R&D CHALLENGES: FUEL CELL ELECTRIC VEHICLE AND HYDROGEN 2020+

REQUIREMENTS ON TECHNOLOGY DEVELOPMENT AND RESEARCH DEMAND

The hydrogen and fuel cell technology in Austria offers the opportunity to implement the energy transition quickly and efficiently, to expand and use the country's own renewable resources, to make an important contribution to greenhouse gas reduction, air pollution control and noise protection - especially in metropolitan areas. Additionally, the external trade balance can be improved while creating higher added value as well as new jobs in Austria.

In order to harness these advantages of fuel cell and hydrogen technologies in and for Austria, this technology needs political support and funding. These are recommendations for actions for the period up to 2025:

- Strengthening Austria as a location by building up hydrogen and fuel cell industry
- Expansion of research funding for hydrogen and fuel cell technologies
- Strengthened expansion of renewable electricity generation for hydrogen production
- Certification system for green hydrogen - as hydrogen generated by renewable energies
- Network fee exemption for electrolysis hydrogen with renewable electricity purchases
- Decentralized / regional approach to enable use, grid system release and balancing
- Simplified and standardized approval procedures for hydrogen filling stations and facilities
- Expansion of the hydrogen refueling infrastructure for cars, buses and trucks
- Incentives for the fleet development of fuel cell vehicles assumption of additional costs compared to conventional drives
- Creation of positive incentives (e.g. capex tax and long-term amortization and opex tax type, toll) of fuel cell vehicles

POSITION

Green hydrogen enables an integrated, efficient and socially sustainable energy system. To achieve the climate goals agreed in Paris in 2015, our energy system must be **decarbonized**. Green electricity and green hydrogen are the only zero-emission and carbon-free energy sources for this **energy transition**. They allow a climate-neutral energy cycle and offer a significantly higher level of efficiency and thus lower energy consumption compared to conventional systems. **Hydrogen is the key to expanding renewable electricity production** from wind, water and sun, as excess energy is used and long-term and efficient energy storage is made possible. Hydrogen enables the different energy and usage sectors (household, industry and mobility) to be interwoven, and at the same time offers the necessary flexibility and grid stabilization for energy systems with a high proportion of renewable energy. Due to the essential importance of hydrogen for the renewable energy system, it will be available in large quantities **for mobility**. Fuel cells electric vehicles in combination with hydrogen are offering a possibility for a completely decarbonized mobility system and are perfectly suitable when criteria like long range, high power, high energy consumption and fast refueling are targeted.

The European Commission's timetable earmarks no net emissions of **greenhouse gases in 2050**. For this, the conversion of the transport sector from currently over 90% fossil-based mobility to electromobility offers the greatest prospect of success. Action is needed for on-road and off-road vehicles (e.g.: 2-/3-wheelers, passenger cars, commercial vehicles incl. heavy/long-distance traffic and off-road applications). In the case of **fuel cell mobility**, the separation of **energy storage**, usually the hydrogen tank, and **energy converter**, the fuel cell, means that significantly higher power densities and therefore higher ranges can be achieved with short refueling times (approx. 5 min for cars). For high performance and long ranges, what is of central importance for electromobility in freight transport, electromobility with **Fuel Cell Electric Vehicles (FCEVs)** offers the drive concept of choice. Hydrogen fuel cell vehicles are **locally emission-free** electric vehicles. In particular, **electric vehicles with PEM** (polymer electrolyte membrane) **fuel cells** in combination with **green hydrogen** are of essential importance because they feature **lowest greenhouse gas emissions (GHG)** of all vehicle concepts over the entire life cycle when high driving range is required (production, operation, recycling).[3,4] Moreover, fuel cell vehicles feature potential to achieve low costs at high production volumes[5,6] and guarantee ecological advantages regarding rare resources as well as recycling and low emissions of the whole life cycle. However, high improvement potentials especially concerning overall efficiency, costs, industrialization, materials etc. are still existing.

The promising application of high-temperature fuel cells (SOFCs), which can be operated with hydrogen or other renewable fuels, should also be mentioned. In any case, every fuel cell vehicle also requires a battery for the recuperation of braking energy and is therefore an electric vehicle, so that the battery and fuel cell work together synergistically and do not represent a contradiction.

With hydrogen there is a similar need for the filling station network density as with fossil fuels. **Hydrogen** is safely stored at the refueling station and, as with fossil fuels, high refueling capacities are possible. For a nationwide supply of **hydrogen** there are **significantly lower infrastructure investments** than for battery electromobility, which requires a higher number of charging stations.

Location Austria: Austrian companies, research institutes and universities have been active for a long time in the research and development of fuel cell and hydrogen technologies. Now, developments have to be continued, accelerated and results need to be transferred to the market. Overall, the hydrogen fuel cell is the appropriate zero-emission technology for Europe and especially for Austria, because the existing know-how, the production technologies, the industrial and economic sectors as well as the available resources offer ideal conditions for this. The training and teaching of this subject area must also be pushed further. In addition to courses, academic theses are an excellent way to create optimal training in this field and to support research.

Specific **research demand** on FCEVs exist above all in the further reduction of **costs** and the further increase in **lifetime** and **efficiency**. In addition, the entire production, distribution and use chain based on renewable energies must be optimized with regard to maximum efficiency and lowest costs. There is a **need for research funding** for all types of fuel cells and electrolysis, from cells and stacks to complete systems, vehicle concepts, system concepts, hydrogen storage technologies and development tools, as well as measurement and testing technology, and the establishment and expansion of the laboratory infrastructure required for this.

ESSENTIAL LEGAL FRAMEWORK

When planning, constructing and operating decentralised hydrogen infrastructures, a large number of existing international and national regulations must be observed. Nevertheless, there are numerous open legal questions in the field of hydrogen applications. The resulting legal uncertainty makes it difficult for potential planers, builders and operators to implement new hydrogen plants and hinders the rapid implementation of an environmentally friendly energy system.

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3 Umweltbundesamt: Ökobilanz alternativer Antriebe, 2018.

4 Fraunhofer ISE: „Treibhausgas-Emissionen für Batterie- und Brennstoffzellenfahrzeuge mit Reichweiten über 300 km“, 2019.

5 Salman, P., Wallnöfer-Ogris, E., Sartory, M., Trattner, A. et al., "Hydrogen-Powered Fuel Cell Range Extender Vehicle – Long Driving Range with Zero-Emissions," SAE Technical Paper 2017-01-1185, 2017, doi:10.4271/2017-01-1185.

6 Thompson et al: Direct hydrogen fuel cell electric vehicle cost analysis: System and highvolume manufacturing description, validation, and outlook, Journal of Power Sources 399 (2018) 304–313, Elsevier, 2018.

Open legal questions and recommendations for changes

The legal framework conditions for the implementation of hydrogen technologies and especially for power-to-gas applications have already progressed much further in Germany than in Austria. In many legal acts of the German legal framework the topic hydrogen has already been integrated. [7,8].

Creation of a legal framework for power-to-gas in Austria

Proposals with possible solutions for the adaptation of the legal framework conditions, especially with regard to the operational and organisational conditions of power-to-gas applications, have been developed in a power-to-gas position paper in cooperation with Austrian experts from industry and research, see[8].

The paper calls in particular for the concept of power-to-gas to be anchored in Austrian law. It calls for clear regulations regarding the eco-electricity subsidy, the eco-electricity flat-rate, the CHP flat-rate, the electricity levy and the natural gas levy by power-to-gas plants[8].

In addition, the legal equivalence of hydrogen and synthetic natural gas from power-to-gas plants with regard to the gas grid usage fees for feeding hydrogen into the natural gas grid is demanded.

A regulation to eliminate the double burden for the purchase and the feed-in of natural gas when feeding hydrogen from power-to-gas plants into the grid is also essential[8].

Irrespective of this, it is recommended to exempt electrolysis plants that obtain electrical energy from renewable energies from grid usage charges and grid loss charges for the market introduction phase of the next years.

Further concrete recommendations for action are proposed for the following legal norms and technical guidelines.

Industrial Code (GewO 1994)

If the hydrogen plant is used within the scope of a commercial activity, a licence for the operation of a hydrogen plant shall be granted in accordance with GewO 1994 BGBl 194/1994 as amended. Process plants for the production of hydrogen by chemical conversion are listed in the GewO 1994 in Appendix 3 under point 4.2a. These are large plants with special hazard potential (IPPC plants) to which special and therefore more complex process regulations apply. No clear threshold values are specified for electrolysis plants. [7,9] We recommend to create clear threshold values to enable industry and research to prepare for these threshold values.

Emissions from electrolysis plants are limited to O_2, small amounts of H_2, noise and waste water. Waste water from electrolysis plants can generally be discharged into the existing public sewer system, as the threshold values listed in Annex A of the AEV Technical Gases Ordinance (BGBl 670/1996 as amended) are complied with.

The operator obligations regulated in Section 8a regarding the "Control of major-accident hazards involving dangerous substances" are applied to establishments with dangerous substances exceeding the quantity thresholds specified in Annex 5 GewO 1994 ("SEVESO establishments"). According to Annex 5 Part 2 Z 15 GewO, an establishment in which hydrogen is present in a quantity of 5 to less than 50 tonnes, an establishment of the lower class and an establishment in which hydrogen is present in a quantity of 50 tonnes or more is an establishment of the upper class.

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[7] Sartory, M. (2018) Technische, rechtliche und ökonomische Analyse eines skalierbaren Anlagenkonzepts für die dezentrale Wasserstoffversorgung. Dissertation, TU Graz.
[8] Tichler, R. u. de Bruyn, K.: Power-to-Gas: Vorschlag zur Anpassung der rechtlichen Rahmenbedingungen in Österreich. 2017. http://www.energieinstitut-linz.at
[9] Klell, M., Eichlseder, H., Trattner A.(2018) Wasserstoff in der Fahrzeugtechnik, Erzeugung, Speicherung und Anwendung. 4. Auflage, Springer Vieweg Verlag Wiesbaden, ISBN 978-3-658-20447-1.

It is recommended that a uniform interpretation be established in which non-stationary storage facilities (such as vehicle tanks or ADR shipping containers) that are only temporarily located on the site are not to be used for calculating the quantity of hazardous substances stored.

Shipping Container Ordinance (VBV 2011)

The extension of the definition of fuel gas tanks for hydrogen is necessary[10].

Refuelling systems for fuel gas tanks and similarly equipped cylinders and cylinder bundles shall be included in Appendix A.4 of VBV 2011. In the case of the approval of hydrogen filling stations in Austria that have already been implemented, the Shipping Container Ordinance has been applied analogously to date. A clear declaration of the hydrogen filling stations used for refuelling fuel gas tanks as refuelling facilities is required.

When integrating minimum requirements for hydrogen filling stations into the Shipping Container Ordinance, the regulations for compressed natural gas and biomethane must be adapted accordingly.[10]

Clear framework conditions must be created for the performance of refuelling operations at unmanned public hydrogen filling stations in self-service mode. [10]

Country-specific gas laws and gas safety laws

In country-specific gas laws, matters that are federal in nature are excluded from the scope of application. Commercial facilities are often explicitly listed among the exceptions. The scope of application thus includes all gas installations in private use. This also includes gas installations that cannot be allocated to a federal law due to the lack of legal material. [10]

The different definitions of terms in the country-specific legal standards for combustible gases are also valid for hydrogen. An exception is the *Oö Gasverordnung*. Here an explicit integration of the term hydrogen is required.[10]

The minimum safety requirements for hydrogen systems in the private environment shall be defined and integrated into the gas safety laws. This applies in particular to home refuelling systems and hydrogen systems for energy self-sufficient single-family homes. [10]

ÖVGW guidelines for the gas sector

Hydrogen is to be explicitly included in the regulations as a regenerative gas. Similar to the natural gas and biogas sectors, the entire application range for hydrogen must be covered. [10]

There is currently a particular need for action in the areas of hydrogen production using electrolysis, hydrogen refuelling systems and feeding hydrogen into the natural gas network. The existing Austrian gas infrastructure is able to deal with all variations of gas (be it natural gas, decarbonised gas, synthetic gas, hydrogen), only few adaptions are necessary. No burden of cost is to be expected, no expansion of the grid necessary. But in a first step the gas grid operators need to gain experience on the possible quantity of hydrogen in their grids.

In implementation of the European EN 16726, the Austrian national guideline G31[11] is currently to be adapted into the B210 by ÖVGW Austrian Gas and Water Association). The hydrogen concentration in natural gas shall be increased from currently 4 vol% to 10%.

[10] Sartory, M. (2018) Technische, rechtliche und ökonomische Analyse eines skalierbaren Anlagen-konzepts für die dezentrale Wasserstoffversorgung. Dissertation, TU Graz.

[11] ÖVGW: Österreichische Vereinigung für das Gas- und Wasserfach. https://www.ovgw.at/

Design of guidelines for the implementation of hydrogen plants in Austria

We suggest a stakeholder process for the development of appropriate guidelines for hydrogen plants. While the respective ministry and/or authority shall lead the process, relevant undertakings and stakeholders (institutions *like Fachverband Gas/Wärme*, *HyCentA* etc.) shall contribute with their experiences.[12]

Further recommendations for applications in research and development

For hydrogen systems that are used exclusively for research, development or testing, it is recommended to create clear exemptions and to simplify approval processes. This will allow R&D projects to be implemented more quickly and with lower budgets, and will create the basis for more efficient and accelerated further development of the technologies.

It is recommended to create exemptions for the gas composition in local gas networks. For power to gas plants with hydrogen feed-in to the natural gas grid, it is recommended to allow higher hydrogen concentrations.

LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) of FCEVs involves a range of influencing factors, such as hydrogen production (incl. use of co-products oxygen and heat and system integration, e.g. grid services) for FCEV operation, which can be supplied by various conversion processes and primary energy sources, the system energy efficiency of hydrogen production and use in the fuel cell, the manufacturing of the FCEV propulsion system and related extraction and refining of (critical) raw materials, and the lifetime of the fuel cell in the operation phase. End-of-life aspects include vehicle and fuel cell recycling as an important element to (partly) close (critical) material cycles.

[12] Bonhof, K.: Genehmigungsleitfaden für Wasserstoff-Stationen. https://www.h2-genehmigung.de

RESEARCH REQUIREMENTS

The hydrogen and fuel cell technologies are still at the beginning of their development process, which is why there is still considerable research and development potential and the need for optimization in the long term, particularly in terms of costs, lifetime and efficiency. The research and development needs of the next few years include the following topics (alphabetical order):

- Development tools, measuring and testing technology
  - Optimized test and test benches for fuel cells and hydrogen storage technologies
  - Simulation tools and development methods
- Electrolysis (all types) - cell, stack, system and systems coupled with renewable energies
  - Materials and production technologies
  - Process management and control
  - Inexpensive and efficient auxiliary units (BoP components)
  - Hydrogen distribution for mobile applications
- Fuel cell (all types) - cell, stack and system
  - Materials and production technologies
  - Process management and control
  - Inexpensive and efficient auxiliary units (BoP components)
- Hydrogen refueling technologies for all vehicle categories
  - Process management
  - More efficient components and systems
- Laboratory infrastructure for research and development work
- Vehicle concepts with fuel cells
  - System and vehicle integration - spatial and functional integration
  - Thermal and energy management
  - Control and regulation of the entire drive train (battery, power electronics etc.)
- Hydrogen storage technologies for mobile and stationary applications
  - Material and production technologies
  - Inexpensive components

REQUESTED FUNDING INSTRUMENTS

- Cooperative projects of oriented basic research
- Cooperative R&D projects, experimental development and industrial research
  (Fundamental research with low TRL for knowledge expansion, Industry-related research for knowledge transfer)
- Flagship Project (Industry-related research for knowledge transfer)
- Infrastructure for demonstration plants
- R&D infrastructure funding
  (Support of laboratory infrastructure)