STATEMENT

2022-11-04

Hydrogen storage roadmap 2030 for Germany[1]

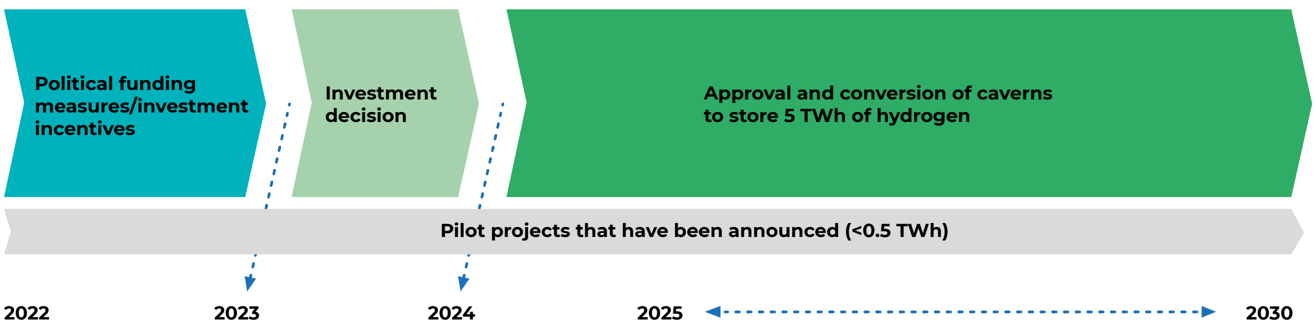
1 INTRODUCTION

In order to convert existing gas storage facilities and build new caverns in which to store hydrogen, it is necessary to estimate the storage demand for hydrogen by 2030. It is also necessary to evaluate the demand for the natural gas market in light of the increased demands on gas storage facilities to secure the gas supply in Germany. The aim of an implementation roadmap must be to reconcile the projected requirements. This must be done in a way that enables the political support measures to incentivise stakeholders to make the necessary investments for the market ramp-up of hydrogen storage when they are needed.

This is needed because the hydrogen storage demand will still be relatively low by 2030, but the investment decisions that need to be made regarding construction and conversion measures must be made around five years before commissioning. Otherwise, it may not be possible to provide hydrogen storage capacities by 2030 and for the following years, as well as to connect to hydrogen (sub)grids.

Figure 1 presents a roadmap with a potential targeted implementation roadmap to cover the hydrogen demand in 2030. The individual elements of this implementation roadmap will be discussed in more detail in the coming sections.

Figure 1: Hydrogen storage implementation roadmap 2030



[1] In addition to the whitepaper from 29 October 2021 'The role of underground gas storage units in the development of a hydrogen market in Germany'.

2 HYDROGEN STORAGE DEMAND 2030

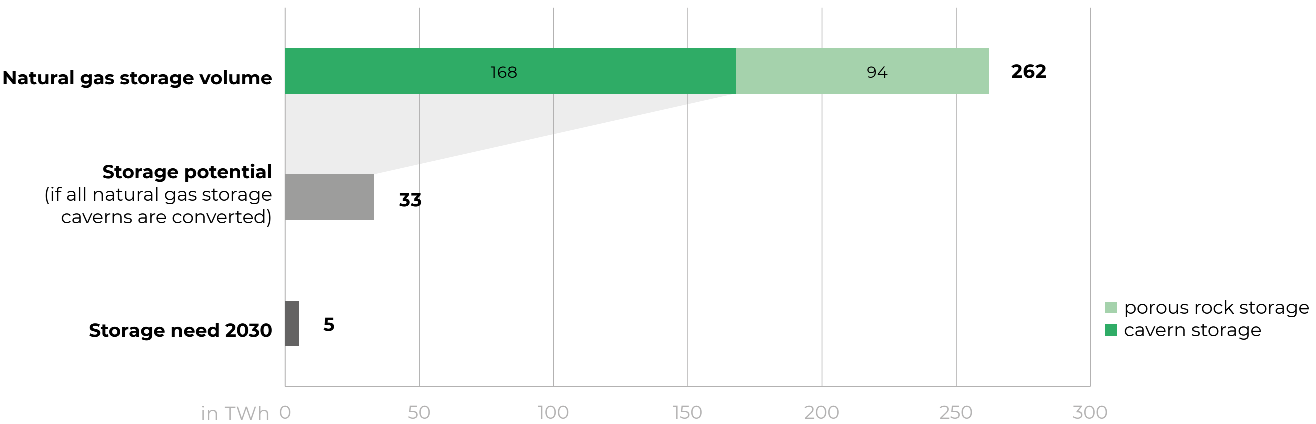
Based on the potential assessment of the German National Hydrogen Council's (Nationaler Wasserstoffrat, NWR) whitepaper 'The role of underground gas storage units in the development of a hydrogen market in Germany' from 29 October 2021[2] (hereinafter referred to as a storage whitepaper), storage demand in a range of 5 to 15 TWh for 2030 was determined for different hydrogen demand scenarios. This result was based on investigations of the load profiles of industrial hydrogen consumers in refineries and chemical parks[3].

This approach has also been confirmed by new studies, which assume a storage demand[4] of six per cent of the annual hydrogen demand for a model grid, depending on the structure of hydrogen production. The German Federal Ministry for Economic Affairs and Energy's (Bundesministerium für Wirtschaft und Energie, BMWi) long-term scenarios[5] 'TN-Strom' (in which greenhouse gas neutrality is achieved through large-scale electrification of the energy system) and 'TN-H_2-G' (in which greenhouse gas neutrality is achieved through large-scale use of green hydrogen) project the development of the required storage capacities in the hydrogen system. These scenarios show that a hydrogen storage demand of 1.8 TWh must be assumed for 2030 (or 47 to 73 TWh for 2050 in the long term).

FNB's[6] scenario planning for 2030 projects a hydrogen demand of 71 TWh. The demand includes the use of hydrogen for energy and material purposes. The National Hydrogen council's[7] new 'Hydrogen Action Plan Germany 2021–2025' indicates a hydrogen demand of 57 TWh (of which 35 per cent is green hydrogen) for the industrial sector (excluding refineries) for 2030 and of around 25 TWh in the mobility sector, with the majority being used directly in fuel cell electric drive forms.

Taking into account the studies and model calculations mentioned above, a hydrogen storage demand of at least 5 TWh by 2030 is therefore assumed using conservative estimates.

Figure 2: Hydrogen storage potential and storage demand 2030



2 https://www.wasserstoffrat.de/fileadmin/wasserstoffrat/media/Dokumente/EN/2021-10-29_NWR-Information_Paper_Hydrogen_Storage.pdf
3 The hydrogen storage demand was assumed to be around ten per cent of consumption. The hydrogen storage demand may also increase in microprojects during the market ramp-up.
4 https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2022/Hy3_Large-scale_Hydrogen_Production_from_Offshore_Wind_to_Decarbonise_the_Dutch_and_German_Industry.pdf.
The storage demand for the industrial and transport sector was also calculated as part of this; including the electricity generation sector could give rise to a higher storage demand (as a percentage of annual consumption).
5 https://enertile-explorer.isi.fraunhofer.de:8443/open-view/10039/42cfafd89c7aae605ddc28c9511098b7.
6 https://fnb-gas.de/wp-content/uploads/2021/09/210909_DE_FNB_GAS_2022_SR.pdf.
7 https://www.wasserstoffrat.de/fileadmin/wasserstoffrat/media/Dokumente/EN/2021-07-02_NWR-Hydrogen_Action_Plan.pdf

The development of a hydrogen infrastructure will vary from region to region. Hydrogen clusters are already emerging in regions, such as North Rhine-Westphalia, Central Germany and Lower Saxony in particular, that are home to energy-intensive production with limited potential for electrification, such as the steel or chemical industries. If these regionally restricted microgrids are connected to one another and demonstrate increasing market development, the demand for large-volume storage in a developing hydrogen grid will also grow.

The demand for storage will result from both the fact that wind and solar power, and with it the supply of green hydrogen, is weather-dependent, and that a continuous and secure availability of hydrogen is needed so that industry is able to purchase it.

Unlike pipe storage facilities or pressure vessels, converting underground caverns into hydrogen storage facilities has the advantage that they can provide large storage volumes while also providing a proportional cost benefit (economies of scale). Furthermore, the existing storage caverns are already firmly integrated into the gas grid and located close to consumer centres and can therefore be converted to store hydrogen as part of a coordinated hydrogen grid plan. Looking to the period of 2030 to 2050, considerable increases in the demand for hydrogen storage are also to be expected during this time. No other more cost-effective or similarly large-volume storage technologies are currently available compared to storage caverns.

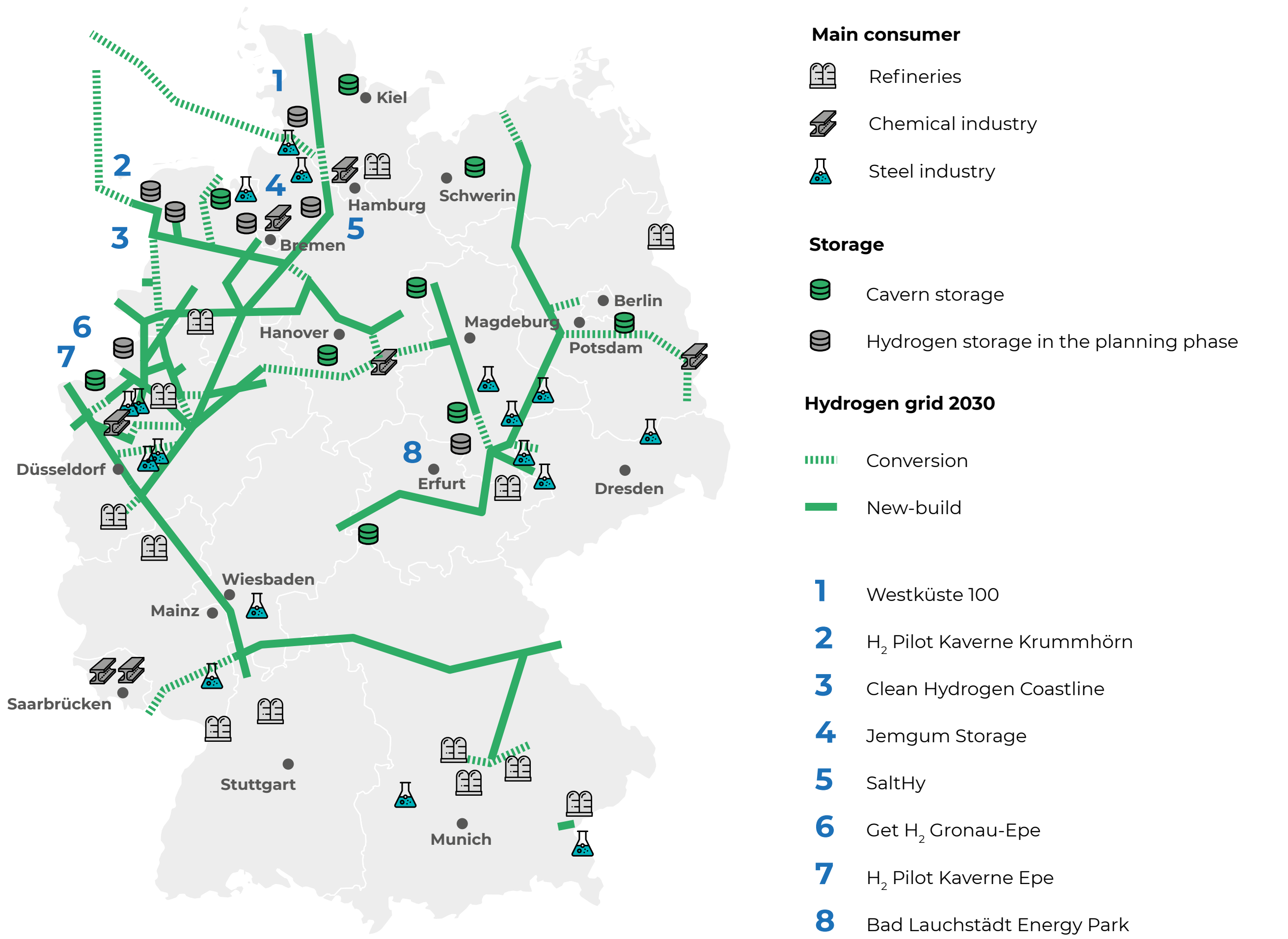
3 HYDROGEN STORAGE PILOT PROJECTS THAT HAVE BEEN ANNOUNCED UP TO 2030

The following pure hydrogen storage pilot projects have been announced by the energy industry, all of which are hydrogen cavern projects:

Table 1: Advantages and disadvantages of cavern and pore storage for hydrogen storage

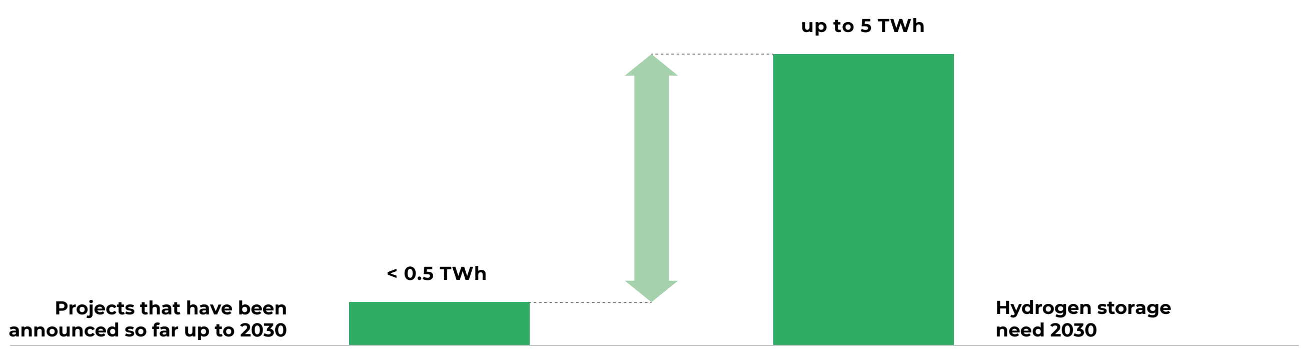
Name	Commissioned	Hydrogen storage volume in TWh	Companies involved
Westküste 100	2025	0.003	Hynamics Deutschland, Holcim Deutschland, OGE, Ørsted Deutschland, Raffinerie Heide, Stadtwerke Heide, Thüga and thyssenkrupp Industrial Solutions
HyCAVmobil	2022		EWE, DLR Institute of Networked Energy Systems
Clean Hydrogen Coastline	2025		EWE Gas Storage
Get H_2 Gronau-Epe	2027	0.067	RWE Gas Storage West
Bad Lauchstädt Energy Park	2028	0.177	Uniper, VNG Gasspeicher, ONTRAS, Terrawatt, DBI
H_2 Pilot Cavern Epe	2028	0.0007	Uniper Energy Storage GmbH
H_2 Pilot Cavern Krummhörn	2024	0.0007	Uniper Energy Storage GmbH
SaltHy	2030	0.001	Storengy Deutschland GmbH
Jemgum Storage	2030		astora GmbH
Total		**0.2494**	

Figure 3: 'FNB Gas' model of an interregional hydrogen grid including storage caverns and the hydrogen storage projects that have already been announced[8]



Comparing the hydrogen storage potential of the pilot projects that have already been published with the projected hydrogen storage demand of 5 TWh by 2030 reveals a significant gap in investment. For that reason, policymakers would need to establish support measures by the end of 2023 as a matter of urgency.

Figure 4: Gap between pilot projects that been announced and hydrogen storage demand 2030



[8] https://fnb-gas.de/wasserstoffnetz/h2-netz-2050/

4 SIDE NOTE: ASSESSMENT OF THE NATURAL GAS STORAGE DEMAND AND CAPACITY BY 2030

There is currently around 262 TWh of storage volume available across all of Germany's underground gas storage facilities. Of this, cavern storage accounts for 168 TWh (a share that will be reduced to 153 TWh by 2030 due to convergence) and porous rock storage accounts for 94 TWh. The natural gas demand for 2021 is 1,016 TWh. This results in a storage capacity of about 25 per cent of the total demand on the German natural gas market that is currently available.

The new statutory storage level requirements to be met by 2025 that came into force on 1 June 2022, the newly introduced licensing requirement for decommissioning gas storage facilities and the massive political efforts to reduce Europe's dependence on Russian imports suggest that the existing natural gas storage capacities will be needed for the most part to ensure security of supply on the natural gas market, at least until 2025.

Some forecasts[9] project a decrease of gas demand and the European Commission[10] recently adopted targets to reduce gas consumption by 15 per cent for 2023. This means that a reduction in storage requirements for the natural gas market synchronised with gas consumption can be expected from 2025 onwards. The EWI's[11] most recent model assumptions even assume a 40 per cent reduction in gas consumption by 2030 in one scenario. Under these assumptions, there would be sufficient potential to convert existing cavern storage facilities to hydrogen during this period: In the case of a 15 per cent reduction in gas consumption by 2030, converting natural gas storage facilities to hydrogen would result in the natural gas storage capacities available today being reduced by around ten per cent, if the conversion were made in the extent of the indicated hydrogen storage demand of 5 TWh – which corresponds to around 25 TWh of natural gas storage capacity. As a result of such a ten per cent reduction, there would still be sufficient storage capacities available for the reduced natural gas market to maintain today's security of supply level, even taking convergence in storage caverns into account. However, the potential of the caverns that are available for conversion to hydrogen throughout the regions is heavily reliant on the following factors: the shape that the political requirements to secure the supply of natural gas in Germany and the EU take, and these requirements continuing to be enforced. Should policymakers decide to increase the requirements to secure the supply of natural gas, this might lead to a conflict of objectives arising between maintaining the existing cavern storage facilities in order to secure the natural gas supply on the one hand and converting them to hydrogen storage on the other. It might also require new caverns to be built to store hydrogen.

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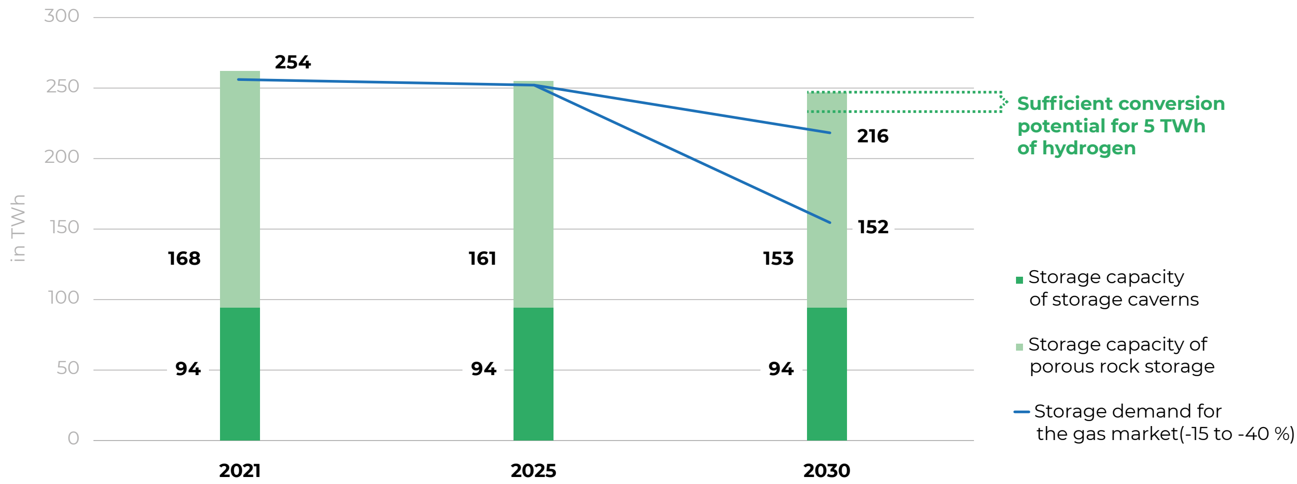
[9] https://fnb-gas.de/wp-content/uploads/2021/09/210909_DE_FNB_GAS_2022_SR.pdf; https://www.langfristszenarien.de/enertile-explorer-de/dokumente/.

[10] EU REGULATION on coordinated demand-reduction measures for gas dated 10 August 2022.

[11] EWI expert report: 'Scenarios for the price development of energy sources', on behalf of the 'Energy systems of the future' [Energiesysteme der Zukunft] (ESYS) academy project, July 2022.

Figure 5: Natural gas storage demand and potential hydrogen storage by 2030 in TWh[12]



For the period after 2030, it is expected that the storage demand will also decrease further as a result of the declining demand for natural gas and the fact that caverns which are no longer needed for the natural gas market will be available to be converted to store hydrogen.

5 TIMEFRAME AND COST ESTIMATE FOR CONVERTING EXISTING GAS STORAGE FACILITIES INTO HYDROGEN STORAGE FACILITIES

The mandated approval procedures as well as the work required to upgrade the aboveground facilities and the underground caverns must be taken into account for conversion of natural gas storage facilities to hydrogen. The time required for the underground work varies depending on the size of the caverns. As already stated in the hydrogen storage whitepaper, the time required to convert an existing cavern is around five years. This is also the same for caverns that are currently being used to store other media such as oil and can be converted.

If no caverns are available for the construction of a new hydrogen storage facility, the time required for construction of the new storage facility will be around five years longer.

The numbers presented here show the lead times that have to be taken into account until such time as a hydrogen storage infrastructure is online. This means that in any event, any decision on whether to invest needs to be made before 2025 in order to meet the hydrogen storage demand on 5 TWh by 2030.

Experience from initial pilot projects shows that the conversion costs for storage of all hydrogen in existing underground storage facilities make up at least 30 per cent of the new investment costs for a gas storage cavern. Extrapolated to include all existing gas storage caverns in Germany, this would require an investment of at least €6.5 billion from now until 2030 in order to convert the facilities for hydrogen storage. A new study by DBI[13] uses a theoretical model storage facility to calculate a lower investment

[12] It is necessary to take into account that hydrogen has a) a lower volume-based energy density and b) different compression characteristics than natural gas when comparing the energy quantities for hydrogen and natural gas. In other words, hydrogen has only 20 per cent of the energy content of the same amount of natural gas.

[13] DBI, June 2022: Transformation trajectories for gas storage facilities. https://erdgasspeicher.de/wp-content/uploads/2022/06/20220617_DBI-Studie_Wasserstoff-speichern-soviel-ist-sicher.pdf.

requirement[14]. With regard to the operation of hydrogen storage facilities, the cost of electricity to run the compressor units used to store quantities of hydrogen represents a major portion of the operating costs incurred (a one-off amount of around 100,000 MWh of electricity will most likely be required to store/compress 5 TWh of hydrogen). These figures therefore make it clear that substantial funding volumes will be needed to provide appropriate investment incentives to convert or build new hydrogen cavern storage facilities and operate them.

6 SECURITY OF SUPPLY IN THE HYDROGEN MARKET

Based on current expectations, the majority of hydrogen during the market ramp-up phase and after 2030 will be covered by imports. Therefore, to ensure the security of supply and on strategic grounds with regard to the market development as well, it will be necessary to set up large-volume storage facilities close to the centres of hydrogen consumption across Germany. It may also be possible to integrate them into a cross-regional hydrogen grid infrastructure. To ensure security of supply in the hydrogen market, preference must be given to market-based hedging instruments such as putting strategic storage options out to tender (as was also recently introduced for the natural gas market in addition to filling level requirements) over regulatory interventions such as establishing a strategic reserve for hydrogen. This reason for this is that the urgently needed investments in commercially operated hydrogen storage facilities might fail to materialise as a result of the expected market distortions that would come with a strategic reserve created by the state.

7 PROPOSALS TO ACCELERATE THE RAMP-UP OF HYDROGEN PRODUCTION AND THE GRID AND STORAGE INFRASTRUCTURE

Based on the regulatory recommendations set out in the National Hydrogen Council's storage whitepaper, priority should be given to implementing the following measures immediately:

Measures to be implemented before 2024 (incentives for investment decisions)

- Increase the amount of financial support available in the form of CAPEX and OPEX-related funding programmes for converting existing caverns and building new hydrogen storage facilities
- Shorten the amount of time approval procedures require (in the same way as was achieved with the German LNG Acceleration Act (LNG-Beschleunigungsgesetz)) by including regulations on hydrogen in the German Ordinance on the Environmental Impact Assessment of Mining Operations (Verordnung über die Umweltverträglichkeitsprüfung bergbaulicher Vorhaben, 'UVP-V Bergbau'), for example. In addition, extending the general operating plans already approved for natural gas storage in abridged, expedited procedures – and not in the form of new procedures – would be appropriate for hydrogen storage
- Create a temporary exemption for pilot plants which guarantees the cushion gas that will remain in the storage facility in the long term does not have to be provided exclusively from green hydrogen if sufficient green hydrogen is not available by 2030
- Introduce a regulatory framework for hydrogen storage projects to create a regulation and access regime that incentivises investments

[14] The investment figures presented in the DBI study do not take into account some elements – such as costs for construction work, land treatment, noise protection, rights of way, cavern rights, sites, personnel and so on – which have a significant impact on the total costs.

Measures to be implemented before 2030 – Checking regulatory incentives and taking into account the system value of hydrogen storage

- An exemption from the imposition of entry/exit fees and surcharges on the connected hydrogen grid for the use of hydrogen storage facilities in order to balance out the system value of the storage facilities to optimise the entire hydrogen value chain
- An exemption from electricity grid fees for the green power consumed for storage, as the cost of electricity to run the compressor units used to store quantities of hydrogen represents a major portion of the operating costs incurred

If you are interested in finding out more or have any questions, please contact:
Hydrogen Coordination Office (Leitstelle Wasserstoff)
E-mail: info@leitstelle-nws.de
Website: www.wasserstoffrat.de/en

H2 NATIONALER WASSERSTOFFRAT

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.

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