GAS QUALITY MONITORING REPORT

First Edition

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1 INTRODUCTION

The increasing diversification of the gas mix in Europe through the injection of renewable and low-carbon gases together with the need to maximise the diversification of EU imports of gas supply sources to decrease dependence on Russian gas bring to gas quality flowing in EU pipelines additional importance as parameter to monitor.

The new Regulation (EU) 2024/1789 on the internal markets for renewable gas, natural gas and hydrogen, requires ENTSOG to publish every two years a gas quality monitoring report covering the following topics:

- developments of gas quality parameters
- developments of the level of hydrogen blended into the natural gas system
- forecasts for the expected development of gas quality parameters and of the volume of hydrogen blended into the natural gas system
- the impact of blending hydrogen on cross-border flows as well as information on cases related to differences in gas quality specifications or in specifications of blending levels and how such cases were settled, with a view to meeting the quality requirements of different end-use applications.

This report provides a summary of relevant developments on gas quality, including the activities carried out in the European standardisation working groups, qualitative forecasts of gas quality changes in the future and information about the management of cross-border gas flows from TSOs in case of differences in gas quality specifications.

The information provided in this report have been collected by ENTSOG and its members, including through inputs from relevant stakeholders, and their involvement in activities related to gas quality. CEN, Marcogaz, EASEE-gas and ISO have contributed providing relevant information related to work carried out on gas quality in CEN/TC234 WG11, CEN TC408, ISO/TC193, Marcogaz Gas Quality Working Group and EASEE-gas Gas Quality Harmonisation Working Group.

Picture courtesy of Gas Connect Austria

2 CURRENT DEVELOPMENTS OF GAS QUALITY PARAMETERS

Numerous initiatives are currently underway across Europe, both at standardisation level and within technical working groups of various European associations. This chapter provides an overview of the latest developments related to gas quality.

2.1 REVISION OF EN 16726, EUROPEAN STANDARD ON THE QUALITY OF GAS OF THE GROUP-H FAMILY

The European Standard EN16726 specifies the gas quality characteristics, parameters and their limits for gases classified as group H that are to be transmitted, injected into and withdrawn from storage facilities, distributed and utilised.

The first edition of EN16726 was published by CEN in 2015 under request of mandate M/400 of the European Commission. As no consensus for the Wobbe Index requirements was possible at that time, the mandate could not be fulfilled; CEN was requested to study the topic of Wobbe Index aiming at completing the mandate with the next revision of EN 16726 as soon as possible.

From 2016, extensive work has been carried out by CEN on Wobbe Index, through the CEN Sector Fora Gas WG "Pre-normative studies of H-gas quality parameters" (abbreviated as CEN SFGas GQS), and additionally on Oxygen by CEN SFGas GQS Task Force 3, put in place in 2018. The reports provided by these two groups built a basis for the revision of the standard EN16726 starting in 2022.

As part of the revision process, the CEN working group dealing with the revision of EN 16726, CEN TC234 WG11, assessed the following H-gas parameters: Hydrogen and relative density, Sulphur, Methane Number, Oxygen, CO_2, and Wobbe Index, resulting in a draft submitted to CEN Public Enquiry from December 2023 to March 2024.

A CEN Public Enquiry gives the opportunity for both National Standardisation Bodies and associated organizations to provide comments and it also includes an indicative vote of the CEN Members on the draft standard. Accompanied by about 650 comments, the voting on the draft EN 16726 was formally positive. Therefore, CEN TC234 WG11 could proceed in the revision process by treating the technical and editorial comments received during the enquiry. A final draft was delivered at the end of this phase for submission to formal vote.

The timeline of EN16726 revision process is illustrated in **Table 1**.

Phase of revision process	Date
Circulation of 1st Working Draft	2023-05-17
Acceptance of the draft	2023-09-21
Start of draft translation	2023-10-19
Submission to Enquiry	2023-12-21
Closure of Enquiry	2024-03-14
Acceptance of draft for Formal Vote	2024-12-20
Submission to Formal Vote	2025-03-01
Closure of Formal Vote	2025-05-01
Ratification	2025-06-01
Definitive text available	2025-07-01
Announcement	2025-10-01
Completion all national publications	2026-01-01
Completion withdrawal national standards	2026-01-01
Start of review	2030-02-01

Table 1: Timeline of EN 16726 revision.

The standard approval depends on the outcome of the formal vote, which is scheduled to be finalised after the publication of this report. As a consequence, this report does not detail the content of the draft standard submitted to vote.

During the standard revision process in 2023 and 2024, considering the latest developments in the European gas markets, new parameters to the 2015 version of EN 16726, such as hydrogen content and Wobbe Index, have been proposed to be included in the revised standard. Additionally, for some parameters already present in the current standard, proposals have been made to modify their limit values. This is the case for relative density, oxygen and sulphur content among others.

Concerning Wobbe Index, the draft standard suggests a decoupling between entry and exit points in order to ensure security and diversification of gas supply, and increase the monitoring and the management of gas quality variations on end-user side.

About blends, a maximum limit of 2 $\%_{mol}$ H_2 is proposed in the draft standard, aligned with the indication in the new Regulation (EU) 2024/1789, with the possibility to allow for local or national deviations depending on the presence of sensitive installations.

For oxygen, a system based on three limit values is suggested, which have to be defined through assessment processes.

If the draft revised standard is approved, EN 16276 will have to be implemented in those countries that decide to apply the standard.

In that case, an implementation phase will follow the standard publication which varies depending on the country. New processes and roles are introduced in the proposed draft standard. Beside the regulatory implementation, also other arrangements, agreements and contracts may be submitted to changes due to the application of the new revised standard. Recommendations on the way to implement the new processes could be developed with the goal to support the Member States in the application of the standard.

2.2 CEN TC408 – BIOMETHANE GAS QUALITY PARAMETERS

CEN TC 408 is the CEN technical committee working on the standard EN 16723 on:

- Biomethane for injection into the gas grid (EN 16723-1)
- Natural gas and biomethane as fuel for vehicles (EN 16723-2)

The standard EN 16723 relies on EN 16726 for the gas quality parameters which are common to both biomethane and natural gas, like combustion properties, oxygen, sulfur etc.

Recently, the scope of TC 408 has been amended in order to include also other renewable and low-carbon gases, such as the synthetic methane produced through methanation process.

The scope of CEN TC408 as approved in 2024 is the following:

- Standardisation of specification for renewable and low-carbon methane rich gases for injection in the gas network.
- Standardisation of specification for natural gas, renewable and low-carbon methane rich gases and mixtures thereof as fuel for engine.
- Standardisation of necessary related methods for sampling, analysis, and testing.
- Standardisation for production of renewable and low-carbon methane rich gases (e.g. anaerobic digestion, pyrolysis, gasification, methanation, power-to-gas). Compressed and liquefied forms of these gases are covered in this scope.
- Mirror committee of ISO/TC 255, *Biogas*, ISO/TC 193/SC 1/WG25, *Biomethane*, ISO/TC 193/WG8, *Knock resistance*, and ISO/TC 28/SC 4/WG17, *Specifications of liquefied natural gas for marine applications*.

TC 408 recently created a Working Group of experts, WG1, for working on the future revision of EN 16723. The goal is to review the parameters and associated limit values for the compounds present in renewable and low-carbon gases.

At the time of drafting this report, CEN/TC 408/WG1 has been collecting information:

- to identify contaminants covered in the initial standards that require clarification or changes
- to identify contaminants that were missing in the initial standards

CEN/TC 408/WG1 is also preparing the extension of the scope of the standards to new production processes.

Finally, CEN/TC 408/WG1 is considering the inclusion in the standard of tables listing contaminants alongside their respective limits and analysis methods, while also clarifying the necessity of measuring each contaminant based on the production process and the products entering the process. This approach aims to enhance efficiency by avoiding measurement of contaminants that are unlikely to be present, thereby reducing overall costs.

The work of CEN TC408 is also supported by a GERG project funded by the EC and started in 2016 aiming at *Removing the technical barriers to uses of biomethane in gas networks*[1].

The goals of the GERG project are:

- Develop and share knowledge on biomethane quality and its impact on the value chain.
- Study the real impact of biomethane quality (corrosive compounds and silicon on the gas supply chain.
- Anticipate potential operational issues for gas operators.

The first phases of the project have shown that biomethane doesn't have any additional health problem for domestic use compared to natural gas. However, the project also recognises that there is a knowledge gap on the impact that some gas quality parameters like sulphur and oxygen may have on gas facilities, confirming that more research is needed on these topics. For this reason, the project was divided in different stages: Phase 2b, from 2020 to 2022, with a budget of € 1.8 M, and phase 2c started in 2023, with a budget of € 3 M.

This project carried out by GERG is currently undergoing phase 2c, and is named "BIOSTAR2c, removing technical barriers to BIOmethane STAndaRdisation Phase 2"[2].

In this last phase, the project is evaluating the impact of siloxanes on industrial boilers, the impact of sulphur on natural gas vehicles and the impact of oxygen and corrosive compounds on underground storage facilities.

The results of the project are expected to be delivered by end 2024 and the final report in March 2025.

1 Removing the technical barriers to uses of biomethane in gas networks by GERG

2 BIOSTAR2c: Removing Technical Barriers to Biomethane STAndaRdisation Phase 2C by GERG

2.2.1 PRELIMINARY RESULTS OF GERG PROJECT

The first phase was conducted internally in GERG before contact was established with CEN/TC 408. The outcomes have been a literature review on biomethane quality, on corrosive trace compounds and on the impact of siloxanes. They concluded that no impact from siloxanes was expected before combustion on the gas infrastructure. But impact is expected after combustion on heavy-duty vehicles and industrial boilers and there is little knowledge on this.

Four Work Packages (WP) were decided with CEN/TC 408 for Phase 2a:

- WP 1: Impact of siloxane on industrial boilers and vehicle engines (experimental program). It was recommended to further test the impact of silica deposition in a heavy-duty vehicle engine equipped with a switching-type oxygen sensor as part of the engine control unit. It was also recommended to further test boilers in cycling mode (start and stop conditions), with more realistic siloxane concentrations (1 mg Si/m^3(n) or lower) and on a longer period.
- WP 2: Impact of sulfur on engine after treatment system (bibliographic review). It was proposed to perform an experimental program on both light and heavy duty vehicle with different total sulfur concentration. It was proposed to combine it with a numerical simulation to understand the mechanism of catalyst poisoning.
- WP 3: Impact of oxygen and corrosive compounds on gas grid and underground gas storage (bibliographic review). It was suggested to perform core flooding experiment using rock cores from representative reservoirs. It was also suggested to study the effect of oxygen on bacterial H_2S generation.
- WP 4: Impact of biomethane on health (bibliographic review). The report showed that there is no specific health impact related to biomethane, so no recommendation for further studies was proposed.

Four Work Packages (WP) were decided with CEN/TC 408 for Phase 2b:

- WP1 Impact of sulfur on:
  - Heavy-duty vehicles. Only very modest changes have been observed in the engine efficiency during the experimental work. No significant changes were observed that could be attributed to silica deposition from the sensors.
  - Boilers. The result was an experimental protocol for the tests in cycling mode to be performed in Phase 2c.
- WP2 Sulfur impact:
  - Increasing sulfur concentrations above 30 mgS/m^3(n) will accelerate the degradation of CH4 conversion of a three-way catalyst. The result was an experimental protocol for a test campaign aiming at achieving thermal ageing in the presence of sulfur of three-way catalysts.
- WP3 Oxygen and corrosive compounds impact:
  - Formation damage on underground gas storage. An experimental programme was defined to validate the liquid phase analysis protocol along with defining the reagents and equipment required.
  - Impact of H_2 on CNG tanks. A literature review was performed and a test programme was defined for Phase 2c.
- WP4 Biomethane knowledge:
  - Data was collected on raw biogas, biomethane, bio-LNG and on the siloxane purification technology.

Five Work Packages were decided with CEN/TC 408 for Phase 2c:

- WP1 Project management and coordination
- WP2 Impact of siloxanes on industrial boilers
- WP3 Impact of sulfur on Natural Gas vehicles (Vehicle engines tests and three-way catalyst ageing)
- WP4 Impact of oxygen on Underground Gas Storage and impact of corrosive compounds. The impact of H_2 on CNG type steel tanks is also evaluated.
- WP5 Improving European Biomethane Knowledge:
  - Database of biogas and biomethane composition frow Swedish data
  - Composition from biogas to upgraded biomethane from French data
  - Impact of purification process on biomethane composition

Phase 2c will end in 2024 and the final report is expected to be delivered in March 2025.

2.2.2 NEXT STEPS

The revision of EN 16723-1 and EN 16723-2 have been started as preliminary work items. They will be activated probably in 2025 when enough data has been collected on the following topics:

- Data on new production methods (pyrolysis, gasification, methanation, power-to-gas), including new contaminants or different levels expected in addition to the previously identified contaminants
- Standards on analysis methods for contaminants specific to biomethane by ISO/TC 193/SC 1/WG25: eight standards have already been published on VOCs, ammonia, compressor oil, siloxanes, terpenes, amines, HCl and HF.
- Standards on calculation of methane number by ISO/TC 193/WG8: publication expected in 2025
- Result of GERG project BioStAR2C

CEN/TC 408 is considering merging both standards EN 16723-1 and EN 16723-2.


Picture courtesy of Enagás

2.3 WORK RELATED TO GAS QUALITY CARRIED OUT BY EUROPEAN ASSOCIATIONS

2.3.1 EASEE-GAS GAS QUALITY HARMONISATION WORKING GROUP

EASEE-gas[3], the European Association for the Streamlining of Energy Exchange – gas, promotes and develops solutions for the simplification and streamlining of trading and physical transfer of gas. EASEE-gas was set up in 2002 and currently comprises more than 80 companies active in the European gas market.

The Gas Quality Harmonisation Working Group (GQHWG) is one of the three working groups within EASEE-gas. Traditionally the GQHWG focussed on gas quality topics related to natural gas but currently most of the activities are related to renewable gases like hydrogen. The GQHWG is composed of stakeholders of almost all parts of the gas value chain. As such, the solutions agreed in this group are based on consensus within the gas value chain.

The results are mostly published in the form of Common Business Practices[4] (CBPs), which are standards, procedures and/or protocols commonly used throughout the gas industry in Europe and which are recommended by EASEE-gas for adoption by all relevant industry players to simplify and streamline business processes across Europe.

In 2022 the CBP Hydrogen Specification[5] was published and recently the CBP on Hydrogen Units[6], which advises on the units to be used in the market processes for hydrogen: contracting, nomination, balancing, allocation.

Current activities carried out by the EASEE-gas GQHWG are:

- To investigate the possibilities for end users of sensitive applications to benefit from information on the actual gas quality to at least partly mitigate the effects of variations in the gas quality, a questionnaire was prepared by the GQHWG which will be sent out in 2025. If the outcome of this questionnaire provides a good starting point, the GQHWG will identify which stakeholder(s) are able to deliver the necessary information. Depending on the requirements, the set-up and operation of systems to provide the necessary gas quality information incur costs. Therefore, in a later stage, a cost benefit analysis is also planned by the working group.
- Review the new insights in the achievable hydrogen quality in repurposed pipelines. Supported by DNV/KIWA, the GQHWG plans to investigate the optimum minimum hydrogen concentration for Europe as a whole.

3 EASEE-gas was set up in 2002 in order to develop and promote business practices to simplify and streamline gas transfer and trading across Europe

4 Business process guidelines for the European gas market by EASEE-gas

5 Hydrogen quality specification by EASEE-gas

6 Units used in hydrogen market processes by EASEE-gas

Picture courtesy of FGSZ

2.3.2 MARCOGAZ ACTIVITIES RELATED TO GAS QUALITY

MARCOGAZ, the Technical Association of the European Gas Industry, is a non-profit international association founded in 1968. MARCOGAZ represents the European gas industry on all technical aspects of the gas system's value chain, focusing mostly on the midstream and downstream sectors.

Working Group Gas Quality, part of Standing Committee Gas Utilisation of MARCOGAZ, is responsible for following gas quality aspects that affect the gas industry.

The main activities of WG Gas Quality focus on any issues affecting natural gas quality. The quality of biomethane, other renewable gases, and hydrogen is part of the scope of the WG as well. This includes the mixture of any of these new gases with natural gas.

The activities of WG Gas Quality can take the form of internal studies for the benefit of member organisations, as well as, documents for the general public, available on MARCOGAZ website.

The most recent activities, along with those currently underway, are as follows:

- Collaboration with CEN/TC234/WG11 "Gas quality" in the revision of the European standard EN16726:2015, Gas infrastructure – Quality of gas – Group H. MARCOGAZ is participating in the process, providing its advice and technical knowledge in discussions for defining the values of the gas quality parameters specified by the standard and the inclusion of a Wobbe index range.
- Publication of the report "*Quality of biomethane required in European countries for injecting into natural gas grid*" (March 2024). Biomethane is theoretically interchangeable with natural gas. MARCOGAZ has undertaken the task of gathering data on the quality standards necessary for biomethane injection into natural gas networks across various European nations, facilitating a comparative analysis of national approaches.

  Each European country exercises its right to establish natural gas quality parameters, employing diverse methods such as national regulations, standards, gas company requirements, and specific contracts with biomethane producers. This updated document which builds upon the 2019 publication, is now incorporating information from 14 European countries, with notable changes observed in quality parameter requirements across several jurisdictions.
- Publication of the report "*Hydrogen regulation/standard in European countries for injecting hydrogen into natural gas grid*" (March 2024). Hydrogen emerges as a key element in the journey towards decarbonizing energy systems. One strategy involves injecting limited amounts of hydrogen into existing natural gas networks through blending. Although this practice remains uncommon, a few demonstration projects are operational. However, injecting hydrogen alters the quality parameters of natural gas, a factor subject to varying approaches across European countries. These approaches include national regulations, standards, gas company requirements, and specific contracts with producers. MARCOGAZ has been gathering data on hydrogen injection requirements across European nations to monitor its adoption. This third update of their publication, following editions in 2016 and 2020, incorporates information from 12 European countries, revealing changes in quality parameter requirements in some jurisdictions.

- "*Liquefied Natural Gas (LNG) quality data base*." As a consequence of the Russian war in Ukraine, LNG supplies to Europe have become a key piece to guarantee the security of supply to the natural gas European market. This has led to the arrival of LNG in Europe from many different supply countries. LNG quality parameters are slightly different to the ones of traditional natural gas supplied to the European market so, through this work, MARCOGAZ is collecting information of LNG arriving to the regasification terminals of its members to provide information about the quality of LNG by country of origin to the European gas markets. It is known that the composition of LNG changes during ship transportation and storage in LNG terminal tanks. Therefore, the information collected will not exactly reflect the quality of the LNG in its country of origin, after the liquefaction train, but the LNG arriving in Europe, after the journey. It is clear that, due to this fact, the LNG quality from a country, (e.g., Qatar) will be slightly different if it is unloaded in Greece or The Netherlands. Nevertheless, the information gathered from MARCOGAZ member LNG terminals will approximately indicate the maximum range of composition and properties expected from a specific LNG origin upon arrival in Europe. The information that will be published will not include commercially sensitive details, such as the volume or energy content of LNG downloaded by individual cargoes at each LNG terminal.

Marcogaz also carries out activities related to the odorisation of natural gas and renewable and low-carbon gases including blends, performed for safety reasons. In the context of gas transmission grids, natural gas is odorised at transmission level only in a few countries in Europe: France, Spain, Hungary and Ireland. In Portugal, gas flows from Spain are also odorised. Other countries mainly odorise gas at distribution level.

Recently, Marcogaz activities related to odorisation have been focused on the odorisation of hydrogen blends with natural gas up to 20 % H_2. A document was published at the end of 2023, and a summary is provided in **section 4.2** of this report.

2.3.3 ENTSOG GAS QUALITY WORKSHOP

In the recent years, ENTSOG organised two public workshops dedicated to gas quality. Different stakeholders of the gas value chain usually participate in this event. The topics that have been discussed are very diverse and cover the following aspects:

- Current development of the H-gas quality standard: revision of EN16726
- Biomethane and synthetic methane, especially concerning the Oxygen management with sensitive applications and at interconnection points
- Technologies for tracking gas quality along the gas grid
- Impact of the recent changes of gas supply sources on gas quality, with a focus on the increase of LNG supply
- Hydrogen Quality: the technical specification published in 2023 (TS 17977) and repurposing of pipelines
- CO_2 quality, works on-going on CO_2 specifications at EU and national level

All the presentations shared during the events are available on the ENTSOG website.

2.4 OTHER DEVELOPMENTS RELATED TO GAS QUALITY

While CEN focuses specifically on European standards, the International Organisation for Standardisation (ISO) develops international standards applicable worldwide. ISO is an independent, non-governmental international body. Through the Vienna agreement, ISO and CEN work jointly on standards that have specific legislative relevance within the EU.

As for CEN, ISO is also organised in Technical Committees. One of the more relevant TCs working on Gas Quality is ISO/TC 193 Natural Gas.

The scope of ISO TC 193 is to standardise terminology, quality specifications, methods of measurement, sampling, analysis and testing, including thermophysical property calculation and measurement, for:

- natural gas
- natural gas substitutes
- mixtures of natural gas with gaseous fuels (such as unconventional gases and renewable gases)
- wet gas

Many standards are developed under ISO/TC 193 and related sub-committees. It is worth mentioning ISO 15112:2018 on Energy determination of Natural gas, ISO 15970 and ISO 15971 for measurements of NG properties, and other ISO standards for the analysis of impurities in biomethane like ammonia, halogens and silicon (ISO 2610-ISO 2620).

Other standards are under development in ISO/TC 193. Here below are some of the standards considered relevant for the report:

- Odorisation (ISO/CD TR 5268, ISO/AWI 13734 and ISO/DTS 18222.2)
- Calculation of methane number for gaseous fuels for reciprocating internal combustion engines (ISO/CD 17507-1 and ISO/CD 17507-2)
- Natural gas- Calculation of calorific values, density, relative density and Wobbe Indices from composition (ISO/AWI 6976)

A complete overview of the work programme of ISO/TC 193 is available on the ISO website[7].

7 Standards by ISO/TC 193

Picture courtesy of Plinacro

3 FORECASTS FOR THE EXPECTED DEVELOPMENT OF GAS QUALITY PARAMETERS

ENTSOG publishes every two years a Long-Term Gas Quality monitoring Outlook (GQO) for transmission systems with the aim of identifying the potential evolution of gas quality parameters in Europe within the next 10 years.

The Gas Quality Outlook usually provides forecasts of Wobbe Index and Gross Calorific Value in the main regions and supply corridors in Europe defined like the regional groupings that develop the Gas Regional Investment Plans (GRIP):

- South corridor: FR, ES, PT
- South-North corridor: DE, BE, FR, IT, CH, LU
- North-West corridor: SE, DK, DE, NL, BE, LU, FR, UK, IE
- Baltic Energy Market Interconnection Plan (BEMIP) corridor: DK, SE, FI, PL, EE, LT, LV
- Central Eastern Europe (CEE) corridor: DE, PL, CZ, SK, AT, HU, HR, RO, BG
- Southern Corridor: IT, AT, SI, SK, HU, HR, RO, BG, GR

The latest edition of the Gas Quality Outlook[8] was published in 2023 and the analysis is aligned with the Ten-Year Network Development Plan (TYNDP) 2022 considering existing and new supply sources. The report illustrates the evolution of WI and GCV in each region between 2025 and 2040.

Figure 1 shows, as an example, the WI evolution in two of the six regions analysed in the GQO: South and North-West regions. Solid lines represent the 50^{th} percentile (median), while dashed lines indicate 2.5^{th} percentile (bottom) and 97.5^{th} percentile (top).

Results of the Gas Quality Outlook show different trends depending on the considered region.

Indeed, the evolution of gas quality parameters is the result of the evolving supply scenario of the region. Gases like LNG, Azerbaijan production or indigenous gas from Denmark are characterised by high Wobbe Index values, while biomethane, Libyan gas, Algerian gas and indigenous production gas in Hungary, the Netherlands and Germany have a lower Wobbe Index.

The scenario of the supply sources of the regions impacts the forecasted gas quality parameters. For regions characterised by high development of biomethane, a decrease of combustion parameters from 2025 is observed. In other regions, when the increase of gas with low GCV and WI such as biomethane is compensated by increased LNG imports, WI and GCV are characterised by a rather stable trend.

In general, the scenario considered in the latest Gas Quality Outlook is based on current trends where a significant decrease in Russian gas in favour of increasing flows of Norwegian gas and LNG are occurring.

The next edition of the Gas Quality Outlook will be based on the TYNDP 2024 scenarios and developed in parallel with the TYNDP2024.

8 ENTSOG TYNDP 2022 Annex F – Gas Quality Outlook

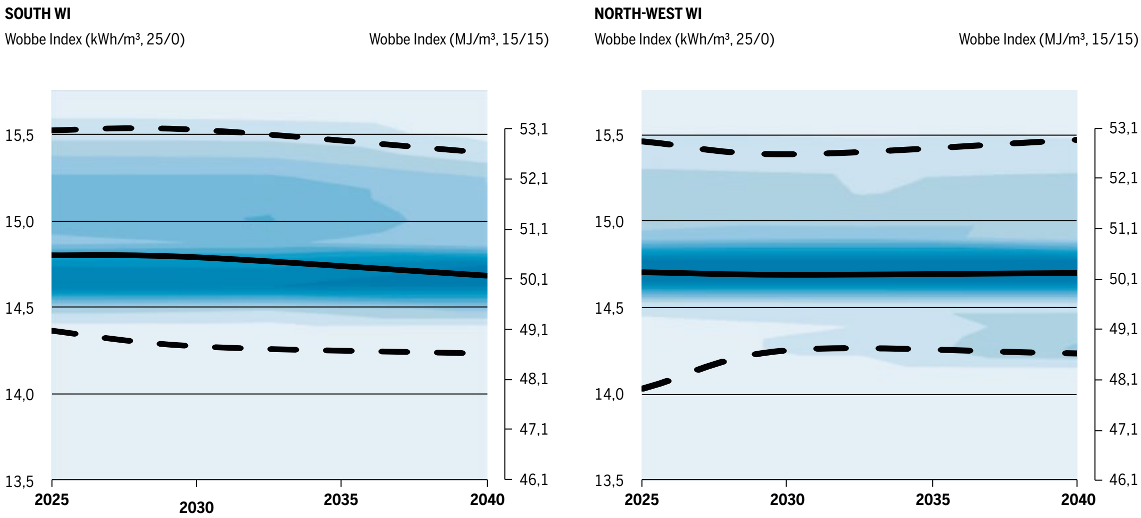

Figure 1 – Evolution of Wobbe Index from 2025 to 2040 in South and North-West regions

4 CURRENT AND FUTURE DEVELOPMENTS OF LEVEL OF HYDROGEN INTO THE NATURAL GAS SYSTEM

Hydrogen can be present in the gas flowing through the grid either from direct injection, as a pure or blended form, or as a component in biomethane and synthetic gas. Compared to natural gas, hydrogen has different characteristics especially in terms of combustion properties.

Conventional gas chromatographs used in gas grids for measuring GCV are not suitable for hydrogen blends without significant modifications[9]. Therefore, adjustment is needed to accommodate hydrogen. For this reason, many TSOs have been assessing the suitability of their equipment and are proceeding with the necessary replacements of the gas chromatographs where necessary throughout the network with new equipment suitable for measuring H_2 content and related GCV in case of hydrogen blends.

Concerning the allowable concentration of hydrogen blended with natural gas in Europe, ACER published the results of a survey in 2022 on the H_2 blends acceptability in different Member States[10].

Additionally, in 2024, Marcogaz published a document[11] which summarises the situation related to H_2 blends in 12 EU countries.

Part of the information available in the literature has been updated by ENTSOG members and is included in this report.

Available information shows that the allowable concentration of H_2 blends in the natural gas grid varies from country to country.

In Belgium and Italy, the maximum allowed concentration for H_2 blended with Natural gas is 2 $\%_{mol}$. Latvia allows the same concentration for H_2 but exception can occur in the presence of storage facilities. In Lithuania, a concentration of 2 $\%_{mol}$ H_2 is allowed at pressures up to 16 bar; at higher pressure, the permitted concentration is reduced to 0.1 $\%_{mol}$[12]. In Hungary and in France a maximum of 2 % H_2 is expected to be allowed in the gas grid. In other countries, this limit can be higher, like in Spain where H_2 is limited to 5 % and in Austria where the limit defined in the Guideline ÖVWG G B210 is 10 % but, based on assessments in distribution networks and furthermore depending on the relevant application, an additional individual assessment can be necessary.

In other countries, the limit for H_2 blended with NG is lower: in Ireland, this limit is 0,1 $\%_{mol}$.; in the Netherlands, the current threshold for H_2 is 0,02 % for TSO High Pressure grids and 0,5 % for TSO regional grids and DSO grids.

In Germany, there is no general value for the maximum allowable H_2 limit in the public H-gas supply. In the technical Standard by DVGW G 260 it is stated that the threshold shall be estimated under observance of the suitability of applications and infrastructure. Additionally, the limit for H_2 blends must fulfil the established limits for other gas quality parameters, such as relative density, among others.

In many EU countries blends are not allowed, however developments are on-going to allow or increase the acceptance of hydrogen into the NG network.

Table 2 summarises the information gathered from the available sources and includes recent updates from ENTSOG members.

9 **H_2 Infographic 2023 by Marcogaz**

10 **The Opinion reviews the most recent editions of the EU gas national development plans by ACER**

11 **Hydrogen regulation/standard in European countries for injecting hydrogen into natural gas grid by Marcogaz**

12 The TSO may grant exceptions for biomethane producers, allowing the injection of biomethane with up to 2 $\%_{mol}$ H_2 content in systems where the pressure exceeds 16 bar. This exception does not apply to hydrogen and natural gas blends.

No blends allowed	Below 2 % H_2	2 % H_2	Above 2 % H_2	No general value	Plan to increase H_2 acceptance
Bulgaria **Croatia** **Cyprus** **Czech Rep.** **Denmark** **Estonia** **Greece** **Hungary** **Luxembourg** **Malta** **Poland** **Romania** **Slovakia** **Slovenia** **Sweden**	**Ireland**: 0.1 % **Lithuania:** 0.1 % if pressure above 16 bar **The Netherlands**: – 0.02 % for TSO high pressure grids – 0.5 % for TSO regional grids and DSO grids in the Netherlands	**Belgium** **Italy** **Latvia**: With exemption in case of UGS connected **Lithuania**: If pressure below 16 bar Expected: **Hungary** **France**	**Spain:** 5 % **Portugal** **Austria:** 10 % (Based on assessment in distribution networks and furthermore depending on the relevant application)	**Germany:** The value depends on the suitability of applications and infrastructure **Finland**	**Bulgaria** **Croatia** **Czech Republic** **Hungary** **Ireland** **Italy** **Lithuania** **Luxembourg** **Poland** **Slovenia** **Sweden**

Table 2: Allowed H_2 concentration (%mol.) in the natural gas grid in some European countries.

Picture courtesy of Fluxys Belgium

4.1 EXAMPLES OF PROJECTS INJECTING H_2 OR BLENDS INTO THE NATURAL GAS TRANSMISSION GRID

This report only includes examples of projects of H_2 injections, pure, blended or through synthetic gas, at transmission system level. However, similar projects at DSO level that may have an influence on the transmission grid are also mentioned.

In Denmark, the interest in producing synthetic gas, i.e. gas produced through methanisation of the excess CO_2 from the biogas upgrading process and preferably green H_2 produced from wind and solar power, in parallel with biomethane, is increasing. A Nature Energy facility by Glansager producing synthetic gas according to the aforementioned process went into production in the fall of 2023, with expectations of reaching 12.000 m^3/day[13]. The facility is currently injecting biomethane and synthetic gas into the local distribution grid with the prospect of injection into the Danish transmission grid within a few years via a reverse point.

This has prompted the Danish TSO, Energinet, the Danish Safety Technology Authority and the Danish DSO, Evida, to collaborate on a common ground for H_2 requirements in the Danish gas grid. Initially, a local requirement has been formulated, which is expected to be implemented directly into future revision of Energinet's Terms and Conditions for Gas Transport[14], where the requirements for H_2 will thus be specified as follows:

"H_2: Traces of hydrogen up to 500 ppm may be present in gas in the Transmission System due to reverse flow from the Distribution Network at the Transition Point. However, under extraordinary operating conditions in relation to the production of Renewable gasses the hydrogen content may for a period of 8 hours constitute up to 1,000 ppm and for a period of 1 hour more than 1,000 ppm but less than 2,000 ppm."

In Spain, Redexis injected for the first time green hydrogen into the natural gas network in Majorca, in the Balearic Islands, in September 2024. The hydrogen is produced in Lloseta plant (2,5 MW electrolyser fed by solar panels) and the infrastructure is equipped with a position for the reception of hydrogen, a 3,2 km hydrogen network to connect the hydrogen production with the natural gas network and a blender. At present, the blending level is 2 %.

In 2014, France started the construction of its first industrial demonstrator of Power-to-Gas (P2G), the Jupiter 1000 project, under the coordination of GRTgaz, French TSO. The installation is characterised by a power rating of 1 MW_e for electrolysis. The green hydrogen produced is mixed on the same site with recycled carbon dioxide in a methanisation process for producing synthetic gas. The produced syngas is then injected into the transmission grid. The hydrogen concentration that will be injected into the grid will have to fulfill the French specifications for blends[15].

In Hungary, the Akvamarin project[16] has been launched where a storage system operator will inject a blend containing a max of 2 $\%_{mol}$ H_2 into the NG transmission system, once blends are allowed in the system. In a later phase, it is planned to inject the mixture also in the gas storage.

In Germany, Gascade has signed a grid connection agreement for HH2E AG's green hydrogen project in Lubmin, enabling the blending of green hydrogen into the natural gas network. The plant, located in Mecklenburg-Vorpommern, is expected to begin operations by late 2026 and will be connected to the European Gas Pipeline Link (EUGAL), initially transporting a blend of natural gas and hydrogen.

In the Netherlands, the PosHYdon[17] pilot project aims to investigate the practical aspects of integrating working energy systems at sea and producing hydrogen in an offshore environment, to see how offshore conditions, including salt, affect the electrolyser. PosHYdon will integrate three energy systems in the North Sea – offshore wind, offshore gas and offshore hydrogen – at Neptune Energy's Q13a-A platform.

13 **Nature Energy facility in Denmark**

14 **Terms and Conditions for Gas Transport by Energinet**

15 In France, the gas quality specification for blends is under revision. A maximum concentration of 2 % H_2 is expected to be allowed.

16 **The Akvamarin project**

17 **The PosHYdon project**


Picture courtesy of Gas Connect Austria

The 1 MW electrolyser will produce a maximum of 400 kilogrammes of green hydrogen per day. The green hydrogen will be blended with natural gas and transported via the existing offshore gas pipeline to the coast and injected into the TSO grid.

First offshore hydrogen production is planned for the end of 2024. For the specific area where the blend reaches the shore, the maximum allowable H_2 concentration was increased from 0.02 $\%_{mol}$ to 0.5 $\%_{mol}$.

4.2 ODORISATION IN CASE OF BLENDS

A study has been carried out by the Marcogaz Odorisation Working Group to assess the odorisation issues related to the addition of hydrogen in natural gas[18].

The study shows no significant issues with odorisation following the addition of hydrogen to natural gas, though experiences are small so far and mainly limited to distribution grids. Preliminary findings suggest that odorisation of natural gas/hydrogen mixtures can be done using the same odorants and concentrations as for natural gas. A safe concentration of hydrogen in the natural gas, for odorisation with traditional odorants, is indicated in the study, and it is up to 20 $\%_{mol}$. However, extending findings from distribution grids to transmission grids is challenging due to higher pressure levels, although hydrogenation, common reaction of hydrogen with organic compounds, is unlikely to take place at the conditions found in gas pipelines.

Marcogaz identified some research needs on the following topics:

- Effects on odorisation due to differences in the physical properties of the gas and odorant mixture (e.g., density, vapor pressure).
- Possible chemical reactions between hydrogen and odorant under high-pressure conditions.
- Effects of high hydrogen concentrations on gas odorants.
- Impacts of impurities from hydrogen production on odorisation.

18 Odorisation of natural gas/hydrogen mixtures and pure hydrogen by Marcogaz

Picture courtesy of GASCADE

5 GAS QUALITY AT CROSS-BORDER FLOWS

Currently, cross-border flows don't contain hydrogen at significant level. However, with the development of renewable and low-carbon gases, hydrogen blends may flow in some interconnection points in Europe in the near future.

Cross-border flows have to fulfil interconnection agreements, contracts that usually include gas quality requirements agreed by the parties involved.

In the event of discrepancies in Gas quality parameters at IPs, Article 21 of the new Regulation (EU) 2024/1789 establishes a procedure for adjacent TSOs to avoid restrictions to cross-border flows. While a similar article already exists in the Interoperability and Data exchange Network Code, Article 15 of (EU) 2015/703, additional measures have been introduced in the new Regulation.

For instance, in the case of H_2 blends, Art. 21 of the new Regulation applies to hydrogen content blended into the NG system only up to 2 $\%_{vol}$. Recital 74 of the same regulation clarifies that adjacent TSOs should remain free to agree on higher or lower hydrogen blending levels for cross-border interconnection points.

In some MSs, the natural gas system is already suitable for handling H_2 blends up to 2 $\%_{vol}$. However, if H_2 blends are expected to flow at IPs, dedicated measurement tools need to be installed. In some countries as in Italy, Belgium and Hungary, the installation of the Gas Chromatographs suitable for H_2 measures is in the preparation stage.

Situations of discrepancies on gas quality requirements at IPs are usually managed by the concerned TSOs through bilateral agreements which demonstrate the good cooperation between TSOs.

However, in some particular circumstances, like for MSs that share their borders with many other countries with distinct gas quality requirements, like Hungary, the challenge of reaching agreements with neighbouring counterparts is higher.

In this report, some examples of how discrepancies on gas quality requirements at IPs were settled are presented.

5.1 HANDLING OF ASYMMETRICAL OXYGEN REQUIREMENTS AT INTERCONNECTION POINTS IN DENMARK

Asymmetrical oxygen requirements in the Danish grid – especially at IPs – require an operational focus on monitoring and handling of oxygen in the grid. Energinet applies different strategies for handling oxygen levels at the three IPs towards Germany, Sweden, and Poland, respectively.

Historically, increased amounts of oxygen were introduced into the Danish transmission grid in 2016 with the first connection of a biomethane plant directly onto the grid. A relaxed requirement of 0.5 $\%_{mol}$ oxygen for biomethane injection was chosen to favor the growth of the biomethane industry while not causing any noticeable effect on gas quality for end-users. Meanwhile, the oxygen limit at the Danish-German border is only 0.001 $\%_{mol}$. To accommodate this requirement for exported gas amounts towards Germany, Energinet is currently utilizing the double piping in the southern part of Jutland towards the German border: assigning one pipeline for export only, while the other pipeline handles biomethane from direct injection or from reverse facilities and delivery of gas to Danish consumers in that area. Along with a reconfiguration of the compressor station at the central branching point of the Danish grid and considerations regarding placement and connection of future biomethane reverse facilities, this ensures that Danish and Norwegian North Sea natural gas, which enters Denmark on the southern west coast of Jutland with very low amounts of oxygen, can be exported directly towards Germany.

However, considering the potential of favoring hydrogen infrastructure by repurposing one of the pipelines towards Germany, this current operational solution would have to be reconsidered, either by removing oxygen catalytically at the border or by changing the oxygen specification.

With the commissioning of the Baltic Pipe connection in the fall of 2022, effectively connecting Norway and Poland through Denmark, Denmark has gained an additional neighboring country in Poland. The eastern part of Denmark therefore has gas flowing towards both Poland and Sweden. The Polish oxygen limit is 0.2 $\%_{mol}$ while the Swedish limit is 0.1 $\%_{mol}$, both rolling 24 h averages. Baltic Pipe is built as an integrated part of the Danish transmission grid, meaning that current biomethane amounts injected into the grid are heavily diluted by the North Sea gas, resulting in very limited amounts of oxygen in the exported gas towards both Sweden and Poland during normal operation. However, in the very rare event that the capacity in Baltic Pipe is significantly reduced due to reasons such as planned or unplanned maintenance, (i.e. minimal or no transit flow), the dilution of biomethane also decreases, and oxygen levels can be high. These situations can lead to pockets of biomethane, creating a minor risk of hindering the reestablishment or maintenance of export of gas eastwards. Through dialogue and collaboration, the Swedish TSO Nordion has agreed to raise its peak-level acceptance requirement for oxygen to 0.5 $\%_{mol}$. Additionally, Energinet is measuring oxygen levels using electrochemical sensors at all entry points into the Danish transmission grid, allowing for simulation of oxygen levels all over the grid and thus upstream of export points. This monitoring of oxygen levels in the grid provides Energinet with the operational possibilities of local dilution of potential biomethane pockets and/or, to some extent, operational management of flows in the grid to divert gas with levels of oxygen exceeding IP-limits away from export points. It should be emphasised, that the risk of oxygen levels exceeding 0.2 $\%_{mol}$ in the eastern part of the Danish transmission grid is practically non-existent given the current transit volumes in the Baltic Pipe, the oxygen levels in Danish-produced biomethane, and the grid-placement of reverse flow facilities.

5.2 MANAGEMENT OF ODORISED GAS FLOWS FROM FRANCE TO GERMANY

In France, natural gas is already enriched with an odorant in the transmission network, while in Germany, this only happens at the level of local distribution networks.

In France, THT (tetrahydrothiophene) is used as the odorant and the following limits apply there:

- Minimum: 15 mg/m^3 THT (equivalent to 5.5 mg/m^3 sulfur from THT)
- Usual concentration: 25 mg/m^3 THT (equivalent to 9.1 mg/m^3 sulfur from THT)
- Maximum: 40 mg/m^3 THT (equivalent to 14.5 mg/m^3 sulfur from THT)

Due to the crisis-induced changes in flow scenarios since 2022 (reduction of Russian natural gas and the maximisation of western entries), importing gas to Germany through the Interconnection Point Medelsheim between France and Germany is another means of diversifying gas import routes. Medelsheim is particularly important for the challenging supply of exits in southern Germany from a network-related perspective.

To ensure the compliance with the natural gas specifications in accordance with the provisions of the German DVGW Code of Practice G 260, the gas coming from France would require treatment to reduce the concentration of the odorant, for example, with a deodorisation plant.

The BNetzA provision "VOLKER" in Germany on volatile costs[19] for various aspects of natural gas transport enables, among other things, the transport of odorised gas from France to Germany, as any claims for damages resulting from the acceptance of gas that does not comply with the provisions of the German DVGW worksheet G 260 might be recognised as volatile costs. Since October 2022, this provision made import of odorised gas from France via Medelsheim, under specific conditions (e.g. publication requirements), possible without increased risk of compensation claims for the TSO, thereby making a valuable contribution to the security of supply. The BNetzA has extended the "VOLKER" provision beyond March 31, 2024, until September 30, 2026.

To note that in Germany, to date, no issues have been reported caused by the flow of odorised gas from France.

19 Volatile cost components are specific costs recognised as subject to fluctuation under the incentive regulation framework for network operators in Germany.

Picture courtesy of Teréga

6 NEW **TRANSPARENCY REQUIREMENTS ON GAS QUALITY**

The new Gas and Hydrogen Package, Regulation (EU) 2024/1789, introduces new Transparency obligations related to Gas Quality. Annex I of the Regulation states that measurements of Wobbe Index, Gross Calorific Value, Methane, Hydrogen and Oxygen content shall be published by TSOs on a daily basis for all relevant points.

Values of WI, GCV, H_2, O_2 and CH_4 content shall be published:

- at all relevant points, whose definition hasn't changed compared to the previous Regulation
- on the internet, in a format accessible to the public, free of charge and without any need to register
- on a daily basis

It's worth mentioning that Regulation (EC) No 715/2009 already requests TSOs to publish WI or GCV on a daily basis at all relevant points. And the new Regulation (EU) 2024/1789 requires H_2, CH_4 and O_2 measurements to be published on the TP and TSOs websites.

For TSOs to be able to publish these new measured values, projects have to be developed which represents a challenge that TSOs are committed to complete as possible.

Indeed, to be able to measure, store and publish values of the gas quality parameters, TSOs may need to have commissioned equipment that allows the analysis of gas and the measurement of the gas quality parameters in their networks. Equipment that fulfils these requirements need (after dialogue and agreement with relevant authorities and the development of the projects) to be procured, certified, installed, connected to the communications system of the TSO, tested and commissioned to finally be put to work.

Additionally, TSOs will need to prepare their communications and alarm systems, data warehouses, databases, etc. (including integration of the relevant parameters in TSO' systems – SCADA, commercial, etc.) to be ready to receive these new parameters, process it and transmit it to relevant stakeholders, including TP.

Although TSOs are experienced in making the necessary developments to fulfil the obligations of their activities, these projects should follow all necessary steps carefully and these processes can take from several months to years to complete.

It should be considered that some of the relevant points are cross-border points. In some cases, the measurement of the parameters for a cross-border point happens only at one side of the border. The data exchange between the adjacent TSOs is defined in the Interconnection agreements and if any of the new parameters (O_2, H_2, CH_4) are not included in the agreed set of data to be exchanged, this would require revision of the existing Interconnection agreement. The process for amendment of an Interconnection Agreement is a complex task and if the cross-border point is connecting the transmission system of a MS and Non-MS, the revision of an Interconnection Agreement could be even more complex.

It is thus important to notice that the compliance of these requirements should take a step-by-step approach starting with the application of the parameters at the points where those parameters can already be measured. Additionally, specificities of each TSO should be considered and a common approach for the roll out of the application of the obligations should not be taken. As such, the compliance by the application date indicated in Article 89 of the Regulation (EU) 2024/1789 may not be able to be realised by many TSOs. Exchange of information in this regard between the TSOs and NRAs is key to managing expectations on the possible delivery date of these new obligations.

CONCLUSIONS

The Gas Quality Monitoring report highlights that many developments are currently underway in the field of Gas Quality. In addition to the publication of the new Gas and Hydrogen Package in July 2024, numerous activities are ongoing across Europe, both at standardisation level in CEN and in technical WGs of various European associations.

At the time of drafting this report, a significant development worth noting is the revision of the European standard for H-gas quality, EN 16726, which introduces two new parameters: Wobbe Index and Hydrogen content.

The standard is expected to be submitted for approval in 2025. In case of standard approval, additional developments are expected, particularly regarding the implementation of the new processes introduced in the revised standard. For instance, concerning the implementation of the Wobbe Index classification system at exit points, further guidance through EU guidelines will be key in the application of the standard at Member States level.

Regarding biomethane, ongoing projects are investigating the impact of specific impurities on sensitive installations. Preliminary results indicate potential effects on some of these installations. However, no specific health impacts related to biomethane have been identified.

Developments on hydrogen blends are also addressed in the report. The information collected indicates that the acceptance of H_2 in the natural gas grid across Europe is not uniform, with varying thresholds established in different MSs. In some countries, blends are not yet allowed, however in most cases, developments are on-going to allow or increase the H_2 acceptance into the natural gas grid.

A few projects involving the injection of H_2 and H_2 blends in TSO system have been reported. In most cases, the H_2 concentration expected in the grid following injection is relatively low.

Additionally, results of recent research on odorisation of blends have been presented. Studies carried out by EU associations show that the odorisation of H_2 blends based on traditional odorants do not constitute an issue, especially if the H_2 concentration remains below 20 %.

Gas Quality is of primary importance for ensuring unhindered cross border flows of gas in Europe between MSs. Examples of how different gas quality requirements at IPs are managed are reported in this document. Most cases highlight that bilateral cooperation among TSOs was essential to manage such situations and keep unhindered gas flows throughout Europe even in difficult circumstances such as after the Russian war in Ukraine.

In this context, it's worth mentioning Article 21 of the new Regulation which establishes a process for solving cross-border issues at IPs due to differences in gas quality.

The new Regulation also introduces additional transparency obligations regarding the publication of Gas Quality information. Specifically, new parameters such as hydrogen, oxygen and methane content have been added to the list of TRA publications required for TSOs, alongside Wobbe Index and Gross Calorific Value. The report highlights the challenges that TSOs may face in implementing these new obligations.

LIST OF **ABBREVIATIONS**

CB	Cross Border
CEN	European Committee for Standardisation
CH_4	Methane
CNG	Compressed Natural Gas
DSO	Distribution System Operator
GERG	European Gas Research Group
EASEE-gas	European Association for the Streamlining of Energy Exchange – gas
ENTSOG	European Network of Transmission System Operators for Gas
EU	European Union
GCV	Gross Calorific Value
GRIP	Gas Regional Investment Plan
GQO	Gas Quality Outlook
H_2	Hydrogen
H-gas	High calorific gas
IA	Interconnection Agreement
INT NC	Interoperability and Data Exchange Network Code
IP	Interconnection Point
ISO	International Organisation for Standardisation
LNG	Liquefied Natural Gas
Mol.	Molar
MS	Member State
NG	Natural Gas
NRA	National Regulatory Authority
NSB	National Standardisation Body
O_2	Oxygen
P2G	Power-to-Gas
TC	Technical Committee
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
UGS	Underground storage
Vol.	Volume
WG	Working Group
WI	Wobbe Index

COUNTRY CODES (ISO)

AL	Albania
AT	Austria
AZ	Azerbaijan
BA	Bosnia and Herzegovina
BE	Belgium
BG	Bulgaria
BY	Belarus
CH	Switzerland
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
DZ	Algeria
EE	Estonia
ES	Spain
FI	Finland
FR	France
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
LY	Libya
MA	Morocco
MD	Moldova
ME	Montenegro
MK	Macedonia
MT	Malta
NL	Netherlands
NO	Norway
PL	Poland
PT	Portugal
RO	Romania
RS	Serbia
RU	Russia
SE	Sweden
SI	Slovenia
SK	Slovakia
TM	Turkmenistan
TN	Tunisia
TR	Turkey
UA	Ukraine
UK	United Kingdom

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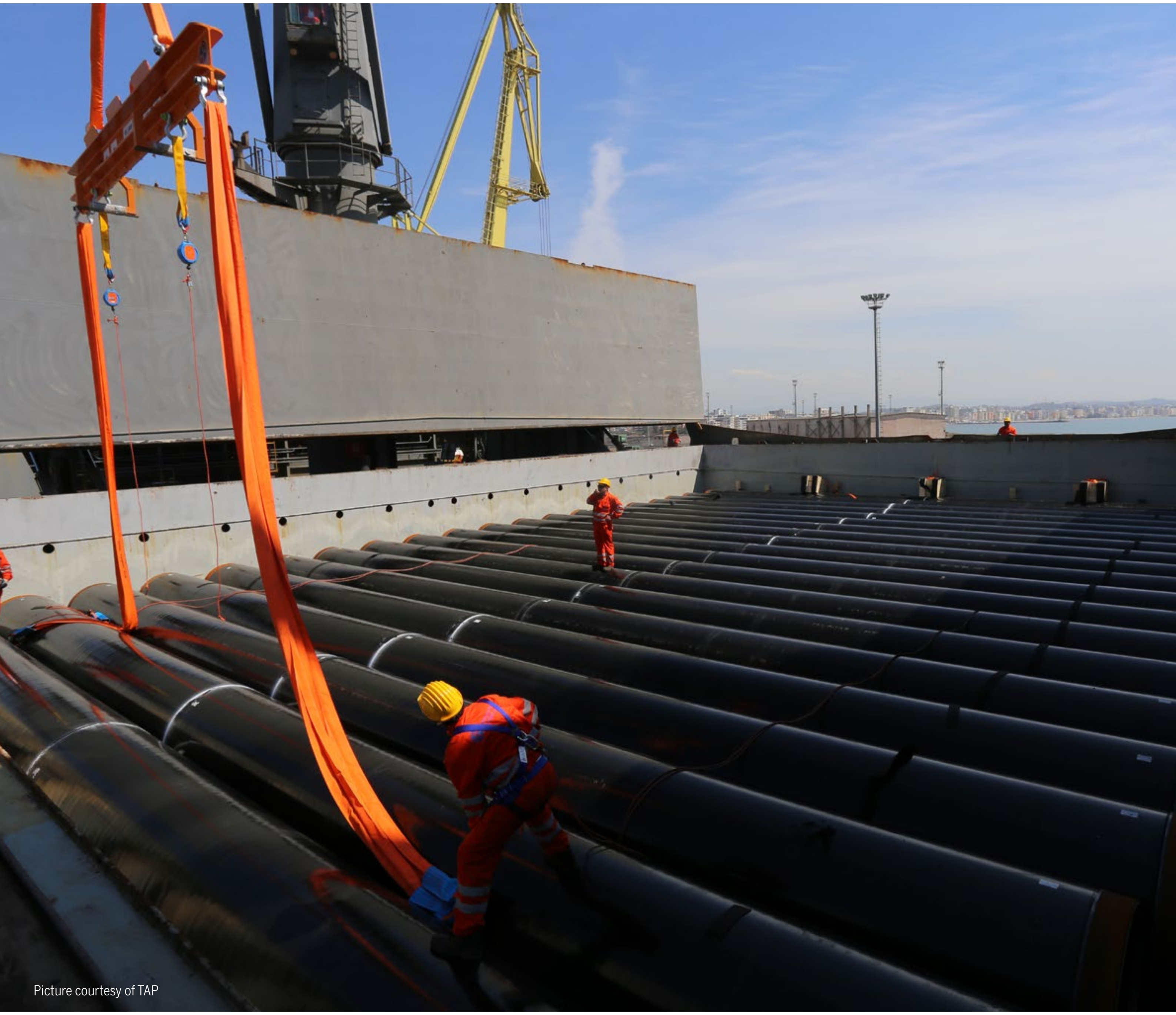

Picture courtesy of TAP

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entsog

european network
of transmission system operators
for gas

ENTSOG AISBL
Avenue de Cortenbergh 100 | 1000 Brussels, Belgium
Tel. +32 2 894 51 00

info@entsog.eu | www.entsog.eu