A3PS Position Paper 2026+

R&D Demand for Advanced Propulsion Technologies, Sustainable Energy Carriers, Software Defined Vehicles, Advanced Materials and Production Technologies

Vienna, May 2026

Introduction

The present **A3PS Position Paper 2026+** summarises envisaged developments and trends, as well as research and technology priorities of the industrial and scientific A3PS members. It provides an overview of the R&D challenges in the coming years and the necessary R&D activities to strengthen Austria as a research and industry location. It summarises anticipated developments as well as industrial and scientific priorities in the context of both national and European policy objectives.

The paper, drafted in accordance with the 5 A3PS expert groups, underlines the relevance of the key technologies and fields of strength of the *Industriestrategie Österreich 2035*[1] (Austrian Industrial Strategy 2035) presented in January 2026. It also emphasises the importance of the announced key technology initiative (*Schlüsseltechnologieoffensive*[2]) and transformation initiative (*Transformationsoffensive*[3]) enshrined in the *FTI-Pakt*[4] (Research, Technology and Innovation Pact) for the years 2027 to 2029.

The industrial strategy, as an ambitious vision for Austria as an industrial nation, aims to make Austria one of the 10 most competitive economies in the world by 2035. A3PS is convinced that very strong measures will be necessary to achieve this. Thus, A3PS outlines in this paper the contributions of R&D activities of the mobility sector to this vision.

At the core of the industrial strategy are the defined key technologies (*Schlüsseltechnologien*) and fields of strength (*Stärkefelder*):

- Key Technologies (Schlüsseltechnologien):
  - Artificial intelligence and data innovation
  - Chips, electronic components and systems
  - Advanced production technologies and robotic
  - Quantum technology and photonic
  - Advanced materials
  - Life-science and Biotech
- Fields of strength (*Stärkefelder*):
  - Energy and environmental technologies
  - Mobility technologies
  - Space and aviation technologies

Existing fields of strength of the Austrian industry are characterised by high competitiveness, innovative strength, a skilled workforce and a strong international market position. Key technologies have an exceptionally high potential for spillover effects. They not only increase the direct innovative capacity of companies but also knowledge, skills and technological progress in adjacent industries and value chains. This leads to productivity gains, new business areas and long-term competitive advantages for the entire industrial sector.

Topics addressed in the A3PS position paper relate mainly to the strength area of mobility technologies. However, A3PS also sees energy and environment, digitalisation technologies, production technologies and advanced materials as essential drivers for achieving the energy, resource and mobility transition. Most R&D challenges require combinations of more than one technology; key technologies can be applied across various fields of strength areas. Finally, the valorisation of key technologies in mobility through the transformation offensive is shown in this position paper. The term vehicle refers to on-road vehicles (e.g. passenger cars, trucks, busses), non-road mobile machinery (e.g. agriculture, forestry, gardening, construction machinery, forklifts) and special purpose vehicles (e.g. municipal, fire trucks, mobile cranes).

Goals:

- Empowerment of the Austrian industry & academia in R&D from global perspective to keep Austria competitive.
- All R&D topics presented in the A3PS area comprise only CO_2-neutral solutions.
- All technologies must offer superior performance and cost-effectiveness compared with state-of-the-art technology.
- Technological capability in mass production, not just at prototype or laboratory scale.
- Use of recycled or reused materials and components based on knowledge of lifetime stress and remaining service life.

[1] https://www.bmimi.gv.at/service/presse/hanke/2026/0116-industriestrategie.html (retrieved 12 March 2026, available in German)
[2] https://www.bmimi.gv.at/service/presse/hanke/2025/0911_schluesseltechnologien.html (retrieved 12 March 2026, available in German)
[3] https://www.ffg.at/en/transformationsoffensive (retrieved 12 March 2026)
[4] https://www.bundeskanzleramt.gv.at/bundeskanzleramt/nachrichten-der-bundesregierung/2026/02/bundesregierung-beschliesst-fti-pakt-fuer-die-jahre-2027-bis-2029.html (retrieved 12 March 2026, available in German)

- Securing the supply chain for European products and production (Critical Raw Materials Act[5]).
- Protecting European markets and supporting European production against dumping, less safe and subsidised products from outside Europe (Industrial Accelerator Act[6]).
- Data aggregation across the entire value chain and data sovereignty for The ten principles of the circular economy[7] (10R) and system optimization (Data Act[8]).

Strategic Importance of Mobility and Vehicle Technologies:

Mobility and vehicle technologies are one of the central pillars of Austria's industrial strategy and play a decisive role in shaping the country's economic, environmental, and technological future. As of 2024, motor vehicles and parts represented the second most significant export segment of Austria's manufacturing sector. With a production value of €17.5 billion in 2024 — of which around 87% is exported — the Austrian sector is deeply embedded in European (export rate of 75%) value chains, underlining its strategic importance for both national competitiveness and the broader European industrial ecosystem.[9]

At the same time, mobility technologies are at the core of the transition towards a climate-neutral economy. Regulatory frameworks at European level, including the phase-out of internal combustion engine vehicles, require a rapid and large-scale transformation of transport systems. This transition is already well underway in Austria: more than 200,000[10] electric vehicles are currently in operation, and the registration rate of battery electric vehicles continues to grow accounting for 21.3% of new passenger car registrations in 2025. As a result of this trend, Austria ranks 9th in the European Union. Projections indicate that by 2030, the number of battery electric passenger cars will exceed 950,000, highlighting both the speed and the scale of this transformation. However, particular attention should be paid to the fact that the anticipated growth of battery-electric lorries will bring crucial challenges to maintaining Austria's momentum. One of them is the highly demanded expansion of charging infrastructure at depots and along key routes.[11]

While electromobility is effective in many mobility segments, some applications will remain difficult to electrify, at least in the short and medium term. Hydrogen fuel cell vehicles, as well as vehicles with internal combustion engines and hybrids operating on renewable fuels play an important role for de-fossilisation of the transport sector.

Considering these developments, the continued and strategic promotion of mobility and vehicle technologies is essential to achieving Austria's industrial and climate objectives by 2035. Public investment not only enables the technological transformation of the sector but also safeguards economic competitiveness, supports employment. The automotive industry employs more than 368,000 people in total - equivalent to one in every twelve jobs in Austria.[9] Mobility technologies are therefore not merely a sectoral priority, but a foundational component of Austria's broader industrial and innovation policy.

Essential Legal Framework

Developments up to 2029 will enter series production in 2031+, as the transition from a proof of concept to a series production project (i.e., final development with corresponding maturity) requires a certain amount of time.

Typically for the industry, only those R&D topics are addressed that pursue a subsequent industrialisation goal. All topics mentioned in this position paper should contribute to the value creation of our own production. Results from the preliminary development projects should enable to achieve KPIs for new product inquiries from the customer such as costs, NVH limits, EMC limits, efficiency, etc.

Collaborative work in standardisation and methodology development can shorten development time and improve the quality of development process stages (thus reducing costs). Sector-specific standards and methods (e.g., CO_2 calculation) must be introduced and regulated by the government to maintain competitiveness.

A broader overview of research needs — covering medium-term (2025–2030) and long-term (2030+) perspectives — is presented in the A3PS Roadmap, which can be accessed at https://www.a3ps.at/a3ps-roadmaps.

[5] https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en (retrieved 12 March 2026)
[6] https://single-market-economy.ec.europa.eu/publications/industrial-accelerator-act_en (retrieved 12 March 2026)
[7] 10R strategies: refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover; sometimes referred as "9R", also see: https://www.bmluk.gv.at/themen/klima-und-umwelt/abfall-und-kreislaufwirtschaft/kreislaufwirtschaft/kreislaufwirtschaftsstrategie.html (retrieved 1 June 2026)
[8] https://digital-strategy.ec.europa.eu/en/policies/data-act (retrieved 12 March 2026)
[9] https://www.fahrzeugindustrie.at/publikation/statistikjahrbuch (retrieved 13 April 2026, available in German)
[10] https://alternative-fuels-observatory.ec.europa.eu/general-information/news/austria-over-200000-bevs-roads-176-market-share-2024 (retrieved 13 April 2026)
[11] https://austriatech.at/assets/Uploads/Themen/Dateien/Fortschrittsbericht_E-Mobilitaet_2025.pdf (retrieved 13 April 2026, available in German)

A3PS – Austrian Association for Advanced Propulsion Systems

A3PS is the **strategic platform** of the Austrian technology policy, industry and research institutions and stimulates the development of advanced propulsion systems and energy carriers – to build up common competence and to accelerate market launches.

A3PS addresses all **advanced powertrain technologies** contributing to the improvement of energy efficiency and to the reduction of emissions and supporting the entire innovation cycle (research, development, deployment).

A3PS members congregate in five thematic expert groups. These expert groups have elaborated positions, trends, R&D demands and requirements concerning the essential legal framework for prospective technologies for this position paper.

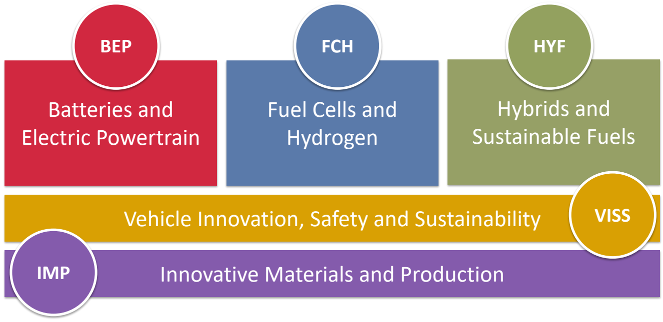

Figure 1: A3PS expert groups

Expert Group VISS – Vehicle Innovation, Safety and Sustainability

The expert group VISS deals with advanced and future vehicle concepts linking to the other expert groups. The vehicle is increasingly understood as part of a **system of systems**. **Energy efficiency** and **safety** are leveraged by this new view. Major effort, however, must be put on **digitalisation**, **automation** and **connectivity** to reach user acceptance and trust in yet new but necessary concepts.

Expert Group BEP – Batteries and Electric Powertrain

The expert group BEP focuses on strong scientific and informative public relations work about energy storage and electric components of **battery electric vehicles**. Thermal consideration is highly essential both for the battery electric propulsion system and for the overall vehicle management. The latter aspects are addressed in the expert Group VISS.

Expert Group FCH – Fuel Cells and Hydrogen

FCH expert group's focus is on **fuel cell technology** for electric vehicles and renewable hydrogen. Regarding **hydrogen**, production from non-fossil sources as well as distribution, storage and hydrogen refuelling stations (HRS) are addressed here. Hydrogen combustion can be found in the expert group HYF.

Expert Group HYF – Hybrids and Sustainable Fuels

The expert group HYF concentrates on the identification of research needs in the fields of **sustainable energy carriers** and all kinds of efficient **hybrid** powertrain technologies, including internal combustion engines - fuelled with sustainable liquid and gaseous fuels, i.e. incl. "green" H_2 - for vehicles. H_2-production from non-fossil sources as well as distribution, storage and hydrogen refuelling stations (HRS) are addressed in the expert group FCH.

Expert Group IMP – Innovative Materials and Production

The expert Group IMP focuses on **design for manufacturing / design for circularity, lightweight materials and hybrid structures**. It aims to empower **production processes** for competitive industries as well as education and human resources in all areas (workers, managers, engineers, scientists) and cost-effective and agile automation.

A R&D Challenges: Vehicle Innovation, Safety and Sustainability 2026-2029

A.1 Main Objectives of the Expert Group VISS – Vehicle Innovation, Safety and Sustainability

As software-defined vehicles mature, a key challenge is converting rapidly evolving cross-domain software into reusable, hardware-agnostic building blocks while shifting safety and regulatory assurance from ECU-centric to platform-level, software-managed concepts enabling virtualised, continuous homologation.

In parallel, R&D focuses on predictive, model-based and AI-supported thermal and energy management that anticipates future operating conditions.

Future SDV, AIDV and automated driving concepts rely on trustworthy virtual, physical and fused sensor solutions for advanced perception and control. Further emphasis is placed on non-exhaust emissions (brakes and tires) and human-centred vehicle operation, supporting measurable environmental, economic and societal sustainability impacts.

A.2 Requirements for Technology Development and Research Demand

In the following section, the most important research tasks for the expert group Vehicle Innovation, Safety and Sustainability (VISS) are listed.

A.2.1 Methodology, Development Tools and Measurement

R&D Topic A1: Software Defined Vehicle

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap A.1 Methodology, Development Tools and Measurement (p. 9f)
- **Targets**: establishment of AI-enabled toolboxes to support an integrated development environment

A **Software-Defined Vehicle** (SDV) represents the transition from traditional, hardware-centric automobiles to modern vehicles that are predominantly controlled by software, emphasising electronic systems over mechanical components. In an SDV, software is the driving force and enables to integrate advanced features such as ADAS and full autonomous driving (AD).

The term SDV refers to all vehicles: on-road vehicles (e.g. passenger cars, trucks, busses), non-road mobile machinery (e.g. agriculture, forestry, gardening, construction machinery, forklifts) and special purpose vehicles (e.g. municipal, fire trucks, mobile cranes), AGVs, etc.

A central SDV challenge is turning fast-evolving vehicle functions into reusable, platform-independent software. Today, strong fragmentation across hardware platforms, operating systems and middleware limits reuse, forces repeated adaptations, slows development, increases costs and creates long-term vendor lock-in.

To reduce development time and cost, R&D must shift towards software-first engineering, supported by large-scale virtual validation using virtual ECUs, digital twins, and automated MiL/SiL/HiL pipelines (also see R&D Topic A6: xCU incl. Software). However, current development still relies on fragmented, domain-specific toolchains with manual integration and late validation on physical prototypes, leading to costly late-phase changes and prolonged cycles.

Service-oriented, virtualised SDV architectures also challenge established ECU-centric safety and homologation practices. Future R&D must adopt platform-level, software-managed safety and compliance concepts with end-to-end traceability and scalable, virtualised homologation processes, including AI-supported testing and automated evidence generation to enable continuous type approval and OTA updates.

Sustainability adds further complexity, as software- and AI-based energy optimisation requires robust methods to ensure that computational overhead does not offset efficiency gains. Finally, the transition to zonal or centralised architectures necessitates robust standardisation and collaboration on non-differentiating layers, shared interfaces and open ecosystems to ensure scalability, economic viability and long-term interoperability.

R&D Topic A2: Automated Driving and Advanced Driver Assistant Systems

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap A.1 Methodology, Development Tools and Measurement (p.9f), A.3 Advanced Vehicle Control Systems and Software (p.12f)
- **Targets**: control functionalities; safety and security; SDV; sensorial capabilities

Automated driving comprises several levels of automation and a wide range of application fields. These levels range from **assisted driving**, where technology supports steering, acceleration, and braking, to **automated driving**, in which the system can perform all driving tasks within its Operational Design Domain (ODD) but requires the driver to take over outside these conditions. The highest level is **autonomous driving**, where no driver input is needed and the system can operate the vehicle under all conditions.

Application fields for automated driving include on-road vehicles, non-road mobile machinery and special purpose vehicles. Key R&D focus areas include **safety and security** (e.g. communication between vehicles, infrastructure, and the environment), **user acceptance**, **artificial intelligence** (intelligent mobility services, sensing, and control), and **testing and validation**.

While the focus for road vehicles is on increasing comfort and road safety, and cost reduction for on-road freight transport, NRMM and special-purpose vehicles prioritize different benefits. To counteract the shortage of skilled workers and implement stricter safety regulations without significantly impacting productivity, remote control of NRMM can offer a more attractive working environment for humans, away from potential hazards around the machines, thus providing significant added value. Supported by modern assistance and partial automation functions, effective work can be carried out even under latency conditions. Furthermore, monotonous tasks can be performed by NRMM in fully autonomous operation. Unlike continuous on-road processes, NRMM operate in cycles, cannot rely on road markings, traffic signs, or unlimited GPS reception, actively change their operating environment, and are exposed to harsh environmental conditions. Developing these mobile robots into robust products is therefore a major challenge, requiring state-of-the-art algorithms, robust sensors, high-performance computing, and AI expertise.

Developing mobile work machines into robust products is therefore a significant challenge. This includes the requirement for cutting-edge algorithms, robust sensors, high-performance computing, and AI expertise.

In addition to ground-based transport, innovations in the field of automated mobility also contribute to increasing the safety, efficiency and sustainability of rail transport, aviation and shipping.

Enabling technologies for these areas include **software-defined vehicles (SDV)** (also see R&D Topic A1: Software Defined Vehicle), (collaborative) perception (also see R&D Topic A7: Predictive Operation & Control), sensors (also see R&D Topic A5: Sensors), connectivity (also see R&D Topic A6: xCU incl. Software), digital twins, cybersecurity, and validation and testing methods. Advances in ADAS R&D offer several benefits, including improved mobility and accessibility for a broader range of users, increased comfort, increased efficiency leading to reduced fuel consumption, and the enablement of new operational use cases. These include the deployment of autonomous machines and vehicles in hazardous working environments or in situations where highly qualified vehicle operators are scarce.

While this expert group focuses on vehicle-level and technology-level topics, SAAM Austria (https://www.saam-austria.at/en/) addresses complementary aspects such as networking, framework conditions, strategy and infrastructure requirements through its other expert groups. Furthermore, SAAM Austria lays a strong focus on the development of an Austrian strategy for autonomous mobility and elaborates a roadmap about automated driving by end of 2026. The 2025 status of Automated mobility is shown in the SAAM-Position Paper[12]

A.2.2 Advanced Auxiliaries, Components and Systems Enabling Energy Savings

R&D Topic A3: Energy and Thermal Management

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap A.2 Advanced Auxiliaries, Components and Systems enabling Energy-Savings / Table A-1: Energy and Thermal Management (p. 11f)
- **Targets**: components in specified range; enhancement of efficiency and optimisation of available energy

Thermal management influences both component operating conditions and cabin comfort. Extreme heating or cooling can greatly reduce the range of (electric) vehicles - sometimes exceeding propulsion energy demand in city driving. Reliable range prediction, therefore, requires accurate forecasting of energy and thermal management. New concepts for utilising waste heat from electric powertrain components, such as motors and power electronics, are increasingly important. Promising approaches include integrated heat-pump systems, compact thermal

Legend:
Key Technologies & Fields of Strength:
Artificial intelligence and data innovation
Chips, electronic components and systems
Advanced production technologies and robotic
Advanced materials
Energy and environmental technologies
Mobility technologies

[12] https://www.saam-austria.at/fileadmin/user_upload/Projektwebsites/strategische-allianz-automatisierte-mobilitaet/Statische_Inhalte/SAAM_Austria_Positionspapier.pdf (retrieved 29 April 2026, available in German)

architectures, improved insulation, heat-storage solutions and chemical heat-storage systems. The latter enable long-term storage without insulation and offer considerable potential; however, they still require substantial R&D.

Thermal management in (electric) vehicles is a mature field; however, it must continuously adapt to emerging battery technologies and energy sources. Further improvements may be achieved through enhanced system-level integration. A key challenge lies in enabling high charging power without accelerating degradation, as temperature gradients and local hotspots remain difficult to control. Sustained high-power charging (>3C) remains thermally limited and typically requires active conditioning and derating. More flexible, spatially resolved cooling concepts are, therefore, needed to address cell-level thermal variations.

Battery temperature control is critical, as it directly affects charging speed, efficiency, as well as degradation processes such as lithium plating. Emerging chemistries and designs - e.g. high-nickel NMC, silicon-rich anodes, and large-format or cell-to-pack architectures - exhibit increased sensitivity to temperature gradients and hotspots. Conventional Li-ion cells operate optimally within a narrow range (~20–40 °C), with fast charging often requiring preheating above 25 °C. Some solid-state battery concepts (also see R&D Topic B1: Development of Novel Battery Concepts Based on Advanced Materials and Components) further increase thermal requirements, as elevated temperatures (≥60 °C) are necessary to achieve sufficient ionic conductivity.

An ongoing area of development is the shift towards predictive, model-based thermal management with AI-supported elements (e.g. reinforcement learning), where control strategies explicitly take account of future operating conditions. Such approaches use route, ambient and system-state information to manage thermal states in advance, for instance through battery preconditioning prior to fast charging. Increasingly, physics-informed, learning-based control methods (e.g. reinforcement learning with embedded physical constraints) are being investigated to address system complexity while maintaining robustness and interpretability.

R&D Topic A4: Heating, Ventilation and Air-Conditioning (HVAC)

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap A.2 Advanced Auxiliaries, Components and Systems enabling Energy-Savings, Table A-2: HVAC (p. 12)
- **Targets**: efficiency in terms of range vs. comfort and power; integration; self-adaptive control

Given the limited capacity of current batteries, HVAC systems significantly reduce vehicle range. More efficient HVAC solutions - such as latent heat storage, zeolite-based materials, active thermal materials, IR heating panels, vehicle integrated photovoltaics (VIPV) and heat pumps are therefore essential. In addition, thermal system layouts must be redesigned, and components compatible with new refrigerants developed, in line with EU Regulation 2024/573,[13] which restricts the use of fluorinated greenhouse gases.

In addition, HVAC systems must be individually adapted to different vehicles, propulsion concepts and operating conditions. As already described in the chapter above, the development of HVAC systems is shifting towards predictive, model-based, AI-supported management. Adaptive algorithms and multiple comfort zones embrace changing environmental conditions and individualised passenger comfort preferences. Higher order physical modelling of the cabin state, the human body and thermal comfort perception remain a challenge in R&D.

The use of additively manufactured or milled microchannels (e.g. pin fins) as heat exchangers or heat sinks presents challenges both in terms of integration into the vehicle system and in their manufacture.

A.2.3 Advanced Vehicle Control Systems

R&D Topic A5: Sensors

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap A.3 Advanced Vehicle Control Systems and Software / Table A-3: Sensors (p. 13)
- **Targets**: enhancement of efficiency; enhancement of perception; lifetime extension

State-of-health monitoring using virtual sensors, along with new non-intrusive sensors for batteries and fuel cells, is essential to capture operating conditions without affecting performance. As vehicles deploy an increasing number of sensors for environmental perception, component monitoring, control functions and future digital twin applications, there is a growing need to use on-board sensing systems efficiently and in coordinated manner.

"Sensors" are of high relevance in 2026, as the transition towards Software-Defined Vehicles requires reliable, efficient and system-integrated sensing concepts as a foundation for advanced vehicle control. Sensor fusion,

[13] https://eur-lex.europa.eu/eli/reg/2024/573/oj/eng (retrieved 23 March 2026)

virtual sensors and non-intrusive sensing technologies, including quantum sensing, enable precise state-of-health monitoring of batteries and fuel cells, thereby allowing efficiency gains and extended component lifetime without additional hardware complexity. At the same time, the increasing interaction between vehicles, charging infrastructure and the energy system requires validated sensor data as an interface to the energy domain, supporting smart charging and sector coupling. The development and validation of such sensor concepts are directly dependent on advanced test and measurement infrastructure, thereby contributing to the objectives of Measure 68 of the Industrial Strategy. Investments in this R&D area therefore address both technological readiness for SDVs and the strengthening of strategic industrial capabilities in testing, measurement and energy-related vehicle integration.

R&D Topic A6: xCU incl. Software

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap A.3 Advanced Vehicle Control Systems and Software / Table A-4: xCU incl. Software (p. 13)
- **Targets**: accelerated market introduction; continuous development of productivity and efficiency; enhancement of efficiency; reduction of emissions; safety; security

The trend towards cross-domain vehicle computers is a fundamental evolutionary step to Software-Defined Vehicles (SDVs) and finally AI-Driven Vehicles (AIDVs). This involves a shift from purely domain-oriented architectures to **more centralised and zonal computing paradigms**.

Key requirements of this trend include:

- **Achieving cross-domain interoperability**: The architecture aims to facilitate seamless interoperability between previously separate domains, such as integration of powertrain and operating-strategy functions, ADAS, IVI, and body systems. This also raises additional requirements with respect to safety and security, typically addressed with implementation of Freedom-from-Interference (FFI) technologies such as HW-supported hypervisors.
- **Supporting real-time performance and scalability**: These centralised compute platforms, conceptualised as the vehicle's "brain," are designed to provide **real-time responsiveness through on-board AI** while complementing cloud computing
- **Mastering complexity and reducing costs**: By adopting pre-integrated, "off-the-shelf" solutions and optimising system integration, cross-domain architectures aim to master the complexity of future vehicles and offer significant hardware cost savings. An important aspect is the validation of those complex systems which needs new approaches such as testing on virtualised targets.
- **Development speed and efficiency** are critical for SDVs due to evolving customer expectations regarding feature availability and the need for faster update cycles even after deployment in the field (e.g. via over-the-air updates). Those development and update cycles are typically not synchronised between the different domains, which creates the need for implementation of Freedom-from-Interference (FFI) technologies such as HW-supported hypervisors, decoupled toolchains, and revised verification and homologation methods.
- **Flexible and scalable hardware architectures**, including modern SoCs and high-speed networking, to manage increasing computational demands for advanced functionalities and higher levels of autonomy

Embedded AI technology is **critical for the evolution from Software-Defined Vehicles (SDVs) to AI-Driven Vehicles (AIDVs)**, serving as the foundational "compute brain" for future automotive architectures. It enables **real-time response through on-board AI at the edge**, complementing cloud computing for large-scale simulation and rapid model iteration. This integration supports **composite AI solutions** across various domains, including advanced ADAS and AI-powered cockpit user interfaces, which are considered essential for future-proof and personalised vehicle platforms.

Chiplet architectures and advanced SoC architectures present an **opportunity** to enable an **evolutionary path towards optimised** SDV and AIDV architectures by offering performance gains, scalability and flexibility.

Legend:
Key Technologies & Fields of Strength:
Artificial intelligence and data innovation
Chips, electronic components and systems
Advanced production technologies and robotic
Quantum technology and photonic
Advanced materials
Energy and environmental technologies
Mobility technologies

R&D Topic A7: Predictive Operation & Control

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap A.3 Advanced Vehicle Control Systems and Software / Table A-5: Predictive Operation & Control (p. 14)
- **Targets**: adjustment of components sizing; enhancement of vehicle efficiency and safety; extension of lifetime; reduction of emissions

Optimised and predictive operating and maintenance strategies, and the consideration of combined controllers are applied in all kinds of on-road vehicles, non-road mobile machinery and special purpose vehicles at vehicle, system and component level (multi-level-control). Overall targets are to improve efficiency, to reduce emissions, to improve drivability and to extend lifetime. In case of particular components there are specific targets like gear shift quality in case gear boxes, health/degradation awareness in case of batteries or regeneration control in case of brakes.

In particular predictive maintenance plays a crucial role in ensuring fail-safe operation and reducing efficiency losses resulting from component degradation. Early fault detection and mitigation rely on appropriate diagnostic functionalities. These enable e. g. the identification of internal battery damage at an early stage, preventing the progression and escalation of degradation.

Future control systems will also need to incorporate AI technologies tailored to the specific requirements of vehicles, systems and components featuring over-the-air diagnosis and updates Data generation, data access, data security and data standards will need to be addressed.

A.2.4 Non-exhaust Particle Emissions

R&D Topic A8: Non-exhaust Particle Emissions

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap A.4 Non-exhaust Particle Emissions / Table A-6: Non-exhaust Particle Emissions (p. 14)
- **Targets**: enhancement of efficiency; innovation of new materials and components; reduction of particles; reinforcement of regulatory compliance

Particulate emissions from brakes and tyre wear are already one order of magnitude higher than exhaust particulate matter and will be limited for the first time in the upcoming Euro 7 emissions standard in the EU for the type of approval of new vehicles.

These limits and further emission reductions can be achieved through individual technologies as well as combinations thereof. Innovative and efficient technologies will penetrate the market in the future and should be researched and further developed. Research can be conducted on components and, in particular, on demonstrators of complete vehicles, in which, for example, electric braking and torque control can be optimised.

Further research is needed to identify effective ways to reduce non-exhaust particle emissions. Approaches include optimising vehicle operating strategies, developing low-emission or particle-capturing tyre and brake materials, minimising road surface abrasion, and applying dust-suppression technologies at construction sites. Additionally, zero emissions brakes such as wet running systems shall be part of the development. New dynamic methods for on-site measurements of non-exhaust particles for netwide investigations need to be developed. AI methods can be applied for modelling.

B R&D Challenges: Battery and Electric Powertrains 2026-2029

B.1 Main Objectives of the Expert Group BEP – Battery and Electric Powertrains

Within the coming years, BEVs must comply with emerging regulations regarding critical raw materials (CRM), mandatory recycled content and enhanced circularity rates. It is essential to optimise these solutions for improved cost-effectiveness, performance efficiency, durability, sustainability, and safety standards.

B.2 Requirements for Technology Development and Research Demand

In the following section, the most important research tasks for the expert group Battery and Electric Powertrains (BEP) are listed.

B.2.1 Development of Novel Battery Concepts Based on Advanced Materials and Components

R&D Topic B1: Development of Novel Battery Concepts Based on Advanced Materials and Components

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap B.1.1 Battery Technologies (p. 17f)
- **Targets**: authorisation of ultra-fast charging while preserving performance and battery lifetime; elevation of energy densities; enhancement of safety

Batteries for BEV applications must be able to meet lifetime, efficiency, and fast charging requirements. In addition, batteries must be safe and operable within the temperature window of the application (~20–40 °C) (further information is provided in VISS chapter A.2.2 R&D Topic A3: Energy and Thermal Management). Already existing high-performance and high-energy cell chemistries and architectures - such as high-nickel NMC, silicon-dominant anodes and large-format cylindrical or cell-to-pack designs - must be further optimised to reduce temperature gradients, local hotspot generation and lithium-plating during fast charging, thereby improving safety and performance. While cooling concepts must be integrated into battery pack design for cells with liquid-based electrolytes, elevated temperatures (→60 °C) may be needed to achieve sufficient ionic conductivity for cells based on solid-state electrolytes. In view of continued Asian dominance of the battery market, European suppliers must advance the development of novel battery concepts based on advanced materials and components such as high-energy cathode active materials, solid-state electrolytes and the use of metallic anodes or anode-free systems. In this framework, AI will be used as a key technology to accelerate materials development. Research and innovation actions must also support the manufacturing of advanced batteries in Europe, and robotics must be developed as a key technology to reduce cell manufacturing and recycling costs. Lastly, sustainability, European autonomy and resilience must be addressed by incorporating sustainable, European-sourced materials into battery design and implementing the 10R framework at an early stage.

R&D Topic B2: Battery Integration into the Electric Vehicle

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap B.1.2 / Table B-4: Structural Battery Integration (p. 21)
- **Targets**: development speed; efficiency; lower cost; safety; sustainability

In addition to high-performance batteries, further efficiency gains can be achieved at the level of battery integration into the electric vehicle. Specifically, the total usable energy at vehicle level can be increased by advancing new architectures such as cell-to-chassis (C2C) and cell-to-vehicle (C2V). These concepts are expected to become more relevant in the future compared to existing cell-to-pack (C2P) technologies, as they enable higher gravimetric and volumetric efficiency, functional integration and structural mass reduction.

The transition towards such highly integrated battery architectures requires a fundamental transformation of the product development process. Battery integration can no longer be treated as a downstream activity but must be addressed as a vehicle-defining system early in the development stage. To meet new automotive standards in terms of development speed, safety, sustainability and cost, an innovation-accelerated approach is required to ensure fast technology uptake. This includes early co-development of battery, vehicle structure,

Legend:
Key Technologies & Fields of Strength:
- Artificial intelligence and data innovation
- Advanced production technologies and robotic
- Advanced materials
- Energy and environmental technologies
- Mobility technologies

thermal management, electrical/electronic architecture, safety concepts and manufacturing processes, supported by model-based systems engineering (MBSE), digital twins, extensive front-loading of virtual validation and AI-assisted design optimisation.

At the same time, C2C and C2V architectures must comply with sustainability and circularity requirements. Designs must enable disassembly, repair, second-life use and recycling in line with cradle-to-cradle and 10R principles. Robotic technologies plays a key enabling role in this context, as automated systems are required for safe battery discharge, dismantling and disassembly of highly integrated vehicle architectures under industrial conditions. Research and innovation actions are therefore needed to develop robotic, sensor-based and AI-supported solutions for end-of-life handling of integrated battery systems.

In parallel, alternative battery integration concepts such as battery swapping systems (see R&D Topic B3: Battery Swapping Systems for the large field of Non-Road Mobile Machinery and Special Purpose Vehicles) represent a complementary solution for specific vehicle segments. While C2C and C2V focus on maximum integration and efficiency for passenger vehicles, battery swapping introduces fundamentally different requirements for product architecture, interfaces and packaging. This is particularly relevant for non-road mobile machinery and special purpose vehicles, where operational availability, flexible energy sizing and rapid energy replenishment are critical. Insights gained from modularisation, interface standardisation and accessibility requirements in battery swapping systems can feed back into the development of integrated battery architectures and contribute to more robust, serviceable and lifecycle-optimised vehicle designs.

From an industrialisation perspective, new development and production methodologies are required to enable both highly integrated battery architectures and exchangeable systems. This includes the synchronised development of product and production, virtual commissioning of assembly processes, scalable integration concepts and accelerated validation strategies to ensure compliance with evolving safety and homologation requirements. Innovation in battery integration must therefore address the full product lifecycle - from concept and development to production, operation and end-of-life - while ensuring consistency and synergies between integrated architectures (B2) and modular or exchangeable concepts (B3).

R&D Topic B3: Battery Swapping Systems for the large field of Non-Road Mobile Machinery and Special Purpose Vehicles

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap B.1.2 Battery Integration (p. 21); B.4 Charging Technologies (p. 25)
- **Targets**: development speed; efficiency; lower cost; safety; sustainability

Battery swapping systems can be developed as an approach toward rapid energy replenishment without long charging times. An exchangeable vehicle battery opens further possibilities compared to a vehicle-fixed battery. On the one hand, comparatively small batteries can be used in operating conditions with moderate energy requirements by operating one battery in the vehicle and charging others at the same time. The other end of the spectrum is determined by range requirements that cannot be met with vehicle-mounted systems due to the installation limits. Here, an interchangeable system can help to extend the operating time without having to take the vehicle or machine out of service for charging, especially for applications with no possibility or availability of ultra-fast charging (Megawatt charging).

Although battery integration for fixed systems has been addressed (see R&D Topic B2: Battery Integration into the Electric Vehicle), significantly different requirements and challenges arise for battery swap systems. Due to the accessibility requirements for the exchange manipulator, there are corresponding restrictions in packaging for vehicles with exchangeable batteries. Furthermore, suitable pluggable and couplable interfaces for electrical power, communication and cooling media need to be developed and made cycle-proof for permanent operation. Another challenge is the process of battery replacement itself, which requires practical manipulators, either vehicle-mounted or vehicle-independent systems.

Due to the variety of types and variants of mobile machines and special vehicles, the development of standardized and identical solutions is expected to be difficult. Therefore, the approach to battery swapping systems requires a high level of standardization across a variety of OEMs and may not be applicable to electric vehicles for passenger transport, especially as ultra-fast charging for passenger EVs becomes more commonplace.

B.2.2 Electric Components and Electric Drive Units (EDU)

R&D Topic B4: Development of Power Modules

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap B.2 Electric Components & Electric Drive Units (EDU) (p. 23f)
- **Targets**: cost reduction; enhancement of durability

Power modules are the most important components in the EDU. They combine multiple power electronic components into a single, thermally optimised package to efficiently switch and control high electrical power. Critical aspects such as the use of novel electrical components (e.g. IGBT or MOSFET), durability at high temperature, novel cooling concepts, packaging, safety and inverter/EDU integration concepts are key factors that influence the design of power modules, costs, functions and efficiency (further information is provided in IMP chapter E.2.1 Design for Manufacturing / Circularity).

R&D Topic B5: Development of (Heavy) Rare Earth free PMSMs (Permanent-Magnet Synchronous Motors) Alternatives

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap B.2 / Table B-6: Electric Motor (p. 22)
- **Targets**: autonomy in CRM; cost reduction; enhancement of efficiency; supply chain security; 10R

Permanent magnets are important components in electric motors; however, the heavy rare earth materials used in such magnets - required to ensure high-temperature operation and, consequently, efficiency and power density - are subject to international trade tensions due to China's market domination. To reduce this dependency, research activities should pursue multiple avenues. These are: (a) the development of recycling technologies and the establishment of a recycling value chain for rare earth permanent magnets; (b) the exploration of alternative materials based on less critical supply chains and; (c)the engineering of alternative e-motor technologies that eliminate the use of heavy rare earth elements while maintaining the required efficiency and power density at comparable cost and within design constraints such as space and volume in the electric motor. High-speed designs and novel control methods are necessary research fields to further improve efficiency, power density and cost-effectiveness. As cost is a significant driving force, all new approaches must be affordable to encourage technology uptake. Furthermore, to be sustainable, the magnetic materials used in alternative approaches should exhibit low CO_2 footprints, be readily accessible and non-critical. Accordingly, research is required to develop advanced motor solutions based on materials sourced in Europe to ensuring European autonomy from global supply chains. Apart from materials aspects, developments must also be made in control strategies for e-motors and inverters, where AI can be applied as a key enabling technology.

R&D Topic B6: Development of Cooling Strategies and Architectures

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap B.2 Electric Components & Electric Drive Units (EDU) (p. 22f)
- **Targets**: enhancement of electric motor power density and efficiency; 10R

To increase the power density and efficiency of the electric motor, cooling strategies, architectures, and systems must also be designed to guarantee reliable battery operation. These innovation activities are required to ensure cooling of the hotspots, especially in the windings and power modules, to achieve high power density, prevent magnet degradation across the full application range and ensure accurate torque control. The industry currently employs standard liquid media to cool the EDU and the battery; however, the development of improved cooling methodologies continues to be a key area of research. In the future, 10R strategies must be incorporated into the design and selection of the liquid cooling medium. To assess the effectiveness of the various cooling strategies and solutions, data on the heat transfer coefficients of the different component materials are required. In addition, models must be developed which can accurately estimate and/or predict temperature distribution and hotspots. In these regards, AI can be used as a key technology to identify, assess, and

Legend:
Key Technologies & Fields of Strength:
- Artificial intelligence and data innovation
- Chips, electronic components and systems
- Advanced production technologies and robotic
- Advanced materials
- Energy and environmental technologies
- Mobility technologies

optimise cooling strategies, taking the energy distribution of the whole vehicle into account (further information is provided in VISS chapter A.2.2 R&D Topic A3: Energy and Thermal Management and R&D Topic A4: Heating, Ventilation and Air-Conditioning (HVAC))

R&D Topic B7: Development of Simulation Methods for FE Analysis and NVH Reduction

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap B.2 / Table B-8: Electric Drive Unit (EDU) (p. 23)
- **Targets**: cost reduction; enhancement of durability; enhancement of functionality; safety; 10R

Research and innovation activities must also be directed towards the development of control methods to actively mitigate or suppress noise, vibration and harshness (NVH) excitations that originate mainly from the electric motor. These are strongly related to: (a) safety, as vibrational excitations can lead to mechanical degradation of components or loss of electrical contact, both of which can affect cooling, short-term vehicle performance (lack of power) and long-term vehicle behaviour (component degradation, lifetime of the electric motor) and (b) human-centred discomfort.

To avoid complex and expensive redesigns of the electric motor, reduce design cost and shorten total development time, novel methods are required a priori from the outset of the R&D. FE models must also be developed for new and/or recycled materials.

Lastly, application software tools play a stronger role in circularity. Specifically, finite element software can be used to calculate the remaining lifetime of EDU and battery components. Therefore, individual vehicle field operating data (health monitoring) are necessary to create and incorporate not-yet-existing rolling material parameters into finite element software tools. The results can be used to design tailored maintenance strategies or to suggest further use of components in second-life application. In both cases, AI and machine learning are seen as key technologies required. In a broader scope, the information can be used to establish design guidelines to enable remanufacturing approaches.

B.2.3 Charging Technologies

R&D Topic B8: Development of Cost-Efficient Components to Enable Bidirectional Charging

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap B.4 Charging Technologies (p. 25f)
- **Targets**: cost reduction, enhancement of efficiency

The development of effective and efficient charging technologies is critical for the success of electric vehicles. Concepts such as bidirectional charging can be addressed, which will allow the integration of electric vehicles into the power grid (V2G mode). This requires effective communication between the vehicle's battery management system and the grid, permitting decision-making based on the potential impact of V2G charging on the state-of-health of the battery. Thus, research and innovation activities are required for the development of software communication tools, combined with battery health assessments, to enable V2G charging without negative impacts on battery performance.

C R&D Challenges: Fuel Cells and Hydrogen 2026-2029

C.1 Main Objectives of the Expert Group FCH – Fuel Cells and Hydrogen

Industrial transformation & tech value addition: Transitioning the automotive sector towards hydrogen by prioritising R&D in electrolysis, storage, and fuel cell technologies to ensure high domestic value creation and technological leadership.

Technological scaling & industrial maturity: Advancing hydrogen projects from "proof of concept" to industrial scale through R&D and the implementation of market frameworks (such as RFNBO certificates) for cost-efficient production.

Infrastructure innovation & integration: Strengthening the technological development of distribution and refuelling systems while coordinating international research activities to ensure a flexible, high-availability and secure hydrogen supply chain.

C.2 Requirements for Technology Development and Research Demand

In the following section, the most important research tasks for the expert group Fuel Cells and Hydrogen (FCH) are listed.

C.2.1 Fuel Cell Vehicle Concepts

This topic focuses on the high-level integration and industrialisation of fuel cell vehicles, bridging the gap between current research and transfer to market-ready series production. While R&D priorities are centred on heavy-duty applications (e.g. trucks, non-road mobile machinery), aviation and shipping to maximise decarbonisation impact, the scope remains technology-open in order to enable cross-sectoral transfer to other vehicle categories.

R&D Topic C1: Fuel Cell Technology Across Vehicle Segments

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap C.1 / Table C-1: Fuel Cell Vehicle Concepts (p. 28f)
- Targets: cost reduction; enhancement of efficiency; enhancement of reliability; extension of service life; improvement of vehicle integration including thermal management and higher fuel cell operating temperatures; increase in customer acceptance; NVH optimisation; recyclability

Between 2026 and 2029, intensive vehicle R&D, demonstration activities and fleet testing will provide the essential foundation for industrial scaling. As critical strategic decisions on drive technologies and suppliers are expected to be taken during this period, urgent cost reductions are vital to ensure the competitiveness of Austrian-developed fuel cell vehicles (FCVs). Securing domestic manufacturing and R&D through European cooperation is crucial to prevent the relocation of technology and employment.

A successful market ramp-up depends on the scalability of subcomponents such as electronics, sensors, and valves, stacks and storage systems alongside the conversion of Austrian facilities for hydrogen component production. Cost efficiency and system longevity will be driven by improved manufacturing, advanced materials, innovative system and vehicle designs. Furthermore, integrating AI to accelerate development cycles and optimising energy as well as thermal management for higher operating temperatures are key technical priorities. These advancements will enable the Austrian supply industry to meet rigorous KPIs and secure a relevant position in the global hydrogen transition.

For FCEVs (on-road vehicles, non-road mobile machinery and special purpose vehicles), packaging poses a challenge due to the greater space requirements for thermal management components. This is because fuel cell vehicles must dissipate greater amounts of waste heat via the cooling circuit than ICE-powered vehicles. Consequently, the development of innovative (more space-efficient) coolers is becoming increasingly important.

R&D Topic C2: PEM Fuel Cell Systems

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap Table C-2: PEM Fuel Cell Systems (p. 30)
- Targets: cost reduction; efficiency; enhancement of lifetime; PFAS-free membranes; power density; recyclability & environmental impact; scaling up for production

Legend:
Key Technologies & Fields of Strength:
Artificial intelligence and data innovation
Chips, electronic components and systems
Advanced production technologies and robotic
Advanced materials
Energy and environmental technologies
Mobility technologies

The 2026–2029 period is decisive for transitioning PEM fuel cell systems from R&D to industrial maturity beyond the "proof of concept". Driven by regulatory pressure (PFAS ban) and by resource efficiency considerations, R&D focuses on PFAS-free membranes and reduced catalyst loading to secure the Austrian value chain.

Key activities include establishing degradation models and predictive frameworks to increase lifetime under real operating conditions, as well as manufacturing research aimed at scaling up the production of electrochemical components. Industrial transfer is supported by optimising power electronics and simplifying cooling systems through higher operating temperatures. In hybrid powertrains, advanced operating strategies utilise the fuel cell as the primary energy source while the battery handles peak loads. The interaction between fuel cell layout, battery architecture, and power electronics is a key area of research, extending to integrated cross-technology diagnostics. Integrating circular design and environmental impact assessments ensures compliance with future mandates, positioning Austria's supply industry in sustainable, high-performance PEM technology.

R&D Topic C3: Solid Oxide Fuel Cells (SOFCs) und Proton-Conducting Ceramic Fuel Cells (PCCFCs)

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap C.1.1: Solid Oxide Fuel Cells / Table C-3: Solid oxide fuel cells (p.30f)
- **Targets**: cost-effective stacks and BoP components; increased power density and long-term stability; new oxygen and proton-conducting ceramic components; reduced operating temperature and start-up time; replacement of critical elements

The application of solid oxide fuel cells, which can be powered by hydrogen or other renewable fuels, is promising for use in heavy-duty road and rail vehicles as well as in ships. These applications also include auxiliary power units (APUs).

Research needs to address new cell components for SOFCs (solid oxide fuel cells) and PCCFCs (proton-conducting ceramic fuel cells) to achieve higher power densities as well as improved long-term stability, thereby reducing or completely avoiding the use of critical elements. R&D includes AI-based optimisation of materials and extension of lifetime. Further goals are lowering the operating temperature and start-up time. This can be achieved through a cost-effective stack design and also by incorporating metal-supported cells and cost-effective BoP components.

R&D Topic C4: H_2 On-Board Storage Systems

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap C.1.3: On-Board Hydrogen Storage / Table C-5: Gaseous hydrogen on-board hydrogen storage, Table C-6: LH_2-storage systems, Table C-7: alternative storage systems (p. 31-34)
- **Targets**: cost reduction; elevation of energy density; elevation of recyclability level; increase in cycle stability; reduction of CO_2 footprint; reduction of refuelling time; safety; weight reduction

This topic focuses on optimising H_2 storage for on-board storage through cost reduction, weight reduction, and modularity. For LH_2, R&D addresses cryopumps, valves, and boil-off management. In the field of CGH_2, research includes the development of type 5 tanks alongside new sensor technologies, system-level diagnostics, and model-based lifetime monitoring to ensure safety and reliability of all types. To secure the Austrian value chain, the use of European raw materials and advanced manufacturing processes is essential. Crucially, R&D aims for multi-certification (UN/ECE R134[14], PED[15], TPED[16]). Enabling cross-sectoral approval for automotive, non-road, and transport applications allows for standardised components across trucks, trains, and mobile refuelling equipment. This synergy reduces development costs and simplifies scaling for the supply industry as well as implementation of mobile refuelling equipment. Furthermore, on-board storage development must align with infrastructure requirements to ensure seamless vehicle-to-station interaction.

R&D Topic C5: Digitalization and AI in FCH Development

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap Table C-13: Test and Validation (p. 38)

[14] https://eur-lex.europa.eu/eli/reg/2019/795/oj/eng (retrieved 9 April 2026)

[15] https://single-market-economy.ec.europa.eu/sectors/pressure-equipment-and-gas-appliances/pressure-equipment-sector/pressure-equipment-directive_en (retrieved 1 April 2026)

[16] https://eur-lex.europa.eu/eli/dir/2010/35/oj/eng (retrieved 1 April 2026)

- **Targets**: establishment of predictive energy and thermal management using route data; establishment of traffic and weather data to maximize efficiency; implementation of real-time on-board diagnostics with virtual sensors and physics-based ageing models; integration of AI to accelerate development cycles and create improved technology designs

This topic focuses on leveraging AI to drastically shorten development cycles. AI methods are specifically applied in material, component, and system development to achieve optimised designs more quickly. Furthermore, new AI-based testing methods - utilising virtual sensors and physics-based ageing models - enable real-time on-board diagnostics without increasing hardware complexity. As vehicle fleets scale up from 2026, wireless, model-based data analysis becomes a decisive factor for predictive maintenance and lifetime optimisation. Predictive energy and thermal management, utilising route, traffic etc. maximises operational efficiency. This digital integration through "digital twins" significantly reduces TCO for heavy-duty applications and secures a technological lead for the Austrian supply industry in software-defined hydrogen powertrains.

C.2.2 Hydrogen Production via Electrolysis

Highly efficient hydrogen production via electrolysis forms the backbone of a sustainable hydrogen economy, where the strategic utilisation of technological synergies between electrolysers and fuel cells - particularly regarding stack components, materials, and manufacturing processes - accelerates scaling and enhances the cost-efficiency of the entire ecosystem.

R&D Topic C6: Advanced PEM Electrolysis (PEMEL)

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap Table C-3: PEM Electrolysers (p. 3)
- **Targets**: assurance of scalability despite raw material scarcity through reduction of iridium loading at the anode; cost reduction through automated CCM (Catalyst Coated Membrane) production and stack assembly; development of manufacturing platforms; development of PFAS-free membranes with high proton conductivity and mechanical stability; improvement of dynamic operational stability for direct coupling with volatile renewable energy sources

As the most mature technology for flexible green hydrogen production, PEMEL is transitioning from small-scale pilots to GW-scale deployment. This requires automated, standardised manufacturing platforms that enable reliable scaling of electrochemical components and strengthen Europe's competitiveness in electrolyser production. R&D must now urgently address the "iridium bottleneck" and upcoming environmental regulations to ensure global competitiveness. Key priorities include a significant reduction in anode iridium loading to enable scalability despite raw material scarcity, alongside the development of PFAS-free membranes that maintain high proton conductivity and mechanical stability.
To support direct coupling with volatile renewable energy sources, research focuses on enhancing dynamic operational stability. Industrial scaling is further driven by cost reductions achieved through automated CCM (Catalyst Coated Membrane) production and advanced stack assembly. By integrating AI-supported material R&D, Austrian suppliers can accelerate development cycles and secure a relevant position in the global electrolyser market, providing high-performance, sustainable components and systems.

R&D Topic C7: Solid Oxide Electrolysis (SOEL) und Proton-Conduction Ceramic Electrolysis (PCCEL)

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap C.2.1: Hydrogen production / Table C-9: Solid Oxide Electrolysers (p. 34f)
- **Targets**: cost-effective BoP components; cost-effective stacks; high pressure applications; increased power density and long-term stability; new oxygen and proton-conducting ceramic components; reduced operating temperature; replacement of critical elements

Solid oxide electrolysis (SOEL), powered by renewable energy, enables the efficient production of green hydrogen or, in co-SOEC mode (co-SOEL), of synthesis gas. This is a mixture of H_2 and CO for the subsequent production of e-fuels (Power-to-X technology). R&D includes AI-based optimisation of materials and enhancement of lifetime.

Legend:
Key Technologies & Fields of Strength:
Artificial intelligence and data innovation
Chips, electronic components and systems
Advanced production technologies and robotic
Advanced materials
Energy and environmental technologies
Mobility technologies

Further research is necessary in the field of new oxygen- and proton-conducting ceramic electrodes, along with electrolytes for solid oxide electrolysis cells (SOECs) and proton-conducting ceramic electrolysis cells (PCCECs) that contain no or reduced amounts of critical raw materials. The cells should exhibit higher power density and long-term stability, even when operated at lower temperatures. Further goals include cost-effective stack designs that are also suitable for high-pressure operation, as well as cost-effective BoP components.

R&D Topic C8: Anion Exchange Membrane Electrolysis (AEMEL)

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap C.2 Electrolysis / Table C-3 (p. 31)
- **Targets**: development of highly stable, hydroxide-conducting membranes and ionomers to increase lifetime (> 20,000h); enhancement of power density to close the performance gap with PEMEL; optimisation of non-PGM catalysts (e.g. based on nickel) for both oxygen and hydrogen evolution reactions; standardisation of stack designs to allow for low-cost mass manufacturing using abundant materials

Positioned as a "promising low-cost electrolysis technology", AEMEL combines the dynamic performance of PEM with the economic advantages of alkaline systems. The primary R&D objective is to bridge the performance gap to PEMEL by developing highly stable, hydroxide-conducting membranes and ionomers aimed at exceeding a 20,000-hour lifetime. A key industrial advantage lies in the optimisation of non-PGM catalysts (e.g. nickel-based), which eliminates reliance on precious metals and ensures a cost-independent production path. Furthermore, advanced electrode and stack architectures are required to minimise internal parasitic losses, with a specific focus on mitigating shunt currents to enhance overall system efficiency. As AEMEL transitions from laboratory research to the pre-industrial stage, focusing on mass manufacturing using abundant materials is critical. By integrating AI-assisted materials science and fundamental research into electrochemical interfaces, Austrian science and industry can establish the technological foundations for high-efficiency, non-precious metal electrolysis, driving the next generation of scalable green hydrogen systems.

C.2.3 Other forms of hydrogen production

R&D Topic C9: Diversified Hydrogen Production

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap Table C-10: Other forms of hydrogen generation (p. 36), and E.3: Biofuels (p. 45)
- **Targets**: advancement of chemical looping systems using solid-metal-based carriers, photo-electrolysis, photolysis, and thermo-electrochemical processes to leverage solar and thermal energy; development of AI-supported catalysts, high-purity gas cleaning, and scalable reactor designs for novel electrolysis variants; enhancement of methane pyrolysis, plasmolysis, and biogenic gasification for CO_2-neutral H_2 and solid carbon; integration of CCS/U to achieve carbon-neutral or negative-emission hydrogen from local waste and biomass

Aligned with Roadmap Table C-10, this topic focuses on diversifying production to ensure security of supply and reduce dependency on electricity price volatility. The research focuses on biomass gasification, fixed-bed chemical looping processes for hydrogen production (where a solid material transfers oxygen between reactions), methane pyrolysis, and plasmolysis to produce hydrogen and solid carbon. Key emerging fields include photo-electrolysis, photolysis, and thermo-electrochemical processes, alongside novel electrolysis variants that leverage thermal or solar energy.

R&D priorities involve AI-supported catalyst development, optimised reactor designs for scalability, and advanced gas cleaning. Integrating CCS/U into biogenic pathways further enables negative emissions. By utilising industrial waste and local feedstock, these diversified routes allow Austria to close material loops and provide a cost-effective, stable hydrogen supply for the ramping-up mobility sector, complementing the primary electrolysis path with highly efficient, alternative technology pillars.

C.2.4 Hydrogen Storage and Distribution

The establishment of a resilient and efficient hydrogen infrastructure — encompassing advanced storage solutions, high-purity processing, and diverse distribution pathways — is the critical link required to bridge the gap between large-scale production and the multi-sectoral demands of a decarbonised economy.

R&D Topic C10: Distribution, Purification and Integration of Natural Hydrogen

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap C.2.2 / Table C-11: Hydrogen Storage and Distribution (p. 36)
- **Targets**: assurance of supply security; cost reduction; enhancement of efficiency; innovation of iron-based transport solutions; safety

This topic focuses on the infrastructure required to integrate diverse hydrogen sources. Key priorities include the extraction of natural (white) hydrogen, the development of energy carriers for intercontinental transport, and the development of international import sources. R&D targets advanced purification technologies tailored to natural hydrogen, alongside the optimisation of compression and liquefaction for both pipeline- and trailer-based supply, and new solutions such as metal-based energy carriers (e.g. iron redox systems), which offer integrated solutions for hydrogen production, storage and transport whilst reducing indirect water consumption and virtual water transfer associated with hydrogen supply chains. Further research focuses on AI-driven ecosystem optimisation to enhance distribution efficiency and safety. By advancing manufacturing processes for compression as well as distribution components and refining gas-cleaning technologies, this topic ensures a resilient, cost-effective hydrogen supply.

R&D Topic C11: Hydrogen Refuelling Stations (HRS)

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap C.2.3 / Table C-12: Hydrogen Refuelling Stations (p. 36f)
- **Targets**: cost reduction (CAPEX and OPEX) of refuelling infrastructure; H_2 supply security; safety

R&D prioritises the rapid rollout of HRS for heavy-duty transport to enable the 2026–2029 market ramp-up. It focuses on improved compression concepts, H_2 quality management, and mobile refuelling equipment to reduce CAPEX and OPEX. To ensure supply security, a hybrid approach combining pipeline, trailer, and on-site production is essential.

A key strategic goal is multi-certification (UN/ECE R134[17], PED[18], TPED[19]), allowing standardised components to serve automotive, non-road, and transport sectors simultaneously. This synergy accelerates production volumes and strengthens the European value chain. By developing scalable manufacturing platforms and high-availability networks, Austrian industry secures technological sovereignty and a leading international position, transforming isolated pilot projects into a robust, cost-effective infrastructure for decarbonised logistics.

Legend:
Key Technologies & Fields of Strength:
- Artificial intelligence and data innovation
- Advanced production technologies and robotic
- Advanced materials
- Energy and environmental technologies
- Mobility technologies

[17] https://eur-lex.europa.eu/eli/reg/2019/795/oj/eng (retrieved 9 April 2026)

[18] https://single-market-economy.ec.europa.eu/sectors/pressure-equipment-and-gas-appliances/pressure-equipment-sector/pressure-equipment-directive_en (retrieved 1 April 2026)

[19] https://eur-lex.europa.eu/eli/dir/2010/35/oj/eng (retrieved 1 April 2026)

D R&D Challenges: Hybrids and Sustainable Fuels 2026-2029

The position paper's focuses on the R&D requirements for hybrid powertrains, which include internal combustion engines (ICEs), in combination with sustainable energy carriers. On-road vehicles (e.g. passenger cars, trucks, busses), non-road mobile machinery (e.g. agriculture, forestry, gardening, construction machinery, forklifts) and special purpose vehicles (e.g. municipal, fire trucks, mobile cranes) need to be addressed targeting de-fossilization of existing and future powertrains through use of alternative fuels.

D.1 Main Objectives for the Expert Group HYF – Hybrids and Sustainable Fuels

Dedicated hybrids and other sophisticated transmission concepts: Significant improvement in the CO_2 balance over the entire life cycle (LCA) and cost reduction for passenger cars, motorcycles, commercial vehicles and non-road applications.

Quantum sensing: Next generation of development and validation tools.

Maximising efficiency and minimising emissions using alternative fuels: Fuels such as natural gas (NG), hydrogen (H_2), ammonia (NH_3) and methanol (MeOH) must be targeted for commercial vehicles. Hydrogenated Vegetable Oil (HVO), Power-to-X, where X can be liquid or gas, (PtX), MeOH, H_2 and NH_3 are to be addressed in case of heavy-duty on-road vehicles, non-road mobile machinery (and special purpose vehicles as well as Flex-Fuel Ethanol (E20-E100) and H_2 in case of passenger cars. Using different fuels always requires adjustments to the combustion process, such as the injection system, ignition system, mixture formation, compression ratio and charge motion.

Synthesis of sustainable fuels and e-alcohols: Improve the Fischer-Tropsch process with efficient, cost-effective and long-term stable catalysts.

D.2 Requirements for Technology Development and Research Demand

In the following section, the most important research tasks for the expert group Hybrids and Sustainable Fuels (HYF) are listed.

D.2.1 ICE and Hybrid Powertrains

R&D Topic D1: New Drivetrain Concepts for Commercial Vehicles Based on ICE (on-road, non-road and special purpose vehicles)

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap D.2 Sustainable Combustion Engine / Table D-1 (p. 39f)
- **Targets**: assurance of supply security; flexibility; multi-fuel suitability; optimisation

The development of innovative drive concepts for commercial vehicles based on internal combustion engine systems (ICE) is a key research focus in both the on-road and non-road segments. The focus is on various vehicle classes, including on-road vehicles, non-road mobile machinery and special purpose vehicles. The diverse operating profiles require differentiated drive architectures that address efficiency, emission reduction, and operational reliability equally. In this context, optimizing the charging system (turbocharger, e-compressor, e-turbo), the fuel injection and combustion system (PFI and DI), and the exhaust aftertreatment system plays a crucial role.

Hybridised drive systems and range-extender concepts are also considered particularly promising transitional technologies in this segment. They enable the combination of highly optimised combustion engines and transmissions with electric drive components. In addition, flex-fuel and multi-fuel capability will be investigated to increase security of supply, price stability, and resilience to geopolitical or market-related fluctuations.

In the non-road and heavy-duty sectors, robust, high-strength hybrid structures are paramount. These include optimised battery concepts, complex novel transmission structures (variable gear ratio, mechanically-electrically power-split), and high-performance electric motors and inverter technology that meet the demanding load requirements of these applications.

Artificial intelligence is playing an increasingly key role in system design and operational strategy optimisation. AI-supported methods enable both the automated design of complex drive architectures and the adaptive optimization of real-world driving.

R&D Topic D2: New Drivetrain Concepts for Large Mobile Engines

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap D.1 Sustainable Combustion Engine (p. 39f)
- **Targets**: efficiency; fossil-free operation

In the coming years, new drivetrain concepts for large mobile engines will be strongly shaped by the need to achieve climate neutrality and independence from fossil fuels. Particularly in decentralised applications, short-term electrification of large engines is often unrealistic due to high energy densities, range requirements, charging/infrastructure needs, and operating profiles – especially but not limited to shipping, mining applications, and freight transport.

Research into flexible dual-fuel concepts will become increasingly important, as conventional diesel operation will remain a necessary backup in many cases. High efficiency natural gas (NG) operation is a bridge technology, but the focus here is particularly on alternative fuels such as ammonia, methanol, and hydrogen, which require adaptable engine and combustion concepts. For stationary applications, on the other hand, monofuel engine concepts are moving increasingly in focus to enable completely fossil-free operation with hydrogen, ammonia, or methanol.

The research requirements here include not only the further development of combustion processes but also the design of injection and fuel systems, the adaptation of lubrication oil technologies to new fuels, and the development of efficient exhaust aftertreatment systems to reliably meet future emission requirements for all the aforementioned concepts. Additionally, a systematic investigation of material compatibility and component compatibility along the fuel pathway (e.g. injection systems, seals, piston rings, plain bearings, etc.) under real operating conditions is necessary.

Furthermore, the effects of alternative fuels and potential reaction products on the lubrication system and the entire tribological system (oil ageing, additive chemistry, corrosion, wear mechanisms, deposits) are largely unexplored and urgently need to be addressed to ensure safe and long-lasting operation. At the same time, the further development of these technologies offers great potential for technology transfer to stationary applications, such as in generator sets, where the insights gained regarding fuel flexibility, component robustness, and operating strategy can be scaled and used to de-fossilise decentralised energy supply.

R&D Topic D3: Dedicated Hybrids for Passenger Cars, Motorcycles and Non-Road Vehicles

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap D.1 Sustainable Combustion Engine (p. 39f)
- **Targets**: enhancement of vehicle efficiency

Dedicated hybrids with a high degree of component and function integration offer huge potential to increase overall vehicle efficiency in the case of passenger cars, motorcycles and non-road applications. Full Hybrid (HEV), Range Extender (REX) and Plug-in Hybrids (PHEV) can be addressed. Different hardware and software aspects need to be addressed to reach this goal. Highest efficiency REX engines with extended expansion provide minimum CO_2 and zero impact emissions, while being increasingly developed for flex-fuel, ethanol and hydrogen capacity. Hybrid drives with efficient, durable and functionally safe electro-mechanical actuation, electronic/electrically controlled CVTs (e-CVTs), Electro-Differentials and compact dedicated hybrid transmissions (DHT) with high-speed e-motors and efficient and durable dog clutches are to be addressed at different levels starting at the mechanical level and extending down to the material level. The latter is addressed, for instance, by choosing advanced manufacturing as well as new coating and material technologies, shifting to silicon carbide (SiC), Gallium nitride (GaN) and wide-bandgap-semiconductors for inverters to reduce losses and vehicle energy consumption. Moreover, coolants and lubricants need to be addressed targeting optimisation of thermal management and friction.

In addition, universal and predictive AI- and model-based control algorithms for both components, transmissions and ICEs are to be investigated. Furthermore, the proportion of driving done electrically can be maximized by combining such control strategies with AI-supported intelligent route selection.

For testing the mentioned functionalities, scalable model- and AI-based test methods for SiL/HiL must be developed at both system and component level.

Legend:
Key Technologies & Fields of Strength:
- Artificial intelligence and data innovation
- Chips, electronic components and systems
- Advanced production technologies and robotic
- Advanced materials
- Energy and environmental technologies
- Mobility technologies

R&D Topic D4: Advanced Transmission Systems for Zero-Emission Commercial Vehicles, NRMM and Special Purpose Vehicles

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap D.2 Transmission / Table D-2 (p. 40f)
- **Targets**: enhancement of efficiency at system level

On-road Commercial vehicles, non-road mobile machinery and special-purpose vehicles typically have several independent drive systems in addition to their main drive system, for example, for operating large auxiliary units, high-performance hydraulic drives, and attachments.

Furthermore, the drive systems of commercial vehicles, compared with passenger cars and buses, are often characterised by a significant need for a wide range of high tractive effort/wheel torque versus vehicle speed/rotational speed. This can push electric direct drives to their limits or result in comparatively expensive solutions due to the requirement for very large components.

The use of sophisticated transmission concepts offers the potential for electrically hybrid vehicles to optimise the component sizes of electric motors and power electronics. This allows for significant cost reductions in the high-voltage drive system and, at the same time, enables the exploitation of optimal efficiency across a wide range of operating conditions. Examples include combinations of electric drives with continuously variable transmissions (e-CVTs) for electric vehicles and electrically split transmission solutions for hybrid vehicles. The use of gearboxes also enables the use of high-speed electric drives for auxiliary units and hydraulic drives. Furthermore, integrating the thermal management of electric motors and power electronics into the gearbox system can be advantageous.

R&D Topic D5: Quantum Sensing for Powertrain Applications

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap A.1 Advanced Vehicle Control Systems and Software (p. 11)
- **Targets**: establishment of highly accurate development and validation tools

Exploring and researching quantum sensing, with Nitrogen-Vacancy-centre-based concepts for magnetic-field sensing is essential e.g. for indirect, contactless current measurement as key building blocks for electrified systems. In parallel, synergies with photonics to enable miniaturisation, higher functional density, and scalable system concepts are to be investigated. While monolithic chip-level integration is not in scope, progress along this direction is expected to reduce system cost through scalable fabrication and to enable highly miniaturised, integrable sensor architectures at system level.

A central element is data intelligence, combining advanced signal processing with AI/ML methods to improve robustness, uncertainty quantification, and actionable information extraction from quantum sensor readouts under realistic operating conditions.

Quantum sensing is also assessed in hybrid measurement chains together with conventional sensors and complementary key technologies, enabling improved sensing performance, redundancy, and system-level diagnosability. These activities are to be accompanied by rigorous benchmarking against established sensor technologies and alternative physical principles, ultimately targeting highly accurate development and validation tools for realisation.

While initial target applications will be in the field of hybrid systems, the approaches are to be designed to be sufficiently general to enable later application in electrified mobility, energy systems, autonomous systems, and beyond.

D.2.2 Sustainable Energy Carriers

The production of Biofuels and Renewable Fuels of Non-Biological Origin (RFNBOs) includes e-fuels (via Fischer-Tropsch synthesis), e-methanol, and e-methane (power-to-X technologies). A technology-neutral approach is supported. The production of renewable fuels aims, on the one hand, to support the Austrian mobility industry in manufacturing zero-emission vehicles. On the other hand, it should enable existing vehicles to be converted to sustainable fuels (securing added value and employment in Austria).

Hydrogen production via electrolysis, synthesis gas production via co-electrolysis and hydrogen production of other sources are covered in chapter C.2.2 Hydrogen Production via Electrolysis and chapter C.2.3 Other forms of hydrogen production.

R&D Topic D6: Fuel Production via Fischer-Tropsch Synthesis and direct CO_2 Hydrogenation to e-alcohols

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap E.2 / Table E-1: Renewable Fuels of Non-Biological Origin (RFNBO), A3PS-Roadmap E.3: Biofuels / Table E-2: Fischer-Tropsch fuels from biomass (p. 44f)
- **Targets**: commercial facilities; cost reduction; long-term stability of catalysts; higher efficiency; pilot plants or demonstration units; replacement of diesel/premium fuel production

Regardless of the hydrogen and renewable carbon source, sustainable fuels can be produced via Fischer-Tropsch synthesis. The Fischer-Tropsch (FT) process is a well-established method for producing high-quality synthetic fuels from carbon-containing materials. This process involves three key stages: gasification of the feedstock to generate raw gas, treatment of the gas to obtain synthesis gas (syngas), and catalytic synthesis to produce liquid fuels. Fischer-Tropsch fuels (FT-fuels) from biomass count as biofuels, FT-fuels from non-biological origin, which are also referred to as synthetic fuels or e-fuels, count as RFNBOs.

The FT process can be further improved with efficient, cost-effective and long-term stable catalysts, including AI, which is accelerating the R&D process. A further approach is the direct hydrogenation of CO_2 to alcohols as fuels and raw material. Technologies for capturing CO_2 from industrial point sources are considered as particularly important soon to enable rapid industrial transformation. Additionally, further development of CO_2 capture from the atmosphere which is currently still too expensive is recommended.

Even though industrial e-fuel plants should be located primarily in regions with availability of cheap renewable electricity as well as a source of non-fossil CO_2, it is sensible to develop and improve the necessary technology in Austria or with Austrian participation, e.g. in demonstration units. Advancing biomass pretreatment methods and improving carbon capture integration are also key priorities.

With the ongoing energy crisis and the shortage of kerosine, the synthesis of sustainable alcohols is especially important. First, methanol and ethanol can be blended into existing fuels (e.g. E20 or E85) which reduces the dependence on imported oil-based sources. Second, alcohols can be transformed to aviation fuels via the already technologically established methanol-to-jet fuel process.

Legend:
Key Technologies & Fields of Strength:
Artificial intelligence and data innovation
Chips, electronic components and systems
Advanced production technologies and robotic
Quantum technology and photonic
Advanced materials
Life-science and Biotech
Energy and environmental technologies
Mobility technologies

E R&D Challenges: Innovative Materials and Production 2026-2029

E.1 Main Objectives for the Expert Group IMP – Innovative Materials and Production

The area of "Innovative Materials and Production" is explicitly designed as a crossover topic within A3PS and is also represented in several other expert groups. This concerns, in particular, the use of critical raw materials, their substitution with alternative materials, and the circular economy. In internal combustion engines, electric drives with battery systems, and fuel cells alike, material properties and, ultimately, material costs play a central role. The concept of 10R is not just an abstract phrase, it is taken very seriously and put into practice in industry.

Europe as a production site and Austria as a small but significant industrial country are currently faced with challenges like never before. Smartly applied digitalisation within value creation networks (e.g., through the establishment and reliable use of data spaces) is not an endpoint in itself, but a logical consequence resulting from the demands of modern communication.

To get back on our competitive level, we need to pull out all the right tools and check the new options. This includes self-learning autonomous guided vehicles (AGVs) and humanoid robot kinematics, which were a major topic just recently at the 2026 Industrial Exhibition in Hannover. All these systems will help us deal with the job market's challenges and lower the costs per unit.

E.2 Requirements for Technology Development and Research Demand

In the following section, the most important research tasks for the expert group Innovative Materials and Production (IMP) are listed.

E.2.1 Design for Manufacturing / Circularity

R&D Topic E1: Development of 10Technologies

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap F.1 Design for Manufacturing / Circularity / Table F-1 (p. 48f)
- **Targets**: assurance of materials/components availability; cost reduction; decrease in dependency of raw material import; enhancement of lifetime; establishing of business case for circular factories; concept design for recycling/reuse; fulfilment of regulation requirements

The disassembly capability of components and systems is crucial to recyclability. Increasing complexity and multi-material design concepts must be considered, if recyclability is faced from the production stage to the end of first use.

Recycling companies must be able to disassemble various items across different industry sectors. AI support must be utilised within these developments. Production processes need to be fundamentally reconsidered, as certain manufacturing techniques, such as welding or soldering, do not permit non-destructive disassembly, thereby preventing the reuse of components. In accordance with the 10R framework, recycling should be considered as the last opportunity, while reuse and refurbishment should be prioritised whenever possible.

Fulfilling the 10R targets requires the development of production technologies for business cases not yet fully defined, such as second-life use or remanufacturing of specific EDU and battery components. AI is playing an increasingly important role in deriving optimal processing parameters for complex material combinations and applied production technologies, thereby reducing costs, improving quality and increasing agility across both electric drivetrain and battery production.

E.2.2 Advanced Materials / Lightweight Hybrid Structures

R&D Topic E2: Cross-Process / Cross-Product harmonized Alloy Concepts (Uni Alloy / One Alloy)

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap F.2 Advanced Materials/Lightweight Hybrid Structures / Table F-2 (p. 49f)
- **Targets**: alternative to gigacasting; improvement in circularity amount for aluminium and magnesium; secure availability of lightweight materials for the automotive industry with increased supply-chain sovereignty

A circular economy for lightweight materials such as magnesium and aluminium is vital for Europe's sovereignty. Because of the fact that a wide range of different alloys is used simultaneously in the automotive sector, recycling in this industry poses significant challenges. Recycling currently works well when the separation of different alloys can be carried out cost-effectively, for example when single-grade production waste can be fed directly back into the recycling process. In the automotive sector, the highest recycling rate is currently achieved for cast alloys used in engine blocks, an application that will cease to exist in the future as the industry transitions towards electromobility. Apart from cast alloys, due to differing requirements, it is hardly feasible to produce recycled alloys for sheet metal production and extrusion, which would be necessary in the automotive sector. It is therefore currently necessary, in line with the 10R approach's R1 "Rethink", to establish new alloy concepts and associated products and value chains that, in line with R2 "Reduce", reduce the complexity of the many specific alloys. The aim is to create base alloys that can be used both as cast and wrought alloys. These alloys should also be suitable for additive manufacturing and weldable, thereby contributing to R4 ''Repair'' and enabling implementation under R8 ''Recycling''. With these "Universal-alloys", it is therefore possible to use a single base alloy—which is not necessarily always the optimal alloy for every application—to cover all production routes (from casting, forging and extrusion to sheet metal production, etc.). This concept therefore represents an alternative to the "Giga-casting approach". As also in the future a variety of components is manufactured using different processes, a standard base alloy will be optimal to maximise the utilisation of the existing resources during the way to fulfil the targets of circular economy.

R&D Topic E3: Coating Technology

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap F.2 Advanced Materials/Lightweight Hybrid Structures / Table F-2 (p. 49f)
- **Targets**: cost reduction; CRM independency; enhancement of durability; enhancement of quality; environmental compatibility; 10R

Coating technologies will gain strategic relevance from 2026 onwards, as they enable existing and emerging materials to meet the changed boundary conditions of future mobility systems. Across all applications, coatings address increasing chemical, tribological, electrical, and thermal loads, including corrosion, cavitation, high voltages, and localized extreme temperatures.

By functionally engineering component surfaces, advanced coatings ensure media compatibility, stabilize tribological and electrical interfaces, improve thermal management, and protect against degradation mechanisms, while preserving established materials and designs. Compared to full material substitution, this approach reduces development effort, material consumption, and cost, while improving durability and quality.

At the same time, coating technologies are a key lever to reduce dependency on critical raw materials subject to regulatory and supply-chain pressures. By transferring functional properties from bulk materials to surface layers, coatings enable the substitution or reduction of critical elements while maintaining performance, safety, and lifetime. They further support lifetime extension, repair, remanufacturing, and reuse, contributing to 10R strategies, circularity, environmental compatibility, and long-term competitiveness of the European mobility industry.

Novel coatings are not typically used on bearings or gears but also in PCB (printed circuit board) for HV automotive application to reduce layer thickness, shorten process cycle time and tank necessary energy consumption in the production (e.g. hardening phase). Applying coatings requires a vast amount on energy therefore new technologies have an important impact on the eco-balance and CO_2 of the product. For innovative e-motor winding materials special coatings are required to meet the material property requests (e.g. dielectric strength). Coatings must always be engineered in conjunction with the applied manufacturing technology and bulk material. Coating has a significant economic impact for the industry and should be highlighted as advanced technology according to the Austrian industry strategy.

E.2.3 Production Processes for Competitive Industries

R&D Topic E4: Development of a Consistent Data Management System

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap F.3 Production Processes for Competitive Industries (p. 50f)
- **Targets**: cost reduction; enhancement of product quality; 10R

In production, assembly and manufacturing, data is collected and accessed at each stage. The Digital Product Pass will enhance and systematise this process in the future.

By networking the individual process steps and locations, crucial data for the production process, all the way to the point of use, can be generated. This networking leads to optimisation, as duplicate measurements can be eliminated. AI is used to link and analyse this data.

Goal: To record data in such a way that it can also be used for process optimisation – across the entire process chain and across company borders. This also requires software solution partners.

R&D Topic E5: Development and Application of Alternative Production Technologies

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap F.3 Production Processes for Competitive Industries (p. 50f)
- **Targets**: cost reduction; decrease in CO_2 footprint; enhancement of product quality; 10R

Alternative production technologies for components are essential to deliver lower costs compared to state-of-the-art technologies and hence make BEVs more affordable and CO_2-neutral in production. Beyond cost reduction, alternative production technologies aim to generate and guarantee the required material properties when processing novel materials and their combinations.

Main research fields in electric powertrains include windings, electric sheets, insulation coatings, HV components, PCBs (printed circuit boards), chips, coolers and covers (e.g. for inverters). In the battery context, this extends to alternative electrode manufacturing processes (e.g. dry electrode coating), advanced calendaring approaches, innovative stacking and winding concepts, tab-less or reduced-tab cell designs, as well as novel insulation and coating solutions for cells, modules and packs.

Jointing technologies play a crucial role in the miniaturisation and integration of single HV components into compact power modules, for busbars or for complete rotor assembly. Similarly, advanced joining and welding (laser welding, ultrasonic bonding, adhesive bonding) are key processes for battery cell interconnection, module assembly and pack integration.

To reduce material scrap from the outset, lower energy consumption, reduce costs and improve electro-magnetic properties, novel stamping technologies for new electric sheets must be innovated. Analogously, scrap-reduction and energy-efficient processes are required in battery production, particularly for electrode coating and drying, cell formation, and module/pack assembly.

Significant R&D efforts are required to innovate new materials and processing technologies for cost-efficient PCBs (material stacks and surface finishing) as well as for SMD and press-fit technologies. Comparable innovation needs exist for battery-relevant materials such as current collectors, separators, housing materials and thermal interface materials. CO_2 reduction through the substitution or reduction of steel and aluminium by alternative materials must be evaluated holistically, including battery housings, covers and cooling concepts.

AM-Processes are becoming more competitive in the large series production. In combination with the fascinating possibilities of design freedom and function integration this technology should be faced and integrated into new production lines.

Machining is still a significant sector and must be improved using data processing (e.g. edge computing) to increase the tool lifetime and product quality.

Legend:
Key Technologies & Fields of Strength:
- Artificial intelligence and data innovation
- Advanced production technologies and robotic
- Advanced materials
- Energy and environmental technologies
- Mobility technologies

R&D Topic E6: Development of Manufacturing Technologies Beyond Existing Boundaries

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap F.3 Production Processes for Competitive Industries (p. 50f)
- **Targets**: decrease in CO_2 footprint; enhancement of energy efficiency; optimisation in geometric boundaries (smaller, larger, faster, more precise); process stabilisation

Some established manufacturing technologies encounter geometric limitations, for example where components with smaller dimensions or diameters cannot be produced due to constraints in production facilities. Further development is required to overcome these boundaries.

E.2.4 Cost-Effective and Agile Automation, Robotic, Sensors

R&D Topic E7: Automation, Robotics and Autonomous Driving Systems for Intralogistics Transport

- Contribution to the further development of
- Application of
- More: A3PS-Roadmap F.4 Cost-Effective and Agile Automation, Robotics, Sensors (p.52f)
- **Targets**: AI-based robot programming (gesture, speech etc.); Development of Handling devices for Humanoids; Evaluation of Scenarios with intensive AGV and Humanoids application; Safety ("Liquid Safety") considering changes in the environment

The classic field of automation is currently undergoing a massive transformation. Self-learning systems, automated guided vehicles, humanoid robots, and other innovations promise disruption in the factory floor. The "dark factory," previously considered an unrealistic concept, is suddenly becoming a possible vision of the future. Nearly all job roles are facing the threat of massive change. All of this will play out first in the automotive world, as cost constraints are particularly strong in the mobility sector right now. The latest robotics products presented at the 2026 Hannover Messe clearly showed the direction we're going. It's likely that humanoid robotics will become a reality sooner than predicted just a short time ago.

Legend:
Key Technologies & Fields of Strength:
Artificial intelligence and data innovation
Chips, electronic components and systems
Advanced production technologies and robotic
Advanced materials
Energy and environmental technologies
Mobility technologies

10R	Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover
AD	Autonomous/Automated Driving
ADAS	Advanced Driver Assistance Systems
AM	Additive Manufacturing
AEM	Anion Exchange Membrane
AEMEL	Anion Exchange Membrane Electrolysis
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AIDV	Artificial Intelligence Driven Vehicle
APU	Auxiliary Power Unit
BEP	Battery and Electric Powertrains
BEV	Battery Electric Vehicle
BMIMI	Federal Ministry Republic of Austria for Innovation, Mobility and Infrastructure
BoP	Balance of Plant
C2C	Cell-to-Chassis
C2P	Cell-to-Pack
C2V	Cell-to-Vehicle
CAPEX	Capital Expenditures
CCM	Catalysis Coated Membrane
CCS	Carbon Capture and Storage
CCS/CCU/CCSU	Carbon Capture and Storage, Utilization
CCU	Carbon Capture and Utilization
CGH_2	Compressed Gaseous Hydrogen
CO	Carbon monoxide
CO_2	Carbon dioxide
CRM	Critical Raw Materials
CU	Control Unit
CVT	Continuously Variable Transmission
DHT	Dedicated Hybrid Transmission
e-fuel	Electricity-based Fuel
e-CVT	Electric Drive with Continuously Variable Transmission
ECU	Electronic Control Unit
EDU	Electric Drive Unit
EMC	Electro-Magnetic Compatibility
FC	Fuel Cell
FCV	Fuel Cell Vehicle
FE	Finite Element
FFI	Freedom-from-Interference
FT	Fischer-Tropsch
GaN	Gallium Nitride
GW	Gigawatt
H_2	Hydrogen
HEV	Hybrid Electric Vehicle
HiL	Hardware in the Loop
HRS	Hydrogen Refuelling Station
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
HVO	Hydrogenated or Hydrotreated Vegetable Oils
HW	Hardware
ICE	Internal Combustion Engine
IGBT	Insulated-Gate Bipolar Transistor
IR	Infrared
IVI	In-Vehicle Infotainment

KPI	Key Performance Indicators
LCA	Life Cycle Assessment
LH_2	Liquid Hydrogen
Li	Lithium
MBSE	Model-Based Systems Engineering
MeOH	Methanol
MiL	Model in the Loop
ML	Machine Learning
MOSFET	Metal Oxide Semiconductor Field-Effect Transistors
MtG	Methanol-to-Gasoline
MW	Megawatt
N_2	Nitrogen
NG	Natural gas
NH_3	Ammonia
NMC	Nickel Manganese Cobalt
NRMM	Non-Road Mobile Machinery
NVH	Noise, Vibration and Harshness
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditures
OTA	Over-The-Air
PCB	Printed Circuit Boards
PCCEC	Proton-Conducting Ceramic Electrolysis Cell
PCCEL	Proton-Conducting Ceramic Electrolysis
PCCFC	Proton-Conducting Ceramic Fuel Cell
PED	Pressure Equipment Directive
PEM	Polymer Electrolyte Membrane
PEMEL	Polymer Electrolyte Membrane Electrolysis
PEMFC	Polymer Electrolyte Membrane Fuel Cell
PFAS	Per- and polyfluoroalkyl substances
PGM	Platinum Group Metals
PHEV	Plug-in Hybrid Electric Vehicle
PMSM	Permanent-Magnet Synchronous Motor
PtX (PtL, PtG)	Power-to-X (X= Liquid or Gas)
R&D	Research and Development
REX	Range Extender
RFNBO	Renewable Fuel of Non-Biological Origin
SAAM Austria	Strategische Allianz Automatisierte Mobilität Österreich
SDV	Software Defined Vehicle
SiC	Silicium Carbide
SiL	Software in the Loop
SoC	System on Chip
SOEC	Solid Oxide Electrolysis Cell
SOEL	Solid Oxide Electrolysis
SOFC	Solid Oxide Fuel Cell
TCO	Total Cost of Ownership
TPED	Transportable Pressure Equipment Directive
UN/ECE	United Nations Economic Commission for Europe
V2G	Vehicle-to-Grid
V2X	Communication from Vehicle to X (e.g. Vehicle, Infrastructure, ...)
VIPV	Vehicle Integrated Photovoltaics
xCU	Any Control Unit
xiL	Model, Software or Hardware in the Loop

Imprint

A3PS – Austrian Association for Advanced Propulsion Systems

A3PS is the **strategic partnership** between the Austrian technology policy, industry and Research institutions.

A3PS stimulates the development of advanced propulsion systems and energy carriers – to build up common competence and to accelerate market launches.

A3PS addresses **all advanced drivetrain technologies** with contributions to the improvement of energy efficiency and reduction of emissions supporting the whole innovation cycle (research, development, deployment).

Media owner and editor

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