R&D Challenges: Hybrids and Sustainable Fuels 2023+

Trends on Technology Development and Research Demand

Although this position paper focuses on the automotive sector with on- and off-road vehicles, other mobility sectors such as aviation and inland/maritime shipping will also benefit from the research addressed in this section - particularly on sustainable fuels (sustainable aviation fuels (SAF), sustainable fuels for ships).

Hybrid powertrains fueled **with sustainable, renewable liquid and gaseous fuels incl. hydrogen** – i.e. biofuels and so-called RFNBOs (renewable fuels of non-biological origin)[14] – 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. As a result, hybrid powertrains can very effectively contribute to achieving climate-neutral mobility.

Therefore, research must focus on further improvements of hybrid powertrain and vehicle efficiency and at the same time on fuels with low pollutant emissions and low (fossil) carbon intensity in the life cycle. Such improvements directly contribute to the reduction of GHG and pollutant emissions in the short and medium term. Today, vehicles powered by sustainable chemical energy carriers (renewable liquid and gaseous fuels and hydrogen) can achieve as low GHG emissions as electric vehicles based on the current carbon intensity of national electric power generation mix. Another important aspect of liquid sustainable fuels is that they can be used in existing vehicles as part of the existing fuel supply infrastructure, and their use has an immediate positive impact on the GHG balance. In addition, the use of hydrogen in internal combustion engines (as well as turbines) can help to increase the demand for hydrogen as a transport fuel in the near future. This could make a hydrogen network and hydrogen refueling stations economically viable much sooner.

Fuel-side measures have a high potential for reducing GHG emissions. First, there is the possibility to increase blending ratios of conventional biofuels such as FAME biodiesel and ethanol, leading to immediate further reduction of GHG emissions. Secondly, 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 used as raw materials. These fuel paths open new regional value creation potential. However, the corresponding production technologies still need to be developed to market maturity through appropriate R&D and demonstration activities. And finally, RFNBOs, e.g. hydrogen as well as e-fuels from renewable electricity and renewable carbon sources can also be made available as high-quality energy carriers for engines. While these technologies are already quite developed, the respective fuels are not yet commercially produced.

In summary, the following specific research needs for product development for the European and global market (to strengthen the European competitiveness and the European exports) can be identified for the years 2023+:

1) Efficiency improvement of the powertrain system by hybridization, optimal and predictive thermal and energy management, waste heat utilization (e.g. on-board fuel

[14] https://energy.ec.europa.eu/publications/delegated-regulation-union-methodology-rfnbos_en, retrieved 8 May 2023

reforming from waste heat recovery) and loss reduction through electrification of auxiliary units.

2) Continuous development of sustainable fuels - including the efficient production of hydrogen from renewable electricity sources and CO_2, or from synthesis gas e.g. by co-electrolysis of H_2O and CO_2.
3) Technology research and development on hybrid transmissions to achieve highest powertrain operation efficiency.
4) Overall efficiency improvement of internal combustion engines (ICE) for hybrid powertrains in combination with sustainable liquid and gaseous fuels including hydrogen.

Essential Legal Framework

As to facilitate the deployment of sustainable fuels and hybrid powertrains, recommendation to policy makers is to:

- Create 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.
- Adapt legislation, taxation, codes, and standards, as well as powertrain technologies to allow higher biofuel blends.
- Provide incentives for production or supply of sustainable fuels.
- Adapt the (EU-wide) CO_2-regulation to include well-to-wheel GHG emission benefits using renewable energy carriers (biofuels and RFNBOs). This would allow the automotive industry to consider renewable fuels in their targets and would thus encourage the adaptation of ICEs to higher blends of renewable fuels.

These frameworks (i.e., legislation and regulations) should be 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.

These frameworks also need to be long-term, since otherwise there is great uncertainty for customers and especially for industry and companies. Industry is prepared to make innovative long-term yet very costly investments, but these can only be made on a sound basis.

Life Cycle Assessment and Circular Economy

Key factor for Life Cycle Assessment (LCA) of hybrid vehicles is the energy demand and efficiency during the entire lifetime of the vehicle from production via operation to recycling. While research focuses on increasing system efficiency, LCA has to consider a “bigger picture”, e.g. taking into account the effect of the additional weight of hybrid vehicles on energy consumption in real world driving.

LCA of biofuels and RFNBOs 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 and the degree of process integration and system efficiency. On top of traditional LCA, also dynamic LCA should be conducted, to assess the impact of EU-wide deployment of sustainable fuels and hybrid powertrains.

In a future fully circular economy, all developments must aim for zero waste, i.e. the recycling and reuse of all materials. Therefore, research is needed to achieve closed-loop materials cycles of future products.

Research Requirements

The research requirements listed below are expected to be most relevant within a short-term perspective (2023-2025).

A more extensive list of research requirements including mid-term (2025-2023) and long-term (2030+) topics can be found in the A3PS Roadmap "Austrian Roadmap for Sustainable Mobility – a long-term perspective, Version 2022 (https://www.a3ps.at/a3ps-roadmaps).

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, power steering pump, components of the air management (charging) system
  - Electric machines for electric auxiliary units including control – especially powerful units for commercial vehicle applications

- 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 of hybrid powertrain systems
  - Thermodynamic waste heat recovery (Rankine cycle, thermo-chemical and thermo-electric heat recovery)
  - Optimal predictive thermal control (e.g. predictive cooling)
  - Combined control of heat and power flux
  - Adaptation of the operating strategy to optimize the life-time of the hybrid system (e.g. the battery)

- 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. Sustainable Fuels

- Efficient and “green” (i.e. sustainable) fuel production, on-board storage and fuel use
  - Efficient production of drop-in fuels (biofuels and RFNBOs) to power existing vehicle technologies (and in the current legacy fleet)
  - Production processes of RFNBOs (produced from hydrogen from renewable electricity sources and CO_2, or from synthesis gas e.g. from co-electrolysis of H_2O and CO_2) in view of efficiency and cost-per-unit impact
  - Processes for capturing CO_2 from exhaust gases, flue gases, or other 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 bio-based intermediate energy carriers such as pyrolysis oils, bio-oils and Fischer-Tropsch-liquids
  - Adaptation of powertrain systems for the application of higher blends of sustainable fuels
  - Efficient energy storage for liquid and gaseous sustainable fuels
  - Measurement and analysis techniques for increased quality requirements as well as for online analysis of the gas constituents for optimal setting of the ICE
  - LCA of sustainable fuels and their application in hybrid vehicles

- 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 ICE including Exhaust Gas Treatment

- Combustion technologies for sustainable fuels incl. hydrogen in compliance with future legal requirements
  - 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
  - Optimal adaptation of engines to hybrid systems
  - Further NVH reduction of hybrid systems

- Enhanced exhaust gas after-treatment for sustainable fuels in compliance with future legal requirements
  - Elimination of ultra-fine particle emissions
  - Sensors and control systems for RDE (real driving emissions) exhaust gas monitoring
  - 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 …)
  - Design for recyclability, refurbishment, and reuse of materials and components
  - Material, design and production processes for do-no-significant-harm principles

Requested National Funding Instruments for "Hybrids and Sustainable Fuels"

- Low TRL research
- Co-operative industrial research and experimental development
- Flagship projects
- Funding of demonstration plants, i.e. to produce biofuels or RFNBOs
- Common transnational funding instruments of EU-MS

Estimated National R&D Project Volume for “Hybrids and Sustainable Fuels”

Starting in 2023, an annual volume of 65 M€ is estimated for R&D projects on the hybrid system and powertrain and sustainable fuels. The list below is an assessment of project types needed to cover all topics from basic to applied research, demonstration and R&D infrastructure:

- 8 M€ low TRL research: 8 projects à 1 M€
- 12 M€ for applied & cooperative research: 6 projects à 2 M€
- 30 M€ for flagship projects / cluster of flagship projects: 2 projects à 10-20 M€
- 15 M€ per year for R&D infrastructure

This **total R&D project volume of 65 M€** should be supported with a **funding volume of about 32,5 M€** considering an average funding rate of about 50 %.

Suggested allocation of projects/funding volume to the research areas in this chapter:

1. Hybrid System: 1/5
2. Sustainable Fuels: 2/5
3. Hybrid Powertrain: 1/5
4. Thermodynamics of the ICE including exhaust gas treatment: 1/5