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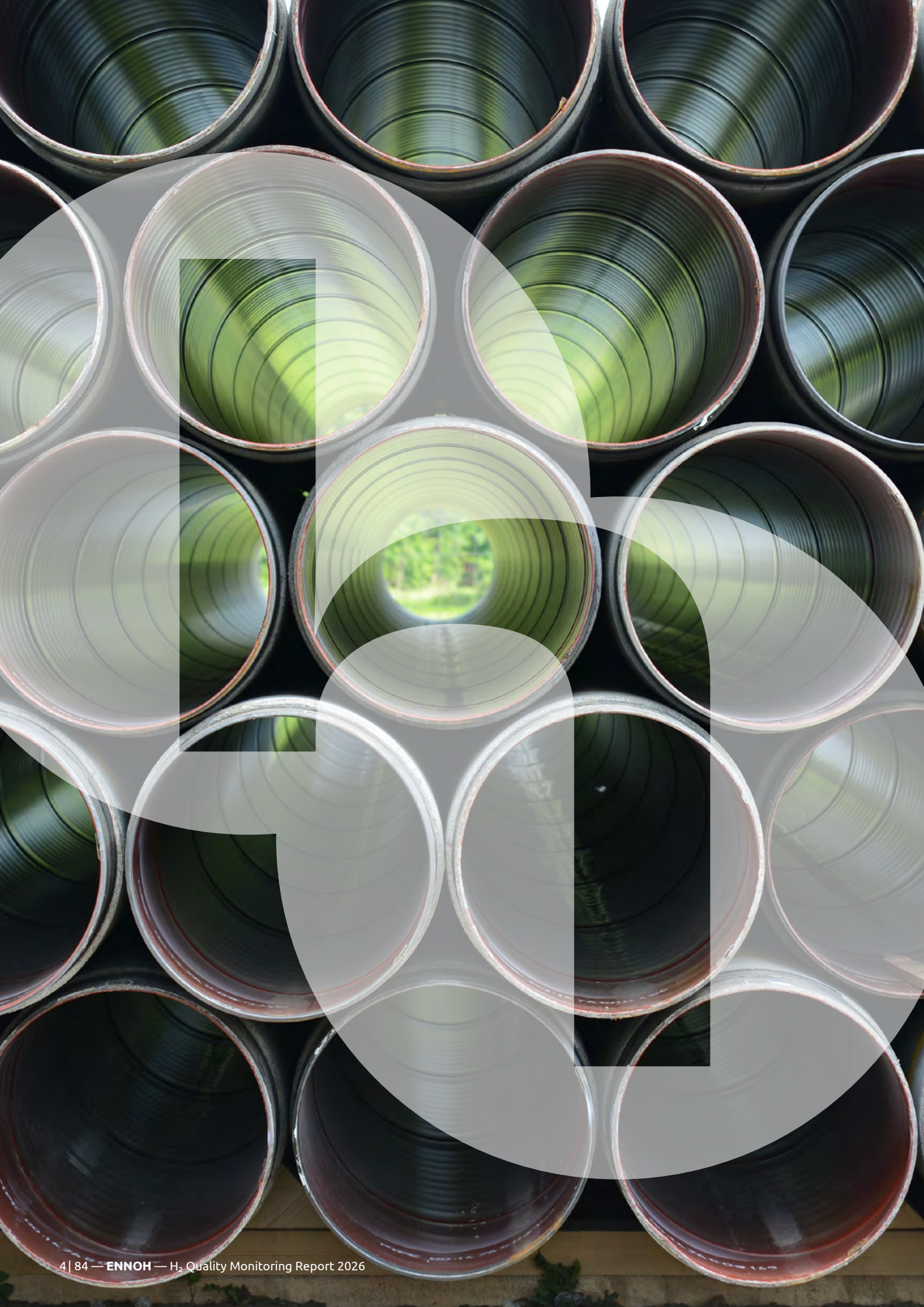
H₂ Quality Monitoring Report 2026



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1 INTRODUCTION/ REGULATORY FRAMEWORK

Article 59 of the Regulation (EU) 2024/1789 on the internal markets for renewable gas, natural gas and hydrogen (hereinafter “Regulation (EU) 2024/1789”) tasks ENNOH with “adopt a hydrogen quality monitoring report and every 2 years thereafter, including developments and forecasts for the expected developments of hydrogen quality parameters, as well as information on cases related to differences in hydrogen quality specifications and how such cases were settled”.

This report is the first one and collects the most recent information available on that topic, including references on recent studies or work conducted by DG ENER¹, Eassee-Gas², as well as GIE³. It includes also a compilation and a synthesis of the material and events related to the public consultation, which was organised from 30 January to 30 March 2026. A workshop was held on 12 February 2026 in the framework of the public consultation.

Hydrogen networks in Europe are currently still structured as isolated clusters, which should be interconnected through a European backbone in the upcoming years. Hydrogen flows are therefore confined to limited areas, rendering any forecast modelling pointless. However, it is important to have today hydrogen quality specifications as close as possible in Europe in order to facilitate the achievement of a unified pan-European quality specification target. In addition, Article 50 of the Directive (EU) 2024/1788 on common rules for the internal markets for renewable gas, natural gas and hydrogen (hereinafter “Directive (EU) 2024/1788”) tasks hydrogen network operators (HNOs) to be responsible for providing to the operator of other networks or systems with which its system is interconnected sufficient information, including on hydrogen quality, to ensure the secure and efficient operation, coordinated development and interoperability of the interconnected system. Achieving at an early stage a unified set of specifications could therefore contribute to the establishment of relevant, robust and enduring interoperability rules to be enacted in the upcoming Network Code on Interoperability and Data Exchange.

As per Article 2 of the Directive (EU) 2024/1788, hydrogen quality is defined as “hydrogen purity and contaminants in line with applicable hydrogen quality standards for the hydrogen system”. This report considers how to tackle and concile purity level and contaminants thresholds issues, particularly in light of the work carried out by the Gas Quality Working Group of the CEN/CENELEC (Technical Committee 234).

EU DSO entity shall provide input to ENNOH for the hydrogen quality monitoring report to be adopted pursuant to Article 59(1), point (j), of the Regulation (EU) 2024/1789 with regard to the hydrogen distribution networks where HDNOs are responsible for hydrogen quality management pursuant to Article 50 of the Directive (EU) 2024/1788. This association will be able to provide its input during the preparation of the second report, mandated for 2028.

1 DG ENER study on hydrogen quality in dedicated infrastructure and standardisation, published in October 2025. This study was conducted by Trinomics B.V. in association with Ludwig-Bölkow-Systemtechnik GmbH, DNV Netherlands B.V. and DBI Gas- und Umwelttechnik GmbH.

2 EASEE-GAS study conducted by Kiwa Technology and DNV on the optimum hydrogen purity in Europe.

3 Position paper of GIE on Hydrogen Quality Specifications.



2 PUBLIC CONSULTATION FEEDBACK

A public consultation took place from 30 January to 30 March 2026, and a workshop was held on 12 February. All the responses to the consultation, as well as the material presented at the workshop, are provided in the annexes

II and III to this report. Annex I includes a summary of the points raised by the stakeholders for each question, together with comments from ENNOH.

Responses to the public consultation were received from the following stakeholders:

- | | | | |
|-----------------------|--------------------|------------|---|
| – BVEG | – SEFE Storage | – Gasgrid | – Swissgas/Transitgas/FluxSwiss |
| – Gas Connect Austria | – NaTran | – Europex | – Frontier Economics (on behalf of H2eart for Europe) |
| – GNI | – BDH | – GIE | – RAG Austria AG |
| – Engie | – ÖVGW | – Gasunie | – Nordion Energi H2 AB |
| – IFIEC | – Open Grid Europe | – Storengy | |
| – EIGA | – Italgas | – bp | |
| – ENTSG | – Marcogaz | – DVGW | |

2.1 General principles raised

Various opinions have been expressed on the main purpose, as well as on the most important topic to be considered regarding hydrogen quality.

We can mention the following key points identified:

- **Need for establishing representative standards:** technical specifications regarding hydrogen transported through pipelines should be framed by the establishment of **representative European standards**.
- **Monitoring needs:** monitoring quality data is at the heart of the hydrogen value-chain in terms of operation strategy. It appears in particular that contaminants' contents **should be monitored as soon as possible** in a transparent and reliable manner.
- **Safety:** EIGA raised this point by focusing on oxygen ingress. More generally, contaminants' thresholds specifications should take into account safety requirements.
- **Repurposing:** this is pointed out by ENTSG, which considers that repurposed pipelines are not a key bottleneck for the hydrogen purity, as measures taken in this regard have to be considered as a transition phase, related purification costs incurred are temporary and **should not be interpreted as recurring expenses**.
- **Need for a European interconnected hydrogen backbone without distinctions between hydrogen grades or types:** this would strongly support the creation of a well-functioning European hydrogen market, provided that a harmonised hydrogen quality specification across Member States **facilitates cross-border transport and trade** and avoids additional technical measures or purification steps at interconnection points.

2.2 Respondents' perception of the role of operators

2.2.1 Storage facilities

Most stakeholders agree that storage facilities are essential for the hydrogen European backbone and are **key to unlock the hydrogen potential**. Storage facilities also play a very important role in providing flexibility, just as natural gas storage does.

In this respect, the needs and constraints of storage facilities shall be taken into account when **setting realistic specifications** regarding the content and purity of hydrogen, whilst reconciling the needs of connected consumption sites or distribution networks.

2.2.2 Transmission networks

Some important principles are pointed out by stakeholders. In particular, the hydrogen transmission network operators should be able to guarantee that **the same quality** corresponding to the specification is delivered at exit points as those specified at entry points. This implies that HTNOs shall be able to monitor the hydrogen quality, particularly at interconnection points. This also implies that specifications regarding hydrogen quality (Wobbe index, contaminants thresholds, etc.) shall be subject to a contract between shippers/suppliers and HTNOs at entry points, provided that HTNOs commit to delivering hydrogen with the same quality at exit points. This also requires consistency among the specifications defined at the entry points of transmission networks, taking into account the needs of end users, **in a way that is cost-effective for the entire European hydrogen interconnected system**.

2.2.3 Distribution networks

Most stakeholders consider that hydrogen distribution network operators (HDNOs) are not yet fully identified. These operators should therefore be accountable of the hydrogen delivered **as per the specifications defined by HTNOs**.

The case of **geographically confined networks** was pointed out: these networks are subject to exemptions as long as they are not connected to the European interconnected backbone. However, once connected, HDNOs operating these networks should receive hydrogen delivered at the entry points with the quality specified by HTNOs.

2.2.4 Terminals

As terminals will be connected to transmission networks, the hydrogen terminal operators will have to comply with the applicable hydrogen specifications. According to some HTNOs, terminals may introduce **specific contaminants** like nitrogen and ammonia.

2.2.5 Production facilities

Some issues related to the **quality stability** have been identified by stakeholders. In addition, areas of concern are identified regarding the performance of purification units, the **reliability of measurements**, trace contaminants potentially affecting infrastructure and metering, as well as a lack of harmonised measurement at production sites.

2.2.6 End users

Most of the respondents doubt that in case of very high purity level requirement on the European transmission network, this could avoid local purification units. In other words **this would not achieve the economic benefits** of an interconnected backbone; that is why it is important to find a techno-economic optimal way to reconcile all stakeholders' needs in the value-chain.

2.3 Overcoming the dilemma purity level/contaminants thresholds

A vast majority of the respondents to the public consultation consider that reaching a consensus on contaminants thresholds is a priority, as the hydrogen purity level should derive from this. Such consensus appears actually **not yet reached**: areas of concern regarding methane content, oxygen content and possibly sulfur content are

remaining. Missing requirements are also mentioned for power plant turbines and for microbial impact in varying geological environments for underground storages. The need of **stability** regarding the contaminants has been frequently mentioned.

2.4 Standardisation

We can see a consensus on the need for standardisation **within a European institutional framework**. This would be essential for establishing a **frame of reference** regard-

ing the HTNOs' technical prescriptions at interconnection points, thereby ensuring a smooth transmission of hydrogen across the European backbone.

2.5 Data monitoring priorities

The review of the responses to the public consultation clearly shows that there is a **genuine need for monitoring**, and certain priorities have been identified. With regard to contaminants, measurements should be primarily

focused on those substances the occurrence of which is initially suspected, given the origin of the hydrogen. Wobbe index, HCs, Sulphur are also mentioned.

2.6 Needs for developments related to hydrogen quality. Possible hydrogen purification costs reduction options

A stakeholder raised that **analysing hydrogen is currently expensive and time-consuming**, requiring further development, as well as lab certifications. Storage operators consider also that steel compatibility regarding aggressive contaminants like CO₂ or H₂S still needs to be assessed. GIE considers that investment is needed in measurement technologies, monitoring along underground storage cycles, pilot projects and demonstrators for both renewable

and low-carbon hydrogen, as well as digitalisation and interoperability tools. With regard to purification costs reduction options, a respondent mentioned promising areas, including advanced membranes and sorbents with **lower hydrogen losses** avoiding or limiting tailgas, modular purification technologies, digital quality tracking and predictive modelling, as well as potentially improved sensors and real-time analysers.

2.7 Cost allocation and possible incentive mechanisms

Converging views were noted regarding cost allocation for hydrogen purification processes, stating that cost allocation in general **should reflect responsibilities across the entire value chain**. It should encourage the whole hydrogen value chain to conduct detailed cost analyses for infrastructure adaptation to meet hydrogen purity standards needed, providing stakeholders with the transparency and clarity for decision-making. This could include:

- The **polluter-pays principle** for the upstream side to minimise the need for infrastructure based purification and to support fair competition between production pathways. This would lead to harmonisation before injection into hydrogen networks.
- Regulated recovery for infrastructure relating to quality management with a special attention to storage

operators, which is **essential for system integrity** and should benefit all market participants.

- Applications requiring higher purity than the network specifications should implement local purification solutions. This avoids cross-subsidisation and ensures that the broader market is **not burdened with unnecessary costs**.

Opinions are divided regarding possible incentive mechanisms. Some respondents state that incentives could ensure compliance with network specifications, support innovation in purification and monitoring, as other respondents would tend to consider that the best incentive would consist in having an official standard framework obliging as such the market participants without distorting the underlying commodity market.

2.8 Bilateral meetings held with ENNOH related to the public consultation

HDF Energy, a producer who presented an insight in the stakeholders's workshop on 12 February 2026, asked for a bilateral meeting with ENNOH, which was held on 5th March. HDF Energy raised the high level of hydrogen purity needed by fuel cells. In addition, first and foremost, **the contaminant thresholds should be considered rather than the purity level** as such.

A bilateral meeting with IFIEC was held on 9 April. IFIEC recalled their policy asks, which can be found in their position papers. They raised the issue of **geographically confined networks**, in particular the impact of their connection to the backbone. They considered also the primary importance of defining **contaminant thresholds, rather than necessarily the purity level**.



3 CONCLUSION – ENNOH RECOMMENDATIONS

This first report stands out in that it does not rely on hydrogen flow data. We can therefore expect the next report, due to be published in 2028, to be based on concrete **monitored operational data** coming from pipelines with third-party access. Nevertheless, based on the feedback from the public consultation, the workshop and discussions with stakeholders, as well as with HTNOs members of ENNOH, some recommendations can be made by ENNOH.

It is important to note that we are in an emergent stage of the hydrogen market and, in light of this, **no-regret options** should be taken above all.

It is also important to keep in mind the aim of establishing a pan-European interconnected transmission network: **all decisions should therefore serve this objective**. Monitoring hydrogen quality should thereby contribute to supporting the ramp-up of the hydrogen market. In addition, monitoring the quality of hydrogen **contributes to the market confidence**.

It can therefore be considered that the main purpose of hydrogen quality monitoring consists of establishing **trust, stability and predictability** in the emerging hydrogen market.

More generally, and in line with the aim of establishing an interconnected European hydrogen system, it can be said that establishing hydrogen as a **standardised commodity** is also a primary purpose. Monitoring hydrogen quality contributes here aiming at achieving a cost and efficiency optimum for the commodity hydrogen by mitigating and managing contaminants. Last but not least, in line with the general view of stakeholders, future works on hydrogen quality should focus on **contaminant thresholds**, as the purity level of hydrogen will derive from this.

Based on the above statement, ENNOH is in a position to formulate the following three recommendations.

i. Initiate the monitoring of hydrogen quality data as soon as possible.

This recommendation is key in view of the next report to be released in 2028, which will need to be based on **reliable operational data**.

This implies for ENNOH to operate shortly the upcoming Transparency Platform and for HTNOs to be able to send hydrogen quality data⁴, as soon as they operate a hydro-

gen transmission network in a similar format and protocol as those used for natural gas. Therefore, these necessary evolutions need to be implemented **in the most cost-effective way** for operators. This will also **facilitate the drafting of the forthcoming Network Code** on Interoperability and Data Exchange, as a well-established practice will already be in place.

⁴ And also other information as defined in Reg. EU 2024/1789 (data on capacity, quantities, as well as tariff data)

ii. Provide an official endorsement for European standardisation work relating to hydrogen quality.

Standardisation work is already underway on hydrogen quality within CEN/CENELEC Technical Committee 234. A vast majority of stakeholders feel that the European Commission should mandate CEN/CENELEC to draw up **specifications which can be adopted by all Member States**. This would strongly facilitate consistency among HTNOs technical prescriptions at interconnection points.

Such a mandate would be consistent with the **2026 annual Union work programme for European standardisation**⁵, in particular the action 22 referring to transport and storage of hydrogen and covering specifications for hydrogen gas quality parameters test methods, sampling, metering, odourisation, contamination control.

This standardisation work should focus on assessing **contaminant thresholds** (e.g. methane, oxygen, etc.), as well as combustion rates like Wobbe Index.

iii. Call for the Network Code on Interoperability and Data Exchange to be included as soon as possible in the priority list of the European Commission.

This recommendation is consistent with the first one. Given the importance of monitoring the hydrogen quality data **as soon as possible**, initiating discussions on the first hydrogen Network Code on Interoperability and Data

Exchange at an early stage would enable the establishment of the general principles needed for **interconnection agreements** governing data exchange, hydrogen quality and flow control.

5 see [here](#)



ANNEX I

Summary of the points raised in the questions posed to stakeholders

What do you consider to be the main purpose of hydrogen quality monitoring?

The main objective is to ensure that hydrogen meets agreed purity and impurity specifications across the entire value chain, from production to end use. This underpins safety, infrastructure integrity, and reliable operation of networks and end-user equipment, which can be highly sensitive to contaminants. Monitoring also enables interoperability between interconnected systems and supports cross-border flows, making it essential for building a harmonised European hydrogen market.

A second key role is to provide transparency, trust, and compliance verification. By tracking hydrogen composition, stakeholders can detect deviations, take corrective actions, and ensure adherence to contractual and regulatory requirements. This also supports fair billing and accurate energy measurement, as gas quality affects calorific value. Finally, hydrogen quality monitoring contributes to market development and efficiency. It helps establish hy-

drogen as a standardised commodity, enabling predictable costs, stable contracts, and investment confidence. It also supports the integration of renewable gases, optimisation of operations (including storage and transport), and long-term system planning.

Overall, respondents view monitoring as a foundational tool for safety, market trust, and the creation of a consistent, interoperable European hydrogen system.

— ENNOH comment

These general principles should be duly kept in mind.

HTNOs should act as trusted third parties; in this context, the upcoming ENNOH transparency platform is of paramount importance.

Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

There is broad agreement that the key decision is to define a harmonised European hydrogen quality framework. This includes setting clear specifications for hydrogen purity and, more importantly, acceptable limits for critical trace components, rather than focusing solely on a single purity threshold.

A central aspect is balancing safety, technical feasibility, and cost-efficiency, ensuring that standards support infrastructure operation, end-user requirements, and market development without creating unnecessary costs or barriers. Many responses stress the need for pragmatic and flexible thresholds (e.g. around 98–99.5 % purity) that can enable rapid deployment and be refined over time.

Another major decision concerns what and how to monitor (e.g. impurities vs H₂ concentration), including responsibilities, measurement points, and regulatory implementation.

More broadly, stakeholders highlight the importance of aligning this framework with a long-term strategic vision—supporting interoperability, cross-border trade, and the scaling of a European hydrogen market, while guiding infrastructure choices. Overall, the priority is to establish a clear, practical, and standardised approach that enables early market development while remaining adaptable as knowledge and experience evolve.

— ENNOH comment

As we are in an emergent phase of the hydrogen market, no-regret options have to be selected.

Standardisation is key in this context, as we have the opportunity to design harmonised suitable specifications for the future interconnected backbone.

Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

There is broad support for the principle of a single, interconnected hydrogen network with harmonised quality standards, seen as key to enabling interoperability, cross-border trade, market liquidity, and efficient infrastructure use. A unified approach would reduce fragmentation, avoid costly purification at interconnection points, and support the development of a competitive European hydrogen market.

However, most respondents stress that this should be a long-term objective, implemented progressively. In the short to medium term, flexibility is necessary, as regional networks, industrial clusters, or specific users may require different hydrogen grades or higher purity levels. Imposing a strict, uniform standard too early could increase costs, slow infrastructure deployment, and hinder market ramp-up.

Many highlight the need for pragmatic and feasible specifications, balancing user requirements, operational constraints, and cost-efficiency. Transitional solutions—such as local standards, tolerance for impurities, or downstream purification—are widely supported.

Overall, stakeholders agree on the direction of a unified network, but emphasise a phased, flexible approach to avoid creating barriers during early market development.

— ENNOH comment

It is important to underline the long-term vision in relation to that question.

Standardisation work in an official framework should help progressively to give consistency among initial clusters regarding hydrogen quality specifications.

Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

There is broad agreement that storage facilities are a critical element of the hydrogen value chain, particularly for balancing supply and demand, enabling seasonal flexibility, and ensuring security of supply. They are seen as key enablers for integrating intermittent renewable hydrogen and supporting system reliability.

However, most respondents do not consider storage as the single most critical link, emphasizing instead a system-wide perspective where production, transport, and end-users are equally important. The relative importance of storage depends on market development and should be assessed alongside other infrastructure components.

A major concern is the impact of storage on hydrogen quality, especially for repurposed underground storage, where impurities (e.g. methane, nitrogen) and purification challenges may arise. Storage-related purification can be technically complex, costly, and constrained by space or regulation, making it a key cost driver.

Overall, stakeholders view storage as essential but not uniquely dominant, stressing the need for a balanced, integrated approach and realistic quality requirements that do not hinder storage deployment or slow market development.

— ENNOH comment

Storage facilities are indeed not the unique critical link, as other types of infrastructure facilities have to be considered, e.g. the compressor stations.

How do you assess the role of hydrogen transmission network operators (HTNOs)?

Hydrogen transmission network operators (HTNOs) are seen as central actors in the hydrogen value chain, with a role largely analogous to natural gas TSOs. Their primary responsibility is to ensure safe, reliable, and efficient transport of hydrogen, while maintaining system integrity and supporting the development of a scalable European network.

A key function is guaranteeing hydrogen quality during transport – monitoring compliance with agreed specifications, rejecting off-spec hydrogen at entry points, and ensuring predictable quality at delivery. HTNOs are also expected to provide transparency on gas composition and coordinate quality management across borders and with connected assets (production, storage, terminals).

They are further viewed as neutral market facilitators, ensuring non-discriminatory access, enabling network balancing, and supporting cross-border interoperability and market integration. Their role includes infrastructure planning, aligning network development with user needs and decarbonisation goals. Overall, HTNOs are considered essential enablers of a reliable, interoperable, and transparent hydrogen market, bridging stakeholders and supporting the transition from pilot projects to a fully integrated European hydrogen system.

— ENNOH comment

The central role of HTNOs is recalled here, as well as the role of HTNOs as neutral market facilitators. Trust and transparency are key in the HTNOs activity, as well as for ENNOH.

Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

There is strong consensus that specifying hydrogen quality at entry points is necessary but not sufficient. While clear entry specifications are essential to ensure interoperability and avoid market fragmentation, most stakeholders stress that they do not guarantee consistent quality throughout the network.

Many respondents highlight that hydrogen composition can change during transport and storage, particularly due to contamination risks (e.g. from repurposed pipelines or storage facilities). Therefore, HTNOs must also ensure quality at exit points, supported by continuous monitoring, modelling, and quality management systems. A recurring theme is the need for end-to-end responsibility across the value chain, with all actors accountable for maintaining agreed specifications. Several stress that HTNOs cannot be seen as purely passive carriers, as their infrastructure may influence gas quality.

Overall, stakeholders call for a harmonised, system-wide approach, including aligned entry and exit specifications, transparency on gas composition, and potentially more prescriptive regulation to ensure reliable delivery to end-users. Only a minority consider entry specifications alone sufficient if strict compliance at exit is guaranteed.

— ENNOH comment

Clarification is needed regarding this question: HTNOs may refuse hydrogen out of specifications at the entry points; once accepted, hydrogen shall be delivered at exit points with a quality in line with the specifications at entry point.

HTNOs do not own the transported hydrogen volumes, as this energy carrier is subject to a contract between a shipper/supplier and a consumer (possibly through a wholesale market when it will exist). The transmission contract signed between an HTNO and a shipper should mention that the shipper is responsible for the compliance of H₂ specifications at entry points and the HTNO is responsible to receive the compliant H₂ at entry points and to deliver it at exit points as per the technical prescriptions required at entry points (quality parameters like Wobbe Index, contaminants thresholds, etc.).

How do you assess the role of hydrogen distribution network operators (HDNOs)?

Hydrogen distribution network operators (HDNOs) are generally seen as more locally focused actors, with a role less defined and, in the short term, less prominent than transmission operators. Most stakeholders consider that hydrogen distribution network operators (HDNOs) are not yet fully identified.

HDNOs act as the interface with end users and local producers, ensuring that hydrogen delivered meets required quality specifications and supporting safe, reliable distribution. They are responsible for managing local network conditions, including pressure, metering, and potential quality variations, and may also handle functions such as odourisation.

Another role highlighted is enabling local market development, facilitating access for smaller producers and con-

sumers, and supporting the repurposing of existing gas networks. HDNOs also contribute to monitoring, digitalisation, and operational control at the local level. Strong coordination with HTNOs is considered essential to ensure consistent hydrogen quality across the value chain.

— ENNOH comment

The cooperation between HTNOs and HDNOs is underlined. Regional cooperation, in particular with the HDNOs, is a task of ENNOH according to the gas/H₂ package.

The connection of local networks to the European hydrogen interconnected system is clearly addressed as an important issue, as already seen in the general principles stated in the report.

Do you identify any specific considerations or challenges related to terminals?

Responses highlight that hydrogen terminals are critical for market ramp-up, acting as key entry points for imported hydrogen and linking global supply to the European network. Their role is essential for supply diversification, flexibility, and security.

A major challenge is quality management and interoperability. Terminals must handle hydrogen from diverse sources and conversion processes (e.g. ammonia cracking), which may introduce impurities or variability. This requires harmonised specifications, strict monitoring, and clear interface standards to avoid costly downstream purification and ensure compatibility with networks and end users.

Regulatory and infrastructure constraints are also noted. Current rules limiting terminal connections (e.g. only to transmission networks) may reduce flexibility and increase costs. Better integration with storage, industrial clusters, and other infrastructures is seen as beneficial.

Additional challenges include safety requirements, permitting, and investment coordination, given the scale and technical complexity of terminal operations.

Overall, terminals are viewed as essential but complex nodes, requiring strong standardisation, coordination, and governance to support efficient hydrogen market development.

— ENNOH comment

Some specificities are raised regarding the impurities generated.

Terminals are currently not yet in operation, but specifications at entry points connected with this infrastructure have to be assessed. The standardisation process could be a good framework.

What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

There is a strong consensus that agreeing on contaminant thresholds is more important than defining a single hydrogen purity level. Most stakeholders argue that purity is a derived parameter, resulting from the sum of allowed impurities, while contaminants directly determine safety, infrastructure compatibility, storage performance, and end-use suitability.

Contaminants are seen as the key drivers of technical risks (e.g. damage to catalysts, materials, or storage systems) and interoperability across the value chain. Harmonised limits would reduce the need for costly purification and enable cross-border trade.

Several respondents emphasise a pragmatic, phased approach, prioritising EU-wide thresholds for critical trace components while allowing flexibility for non-critical impurities. This could result in a range of acceptable purity

levels (e.g. ~98–99%+), adaptable to different use cases and evolving market conditions. A minority highlight that both elements are interconnected and necessary, with purity levels supporting standardisation and trading, but still dependent on contaminant definitions.

Overall, the priority is clear: define harmonised contaminant limits first, with purity emerging as a consequence, enabling a flexible yet robust framework for market development.

— ENNOH comment

The standardisation work currently ongoing, which we would like to be carried out within a clear European institutional framework, should lead to the establishment of a reference value for the levels of the relevant contaminants deemed acceptable in the transmission network.

With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

There is broad agreement that a full consensus on contaminant threshold values has not yet been reached, although convergence is progressing and partially aligned for some impurities.

Key uncertainties remain due to diverging stakeholder requirements, limited data, and varying national approaches. A major area of concern is methane content, including acceptable limits, measurement accuracy at low levels, and its impact on storage operators regarding purification, as well as the Wobbe Index. Other critical contaminants include oxygen, sulphur, inert gases, water, and CO/CO₂, particularly regarding their effects on infrastructure, storage behaviour, and sensitive end uses.

Additional challenges relate to knowledge gaps, such as the impacts of variations in the hydrogen specification on turbines and materials, the impact of underground storage infrastructure (e.g. microbial or geochemical effects) on the hydrogen specification, as well as cost allocation and feasibility of purification technologies. Differences in end-user requirements, especially for highly sensitive sectors (e.g. fuel cells, semiconductors), further complicate harmonisation.

— ENNOH comment

The responses provide an indication of which contaminants could be prioritised.

Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

There is an almost unanimous consensus that CEN/CENELEC should receive a clear mandate from the European Commission to develop hydrogen quality specifications recognised across Member States. Respondents see this as essential for harmonisation, interoperability, and market integration, helping to avoid fragmentation and ensure consistent rules across Europe.

A formal mandate is expected to accelerate standards' development, provide regulatory clarity, and support the creation of a common European rulebook, enabling cross-border trade, standard contracts, and investment certainty. Many highlight that CEN (notably TC234) is the appropriate body, given its expertise and established stakeholder processes.

However, some note practical considerations: even with a mandate, implementation may vary across Member States, and standards should remain inclusive of different stakeholder needs and adaptable to national specificities.

Overall, stakeholders strongly support an EU mandate as a key enabler for a coordinated, efficient, and scalable hydrogen market, while recognising the need for flexibility in application.

— ENNOH comment

This is in line with the second recommendation made in the report.

Do you identify any areas of concern related to hydrogen production?

Responses highlight several key concerns related to hydrogen production, mainly linked to variability in quality and impurity profiles across different production technologies (e.g. electrolysis, SMR, imports). This variability makes it challenging to ensure consistent compliance with network specifications and requires robust purification, monitoring, and quality control.

A major issue is the performance and reliability of purification and drying systems, as well as the risk of trace contaminants affecting infrastructure, metering, and end-use applications. Stakeholders also stress the need for harmonised measurement standards and quality requirements at production sites.

Economic incentives are another concern: poorly designed frameworks could encourage producers to only meet minimum standards or introduce impurities (e.g. hydrocarbons), rather than optimise quality.

Finally, there is a need to align production specifications with infrastructure and end-user requirements, ensuring system-wide compatibility. Overall, respondents call for coordinated standards, monitoring, and regulatory frameworks to manage production diversity and ensure stable, high-quality hydrogen supply.

— ENNOH comment

Various production sites will be connected to the European network: the producers will have anyway to comply with specifications required at the entry point of the transmission network.

With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Responses indicate that natural (white) hydrogen is still at an early stage, with limited data on volumes, production stability, and scalability. As a result, it is generally seen as a long-term opportunity rather than a near-term supply source.

The main anticipated challenge is uncertain and variable gas composition, with potentially different contaminant profiles compared to other hydrogen sources (e.g. helium, methane, sulphur compounds). This variability, driven by geological conditions, would require robust monitoring, characterisation, and likely purification before injection into networks.

Additional concerns include lack of operational experience, site dependency, and the need to assess environmental impacts, extraction methods, and long-term re-

source availability. Integration into existing systems would also require clear regulatory frameworks, including quality standards and certification schemes.

Overall, while white hydrogen could diversify supply in the future, stakeholders emphasise that it must meet the same harmonised quality requirements as other hydrogen sources, and that further research and practical experience are needed before large-scale deployment.

— ENNOH comment

Although this production mode is still in an early stage, it is important to develop and keep close contact with producers in order to keep them informed of the ongoing standardisation work regarding the contaminant thresholds to be set at points of entry.

Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

There is broad agreement that a very high network-wide purity level (>99.97%) would not eliminate the need for local purification units. While such a standard could reduce purification needs in some cases, it is technically challenging, costly, and not sufficient for all end uses.

Many stakeholders highlight that infrastructure constraints (e.g. storage, repurposed pipelines) make it difficult to consistently achieve ultra-high purity across the network. Based on the currently available information, a hydrogen specification of 99.97% could not be guaranteed in all infrastructure across the network. Hydrogen quality can vary during transport, requiring additional control, although potential impacts on the hydrogen specification from repurposed pipelines will decrease over time.

A key point is that sensitive applications (e.g. fuel cells, semiconductors, catalytic processes) require extremely strict and specific contaminant limits, often beyond the 99.97% limit. These users will continue to rely on on-site purification even with a hydrogen specification of 99.97%.

Most respondents advocate a layered approach: define a realistic, harmonised network quality (e.g. ~98–99.5%) for cost-efficient transport, likely requiring local purification for some users. Imposing ultra-high purity across the system would create disproportionate costs for the majority of users and could hinder market development.

Overall, local purification remains necessary, and system optimisation should balance cost, feasibility, and end-user requirements.

— ENNOH comment

These responses tend to confirm that a specification of 99.97% would not eliminate the need for purification at some end-users sites.

What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

Responses highlight that the main priorities for a transparency platform are reliable, accessible, and standardised data supporting safe operations and market development.

A key focus is on real-time or near-real-time operational data, including flows, pressures, capacities, and availability, as well as hydrogen quality information (purity, contaminants, Wobbe Index, deviations). Providing this data—especially at exit points—enhances system reliability, avoids duplication of measurements, and supports user decision-making.

Stakeholders also emphasise the importance of historical data, traceability, and visibility of constraints or maintenance, enabling planning, investment signals, and coordination across the value chain. Standardisation is critical:

data should be harmonised, comparable, and provided in interoperable formats across Europe.

Several respondents advocate a phased approach, prioritising essential data (capacity, flows, tariffs, basic quality) during market ramp-up, with more detailed reporting introduced later to avoid excessive complexity and costs.

Overall, transparency platforms should deliver clear, system-relevant information to ensure safety, interoperability, and confidence in the emerging hydrogen market.

— ENNOH comment

This is in line with the recommendation that the ENNOH transparency platform should start collecting actual data as soon as possible.

Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Responses indicate that innovation opportunities to reduce hydrogen purification costs do exist, but most are still at an early stage, with limited short-term impact and greater potential in the medium to long term.

Key promising areas include advanced membrane and adsorption technologies (e.g. palladium membranes, hybrid systems), which could improve separation efficiency and reduce hydrogen losses. Modular purification solutions and process optimisation are also seen as ways to adapt to infrastructure constraints and lower costs.

Digital innovations—such as real-time sensors, monitoring, and predictive modelling—could improve quality management and reduce unnecessary purification. Additionally, better handling of PSA tail gas losses and integration with production or storage processes may enhance efficiency.

Some respondents also highlight upstream improvements, such as better electrolyser performance or contamination prevention, which could reduce the need for purification altogether.

However, several note that current technologies are already mature, and no immediate breakthrough is expected. Overall, innovation is viewed as important and promising, but cost reductions will likely be gradual and market-driven.

— ENNOH comment

As innovation is an ENNOH task, We will closely monitor the work currently ongoing on these issues in order to facilitate coordination and the sharing of information among the HTNOs.

Do you identify a need for investment in developments related to hydrogen quality?

Responses show strong consensus that investment in hydrogen quality developments is necessary, particularly to support safe, reliable, and scalable system integration.

Key priority areas include measurement and monitoring technologies (especially real-time and online systems), quality management and digitalisation tools, and data platforms to ensure transparency and interoperability. Investments are also needed in purification and gas treatment technologies, although these are considered relatively mature and should focus on improving efficiency, hydrogen recovery, and robustness under varying conditions.

Several respondents highlight the importance of pilot projects, demonstrations, and R&D, particularly for storage, blending, and diverse production routes, as well as addressing material compatibility issues (e.g. steel with

contaminants like CO₂ or H₂S).

There is also a strong emphasis on system optimisation: investments should be targeted and cost-efficient, avoiding overly stringent purity requirements that could increase costs across the value chain.

Overall, stakeholders call for focused, strategic investment in innovation, monitoring, and infrastructure readiness to enable a harmonised and efficient hydrogen market.

— ENNOH comment

Same comment as the previous question, as for instance the Clean Hydrogen Partnership can allocate significant funds for R&D projects.

In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

Responses converge on a balanced, value-chain-based approach to cost allocation for hydrogen purification. A key principle is the “polluter pays” rule at entry points, meaning producers should ensure compliance with baseline grid specifications and bear costs if their hydrogen requires additional treatment.

At the same time, regulated infrastructure operators should be allowed cost recovery for monitoring, quality management, and purification measures that benefit the overall system. Where purification improves interoperability or supports network-wide standards, costs can be socialised within regulated frameworks.

Conversely, end-use-driven purification – for applications requiring higher-than-standard purity – should be borne by individual users, typically via local or contractual solutions, to avoid cross-subsidisation.

Many stress that costs should be allocated where they arise and where benefits are realised, ensuring transparency and avoiding distortions in hydrogen pricing. A purification approach that minimises purification needs at end-users' sites is often preferred for efficiency but must remain economically justified.

Overall, stakeholders advocate a fair, pragmatic allocation model that supports system optimisation, market development, and avoids imposing disproportionate costs on the wider hydrogen system.

— ENNOH comment

The proposed approach is similar to that currently in place for the natural gas system. Cost allocation does not mean that the burden should be placed on every link in the value chain, but rather that a fair balance should be sought by maximising overall benefit. As operators, we will need to advise the NRAs on this matter. Once again we should keep in mind the target of an interconnected pan-European backbone.

Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

Responses show mixed views on incentive mechanisms for hydrogen quality. Many stakeholders emphasise that clear, harmonised technical standards and obligations are more important than incentives, warning that poorly designed mechanisms could create undesirable effects, such as encouraging minimal compliance or even intentional introduction of contaminants.

Several respondents are sceptical about public subsidies or cost socialisation, arguing these are not sustainable and may distort the market. Instead, some highlight market-based incentives, such as certificate schemes, as more effective signals.

At the same time, others see value in targeted incentives, particularly to:

- encourage higher and more consistent quality at production
- support innovation in purification, monitoring, and storage technologies

- promote pilot projects and early deployment

- enhance transparency and reliability

A common view is that incentives should complement—not replace—regulation, and remain aligned with market ramp-up and cost efficiency.

Overall, while incentives can be useful if well designed, stakeholders stress that robust standards and regulatory clarity are the primary drivers for ensuring hydrogen quality.

— ENNOH comment

This issue deserves further consideration.

Regulation should be the primary driver of hydrogen specification. Incentive mechanisms, if used to complement regulations, should always be market-based. Any mechanisms considered should be designed to foster the market ramp-up.



ANNEX II

Responses to the public consultation

BVEG response to the PC

1. Please provide your name, your position, and the organisation you represent.

Ingo Forstner, head of UGS & geothermics, BVEG (German Association of Natural Gas, Oil, and Geoenergy)

2. What do you consider to be the main purpose of hydrogen quality monitoring?

- enabling a European market with consistent and common hydrogen quality along the value chain (end users, SSOs, etc) that can be counted on.
- ensuring a basis for correcting actions if quality issues arise.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

- it is the question of what should be monitored and defined primarily: H₂-concentration or (preferred) contaminant component concentrations → we see the latter to be the better way
- additionally, the regulatory aspects of implementing (cost association, ...) are important

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

Yes. See answer to question #3 for details.

However, existing dedicated stand-alone hydrogen networks will exist in parallel.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Yes. They are essential for the existence of a working hydrogen system. And they are required to be geographically distributed, which means also under varying geological constraints.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

Analogous to in the natural gas system. TSOs are necessary.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Entry and exit points are not necessarily identical qualities.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

At this point, there are few or none identified. There is benefit in certain locations, especially when large industrial consumers are connected via the HDNO.

9. Do you identify any specific considerations or challenges related to terminals?

They are necessary for the ramp up of the market. And they need to be considered also, when hydrogen quality is being assessed.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Contaminant thresholds are more important

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

The consensus is not fully reached yet, but in sight. Main area of concern is missing information about major technical parameters, e.g. requirements for power plant turbines and for microbial impact in varying geological environments for UHS.

Additionally, the related regulatory aspects need to be addressed in parallel.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes. And we see TC234 as the natural body for that.

13. Do you identify any areas of concern related to hydrogen production?

There must be no economic incentive to “just meet” requirements, even if “normal purification” would allow for better-than-required. E.g. no incentive to mix in hydrocarbons “to the limit” because their energy content is higher than that of hydrogen.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

The mix of contaminants would be considerably different from other sources e.g. helium. Once this can be quantified, hydrogen quality requirements should be reviewed. At this point we don't see need for action, though.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

In many places yes, but not fully. It also depends on the remaining contaminants.

However, even if at some locations purification can be avoided, it would not be economical on a market level. This purification would need to be done elsewhere and for larger amounts of hydrogen. This would be more costly in the end. It is also questionable if such a high purity level can technically be achieved in the gas infrastructure realistically.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

1. Pressures
2. flow rates
3. Wobbe-Index
4. change rates
5. Sulfur
6. HC
7. Oxygen

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

- tail gas usage is important for PSA. Any improvements there would help greatly.
- purification needs reduction: microbial growth inhibition – for various parts of the infrastructure (pipelines, UHS, ...)

18. Do you identify a need for investment in developments related to hydrogen quality?

- investment in purification plants depend on the required optimum of hydrogen purity
- still some aspects of steel compatibility with hydrogen with aggressive contaminants such as CO₂ or H₂S

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

- The cost would ideally be shared along the various partners along the value chain.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

- it should be avoided that there are incentives to do the opposite: intentional mixing-in of contaminants. Different pricing for different qualities should be avoided, though.

GAS CONNECT AUSTRIA response to the PC

1. Please provide your name, your position, and the organisation you represent.

Patrick Rockenschaub, Sales Manager, Gas Connect Austria GmbH

2. What do you consider to be the main purpose of hydrogen quality monitoring?

The main purpose of hydrogen quality monitoring is to ensure compliance with agreed purity and impurity specifications according to common rules.

It supports safe and reliable network operation, interoperability across the system, and confidence for network users and end customers. Furthermore, we pursue our anticipated liability through users in this manner. Such fulfilled preconditions make costs for market participants more predictable.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

A combination of timing (it's necessary to get quick decisions!), harmonisation and affordability. It would therefore be advantageous to agree on a lower limit of 98 mol % for H₂ purity rather than setting it very high at the outset in order to enable faster implementation. The threshold could potentially be adjusted after experiences with the whole system, all market participants and an evaluation at a later date if needed.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

We broadly agree with the principle of building a single, interconnected hydrogen network.

A common quality standard is important for interoperability and market integration across national borders and therefore Europeanwide. Defining a minimum hydrogen purity of 98% can provide such a baseline, while still allowing for higher purity levels in parts of the network, where required.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Storages will certainly play a vital role, but so will transmission infrastructure. Their relative importance will depend heavily on how the hydrogen market develops over the coming years. Before the large scale ramp up of hydrogen production, demand, and cross border flows has fully materialised, it is premature to draw firm conclusions about which component will ultimately be the most critical. A balanced and integrated perspective is essential to ensure that both storage and pipeline infrastructure can

evolve in a coordinated way to support a reliable and efficient hydrogen system.

However we do agree that storage facilities represent a critical element of the hydrogen value chain. The product itself gets higher attractiveness for end customers if continuous supply is possible and this is only the case with enough storages.

Storage facilities may face specific technical constraints, including limitations on achievable hydrogen purity levels, which make their integration into a single, interconnected network particularly important.

Ensuring that storage can be efficiently connected to the network is therefore essential for overall system functionality and security of supply.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

HTNOs play a central role in managing hydrogen quality within the transmission network.

They are responsible for monitoring and ensuring compliance with agreed purity and impurity specifications, while coordinating quality management across borders and with connected system elements such as production, storage, and terminals.

Clear responsibilities and sufficient competencies for HTNOs in the area of hydrogen quality are therefore essential to ensure a Europeanwide reliable and interoperable network. However, since a future HTNO will also play a role in security of supply, it could happen (dependent on its obligations) that the HTNO has would have to stop any H₂ flow that does not meet regulatory requirements, which would lead to shortages and price increases. The higher the required H₂ purity, the more likely this possibility becomes.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

The higher the degree of harmonisation is (e.g. harmonisation of hydrogen quality at ALL entry points), the higher is the possibility that the transport of H₂ will be operated without restrictions and interruptions. As we expect that HTNOs do not have the possibility (without additional costs?) to "adapt" the quality in the first instance, we support harmonised requirements at the entry points of the network, so that the probability of changed H₂ quality during the transport to the exit points (and finally to end customers) is nearly zero.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

They are responsible for ensuring that hydrogen delivered to end users meets applicable purity and impurity specifications, taking into account local network conditions and other parameters.

Close coordination between HDNOs and HTNOs on hydrogen quality management is essential to ensure seamless system operation and consistent quality along the value chain. In Austria, odourisation takes place at the DSO level (and this should also be the case in the future!). This places a greater burden on HDNOs. On the one hand, because quality monitoring will also have to be carried out here and, on the other hand, because contaminants can continuously enter the system through the connected storage facilities (in Austria the storages are connected at the DSO-level and storages connected at the TSO-level should be counted as entry point to TSO-pipelines).

9. Do you identify any specific considerations or challenges related to terminals?

Austria is a landlocked country, therefore this question should be answered by countries, which are affected in the first instance.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

It is more important to try to achieve consensus on a uniform purity level in Europe (see above: 98 %), as the permanent measurement of all impurities is more costly than the permanent measurement of the H₂ content with random samples of impurities. However, this is only possible if the fuel cells do not require direct consumption via the grid, e.g. cars or trucks.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

Yes, it should be at least possible to reach a Europeanwide consensus on the basis of thresholds. Concerns of course stay existend because regional/national specialties could cause further difficulties in finding solutions for crossborder business and such solutions finally could distort competition. In addition to the regionally varying requirements of end consumers regarding hydrogen, the role of storage operators and the possible hydrogen purities for them must also be considered. This consensus will be strongly driven downstream.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes, it would be advantageous to have uniform and coordinated specifications, all the experts are concentrated there and the processes for stakeholder involvement are well established.

13. Do you identify any areas of concern related to hydrogen production?

Potential areas of concern on the production side may arise depending on the specific context.

These could, in particular, relate to variations in hydrogen purity and impurity profiles linked to e.g. different production technologies, as well as the ability to consistently meet agreed quality specifications at network entry points.

Such aspects may need to be assessed on a case-by-case basis in close coordination with network operators. The training of local staff will also play an important role in this context.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Possible challenges could arise in the event of a broader deployment of natural (white) hydrogen.

In some cases, the specific geological and production conditions may affect achievable hydrogen quality and conformity with network specifications.

As experience with this production pathway develops, approaches to address these aspects can be refined. At present, however, it can be assumed that natural hydrogen will behave similarly to hydrogen from storage facilities. Purification is therefore unavoidable.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97 %), local purification units (e.g. for fuel cells) could be avoided?

From a system perspective, certain infrastructure elements such as storage facilities may face technical limitations in consistently achieving purity levels significantly above 98 %.

Very high networkwide purity requirements would therefore still necessitate additional purification steps (with additional high costs?) in parts of the value chain.

A minimum network-wide purity level of around 98 % is therefore considered more realistic, more favourable in regards to market development and competition and technically feasible, while allowing higher purity levels to be achieved locally where required by specific end uses. The costs of purification to over 99 % purity will not be accepted by all end users, as the majority of the industry wishes to use it thermal-ly.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

Transparency requirements in the gas sector have evolved in parallel with the development of various network codes (CAM, TAR, INT, BAL).

General publication obligations – such as network and service descriptions (including ramp up charges, access arrangements, and contractual frameworks) and the most essential capacity data at relevant points – already make sense during the initial ramp up phase.

Additional publications, such as quality parameters, congestion management measures, or TAR NC related publications, would only be feasible once harmonised European regulatory provisions exist. Ideally, these should only be introduced during the market development phase in order to avoid excessive information requirements and to establish a cost-efficient transparency platform.

To support the ramp up of the hydrogen market, only the most essential data should therefore be published. This includes:

- Capacity data (technical, booked, and available capacity)
- Flow data (nominations and physical flows)
- Tariff information (ramp up tariff)
- Service descriptions (network data and contractual frameworks)

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Yes, in the membrane sector: purification of over 98 % is currently possible on an industrial scale using a membrane PSA plant. However, these have high OPEX and CAPEX for our enormous flows.

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes, investments will be needed for developments related to hydrogen quality.

These may include monitoring and measurement equipment, quality management systems, and, where necessary or if the legal requirements include them, purification or conditioning technologies at different points of the value chain. Such investments could will be important to ensure compliance with agreed quality specifications and reliable system operation.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

As mentioned above, we are critical of the socialisation of purification costs. Keeping the system expensive for a few users (high purification costs) will not prevail from a techno-economic perspective.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

No. From today's perspective, we do not see any mechanism on the HTNO side that would incentivise the system to increase purity from 98 % to 99.5 %. Achieving such an improvement would require supporting the entire purification process – and this across the whole system.

21. Please enter your email address to receive a copy of the information you submitted.

patrick.rockenschaub@gasconnect.at

GNI response to the PC

1. Please provide your name, your position, and the organisation you represent, or indicate if you wish to remain anonymous.

Mary.OMahony@gasnetworks.ie, European Affairs Innovation & Policy

2. What do you consider to be the main purpose of hydrogen quality monitoring?

Hydrogen quality monitoring provides a number of important benefits including (i) Ensuring hydrogen deliveries meet set/agreed level of quality (ii) provide network operators and network users with confidence that hydrogen quality will remain within predefined limits and any anomalies on gas quality are promptly identified and (iii) Ensure safety is maintained by consistent monitoring of hydrogen quality.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

The upper and lower quality limit and delivering a level of consistency of hydrogen quality when considering hydrogen that may move across jurisdictions.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

Yes.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Storage facilities will play an important role in the overall hydrogen economy, but full value chain is equally important from an Irish perspective.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

Providing a Tx network suitable for the transportation of hydrogen.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Yes, and this aligns with the protocol successfully deployed in natural gas networks (if end user has specific requirements, must be agreed prior to connection).

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

Providing a Dx network suitable for the transportation of hydrogen.

9. Do you identify any specific considerations or challenges related to terminals?

–

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Both are equally important and should be aligned as far as possible between the EU and interconnected 3rd countries.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

We aim to align with standards and industrial best practice in relation to contaminants.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes, this will help deliver consistency in hydrogen quality parameters.

13. Do you identify any areas of concern related to hydrogen production?

Nascent industry with standards to be established.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

NA – we don't currently envisage the deployment of white hydrogen in an Irish context at present.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

In theory yes, but odorant requirements etc will need consideration. Repurposed pipelines may initially result in contamination and this would need to be considered with respect to potential cost savings of repurposing pipelines.

Operational difficulties of the hydrogen generators with maintaining high quality levels.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

A gas quality transparency platform provides open, standardised, and easily accessible information—especially on gas quality—to ensure fair competition, efficient network access, and seamless cross border gas system operation.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Yes as it's another nascent industry.

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

NA (too early to comment).

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

Incentives need to be balanced with the overall gas quality management requirements of the network.

21. Please enter your email address to receive a copy of the information you submitted.

Mary.Omahony@gasnetworks.ie

ENGIE response to the PC

1. Please provide your name, your position, and the organisation you represent.

Dr. Maxime DUFOND, Research program manager, ENGIE

2. What do you consider to be the main purpose of hydrogen quality monitoring?

The main purpose is to control the quality of the H₂ from the production to the delivery.

- For contractual relationship between stakeholder;
- For safety purpose.

H₂ Quality monitoring is at the heart of operation strategy of H₂ value chain.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

To my point of view, the two main decisions are to develop and harmonised and clear european framework for H₂ transported by pipeline (injection, transport and delivery).

The second is go through laboratory certification in order to validate the capacity of a laboratory to deliver representative results -> Key because non representative results can lead to strong OPEX and CAPEX impact for H₂ asset operators and end users.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

I am not enough expert to answer.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Yes. Storage is the key to unlock the H₂ potential.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

They need to be accountable of the change of quality between injection and delivery.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Non. A gas quality monitoring is needed before the delivery. Probably focalised on few impurities.

In any case, a Quality Risk Assessment is required to define the best analytical strategy (sampling point, type of analysis, scope to target, threshold...).

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

They need to be accountable of the gas delivered.

9. Do you identify any specific considerations or challenges related to terminals?

—

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Contaminants thresholds otherwise interconnexion will be difficult.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

This work is ongoing for the network and well defined for mobility standard.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes

13. Do you identify any areas of concern related to hydrogen production?

Quality Risk Assessment must be required.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

–

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

Yes but i am convinced that, it will be really difficult for the network to ensure such high purity with purification unit. The cost of H₂ delivered will probably be really high. To my point of view, transport should be allowed at lower purity.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

Flow and Quality + Quality risk assessment.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Not expert enough but i think so.

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes, the cost of H₂ analysis is really expensive and time consuming. There is a need to develop analytical strategies adapted to new uses + certification of the Lab. Additionally, online monitoring is still at its early stage and need to be push forward.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

–

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

–

21. Please enter your email address to receive a copy of the information you submitted.

maxime.dufond@engie.com

IFIEC response to the PC

1. Please provide your name, your position, and the organisation you represent.

Paul Villalobos Valdivia, Policy advisor energy at VEMW, Rapporteur of the IFIEC Working Party Gases, Representing IFIEC Europe

2. What do you consider to be the main purpose of hydrogen quality monitoring?

The main purpose of hydrogen quality monitoring should be to ensure transparency and comparability of hydrogen quality specifications across Member States and across the hydrogen value chain. Reliable monitoring allows network operators, regulators, and users to verify compliance with agreed specifications, identify deviations, and ensure that hydrogen delivered through interconnected infrastructure remains compatible with end-user requirements. This is essential for enabling cross-border trade and building trust in the emerging European hydrogen market.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

The key decision at this stage is the establishment of a hydrogen quality standard that supports the scaling up of the hydrogen market while remaining aligned with the technical requirements of hydrogen end-users.

In particular, the standard should enable current and future feedstock users, such as refineries, chemical producers and fertilizer manufacturers, to access hydrogen with a quality in line with their necessities. Ensuring that the infrastructure quality standard aligns with the needs of these users will provide companies with the certainty required to make investment decisions and will therefore contribute to the development of a liquid hydrogen market. Please find our position paper attached.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

Yes, the development of a single, interconnected hydrogen network without distinctions between hydrogen grades would strongly support the creation of a well-functioning European hydrogen market. A harmonised hydrogen quality specification across Member States facilitates cross-border transport and trade and avoids additional technical measures or purification steps at interconnection points. Such fragmentation would increase costs and could inhibit the development of the internal hydrogen market.

Unlike natural gas systems, where different gas qualities exist due to differences in sources, the hydrogen system can be designed from the outset around a uniform specification.

However, the chosen quality standard must reflect the requirements of hydrogen users. IFIEC Europe therefore supports a high hydrogen quality specification of ≥ 99.9 mol %, combined with appropriate contaminant thresholds, which allows current and future feedstock users to connect to the hydrogen infrastructure. Ensuring that the infrastructure quality standard aligns with the needs of existing hydrogen consumers represents the most effective way to enable the rapid scaling of the hydrogen economy.

At the same time, some flexibility may be necessary in cases where national user structures differ significantly. If a Member State has industrial users with stricter quality requirements than the European baseline, the possibility for higher national specifications should remain available.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Hydrogen storage facilities will play an important role in the future hydrogen system, particularly in balancing differences between hydrogen production and consumption patterns. Current hydrogen demand in industry is largely baseload, while future hydrogen production, especially RFNBO hydrogen produced via electrolysis, will depend heavily on the availability of renewable electricity and therefore on weather conditions.

As a result, storage will likely become an important flexibility tool in the hydrogen system. Hydrogen may also play a role in providing CO₂-free dispatchable electricity generation during periods of low renewable generation, which could further increase the importance of storage.

At the same time, storage facilities must be able to deliver hydrogen at the required quality levels. Treatment or purification units may therefore be required when hydrogen enters or exits storage facilities. These purification steps should be considered as part of the infrastructure system rather than shifting the responsibility and costs to downstream users.

New salt cavern storages are technically capable of storing and delivering hydrogen at very high purity levels. However, repurposed storages previously used for natural gas or oil may face greater challenges in maintaining consistent hydrogen quality over the long term. While the reuse of existing infrastructure can be beneficial, these con-

siderations should not lead to a lowering of the hydrogen quality standard, as doing so would shift risks and costs to industrial users.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

Hydrogen transmission network operators will play a crucial role in the development of the European hydrogen market. They are responsible for ensuring the safe and efficient transport of hydrogen, maintaining system integrity, enabling cross-border trade and connectivity between hydrogen clusters.

HTNOs will also play an important role in monitoring hydrogen quality, ensuring compliance with the agreed specifications, and providing transparency regarding hydrogen composition across the network.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

No. Hydrogen quality specifications should be clearly defined for both entry and exit points of the hydrogen network.

Users must have certainty that the hydrogen delivered to them meets the expected quality specification. Defining specifications only at entry points is therefore insufficient unless the network operator guarantees that the same quality is delivered at exit points. Alignment between entry and exit specifications is essential to provide confidence to hydrogen users and avoid the need for decentralised purification.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

In the short to medium term, hydrogen distribution networks are likely to play a limited role compared with transmission infrastructure.

IFIEC Europe sees an important role for geographically confined hydrogen networks in industrial clusters. The current state of legislation, specifically Article 52 of Directive 2024/1788, severely limits the potential of these networks. Especially in the short to medium term, these networks can potentially fulfil a larger role in distributing hydrogen within a geographically confined area.

Please consult the IFIEC Europe position paper on Article 52. Additionally, the existing hydrogen networks (Article 51 of Directive 2024/1788) will continue to remain vital in supplying hydrogen now and in the future.

9. Do you identify any specific considerations or challenges related to terminals?

Yes. Under the current Hydrogen and Decarbonised Gas Market Package, terminals are only allowed to connect to transmission networks. This limitation may unnecessarily restrict system flexibility.

Allowing terminals to connect to other types of hydrogen infrastructure – such as storage facilities, industrial clusters or geographically confined networks – could improve system integration and reduce infrastructure costs. Removing this limitation would therefore support the efficient development of the hydrogen import value chain.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Reaching consensus on contaminant thresholds is more important.

Once acceptable contaminant limits are defined, the resulting hydrogen purity level can be derived from those thresholds. Since different contaminants have different impacts on industrial processes, catalysts, and equipment, clearly defined contaminant limits are the most relevant parameter for ensuring compatibility with hydrogen end-use applications.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

No. A full consensus on contaminant thresholds has not yet been reached. Please consult the IFIEC position paper on hydrogen quality.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

-

13. Do you identify any areas of concern related to hydrogen production?

-

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

-

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

Yes. Please consult our position paper.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

The main priority should be the provision of reliable and real-time data on hydrogen quality across the network specifically at exit-points. This should include information on

hydrogen purity levels, contaminant concentrations, and any deviations from the agreed specifications.

Providing such information in real time would enhance transparency and support operational decision-making by users.

It would also prevent the need for the double installation of a measuring station. The HTNO will install measuring stations across the network and at the exit points. Making the data available measured at the measuring station to industrial offtakers in real time prevents the necessity for the installation of additional measuring stations operated by the industrial offtaker.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

-

18. Do you identify a need for investment in developments related to hydrogen quality?

-

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

From a system perspective, purification should preferably take place at central points within the hydrogen infrastructure rather than at individual user sites. Centralised purification avoids the duplication of installations across multiple industrial users and therefore reduces overall system costs.

This approach also prevents industrial users from being forced to invest in decentralised purification installations due to inadequate infrastructure quality. Please read our position paper.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

-

21. Please enter your email address to receive a copy of the information you submitted.

pv@vemw.nl

Attachments:

[IFIEC position on H₂ quality and article 52 of EU Directive 2024/1788](#)

EIGA response to the PC

1. Please provide your name, your position, and the organisation you represent.

Sandrine Devos, Head of Public Affairs, EIGA (European Industrial Gases Association)

2. What do you consider to be the main purpose of hydrogen quality monitoring?

- Safety of the grid itself and the downstream customers, e.g. oxygen ingress.
- Functionality of the processes of hydrogen consumers, i.e. avoiding consequential damages due to off-spec hydrogen supply and inerts for flame stability.
- Invoicing of hydrogen (if not high-purity) accounting for heating value.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

Due to the eco-political change on hydrogen demand, there is at this stage no need to develop a standard on hydrogen quality in the backbone. Currently using hydrogen as fuel is not economically viable.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

No. A one-fits-all solution is not economically feasible.

The future hydrogen backbone will not develop the same way as the gas network. Having a single hydrogen quality standard across Member States will in no way be the most determining factor for triggering investment into hydrogen transmission infrastructure: getting certainty on the use of this infrastructure will be far more important. This certainty will only stem from core end-users' investment decisions. While a unique standard could later help better connect different networks that may be developed separately at first, it should not become a hurdle for the more local networks to develop (for instance, because high purity users would have to invest in purification). Therefore, we call for an approach that focuses on facilitating the early deployment of the backbone and commitment of end-users.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Hydrogen producers/suppliers and hydrogen consumers are the most critical link in the hydrogen value chain, and for the deployment of the backbone infrastructure. Decisions on quality in the backbone should be based on the users' needs, rather than the needs of other service providers. Storage facilities are a major element of the future solution.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

Safety should be the number one priority and a common thread in all missions carried out by HTNOs.

The role of HTNOs is well defined in the Gas Package (including maintenance, statutory inspections, leak detection and repairs). The first and most important mission of HTNOs is to ensure fair access to the backbone infrastructure and adequate planning of the network development according to the needs of the network users.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

It is not a sufficient safeguard. While producers/suppliers should be responsible for the quality of hydrogen that is injected, HTNOs must be accountable for hydrogen quality at exit points.

The storage, recompression and general maintenance will add impurities to the network, which should be safeguarded.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

See question 6.

9. Do you identify any specific considerations or challenges related to terminals?

No specific considerations.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

These two elements should not be considered separately. The thresholds set for the contaminants will determine the maximum level of impurity in the hydrogen. For clarity, contaminants also include inerts, and no portion of the acceptable hydrogen quality should remain unspecified.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

Alignment on these threshold values is not yet reached at EU level, due to large disparities and uncertainty around the specific distribution of end-users and their quality requirements, within planned networks and between networks. We do not know exactly the impurities that might be injected in re-purposed pipelines.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes. Art 69 of the 2024 Gas Regulation states that the Commission ultimately has the last word on the harmonised standards to be proposed. It is preferable for the Commission to provide clear guidance to the selected standardisation bodies, in order to facilitate the swift adoption of these standards.

13. Do you identify any areas of concern related to hydrogen production?

Quality, reliability and economics. The lowest quality injected impacts all consumers in the backbone system. Pressure and flow control affects all consumers.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Quality might be challenging.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

No. The most cost-efficient approach to facilitating cross-border flows without affecting the development of the backbone or the uptake of network users, is to align on hydrogen specifications across the borders. However, in cases where there is no plan for interconnections in the foreseeable future, a harmonised EU-wide standard may not be the most cost-efficient.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

Safety should be the number one priority and a common thread in all missions carried out by HTNOs. The data provided through a transparency platform should be easy to access for network users, and sufficiently granular to ensure that users are kept aware of any quality issue in due time. Granular data on contaminants should be provided.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

No

18. Do you identify a need for investment in developments related to hydrogen quality?

No. The question is not clear.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

The question is not entirely clear. Each party shall be responsible for meeting the agreed quality in the backbone.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

Assuming you mean subsidies, we believe a solution should be found that does not require public support for purification. Socialisation of the purification costs is not a sustainable way of dealing with this challenge.

21. Please enter your email address to receive a copy of the information you submitted.

s.devos@eiga.eu

ENTSOG response to the PC

1. Please provide your name, your position, and the organisation you represent.

David Gil, Subject Manager, Interoperability and data exchange, ENTSOG

2. What do you consider to be the main purpose of hydrogen quality monitoring?

No opinion.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

The development of a pan-European hydrogen network, based on both repurposed and newly built pipelines, requires careful consideration of hydrogen quality needs along the entire value chain. In this context, ENTSOG welcomes the public consultation launched by ENNOH.

Regarding the studies presented by ENNOH in its document named “ENNOH HYDROGEN QUALITY MONITORING REPORT 2026: PUBLIC CONSULTATION GROUNDWORK DOCUMENT”, ENTSOG would like to provide comments to the “Study on hydrogen quality in dedicated infrastructure and standardisation ordered by DG ENER”:

1) Repurposed pipelines as key bottlenecks for H2 purity

Statement from the report: The report highlights repurposed pipelines and certain types of underground storage (UGS) as major bottlenecks, leading to significant purification efforts. (e.g. p. V, IX and 114 of the report).

ENTSOG comments:

It is important to clarify that repurposed transmission pipelines should not be equated with UGS in this regard. Cleaning of transmission pipelines can achieve hydrogen purity levels of 98 % or more, although requiring increased expenses for high purity percentages. After the cleaning phase, a transition phase may be needed. After these phases, reaching the established purity can be done without the need of installing additional purification systems.

In contrast, UGS facilities may need permanent purification technologies to reach similar purity specifications. However, since pipelines and storages constitute an essential and complementary infrastructure for operating molecules systems in efficient and secure ways, both assets' requirements must be considered. Ultimately, identifying the most efficient solution requires an overall evaluation, including all relevant infrastructures, users' requirements and related costs.

A few tests have been performed so far to assess the ability of natural gas transmission pipelines to be repurposed to H₂. Two recent preliminary experiments have been conducted in France and Germany. One odorized pipeline was also part of these tests. Despite the short duration of the experiments (around two weeks), the findings from both projects show that cleaning of the examined pipelines is effective in achieving a hydrogen purity of 99.5 %. While long-term testing is needed, these initial findings from the French and German projects are encouraging and suggest that repurposed pipelines could achieve hydrogen purity of both 98 % and 99,5 % through effective cleaning processes.

ENTSOG proposal:

ENTSOG proposes deleting from the report and slides the reference to repurposed pipelines as key bottlenecks for hydrogen purity.

2) Hydrogen embrittlement

Statement from the report (p. 128): “In addition to these purification costs, also further costs for hydrogen transport in repurposed pipeline need to be considered: older steel pipes are more susceptible to hydrogen embrittlement, increasing the need for regular inspections and maintenance.”

ENTSOG proposal:

Suggestion to rephrase “older steel pipes could be more susceptible to hydrogen embrittlement”

Indeed, the embrittlement of a repurposed pipeline depends on the combination of several factors, eg: dimension, type of steel, age, standards followed when the pipeline was installed etc.

Statement from the report (Remarks to the text p. 128)

“Compared to current natural gas use, also the fact of a lower density of hydrogen result in either higher operating pressures or larger volume flows or higher flow rates that are required to transport the same energy content. This results in additional capital expenditures for compression and monitoring, which are reflected in operational costs of gas transport. In contrast, new hydrogen pipelines are specifically designed for the transport of high-purity hydrogen and ...”

ENTSOG comments:

The sentences above cannot be associated exclusively with repurposed pipelines; it describes the physical properties of hydrogen in general.

3) Intensive cleaning of H2 pipelines

Statement from the report (p. 113) “intensive cleaning and purging procedures are needed for repurposing – however, it will not be possible to remove all potential sources for contamination”

ENTSOG comments:

The cleaning and transition phases may be necessary steps when repurposing natural gas transmission pipelines for hydrogen transport. However, the sequencing and scope of these phases are determined by each operator and should be based on a technical and economic assessment specific to the individual case. Consequently, it may be inaccurate to assume that residues leading to a breach of hydrogen quality specifications are present during the transition phase in all circumstances.

For example, an operator may choose to clean the pipeline to fully achieve the hydrogen quality specifications during the cleaning phase, in which case no residues should be expected during the transition phase. In addition, the term “intensive” is subjective and would require

further characterisation to ensure a consistent and unambiguous interpretation.

ENTSOG proposal:

As such, ENTSOG proposes that the statement be amended as follows:

“intensive cleaning and purging procedures may be needed for repurposing – however, residues from NG usage may be present in the transition phase”

4) Impact of new pipeline share on purification costs

Statement from the report (page 101)

ENTSOG comments:

The graph illustrating purification costs in relation to the share of new pipelines may lead to misunderstanding without a proper description of the considered assumptions.

In case of 98 and 99,5 % H2 purity, purification costs associated with repurposed transmission pipeline are primary linked to the cleaning process. Cleaning, necessary step to remove residues left from previous natural gas usage, generally represents a temporary expense rather than a recurring operational cost. Moreover, as stated on page 68 of the report, the hydrogen quality in repurposed pipelines increases over time. This means that additional purification steps are generally not required for transmission pipelines to achieve a H2 purity of 98 and 99,5 %.

Therefore, if purification costs indicated in the graph represent the initial cleaning of repurposed pipelines, it is important to clarify that these costs are temporary and should not be interpreted as recurring expenses. It is important to note that higher purity standards would require additional treatment expenses for the hydrogen infrastructure, which includes both pipelines and storages that are interlinked for a safe and efficient molecule system operations.

Failing to make this distinction could lead to misrepresentation of the long-term operational costs associated with repurposed hydrogen pipelines.

Additionally, the graph lacks details regarding the initial hydrogen purity level before purification begins. The costs associated with increasing hydrogen purity from 98 % to 99.97 % can differ from those required to purify from 99.5 % to 99.97 %.

ENTSOG proposal:

If the graph is intended to depict a worst-case scenario, this should be clearly mentioned in the report/slides, and the assumptions considered should also be detailed to prevent any potential misinterpretation or incorrect conclusions.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

No opinion.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

No opinion.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

No opinion.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

It's important to emphasise that from the perspective of a transmission operator, as long as the gas transported, in the case of HTNOs, hydrogen, is within the defined specifications, doesn't influence the integrity of the system operator's infrastructure and the system operator is able to transmit the hydrogen through “technically cleaned” rededicated natural gas pipelines and/or newly built hydrogen pipelines, HTNOs will be able to transport the defined H2 quality.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

No opinion.

9. Do you identify any specific considerations or challenges related to terminals?

No opinion.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

No opinion.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

No opinion.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

No opinion.

13. Do you identify any areas of concern related to hydrogen production?

No opinion.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

No opinion.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

No opinion.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

No opinion.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

No opinion.

18. Do you identify a need for investment in developments related to hydrogen quality?

No opinion.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

No opinion.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

No opinion.

21. Please enter your email address to receive a copy of the information you submitted.

david.gil@entsog.eu



SEFE Storage GmbH response to the PC

1. Please provide your name, your position, and the organisation you represent.

Florian Hatesuer, Head of Hydrogen, SEFE Storage GmbH.

2. What do you consider to be the main purpose of hydrogen quality monitoring?

- enabling a European market with consistent and common hydrogen quality along the value chain (end users, SSOs, etc) that can be counted on
- ensuring a basis for correcting actions if quality issues arise.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

- It is the question of what should be monitored and defined primarily: H₂-concentration or (preferred) trace component concentrations → we see the latter to be the better way
- Additionally the regulatory aspects of implementing (cost association, ...) are important.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

Yes. See questions #3 for details.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Yes. They are essential for the existence of a technical and commercial valid hydrogen ecosystem: Due to their large-scale storage capacity, they provide resilience and flexibility to the entire hydrogen system as they represent the critical component for structuring. Moreover, storages need to be geographically distributed to ensure technical stability and performance.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

Analogous to in the natural gas system. TSOs are necessary for a scalable hydrogen economy. They connect key market players such as producers/ importers and off-takers, as well as storage facilities.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Entry and exit points are not necessarily identical qualities.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

At this point, there are few or none identified. There is benefit in certain locations, especially when large industrial consumers are connected via the HDNO.

9. Do you identify any specific considerations or challenges related to terminals?

The commodity hydrogen will be imported to some extent. This requires terminal infrastructure ensuring entry capacity to the European H₂ market. Thus, this type of infrastructure is necessary for ramping up the market. And they need to be considered also, when hydrogen quality is being assessed.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Contaminant thresholds are more important.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

The consensus is not fully reached yet, but in sight. Main area of concern is missing information about major technical parameters, e.g. requirements for power plant turbines and for microbial impact in varying geological environments for UHS.

Additionally, the related regulatory aspects need to be addressed in parallel.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes. And we see TC234 as the natural body for that.

13. Do you identify any areas of concern related to hydrogen production?

There must be no economic incentive to “just meet” requirements, even if “normal purification” would allow for better-than-required. I.e. no incentive to mix in hydrocarbons “to the limit” because their energy content is higher than that of hydrogen.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

The mix of contaminants would be considerably different from other sources. E.g. helium. Once this can be quantified, hydrogen quality requirements should be reviewed. At this point we don't see need for action, though.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

In many places yes, but not fully. It also depends on the remaining contaminants.

However, even if at some locations purification can be avoided, it would not be economical on a market level. This purification would need to be done elsewhere and for larger amounts of hydrogen. This would be more costly in the end. It is also questionable, if such a high purity level can technically be achieved in the gas infrastructure realistically.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

1. Pressures
2. Flow rates
3. Wobbe-Index
4. Change rates
5. Sulfur
6. Lower HCs
7. Higher HCs
8. Oxygen

assuming that the gas in the transport system is dry.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

- The purification methods are well-established and proven; we are not aware of any innovation that is on the verge of hitting the market and would represent a game-changer
- Tail gas usage is important for PSA. Any improvements there would help greatly.
- Perhaps there are still ongoing developments in the field of membrane processes that could help to increase the efficiency in separating single contaminants
- By means of microbial growth inhibition level of contaminants can be avoided or decreased also lowering the need of purification – for various parts of the infrastructure (pipelines, UHS, ...)

18. Do you identify a need for investment in developments related to hydrogen quality?

- Investment in purification plants depending on the required optimum of hydrogen purity, especially also depending on the allowed concentrations of each contaminant.
- Still some aspects of steel compatibility with hydrogen with aggressive contaminants such as CO₂ or H₂S.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

- The cost would ideally be shared along the various partners along the value chain.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

It should be avoided that there are incentives to : intentional mixing-in of contaminants. Different pricing for different qualities should be avoided, though.

21. Please enter your email address to receive a copy of the information you submitted.

florian.hatesuer@sefe.eu

NaTran response to the PC

1. Please provide your name, your position, and the organisation you represent.

Adoir Nicolas, gas quality expert, NaTran (french TSO)

2. What do you consider to be the main purpose of hydrogen quality monitoring?

The main purpose of H₂ quality monitoring is to verify that the H₂ complies with the impurity thresholds set out in contractual commitments with various stakeholders. These thresholds shall be defined to ensure infrastructure integrity and safety, interoperability across interconnected network and technico-economical optimisation for the entire value chain of the European hydrogen market.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

This standardisation work is currently being undertaken within the framework of CEN TC 234 WG11 although there has not yet been any "official" standardisation request from European Commission for hydrogen quality. Our company supports this CEN initiative.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

In principle, yes. A single interconnected hydrogen network supports efficient infrastructure use.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

According to studies and/or exchanges within GIE, Eassee-gas,... storage facilities seem to represent indeed the most critical link in the hydrogen value chain due to use of PSA purification units on site (environmental constraint, regulation) and tailgas usage.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

Hydrogen transmission network operators play a central role in ensuring cross-border interoperability and system integrity. HTNO's should guarantee H₂ quality during transport in compliance with H₂ specifications, provide transparent quality data, implement network balancing,...

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

The hydrogen quality specification (given by a common standard) should be applicable for the whole value chain. Every stakeholder along the value chain is responsible to maintain the quality parameters.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

To be answered by HDNOs

9. Do you identify any specific considerations or challenges related to terminals?

Terminals may introduce specific contaminants (e.g. nitrogen, ammonia traces). To be completed by terminals.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

A consensus on contaminants thresholds is more important than defining a H₂ purity level. The H₂ purity becomes a consequence of contaminants thresholds.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

The main remaining area of concern seems to be methane content and oxygen content (may be sulfur content as well).

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes, CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States.

13. Do you identify any areas of concern related to hydrogen production?

Areas of concern could include performance of purification units. To be completed by H₂ producers.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Expansion of this type of production could be a game changer for H₂ market (whether production costs are lower than for the other types of production).

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

Further purification would only be necessary where requirements exceed 99.97% purity (e.g., semiconductor industry). To be completed by very sensitive consumers.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

The main priorities regarding data provided by HTNOs through a transparency platform should be real-time or near-real-time quality data and flows, historical data and interoperable data exchange formats. ENTSOG transparency platform should be a great help.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

–

18. Do you identify a need for investment in developments related to hydrogen quality?

Storage facilities seem to represent a critical link in the hydrogen value chain. R&I investments to solve storage concerns are may be a priority.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

Regulated cost recovery for hydrogen purification processes for TSOs/SSOs

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

CBP EASEE-gas 2023-001/01 gives the following recommendation: "Unlike the units used in natural gas market processes, the determination of the energy content of hydrogen is only based on the energy content of the hydrogen molecules present which means the energy content of all other components is not taken into account." This recommendation is an incentive mechanism that could be useful for hydrogen quality.

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BDH response to the PC

1. Please provide your name, your position, and the organisation you represent.

Association of the German Heating Industry (BDH)

2. What do you consider to be the main purpose of hydrogen quality monitoring?

Hydrogen quality monitoring is essential because hydrogen appliances can be very sensitive to impurities, and even small deviations can cause technical, safety, and regulatory problems.

Hydrogen is used in systems (end-user appliances) that are highly sensitive to contaminants, especially: industrial burners.

We consider two monitoring steps as relevant:

- 1) The primary purpose of monitoring is to ensure compliance with a specific and defined gas quality.
- 2) A measurement may also be necessary if the range of fluctuations is so large that knowledge of the current gas composition is required to compensate for those fluctuations.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

- Granting of a hydrogen purity level (ideally 99,5 Vol- %) to keep the number of uncertainties small
- This makes variations caused by impurities manageable, among other things Wobbe Index (WI) and air-fuel ratio requirements.

- A gas quality in the range of 98,0 vol- % to 99.5 vol- % is manageable, if the impurities are specified in such a way that key combustion characteristics - particularly the Wobbe Index (WI) and air-fuel ratio - do not cause excessive variability.
- Define responsible entity of the agreed H₂-quality to end users

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

From the perspective of burner manufacturers, a single, interconnected hydrogen system has clear advantages regarding system stability and system security.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

No comment

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

In the past, stability in gas quality was a key factor to guarantee safe and stable burner operations.

Requirements:

- Ensuring low fluctuations of gas quality in the future; see also point 2 and 3
- transparency of the actual gas quality provided by network operators
- access to local gas composition data

Statement addressed to the HTNOs:

- HTNOs should ensure predictable hydrogen quality
- HTSOs should communicate the hydrogen quality at exit points not just define a nominal value.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Not enough. See comment under point 6. HTSOs should communicate the hydrogen quality at exit points.

Note: Gas qualities at the entry and exit point may differ. More relevant is the knowledge of the gas quality at the exit point at any time.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

See statements mentioned before. The system level (TSO/DSO) is less significant; the product quality at the exit point is decisive.

9. Do you identify any specific considerations or challenges related to terminals?

–

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Reference to answer 2 + 3

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

Impurity thresholds alone (Inert gases (Ar, CO₂, He, N₂): ≤ ~2 vol %; CH₄: ≤ ~2 vol %) are not sufficient. Additional control parameters e.g. Wobbe-Index (WI), narrow banded air-fuel ratio, stability must be explicitly considered.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

- Yes, A mandate in principle.
- Broken down, for example, into EN 16726 EN 16726 “Gas infrastructure - Quality of gas - Group H”

13. Do you identify any areas of concern related to hydrogen production?

No comment

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

No comment

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

No comment

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

- Stable H₂-quality according to set specification at exit points to end consumers
- Delivered H₂ composition quality on-line reporting to end users
- Responsibility for a reliable network operation

See the statements done in number 2 and 3

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

We must consider even the opposite: A lack of purification could increase significantly the cost of end-user-devices. If, for example, every single forced draught burner would need a safe Wobbe-Index-Controller, then appliances would become more expensive.

But also mentioned here, like done in point 6: In the past, stability in gas quality was a key factor to guarantee safe and stable burner operations.

18. Do you identify a need for investment in developments related to hydrogen quality?

–

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

–

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

–

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ÖVGW response to the PC

1. Please provide your name, your position, and the organisation you represent.

ÖVGW (Austrian Association for Gas and Water)

2. What do you consider to be the main purpose of hydrogen quality monitoring?

The main purpose of monitoring hydrogen quality is to ensure:

- The integrity and safety of the infrastructure, including compatibility with existing infrastructure (ensuring the quality of transportable H₂), underground storage facilities and use in end-use devices.
- Interoperability between connected networks and network levels to enable cross-border hydrogen flows (including outside the EU).
- Reliable measurement of calorific value for billing purposes, as impurities can affect the calorific value.
- Market confidence to ensure that the hydrogen supplied meets the agreed specifications.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

The ÖVGW and its members are in agreement that the most urgent decision is to establish a uniform EU-wide standard with a hydrogen content of 98 %, Grade A (residual components in accordance with the applicable ÖVGW guideline H B100 'Hydrogen Composition').

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

Yes, a single, interconnected hydrogen network supports market liquidity and the efficient use of infrastructure, and provides certainty for planning purposes.

It should also be taken into account that the construction of H₂ transport networks is currently beginning with regional projects, for which local agreements can be reached to define a specific H₂ quality. These may differ regionally from the values proposed in European studies.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Yes, we agree, but from the ÖVGW's perspective, storage facilities are essential, as they represent the only means of shifting energy production between seasons.

In Austria there are several large-scale porous storage facilities, which are of major importance. They are former natural gas reservoirs, which implies the presence of contaminants that may require expensive and large-scale treat-

ment units. Specific monitoring and operational procedures will also be required at storage interfaces, similar to those at producers' exit points.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

Operators of hydrogen transmission networks should:

- Ensure the minimum quality (98 % H₂) during transport.
- Ensure the reliability and availability of the gas transmission infrastructure and guarantee transit under optimal conditions in terms of safety and cost, whilst taking environmental protection into account.

HTNOs play a central role in ensuring cross-border interoperability and system integrity.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

From the ÖVGW's perspective, this is a necessary but not sufficient condition.

We aim to establish a uniform hydrogen quality specification that applies across the entire value chain and is compatible with all infrastructure operators.

Every stakeholder along the value chain is equally responsible for complying with the quality parameters established by a common and agreed standard.

HTNOs should therefore ensure both compliance with inlet specifications and the quality management of the network, supported by monitoring and modelling.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

HDNOs play a crucial role as the interface with all users (storage facilities, feeders, consumers, etc.). The role is similar to HTNOs:

- Ensuring the minimum quality (98 % H₂) during distribution.
- Ensuring the reliability and availability of the gas distribution infrastructure and guaranteeing transit under optimal conditions in terms of safety and cost, whilst taking environmental protection into account.

9. Do you identify any specific considerations or challenges related to terminals?

Currently a minor issue in Austria.

The same quality requirements apply to terminal interfaces as to the rest of the value chain.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

In the ÖVGW's view, both the establishment of a uniform EU-wide quality standard of 98% hydrogen content (Grade A) and the agreement on residual components (in accordance with the current ÖVGW guideline H B100 'Hydrogen Quality') are important.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

A broad consensus has already been reached on threshold values for most impurities relevant to hydrogen transport and distribution.

One area of concern relates to methane content and inert gas content, and the associated variation in the Wobbe index.

Another area of concern relates to sulphur, which may be present, particularly in converted distribution networks, due to odourisation.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes. A clear mandate from the European Commission to CEN/CENELEC would speed up harmonisation and prevent fragmentation among Member States.

13. Do you identify any areas of concern related to hydrogen production?

Concerns include:

- Variability in production processes and the associated impurity profiles (differing quality criteria at the feed-in point, e.g. the requirement for higher minimum feed-in quality in electrolysis)
- Inadequate drying and purification performance (cost-cutting in the treatment of the production plant).
- Trace elements that affect the infrastructure and measurements
- Lack of harmonised guidelines for carrying out measurements at production sites

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Potential challenges include:

- Uncertain composition of the contaminants
- Variability over time
- Presence of inert gases or sulphur compounds
- Need for special treatment and monitoring

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

No, the ÖVGW does not believe that local purification units can be dispensed with. Even if a high global standard of hydrogen purity (>99.97%) were to be set for all interconnected European networks, local purification units would still be required for certain sensitive applications.

In that case, a European hydrogen network would be impossible, and only local clusters would emerge. Consistent compliance with such specifications across Europe is not feasible.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

Main priorities are:

- Flow rates and pressures at transfer points
- Wobbe index
- Standardised parameters and units
- Traceability and historical data

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Promising areas include:

- Advanced membranes and sorbents
- Modular purification technologies
- Digital quality tracking and predictive models
- Potentially improved sensors and real-time analysers

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes, investment is needed in hydrogen production processes for production and storage facilities.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

Within a regulated framework, an optimal cost allocation should reflect the responsibilities of producers, network operators (TSOs/DSOs) and storage operators (SSOs), whilst preserving market development.

A balanced approach would include the following:

- The polluter-pays principle at entry points, with producers ensuring compliance with basic grid quality standards
- Regulated cost recovery for TSOs/DSOs/SSOs for monitoring, quality tracking and operational measures necessary to maintain quality within the grids and storage facilities

- Recognition that storage facilities may require specific quality management measures, with the associated costs treated as regulated infrastructure costs where they benefit the overall system
- End-use-driven cleaning costs, where purity exceeds grid specifications, are to be borne by the user

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

There should be a binding obligation for producers to meet the highest possible quality standards.

The focus should be on the early introduction of harmonised solutions; incentives alone will not bring this about.

Yes, incentives could, for example, promote innovation in cleaning and monitoring in general, particularly for underground storage facilities (e.g. high pressure, high flow rates, limited space).

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OPEN GRID EUROPE response to the PC

1. Please provide your name, your position, and the organisation you represent.

Tobias van Almsick, Head of Gas Quality, Open Grid Europe GmbH, TSO in Germany

Christian Danker, Head of Network, Open Grid Europe GmbH, TSO in Germany

2. What do you consider to be the main purpose of hydrogen quality monitoring?

Monitoring the quality of H₂ brings security to the markets. Proof of compliance with standards is the basis for the safe transport and use of hydrogen.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

The crucial point is to determine a methane concentration in hydrogen that is acceptable to all market participants. The permissible limits for the other trace components have almost been determined. The question of hydrogen purity therefore does not need to be addressed directly. It arises from the possible concentration of trace components.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

Agreed. An interconnected European hydrogen network is the basis for a successful market ramp-up. It is essential to prevent transport barriers from being created. European harmonisation of hydrogen quality is indispensable for this.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

With regard to the properties of hydrogen, this may well be true. However, there is still a lack of experimental findings on a field scale. Nevertheless, there is a tendency to overlook the requirements of end users all too often.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

All HTNOs should respect the valid national and international standards on hydrogen quality and should contribute to avoiding violations, as should be the case for all market participants along the value chain.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

It is essential to avoid making any distinction between entry and exit specifications. There is a specification for hydrogen quality. This must be complied with at all points of the public gas supply.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

All HDNOs should respect the valid national and international standards on hydrogen quality and should contribute to avoiding violations, as should be the case for all market participants along the value chain.

9. Do you identify any specific considerations or challenges related to terminals?

Terminal operators should respect the valid national and international standards on hydrogen quality, as all other market participants are obliged to.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

See question 3. The question of hydrogen purity can remain unanswered, at least in a direct sense. It is calculated as the sum of permissible impurities. Add to this a specification for the Wobbe index, and the standard is almost complete. Methane is the decisive component.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

There are still some uncertainties regarding methane. However, discussions with many market participants suggest that a compromise can be reached at a methane concentration of 1 mol %. CEN has already begun work on drafting a new standard.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Such a mandate would rightly give special significance to a hydrogen quality standard. CEN TC 234 has been waiting for the standardisation mandate from DG Ener for over two years now. Discussions with Ruta Baltause have revealed that DG Ener is still uncertain about the exact details of this mandate. However, it will probably be available in the first half of 2026. Work at CEN has already begun, and the mandate can then be linked to this work as it progresses.

13. Do you identify any areas of concern related to hydrogen production?

- Variability of production routes and associated contaminant profiles
- Drying and purification performance
- Trace contaminants affecting infrastructure and metering
- Lack of harmonised measurement at production sites

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Fundamentally, too little is still known about white hydrogen today to be able to accurately assess its contribution to the European hydrogen economy.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

No. A quality such as that specified in EN 17124 cannot be maintained in supra-regional networks with connected storage facilities in such a way that partial purification at exit points would become unnecessary.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

As foreseen in the Gas Regulation, HTNOs should publish data on the purification level of hydrogen at relevant network points on the European transparency platform operated by ENNOH. With respect to trace components, the

measurements should be limited to those components for an initial suspicion exists based on the hydrogen's origin.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Significant innovation opportunities exist that could reduce hydrogen purification costs, including:

- Advanced membrane and adsorption technologies with lower hydrogen losses
- Modular purification solutions adaptable to infrastructure constraints
- Improved trace contaminant sensors and real-time analysers
- Digital quality tracking and predictive modelling, particularly for storage and network interactions

Such innovations are especially relevant for storage and terminal operators, where purification of large flow rates and varying compositions presents technical and economic challenges.

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes. Investment is needed in:

- Measurement technologies
- Online monitoring systems
- Storage conditions gas treatment processes
- Digitalisation and data platforms

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

Technical specifications for hydrogen quality should be set in a way that limit costs for purification processes as much as possible. Should network operators incur costs for purification processes necessary for upholding the valid technical specifications, such costs should be recognised by the Regulatory Authority in the regulated framework. Costs for purification processes at consumption points that go beyond the legal requirements should be covered by the individual consumers.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

Yes. Incentives could:

- Encourage producers to meet higher quality standards
- Promote innovation in purification and monitoring in general and more specifically for underground storages (e.g.: high pressure, high flow rate, little space)
- Reward transparency and quality reliability
- Support early deployment of harmonised solutions

ITALGAS response to the PC

1. Please provide your name, your position, and the organisation you represent.

Leonardo D'Acquisto, Head of Institutional Relations Italy and Europe, Italgas

2. What do you consider to be the main purpose of hydrogen quality monitoring?

The main purpose of hydrogen quality monitoring in gas distribution networks is to ensure that the hydrogen injected or transported within the grid meets the technical, safety and regulatory specifications required for reliable grid operations and for protecting end-use appliances and infrastructures.

In particular, hydrogen quality monitoring serves to:

Guarantee network safety: monitoring key parameters (e.g. hydrogen concentration, presence of impurities, calorific value, Wobbe Index) ensures that the gas mixture remains within the safe operating limits of pipelines, pressure regulators, odourisation systems and metering devices. This is critical to avoid embrittlement phenomena, operational instability or abnormal combustion behaviour. Taking the example of compressors, which are designed for the physical properties of hydrogen, quality monitoring ensures that the presence of heavier gases (such as nitrogen or oxygen) does not increase the work required for compression, causing premature wear of mechanical components. The presence of impurities such as oxygen or nitrogen affects also storage capacity, as they reduce the transported volumetric energy density. To obtain the same energy at the delivery point, the volume transported is greater. Moreover, the monitoring allows to optimize the logistics.

Protect customer appliances and ensure performance: end-use appliances (industrial burners, boilers, CHP units) have specific tolerance thresholds. Continuous monitoring prevents quality deviations that could impact combustion efficiency, emissions or appliance durability.

Giving more detailed examples:

- Fuel cell safety: PEM fuel cells (used in vehicles) are extremely sensitive. Even the smallest traces of carbon monoxide (CO) or sulfur can "poison" the platinum catalyst, quickly rendering the system unusable.
- Industrial process quality: in sectors such as semiconductor manufacturing or ammonia synthesis, hydrogen acts as a reagent. The presence of impurities can compromise the quality of the finished product or generate unwanted byproducts.
- Reduced maintenance: for hydrogen boilers or turbines, a pure gas ensures cleaner and more consistent combustion, reducing deposits and nitrogen oxide (NOx) emissions from organic impurities.

Ensure regulatory compliance and market integrity : as hydrogen introduction becomes regulated at national and EU levels, quality control is essential to comply with standards (e.g. EN 16726 for natural gas, ongoing work for H₂ blends) and to support the traceability and certification of renewable gases injected into the network.

Enable progressive integration of renewable gases: accurate quality monitoring is a foundational element for safely increasing the share of hydrogen and biomethane in distribution grids. It allows operators to validate blending strategies, optimize pressure management and support the longterm transition towards dedicated hydrogen-ready infrastructures.

Improve metering accuracy and operational control: variations in gas composition directly affect flow measurement, energy calculation and billing. Monitoring ensures that metering systems can adapt to hydrogen-enriched gases, guaranteeing transparency and fairness for end users.

While we consider hydrogen quality monitoring a crucial and necessary activity, we would also like to highlight some downsides:

- High purification costs: achieving high levels of purity (e.g. 99.97% or higher) requires technologically advanced processes, increasing the cost per kg of transported gas.
- Complex monitoring: ensuring that purity remains consistent across hundreds of kilometers requires advanced and expensive sensors to detect trace contaminants in real time.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

Despite the various studies and position papers produced so far, the key decision that must now be made concerns the definition of a clear and harmonised regulatory framework for hydrogen quality and the related acceptance ranges within gas distribution networks.

Following the definition of this framework, the other decisions to be taken will concern:

1. The quality and blending limits of hydrogen allowed in distribution networks

Operators need clarity on:

- maximum allowable H₂ blending percentage;
- acceptable impurity levels and gas composition limits;
- reference standards for safety, materials compatibility and combustion behaviour.

Without this regulatory certainty, it is impossible to plan network upgrades, monitoring systems or customer conversion strategies.

2. Monitoring requirements and responsibilities

A decision is needed on:

- which parameters must be monitored (H₂ %, impurities, Wobbe Index, calorific value, moisture, etc.);
- accuracy and frequency with which these parameters must be monitored;
- at which points of the network these specifications should be observed (REMI, injection points, district regulators, end-user interface);
- who holds the responsibility of this monitoring across the value chain (production, injection, distribution, end-use).

This is essential to ensure safety, interoperability and fairness in metering and billing.

3. The long-term vision: blended network vs hydrogen-ready segments

Europe is debating whether:

- to progressively increase blending levels or
- to create dedicated hydrogen-ready pipelines and districts.

Distribution companies need a firm strategic orientation to guide investment, R&D and asset management plans.

To conclude and summarize the key points, the main decision is to establish a unified regulatory and technical framework that defines hydrogen quality specifications, monitoring requirements and infrastructural pathways for the integration. Only with this clarity operators like Italgas can scale up pilots, standardize solutions and support the energy transition reliably.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

We believe that, in the long term, developing a single, interconnected hydrogen network is a desirable objective, as it maximises system efficiency, interoperability and market liquidity. A unified infrastructure would simplify operations, reduce fragmentation and support the creation of a competitive European hydrogen market.

However, from the perspective of a gas distribution system operator, achieving this vision requires a gradual and pragmatic approach.

In particular:

- clear and harmonised quality standards must be defined at European level to effectively integrate different hydrogen sources;
- operational requirements for distribution grids - including safety, materials compatibility and metering accuracy - must be addressed to ensure that all hydrogen transported in the network meets minimum quality thresholds;

- transitional phases may be necessary, where different types or grades of hydrogen coexist, supported by appropriate monitoring systems.

In summary, while the long-term vision of a single, interconnected hydrogen network is fully aligned with efficiency and market development goals, its implementation must be progressive and supported by robust technical and regulatory frameworks to ensure safety, reliability and fair access for all users.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Yes, storage facilities can be considered one of the most critical assets in the hydrogen value chain, although they are part of a broader infrastructure challenge.

Recent analyses show that:

- the infrastructure gap (including storage, pipelines and distribution) is currently the primary bottleneck preventing large-scale hydrogen deployment;
- hydrogen value chain studies confirm that storage technologies are essential, with physical storage methods being the most deployed in real applications;
- the IEA's Global Hydrogen Review 2025¹ highlights that infrastructure readiness remains a major barrier to hydrogen growth worldwide.

Since these assets represent a strategic part of the infrastructure, their operability must be preserved by preventing impurities such as oxygen and nitrogen from entering them through a careful monitoring, especially when they are retrofitted from natural gas storage.

To sum up and conclude, storage is indeed a critical element – essential for balancing production and demand –, ensuring security of supply and enabling flexible transport modalities. However, it must be developed in parallel with transport and distribution infrastructure and attentively monitored; otherwise, the entire hydrogen value chain risks stalling.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

For Italgas, HTNOs represent crucial enablers of the hydrogen economy.

Their work ensures:

- reliable and interoperable transmission backbones;
- regulatory clarity for investors and operators;
- infrastructure planning aligned with decarbonisation targets;
- efficient integration between transmission and distribution networks.

In summary, HTNOs are essential in ensuring that Italy and Europe can move from pilot projects to a mature and interconnected hydrogen market capable of supporting industrial decarbonisation and energy security.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Specifying hydrogen quality at entry points is necessary, as common purity thresholds and contaminant limits are essential to ensure interoperability and avoid market fragmentation. However, it is not sufficient on its own: harmonised EU-wide standards and continuous quality monitoring across the entire network are required to guarantee safe and consistent hydrogen delivery at exit points

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

Hydrogen Distribution Network Operators (HDNOs) play a critical role in enabling the local integration of hydrogen into the energy system. European analyses highlight that local gas distribution networks are essential to becoming the leading hydrogen distribution infrastructure, thanks to their flexibility, reliability and ability to connect distributed production, storage and final demand.

From Italgas' perspective, HDNOs are key to:

- repurposing and converting existing networks to hydrogen in a safe and efficient way;
- supporting market development, offering access to hydrogen for industrial clusters and communities;
- driving digitalisation and smart operations, essential for monitoring quality, flows and safety in hydrogen-ready grids;
- managing local quality variations and pressure regimes;
- ensuring metering accuracy.

In summary, HDNOs are indispensable to achieving a widespread, reliable and customer centric hydrogen distribution system aligned with EU decarbonisation goals.

9. Do you identify any specific considerations or challenges related to terminals?

Key considerations and challenges:

1. Interoperability and quality management

Hydrogen terminals must handle hydrogen coming from diverse production sources and international supply chains, requiring strict and harmonised quality specifications to avoid costly purification and ensure compatibility with pipelines, storage and end-use applications.

2. Safety, permitting and operational standards

Handling hydrogen at large scale requires specialised safety protocols, adapted materials and robust operational standards - all of which are still being harmonised at EU level.

3. Investment and long-term planning

Terminals must align with EU hydrogen supply chain goals, including large scale import pathways and port based hy-

drogen hubs, requiring coordinated planning with TSOs, DSOs and industrial off-takers.

For Italgas, hydrogen terminals represent critical nodes for ensuring system flexibility and supply security. However, their effective role depends on:

- clear and harmonised EU quality standards;
- strong integration with transmission and distribution networks;
- robust safety and operational frameworks.

Terminals will become essential interfaces between global hydrogen flows and local markets, but they require a careful governance and coordinated infrastructure development.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

For Italgas, both elements are important, but agreeing on a clear and harmonised contaminants thresholds is the priority.

European studies show that inconsistent contaminant limits can restrict crossborder flows and force costly purification steps, undermining interoperability and market development. At the same time, industry surveys highlight significant differences in acceptable impurity levels across operators, confirming the need for aligned thresholds to ensure compatibility with infrastructure and end-use technologies.

A unified purity level will be needed over time, but contaminants thresholds are the foundation for safe operations, infrastructure readiness and a functioning EU wide hydrogen market.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

Current evidence indicates that a full consensus on contaminant threshold values has not yet been reached in Europe. Stakeholders still diverge significantly on acceptable impurity levels, as shown by operator surveys and technical assessments. Additionally, EU studies warn that misaligned contaminant limits may restrict crossborder hydrogen flows and increase purification costs, signalling that harmonisation is still incomplete.

Remaining concerns include:

- non-aligned national approaches on impurity limits;
- impacts of contaminants on pipeline materials and storage assets;
- compatibility with fuel cells and other sensitive end-uses;
- management of purification-related costs when quality levels do not match.

For Italgas, achieving harmonised contaminant thresholds remains essential to ensuring safety, interoperability and efficient market development.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes. For Italgas, a clear EU mandate to CEN/CENELEC is essential. The ENNOH groundwork document highlights that harmonising hydrogen quality across Europe is critical and that CEN/CENELEC will play a key role in building consensus among stakeholders and developing European-wide specifications.

Given the current differences between Member States in purity levels and contaminants thresholds, a formal mandate would help ensure consistent, interoperable and stable quality rules across the hydrogen system.

13. Do you identify any areas of concern related to hydrogen production?

Yes, there are several areas of concern related to hydrogen production, but many of these can be effectively managed through coordinated standards and system-wide approaches. Hydrogen production technologies deliver different impurity profiles, meaning that the output quality can vary depending on the process used. This makes it important to ensure that purification, monitoring and quality control practices are aligned so that hydrogen entering the system meets consistent and predictable thresholds. Electrolysis also depends on the quality and availability of feedwater, while hydrogen imported from global suppliers may have different specifications, reinforcing the need for harmonised European practices. Over time, production plants may also experience performance drift, which requires continuous monitoring to maintain the expected quality levels.

At the same time, Italgas considers hydrogen blending an essential enabler in the transition phase. Blending allows early decarbonisation of existing gas networks, accelerates market ramp-up and supports the progressive adaptation of end-use technologies. It represents a practical and scalable pathway to integrate hydrogen while production volumes and dedicated hydrogen infrastructures are still developing. In this context, ensuring stable contaminant thresholds is a key element to safely and efficiently manage blended gas across different network segments and user categories.

For Italgas, the priority is to ensure that hydrogen production – whether pure or blended – provides high, stable and interoperable quality, enabling safe system operation, supporting end-use readiness and contributing to a smooth and efficient energy transition.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Yes. The expansion of natural (white) hydrogen could introduce several considerations.

White hydrogen extraction may show variability in purity and contaminant levels depending on geological conditions, requiring appropriate monitoring and treatment before its injection into the network. There may also be limited operational experience with large-scale extraction, including the need to assess long-term sustainability, environmental impacts and resource availability.

For Italgas, the priority is ensuring that any natural hydrogen entering the system – pure or blended – meets stable, predictable and harmonised quality thresholds, enabling safe operations and smooth integration with transmission and distribution infrastructures.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

Even if a very high purity level (e.g. >99.97%) were adopted across all interconnected European networks, local purification units would still remain necessary for certain sensitive applications. Notwithstanding purity represents often a binding technical requirement, especially in the mobility and chemical industries, its compliance prevents the presence of impurities that make the operation of some end uses ineffective.

Giving some examples that illustrates the benefits of a high degree of purity:

- fuel cell safety: PEM fuel cells (used in vehicles) are extremely sensitive and have strict and highly specific requirements not only for purity, but also for individual contaminant thresholds, humidity levels and trace compounds. Even the smallest traces of carbon monoxide (CO) or sulfur can “poison” the platinum catalyst, quickly rendering the system unusable.
- Industrial process quality: in industries such as semiconductor manufacturing or ammonia synthesis, hydrogen acts as a reagent. The presence of impurities can compromise the quality of the finished product or generate unwanted byproducts.
- Reduced maintenance: for hydrogen boilers or turbines, a pure gas ensures cleaner and more consistent combustion, reducing deposits and nitrogen oxide (NOx) emissions from organic impurities.

A single universal network specification cannot fully guarantee the stability and precision required for local purification units. For Italgas, the priority is to define harmonised and realistic network-wide quality thresholds, while allowing local purification where end-use technologies demand ultra-high or application-specific requirements.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

For Italgas, the main priorities for data provided by HTNOs on a transparency platform are:

- clear and consistent hydrogen quality information, including purity levels and contaminant thresholds, to support interoperability across interconnected networks.
- Realtime and reliable operational data on flows, pressure, availability and capacity, enabling safe system operation and planning.
- Early visibility on constraints, maintenance and future network developments, to ensure coordinated operations between transmission and distribution operators.
- Standardised data formats and reporting rules, guaranteeing comparability and efficient integration into digital systems.

These elements allow all network users – including HDNOs, producers and end-users – to operate safely, efficiently and with full transparency.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Yes. Several innovation opportunities could help reduce hydrogen purification costs over time.

Advances in electrolyser technologies, improved catalyst durability and more efficient gas cleaning and separation systems are likely to lower the amount of downstream purification required, especially for applications requiring high purity. Emerging approaches such as modular purification units, enhanced monitoring and sensing technologies and process integration with storage and production assets can further optimise operating costs. For Italgas, innovation that reduces purification needs – both for pure hydrogen and for blended gases – supports a more efficient and scalable hydrogen system.

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes. Italgas considers it important to invest in developments that improve hydrogen quality management.

As hydrogen production routes diversify and networks become progressively interconnected, ensuring stable, harmonised and predictable quality parameters will be essential for safe operations and efficient system integration. Investments in advanced monitoring, sensing and purification technologies, as well as in standardised quality control practices, can support consistent network entry conditions.

At the same time, hydrogen blending represents a strategic pathway to accelerate the energy transition. Strengthening quality related innovations that enable effective and reliable blending – such as improved contamination-tolerant sensors and adaptive quality management tools – will

help ensure compatibility across infrastructures and end-use applications.

For Italgas, supporting innovation in hydrogen quality – both for pure hydrogen and blended gas – is an important enabler for a scalable and future-proof hydrogen ecosystem.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

In a regulated framework, Italgas considers it important to allocate purification costs in a way that supports fairness and system efficiency.

A good approach is to combine two principles:

- Producers contribute when purification is required due to the characteristics of their hydrogen.
- The system covers part of the costs when purification improves interoperability, enables blending or brings benefits to all network users.

This balanced model helps ensure transparent costs, reliable hydrogen quality and a smoother development of both pure hydrogen and blended gas markets.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

Yes. Incentive mechanisms can play an important role in supporting the development of consistent and high quality hydrogen.

They can encourage producers to deliver hydrogen that aligns with harmonised quality thresholds, reduce variability across production routes and accelerate the adoption of technologies that improve purity and monitoring. Incentives can also support solutions that facilitate blending, helping ensure that mixed gases remain compatible with networks and end users. In particular, regulatory instruments should focus on reducing quality variability and ensuring a steady compliance with network's technical specifications.

For Italgas, well designed incentives can strengthen hydrogen market maturity, promote innovation and help to ensure a stable, predictable and interoperable quality across the system.

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MARCOGAZ response to the PC

1. Please provide your name, your position, and the organisation you represent.

Eleonora Diakoumi, Head of Technical Program,
MARCOGAZ

2. What do you consider to be the main purpose of hydrogen quality monitoring?

The primary purpose of hydrogen quality monitoring is to ensure:

- Infrastructure integrity and safety, including compatibility with pipelines, underground storage, and utilisation in end-use appliances.
- Interoperability across interconnected networks, enabling cross-border hydrogen flows.
- Reliable metering and billing, as contaminants may affect measurement technologies and calorific value determination.
- Market confidence, ensuring hydrogen delivered meets agreed specifications.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

The key decision is to determine the regulatory philosophy for hydrogen quality:

- Whether Europe should adopt a single network specification with limited flexibility, or
- A harmonised framework based on contaminant thresholds with application-specific requirements.

MARCOGAZ considers that agreement on contaminants thresholds and measurement methodologies is more urgent than defining a single purity number.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

In principle, yes. A single interconnected hydrogen network supports market liquidity and efficient infrastructure use. However, this should be based on a common baseline quality envelope, taking into account that limitations for end-use applications and underground storages may occur.

Also, we should consider that the construction of H₂ transport networks begins today with regional projects for which local agreements defining a specific quality of H₂ may be found. These may differ from the values proposed in European studies.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Storage facilities are indeed critical due to:

- Potential presence of impurities (from the underground) in the withdrawn gas (e.g. moisture, sulfur species, hydrocarbons) possibly due to mixing effects and cushion gas interactions, but also underground water and bacteria.
- Implementation of costly gas treatment units considering underground storages pressures and flow rates; keeping in mind that processes generating too much tailgas will not be applicable.
- Lack of space to implement such treatment units on some existing storages.

A special attention should be devoted to H₂ underground storage as many of them will be retrofitted from NG gas, implying the presence of impurities that may require expensive and huge treatment units, if feasible. On a long term basis there will be the same challenge with porous storages (aquifers and/or depleted fields). However, hydrogen storage is critical for the development of an interconnected market, the initial market movers are equally invaluable in establishing and sustaining the hydrogen economy.

Specific monitoring and operation procedures will be necessary at Storages interfaces, similar to those at producers exit points.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

Hydrogen transmission network operators should:

- Guarantee quality preservation during transport
- Provide transparent quality data
- Implement network balancing and mixing management
- Ensure the reliability and availability gas transport infrastructure and guarantee transit under optimal conditions in terms of safety and cost, while respecting the environment.

HTNOs are central in ensuring cross-border interoperability and system integrity.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

We strive to have one hydrogen quality specification applicable for the value chain as a whole and compatible with all operators of infrastructures.

Every stakeholder along the value chain is equally responsible for maintaining the quality parameters given by a common and agreed standard.

HTNOs should therefore ensure both entry compliance and network quality management, supported by monitoring and modelling.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

HDNOs play a crucial role as the interface with end users:

- Managing local quality variations and pressure regimes
- Ensuring metering accuracy
- Facilitating connections for diverse consumers with different quality sensitivities
- Supporting deployment of local purification where required

9. Do you identify any specific considerations or challenges related to terminals?

Terminals may introduce variability due to:

- Conversion processes (e.g. cracking of carriers, liquefaction/regasification)
- Transient operations and start-up phases
- Potential introduction of specific contaminants (e.g. nitrogen, ammonia traces)

The same quality requirements apply to terminal interfaces as to the rest of the value chain.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Reaching consensus on contaminants thresholds is more important than defining a single purity level.

From a network perspective, specific contaminants drive safety, material compatibility, and metering performance, while overall purity is a derived indicator. Also, including a Wobbe-Index range would support this approach.

It should be noted that adopting higher purity standards would entail additional treatment costs for the hydrogen infrastructure, including both pipelines and storage facilities, which operate as interconnected assets to ensure the safe and efficient functioning of molecule based energy systems.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

A broad consensus has already been reached on threshold values for most contaminants relevant to hydrogen transport and distribution.

The main remaining area of discussion concerns methane content, in which some progress is already made.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes. A clear mandate from the European Commission to CEN / CENELEC would accelerate harmonisation and avoid fragmentation between Member States.

13. Do you identify any areas of concern related to hydrogen production?

Concerns include:

- Variability of production routes and associated contaminant profiles
- Drying and purification performance
- Trace contaminants affecting infrastructure and metering
- Lack of harmonised measurement at production sites

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Potential challenges include:

- Uncertain contaminant composition
- Variability over time
- Presence of inert gases or sulfur species
- Need for dedicated treatment and monitoring

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

Even if a globally high hydrogen purity level were specified across interconnected European networks (e.g. >99.97%), local purification units would likely still be required for limited sensitive applications (e.g. electronics).

In that case, a European hydrogen network would be highly unlikely, with only local clusters emerging, as ensuring consistent adherence to such a specification across Europe would be nearly impossible.

The most efficient solution is:

- Establishing a harmonised baseline network specification that ensures infrastructure integrity, interoperability and safe storage operation, all at reasonable economic costs.
- Allowing application-specific polishing at the point of use where ultra-high purity is required (e.g. fuel cells, electronics, mobility hubs)
- Avoiding overly stringent network-wide purity requirements that could significantly increase costs and operational complexity for transmission, distribution and storage assets
- Bear in mind that eventually, all end-users will have to support the costs of both production and infrastructures (distribution, transmission and underground storages).

This layered approach minimises system costs, preserves operational flexibility (including storage cycling and network mixing), and avoids transferring end-use driven purification burdens onto network operators.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

Key priorities:

- Real-time or near-real-time quality data
- Standardised parameters and units
- Traceability and historical data
- Information on deviations and corrective actions
- Interoperable data exchange formats

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Promising areas include:

- Advanced membranes and sorbents
- Modular purification technologies
- Improved sensors and real-time analysers
- Digital quality tracking and predictive models

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes. Investment is needed in:

- Measurement technologies
- Online monitoring systems
- Storage conditions gas treatment processes
- Digitalisation and data platforms

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

In a regulated framework, an optimal cost allocation should reflect responsibilities across producers, network operators (TSOs/DSOs), and storage operators (SSOs), while preserving market development.

A balanced approach would include:

- Polluter-pays principle at entry points, whereby producers ensure compliance with baseline network quality specifications
- Regulated cost recovery for TSOs/DSOs/SSOs for monitoring, quality tracking and operational measures necessary to preserve quality within networks and storage
- Recognition that storage facilities may require specific quality management measures, with associated costs treated as regulated infrastructure costs where they benefit the overall system
- End-user driven purification costs allocated locally when purity exceeds network specifications

This approach ensures cost reflectivity, avoids cross-subsidisation, and supports efficient network and storage utilisation while maintaining interoperability.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

- Yes. Incentives could:
- Encourage producers to meet higher quality standards
- Promote innovation in purification and monitoring in general and more specifically for underground storages (e.g.: high pressure, high flow rate, little space)
- Reward transparency and quality reliability
- Support early deployment of harmonised solutions

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GASGRID response to the PC

1. Please provide your name, your position, and the organisation you represent.

Gasgrid

2. What do you consider to be the main purpose of hydrogen quality monitoring?

Hydrogen quality definition and the consequent monitoring is a key functional element of the future hydrogen system. Consensus on the quality between hydrogen producers, end-users, TSOs and storage system operators is a key. From TSO's perspective the main purpose for monitoring is to be able to guarantee hydrogen that qualifies with the defined specification. Also, it is important to avoid accumulation of any trace elements to the pipeline.

Proper monitoring is crucial especially from the end-users' point of view, especially for those sensitive to certain trace elements. The other core objective for monitoring is the objective of a well-functioning cross-border hydrogen market.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

As noted, many studies have been conducted. It would be essential to draw the main conclusions, open questions and next action points from these studies and make them visible to all stakeholders. Based on the first experiments of repurposing gas pipelines for hydrogen, the purity issues have been clarified, which is a good example of concluding things and moving forward. It would be essential to better understand the implications of underground hydrogen storage to hydrogen purity. Based on the best available knowledge, an impact assessment is needed to define where the purification costs shall be allocated to have the most cost-competitive system.

It is good approach to start the definition of quality specification from trace elements. Fixing a certain value should not be a barrier for developing the infrastructure projects forward. In the case of hydrogen transmission infrastructure projects, a good starting point is to have a higher purity requirement in the beginning that can be lowered if needed.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

In principle, a common EU hydrogen quality specification at interconnection points would be ideal for an efficient and cost-competitive EU wide hydrogen market. However, exceptions e.g., for DSO networks and industrial areas shall be assessed to provide flexibility.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

We agree that storages are an essential part of hydrogen value chains, however, we do not understand how this question is essential for the hydrogen quality discussion. In addition to hydrogen storages, also other flexibility measures can play a role. The timely demand and development of storages shall be considered – when do we need large-scale hydrogen storages in the system. This should be assessed as maybe there will be more time to investigate the hydrogen purity in the case of storages and develop solutions and ways to integrate them to the system.

The implications of UGS for the hydrogen purity shall be assessed similarly than the implications of other parts of the hydrogen value chains. It must be also noted that not all the hydrogen storage technologies cause similar issues for the purity as now discussed, for instance, UGS based on Lined Rock Cavern technology is not foreseen to have issues with higher purity requirements (e.g., 99.5 %).

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

The role of HTNOs is established in the DIRECTIVE (EU) 2024/1788 and the REGULATION (EU) 2024/1789. Benchmark shall be sought from the already established practices applied in the operation of the natural gas transmission infrastructure.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Specifying and monitoring the quality at the entry points is necessary (production and storage).

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

The role of HDNOs is established in the DIRECTIVE (EU) 2024/1788 and the REGULATION (EU) 2024/1789. At this stage, it is still unclear which part of the hydrogen network will be considered transmission vs. distribution network. Therefore, the role of HDNOs will be further clarified once the division between transmission and distribution network becomes clearer.

9. Do you identify any specific considerations or challenges related to terminals?

Terminals shall be handled as entry/exit points.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

No opinion.

Consensus on contaminant threshold values is a good starting point. The cost of measuring these (from the sensitive end-user point of view) shall be assessed. The lower the accepted hydrogen purity level, naturally the more contaminants can be included, which may affect the measurement requirements.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

No opinion. This shall be discussed with different end-users.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes.

13. Do you identify any areas of concern related to hydrogen production?

When the system is mostly based on electrolyser-based hydrogen production, no issues are anticipated. Impact assessment shall include perspectives from all the production technologies and their business models to handle the purification.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

No opinion.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

It is possible that in the case of very high purity requirement, local purification units could be avoided. However, a proper impact assessment taking into account all the parts of the hydrogen value chain shall be conducted to find the system optimum.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

No opinion.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

No opinion.

18. Do you identify a need for investment in developments related to hydrogen quality?

No opinion.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

It is crucial to first identify the optimum purity level and impurity levels (quality specification) and then consider how the purification costs shall be allocated.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

No opinion.

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EUROPEX response to the PC

1. Please provide your name, your position, and the organisation you represent.

Julia Menezes, Policy adviser, Europex

2. What do you consider to be the main purpose of hydrogen quality monitoring?

The primary purpose is to establish hydrogen as a standardised commodity. This allows standard contracts to be used, supports exchange-based trading and provides the transparency necessary for accurate price signals and cross-border market integration.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

The most important decision is to formally standardise hydrogen as a commodity. This will lay the groundwork for a trading-friendly market model, including the early establishment of virtual trading points and liquid spot markets.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

Yes. Having a single network prevents market fragmentation and supports a gas market model. It enables the creation of a virtual trading point where all volumes are fungible, which maximises liquidity and ensures efficient price formation across European markets.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Storage is a necessary component of balancing, but the market model itself is equally important. To provide the flexibility that market participants require, storage must be integrated into exchange-based balancing mechanisms.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

HTNOs must act as neutral market facilitators. This involves managing the network to support exchange-based balancing, ensuring non-discriminatory access and providing data transparency to inform investment decisions.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

While entry-point quality specifications are necessary, they are not sufficient on their own. HTNOs must also ensure that quality at exit points remains consistent with these specifications in order to protect the integrity of standard trading contracts.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

HDNOs facilitate the participation of smaller producers and local consumers in the wider commodity market. Their primary obligation is to guarantee that local injections do not compromise the standardised quality on which wholesale trading depends.

9. Do you identify any specific considerations or challenges related to terminals?

Terminals are entry points that must meet strict quality standards to ensure that imports are compatible with the European grid. Without proper standardisation at these interfaces, imported volumes cannot be traded on European platforms without incurring additional costs and technical barriers.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Consensus on both is required. Contaminant thresholds address technical safety, while a unified purity level makes harmonised standard contracts possible across trading platforms. Neither can substitute for the other.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

Consensus is still developing. The main concern is that the thresholds should not be set so restrictively that they reduce the volume of gas that is eligible for trading. Standards must strike a balance between technical necessity and the requirements of a liquid market.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes. A clear mandate is essential for establishing a common European rulebook. This is a prerequisite for exchange-based trading and the use of standard contracts across different jurisdictions.

13. Do you identify any areas of concern related to hydrogen production?

The main concern is integrating diverse production sources into a single market without fragmenting it. In particular, for green hydrogen, the certificate market must function efficiently on a cross-border basis so that producers can realise the value of their product through a liquid market for Guarantees of Origin (GOs).

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Any expansion would require clear rules on how white hydrogen fits within existing commodity and certificate frameworks. It must meet the same standardised quality levels as other production sources in order to be traded on common platforms.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

A high-purity standard across the backbone would eliminate the need for local purification in most cases. While some particularly sensitive users may still require additional polishing, a robust network standard would reduce transaction costs and simplify trading for the vast majority of market participants.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

The priority is data that supports price discovery, such as real-time flows, storage levels and quality specifications. This information serves as a primary investment signal for market participants and infrastructure developers alike.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Yes. Lower purification costs mean that a wider range of production methods can meet commodity-grade quality requirements, thus broadening the supply base and supporting market liquidity.

18. Do you identify a need for investment in developments related to hydrogen quality?

Investment should focus on automated, real-time quality tracking. This technical infrastructure is required to underpin a reliable, exchange-based balancing system. Regulation and cost allocation.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

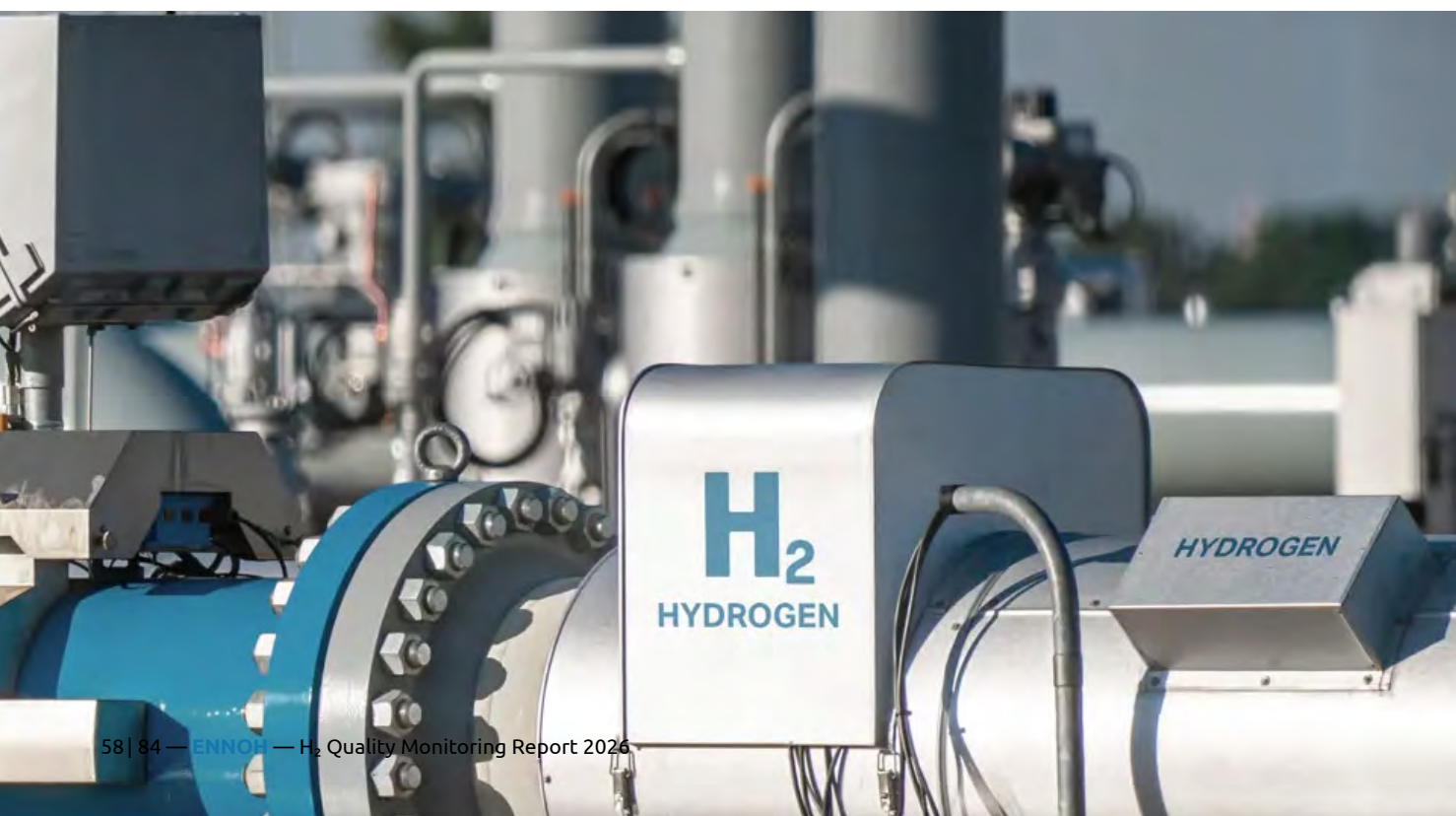
Costs should be allocated in a way that does not distort the commodity price. A market-based approach, in which specific quality requirements are reflected in the relevant part of the value chain, is preferable to indiscriminate cost allocation and the risk of cross-subsidisation.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

The most effective incentive is a well-functioning certificate market. Properly functioning Guarantees of Origin across borders provide the necessary financial signals without distorting the underlying commodity market.

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GIE response to the PC

1. Please provide your name, your position, and the organisation you represent.

Gas Infrastructure Europe (GIE)

2. What do you consider to be the main purpose of hydrogen quality monitoring?

Hydrogen quality monitoring is essential to:

- Preserve infrastructure integrity and operational reliability
- Support tracking of hydrogen quality variations along the value chain, especially to accommodate the needs and constraints of underground storages and repurposed pipelines
- Support interoperability across interconnected European hydrogen infrastructure networks
- Provide transparency and confidence to market participants

From a GIE perspective, monitoring is also critical for quality tracking through underground storage cycles and terminal processes, where composition changes may occur.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

The main decision is to establish a practical and harmonised hydrogen quality framework balancing:

- Operational feasibility
- Cost-efficiency and technical requirements
- Safety standards

GIE believes that establishing practical hydrogen quality specifications is fundamental to enabling early network deployment. At the same time, GIE emphasises the importance of realistic contaminant thresholds.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

GIE supports the development of a single harmonised and interconnected hydrogen network, striving for a hydrogen purity standard across the EU to guarantee interoperability.

However, the specification must remain operationally feasible for all infrastructure operators, including underground storages and terminals, avoiding requirements that could hinder infrastructure utilisation.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Yes. Storage facilities are key enablers of large-volume hydrogen storage and (seasonal) supply-demand balancing. They are vital for the integration of different production and import sources and play a central role across the system in relation to hydrogen quality and quantity.

In the value chain, they are a critical link due to:

- Geochemical and process-related quality changes
- Cushioned gas interactions
- Space, environmental and permitting constraints limiting purification installations
- Tailgas usage

Storage operators therefore require flexible and realistic quality thresholds.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

HTNOs play a key role in:

- Ensuring cross-border interoperability
- Monitoring hydrogen quality
- Providing transparency on quality parameters
- Integration of diverse production and storage sources

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Entry specifications are necessary but not sufficient.

Hydrogen composition may vary during transport and storage; therefore, we require quality management systems, including monitoring tools, to ensure that end-users receive hydrogen with consistent and reliable characteristics.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

Although GIE membership mainly covers transmission, underground storage and terminals, distribution operators remain important interfaces with end users and some producers. Coordination across network levels is essential to maintain quality consistency.

9. Do you identify any specific considerations or challenges related to terminals?

Terminals may introduce variability due to:

- Hydrogen carrier conversion processes
- Liquefaction/regasification steps
- Transient operations

Clear interface specifications and monitoring are required.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Reaching consensus on contaminants thresholds is more important than defining a single purity level. From a GIE perspective, contaminants are the key drivers for:

- Infrastructure compatibility and material integrity
- Storage operability and geochemical interactions
- Metering and billing safety considerations
- Safety concerns
- Interoperability between infrastructure segments

GIE Members broadly recognise the importance of contaminant thresholds and measurement methodologies as the priority to enable cross-border hydrogen transport and underground storage.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

A broad consensus has already been reached on threshold values for most contaminants, largely aligned with existing European work and standards.

One of the main remaining areas of discussion concerns methane content, particularly regarding:

- Measurement methodologies and uncertainty at very low concentration levels
- Potential accumulation effects in storage facilities
- Compatibility with sensitive end uses

Clarification and harmonisation of methane limits would support interoperability while maintaining operational feasibility for infrastructure operators. Consensus on this crucial topic can be a fundamental way forward in the discussion.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes. A clear mandate to standardisation bodies such as CEN/CENELEC would support harmonisation and interoperability.

13. Do you identify any areas of concern related to hydrogen production?

Key concerns include:

- Variability of hydrogen quality depends on (cross-border) production routes
- Trace contaminants may affect infrastructure and metering
- Alignment between production specifications, infrastructure capabilities and end-users

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Potential challenges include variable composition and uncertain contaminant profiles, requiring monitoring and possibly treatment before injection into networks. Meanwhile, the natural hydrogen production sector is still immature and site dependent.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

Even if a globally high hydrogen purity level were specified across interconnected European networks, local purification units would still be required for certain sensitive applications.

From a GIE perspective, the most efficient solution is a layered approach:

- A harmonised network specification ensuring infrastructure compatibility and global cost-efficient system operation
- Local purification or polishing at the points of use where higher purity is required

This approach avoids transferring end-user driven purification requirements to transmission, underground storage and terminal infrastructure, where purification at high pressure and high flow rates may be technically challenging and economically inefficient.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

Priorities include:

- Historical data and traceability
- Information on deviations
- Standardised reporting formats
- Data relevant to underground storage cycles, terminal operations and import flows

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Significant innovation opportunities exist that could reduce hydrogen purification costs, including:

- Advanced membrane and adsorption technologies with lower hydrogen losses – avoiding or limiting tailgas
- Modular purification solutions adaptable to infrastructure constraints
- Improved trace contaminant sensors and real-time analysers
- Digital quality tracking and predictive modelling, particularly for storage and network interactions

Such innovations are especially relevant for storage and terminal operators, where purification of large flow rates and varying compositions presents technical and economic challenges.

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes. Investment is needed in:

- Measurement technologies
- Monitoring along underground storage cycles
- Pilot projects and demonstrations for both renewable and low-carbon hydrogen
- Digitalisation and interoperability tools

These initiatives provide valuable insights and practical knowledge to refine hydrogen quality standards and ensure the infrastructure is ready for large-scale hydrogen integration.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

In a regulated framework, an optimal cost allocation should reflect responsibilities across the entire value chain. It should encourage the whole hydrogen value chain (from production to end-use) to conduct detailed cost analyses for infrastructure adaptation regarding hydrogen purity, providing stakeholders with transparency and clarity for decision-making.

A balanced approach would include:

a. Entry-point responsibility (polluter-pays principle)

To minimise the need for infrastructure-based purification and to support fair competition between production pathways, a harmonised network specification should be agreed upon at the point of production, before injection into the hydrogen network

b. Regulated recovery for infrastructure-related quality management

TSOs, SSOs and LSOs should be allowed regulated cost recovery for:

- Quality monitoring and measurement systems
- Operational measures required to preserve quality during operative transport, storage and terminal processes
- Digital quality tracking and transparency platforms

These activities are essential for system integrity and benefit all market participants.

c. Recognition of underground storage-specific constraints

Storage operators may face significant CAPEX and OPEX increases when higher purity requirements are imposed, particularly due to:

- Large flow-rate and high pressure purification needs
- Space and permitting limitations at storage sites
- Hydrogen losses and additional compression linked to PSA technologies

Where purification is required to maintain a harmonised network specification due to system-wide benefits, associated costs should be considered regulated infrastructure costs.

d. End-use driven purification allocated locally

Applications requiring higher purity than the network specification should implement local purification solutions. This avoids cross-subsidisation and ensures that the broader market is not burdened with unnecessary costs.

e. Transitional arrangements

During market ramp-up, hybrid solutions and temporary regulatory support may be needed to address uncertainty in demand and quality requirements while infrastructure utilisation grows.

Overall, this allocation framework encourages the entire hydrogen value chain to conduct detailed cost analyses for infrastructure adaptation regarding hydrogen purity, providing stakeholders with transparency and clarity for decision-making.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

Yes. Incentives could:

- Ensure compliance with network specifications
- Support innovation in purification and monitoring
- Facilitate pilot projects and infrastructure adaptation
- Promote cost-efficient quality management solutions

21. Please enter your email address to receive a copy of the information you submitted.

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GASUNIE response to the PC

1. Please provide your name, your position, and the organisation you represent.

Lizzie German, Markets and Regulation, Gasunie Netherlands

2. What do you consider to be the main purpose of hydrogen quality monitoring?

As long as there is no harmonised European standard available, hydrogen quality monitoring by ENNOH should provide information to interested stakeholders on hydrogen quality in the network. This may support the scale-up of the hydrogen market by providing useful information to market participants. It may also help improve the efficiency of operation and regulation of the system by providing information to TSO's, technical certification bodies and regulators. It may also indicate if there is the need for further research or development around hydrogen quality. After a harmonised European standard is available and adopted by Member States, hydrogen quality monitoring in the system is no longer strictly necessary, and if carried out should focus on identifying trends in hydrogen quality development which could indicate need for a revision of this European standard.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

A mandate from the European Commission should be issued, instructing CEN/CENELEC to develop a standard for a European-wide hydrogen specification. This needs to be issued as soon as possible. This European specification should provide long-term certainty to the market and should promote pan-European harmonisation by being taken up by all Member States. Such a European specification will likely take several years to develop. Some countries may have operational hydrogen networks and cross-border interconnection points prior to the finalization of a CEN standard. For these regions, a hydrogen specification will need to be defined prior to the completion of the CEN standard. This should as far as possible mirror the scope and approach of the CEN standard to minimize changes when the CEN standard is ultimately adopted.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

Agree that the principle of a single interconnected hydrogen network is an important principle to support the scale-up of an efficient pan-European market. Requirements around specification from the different actors in the hydrogen supply chain are not uniform. The specification of hydrogen within the European hydrogen network

should be designed to serve as many of these stakeholders as possible whilst minimizing system costs, given the differences in hydrogen grades that different end-users may require.

There may in practice be some deviations or exceptions to the single interconnected hydrogen network, for example for private networks serving dedicated customers.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

All elements in a network are important to the functioning of the network, including producers, pipelines, offtakers and storage. Hydrogen storage is expected to be required in the future hydrogen network in scenarios developed for example by the Dutch Association of Network Operators. Storage is expected to play a critical role in balancing the network when no sun and wind are available for electrolytic hydrogen production and demand is high.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

The HTNO has the responsibility to refuse entry to hydrogen that does not meet the correct specification. In this manner HTNO's ensure that the hydrogen leaving the network is also of the required specification. HTNO's do not change the specification of gas in the network and are only responsible for the transmission.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Gas specification should be measured at the entry point, assuming that in the hydrogen network storages inputting as to the network are also included under the definition of "Entry Point". In the Dutch methane network this is carried out by the parties inputting gas to the network. The HTNO will monitor the quality at the entry point to the network, and has the responsibility to refuse entry to hydrogen that does not meet the correct specification. In this manner HTNO's ensure that the hydrogen leaving the network is also of the required specification. HTNO's do not change the specification of gas in the network and are only responsible for the transmission. Monitoring and measurements will be carried out as required in order to ensure compliance with this responsibility.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

The role of HDNO's in the hydrogen network has not yet been fully confirmed by the government in the Netherlands.

9. Do you identify any specific considerations or challenges related to terminals?

All entry points to the hydrogen network, including terminals, would have to conform to the same requirements in terms of hydrogen specification.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Contaminants (i.e. non-hydrogen components of a hydrogen mixture) are generally the components that can be damaging to some end-user processes, and can be challenging to remove. Therefore reaching a consensus on contaminants is more important in addressing industry concerns than meeting a consensus just on the required percentage of hydrogen.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

There is not yet a European-wide consensus on contaminant values. EASEE-GAS is working on a Common Business Practice to define contaminant values (excluding hydrogen and methane). The percentage of allowed methane should also be defined.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes. The European Commission should provide a clear mandate to CEN / CENELEC to develop a European-wide hydrogen specification for the hydrogen network. This should be issued as soon as possible, given the time typically taken to develop CEN standards.

However it should be noted that whilst national standards with the same scope as CEN standards should be replaced by the corresponding CEN standard, it is not mandatory for European member states to use CEN standards. Moreover, deviations to CEN standards are sometimes implemented in order to take account of specific requirements in member states. Therefore even if a standard is developed by CEN, this does not necessarily mean that this will be immediately and wholly implemented by all Member States.

13. Do you identify any areas of concern related to hydrogen production?

The contaminants that are potentially present in hydrogen according to the different production methods are well described in the existing literature, as summarized in the ENNOH public consultation Groundwork document.

One additional point concerning commercial incentives should be highlighted: Hydrogen produced by SMR / ATR can contain unconverted methane. If the unit for measuring (and hence billing) is kWh hydrogen measured accord-

ing to only the composition of hydrogen present in the gas mixture (i.e. excluding contributions to the energy content from other components such as methane) then there is a commercial incentive for producers to maximise hydrogen conversion from methane. This would be consistent with EASEE-gas Common Business Practice 2023/001-01 "Hydrogen Units" and HyDelta project D4a.2 "Infographic hydrogen metrics". However this proposal is not adopted in all Member States.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Hydrogen from all production processes should conform to the technical specification.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

A hydrogen purity level of above 99.5% is currently not possible to guarantee in repurposed natural gas pipelines, therefore a hydrogen purity level of >99.97% could not be guaranteed across the interconnected hydrogen network. 99.97% could also not be guaranteed by storage operators.

Defining a hydrogen purity across the European hydrogen network at >99.97% purity would incur unnecessary purification costs for users which do not require hydrogen of such high purity. Moreover the location of hydrogen refuelling stations along highways means that they will not necessarily be served by hydrogen pipelines – on-site hydrogen production or road delivery will be needed when hydrogen refuelling stations are located remote from hydrogen pipelines.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

Reporting should be proportional to the needs of the system to support the development and scale-up of a European-wide hydrogen network. The existing requirements in the natural gas network for monitoring and reporting of hydrogen quality stem from the significant differences in the natural gas specification between countries / regions. Once a European-wide hydrogen specification is developed and adopted, reporting information on hydrogen quality through a transparency platform would not be required.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Cost-efficient purification is important for the efficient and cost-effective functioning of the hydrogen network, therefore research into this is valuable and should be promoted and supported through both ongoing and new projects.

18. Do you identify a need for investment in developments related to hydrogen quality?

See answer to question 17.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

As with the natural gas network, the party which incurs the cost of purification should in general bear the costs of this (Polluter Pays Principle).

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

The hydrogen specification should be a technical requirement of the system and therefore adhered to by all users, incentives are not necessary. Incentives to further maximise or minimize some components beyond the level required by the technical specification may indirectly occur as a result of commercial considerations (see also answer to question 13).

21. Please enter your email address to receive a copy of the information you submitted.

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STORENGY response to the PC

1. Please provide your name, your position, and the organisation you represent.

Xavier Campaiggnolle, Expert Technical Lead, Storengy SAS.

Fabrice Galeron, H2 Lead Technical Designer, Storengy SAS.

2. What do you consider to be the main purpose of hydrogen quality monitoring?

The main purpose of hydrogen quality monitoring is to enable an harmonised European framework that limits the critical components in order to achieve an agreed purity level that best meets the technical and economic needs of end users and gas infrastructure operators (DSOs, TSOs & SSOs). It must target a cost and technical efficiency optimum for the H₂ commodity.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

The results of these studies remain highly sensitive to key underlying assumptions :

- assumptions for H₂ demand at different purity levels;
- related efforts and cost at corresponding entry or exit points of the hydrogen network.

Moreover, there is non consensus on the impacts of H₂ impurity levels on UGS CAPEX and OPEX, which calls for cautious interpretation of these studies.

It would be more reasonable to concentrate on :

- establishing a harmonised limitation for a limited number of critical trace components,
- combined with appropriate flexibility for unavoidable impurities, especially those originating from underground storage facilities.

For certain components that are not critical for specific end-use applications and acceptable to other value chain

actors, removal should remain at the consumer level discretion. This would thereby limit unnecessary treatment requirements costs on the entire network.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

In order to sufficiently ramp-up the hydrogen network in an optimal technico-economic way, all available H₂ sources will initially be needed before an increasing share of renewable hydrogen progressively prevails.

To support this development in a optimal technico-economic manner, it is essential to limit a number of critical impurities and allow defined tolerances for impurities affecting the Wobbe index. At the same time, it must be recognised that imposing stringent impurities levels across the whole gas chain to meet the needs of a limited end-consumers would result in socialising these extra costs to all network users. This may potentially slow down the development of an interconnected H₂ network.

In this context, while a homogeneous European hydrogen network remains a necessary long term objective, an interim approach is required.

The creation of an homogeneous interconnected hydrogen network without distinctions between hydrogen grades is indeed a necessary long term objective. In the short to medium term, the development of hubs with local interconnections between value chain players could initially rely on specific, local, hydrogen grades.

As European quality standards progressively converge, purification facilities could be deployed either downstream (close to end user) or midstream (at the transmission level) to meet the targeted standard quality. Eventually, this phased approach would allow the system to converge towards high grade H₂ across the entire network, without creating unnecessary cost barriers in the early stages of market development.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

No, this point of view is rather simplistic. While underground storage facilities are a key element of the H₂ value chain, their role is primarily to balance supply and demand over time, rather than constituting the most critical link.

At this stage, regulation has not yet defined the trace components to be considered, and the quality of the H₂ that will be withdrawn from converted storage facilities is not yet sufficiently documented. It is therefore not possible to design the purification chain necessary to remove undesirable trace compounds...

Based on the available information today, a purity threshold of 98 % appears to be an achievable and permissive objective with trace compounds. In addition, this threshold would allow the reuse of already existing equipments (presently natural gas underground storages) such as dehydration units by TEG process.

To reach a gas quality > 98 % and eliminate trace compounds, it would be necessary to use PSA filtration processes, as it offers a better selectivity than TSA products and therefore produces a purer H₂. However, PSA technology has a lower efficiency because 10 to 15 % of the H₂ is "lost" in the column generation process. This 'lost' H₂ ends up with the impurities in a flow called "tail gas". To improve the efficiency of a PSA process, it would be necessary to reinject this tailgas into the system and therefore perform additional downstream filtration (often membrane filtration) and recompression.

In addition, the high costs for huge PSA purification plants will be exacerbated by the high delivery rates and pressures of underground storages. Furthermore, applying PSA technology and additional filtration on site would be impossible at many existing sites because of limited available space and environmental limitations in protected and agriculture landscapes.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

N.A. as Storengy is an Underground Storage operator. Still, HTNO will have to support and integrate various sources of H₂ (production, terminals and underground storages) and interface them with some end-users.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Hydrogen quality at all entry points shall comply with clearly defined, agreed, and justified requirements on the concentration of critical trace components. In this respect, hydrogen transmission network operators cannot be just neutral actors. Indeed, they may be potential contributors to hydrogen contamination, particularly when operating repurposed CH₄ pipelines. It is therefore necessary to adopt a more prescriptive regulatory framework, under

which transmission operators are explicitly accountable for the quality of the hydrogen transported through their infrastructures. Higher purity levels at production or import points should be encouraged, where technically and economically feasible, but strict quality obligations along the transmission network will be required too.

Given that a significant part of the future European hydrogen transmission network (estimated at over 60 %) will be based on repurposed CH₄ pipes, there is a risk that residual compounds historically associated with natural gas may persist. Such compounds could be released into the hydrogen stream and lead to transport related contamination specific to hydrogen networks. Eventually they will disappear.

It is therefore essential to implement systematic hydrogen quality monitoring at each interface between network operators, ensuring that each operator remains accountable for the quality of the hydrogen delivered at the outlet of its infrastructure. Where necessary, additional purification steps should be deployed to guarantee compliance with hydrogen quality requirements downstream.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

N.A. as Storengy is an Underground Storage operator. Distribution operators could be interfaced with H₂ production, end-users and maybe transmission operators. Coordination of gas quality will therefore be mandatory.

9. Do you identify any specific considerations or challenges related to terminals?

The ramp up of the hydrogen system will depend on import possibilities for hydrogen and will rely on different sources of different qualities. Ensuring the limits of critical trace components at terminal entry/exit points will be required similarly to any other infrastructure (DSO/TSO/SSO).

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

We believe reaching consensus on contaminants threshold is more important than defining a single purity level.

The initial development of the hydrogen market is expected to rely on regional hubs. Within these hubs, hydrogen purity levels will be harmonised for end users. Therefore, at this stage, it appears more appropriate to prioritize the definition of threshold values for critical trace components (depending on the end-user technologies criticality), rather than imposing a single, uniform hydrogen purity level. Current discussions indicate that the difference between a minimum purity of 98 % and a purity above 99.xxx % may be primarily driven by residual methane content. The removal of methane requires dedicated and potentially costly purification processes.

A pragmatic and progressive approach would therefore consist in harmonising, at European level, limits for critical trace components, while allowing flexibility for non critical impurities within a defined bandwidth. In this context, a range of hydrogen purity levels (for example between 98 % and 99.xx %) could be specified where justified and aligned with a clear transition timeline.

Hydrogen producers and network operators could determine, or contractually agree upon, the appropriate purity level within this range.

Transmission system operators should further ensure that hydrogen purity requirements are consistently agreed with connected consumers, up/downstream network operators, and storage system operators (SSOs), in order to guarantee end to end compatibility, transparency, and accountability across the hydrogen value chain.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

No. At this stage, there is no consensus on contaminant threshold values. Ongoing discussions on contaminant thresholds were approached with a partial and partisan vision in which each operator defends its own point of view. For this reason, we do not think that there is yet any consensus on these thresholds. A technical and economic analysis would have to be carried out in order to see where the purification effort should be carried out according to its costs (CAPEX & OPEX) for each element of the gas chain (producer/distribution/transmission/storages/end-users) taking into account actual flowrates and pressures.

Remaining areas of concern notably include the acceptable bandwidth for non critical impurities and their potential effects on hydrogen properties such as heating value and Wobbe index. In addition, several categories of critical consumers require significantly higher hydrogen quality levels than those typically discussed for general network operation. This applies not only to fuel cell applications, but also to industrial sectors such as the semiconductor industry, whose processes are extremely sensitive to trace contaminants. These applications require hydrogen qualities well above mobility grade specifications and impose much more stringent impurity thresholds for certain components.

However, due to the ultra-sensitivity of these processes, such end users already rely on dedicated specific purification steps prior to hydrogen use. This further illustrates that imposing uniformly high purity requirements across the entire hydrogen network would neither eliminate the need for local purification, nor represent a cost efficient solution for the majority of users. This reinforces the conclusion that a single consensus on contaminant thresholds for all actors has not yet been achieved and that a fit for purpose, differentiated approach remains necessary.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

We would welcome this approach (if it is not driven by a single typology of operator) and we are willing to actively participate to this NWIP (new work item proposal).

13. Do you identify any areas of concern related to hydrogen production?

An other area of concern is the overall position of hydrogen within the energy transition, particularly for low carbon and renewable hydrogen. Today, hydrogen produced from decarbonized energy sources remains less competitive than derived from fossil fuels. Carbon pricing or taxation mechanisms are often identified as key levers to encourage the transition from fossil based energy systems towards renewable hydrogen. While such instruments may improve the relative attractiveness of low carbon hydrogen, they also generate additional costs along the industrial value chain. These additional costs are ultimately reflected in higher prices for finished products.

In a globalised market, the risk is to reduced competitiveness of European industries compared to regions where environmental requirements are less stringent and where energy production relies heavily on fossil resources. Without appropriate safeguards, carbon pricing policies may therefore lead to carbon leakage effects rather than a genuine global decarbonization.

As a result, hydrogen production faces a structural dilemma : providing strong economic signals to support the transition towards low carbon hydrogen, while at the same time preserving the competitiveness of the European industrial value chain exposed to international competition.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Natural hydrogen (white hydrogen) is still currently at a very early stage of development. While there are initial indications of occurrences, reliable data on volumes and long term production are not yet available. Industrial production at a commercial scale is therefore not expected in the foreseeable future. White hydrogen should currently be regarded as a long term research and observation option, rather than a mature technology likely to make a substantial contribution to hydrogen supply or market in the short to medium term.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

No. Defining a uniformly high hydrogen purity level across all European networks would not eliminate the need for local purification. This issue goes beyond fuel cell applications. While fuel cells are highly sensitive to impurities, other industrial users, such as the semiconductor industry, require even higher hydrogen qualities, well above mobility standards. They already rely on additional on site purification.

This demonstrates that no single network wide hydrogen quality can meet the needs of all end users. Imposing very high purity across the entire network would therefore generate unnecessary and disproportionate costs for the majority of consumers, who are not so sensitive.

A more pragmatic approach would be to:

1. define a realistic minimum hydrogen quality at network level, sufficient to support early industrial conversion to hydrogen, while allowing higher purity requirements to be addressed locally when strictly necessary.
2. once hydrogen adoption has confirmed, purity requirements could be gradually increased to encourage the conversion of additional industries.

However, even in this case, on site purification would remain unavoidable for users requiring hydrogen qualities above standard network grades.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

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17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

In principle, there are innovation opportunities : improved membrane (palladium), adsorption technologies, or hybrid architecture. Membranes can be coupled with adsorption process. However, many of these approaches are still in development or in the early market entry stage, meaning that only limited cost reductions can be expected in the short term.

In the meantime, on a short term basis, high purity H₂ in interconnected infrastructures will be a challenge; but foreseeing innovations, it will eventually become possible. This is why we recommend a two steps approach on H₂ purity.

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes.

Hydrogen purification technologies are already mature, although they remain costly, and will require further scaling up and efficiency-improvement. Investments priorities should therefore focus on research and development to improve performance, hydrogen recovery and robustness under the operating conditions of all chain value actors (e.g.: high pressures, high flow rate ...).

More broadly, investments should prioritise system optimisation, rather than imposing uniformly high purity requirements across the value chain. Such an approach would unnecessarily increase transport and storage costs and could slow down the ramp up of the hydrogen system, without delivering proportional benefits for most end users.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

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20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

–

21. Please enter your email address to receive a copy of the information you submitted.

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bp response to the PC

1. Please provide your name, your position, and the organisation you represent.

Lyubomira Efremova, Senior Manager, H2&CCS, bp

2. What do you consider to be the main purpose of hydrogen quality monitoring?

A clear European regulatory framework supports the ramp up of the hydrogen market. An aligned EU hydrogen quality specification in the European hydrogen backbone (TSO grid) is seen as central. Such standard will support investment case and avoid stranded assets.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

In bp's view, the guiding principle for setting the hydrogen quality requirement for the European TSO grid should be to minimize the overall cost across the participants of the hydrogen value chain and the wider society. For that reason, bp supports a neutral study, which has already started in NL in 2021 and the EU in 2022, as long as the questions focuses on lowest optimised market and systemic costs (not: TSO pipeline optimisation costs), the data used is transparent and meaningful and the analysis is performed by a neutral party.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

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5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

While we believe hydrogen storage plays an important part to balance supply and demand, we believe other parts of the value chain are more critical.

Purity can be a major cost driver in a hydrogen system (e.g. additional CAPEX, 10–18 % H₂ loss during purification, treatment and handling of off-gases etc.), especially if high purity streams are diluted and later purified again on the demand side. We believe end-users, especially chemical and refining industries, should have a lead say as one of the key outlets for hydrogen. These industries require a higher purity for their chemical processes and equipment, such as catalysts which are very sensitive to impurities. A lower purity in the grid requires purification units on the customer's end, and/or leads to accelerated depreciation of equipment, increasing costs and burden for customers.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

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7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

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8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

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9. Do you identify any specific considerations or challenges related to terminals?

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10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

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11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

Purity is not just about the H₂ concentration (98 % or 99.97 %), it is also the other included gases in the gas stream. They can have huge economical and technical implications on sensitive industry sectors, such as the fertilizer industry. Therefore, potential hazardous particles should be minimized. As bp plans to use green H₂ in its refineries, it is vital that the concentration of CO and CO₂ is minimal. Thus, bp supports a H₂ specification that requires well below 20 ppm for CO and CO₂. To minimize corrosive effects, bp also supports a H₂ specification with sulphur concentration of well below 3 ppm.

In addition, current specifications such as DVGW G260 require oil free compressors which causes higher investment/maintenance costs for hydrogen producers and grid transporters. In case no customer would need this high purity level, bp would strive for an adequate level of purity allowing for oil lubricated compressors to be used.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

bp has been contributing to the groundwork that the HyQual project has been developing over the past few months on hydrogen quality. We believe a common European standard, developed by CEN, would be important as the European backbone is becoming operational.

In bp's view, the guiding principle for setting the hydrogen quality requirement for the European TSO grid should be to minimise the overall cost across the participants of the hydrogen value chain and the wider society.

13. Do you identify any areas of concern related to hydrogen production?

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14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Potential expansion to cover natural hydrogen, should also consider following considerations:

- Address purity issues – Accounting for methane and CO₂ emissions, including sequestering the CO₂.
- Drilling and producing natural hydrogen may also release some carbon this will also need to be accounted for
- other quality measure may include trace elements like Helium in the gas.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

The speed of a market ramp is determined by a clear regulatory framework and economic attractiveness. The question of a future EU hydrogen quality specification in the European hydrogen backbone (TSO grid) is seen as central. A provisional expected optimum for bp is 99.97% purity, with 99.5% workable as well.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

–

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

–

18. Do you identify a need for investment in developments related to hydrogen quality?

–

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

Regulated parties should not set their own conditions, alone or through their industry bodies, as they are not a neutral party. Setting conditions such as purity should be done by a ministry or regulator (involving all stakeholder in an open and structured process), not by a TSO (or their association). Any set specification needs to cover not only the current market, but also to anticipate the market needs in the upcoming decades.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

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DVGW response to the PC

1. Please provide your name, your position, and the organisation you represent.

Frank Dietzsch, Head of regulatory framework on gas technologies and energy systems, DVGW German Association on Gas and Water

2. What do you consider to be the main purpose of hydrogen quality monitoring?

Standardisation facilitates the free flow of goods, the market and transport process.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

Some more studies are ongoing that will bring valuable findings on the matter, e.g. DVGW Study 'H₂Optimum'.

The creation of a European CEN standard for H₂ quality in pipeline bound hydrogen supply is under ballot with deadline 15 May 2026. All interested parties will be invited to join the process.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

In the DVGW Study "H₂Optimum" specific quality categories have been factual-technically investigated for the overall value chain, including the thresholds specified in standards (Grade A + Grade D) and/or in literature.

The result of the study will be available in April/May 2026.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

The DVGW Study "H₂Optimum" also considers the requirements of storage facilities in accordance with the current German scenario and hydrogen forecast for the sources and use of hydrogen in the Network Development Plan.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

The "H₂Optimum" also considers the requirements of transmission network operators in accordance with the current German scenario and hydrogen forecast for the sources and use of hydrogen in the Network Development Plan.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

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8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

"H₂Optimum" also considers the requirements of hydrogen distribution network operators in accordance with the current German scenario and hydrogen forecast for the sources and use of hydrogen in the Network Development Plan.

9. Do you identify any specific considerations or challenges related to terminals?

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10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

The first step in European CEN standardisation focusses on thresholds on contaminants, trace components and combustion properties (GCV, WI) to give a framework for the ramp-up of hydrogen. In that step hydrogen purity will not be stipulated.

The creation of a European CEN standard for H₂ quality in pipeline bound hydrogen supply is under ballot with deadline 15 May 2026. All interested parties will be invited to join the process.

Generally, limitations to specified trace components optimise the purification process and make it more cost effective.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

Reference made to the starting CEN standardisation process; the ENNOH Workshop presentation gave good input on the topic.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

CEN standardisation on hydrogen quality is starting; an EC Standardisation Request can support this action.

13. Do you identify any areas of concern related to hydrogen production?

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14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

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15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

The DVGW Study "H₂Optimum" investigates on this topic, including the effect of the end-use composition in a network. The results are expected in April/May 2026.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

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17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

DVGW Study "H₂Optimum" identified the main cost drivers regarding PSA, showing high hydrogen losses. Thus, innovation how to use these losses (e.g. electrification, heat) in the PSA process. Furthermore, innovation in alternative

purification technologies with less losses could be supported.

18. Do you identify a need for investment in developments related to hydrogen quality?

Principally, yes, after a good gap analysis what is still needed. In Germany the national roadmap for hydrogen standardisation concluded in autumn 2025; part of results was a detailed gap analysis.

Furthermore on European level EISMEA HyQual Net bundles available knowledge from studies in Europe.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

The DVGW Study "H₂Optimum" identifies which purification facilities (e.g. PSA, Membrane, Adsorption, catalytic O₂ elimination) should be installed at which location to achieve best cost efficiency in Germany. Such an analysis should be aligned with findings from different European countries, if a regulatory framework is set.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

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SWISSGAS/TRANSITGAS/FLUXSWISS response to the PC

1. Please provide your name, your position, and the organisation you represent.

Kresimir Kosanovic, Senior expert TSO, Swissgas AG

Etienne Berner, Innovation & Emission Expert, Transitgas AG

Marco Marcon, Operations and Special Projects Manager, FluxSwiss Sagl

2. What do you consider to be the main purpose of hydrogen quality monitoring?

To ensure safety, reliability, and the transport interoperability of hydrogen infrastructure

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

Cross-border operational rules

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

Yes

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Partly. Storage facilities are critical when ultra-high-purity hydrogen is released into the transmission grid. To avoid quality issues, hydrogen injected from storage facilities must be continuously monitored according to the agreed quality control measures and specifications.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

Provide safe, prudent, reliable and robust hydrogen transportation infrastructure. HTNOs should be accessible as neutral market enablers providing non-discriminatory open-access services.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Yes, entry and exit points should have the same specifications. If hydrogen is injected within the HNTO, quality monitoring must be carried out. To ensure the specified quality is maintained, each HTNO should provide redundant quality monitoring at its exit points.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

The role is to manage a potential distribution network and enable current and future hydrogen producers to deliver their product to customers

9. Do you identify any specific considerations or challenges related to terminals?

From a quality perspective, no major challenges are foreseen because liquefied hydrogen is inherently pure. However, the injection process itself remains technically challenging.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Reaching consensus on any quality standard seems challenging. Contaminants thresholding requires more specific analytics, and enhances costs. But both aspects are inherently connected. As specific use requires specific contaminant thresholds, purity level agreement seems simpler to achieve

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

We believe that alignment is still ongoing regarding hydrocarbons, inert components, sulfur-containing compounds, water and oxygen

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes

13. Do you identify any areas of concern related to hydrogen production?

Each production route presents different purification challenges depending on the underlying technology (e.g., SMR, pyrolysis from biomass or natural gas, or electrolysis using AWE, PEM, or AEM). Once a common quality standard is defined, each production route can adapt its purification process accordingly.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

As noted above, each production route can and shall adapt its purification process to meet the common quality standard

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

In theory, yes. However, supplying fuel cell grade hydrogen across all interconnected European networks would be very costly, and every exit point would require highly stringent quality measurement. It is more efficient to transport at a standard grade and perform localized purification only where required by specific end-uses.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

Quality data should be provided in harmonised, real time formats to support interoperability across European platforms. Historical data (e.g., on an hourly basis, to be defined) should also be accessible to ensure transparency.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Purification costs will be market driven. As production volumes increase, greater competition and process optimisation, alongside innovation, can be expected to reduce costs.

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes, although the required investment cannot yet be quantified.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

Injectors should provide the baseline grid specification (purification), while any higher specifications should be funded by the end users requiring them.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

Incentives should not replace clear rules or unnecessarily complicate the system.

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FRONTIER ECONOMICS response to the PC

(on behalf of H2eart)

1. Please provide your name, your position, and the organisation you represent.

Frontier Economics, acting on behalf of H2eart for Europe, a European alliance for underground hydrogen storage (UHS).

2. What do you consider to be the main purpose of hydrogen quality monitoring?

Finding a harmonised, European approach to mitigating and managing critical trace components, and achieving an accepted purity level that fits best for producers, end consumers and hydrogen infrastructure operators aiming at achieving a cost and efficiency optimum for the commodity hydrogen.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

The referenced studies show a strong dependency of the final results on the assumptions taken for

- (i) hydrogen end-use demand with different purity levels, and
- (ii) impurity-related costs and efforts for infrastructure elements (e.g. entry or exit points to the hydrogen network, storage facilities) at capital and operating cost level.

In addition, the studies do not factor in practical feasibility (e.g. environmental permits for PSA or constraints to cleaning repurposed pipelines).

Rather than overstating model outcomes that depend heavily on a concrete set of assumptions, we consider it more reasonable to focus on a harmonised approach to mitigating and managing critical trace components at EU-level.

We consider it vital to allow some flexibility in impurity levels coming from different parts of the value-chain - underground storage facilities, networks, various production pathways, and conversion plants for imported hydrogen (derivatives) – to reduce overall costs and engage all infrastructure partners.

The key decisions to be made at this point therefore relate to identifying the most critical trace component and specifying limits suitable to the majority of applications.

If specific use-cases require thresholds exceeding the system wide standards, further purification can be introduced at the consumer level or may even be readily available (for example in the chemical industry).

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

To assess this question, it is helpful to first consider the broader objective of developing the hydrogen system in a way that is both economical and scalable. For this purpose, any available hydrogen from different sources will be needed before increasing volumes of pure renewable hydrogen over time. While limiting critical impurities and maintaining an appropriate Wobbe index is essential, enforcing a uniform high-purity standard across the system at an early stage may impose significant costs. These costs would be socialised across all end-users – in the early stages, a small group – including those without high purity requirements, and could hinder the development of an interconnected European hydrogen system.

Therefore, we agree that there is value in the European hydrogen transport system having a single grade/quality definition eventually, allowing seamless cross-border and third-country hydrogen trading. It should, however, be kept in mind that individual, more regional hydrogen clusters with local interconnections, particularly those with predominantly high-purity demand, could always opt for a higher purity level. This may be particularly impactful during the market ramp-up phase: Over the longer term, as purification units are installed at the transport network level, achieving higher purity grades across the system may become more feasible than before.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Hydrogen storages are pivotal to a successful hydrogen market as they are the only large-volume technology to structure intermittent supply patterns to match the heterogeneity of hydrogen demand patterns. Hence, the availability of sufficient underground storage capacities across Europe is key for the successful operation of the hydrogen system.

The effect of UHS on hydrogen purity is not unequivocal – aspects such as the type of storage (cavern vs. porous) and previous use (new vs. repurposed) impact not only the overall hydrogen purity, but also the specific critical trace components.

Regulation has not yet defined the relevant thresholds, and the quality of hydrogen extracted from storage facilities is not yet sufficiently documented. It is therefore difficult to predict the purification chain necessary to remove critical trace compounds.

The main critical aspect for hydrogen discharged from repurposed UGS sites used for UHS is the presence of impurities from short chained hydrocarbons (mainly methane).

At UHS storage sites, the purification of short chained hydrocarbons can be difficult and may result in significant efficiency losses, for example where PSA is required. In addition, the necessary investments into relevant purification technologies can be associated with extreme costs. Furthermore, deploying relevant technologies, like PSA and associated filtration, on site is often not feasible at many existing facilities due to space constraints and environmental restrictions in protected and agricultural landscapes.

By contrast, other critical trace components that may be introduced by storing hydrogen in UHS (e.g. water/moisture or sulphur-components) can be managed to levels comparable to those in the transport network using established technologies.

Given these considerations, we reiterate our suggestion to introduce thresholds for critical trace components suitable for most applications, rather than a uniform stringent purity level. Should specific applications require lower levels of key components – such as short-chain hydrocarbons – purification should be targeted at end-users with higher purity requirements. General purification would be disproportionate, as hydrogen withdrawn from UHS is already sufficiently pure for many applications (e.g. power generation or industrial heat). It is worth noting that the sectors requiring particularly high hydrogen purity also tend to be those that rely on a secure and steady hydrogen supply, which in turn depends on a sufficient presence of UHS in the system – underscoring the need for a balanced and integrated approach.

Excessively high purity requirements at network level risk excluding repurposed storage options – which are critical to achieving scale for UHS – and slowing the pace of market ramp-up.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

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7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

While at a minimum, hydrogen quality should comply with clearly defined, agreed and justified requirements on critical trace components at all entry points, we do not agree that this is a sufficient condition.

In this context, it is important to regard hydrogen TSOs not only as a neutral passage, equating entry to exit purity – but also to acknowledge their potential contribution to hydrogen contamination, particularly when operating repurposed methane pipelines.

A more prescriptive regulatory framework is therefore needed, under which transporters are explicitly accountable for the quality of the hydrogen conveyed through their infrastructure. Higher purity level at production or import points should be encouraged further where technically and economically feasible – but this cannot substitute for quality obligations along the transmission network.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

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9. Do you identify any specific considerations or challenges related to terminals?

The ramp-up of the hydrogen system will depend on a variety of import options, likely to consist of different sources with varying quality levels. Ensuring compliance with defined limits for critical trace components at terminal entry points will be required.

Also, close to terminals, there is a greater need for hydrogen structuring to ensure continuous supply into hydrogen networks when handling bulk shipped volumes – which can be served by UHS.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Given that the early development of the hydrogen market is expected to rely on regional clusters, within which hydrogen purity levels can be aligned with end-user requirements, we believe it is more appropriate at this stage to prioritise the definition of threshold values for critical trace components – rather than imposing a single, uniform hydrogen purity level.

A pragmatic and progressive approach would therefore be to harmonise limits for critical trace components at European level, while allowing flexibility for non-critical impurities within a defined bandwidth. Within this range, hydrogen producers and network operators could determine, or contractually agree upon, the appropriate purity level, referencing the European level as an overarching framework.

Hydrogen TSOs should further ensure that hydrogen purity requirements are consistently agreed with connected consumers, downstream network operators, and storage system operators (SSOs), in order to guarantee end-to-end compatibility, transparency, and accountability across the hydrogen value chain.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

Current discussions on contaminant thresholds reflect the different perspectives of stakeholders, with each focusing on their own operational context. We do not believe that a clear consensus on these thresholds has been reached yet.

Remaining areas of concern include the acceptable bandwidth for non critical impurities and their potential effects on hydrogen properties, such as heating value and Wobbe index.

In addition, another area of concern often raised in this context relates to specific categories of critical consumers who require particularly high hydrogen quality levels. This includes fuel cell applications, but also to industrial sectors such as the semiconductor industry, where processes are highly sensitive to trace contaminants. These applications require hydrogen qualities well above mobility grade specifications and impose more stringent thresholds for certain impurities.

However, given the high sensitivity of these processes, such end users already rely on dedicated, application specific purification steps prior to hydrogen use (see also Question 15). We believe that this further illustrates the fact that imposing uniformly high purity requirements across the entire hydrogen network would (i) neither remove the need for local purification, nor (ii) represent a cost efficient solution for the majority of users.

It reinforces the conclusion that a single consensus on contaminant thresholds for all actors has not yet been achieved and that a fit for purpose, differentiated approach remains necessary.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

We would welcome such an approach, provided that it reflects the perspectives of the different types of operators across the value chain. The members of H2eart would be willing to contribute to the corresponding new work item proposal (NWIP).

13. Do you identify any areas of concern related to hydrogen production?

Allowing a bandwidth of non-critical impurities may, for economic reasons, reduce the incentive to achieve higher purity levels at production sites, where higher purity may be easier to achieve than in other parts of the value chain.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Natural hydrogen (white hydrogen) is currently still at a very early stage of development. While there are initial indications of potential occurrences, a reliable data basis on volumes and long-term production stability as well as mature, scalable extraction and processing technologies are not yet available. Industrial production at a commercial scale is therefore not expected in the foreseeable future.

Against this background, white hydrogen should currently be regarded as a long-term research and observation option rather than a technology expected to make a substantial contribution to hydrogen supply or market relevance in the short to medium term. With respect to a hydrogen quality standard, white hydrogen does not alter any of our positions, as it also need to be purified before injection into the infrastructure.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

No. Defining a uniformly high hydrogen purity level across all European networks would not eliminate the need for local purification for critical consumers.

Critical consumers, such as fuel cell applications and selected industrial sectors (e.g. the semiconductor industry or catalytic processes more generally), are extremely sensitive to any impurity and require hydrogen qualities well above mobility standards. Therefore, they have to rely on additional on-site purification as state-of-the-art today and in the future to avoid damage of the high-value production equipment.

This demonstrates that no single network-wide hydrogen purity can meet the needs of all end users. Imposing very high purity requirements across the entire network would therefore generate unnecessary and disproportionate costs for the majority of consumers, whose applications can tolerate much higher impurity levels, ultimately making hydrogen less competitive, thus hindering overall sector developments.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

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17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

In principle, there are innovation opportunities, particularly through advances in membrane technologies (e.g. palladium), adsorption technologies, and hybrid architectures (such as membrane-adsorption combinations), as well as through optimised process design and greater standardisation of quality requirements.

However, many of these approaches are still at the development or early market entry stage, meaning that only limited cost reductions can be expected in the short term. More substantial effects are likely in the medium to long term.

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes, there is a selective need for investment in developments related to hydrogen quality, but in a targeted manner.

At large scale, hydrogen purification technologies are already mature, although they remain costly and could further improve their efficiency. Main investments should be focused on R&D to enhance performance, increased hydrogen recovery, and improved robustness under the varying operating conditions across the value chain.

Investments should be consistent with the objective of system optimisation rather than uniformly high purity requirements across the entire value chain, which would disproportionately increase costs and would hinder the timely and successful ramp-up of the hydrogen system.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

The key consideration with regard to cost allocation from hydrogen purification is the alignment with the respec-

tive regulatory framework. The reflection of costs borne by operators to achieve agreed purity levels needs to be ensured in regulated regimes and permitted in the calculation of negotiated fees.

Measures required to meet an agreed minimum purification standard should be shared by all consumers. This should also include any measures required at connected storage sites to comply with these standards.

By contrast, costs associated with higher purification levels – driven by the specific requirements of specific consumers – could be allocated separately, for example through individual or contractual arrangements.

Ultimately, the costs of purification borne by producers or infrastructure operators will be passed on to end-users, and care should therefore be taken not to socialise the specific needs of a limited number of users across all consumers neither to impose overly restrictive requirements to the overall markets, ultimately making hydrogen less competitive.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

Yes, it might be possible to keep purification measures elsewhere in the system as low as possible if production and import ports were enhanced to feed in with the highest possible purification standard. However, any requirements imposed on producers should be in line with the overall objective of enabling the rapid sourcing of large volumes of low-cost hydrogen and supporting an effective market ramp-up.

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RAG AUSTRIA AG response to the PC

1. Please provide your name, your position, and the organisation you represent.

Verena Friedl, Project Manager Advocacy & Innovation, RAG Austria AG

2. What do you consider to be the main purpose of hydrogen quality monitoring?

Hydrogen quality monitoring is essential to support a harmonised European approach to mitigating and managing critical trace components and to achieve a purity level that best fits producers, end consumers and hydrogen infrastructure operators, aiming at a cost and efficiency optimum for hydrogen as a commodity. It also helps preserve infrastructure integrity and operational reliability, manage quality variability along the value chain, especially to accommodate the needs of storage and repurposed pipelines, support interoperability across interconnected

European hydrogen networks, provide transparency and confidence to market participants, and determine relevant gas quality parameters for market and operational purposes, including the Wobbe Index.

3. Several studies have been carried out and position papers have been issued on this topic. In your view, what is the main decision that needs to be made at this stage?

Several studies and position papers have already highlighted that the outcome depends strongly on the assumptions made, in particular regarding end-use demand with different purity levels, impurity-related costs and efforts for infrastructure elements, and practical feasibility. At this stage, the main decision should therefore be to establish a practical and harmonised European hydrogen quality framework that balances operational feasibility,

cost-efficiency, and technical and safety requirements. In this context, the priority should be to identify the most critical trace components and define limits suitable for the majority of applications, rather than overstating model outcomes or focusing primarily on a single uniform purity level.

4. Do you agree that one of the most important principles is to build a single, interconnected hydrogen network without distinctions between hydrogen grades or types?

We support the development of a single, interconnected European hydrogen network, striving for a common hydrogen quality specification across the EU to guarantee interoperability. The backbone for hydrogen transport, especially for cross-border and third-country hydrogen trade, needs one specific hydrogen quality composition. However, the specification must remain operationally feasible for all infrastructure operators, including storage and terminals, and should avoid requirements that could hinder infrastructure utilisation. This is particularly important during market ramp-up, when overly stringent requirements could slow down the efficient development of the hydrogen market.

5. Do you agree that storage facilities represent the most critical link in the hydrogen value chain?

Yes. Storage facilities, especially large-volume underground hydrogen storage, are key enablers of large-volume seasonal energy storage, supply-demand balancing, and the integration of different production and import sources. They therefore play a central role in the future hydrogen system. At the same time, storage may have a particular relevance for hydrogen quality, as factors such as storage type, previous use, cushion gas interactions and process-related effects may influence gas composition. In particular, repurposed storage sites may face challenges related to short-chain hydrocarbons such as methane, while purification at storage sites can be technically difficult, costly, and constrained by space and permitting conditions. Quality requirements should therefore remain realistic and should not unintentionally hinder the use of storage, which is indispensable for market ramp-up and system development.

6. How do you assess the role of hydrogen transmission network operators (HTNOs)?

Hydrogen transmission network operators play a key role as an important link in the hydrogen value chain. They enable cross-border interoperability, monitor hydrogen quality, provide transparency on relevant quality parameters, and link different production, import and storage facilities within the hydrogen system.

7. Do you agree that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with the entry specifications?

Specifying hydrogen quality at entry points is necessary, but not sufficient. Hydrogen composition may vary during transport and storage; therefore, we require quality management systems, including monitoring tools, to ensure that end-users receive hydrogen with consistent and reliable characteristics.

8. How do you assess the role of hydrogen distribution network operators (HDNOs)?

Hydrogen distribution network operators are important interfaces with end users and some producers. This is particularly relevant in Austria, where industrial customers are largely connected via the distribution network. Coordination across network levels is therefore essential to maintain quality consistency throughout the hydrogen system.

9. Do you identify any specific considerations or challenges related to terminals?

Yes. The ramp-up of the hydrogen system will depend on a variety of import options with varying quality levels. Compliance with defined limits for critical trace components at terminal entry points will therefore be required. In addition, close to terminals, hydrogen structuring will be needed to ensure continuous supply into hydrogen networks when handling bulk shipped volumes, which can be served by underground hydrogen storage.

10. What do you consider more important: reaching a consensus on a unified hydrogen purity level in Europe, or primarily reaching a consensus on contaminants thresholds?

Reaching consensus on contaminants thresholds is more important than defining a single overall hydrogen purity level. The priority should be to define harmonised limits for critical trace components, as these are the key drivers for infrastructure compatibility, storage operability, safety and interoperability across the hydrogen value chain.

11. With regard to contaminants, do you believe that a consensus has already been reached on threshold values? What are the remaining areas of concern?

A broad consensus has already been reached on threshold values for most contaminants, largely aligned with existing European work and standards. One of the main remaining areas of discussion concerns methane content. The main critical aspect for hydrogen discharged from repurposed UGS sites used for UHS is the presence of impurities from short-chain hydrocarbons, mainly methane, which can occur with an amount of up to 2 % at underground hydrogen storages. Clarification and harmonisation of methane limits would support interoperability while maintaining operational feasibility for infrastructure operators.

12. Do you think that standardisation bodies such as CEN/CENELEC should receive a clear mandate from the European Commission to issue specifications recognised by all Member States?

Yes. A clear mandate to standardisation bodies such as CEN/CENELEC would support harmonisation and interoperability across Member States.

13. Do you identify any areas of concern related to hydrogen production?

Yes. Key areas of concern include variability of hydrogen quality depending on renewable and low-carbon hydrogen production routes, including cross-border production routes, the possible presence of trace contaminants affecting infrastructure and metering, and the need for alignment between production specifications, infrastructure capabilities and end-user requirements.

14. With regard to natural hydrogen (white hydrogen), do you foresee potential challenges in the event of an expansion of this type of production?

Potential challenges include variable composition and uncertain contaminant profiles, which may require monitoring and possibly treatment before injection into the network. At the same time, natural hydrogen remains at an early stage of development and is highly site-dependent. If developed further, it could become an additional production pathway supporting hydrogen market ramp-up and source diversification.

15. Different levels of purity are required depending on end uses. Do you believe that, if a globally high level of purity were specified across all interconnected European networks (e.g. >99.97%), local purification units (e.g. for fuel cells) could be avoided?

No. Even if a globally high hydrogen purity level were specified across interconnected European networks, local purification would still be required for certain sensitive applications. A layered approach is therefore more efficient: a harmonised network specification for infrastructure compatibility and cost-efficient system operation, combined with local purification where higher purity is required. The mass market cannot bear the costs of high-quality hydrogen across the entire system, since only a very small fraction of users requires such high purity.

16. What do you consider to be the main priorities regarding data provided by HTNOs through a transparency platform?

Main priorities should include historical data and traceability, information on deviations, standardised reporting formats, and data relevant to underground storage cycles, terminal operations and import flows.

17. Do you foresee significant innovation opportunities that could reduce hydrogen purification costs?

Yes. Innovation opportunities to reduce hydrogen purification costs include advanced membrane and adsorption technologies, modular purification solutions, and digital quality tracking and predictive modelling. However, many of these approaches are still at an early stage, so stronger cost reductions are more likely in the medium to long term.

18. Do you identify a need for investment in developments related to hydrogen quality?

Yes. Investment is needed in measurement and monitoring technologies, pilot projects and demonstrations, digitalisation and interoperability tools, and R&D to improve purification efficiency and system readiness for large-scale hydrogen integration.

19. In a regulated framework, what would you consider to be the optimal approach to cost allocation for hydrogen purification processes?

In a regulated framework, cost allocation for hydrogen purification should reflect responsibilities across the value chain and avoid burdening the wider market with the specific requirements of a limited number of users. Measures required to meet an agreed minimum purification standard should be recoverable within the regulated framework, including any necessary measures at connected storage sites to ensure compliance with these standards. By contrast, costs associated with higher purification levels driven by the needs of specific end users should be allocated separately, for example through local or contractual arrangements. Overall, the approach should support transparency, system optimisation and market ramp-up, while avoiding disproportionate costs for the hydrogen system as a whole.

20. Do you think that incentive mechanisms could be useful in relation to hydrogen quality?

Yes. Incentive mechanisms could be useful to support compliance with network specifications, innovation in purification and monitoring, pilot projects, and infrastructure adaptation. At the same time, such mechanisms should remain consistent with the objective of enabling rapid market ramp-up and the sourcing of large volumes of hydrogen at competitive cost.

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NORDION ENERGI H2 AB response to the PC

1. Please provide your name, your position, and the organisation you represent.

Erik Fiedler-Blackhammar, Technical Specialist Hydrogen, Nordion Energi H2 AB

2. What do you consider to be the main purpose of hydrogen quality monitoring?

Nordion Energi considers the main purpose of hydrogen quality monitoring to be the establishment of trust, stability and predictability in the emerging hydrogen market. Quality monitoring is essential to ensure the secure and efficient operation of interconnected hydrogen networks, to support interoperability, and to enable coordinated infrastructure development in line with future Network Codes.

3. What is the main decision that needs to be made at this stage?

At this stage, the key decision is to define harmonised and pragmatic hydrogen quality specifications that are sufficiently aligned across Europe to support early interconnection of networks. Early convergence is critical to avoid fragmentation, limit unnecessary costs, and ensure that future interoperability rules can be robust and enduring.

Infrastructure

4. Single, interconnected hydrogen network

Nordion Energi agrees that a single, interconnected hydrogen network without distinctions between hydrogen grades should be the guiding principle at transmission level. A unified network design supports market liquidity, cross border trade and efficient utilization of infrastructure, particularly during the market ramp up phase.

5. Storage facilities as a critical link

Nordion Energi agrees that storage facilities represent one of the most critical links in the hydrogen value chain. Storage is particularly sensitive to hydrogen quality parameters and is a key cost driver. Quality requirements should therefore carefully consider storage constraints and avoid imposing system wide specifications that disproportionately impact storage feasibility.

6. Role of hydrogen transmission network operators (HTNOs)

Nordion Energi sees the role of HTNOs as providing neutral, regulated and non-discriminatory infrastructure, while ensuring compliance with agreed hydrogen quality specifications at system level. HTNOs should enable interoperability and coordinated system development, rather than tailoring hydrogen quality to individual end use requirements.

7. Quality specifications at entry points

Nordion Energi agrees that specifying hydrogen quality at entry points is a necessary and sufficient condition for HTNOs, provided that hydrogen is delivered at exit points in accordance with those specifications. Clear entry requirements, combined with monitoring and transparency, form a robust basis for system responsibility.

8. Role of hydrogen distribution network operators (HDNOs)

Hydrogen distribution networks are closer to end users and therefore better positioned to address local or sector specific quality requirements. Nordion Energi considers this differentiation of responsibilities between transmission and distribution levels to be appropriate and cost efficient.

9. Considerations related to terminals

Nordion Energi identifies the need for clear interface definitions, responsibility allocation and quality requirements at such points.

Purity levels and contaminants thresholds

10. Unified purity level vs contaminants thresholds

Nordion Energi considers that agreement on contaminants thresholds should be balanced against the definition of hydrogen purity levels. Specific contaminants have a greater impact on infrastructure integrity, storage performance and sensitive applications than total hydrogen content alone.

11. Consensus on contaminants thresholds

While convergence exists for several contaminants, Nordion Energi notes that further work is required on certain thresholds, particularly where material compatibility, measurement and storage performance are concerned. Continued harmonisation efforts at European level are therefore essential.

12. Mandate to standardisation bodies

Nordion Energi supports providing CEN/CENELEC with a clear mandate from the European Commission to develop hydrogen quality specifications recognised across all Member States. Such a mandate would support consistency, regulatory certainty and efficient market development.

Production

13. Areas of concern related to hydrogen production

Different production pathways may lead to variations in hydrogen quality. Nordion Energi sees a need for clear and enforceable connection requirements to ensure that production-related quality variations do not create risks or additional costs for the transmission system.

14. Natural (white) hydrogen

Nordion Energi has no established position at this stage regarding natural hydrogen. Potential challenges may relate to quality characterisation, contaminants and traceability, which would need to be addressed before large scale integration into public networks.

Consumption

15. Global high purity across all networks

Nordion Energi considers a balanced approach to hydrogen purity to be essential, where the benefits of higher purity levels are carefully weighed against their system wide cost implications. While high purity is required for certain applications, a uniform requirement across all interconnected networks risks being disproportionate, whereas local purification solutions can offer a more cost effective and system efficient outcome.

16. Transparency platform – priorities

The main priorities for data provided through transparency platforms should be reliable, comparable and system relevant information on hydrogen quality, supporting operational coordination, investment decisions and market confidence.

Research and development

17. Innovation opportunities

Nordion Energi continuously monitors innovation potential in system design, monitoring technologies, standardisation and alternative purification approaches, and will adapt its approach where such developments can reduce overall system costs without compromising safety or interoperability.

18. Need for investment related to hydrogen quality

This principle is not materially different from existing natural gas systems. There is always a clear need for gas infrastructure investment in measurement, monitoring, quality assurance and system integration, especially during the early phases of hydrogen infrastructure deployment.

Regulation and cost allocation

19. Cost allocation for hydrogen purification

Nordion Energi considers that costs related to hydrogen purification should be allocated where they arise and where the benefit is realized. Transmission systems should be designed for a common baseline, while user specific requirements should be addressed outside the core network.

20. Incentive mechanisms

Clear, predictable and harmonised rules to be met by operators are the most important drivers for correct behavior regarding hydrogen quality.

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