
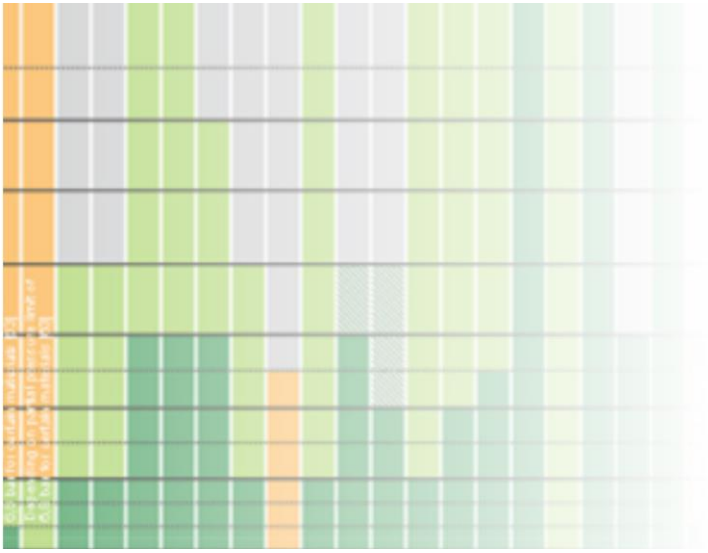

marcogaz

# Overview of available test results* and regulatory limits for hydrogen admission into existing natural gas infrastructure and end use

## Infographic

## Version 2023

*According to the list of references.

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# ABOUT MARCOGAZ

Founded in 1968, MARCOGAZ represents 29 member organisations from 20 countries. Its mission encompasses monitoring and policy advisory activities related to the European technical regulation, standardisation and certification with respect to safety and integrity of gas systems and equipment, rational use of energy as well as environment, health and safety issues. It is registered in Brussels under number BE0877 785 464.

# DISCLAIMER

# ACKNOWLEGDEMENTS

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## OVERVIEW OF AVAILABLE TEST RESULTS* AND REGULATORY LIMITS FOR HYDROGEN ADMISSION INTO THE EXISTING NATURAL GAS INFRASTRUCTURE AND END USE

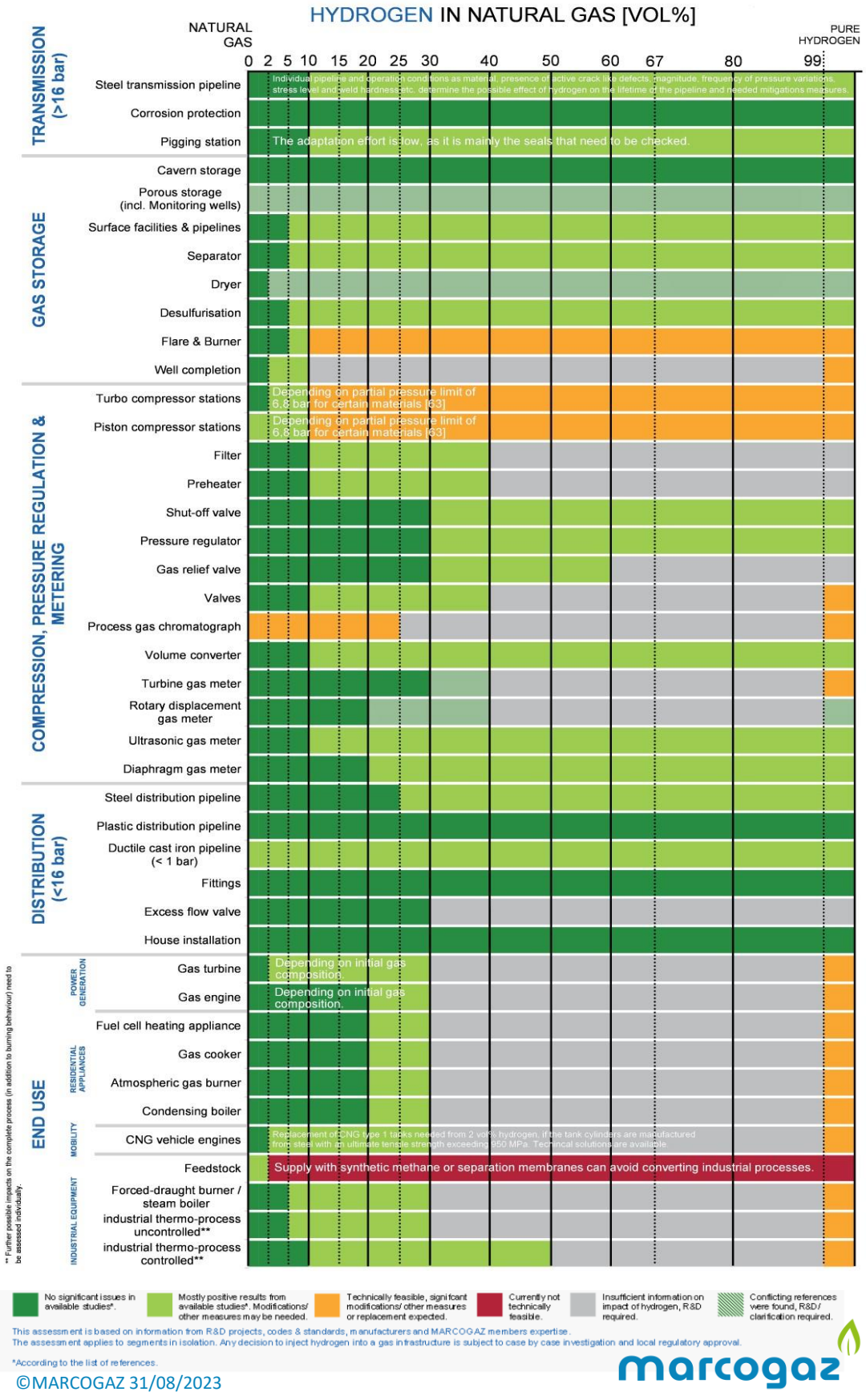


*Figure 1: Overview of available test results and regulatory limits for hydrogen admission into the existing natural gas infrastructure and end use. Version 2023.*

# 1. BACKGROUND AND THE PURPOSE OF INFOGRAPHIC

In October 2019, MARCOGAZ published its first version of the infographic (see Annex I) to provide an overview of the technical readiness of the gas infrastructure and end-use equipment to handle hydrogen-natural gas ($H_2$-NG) mixtures at each stage of the gas midstream and downstream value chain. Since the properties of mixtures of $H_2$-NG are different from those of pure hydrogen ($H_2$) or natural gas (NG), questions arose about the suitability of the existing natural gas infrastructure and end uses equipment for utilizing such mixtures.

Following the release of the first version of the infographic, $H_2$-NG mixtures (up to 30 vol.-% $H_2$) and pure $H_2$ have received more attention and research on this topic has increased both in the gas industry and academia. Therefore, MARCOGAZ has been following the $H_2$ development trends and revised the infographic with the current state of knowledge of NG transmission and distribution systems, including underground storage, gas pressure regulation and metering and end use, drawing on the wide expertise and experience of operators and experts.

The level of knowledge and available sources on $H_2$ tolerance may vary by infrastructure sector. In rare cases, this leads to differences in the listed $H_2$ tolerances for assets represented in different areas of the gas infrastructure. The infographic takes this into account as best as possible.

The infographic aims to:

- Provide an overview of the technical readiness of the gas infrastructure and end uses equipment to handle $H_2$-NG mixtures at each stage of the gas midstream and downstream value chain. The infographic currently focuses on material aspects and functional principles. It does not consider the effect of increasing levels of $H_2$ on performance, efficiency and output.

- Identify gaps in knowledge and areas where R&D is required to remove barriers that limit $H_2$ uptake in the supply chain and enable new applications for $H_2$ and $H_2$-NG mixtures.

- Collect and assess the most up-to-date knowledge on the use of $H_2$ and $H_2$-NG mixtures based on evidence and experience from gas network and storage operators and end use experts.

- Collect and appraise the current state of knowledge of transmission, storage, distribution and end-use of $H_2$-NG mixtures and $H_2$, drawing on the wide expertise and experience of network operators, storage operators and end use experts.

- Assist with the investigation into the opportunities with the existing gas infrastructure to achieve the best benefits and contribute to reaching climate goals.

# 2. SUMMARY

MARCOGAZ members with experience in operating gas infrastructure or involved in pertinent R&D activities have reviewed over 80 references on the $H_2$ tolerance of the existing gas infrastructure and end use applications and collected extensive data from the industry. In general, based on the throughout assessment conducted, it can be presumed that major elements of the gas infrastructure and end use equipment are expected to be able to handle $H_2$-NG mixtures in the range of 0-10 vol.-% $H_2$ without modifications[1]. With measures and replacement, most elements of the gas infrastructure and end use are expected to be able to accept concentrations of up to 30 vol.-% $H_2$. No conclusions could be drawn for the $H_2$-NG mixtures in the range between (but excluding) 30-100 vol.-% $H_2$ given that this was out of the scope of the study.

The main outcomes per infrastructure category are given below:

**Transmission (> 16 bar):**

- The main elements in the transmission infrastructure are expected to be able to accept $H_2$-NG mixtures in the range of 0-10 vol.-% $H_2$ without modification. With modification, concentrations up to pure $H_2$ are expected to be accepted.
- Individual pipeline and operation conditions determine the specific mitigation measure for steel pipelines to accept more than 10 vol.-% $H_2$ concentrations in a $H_2$-NG mixture.
- Some networks and residential appliances are already being operated with $H_2$-NG mixtures in the range of 0-20 vol.-% $H_2$ [62].

**Storage:**

- Major elements in the gas storage infrastructure are able to handle $H_2$-NG mixtures in the range of 0-5 vol.-% $H_2$ without modifications. With modification, most gas storage components are able to handle concentrations up to pure $H_2$.
- Above 10 vol.-% $H_2$, flare & burner components need significant modifications or replacement. Suitability of higher concentrations will require further R&D to determine the readiness when complete information is gathered.
- Porous gas storage and dryer installations require more R&D to clarify their suitability for $H_2$ mixtures.

**Compression, Pressure Regulation and Metering:**

- Most elements of compression, pressure regulation and metering are able to handle $H_2$-NG mixtures in the range of 0-10 vol.-% $H_2$ without mitigation measures.
- Turbo and Piston compressors are a limiting factor and are able to reach 10 vol.-% $H_2$ in $H_2$-NG mixtures with minor modifications. With higher concentration, signification mitigation measures or replacement are expected, depending on the partial pressure limit of certain materials.
- Process gas chromatographs are unlikely expected to be able to handle any $H_2$ mixtures. Nonetheless, with significant modifications, $H_2$-NG mixtures in the range of 0-25 vol.-% $H_2$ can be reached.

[1] Modifications refer to the relevant changes mentioned in the studies listed in the References accordingly.

### Distribution (<16 bar):

- Major elements in the gas distribution infrastructure are able to handle $H_2$-NG mixtures in the range of 0-30 vol.-% $H_2$.
- With modifications, almost all components are expected to be able to handle $H_2$-NG mixture in the range of 0-100 vol.-% $H_2$. More R&D should be done on the readiness of excess flow valves with higher concentrations.

### End Use Equipment:

- Residential appliances are expected to be able to handle $H_2$-NG mixtures in the range of 0-20 vol.-% $H_2$ without any modification and are expected to reach 30 vol.-% $H_2$ acceptance with minor modifications.
- Many industrial processes (except feedstock) are expected to be able to handle $H_2$-NG mixtures in the range of 0-5 vol.-% $H_2$ without modification.
- Current power plant gas turbines, industries using natural gas as feedstock and also CNG steel tanks are assessed to be sensitive to even small quantities of $H_2$ and need further R&D/mitigation measures when planning to convey higher $H_2$ concentrations.
- Higher concentrations (> 30 vol.-% $H_2$ ) for end use equipment requires R&D and can possibly be reached by mitigation measures or replacement.

# 3. MAIN UPDATES TO THE INFOGRAPHIC

The large number of new experiences and research results within the last few years make it necessary to update the infographic. Therefore, new components have been added and, information on existing components has been updated.

## 3.1 The following components were ***added*** to the infographic:

**For compressor stations:**

- The original compressor component was divided into two types: turbo compressor stations and piston compressor stations. The assessment was carried out based on the References "Consequences of $H_2$ in NG infrastructure" of CEN/TC 234 [65] and "Conversion of compression station for $H_2$ – Cost study" of MARCOGAZ [66].

**For underground gas storage:**

- The valves, piping and pipelines on the surface facility of an underground gas storage were grouped together as the "Surface facilities and pipelines" component [67-72].
- Desulphurisation for gas treatment after underground gas storage withdrawal was included [67-72].
- In addition, the combustion of gases in connection with underground gas storage facilities is summarised in the two components "Flare & Burner" [67-72].

## 3.2 The following components were significantly ***updated***:

- **Pigging station:** In analogy to the (pipeline) steels typically used, it can be assumed that the material is suitable for $H_2$. From $H_2$-NG mixtures of 10 vol.-% $H_2$, only the seals must be tested for suitability and adapted if necessary.
- **Shut off valve and gas relief valve:** These are suitable for $H_2$-NG mixtures in the range of 0-30 vol.-% $H_2$. The basic physical principle for activating the valves remains unchanged. In addition, standard natural gas components were installed in a pressure station as part of the "H2-Netz" project [73] and as part of a DBI project [74] for industrial thermoprocessing plants and operated with 100 vol.-% $H_2$ . The long-term tests have so far resulted in no functional restrictions as well as effects on seals.
- **Volume converter:** For $H_2$ admixtures greater than 10 vol.-% $H_2$, it must be examined whether a changeover to one of the two calculation methods (SGERG-mod-H2 or AGA8-92DC) can be made. These are applicable for all $H_2$ contents in NG according to DVGW G 685-6 "Gasbilling – Natural Gas Compressibility Factor" [75]. According to ISO 20765-2, the equation of state GERG-2008 can be used up to 40 vol.-% hydrogen [76].

- **Turbine and ultrasonic gas meter:** According to the results of the project DNV JIP "Suitability of Flow Meters for Renewable Gases" [77], flowmeters normally used in transmission grids (turbine and ultrasonic gas meters) can be operated with $H_2$-NG mixtures in the range of 0-30 vol.-% $H_2$ with an uncertainty in the measurement inside the requirement of the reference normative (OIML).
    - Although the JIP test results show measurement errors inside the acceptable range defined by standards for 30 vol.-% $H_2$ for ultrasonic meters, the bias in some specific meter types could be significant for fiscal measurement purposes carried out on large metering stations, for which high quality (very low uncertainty) measurement is required. For this reason, some manufacturers ask their costumers to contact them before using existing gas meters for applications with $H_2$-NG mixtures above 10 vol.-% $H_2$. Nonetheless, some new gas meters have already obtained their metrological certification for applications with $H_2$-NG mixtures in the range of 0-30 vol.-% $H_2$.
- **Diaphragm gas meter:** In the DVGW research project G 202010 "H2 measurement accuracy" [78], the measurement deviations of bellows gas meters with different gases (methane, 20, 30 and 100 vol.-% $H_2$) were investigated. A suitability for all gases could be proven. A custody transfer measurement is not yet possible due to the lack of a separate approval for $H_2$ contents in $H_2$-NG mixtures greater than 20 vol.-% $H_2$. The suitability for concentrations up to 20 vol.-% H2 has also been proven by further investigations [79].
- **Ductile cast iron:** In a $H_2$ project from Sedigas [80], ductile iron pipes were tested for their suitability for hydrogen. For this purpose, pipes were examined that had already been operated with town gas and those that had only been operated with NG. The latter were also exposed to different hydrogen concentrations (up to 100 vol.-% $H_2$). The mechanical parameters were all compliant with manufacturing standard (UNE-EN 969) and the brittle fracture surfaces also showed no abnormalities.
- **Fittings and house installation:** For house installation, it is assumed that all common materials are suitable. In addition, leak tests on the fittings have not revealed any abnormalities with $H_2$-NG mixtures up to 100 vol.-% $H_2$. The evidence was provided in the DVGW research project G 201615 "Influence of hydrogen components in natural gas on gas installation components" [81].
- **Gas engine, fuel cell heating appliance, gas cooker, atmospheric burner, condensing boiler:** According to the THyGA project [82], operation with $H_2$-NG mixtures in the range of 0-20 vol.-% $H_2$ is possible for these end use applications. Even $H_2$-NG mixtures up to 30 vol.-% $H_2$ can be ensured through minor adjustments.
- **Forced-draught burner /steam boiler, industrial thermo-process uncontrolled:** Through individual assessment and, if necessary, some adjustments, $H_2$-NG mixtures in the range up to 30 vol.-% $H_2$ suitability can be ensured [82].
- **Industrial thermo-process controlled:** There is suitability of operating $H_2$-NG mixtures in the range of 0-10 vol.-% $H_2$ [82].

# 4. NEXT STEPS

- To enable $H_2$ concentrations of 10 vol.-% $H_2$ in $H_2$-NG mixtures, R&D is recommended to understand the effect on compressor stations, gas turbines, process equipment in the chemical industry using NG feedstock and steel tanks for CNG vehicles.

- To exceed $H_2$ concentrations of 10 vol.-% $H_2$ in $H_2$-NG mixtures in addition to the topics mentioned before, special R&D focus is required on underground gas storage (including well completion, flare and burner equipment, dryer installations and the suitability of porous rock structures). Furthermore, compressor stations, metering devices and industrial gas use need to be addressed in more detail.

- R&D for residential appliances is especially recommended for $H_2$-NG mixtures with concentrations above 30 vol.-% $H_2$ as well as to understand the impact of varying $H_2$ concentrations in general. A few cases are expected where R&D will be recommended for $H_2$ concentrations as from above 20 vol.-% $H_2$.

- For pure $H_2$ usage (100 vol.-% $H_2$), research should focus on the readiness and mitigation measure for underground gas storage, compression, pressure regulation and measuring devices, and end use equipment.

- Further focus should be put on the development of retrofit solutions for existing installed appliances to allow them to handle $H_2$-NG mixture.

- Mitigation technologies, such as membranes and methanation, used to reduce the vol.-% $H_2$ concentration in gas grids exist. They are considered to be very important to protect sensitive equipment and processes and can be installed beforehand. Where required, further R&D[2] may be recommended.

[2] R&D does not mean that the equipment is not suitable for use with $H_2$-NG mixtures or that no modification measures are currently available. Rather, it reflects the need for innovation to develop new opportunities with the aim of obtaining the maximum benefit from the existing infrastructure.

# 5. ADDITIONAL REMARKS

- Equipment in the gas infrastructure, underground gas storages and end use are diverse and have different life/usage times. Nevertheless, all equipment needs to be renewed at the end of its useful economic life. This is a continuous process that naturally offers the opportunity to install optimised and more future-proof equipment. Hence, renewal cycles should be used to increase the tolerance of the gas infrastructure and end uses to higher $H_2$ concentrations.

- For many currently installed end use applications, the presence of $H_2$ in NG remains a relatively new topic. Given the wide variety of end uses across all sectors (residential, commercial, industry, power generation and mobility), R&D activities are required to investigate the impact of higher levels of $H_2$ and to develop technology solutions for "$H_2$ readiness". The aim is to maintain highest levels of performance in terms of efficiency, fitness for purpose, flexibility and low-pollutant emissions that these appliances and applications have achieved over the last decades.

- Sensitive end use equipment could require the use of digital reproduction systems, local gas quality measurement and appropriate control technology.

- As part of the Fit-for-55 package from the European Commission (EC) to reduce the use of fossil fuels, the EC has revised the Gas Package and proposed the acceptance of $H_2$ blends into natural gas networks at international connection points in the regulation *on the internal markets for renewable and natural gases and for hydrogen* [83].

# ANNEX I: H2-INFOGRAPHIC 2019 VERSION

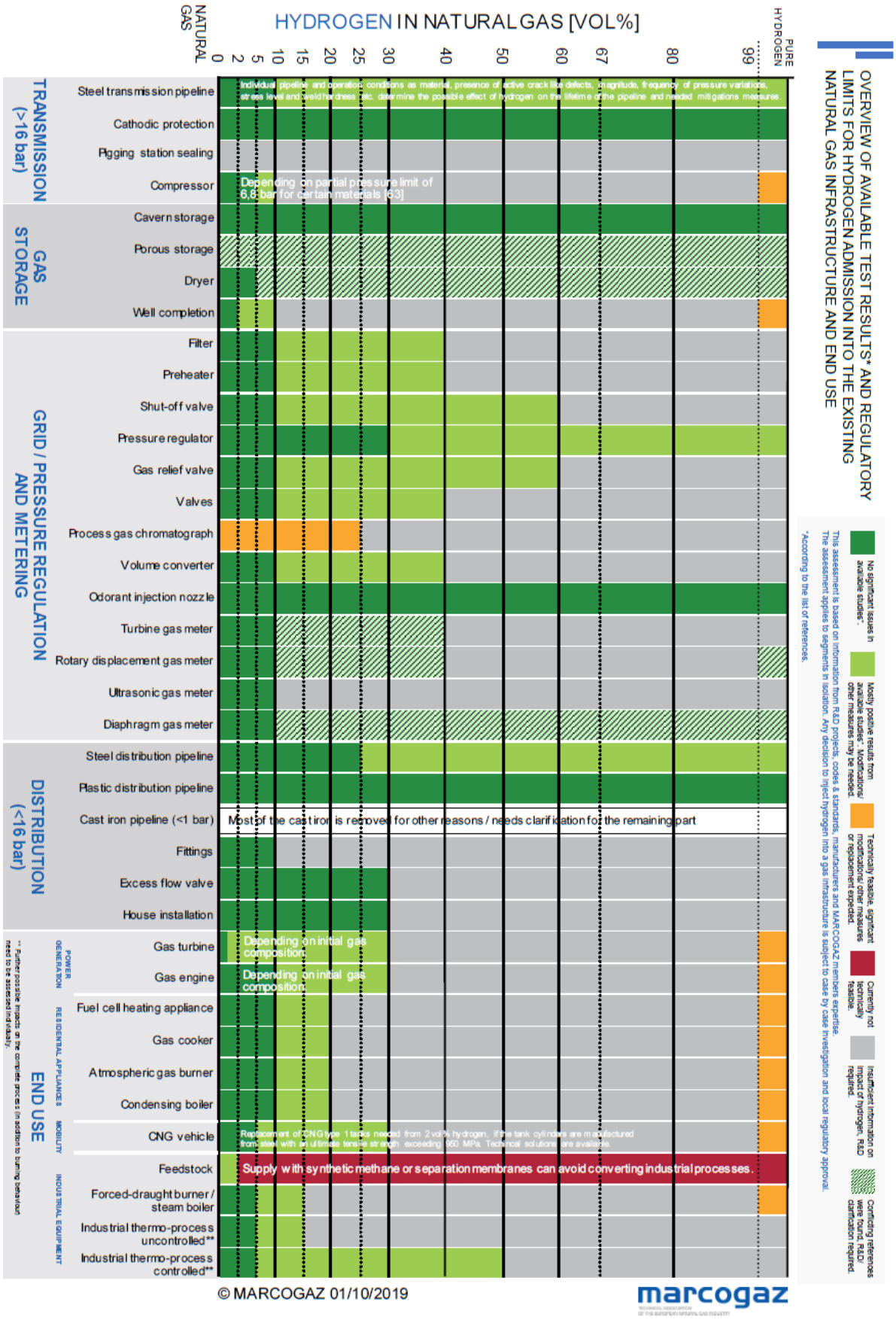


*Figure 2: Overview of available test results and regulatory limits for hydrogen admission into the existing natural gas infrastructure and end use. Version 2019.*

# 6. REFERENCES

This assessment is based on public and non-public information R&D projects, Codes & Standards as well as manufacturer and MARCOGAZ member expertise.


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