects
- Funding of demonstration plants, i.e., to produce biofuels, e-fuels or other synthetic fuels