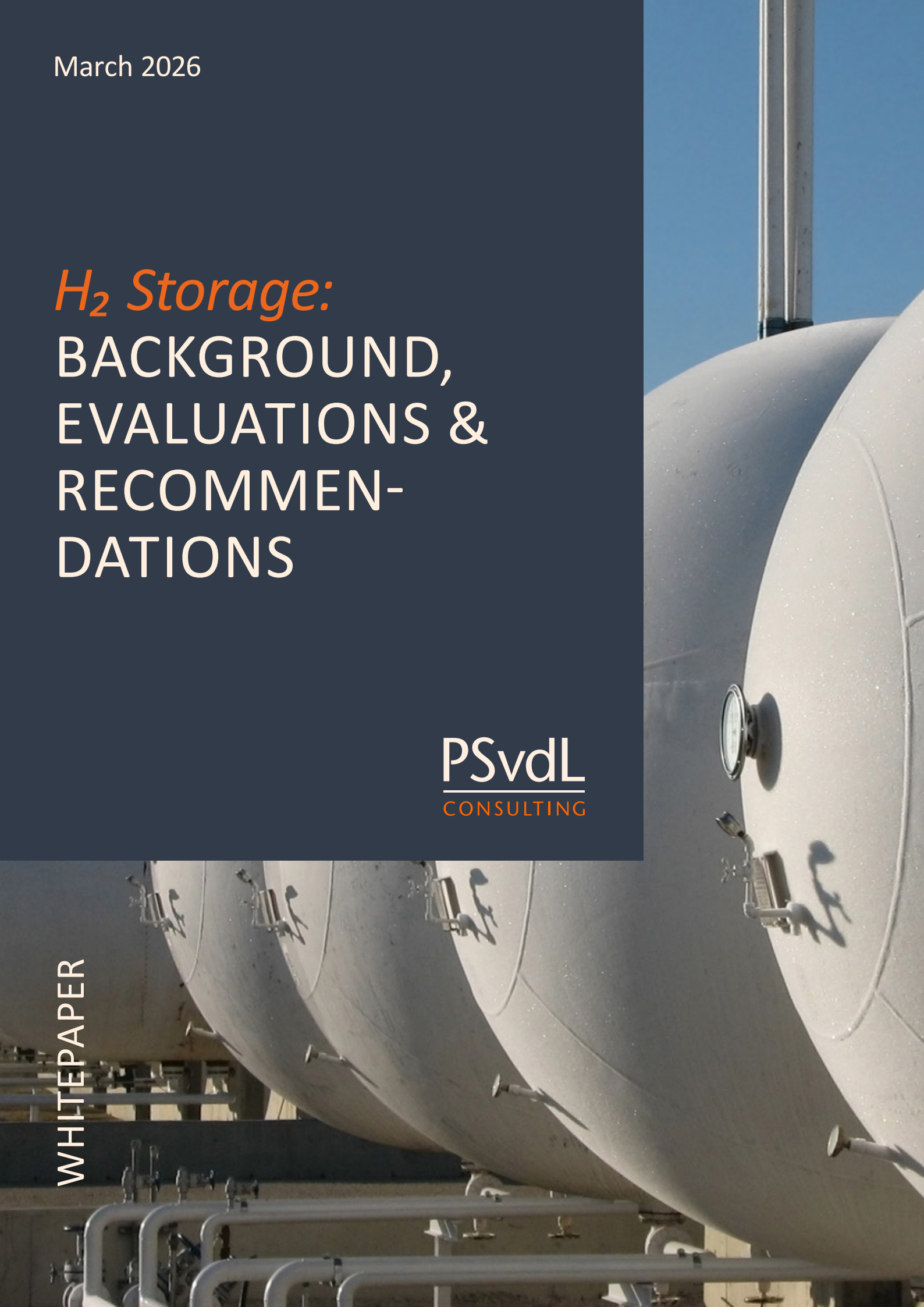


March 2026

H₂ Storage:
BACKGROUND,
EVALUATIONS &
RECOMMEN-
DATIONS

PSvdL
CONSULTING

WHITEPAPER



About PSvdL

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Introduction

The ramp-up of hydrogen in Germany requires addressing key challenges: the provision of sufficient quantities at competitive prices, the development of infrastructure, and the use of hydrogen by first anchor customers. The initial hydrogen euphoria has noticeably subsided in recent months, and many discussions with market participants are increasingly characterised by scepticism. They expect hydrogen to be more expensive in the long term than predicted in earlier scenarios. Accordingly, there are increasing reports of projects being put on hold and subsidies being rejected. The monitoring report on the energy transition published by the Federal Ministry for Economic Affairs and Energy (BMWE) on 15 September 2025, also announces a more cost-efficient approach to the ramp-up of hydrogen.

Nevertheless, there are also positive signs: the development of the H₂ core network is gaining momentum, many project developers are reserving initial capacities, and the first storage capacities and transport contracts are being marketed. Since a functioning market requires reliable transport and storage capacities, rapid expansion steps are crucial for the connectivity of potential customers who want to invest in new hydrogen technology.

Infrastructure development: Progress on the transport network, question marks over storage facilities

The H₂ core network is an important pillar currently being developed. Thanks to the financing mechanism implemented through the amortisation account and the WaKandA and WasABi regulations of the Federal Network Agency (BNetzA), the financial and regulatory framework for the development of a national transport network has largely been defined. Many operators have already begun the physical construction or conversion of their pipelines. When it comes to storage expansion, however, the picture is diffe-

rent: although the need for H₂ storage is generally recognized, there is a lack of concrete support programmes and clear market rules. Given construction times that can exceed a decade in some cases and foreseeable storage requirements from 2030 onwards, this raises the question of how urgently needed storage capacities can be realized in time. There is a risk that an insufficient supply of storage facilities will slow down the development of the hydrogen market, as many players will postpone their investment decisions without security of supply and system flexibility.

The white paper on H₂ storage published by the BMWE in April 2025 addresses this issue. However, despite a comprehensive analysis of the current market situation, it contains hardly any concrete recommendations for action.

The PSvdL white paper creates transparency and derives recommendations for action

Against this background, this white paper on H₂ storage was created. It is based on around 20 interviews with relevant market players, primarily storage and network operators, who were asked questions based on the same structured set of topics. Based on the interview statements, the white paper describes and discusses the different ideas along the hydrogen value chain regarding the necessity, target vision, and financing of H₂ storage. The aim of the white paper is to provide relevant industry representatives, legislators, and regulators with a transparent market overview of the various perspectives and requirements and to highlight recommendations for action for the development of H₂ storage facilities.

Figures, Data and Facts

CALORIFIC VALUES

Natural gas (H-gas)

approx. 10–13,1 kWh/m³

Hydrogen

3,54 kWh/m³ (at the same quantity of energy, this results in approx. four times the storage volume compared to natural gas)

CAVERN GAS STORAGE

Currently used sites with cavern storage

29 (mainly in north-western and central Germany)

Storage capacity in Germany

155 TWh

Assessment compared to porous storage

- Smaller geological volumes
- Faster injection and withdrawal rates
- Lower purification requirements

Cushion gas requirement

20–40 % of total filling

POROUS GAS STORAGE

Currently used sites with porous storage

14 (across Germany)

Storage capacity in Germany

95 TWh

Assessment compared to cavern storage

- Larger geological volumes
- Slower injection and withdrawal rates
- Higher purification requirements

Cushion gas requirement

50–80 % of total filling

DEVELOPMENT OF HYDROGEN STORAGE CAPACITIES

Required storage capacities in 2045

32 to 80 TWh (BMWE) / 94 TWh (DVGW)

Conversion of existing cavern storage

Up to 36 TWh (approx. 31 TWh from natural gas caverns and approx. 5 TWh from crude oil caverns)

Technical potential for new cavern construction

4.090 to 11.000 TWh

Conversion of existing porous storage

(assuming technical maturity is achieved)

Theoretically up to 20 TWh (DVGW) / 29 TWh (BMWE)

Technical potential for new porous storage construction

3.200 to 27.300 TWh

01.

Relevance of H₂ Storage

H₂ storage makes a significant contribution to the decarbonisation of the future energy system by enhancing both flexibility and security of supply. They enable the use of surplus renewable energy through systemic flexibility and form a key interface for sector coupling. In addition, they can reduce import dependency by storing energy for months and releasing it during periods of high consumption. However, their expansion requires close coordination with the development of the transport network in order to reduce system costs and further increase supply reliability.

According to current scenarios from the BMW white paper, storage requirements will range between 2 and 7 TWh by 2030, rising to between 32 and 80 TWh by 2045. The main driver for this is the use of hydrogen in power plants for reconversion into electricity and in industry. Across Europe, storage requirements of up to 161 TWh are forecast by 2050.

Central role in the hydrogen ramp-up

According to the majority of interviewees, H₂ storage is essential for the success of the planned hydrogen ramp-up, as without it, sufficient security of supply cannot be achieved. For many end users, a switch to hydrogen is only possible with a stable supply guaranteed.

»Security of supply is a basic requirement for our customers to consider switching to hydrogen.«*

During the ramp-up phase in particular, there will be a gap between fluctuating production and feed-in of green hydrogen and the more consistent demand and corresponding discharge of early end users, which must be closed by both the buffer of the transport infrastructure, and by appropriate storage capacities. Increased use of blue hydrogen could reduce the need for storage flexibility due to its constant production profile, while flexible blending of hydrogen with natural gas in combustion processes may also be feasible in certain cases without direct H₂ storage integration. As ramp-up progresses, seasonal demand trends are expected to become increasingly decisive for the required storage capacities. H₂-powered combined heat and power plants (CHP) and power plants are considered the main drivers in this regard.

*Analogous statement from a sector representative

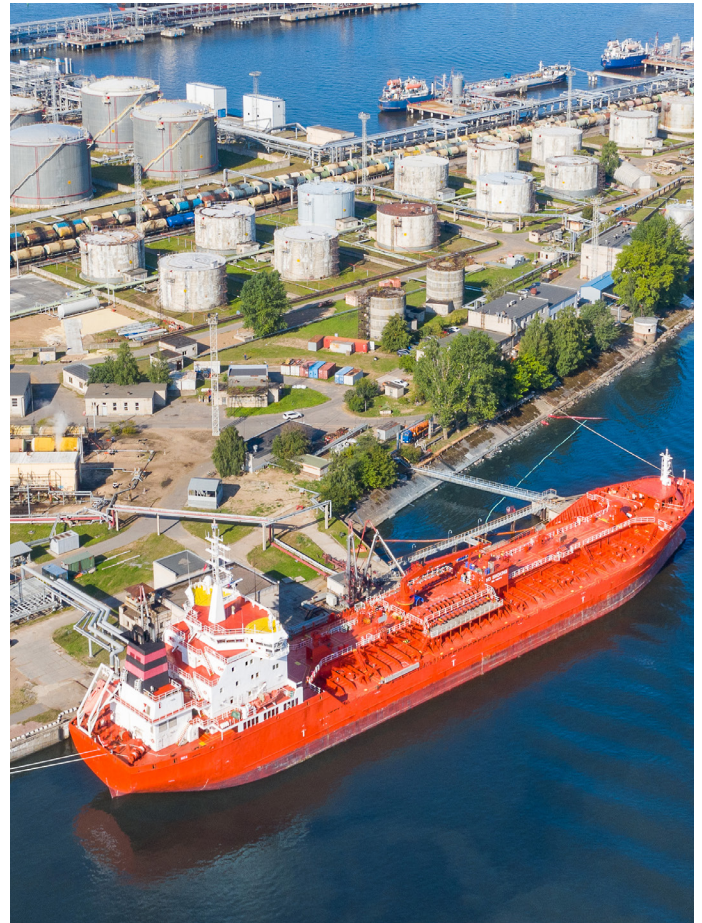
Realistic demand tends to be at the lower end of the scenarios

According to several interviewees, actual storage demand is likely to be at the lower end of the range indicated in the scenarios. Among other things, they cite a slower ramp-up of hydrogen than had been assumed one to two years ago. In addition, hydrogen derivatives are likely to play a greater role than had been taken into account in previous forecasts.

The interviews repeatedly emphasized that industry, CHP plants, and H₂ power plants are considered the main drivers of storage demand. For the electricity sector, it was emphasized that H₂ power plants and storage facilities should be planned in close coordination to ensure reliable schedules and continuous supply. A consistent H₂-ready power plant strategy could thus contribute to better demand planning and favour decisions to invest in storage.

It remains to be seen what impact the German government's agreement on the power plant strategy of 14 November 2025, will have. This provides for a request for proposal for 10 to 12 GW of gas-fired power plants starting in 2026, of which at least 8 GW will be H₂-ready. Originally, according to the coalition agreement, the proposal was planned for 20 GW with a technology-neutral and market-based capacity mechanism that had not yet been defined in detail.

»Large storage facilities are needed at central locations and north-south distribution must also be taken into account.«*



Desire for closer coordination in the development of network and storage infrastructure

Political attention has so far focused on the H₂ core network. The majority of participating transport network and storage infrastructure operators would also like to see spatially and time-coordinated cooperation between market players for the development of the necessary storage facilities.

There is broad consensus that network and storage infrastructure must be considered and implemented together. A total of twelve H₂ storage projects is already included in the approved H₂ core network. If storage facilities do not go into operation, interviewees noted that flexibility and the necessary capacity in peak load scenarios must be compensated for by additional transport infrastructure between northern and southern Germany, among other places.

*Analogous statement from a sector representative

02.

Development of H₂ Storage

Hydrogen can be stored underground using salt cavern storage and porous storage:

- **Salt caverns** are created by artificially hollowing out deep salt domes or layers. Their very low permeability and long-term stability make them suitable for use as pressure-resistant underground storage facilities. The geological conditions for this are particularly favourable in northern and central Germany. In Germany, around 29 sites are currently used for cavern storage of natural gas.

- **Porous storage facilities** store gas in the pore space of porous storage rock (e.g. sandstone) under an impermeable cap rock. There are currently around 14 natural gas porous storage facilities in operation in Germany, mainly in southern Germany.

Both technologies are established in the natural gas sector. Salt caverns are currently considered more technologically mature for hydrogen storage, but porous storage has also been successfully tested in pilot projects. Alternatively, above-ground pressure or liquid hydrogen storage facilities enable decentralised and rapidly available supply, but are more suitable for short- to medium-term applications due to their lower energy density.

»Since the framework conditions are not right, construction of H₂ storage facilities cannot begin.«*

Both repurposing and new construction of storage facilities are necessary

Storage operators are faced with the challenge of preparing for a future with lower natural gas storage demand and increasing H₂ storage demand while meeting current natural gas storage needs. This requires comprehensive planning for the transition from natural gas to hydrogen.

The current competition for use also leads to regulatory obstacles: operators of natural gas storage facilities are obliged to notify the Federal Network Agency regarding the decommissioning or shutdown of a natural gas storage facility at least twelve months in advance and to justify their decision. The Hydrogen Acceleration Act passed by the Federal Cabinet of Germany in November 2025 aims to remove these obstacles – if the final bill is passed, a notification period of six months will suffice, while the Federal Network Agency will have four months to raise any objections.

*Analogous statement from a sector representative

However, even if all current natural gas storage facilities were theoretically repurposed for hydrogen, additional new construction would be necessary due to the lower energy density. Repurposing usually requires new above-ground facilities and, according to the interviewees, takes about four to seven years. The construction of a new cavern with existing above-ground infrastructure (brownfield approach) takes around six to ten years; a completely new construction (greenfield approach) usually exceeds ten years of planning and construction time.

Demand risk inhibits expansion of storage capacity

Discussions with market players have made it clear that the construction of storage facilities is being hampered by the uncertain market situation. First and foremost, capacity contracts with customers are needed to drive forward the financing, planning and construction of storage facilities. However, there is a lack of certainty in the market as to when large, economically viable quantities of hydrogen will be available.

Due to the combination of pending financing decisions, a lack of a financing framework and

long construction and conversion times, there is a real risk that the ramp-up of hydrogen will be slowed down by a lack of storage facilities. (> see also chapter on financing).

Hydrogen quality as a topic of discussion

The required purity of stored hydrogen poses another challenge. The desired purity levels of 99.97 % (e.g. for industrial applications) can only be achieved by storage operators at increased purification costs. Storage operators are therefore advocating decentralised purification at the consumer end, provided that particularly pure hydrogen is required there. In combustion processes, however, a hydrogen quality of 98 % is usually sufficient. Whether centralised processing of larger quantities or several decentralised plants are more economical is still open at this stage.

»In many respects, repurposing and new construction are quite similar; both typically require new above-ground facilities.«*



*Analogous statement from a sector representative

03.

Regulatory Framework

Underground storage facilities in salt caverns or pore reservoirs are subject to the Federal Mining Act (BBergG). Operators require valid operating plans, which may necessitate an environmental impact assessment depending on their scope. In this case, a planning approval procedure involving comprehensive public authority participation must be completed. The repurposing of existing natural gas storage facilities into H₂ storage facilities also generally triggers a permit requirement; under mining law, a new operating plan must be issued. The amendment to the BBergG passed on 22 December 2025 sets a two-year deadline for the approval of underground H₂ storage facilities, thereby accelerating their implementation.

The planned Hydrogen Acceleration Act, introduced in the German Bundestag on 3 November 2025, is intended to significantly simplify approval procedures for the entire H₂ value chain. Particularly relevant for the expansion of H₂ storage facilities is the fact that storage facilities with a capacity of 25 tonnes or more (equivalent to around 1 GWh) are now included in the accelerated procedure. The authorities must issue approvals within shorter deadlines and the procedures themselves must be handled entirely digitally.

The Act also classifies hydrogen projects as projects of 'public interest', which gives them greater weight in balancing decisions. Projects may no longer be delayed without further ado by suspen-

sive objections, as appeals and actions for annulment do not have automatic suspensive effect.

The specific details of the fee regulation for H₂ storage are currently still being clarified. Although the upcoming implementation of EU Directive 2024/1788 in the Energy Industry Act (EnWG) provides for non-discriminatory access to large H₂ storage facilities, the Federal Network Agency is currently pursuing a largely competitive approach. In doing so, it would primarily establish the methodological basis for price determination without, however, establishing a strict cap on revenues (e.g. in the form of a revenue cap regulation).

Potential for speeding up approvals

Many interviewees pointed out that the level of digitalisation in the approval authorities is insufficient. There are reports of both positive and negative experiences with approval practices, with differences between individual authorities and projects.

One concern that was repeatedly mentioned is the need to rethink and, if necessary, simplify the environmental impact assessment required for the repurposing of natural gas storage facilities.

»Greater pragmatism from the authorities would be welcome given the challenges of approving hydrogen storage facilities.«*

Other suggestions are based on positive experiences with the approval of LNG terminals, in particular close cooperation between authorities, project developers, and clearly designated contact persons to speed up approval processes. It now remains to be seen whether the Hydrogen Acceleration Act can have the intended effect on the challenges it addresses.

Lack of technical regulations complicates approvals

The approval authorities are faced with the task of issuing storage approvals quickly, while at the same time crucial technical regulations are lacking. According to market players, this sometimes makes it difficult for the authorities to make legally sound decisions. In addition to the need for regulations, it is emphasised that testing and certification requirements must not be overly complex, time-consuming or costly.



*Analogous statement from a sector representative

04.

Economics & Financing

Investment decisions for H₂ storage facilities are currently hampered by insufficient hydrogen demand and unclear market prospects. The appropriate level of government intervention must be weighed up in order to bridge volume and price risks. Against this backdrop, the German Energy Agency (July 2024 on behalf of the BMWK) and Frontier Economics (August 2024 on behalf of the BDEW) have compared various financing models.

These models are evaluated in the BMWK white paper published under the previous federal government. The promotion of hydrogen demand is prioritised as a key measure to create planning security for storage projects through increased demand.

Demand support

Indirect support through support of hydrogen consumers

- Volume and price risks are indirectly reduced
- Facilitates competitive structures among H₂ storage

Amortisation or balancing account

Financing via a loan or similar instrument, whereby the account can be balanced through a levy or regulated charges. The state assumes subsidiary coverage of the deficit.

- De-risking measure to improve bankability
- Less suitable than for the core network due to the competitive environment

Revenue-based Contracts for Difference (CfD)

Usage-independent, fixed minimum revenue guaranteed by the state

- Compensation for volume and price risks
- High effectiveness, efficiency and flexibility

»For storage funding, electricity market mechanisms of power plants or offshore wind offer valuable lessons: Revenue based CfD are often used«*

Market players call for financing model for H₂ storage

The market players interviewed report that the available studies on the financing gap for storage contain overly optimistic expectations regarding the ramp-up of hydrogen: On the one hand, it was assumed that the prices achievable for storage operators would cover costs, and on the other hand, the ramp-up was set too early.

Investments in H₂ storage currently appear unattractive, both in terms of equity and investors. On the one hand, it is unclear what revenues can be achieved from the feed-in and discharge of hydrogen, and on the other hand, it remains unclear when and what quantities of hydrogen will be available on the market. From the perspective of storage operators, increased investment in storage is only to be expected once the price and volume risk has been mitigated by a targeted financing model.

Various financing instruments conceivable, revenue-based contracts for differences preferred

Both in the current studies and in discussions with market players, various options for addressing the financing gap are being discussed. The demand promotion favoured by the BMW in the previous government's white paper, alongside an otherwise purely market-based mechanism, is welcomed in principle by market players, but is considered insufficient on its own.

This means that it will be difficult to achieve a sufficiently high willingness to pay over a long period of time.

Some interviewees consider an amortisation account similar to the H₂ core network to be effective. However, due to the high costs involved, it is considered politically undesirable and therefore unlikely to be implemented.

Revenue-based contracts for difference (CfD) are viewed positively by a large majority for the period in which storage operators are not yet able to generate cost-covering revenues. The use of CfD could be limited to a minimum storage capacity requirement derived from studies. A tendering mechanism would create an effective and efficient instrument for developing the hydrogen infrastructure, enabling positive investment decisions.

More flexibility desired within IPCEI and PCI funding

The existing funding mechanism for IPCEI and PCI projects is generally considered helpful for the ramp-up of hydrogen. At the same time, some interviewees would like to see a more flexible and faster implementation of the funding mechanism. Technical and economic uncertainties that lead to changes in project conditions are difficult to reflect under IPCEI. In addition, individual requirements – such as green cushion gas for the initial filling of underground storage facilities – are considered questionable or difficult to implement. Faster funding approvals are also mentioned as an important starting point for improvements.

*Analogous statement from a sector representative

05.

Conclusions & Recommendations for the Successful Integration of H₂ Storage

1. Establishment of a financing model for H₂ storage

The communicated relevance of storage is not currently reflected in the incentive mechanisms. According to current estimates, the previous political requirement to focus on promoting demand will not be sufficient on its own to solve the chicken-and-egg problem. The existing volume, price and timing risks require targeted mitigation through appropriate support instruments. Discussions have revealed that revenue-based CfD for a tendered minimum storage capacity

are the preferred option. Improvements to the existing support mechanisms are also desired. In order to build up H₂ storage capacities, IPCEI and PCI funding requires greater flexibility and faster implementation for quicker approval, planning and realisation of the funded projects.

2. Holistic planning of H₂ infrastructure to ensure security of supply

The majority of interviewees are in favour of closer cooperation between the relevant stakeholders in the hydrogen market in order to enable the pragmatic implementation of storage expansion. Coordinated planning of pipelines, storage facilities and future large-scale consumers (e.g. industry and H₂ power plants) can increase both security of supply and the effectiveness and efficiency of processes. This requires a transparent view of demand and willingness to pay over time.

In particular, security of supply can only be achieved through the joint efforts of all market players.

Since the liberalisation of the gas market, there has been no clear division of responsibilities, meaning that storage operators, network operators and traders are all considered responsible to varying degrees. Cooperation can be intensified through regulatory incentives, associations or discussions between individual players. Some interviewees positively emphasise that they have already stepped up exchanges with geographically connected players and are continuing to deepen these.

3. Utilising regulatory potential

Potential for regulatory improvement in the development of H₂ storage infrastructure is seen in particular in the speed of operational plan approvals. Reducing complexity and improving the resources available to the authorities would be helpful in this regard. In addition, market players would like to see uniform technical regulations; the lack of such regulations further delays the approval processes.

In order to generate more demand for storage capacity, many market players are calling for a

reduction in regulatory requirements for green hydrogen, as these contribute to the current uneconomical price of hydrogen. Increased use of blue hydrogen is also seen as a way to accelerate the ramp-up of hydrogen and thus enable the development of H₂ storage infrastructure. The recently published update to the power plant strategy could be counterproductive: with less capacity being tendered and no fixed date for the switch to hydrogen, no positive market signal for the development of H₂ storage facilities is to be expected.

Interview Participants

The white paper is based on approximately 20 interviews with relevant market players. We would like to thank all the companies and experts who contributed. Without their professional expertise and commitment, this result would not have been possible.

Among others, the following companies participated in the white paper:

- **bayernets GmbH**

- **Equinor ASA**

- **EWE Gasspeicher GmbH**

- **Ferngas Netzgesellschaft mbH**

- **GASCADE Gastransport GmbH**

- **Gastransport Nord GmbH**

- **MET Germany GmbH**

- **SEFE Energy GmbH**

- **STORAG ETZEL GmbH**

- **Storengy Deutschland GmbH**

- **terranets bw GmbH**

- **Thyssengas GmbH**

- **Uniper Energy Storage GmbH**

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