NATIONALER WASSERSTOFFRAT

STATEMENT 2026-02-26

Hydrogen and e-fuels masterplan for the mobility sector: Input from the NWR

EXECUTIVE SUMMARY

Germany faces a double challenge in the transport sector: to reduce emissions quickly and reliably while simultaneously securing industrial strength, jobs and technological sovereignty.

This statement is intended as additional input for the hydrogen and e-fuels masterplan. Hydrogen can play a role in all modes of transport – road, rail, air and water. These sectors are at completely different stages of development in terms of hydrogen utilisation. This input focuses on road-based heavy goods transport.

The starting point is the realisation that complementarity rather than competition applies, at least for road-based transport: Battery-electric drives are driving decarbonisation in areas where charging is easy and the energy requirement per kilometre remains moderate; hydrogen and its derivatives are becoming a key technology in segments with particularly major challenges in the transition to climate neutrality, such as shipping, aviation, rail transport, heavy road transport and special vehicles.

This segment logic is not only technically justified, but also reflects the EU legal framework: ReFuelEU Aviation introduces binding quotas for sustainable aviation fuels (SAF), including a specific sub-quota for fuels of non-biological origin (renewable fuels of non-biological origin, RFNBO; e-fuels); FuelEU Maritime gradually reduces the greenhouse gas intensity of marine fuels up to 2050; and stricter CO_2 standards for heavy-duty vehicles make zero-emission powertrains the new industry standard[1]. In addition to climate neutrality, however, issues of resilience and competitiveness have also come to the fore in recent years. In the hydrogen and fuel cell sector in particular, the European industry is on a par with or even superior to its Asian competitors.

For the market ramp-up to succeed, a holistic integration of different measures along the entire value chain, including hydrogen supply in upstream, midstream and downstream, is required. Beyond the technological dimension, hydrogen mobility also has an important industrial policy component.

[1] The EU has adopted stricter CO_2 standards for new heavy commercial vehicles (lorries, buses) in order to drastically reduce emissions in the transport sector. The targets call for a reduction in fleet emissions of 15% from 2025, 45% from 2030, 65% from 2035 and 90% from 2040 (in each case compared to 2019/2020). In addition, new city buses must emit 90% less CO_2 by 2030 and be 100% emission-free from 2035.

The employment potential along the entire value chain is in the six-figure range by 2050[2]. Germany has a unique competence base in electrolysers, fuel cells, tank systems, compressors, standardisation and plant engineering. Without a domestic market, scaling and reliable demand, there is a risk of cost disadvantages compared to Asian competitors and the loss of key competences.

To sustainably scale the hydrogen rollout into a self-sustaining market, a number of concrete measures are proposed.

1. HYDROGEN AND MOBILITY

1.1 FUNDAMENTAL CONSIDERATIONS

In Germany, hydrogen will be able to make a significant contribution to the transformation of the mobility sector – especially in those segments with particularly major challenges in the transition to climate neutrality, such as aviation and shipping or road transport, where hydrogen is the second attractive option for emission-free transport alongside battery-electric mobility. Binding paths towards hydrogen-based fuels have already been defined for aviation and maritime shipping with European guidelines such as ReFuelEU Aviation and FuelEU Maritime. In heavy road haulage, high daily mileages and tight loading and delivery windows create operating conditions in which hydrogen-powered trucks can play to their strengths. For these segments, hydrogen – in gaseous or liquid form – is becoming a key technology for achieving the sectoral CO_2 targets, ensuring security of supply and strengthening European competitiveness.

Hydrogen mobility is therefore a strategic pillar of Germany's industrial and technological sovereignty. In the global competition for emission-free drive technologies, Germany's and Europe's competitiveness will depend crucially on securing value chains, achieving industrial scaling and accelerating innovation cycles. A consistent and credible policy framework for hydrogen is therefore needed to maintain industrial capacity, ensure engineering excellence and promote highly skilled employment.

Global competitors are stepping up the pace: China is increasingly positioning hydrogen mobility as a strategic component of national industrial planning, expanding its subsidy policy, strengthening industrial clusters and actively developing standards for hydrogen and CO_2 reduction sectors. Despite this rapid technological progress in China, Germany has the technological and commercial potential to compete globally.

Germany and Europe have considerable potential – provided there is a corresponding demand. According to the study "Green Molecules: The Upcoming Revolution in the European Employment Market", around 145,000 new jobs could be created in Germany by 2040 along the green hydrogen value chain – from production, system integration and refuelling technology to services[3]. Due to its long hydrogen history and technological expertise, Germany in particular has the opportunity to benefit from this in terms of economic policy. The local and regional supplier landscape in Germany with global technology champions will be able to maintain and further expand value creation.

---

[2] Green Molecules: The Upcoming Revolution in the European Employment Market (ManpowerGroup, Cepsa 2024).
[3] Green Molecules: The Upcoming Revolution in the European Employment Market (ManpowerGroup, Cepsa 2024).

1.2 AVIATION

In aviation, both fuel cells and batteries are only suitable for small and regional aircraft for the foreseeable future, despite their high efficiency. The use of hydrogen or its derivatives in aircraft, i.e. in fuel cells or for combustion in engines, is the subject of current research. Assessing the effects of emissions from fuel cells (water or water vapour) and from hydrogen combustion (water, water vapour and nitrogen oxides) is highly relevant, as non-CO_2 effects on the atmosphere can be significant.

From a technological perspective, the development of new aircraft concepts with integrated hydrogen architecture is particularly relevant. In addition to the engines and fuel cells, the tank and conditioning systems for cryogenic, liquid hydrogen are of particular relevance in preparing for the use of hydrogen in regional and short-haul aeroplanes through to demonstration.

With regard to medium and long-haul flights, SAFs, which are fuelled in the form of drop-in and near-drop-in aviation fuels, represent the most realistic alternative to conventional kerosene from today's perspective due to their high energy density. By gradually switching to bio-based and increasingly synthetic fuels, which are produced on the basis of renewable energies and green hydrogen, aviation can significantly reduce its emissions and pave the way for climate-friendly flying. Fuels that are already authorised may currently be blended with conventional kerosene up to 50%. In the long term, so-called aromatic-free fuels will also be used. Without these chemical compounds, less soot is produced in the aircraft turbines, which means that the fuels burn more cleanly. In order to achieve the aviation industry's ambitious goals in line with the targets of the ReFuelEU Regulation, it is necessary to create planning certainty and scaling options. This includes clear, harmonised and reliable regulatory requirements on sustainability, eligibility and quotas as well as stronger financial support for investments and production scaling. In addition, market-stabilising instruments such as standardised certification systems and suitable demand incentives are needed so that the production, infrastructure and use of SAF can grow in an economically viable manner. Bio-based SAF is already available on the market, but its capacity is limited and must therefore be supplemented by synthetic fuels in the long term. For the latter, there is a significant need for R&D regarding cost reduction and upscaling of manufacturing processes, as well as fuel optimization with a view to environmental impact and market launch.

1.3 SHIPPING

The same applies in principle to shipping; here too, bio-based or synthetic hydrocarbons (i.e. hydrogen derivatives such as methanol, ammonia and LNG) are indispensable as energy sources. Another speciality is ammonia, which can be used directly as a fuel in newly developed engines. Planning certainty is also an indispensable prerequisite here – however, this goal has suffered considerable damage due to the postponements of international regulations by the IMO (International Maritime Organization). It is to be hoped that the European requirements of FuelEU Maritime will at least provide some initial impetus. Beyond the innovation-driving scaling, there is a need for development, for example in exhaust gas purification in the context of ammonia combustion.

1.4 ROAD TRANSPORT

Germany's strategy for the transformation of road-based freight transport should be based on the duality **between hydrogen and battery-electric solutions**. Battery-electric heavy goods vehicles (BEV) will play a central role in the future freight transport system, particularly but not only for shorter transport distances. In light of the very different business models and truck deployment strategies in the heavy goods transport sector and the advantages and disadvantages of BEV and hydrogen trucks that are relevant to varying degrees (battery weight, charging times, ranges, infrastructure availability, operating conditions internationally, including outside Europe), hydrogen drives have a significant leverage effect in long-distance heavy goods transport. This applies both to hydrogen trucks with fuel cell drives and – particularly for the short-term timeframe – hydrogen combustion engines. Viewing the two options as competitors runs the risk of polarising the debate and delaying the transformation.

A **dual-technology approach reduces systemic risks and increases resilience**. The use of two emission-free technologies reduces dependence on non-European supply chains, including for potentially scarce raw materials. This would strengthen the resilience of the European automotive industry. By combining battery-electric and hydrogen-powered vehicles, Germany can unleash synergies, accelerate the expansion of zero-emission transport and create a balanced path that guarantees security of supply while ensuring industrial competitiveness.

The importance of hydrogen-powered vehicles is highlighted in the study on the "Market development of climate-friendly technologies in heavy goods transport" prepared by NOW GmbH. According to this evaluation of cleanroom discussions with European truck manufacturers, there will be an annual hydrogen demand of more than 500,000 tonnes for heavy commercial vehicles in Germany as early as 2033[4]:

Table 1: Projected vehicle numbers and hydrogen demand

Vehicles and H_2 requirements	Year							
	2024	2025	2026	2027	2028	2029	2030	2033
H_2 fuel cell vehicles	100	300	700	1,400	2,500	7,200	12,300	16,000
H_2 ICE vehicles	–	–	–	500	1,600	2,600	5,500	4,800
Accumulated vehicles in the field	100	400	1,100	3,000	7,100	16,900	34,700	55,500
Hydrogen demand [t]	960	3,840	10,560	28,800	68,160	162,240	333,120	532,800

The discussion about battery-electric and hydrogen-based mobility is usually reduced to the energy efficiency of the various process chains. However, the NWR emphasises that such energy efficiency considerations are only of very limited value. The decisive factors are the costs for the provision of the various energy sources and their use for the different areas of application. These costs depend in part, but not exclusively, on the energy efficiency of the respective process chain.

Hydrogen-based synthetic fuels make a contribution to national resilience over and above their significance for transport and industrial policy. State security organisations such as the German Federal Armed Forces, Federal Police and disaster control are permanently dependent on storable, high-energy and interoperable liquid fuels that are compatible with existing vehicle fleets. Green hydrogen produced in Germany or Europe enables the development of resilient domestic value chains for synthetic fuels and reduces strategic dependencies. Domestic hydrogen production thus strengthens both Germany's crisis-proof energy supply and its ability to act in terms of security policy.[5]

[4] Market development of climate-friendly technologies in heavy road freight transport 2024 (NOW 2024); Assumptions for calculating H_2 requirements: annual mileage 120,000 km, mixed average consumption 8 kg/100 km.
[5] Position paper on the necessity of using synthetic fuels (BMVg, BMI 2021).

Hydrogen mobility in road freight transport as well as air and sea transport should be treated as part of the industrial policy priority – not as a niche technology. Clear market signals, regulatory reliability, economic incentives and scalable infrastructure for all vehicle segments send the decisive signal that Germany is striving to play a leading role in zero-emission drive systems instead of becoming dependent on imported technologies.

Consistent action strengthens European sovereignty, accelerates innovation and ensures that the transition to climate-neutral transport goes hand in hand with **value creation and employment "Made in Germany"**.

The development of hydrogen mobility acts as a catalyst for the entire value chain of the hydrogen economy – from the generation of renewable energies and electrolyser production to storage, distribution, filling station infrastructure and hydrogen drive technology for vehicles. This creates highly qualified jobs, secures the competitiveness of the industry and supports the transformation of important sectors such as the automotive, logistics and heavy industry. Compared to battery technology, hydrogen technologies require significantly fewer and more readily available raw materials. German and European companies can establish themselves as global market leaders in the field of climate-friendly technologies and thus gain market share in the rapidly growing international hydrogen economy. In this way, hydrogen combines climate protection with industrial policy and strengthens Germany's economic power in the long term.

2. UPSTREAM – REQUIREMENTS AND SOLUTIONS FOR LOW-COST GREEN HYDROGEN

Germany is faced with the task of reliably meeting industrial hydrogen consumption for decarbonisation and at the same time new areas of demand – particularly in mobility. At the same time, today's market is still strongly characterised by conventional methods: in 2024, the total European demand for hydrogen was around **8 million** tonnes, while production capacity reached around **11 million** tonnes[6] – predominantly from fossil processes. This increases the transformation pressure on supply, certification and import paths. Cost-effective green hydrogen is produced through a tiered generation and supply mix that is integrated across **local, regional and supra-regional** levels.

Locally produced hydrogen via on-site electrolysis reduces logistics and loss costs, creates planning security and can support the early phase of demand; the downside is higher CAPEX/OPEX (compression, pre-cooling) and capacity utilisation risks without accompanying demand instruments. For domestic production, it is therefore important to increase economic efficiency and thus investments in generation plants through adapted certification regulations and long-term cost reductions in electricity procurement for electrolysers. The EU electricity purchase criteria for the production of green hydrogen and RFNBO are too restrictive. They are slowing down urgently needed investments in production capacities and slowing down the market ramp-up of green hydrogen – both in Europe and with potential import partners. The requirements for additionality and temporal and, where applicable, spatial correlation should therefore be adapted and the transitional provisions extended beyond 2027, i.e. until 2035 (see measure 1).

[6] Clean Hydrogen Monitor 11-2024 (Hydrogen Europe 2024).

Regional distribution opens up the supply of smaller and medium-sized hubs within a radius of typically 100 to 200 km via gas trailers (200-550 bar) and lowers the investment barriers to market activation. The hydrogen price is calculated from the H_2 purchase price and the costs of the filling station itself, taking capacity utilisation into account. In individual cases, it is already possible to offer hydrogen for road freight transport at a competitive price with local and regional distribution. However, this price situation is not yet an indication that petrol stations will be able to operate sustainably across the board.

In the long term, **supra-regional solutions via pipeline and liquid hydrogen import** represent the most efficient option for large, continuous volumes. However, no hydrogen distribution network comparable to today's natural gas network is to be expected in the next ten years, so that other forms for mass flows of up to approx. 10 tonnes/day should be selected for one customer for economic reasons.

The German government is already planning to import up to 70 per cent of hydrogen. In view of Germany's central role in the European hydrogen backbone, it should advocate a similarly ambitious and binding import strategy for the entire EU. The first examples of initiatives for the development of liquid hydrogen imports can be found in consortia around Hamburg[7], but also in neighbouring countries, e.g., the Netherlands[8].

What is needed are robust hydrogen partnerships with third countries, internationally harmonised balancing rules and the development of corresponding import infrastructures. In addition, greater regulatory leeway should be created for the procurement of carbon for transportable hydrogen derivatives.

This **hybrid mix increases system resilience**, reduces price volatility and makes it possible to link the expansion of renewable electricity generation to hydrogen demand in terms of space and time.

Technologically, an “either-or” approach between **gaseous** and **liquid** hydrogen is not appropriate, but rather a “both-and” approach depending on the use case. Depending on the price of hydrogen, road-based transport could quickly consume significantly more than 500 kt of H_2 in the first half of the next decade, whether in heavy goods transport, public transport or private transport. The demand for hydrogen could increase significantly with air and sea transport. As outlined in section 1.4, road freight transport alone will generate an annual hydrogen demand of over 500,000 tonnes in the early 2030s. With a view to 2045, studies indicate a significant ramp-up in demand for hydrogen. The BMWK's ambitious system development strategy indicates a total demand of around 360 to 500 TWh of hydrogen and its derivatives.[9] Breakdowns by sector show that in scenarios up to 25-35% of hydrogen demand in Germany could be accounted for by the transport sectors (including air and sea transport).[10]

These quantities probably cannot be produced cost-effectively in Germany. For this reason, import routes for hydrogen must be established to ensure a supply of largely climate-neutral hydrogen. This applies firstly to ammonia, which is easy to transport and for which attractive production conditions exist in regions with better or cheaper yields from renewable energy sources. A similar situation arises for synthetic hydrocarbons if better access to climate-neutral hydrocarbons can be made possible.

---

7 Daimler Truck, HHLA and Kawasaki Heavy Industries launch strategic partnership to establish a supply chain for liquid hydrogen in Europe (www.daimlertruck.com).
8 German-Dutch hydrogen corridor being examined (www.enbw.com).
9 Make. Energy. Efficient (ewi | BET 2025).
10 Electricity consumption by 2045 (e.venture 2024).

3. MIDSTREAM – COST-EFFICIENT DISTRIBUTION OF HYDROGEN ACROSS GERMANY, TRANSIT REQUIREMENTS

The national distribution of hydrogen and the connection to consumers can take place in different ways – each with specific advantages, restrictions and fixed time horizons. This diversity makes it possible to adapt hydrogen logistics to the respective local situation and to flexibly integrate hydrogen mobility into emerging hydrogen ecosystems.

MEDIUM TO LONG TERM: TRAILER DELIVERY AS THE DOMINANT MODEL

In the medium time horizon, supply by trailer remains the dominant solution.

- **Gas trailers (200 to 550 bar)** transport 250 to 1,100 kg of hydrogen and are suitable for small and medium-sized stations within a radius of 150 to 250 km.
- **Liquid hydrogen (LH_2)**, on the other hand, offers significantly higher transport volumes per trailer (3,000 to 4,000 kg) and reduces delivery frequency and logistics costs – especially for locations with high throughput (≥ 2 tonnes/day) or remote regions. LH_2 also allows for flexible refueling: either directly as liquid fuel or after regasification for 350-/700-bar refueling.

Restrictions currently result from still limited production capacities and the high energy requirements of liquefaction, although significant improvements are expected by 2030. In addition, the cost-effective distribution of liquid hydrogen will play an important role in the **import of hydrogen to Europe**.

PIPELINES – AS AN EFFICIENT LONG-TERM SOLUTION FOR LARGE-SCALE CENTRALISED CONSUMPTION

Pipelines are an efficient option for a continuous supply of large quantities. They offer a high level of supply security for locations with very high demand (from 2 tonnes/day), but require long-term planning, high initial investment and on-site cleaning and compression in order to meet the quality requirements of fuel cells. A comprehensive European pipeline network is **not** expected to be available **before 2035**. Until then, the first pilot projects connecting hydrogen refuelling stations to the emerging pipeline network are possible – even if they will not be the norm.

NO DOMINANT SUPPLY CHANNEL – THE FUTURE REMAINS HYBRID

It follows from this: **Future hydrogen refuelling stations must be modular and open to all technologies** in order to be able to serve different vehicle categories, supply options and changing cost structures. Specifically, this means the integration of **350-bar, 700-bar and LH_2 refuelling technologies** within a flexible system concept.

CHALLENGES IN EUROPEAN HARMONISATION

The cross-border transport of hydrogen poses additional regulatory, technical and logistical challenges. Although the European hydrogen market is to be highly integrated in the future, there are currently **different standards for purity grades, pressure levels, safety requirements and certification systems**, which make operational exchange difficult. This applies to both gaseous hydrogen (CGH_2) and liquid hydrogen (LH_2). Furthermore, **authorisation and dangerous goods regulations** diverge, particularly in the area of ADR, TPED and PED conformity,[11] which complicates transport chains and can limit the availability of suitable transport containers. In addition, there are **differences in national tax and levy systems** – for example in the areas of renewable fuels or guarantees of origin – which influence the profitability of cross-border supply models. In the future, the development of an EU-wide harmonised certification and quality framework, the harmonisation of technical standards and the expansion of cross-border infrastructure – including pipeline corridors – will be crucial in order to enable an efficient European hydrogen internal market and stable supply lines across national borders.

4. DOWNSTREAM – NECESSARY PETROL STATION NETWORK FOR THE SUCCESSFUL IMPLEMENTATION OF THE VEHICLE RAMP-UP

For commercial vehicles, especially heavy goods vehicles, the energy demand along motorways and main roads is enormous, comparable to the demand of small towns at every service station.

By combining both perspectives – lorries and buses as the backbone and cars as a flexible supplement – hydrogen mobility can accelerate the energy transition as a whole. In addition, the infrastructure created for road transport generates positive side effects for other sectors such as industry, shipping and aviation. This makes mobility not just an end in itself, but a catalyst for the emergence of a more comprehensive hydrogen economy.

A functioning hydrogen refuelling station infrastructure is a necessary prerequisite for the ramp-up of hydrogen mobility and thus for achieving the climate targets in the transport sector. For a successful market ramp-up, the infrastructure must be synchronised with the vehicle ramp-up, but must be ahead of it in order to create trust in the new technology among end users. However, since a certain minimum turnover is required for the economic operation of hydrogen refuelling stations, the ramp-up years must be supported by the state in order to achieve the hydrogen prices required for diesel parity at the refuelling stations and to ensure investment security for the operators.[12]

To achieve this, the hydrogen refuelling station network should be consistently aligned with the projected demand, which in turn is derived from the CO_2 targets. NOW GmbH's forecasts, based on regular cleanroom discussions with lorry manufacturers, can form a basis for this[13]. The ramp-up and progress of the filling station infrastructure should be recorded and controlled by a central control centre – similar to battery electric mobility (see measure 2).

In principle, there are two strategic approaches to planning expandable stations:

1. BOTTOM-UP APPROACH

Each expansion stage is adapted to current demand.

- **Advantage:** Investment and operating costs (CAPEX/OPEX) are closely aligned with actual requirements.
- **Disadvantage:** Components may need to be replaced or adapted as soon as higher capacities are required.

---

11 ADR: "Accord relatif au transport international des marchandises dangereuses par route"; TPED: "Transportable Pressure Equipment Directive" (2010/35/EU)"; PED: "Pressure Equipment Directive" (2014/68/EU).
12 Market Activation Strategy: Gearing Up for Heavy-Duty Market Activation by 2030 (GHMA 2025).
13 Market development of climate-friendly technologies in heavy goods road transport (NOW 2024).

2. TOP-DOWN APPROACH

The final target capacity is taken into account from the outset; the system grows proportionally.

- **Advantage:** A modular overall concept enables standardised components across all expansion stages.
- **Disadvantage:** Intermediate stages can be temporarily oversized.

Both strategies are valid and should be selected on the basis of location-specific factors – available space, expected market development, investment flexibility. In addition, innovative technical concepts such as **liquid-to-gas refuelling** or the direct supply of the station **with higher pressures (e.g., 500 or 1,000 bar)** should already be considered in the planning stage. The decisive success factor is the synchronisation between vehicle registrations and the ramp-up of the filling station fleet.

At European level, the Alternative Fuel Infrastructure Regulation (AFIR) forms the basis for both the electric charging infrastructure and the hydrogen refuelling station network. However, the EU requirements only represent a necessary minimum and should be expanded, for example with regard to requirements for lorries in the review in 2026. In particular, "700 bar" should also be explicitly included for lorries along the TEN-T network – as well as liquid hydrogen at selected locations for heavy goods traffic.[14]

For Germany, this results in a demand of around 110 petrol stations, although this is already covered by some of the existing petrol stations.[15] In January 2026, the German government launched a new funding project with a total volume of 220 million euros for infrastructure and vehicles to further expand the necessary filling station infrastructure.[16] This corresponds to the promotion of up to 40 petrol stations.

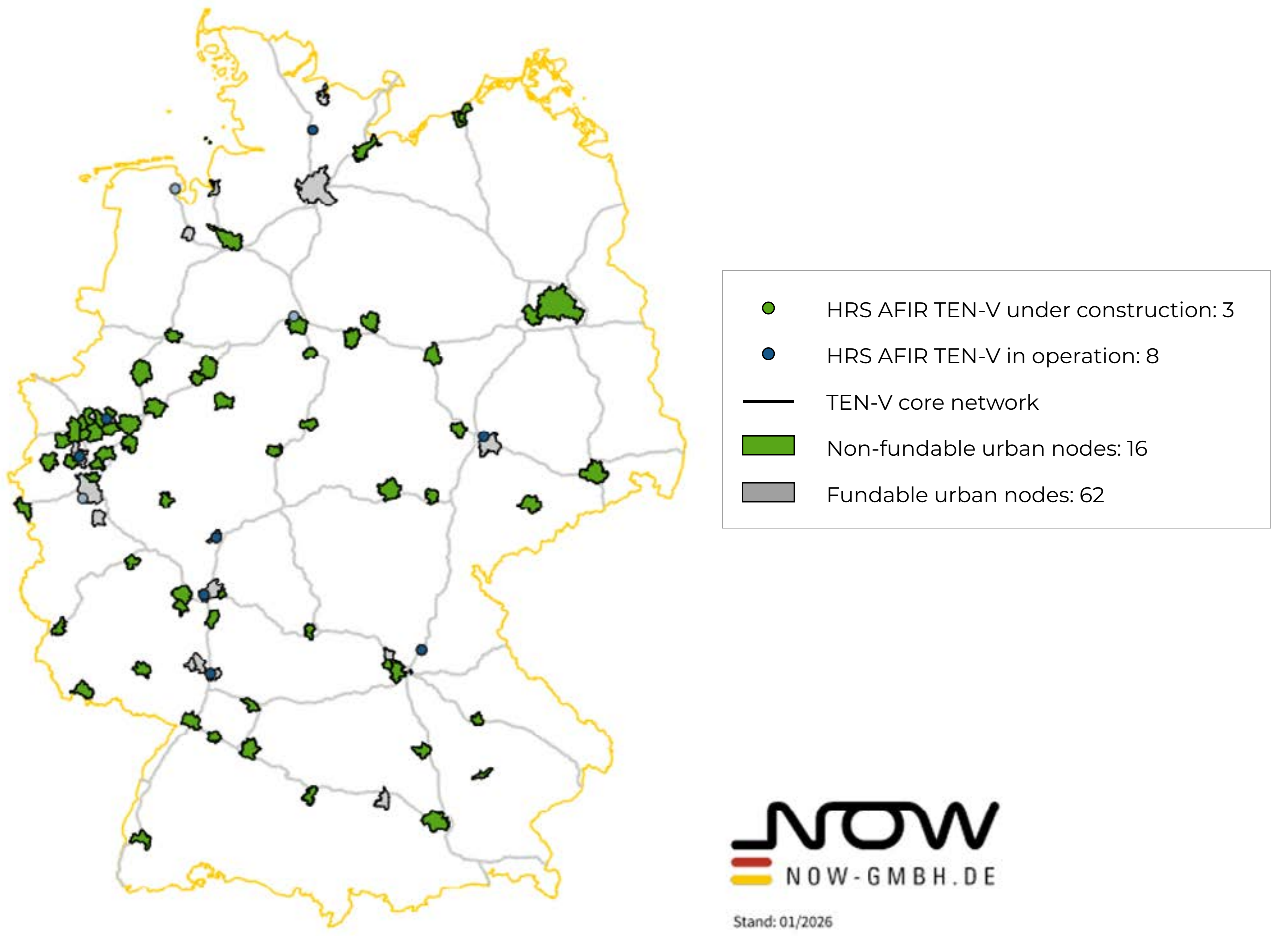
---

[14] Report of the "Sub-Group on Hydrogen Refuelling Infrastructre for Road transport" of the Sustainable Transport Forum. Publication pending. See also: Sub-group on hydrogen refuelling infrastructure for road transport vehicles (RegEx E03321/9).

[15] Information event on the national strategy framework in accordance with the EU regulation on the deployment of alternative fuels infrastructure (AFIR) – focus on "Infrastructure for hydrogen refuelling of road vehicles" (NOW 2024).

[16] BMV promotes climate-friendly heavy goods transport (BMV 2026).

Figure 1: overview of AFIR-compliant petrol stations and eligible locations for the 01/2026 funding call[17]



Germany should campaign at **European level** in the AFIR review for an **update of the targets for 2030 or their extension to include commercial vehicle requirements** (700 bar, liquid hydrogen), see measure 3. In addition, there is a need for regular monitoring, clear expansion targets up to 2050 with interim targets and coordinated cross-border planning. The combination of urban petrol stations and locations along the main traffic arteries described in the AFIR is considered to be expedient, although a **more ambitious implementation** such as an extension of the TEN-T "core" network to the TEN-T "comprehensive" **network** is recommended **for Germany**, see measure 4. The hydrogen refuelling station network should be open to all types of vehicles and accessible at all times in order to maximise synergies: Trucks, city buses and coaches as well as light commercial vehicles and cars. Depot petrol stations should also include a publicly accessible section. When designing the system, it is important to ensure a reliable hydrogen supply on the one hand and scalability in the event of increasing demand on the other. The hydrogen supply to the individual refuelling stations depends on the local conditions. In addition to local in-house production through electrolysis, for example – ideal when local renewable energy is available – lorry delivery has become the standard. While gaseous deliveries are currently used, liquid deliveries will play an increasingly important role in the future, as larger quantities can be transported, thus reducing transport costs. In the future, connecting hydrogen refuelling stations to hydrogen pipelines is also a good way of reducing transport costs. This aspect should therefore also be taken into account when selecting sites and mobility as a consumer when planning hydrogen distribution networks.

---

[17] www.ptj.de.

Technically mature systems with combined filling station concepts for liquid and gas refuelling are available, serve all vehicle segments and increase station capacity utilisation. This reduces hydrogen costs at the petrol pump and increases operational efficiency.[18]

While no challenges are expected here for aviation, as E-SAF can be integrated into existing logistics chains, new infrastructure will have to be set up for shipping, particularly with regard to ammonia. Some harbours are already moving in this direction, which is often a challenge due to limited space.

5. SUCCESSFUL VEHICLE RAMP-UP – SCALING OF FUEL CELLS AND H_2 COMBUSTION ENGINES

Various studies, including one by the Global Hydrogen Mobility Alliance on market activation[19], have shown that the key to economic viability lies in scaling. On the one hand, hydrogen refuelling stations, including the associated logistics and production, require sufficient daily purchase quantities (50 to 70% of capacity). Trucks have the highest daily fuel consumption of all road vehicles and can act as a catalyst for other vehicle categories. Both fuel cell trucks and H_2 combustion engine trucks should be considered, depending on the application. It can be assumed that both technologies have their justification. In addition, the petrol stations should be designed for all vehicle categories (in addition to trucks, also for coaches and city buses as well as light commercial vehicles and cars). This ensures maximum synergy and enables effective CO_2 emission reductions.

On the other hand, technology costs are also heavily dependent on the number of systems and components produced. Hydrogen can become much less dependent on raw material prices, and significant scaling effects through automation can already be expected with production quantities of a few tens of thousands per year[20]. As a result, vehicle prices similar to those of battery electric vehicles can be achieved in the medium term. As fuel cell technology is largely independent of the application, a synergy between trucks, buses and light commercial vehicles as well as cars is possible for many components. The parallel ramp-up of different vehicle types can therefore reduce system costs across all applications through synergies, benefiting all users and contributing to CO_2 emission reductions in the transport sector.

While fuel cells realise their greatest efficiency advantage particularly in long-distance transport with long, steady load profiles, and technological progress is revealing clear cost reduction pathways towards **50 Euro/kW** (e.g., through economies of scale in stacks, balance of plant, automation and material optimisation), hydrogen combustion engines are characterised by their proximity to the existing vehicle, powertrain and manufacturing landscape.

Vehicle manufacturers incur lower conversion costs because significant parts of the vehicle and engine platform, production lines and service infrastructures can continue to be used. This shortens development cycles and enables early market entry, particularly in segments that require high robustness or the transport of particularly heavy loads, or in construction site transport. The state of the art in hydrogen combustion engines shows that reliable basic concepts are already available today, but they still require further technological development. In particular, **H_2 injection, combustion stability**, the **avoidance**

---

[18] CryoPump-Stationen | Bosch Rexroth Deutschland.
[19] Industry Position – Required Policies (GHMA 2025).
[20] DWV Technology Study (LBST 2023) and Market Activation Strategy: Gearing Up for Heavy-Duty Market Activation by 2030 (GHMA 2025).

of NO_x formation and further improvements in overall **system efficiency** are considered key areas of development. Advances in high-pressure direct injection, adaptive exhaust gas recirculation, rapid mixture preparation and optimised turbocharging concepts are already opening up significant efficiency gains. At the same time, hydrogen burners benefit greatly from decades of combustion engine research, which facilitates the transition to series production and reduces scaling risks.

Overall, the combination of both technologies creates a robust market ramp-up model: Compared to combustion engines, the fuel cell offers high energy efficiency, potentially low operating costs and emission-free potential for decarbonising demanding long-distance transport segments, while the hydrogen burner ensures rapid scalability, industrial connectivity and flexible application options. It is crucial that both paths are treated equally from a regulatory perspective and that each has access to infrastructure, funding and market ramp-up programmes.

6. TECHNOLOGY PROMOTION: MEASURES TO INCREASE THE LEADERSHIP ROLE IN COMPONENT PRODUCTION

In principle, the focus in the coming years should be on two funding objectives – firstly, **sustainable market activation** that leads to a self-sustaining hydrogen market, flanked by long-term **innovation funding to** secure **technological leadership**.

Thanks to many years of funding from the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP), the vast majority of hydrogen technologies and system components have been developed in Germany and German and European industry is in a leading technical position. This presents a unique opportunity to scale up an environmentally friendly technology in the domestic market.

Due to the success of the NIP programmes and in order to maintain competitiveness, a continuation beyond 2026 is recommended. This ensures that the technology leadership achieved can be defended and further expanded (see measure 5).

However, it can be observed that the step from development to industrialisation and series production is currently taking place only very hesitantly due to a lack of demand. Asian suppliers, particularly from China, are not quite at the same technological level, but they have a head start in industrialising and scaling up production. This is already putting considerable cost pressure on German/European manufacturers. Only through decisive action and the creation of a functioning domestic market can the migration of hydrogen technology be avoided.

Five centralised funding mechanisms are currently in place:

- CAPEX promotion for vehicles and petrol stations
- CO_2 component of the toll
- GHG quota model
- national or EU-wide CO_2 pricing through a quantity-based (ETS) model
- Exemption from energy tax (previously only for fuel cell vehicles)

However, these political instruments, which are in principle very powerful, are sometimes associated with considerable uncertainties with regard to their economic impact and sustainability. On the one hand, the energy tax exemption for hydrogen for use in fuel cells has not (yet) been secured in the long term or made possible for use in combustion engines. On the other hand, two of the instruments are based on volume control approaches whose price effects are currently difficult to assess (EU emissions trading system for small installations and road transport – EU ETS-2) or where the risk of a massive drop in prices, e.g., due to fraudulent activities (in the international arena), cannot be ruled out in the future due to past experience.

In view of these uncertainties, considerable risks remain for the economic viability of (also) hydrogen-based lorry drives and private-sector investments in the broad infrastructure, plant and drive technologies are also exposed to significant uncertainties and risks, which could prove to be a central barrier to the market ramp-up.

Only a sufficiently robust cost relationship between conventional technologies and CO_2-neutral technologies can provide planning certainty for private sector investment, enable economies of scale and create a reliable business framework for hydrogen technologies – particularly in the capital-intensive phases of industrialisation.

Against this background, it is sensible and necessary to specify the various options for reducing risk with regard to the price and cost differences for the procurement and operation of diesel versus hydrogen trucks, to examine them with regard to integration into the existing instruments or their stabilisation and, if necessary, into additional instruments. This examination of the different approaches for such price stabilisation mechanisms requires careful analyses with regard to incentive effects, costs (also and especially for the state budget), interactions between the different mechanisms, legal admissibility and realistic implementation horizons.

Underutilisation is the main ramp-up risk for hydrogen filling stations. Even with competitive hydrogen prices, refuelling stations can fail economically in the early phase if only a few vehicles refuel regularly. Accordingly, in the early market phase, they require temporary security for operations with low utilisation. This complements the above-mentioned instruments or any price stabilisation mechanisms and cannot replace them.

In any case, the problem of long-term investment security (e.g., 15 to 20 years) on the upstream side compared to a short and medium-term (five years) business system on the user side. Approaches must be created here that distribute the risks in an affordable way. It may be worth taking a look at other markets, such as Japan, where mechanisms have been created that have led to a clear willingness to invest on the part of the companies and economic sectors involved (see measure 6).

7. TIME FRAME AND FINANCING: 2027 TO 2036 – TIMING AND APPROACHES TO FINANCING

In order to achieve the goal of a sustainably self-supporting market, we are working on the basis of three phases:

Phase I until around 2028, which is primarily concerned with market activation. Specifically, CAPEX funding and innovation funding are needed here. The NIP has successfully laid the foundations for the German hydrogen industry through targeted support for research and development. To maintain competitiveness, the programme should be continued beyond 2026.

The stabilisation and further development of the GHG quota model and emissions trading play an important role.

In addition, targeted promotion of market activation is necessary, including through a suitable price stabilisation model. In the European context, **combined promotion of hydrogen refuelling stations and vehicles** (as implemented, for example, in Germany[21] and the Netherlands[22]) is considered effective, as this combination resolves the so-called “chicken-and-egg problem”. This funding should be continued in **phase II** (2029 to 2033) and extended to hydrogen logistics and other vehicle types (see measure 7).

In addition, the further development of equal energy tax treatment for hydrogen in fuel cells and in combustion engines (see measure 8) and the further development of the tolling system can make an important contribution. At the beginning of this phase, a switch to a price stabilisation system for end users should be examined in order to promote the first phase of market ramp-up and market penetration.

Phase III (2033 to 2036) secures the willingness to invest with the continuation of a price stabilisation instrument and long-term technology leadership with national innovation funding.

This sequencing reduces systemic risks, increases the willingness to invest and ensures that government instruments are used where they have the strongest leverage.

If all activities are summarised, substantial funds in the high three-digit million range per year will be required over the next few years to secure the ramp-up of hydrogen mobility and technological leadership in the R&D sector.

8. MARKET ACTIVATION MEASURES

1. Adjustments to the requirements for RFNBO criteria with regard to additionality and temporal and, where applicable, spatial correlation as well as extension of the transitional regulations beyond 2027 to 2035.

2. Regular forecasting of ramp-up and infrastructure requirements, derived from CO_2 targets; monitoring and management of refuelling infrastructure via a central control unit, for example at NOW GmbH.

3. In the AFIR review, Germany should advocate at European level that the 2030 targets for the number of filling stations be implemented as planned and that the requirements for filling stations be extended to include commercial vehicles (e.g., 700 bar and liquid hydrogen technology).

4. Germany should implement the AFIR more ambitiously at national level than specified by the EU[23] and examine the following:

   a. Extension to TEN-T "comprehensive" instead of TEN-T "core"

   b. Expansion to at least two refuelling stations per urban node for redundancy and higher availability, especially during ramp-up

[21] BMV promotes climate-friendly heavy goods transport (BMV 2026).
[22] SWIM scheme boosts hydrogen in mobility (Hydrogen North Holland North 2024).
[23] National control centre for charging infrastructure for e-mobility in Germany.

c. Definition of interim target 2028

d. Definition of medium-term target in 2035 based on forecasts from measure 2

e. Defining a long-term target by 2050

5. Continuation of hydrogen technology research and development to maintain technological leadership and competitiveness: Extension of the NIP beyond 2026

6. Creation of solutions for long-term investment security for infrastructure operators I to secure the market ramp-up as a targeted continuation of measure 5, with a corresponding area effect and gradual phase-out

7. Continuation of combined funding for the construction of hydrogen refuelling stations and vehicles; examination of expansion to hydrogen logistics and other hydrogen vehicle segments

8. Energy tax equalisation of hydrogen for use in combustion engines with use in fuel cells in the EU – flanked by Germany's national approach

9. Further accompanying measures, e.g:

   a. Ambitious implementation of the Renewable Energy Directive III (RED III) and ambitious continuation beyond 2030 (RED IV): Stronger incentives for fuel suppliers are needed to encourage investment in the production of hydrogen and RFNBO. The Renewable Energy Directive III (RED III) should be further developed in order to create long-term planning security. This includes ambitious interim targets for 2035 and 2040 that are in line with the climate neutrality target. In addition, the member states must ambitiously transpose the existing RED III targets into national law, which has only been partially successful to date.

   b. Strengthening the ETS 2: ETS 2 is a central market-based instrument for decarbonising road transport, promoting demand for zero-emission vehicles and renewable fuels and thereby supporting the EU's CO_2 fleet targets. Its role as a guiding instrument should be strengthened rather than weakened. The success of ETS 2 depends largely on robust framework conditions, including accelerated infrastructure development, increased grid capacity, faster grid connections and tax incentives for emission-free mobility and the use of renewable fuels.

   c. Revision of the EU Energy Tax Directive: After years of stagnation, the revision of the EU Energy Tax Directive must finally make progress. To effectively accelerate the market ramp-up of alternative fuels, especially green and low-carbon hydrogen (and its derivatives), the EU should introduce a cross-sectoral zero tax along the entire value chain, at least for the duration of the market ramp-up. This should also include upstream elements such as electricity for electrolysis and logistical processes such as liquefaction and compression.

THE GERMAN NATIONAL HYDROGEN COUNCIL

On 10 June 2020, the German Federal Government adopted the National Hydrogen Strategy and appointed the German National Hydrogen Council. The Council consists of 22 high-ranking experts in the fields of economy, science and civil society. These experts are not part of public administration. The members of the National Hydrogen Council are experts in the fields of production, research and innovation, industrial decarbonisation, transportation and buildings/heating, infrastructure, international partnerships as well as climate and sustainability. The National Hydrogen Council is chaired by former Parliamentary State Secretary Felix Chr. Matthes.

The task of the National Hydrogen Council is to advise and support the State Secretary's Committee for Hydrogen with proposals and recommendations for action in the implementation and further development of Germany's National Hydrogen Strategy.

Contact: info@leitstelle-nws.de, www.wasserstoffrat.de/en