NATIONALER WASSERSTOFFRAT

STATEMENT

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Supplying the transport sector with green hydrogen and its derivatives

1 SUPPLY FOR THE TRANSPORT SECTOR

How can the supply of green hydrogen and its derivates be ensured for the transport sector – taking into account the determined development in demand (based on the calculations of the German National Hydrogen Council [NWR])? What measures are needed, and what are the consequences of the sectors' sequential developments in demand?

Many different developments are underway in order to make it possible to operate the individual modes of transport in the transport sector in a way that is climate neutral. Such criteria as range, installation space, refuelling time, efficiency and service life determine the solutions and are not only different in the individual segments (road, rail, off-road, water, air), but also at the application level (for example, in the maritime sector: freight, inland waterway shipping, cruise ship transport). Green hydrogen and its derivatives are required. By hydrogen derivatives, we mean ammonia, methanol and e-fuels, among others. A considerable share of this will have to be imported into Germany. The attached chart provides an overview of which energy sources are currently being used in the transport sector, in which segment/ application and in what amounts.

SHIPPING

If we look at shipping, and the overseas sector in particular, ammonia, methanol and synthetic fuels (e-fuels) are currently being discussed as target energy sources, whereby it can be assumed that a considerable proportion of these will have to be imported into Germany. All these energy sources are relatively easy to transport in larger quantities at an affordable price, which means that locations with low production costs will be preferred. The ships' engines are able to burn the energy source directly, so there are no further conversion losses beyond those resulting from the generation of the energy sources. Methanol is currently favoured by some shipping companies, particularly because it is less harmful to the environment and less toxic. Ammonia, on the other hand, is seen as an option in current considerations, especially in segments of the freight shipping industry, whether for anticipated cost reasons or because the chemical 'ammonia' is carbon free (not just carbon neutral) and also already established in industry and as a commodity throughout the world. Furthermore, the higher energy densities compared to methanol speak in favour of this energy source. Ultimately, however, no final decision has been made in this regard, and the discussions in the shipping industry throughout the world are rather intense. Synthetic gas ('SNG' in reference to LNG) is a third option because despite being more expensive, it can work as an alternative, at least for a transitional period. The extent to which other synthetic fuels for shipping applications are used on a large scale depends on the construction of correspondingly large plant complexes and the fuels' ability to compete with methanol and ammonia production. The advantages of these synthetic fuels include their direct compatibility with the marine fuels currently in use and the thus immediate possibility to begin using them in existing fleets.

Because inland waterway vessels require considerably less on-board fuel, the use of pure hydrogen in ships, in addition to battery-electric drives, has already begun.

AIR TRANSPORT

A distinction between long-haul applications and short or medium-haul applications must also be made in the air transport sector. Extensive developments for the latter areas of application are currently underway in order to replace fossil kerosene. In the short term, fuels based on hydrogenated oils will be used in this industry with increasing regularity; in the medium term, liquid hydrogen can also be used for both short and medium-haul transport but not long-haul transport. Mapping out how to supply airports with this energy source at an affordable price is currently the subject of extensive efforts. Synergies with road freight transport, which is also expected to use this form of hydrogen to some extent, may arise in this context.

Due to the amount of on-board energy required for non-stop connections with a range of up to 14,000 km, as of right now, only synthetic fuels appear suitable for decarbonising long-distance flights in the medium to long term.

In Germany, up to 10 million tonnes of kerosene are currently attributed to international air transport. Although Germany does have extensive biomass potential, it seems unlikely that a significant demand for the required kerosene could be met nationally. This means that imports of primarily hydrogen derivatives as well as hydrogen also play a key role in this area.

RAIL TRANSPORT

Even though railways still largely use diesel locomotives these days (approx. 40 per cent of tracks are not electrified), their energy requirements, and thus the resulting CO_2 emissions, are relatively low. Particularly in the regional transport sector, battery drives or fuel cell trains are already being used in initial projects, depending on local conditions and with the latter using gaseous hydrogen. This is because the infrastructure costs involved are lower compared to that of completely electrifying the tracks.

This gaseous hydrogen is currently produced locally in electrolysis plants and distributed by filling stations that are capable of doing so.

PASSENGER CARS

These days, the passenger car transport sector focuses mainly on battery-electric powertrains to meet its CO_2 reduction targets. As long as the expansion of the necessary charging infrastructure, including the associated electricity grids, is successful and the necessary critical raw materials for the battery are made available, a substantial market share should be achieved. Some manufacturers, some of which are focused on areas outside the EU, are also working on further developing fuel cell electric vehicles as a supplementary market segment. It should be stressed that these developments are mostly taking place outside of Germany within different political and geographical frameworks and that economically competitive alternatives to battery electric passenger cars can be expected to come from there. The projected hydrogen demand for passenger car applications is relatively low, at least for 2030.

COMMERCIAL VEHICLES

Hydrogen will become the second major pillar in the use of climate-neutral commercial vehicles (lorries, light commercial vehicles up to 3.5 tonnes and buses); the first being the direct use of electricity. In recent years, we have seen how dynamically and rapidly the ramp-up of electric cars and commercial vehicles has developed. We will also see comparable developments in lorries in a few years' time, and in the second half of this decade, comparable developments will also be possible for hydrogen.

The use of H_2 in lorries, and in the future, also in coaches, plays a key role as regards the demand for hydrogen. Lorries are used with far greater intensity than passenger cars (ten times the annual mileage and 50 times the annual energy consumption per vehicle), which means that – unlike in the passenger car segment – there is less clarity as to whether battery-electric drives are likely to dominate. The H_2 demand in the transport sector will therefore be largely determined by the demand of the commercial vehicle market.

The NWR's white paper on greenhouse gas savings and the associated hydrogen demand in Germany[1] describes the range of the expected demands. It also shows – through the variance of the results – how great of a challenge it is to reliably estimate what the demand will look like in coming years. The results of the 'Cleanroom Talks' held by the German Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr, BMDV)[2] provide valuable additional insights here and create an increasingly resilient data basis for the next ten years.

According to currently available information, the NWR assumes an H_2 demand of 30 to 32 TWh in the transport sector in 2030.[3] This corresponds to just under 1 million tons H_2 and presents an enormous effort for every entity involved – especially with regard to the extremely short lead time. To make matters worse, the demand for hydrogen will increase significantly from year to year after 2030 due to the widespread rollout of hydrogen vehicles.

We see four key requirements that must be fulfilled in order to ensure the supply and demand for H_2 is met: quality, price level, distribution and availability.

- **Quality:** The use of H_2 in fuel cell vehicles requires high-quality hydrogen that meets strict purity requirements. This makes the use of H_2 derivatives as a source of hydrogen unattractive, as they have to be converted back into hydrogen – using the corresponding complex purification processes.

- **Price level:** Hydrogen must already be an affordable energy source in the ramp-up phase and must not cost end customers more than five to six euros/kg at the filling station in 2030. Higher prices have a prohibitive effect.

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[1] See https://www.wasserstoffrat.de/fileadmin/wasserstoffrat/media/Dokumente/2023/2023-02-01_NWR_Grundlagenpapier_H2-Bedarf_2.pdf
[2] See https://www.klimafreundliche-nutzfahrzeuge.de/wp-content/uploads/2023/03/Marktentwicklung-klimafreundlicher-Techn.-im-schweren-Strassengueterverkehr-BARRIEREFREI.pdf
[3] See footnote 1.

- **Distribution:** Today's hydrogen filling stations are primarily based on a relatively low H_2 demand (less than one tonne of H_2 per day for passenger car filling stations). As soon as sales trend toward four tonnes of H_2 per day (for lorry filling stations) and above, distribution in gaseous form is largely uneconomical. This means that liquefied hydrogen and onsite electrolysis are gaining in importance. Gaseous hydrogen can also play an important role, if affordable hydrogen can also be produced locally – corresponding regulations and cost allocations to the electrolyser play a decisive role in this context – or a pipeline connection is possible. In this respect, however, it should be noted that the pipeline-bound hydrogen must be pure enough for use in vehicles or be purified after it has been removed from the pipeline. It should also be noted that this results in additional technical effort, which also changes the prices. That being said, hydrogen generated on site using green electricity can both compete and be competitive.

- **Availability:** H_2 must be available nationwide across all transport infrastructures that are relevant for hydrogen use. This means that an initial filling station network beginning in 2025 must be followed by a network that ensures broad regional coverage and is rapidly solidified by 2030. Doing so requires either a pipeline distribution network that supplies filling stations with hydrogen that is either partly produced domestically or imported. The latter requires infrastructural measures for the procurement of imported hydrogen (for example, liquid H_2 routes from the MENA region or overseas, an H_2 pipeline from Norway as well as the North and Baltic Seas, Spain and France – North Africa could also develop into a pipeline-based supplier). We see both the demand and a complementary market supply of domestic as well as imported H_2. Domestic local production plants will be able to establish themselves using various business models (for example, ppa, demand-led electrolysers and so on). However, liquid and gaseous hydrogen as an imported product can gain in importance due to its cost advantages and be particularly suitable for regional distribution (transport distance is less cost-sensitive). The systemic energy yields improve even more if it is possible to use the discharged cooling.

Even if it is just a very small area of application, which is nevertheless of key importance, the need to ensure a robust energy supply for national security institutions should be pointed out once again. The main challenge for Germany's Federal Police, Federal Armed Forces and security institutions (THW [Bundesanstalt Technisches Hilfswerk – Federal Agency for Technical Relief], among others) is therefore to ensure operational readiness while taking climate protection into account. In this context, synthetic fuels currently offer the only option to guarantee the unrestricted operability of the systems – under special operating conditions on behalf of national security. Incidentally, the same applies for a large number of mobile machines that can only be partially electrified due to technical requirements.

As described, the majority of the demanded hydrogen or derivatives will be imported. The infrastructure needed to do this is largely lacking. Accordingly, the pipeline connections to foreign countries, the necessary import terminals for both green hydrogen derivatives and liquid hydrogen as well as the pipeline infrastructure must go into operation in Germany before the end of the decade. The supply structure required for this must be contractually agreed upon with the exporting countries. Large-scale storage options should also be developed, for example, in salt caverns, and pipe storage facilities should be built as an option to ensure resilient supply in regions where such natural options cannot be developed. Due to the long lead times in road and air transport, these processes must be started immediately in order to provide the necessary planning security. As regards the transport of pure hydrogen, it is worth taking a look at Japan, as this country is already making plans for a corresponding supply of liquid hydrogen from Australia for 2026.

In addition to imported hydrogen and its derivatives, decentralised domestic production should not be disregarded. Onsite electrolysis that benefits the grid, which occurs either regionally as a mother-daughter system or close to the consumption points when the hydrogen demand is two tonnes or more, avoids the expensive transport and additional energy input that liquefaction requires. In addition to resilience and thus international independence, international markets also demonstrate how high-purity hydrogen as an energy source can be produced locally with an insufficient pipeline infrastructure, a high proportion of green electricity or problematic accessibility to renewable energies and how a rapid nationwide ramp-up can succeed.

2 POLITICAL MEASURES

Which measures can policymakers use (for example, those of a regulatory nature: the removal of existing barriers and/or new measures) to further support the realisation of a market mechanism for supplying hydrogen to the transport sector – both from domestic renewable energy sources and via green hydrogen imports?

When questioning which accompanying measures to use and their impact, it is crucial to look at things from the perspective of the target group that will be making the demands for hydrogen in the transport sector: the end customers. And this most notably includes logistics and shipping companies. In the future, they must be able to operate with hydrogen lorries at least as successfully as they currently do with diesel lorries. This means that the total cost of ownership for the alternative (HFC) must turn out to be the same as for the previous solution (diesel) or even cheaper. Since the costs, both for vehicles and for hydrogen, still pose an enormous challenge in the medium term, it is necessary to change the existing framework conditions in such a way that the use of diesel gradually becomes more expensive and the use of H_2 becomes cheaper.

The most effective measures for regulating the market are known, and in Germany, have already been initiated to some extent. Among them is higher CO_2 pricing that ultimately increases over the long term – a measure which will be introduced throughout Europe. The agreement in favour of an ETS II for fuels and a European CO_2 price of €45 per tonne in the ETS II in 2030 is a step in the right direction, but this unfortunately falls very short of the prices needed to advance the transformation at the extreme pace envisaged. Clearly outlined cost differentiation is needed in the lorry toll (CO_2 component of €200 per tonne of CO_2 and maximum reduction of the infrastructure component for zero-emission vehicles), which for zero-emission vehicles should be at least at the level of the current toll (approx. 19 ct/km) with a cost advantage for introduction, and in the medium term, at 30 ct/km compared to a diesel vehicle.

Energy taxes should only be levied on H_2 once a high level of market relevance has been achieved and the ramp-up is so far along that there is no turning back.

In Europe and the EU Member States, when it comes to a market ramp-up of H_2 production capacities and the stimulation of a corresponding demand, it is crucial that the definition of green hydrogen encourages investments and does not produce a prohibitive effect. This is especially true with regard to the use of renewable electricity. In this context, there must be no disadvantageous – for example, more restrictive – guidelines for hydrogen in comparison to those applied to other users and consumers. The revision of the Renewable Energy Directive (RED) is making this so.

This EU directive and its delegated acts are also the main regulatory instruments for the following aspects: the RED not only defines which hydrogen is green, but it also significantly promotes sales via targets for renewable shares in the fuel supply sector and possible sub-quotas.

There is certainly no need in the RED for mandatory sub-quotas for these fuels, as they are the only two options for compliance that do not involve a crediting cap, besides the option for crediting GHG emission reductions resulting from the use of electricity in the transport sector. Due to how ambitious these options are, they will only be used as options for reaching the target in an environment of mutual technology-related competition if they are sufficiently available. Sub-quotas in the transport sector, on the other hand, lead to a concerted effort to achieve the respective targets. In particular, an ambitious sub-quota for RFNBOs would lead to a clear focus on proactively developing the hydrogen infrastructure that is so direly needed for the transport sector and would free up additional funds for bringing hydrogen to market.

Regulatory barriers must be removed whenever they are identified as such. In this context, the development of transport and distribution networks in particular should be brought into focus as well, as such projects have proven to have a long lead time thus far.

3 ROLE OF HYDROGEN DERIVATES

What role do hydrogen derivatives (such as ammonia and methanol) play in supplying the transport sector, especially with regard to the import of green hydrogen?

As described above, hydrogen derivatives (ammonia, methanol, synthetic fuels) will mainly be used in shipping and aviation, but they are also of particular importance for existing fleets as well as specific applications (for example, mobile machinery) and, last but not least, national security. The quantities used in these sectors are substantial throughout the world, which means that a correspondingly efficient industry must be created to be able to produce hundreds of millions of tonnes of derivatives by 2050.

When it comes to road transport, we can already foresee that the demand for H_2 will be great and that it will have to grow rapidly if the climate targets are to be met. H_2 in the transport sector must meet high purity standards for use in fuel cells and be made available nationwide (see first question).

The use of derivatives as transport vectors is most likely not a permanent solution, insofar as pure hydrogen is required in the final application, as is the case for their use in fuel cells. This is because the costs involved, which may be higher than the pure hydrogen routes (pipeline gas, liquid H_2), even in the long term, present a disadvantage. The reason is simple: the conversion of H_2 into derivatives facilitates transport – or even makes it possible in the first place – in areas where no infrastructure currently exists (pipeline, ships, terminals). However, this involves additional steps in the conversion process and thus conversion losses (ammonia synthesis, ammonia cracking, H_2 purification), without eliminating other process steps: liquefaction or compression would still be necessary for distribution to the end consumer, who refuels with either pure liquid H_2 or pure compressed hydrogen. It should be noted that extracting hydrogen from methanol is technically easier than extracting it from ammonia because the hydrogen-containing product gas can be more easily purified of by-products.

For rapid availability, we need such derivatives in the initial phase and, in the early years, may have to offset higher costs for non-ship and non-aviation applications using support mechanisms. The focus with the latter applications is also on their simultaneous use as an energy source. In the long term, the routes that promise the lowest costs are the ones that will be successful.

4 ECONOMIC OPPORTUNITIES

When compared internationally, what economic opportunities arise for Germany as an industrial hub due to investments in the hydrogen and fuel cell industry in the transport sector (for example, for the automotive supply industry), and how can these potentials be tapped in the best way possible?

Numerous companies that have recognised the potential of it have already entered into fuel cell development. There are also many suppliers in the industry who deliver both FC system components as well as vehicle components. An enormous field of innovation is emerging, one that is not only taking shape with incredible momentum, but is ultimately gaining in diversity. Companies have also recognised the need for research and development when going the liquid hydrogen route and identified the opportunities of doing so (terminals, ships, liquefaction and so on). The same applies to the transport and distribution technologies involved with the use of gaseous hydrogen and other supposedly well-known technologies, where every additional innovation and efficiency increase benefits the market ramp-up.

In order to map out the required availability of filling stations, powerful and robust compressors as well as the corresponding filling station technology must be further optimised.

As an initial sales market, transport can reinforce and accelerate this enormous innovation process for the entire sector and aid in building global structures and pave the way for hydrogen to become an inexpensive, internationally traded commodity. The automotive industry, unlike most others, thinks and acts in terms of economies of scale, which results in the development of large-scale production technologies with a wide range of innovations.

In addition to battery-electric drives, the import and use of hydrogen and its derivatives in the transport sector will play an important role in the long term, especially from a global perspective.

These potentials constitute another massive opportunity for Germany as an industrial hub. The support and acceleration of international hydrogen supply chains and production sites in countries rich in solar and wind resources not only enable the availability of H_2 in Europe, but also faster technology transfer and application in the producing countries.

If you are interested in finding out more or have any questions, please contact:
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APPENDIX

Table 1: Use of energy sources in the transport sector in 2021 (in Petajoule [PJ]/megatonnes of oil equivalent [Mtoe])

Transport type	Comsumption		**Vehicle**	Comsumption		**Kraftstoff**	Comsumption	
	PJ	Mtoe		PJ	Mtoe		PJ	Mtoe
Road	**2,033**	**48.6**	Passenger car	**1,348**	**32.2**	Petrol	**644**	**15.4**
						Diesel	**619**	**14.8**
						Biofuels/other[4]	**85**	**2.0**
			Bus	**30**	**0.7**	Diesel	**26**	**0.7**
						Biofuels/other[4]	**4**	**0.0**
			Van/lorry	**655**	**15.6**	Diesel	**609**	**14.6**
						Biofuels/other[4]	**46**	**1.0**
Rail	**51**	**1,2**				Electricity	**39**	**0.9**
						Diesel (incl. biodiesel)	**11**	**0.3**
Air	**258**	**6.2**	national			Aviation fuel	**10**	**0.2**
			international			Aviation fuel	**248**	**5.9**
Ship	**65**	**1.6**	national bunkering			Diesel/heavy fuel oil	**10**	**0.2**
			international bunkering			Diesel/heavy fuel oil	**55**	**1.3**

Sources: BMDV [2022]: Verkehr in Zahlen 2022/2023; Eur'ObservER [2022]: RES in Transport; DTAG [2023]: own estimate

[4] Natural gas and electricity

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 26 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 Katherina Reiche.

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.

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