NOVEL METHODS OF TESTING FOR MEASUREMENT OF NATURAL GAS AND HYDROGEN MIXTURES

D2.1

Roadmap of the potential measuring devices to be tested by the consortium

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Clean Hydrogen Partnership

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TECHNICAL REFERENCES

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VERSIONS

Revision Version	Date	Changes	Changes made by Partner
0	30/04/2024	First release	Enagás, CESAME, FBK, GAZ-SYSTEM, GRTgaz, INRETE, INRIM, METAS, Snam, UNIBO

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TERMINOLOGY

Class 1,0 meter: Meter which has an error of indication between -2 % and +2 % for flow rates Q where $Q_{min} \leq Q < Q_t$, between -1 % and +1 % for flow rates Q where $Q_t \leq Q \leq Q_{max}$ and when the errors between Q_t and Q_{max} have the same sign and they do not exceed 0,5 %.

Class 1,5 meter: Meter which has an Maximum Permissible Error (MPE) of ±3 % for $Q_{min} \leq Q < Q_t$ and ±1.5 % for $Q_t \leq Q \leq Q_{max}$.

DN: The nominal diameter (DN) is a conventional value with which hydraulic components such as pipes, flanges and valves are identified.

Error (E): Expressed as a percentage, it results from the measured value minus the reference value divided by the latter value.

G: It indicates the size of the gas meters. It indicates the nominal gas flow rate through the meter in SCMH (standard cubic meters per hour). Discrete values for G exist and differ for the minimum, the maximum and transitional volumetric flow rate.

Linearity: it is the ability of the meter to respond to changes in a measured variable in the same way across the full range.

Maximum flow rate (Q_{max}): The maximum flowrate is the highest flowrate at which the gas meter provides indications that satisfy the requirements regarding the MPE.

Minimum flow rate (Q_{min}): The minimum flowrate is the smallest flowrate at which the gas meter provides indications that satisfy the requirements regarding the MPE.

PN: It represents the nominal pressure of the component, i.e., the maximum pressure (expressed in bar) to which the component withstands without failure.

Rangeability: The ratio between the minimum flowrate (Q_{min}) and the maximum flowrate (Q_{max}), for which the meter performs within the MPE.

Transitional flowrate (Q_t): The transitional flowrate is the flowrate occurring between the maximum and minimum flowrates at which the flowrate range is divided into two zones, the ‘upper zone’ and the ‘lower zone.

More terminology is found in the relevant technical standards cited in the document.

ACRONYMS AND SYMBOLS

Acronym/Symbol	Definition
AGA	American Gas Association
CEN	European Committee for Standardization
CF	Conversion Factor
CPU	Central Processing Unit
DN	Nominal Diameter
DSO	Distribution System Operator
E	Energy
EoS	Equation of State
G	Meter size
GERG	The European Gas Research Group
H2	Hydrogen
H2NG	Natural gas and hydrogen admixture
HV	Heating Value
HHV	High Heating Value
ISO	International Organization for Standardization
MPE	Maximum Permissible Error
NG	Natural gas
P	Pressure
P_{op}	Pressure at operating conditions
P_{ref}	Pressure at reference conditions
Q_{max}	Maximum flow rate
Q_{min}	Minimum flow rate
Q_t	Transitional flow rate
SAB	Stakeholder Advisory Board
SoS	Speed of Sound
T	Temperature
T_{op}	Temperature at operating conditions
T_{ref}	Temperature at reference conditions
TDLAS	Tunable Diode Laser Absorption Spectrometers
TSO	Transmission System Operator
V_{op}	Volume at operating/actual conditions
V_{ref}	Volume at reference conditions
WP	Work Package
Z	Compressibility factor
Z_{op}	Compressibility factor at operating conditions
Z_{ref}	Compressibility factor at reference conditions

The extended name of the THOTH2 partners is reported in the Deliverable D2.1 as indicated in Table 1.

Table 1. Partners' extended name, country and acronym.

Partner extended name (country)	Acronym
ENAGAS TRANSPORTE SA (SPAIN)	ENAGAS
CESAME-EXADEBIT SA (FRANCE)	CESAME
FONDAZIONE BRUNO KESSLER (ITALY)	FBK
OPERATOR GAZOCIAGOW PRZESYLOWYCH GAZ-SYSTEM SPOLKA AKCYJNA (POLAND)	GAZ-SYSTEM
GRTGAZ (FRANCE)	GRTGAZ
ISTITUTO NAZIONALE DI RICERCA METROLOGICA (ITALY)	INRIM
INRETE DISTRIBUZIONE ENERGIA S.P.A. (ITALY)	INRETE
EIDGENOSSISCHES INSTITUT FUR METROLOGIE METAS (SWITZERLAND)	METAS
SNAM S.P.A. (ITALY)	SNAM
ALMA MATER STUDIORUM - UNIVERSITA DI BOLOGNA (ITALY)	UNIBO

1. EXECUTIVE SUMMARY

In the framework of Work Package 2 'Methodology and test protocols', this deliverable describes the selection of measuring devices to be tested. THOTH2 project focuses on energy measurement in natural gas infrastructure, but also includes measuring devices for emissions detection in the gas grid.

The selection is based on the provided information of the measuring devices installed in the existing gas grids of the four TSOs (Enagás, GAZ-SYSTEM, GRTgaz and Snam) and one DSO (INRETE) participating in the project. As summary:

- Gas meters: 25 meters selected.
    - Transmission grid: 13 meters selected, including rotary pistons, turbine and ultrasonic types in the Q_{max} range from 160 to 8,000 m^3/h.
    - Distribution grid: 12 meters selected, including diaphragm, thermal mass and ultrasonic types in the Q_{max} range from 6 to 100 m^3/h.
- Pressure transducers: 6 transducers selected, including piezoresistive and resonant technologies.
    - Quality analysers: 6 water dew point analysers selected, including aluminium oxide sensor, ceramic metal oxide moisture sensor and TDLAS technologies.
- Flow computers:
    - 2 methods selected for compressibility factor calculation (AGA8 and SGERG-88).
    - 1 model selected for testing with EU-type examination certificate for AGA8 and SGERG-88, and a method valid for pure hydrogen.
- Leak detectors: 10 detectors selected, including catalytic, infrared, semiconductor, thermal conductivity and electrochemical technologies.

Contact with manufacturers shall be initiated to request their collaboration in the project by providing the selected measuring devices. In just in a few cases, partners are able to provide selected measuring devices.

Technical specifications for each device, such as materials, operating range, nominal pressure, etc., will be established according to the availability of existing ones in the consortium or the capabilities of manufacturers for providing them.

2. INTRODUCTION

In the framework of Work Package 2 'Methodology and test protocols', this deliverable collects the selection of each measuring devices. THOTH2 project focuses on energy measurement in natural gas infrastructure, but also includes measuring devices for emissions detection in the gas grid.

For energy measurement based on volume measurement following devices are necessary (Figure 1):

- Gas meter. Measurement of volume in actual conditions.
- Pressure transmitter. Measurement of operating pressure.
- Temperature transmitter. Measurement of operating temperature. This device is not tested in the project as is installed inside a thermowell and therefore is not in contact with the gas, therefore not subject to the potential impact of hydrogen on instrument integrity and measurement performance.
- Quality analyser. Analysis of gas composition for heating value determination. Additionally, gas grids include specific devices for water dew point analysis, hydrocarbon dew point analysis and sulphur compounds analysis.
- Flow computer. Calculation of operating compressibility factor (Z), conversion factor, volume in reference conditions and energy.

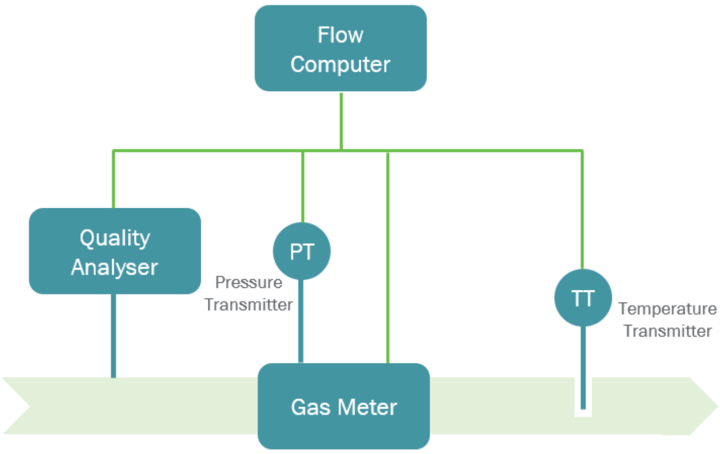

Figure 1. Scheme for energy measurement based on volume measurement.

Energy is calculated with Equation 1:

Equation 1.

$$E = V_{ref} \cdot HHV$$

Where E is the energy, V_{ref} is the volume at reference conditions and HHV is the high heating value.

The volume at reference conditions is obtained with Equation 2:

Equation 2.

$$V_{ref} = V_{op} \cdot CF$$

Where:

- V_{op} is the volume at operating/actual conditions. V_{op} can include the correction of the gas meter error curve depending on calibration conditions.
- CF is the conversion factor refers to a multiplier used to convert measurements taken under one set of conditions (usually actual operating conditions) to another set of standardized conditions (often reference conditions). The conversion factor is calculated with Equation 3:

Equation 3.

$$CF = \left(\frac{P_{op}}{P_{ref}}\right) \cdot \left(\frac{T_{ref}}{T_{op}}\right) \cdot \left(\frac{Z_{ref}}{Z_{op}}\right)$$

Where:

- P_{op} and P_{ref} are the pressures at operating and reference conditions respectively.
- T_{op} and T_{ref} are the temperatures at operating and reference conditions respectively.
- Z_{op} and Z_{ref} are the compressibility factors at operating and reference conditions respectively.

In the case of mass measurement, no pressure and temperature transmitters are necessary.

This deliverable focuses on the selection of measuring devices while the overview of the measuring devices technologies and technical/normative gaps can be achieved in the following project Deliverables:

- D1.1 'SoA of measuring devices installed in NG transmission and distribution networks'.
- D1.2 'Barriers and gaps of SoA NG transmission and distribution measuring devices in H2NG flows'.
- D1.3 'Normative gaps towards H2NG gas grid'.

It has to be noted that D1.1 and D1.2 provide an overview based on the data provided by THOTH2 partners and manufacturers participating to the project Stakeholders Advisory Board. Furthermore, since different configurations and versions were indicated for each model during the data collection phase of the Task 1.1, these data were aggregated in different models reported in D1.1. Starting from this preparatory activity and on the inventory designed in Task 1.1, Task 2.1 investigated the measuring devices installed by detailing the models, whether possible based on available data, in terms of version and configuration in order to prioritize and select specific devices to be tested. Specifically, deliverable D2.2 'Testing protocols will be provided to WP3 as an input for testing' collects the results of Task 2.2, whose objective is the definition of test protocols to apply to the different categories of selected measuring devices. The selected measuring devices and defined test protocols are the inputs of Work Package 3 'Testing and validation'.

3. METHODOLOGY

This section describes the methodology considered for the selection of the measuring devices, separated into the following stages (Figure 2):

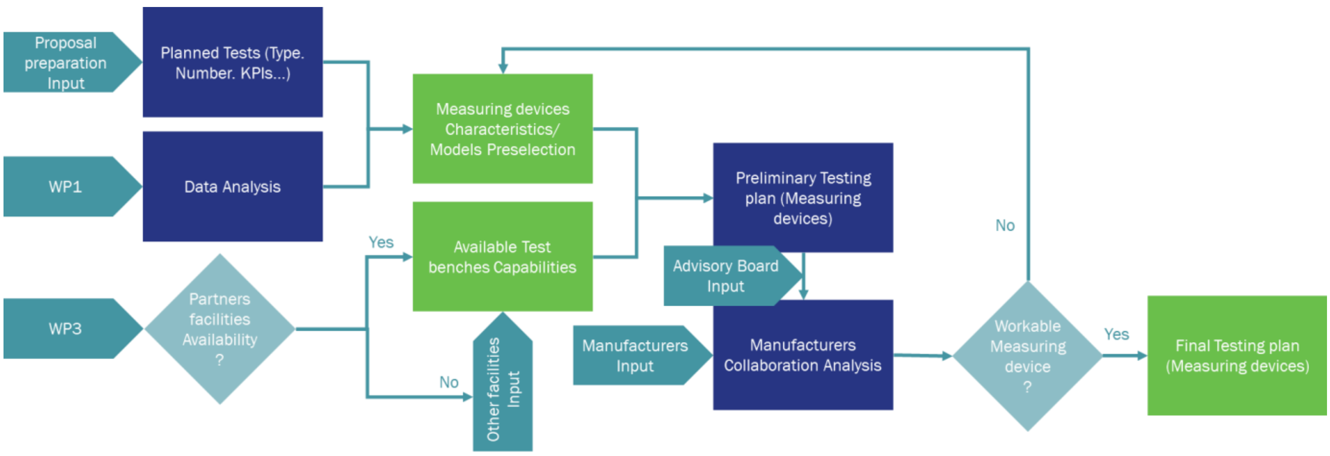

Figure 2. Methodology for the selection of the measuring devices.

- A preselection of measuring devices characteristics/models is defined according to planned tests during proposal preparation and input from Work Package 1 ‘SoA, Barriers and bias on metering devices for NG blend’.

  Input from proposal preparation established the resources of each partner in the consortium (availability of facilities, budget, and type and number of tests).

  The information on the measuring devices installed in the existing gas grids of the four TSOs (Enagás, GAZ-SYSTEM, GRTgaz and Snam) and DSO (INRETE) participating in the project is obtained from Work Package 1.

  For the selection of measuring devices in Work Package 2, an aggregation of the installation/use of the different models/version across the partners gas grids is performed. This aggregation is based on percentages assigning the same weight to each partner (For example, in the case of TSOs data, if 50 % of gas meters from a partner is a specific turbine model this model contributes with a weight of 12,5 % (50 % × 25 %, due to the participation of four TSOs) in the total figure).
- In a parallel stage, the current partners capabilities are evaluated under the scope of Work Package 3. If the consortium lacks the capability for a specific test, subcontracting is evaluated. Fortunately, the consortium has many capabilities for performing the planned tests.
- As a result of previous stages, a preliminary list of measuring devices to be tested is generated.

- The general characteristics of these measuring devices (number, technology and size in case of gas meters. Other data are initially unavailable for confidentiality reasons) are shared with the Stakeholder Advisory Board for its input during the second SAB meeting organised on the 16th of April 2024.
- Following, contact with manufacturers is initiated to request their collaboration in the project by providing the selected measuring devices. In just in a few cases, partners are able to provide selected measuring devices.
- If the selected measuring device is available from partners or manufacturers, the devices is included in the final list. In other cases, a new iteration in the corresponding category is necessary for a new model selection.

4. MEASURING DEVICES SELECTION

This section describes the selection agreed in the project consortium for each category. Technical specifications for each device, such as materials, operating range, nominal pressure, etc., will be established according to the availability of existing ones in the consortium or the capabilities of manufacturers for providing them.

4.1. GAS METERS

Gas meters used in natural gas volume measurement can be:

- Volumetric: They consist of a series of parts that move cyclically as a result of the pressure difference between the meter inlet and outlet. In each cycle, a specific volume of gas passes from the inlet to the outlet of the meter: Some examples are:
  - Diaphragm.
  - Rotary displacement.
- Non-volumetric: The volume or mass of gas is obtained indirectly from the determination of the instantaneous flow passing through a section of pipe. Some examples are:
  - Differential pressure (Orifice plates and Venturi).
  - Volumetric flow meters (Turbine and Ultrasonic).
  - Mass flow meters (Coriolis and Thermal mass)

For more details on the classification of different gas measuring devices and their characteristics, please also refer to deliverable D1.1.

4.1.1. TRANSMISSION GAS GRID

In the transmission gas grid under evaluation the representative gas meters are rotary displacement, turbine and ultrasonic:

- Rotary displacement: The measuring principle is based on the pistons rotation with the fluid circulation. Each rotation traps and transfers a specific volume of gas.

  The ranges, construction, performances, output characteristics and testing of rotary displacement gas meters for gas volume measurement are defined in Standard EN 12480 [1].

  Regarding the performed analysis and accordingly with the premises in the introduction, the main conclusions are:
  - 28 different models are installed in the evaluated gas grids with the distribution shown in Figure 3.
  - Typical size is mostly around G65 - G250 as represented in Figure 4.

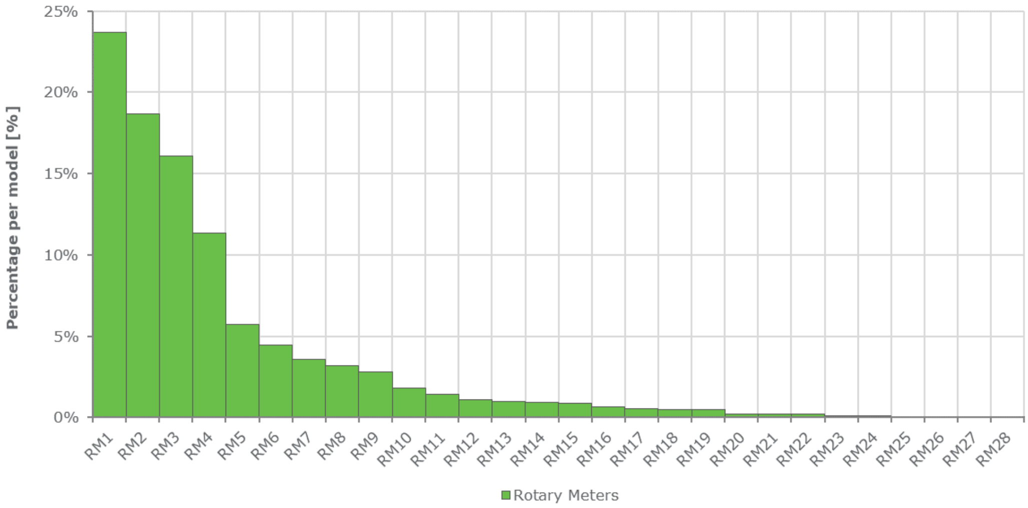

Figure 3. Representation of the rotary displacement gas meters (RM) models installed in the transmission gas grids of partners.

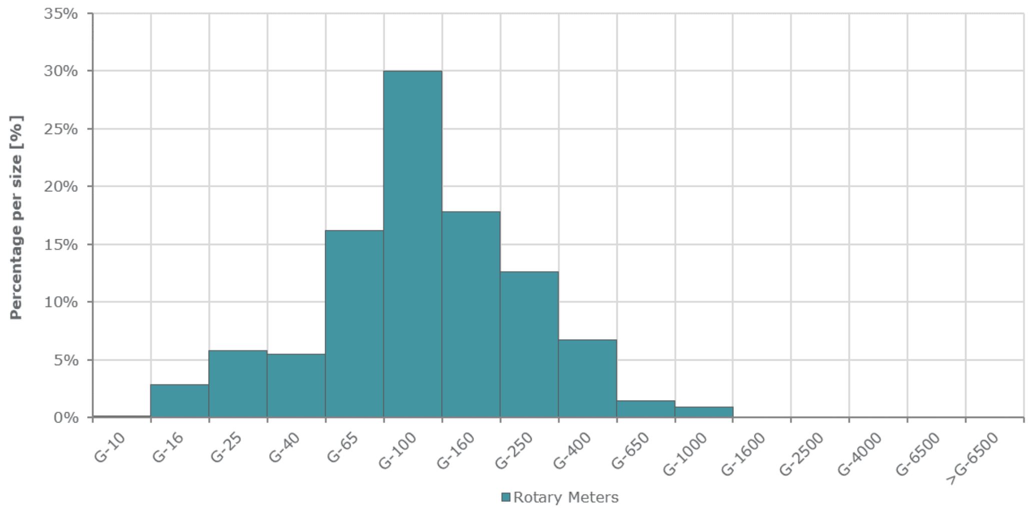

Figure 4. Representation of the size of rotary displacement gas meters (RM) installed in the transmission gas grids of partners.

- Turbine: The measuring principle is based on the rotation of a bladed rotor induced by fluid circulation. The rotor’s angular speed is proportional to the average axial speed of the gas and therefore to the volumetric flow.

  The measuring conditions, requirements and tests for the construction, performance and safety of class 1,0 axial and radial turbine gas meters are defined in Standard EN 12261 [2].

  In the case of operation with hydrogen, maintaining the maximum flow rate reduces the measured energy range with respect to natural gas (HHV of hydrogen on a volumetric basis is more than three times lower than for natural gas). However, as the density of hydrogen is much lower than that of natural gas, it is possible that the maximum speed can be increased in this case.

The lower density of hydrogen compared to natural gas (around 11 times lower for transmission pressure and temperature) may have an impact on the meter linearity and at the minimum flow rate.

Regarding the performed analysis and accordingly with the premises in the introduction, the main conclusions are:

- 14 different models are installed in the evaluated gas grids with the distribution shown in Figure 5.
- The typical size is mostly around G160 - G1000 as represented in Figure 6.

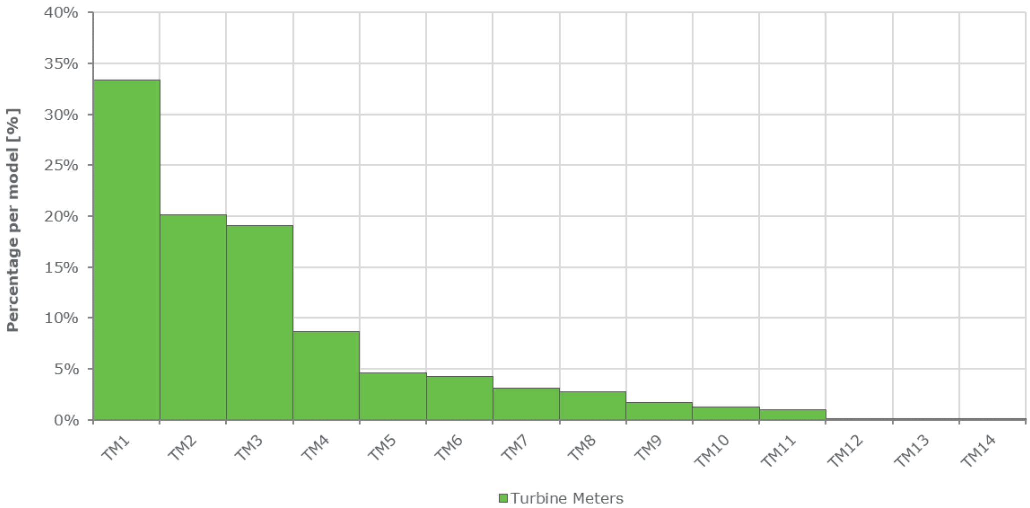

Figure 5. Representation of the turbine meters (TM) models installed in the transmission gas grids of partners.

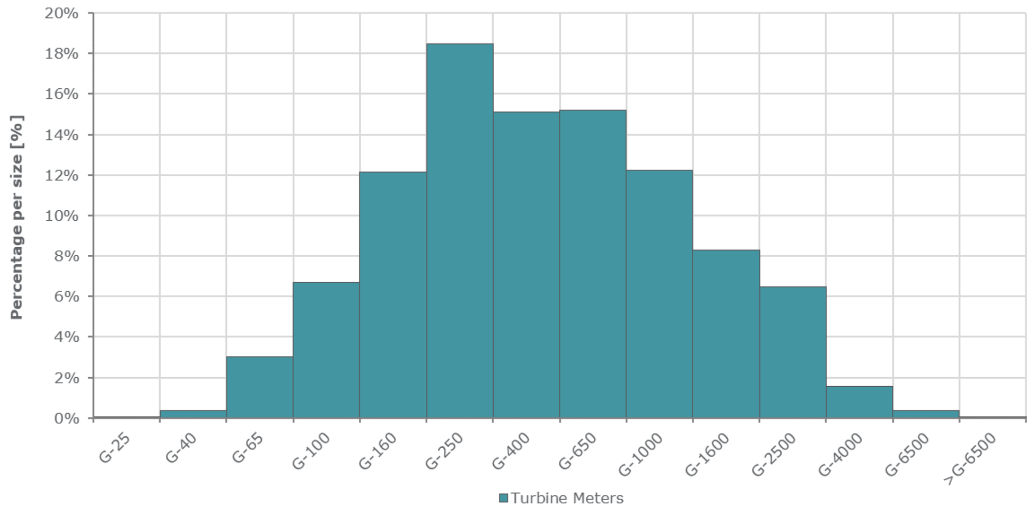

Figure 6. Representation of the size of turbine meters (TM) installed in the transmission gas grids of partners.

- Ultrasonic: The measuring principle is based on the propagation time of acoustic waves inside the meter. It consists of one or several pairs of transducers that function simultaneously as an emitter and receiver of ultrasonic waves. When there is gas flow there are differences in the transit time measured in each direction between the transducers which are proportional to the axial velocity of the flow. Due to this principle this meter is bidirectional.

  The requirements and recommendations for ultrasonic gas flow meters are defined in Standard ISO 17089-1 [3].

  In the case of hydrogen the speed of sound is around 3.4 times higher compared to natural gas (1,373 m/s for hydrogen and around 404 m/s for a typical composition of natural gas).

  Regarding the performed analysis and accordingly with the premises in the introduction, the main conclusions are:

  - 24 different models are installed in the evaluated gas grids with the distribution shown in Figure 7.
  - In this case, no G classification is used and generally this technology is installed for the measurement of high flows.

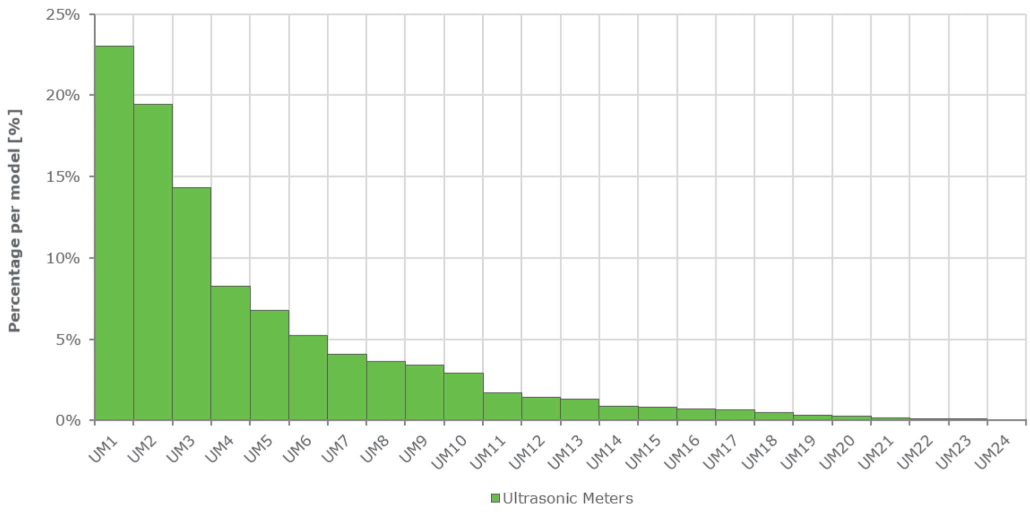

Figure 7. Representation of the ultrasonic meters (UM) models installed in the transmission gas grids of partners.

According to the previous evaluation, the selected gas meters are indicated in Table 2:

- Rotary displacement gas meter G100: Q_{max} of 160 m^3/h and DN50/DN80.
- Rotary displacement gas meter G250: Q_{max} of 400 m^3/h and DN80/DN100.
- Turbine gas meter G160: Q_{max} of 250 m^3/h and DN80/DN100.
- Turbine gas meter G650: Q_{max} of 1,000 m^3/h and DN150/DN200.

- Ultrasonic gas meter DN100: Q_{max} around 1,000/1,600 m^3/h.
- Ultrasonic gas meter DN300: Q_{max} around 7,800/8,600 m^3/h.

Table 2. Selection of transmission gas grid meters to be tested.

Technology	Model	Size
Rotary displacement	Common CGR-01	G100
	Common CGR-01	G250
	Itron Delta S1	G100
	Itron Delta S1	G250
Turbine	Honeywell SM-RI	G160
	Honeywell SM-RI	G650
	Itron Fluxi	G160
	Itron Fluxi	G650
Ultrasonic	Honeywell Q.Sonic-4	DN300
	KROHNE ALTOSONIC V12	DN100
	KROHNE ALTOSONIC V12	DN300
	SICK FLOWSIC600	DN100
	SICK FLOWSIC600	DN300

4.1.2. DISTRIBUTION GAS GRID

In the distribution gas grid under evaluation the representative gas meters are diaphragm, thermal mass and ultrasonic:

- Diaphragm: The measuring principle is based on the use of measuring chambers with deformable walls. The diaphragms expand and contract with each gas inflow triggering a counter.

  The requirements and tests for the construction, performance, safety and production of class 1,5 diaphragm gas meters are defined in Standard EN 1359 [4].

- Thermal mass: The measuring principle is based on the heat being drawn from a heated body when a fluid flows past. As the gas flows in the measuring tube, the heated temperature sensor cools off. The electric current required to maintain the temperature differential is thus a direct measure of mass flow.

  The requirements and tests for the construction, performance, safety and production of battery powered class 1,5 Capillary Thermal-Mass Flow sensor gas meters are defined in Standard EN 17526 [5].

- Ultrasonic: The same measuring principle as described in the transmission gas grid section.

In this case, the available data are not statistically significant. In fact, only one DSO participates to the THOTH2 project as a partner while few answers were received from other DSOs contacted through the Advisory Board. Therefore, no figures with the weighted contribution of each meter by partner are necessary. Selected gas meters are indicated in Table 3:

- Diaphragm gas meter G4: Q_{max} of 6 m^3/h.
- Diaphragm gas meter G6: Q_{max} of 10 m^3/h.
- Diaphragm gas meter G10: Q_{max} of 16 m^3/h.
- Diaphragm gas meter G16: Q_{max} of 25 m^3/h.
- Diaphragm gas meter G40: Q_{max} of 65 m^3/h.
- Diaphragm gas meter G65: Q_{max} of 100 m^3/h.
- Thermal mass gas meter G6: Q_{max} of 10 m^3/h.
- Thermal mass gas meter G25: Q_{max} of 40 m^3/h.
- Ultrasonic gas meter G4: Q_{max} of 6 m^3/h.
- Ultrasonic gas meter G6: Q_{max} of 10 m^3/h.

Table 3. Selection of distribution gas grid meters to be tested.

Technology	Model	Size
Diaphragm	Honeywell BK	G40
	Honeywell BK	G65
	Sagemcom EG4	G4
	Sagemcom EG4	G6
	Sagemcom/Siconia/Sacofgas EG	G10
	Sagemcom/Siconia/Sacofgas EG	G16
Thermal Mass	Metersit Domusnext	G6
	Metersit Domusnext	G25
Ultrasonic	Flonidan SciFlo	G4
	Flonidan SciFlo	G6
	Sagemcom Siconia ES4 EVO	G4
	Sagemcom Siconia ES4 EVO	G6

4.2. PRESSURE TRANSDUCERS

45 different models are installed in the evaluated gas grids with the distribution shown in Figure 8.

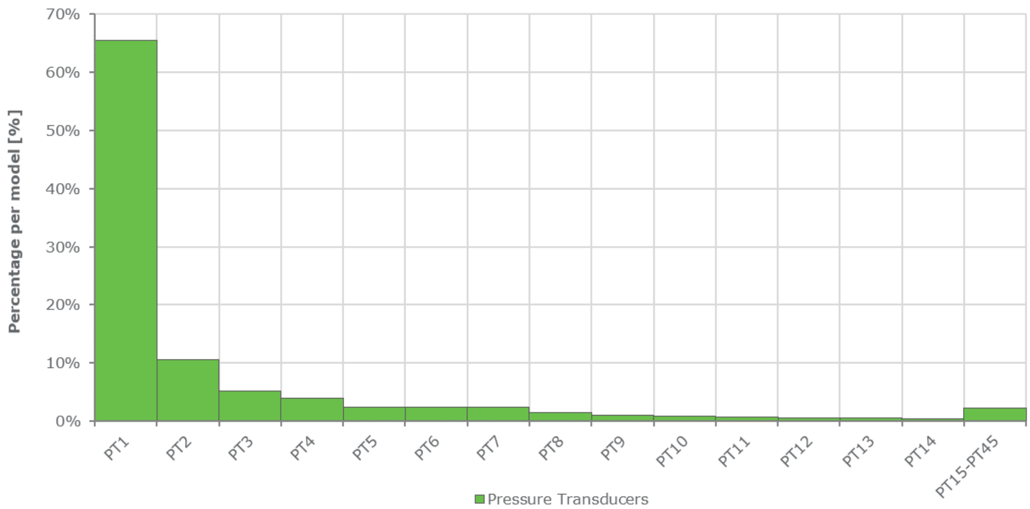

Figure 8. Representation of the pressure transducers (PT) models installed in the transmission gas grids of partners.

According to previous evaluation the selected pressure transducers are indicated in Table 4:

- DPharp Digital Sensor uses two single crystal silicon resonators vibrating at their natural frequencies. When pressure is applied, one of the resonators goes into tension, while the other goes into compression mode. The CPU directly counts the sensor output frequencies without any additional analog to digital (A/D) conversion.
- Piezoresistive technology uses a strain gauge made from a conductive material that changes its electrical resistance when it is stretched. The strain gauge can be attached to a diaphragm that recognises a change in resistance when the sensor element is deformed. The change in resistance is converted to an output signal.
- Resonant technology based on the change in the resonant frequency of a mechanical structure when subjected to an external force or pressure. The resonant frequency is the natural frequency at which a structure vibrates when it is not subjected to any external forces.

Due to considerations about the market penetration on the examined grids and on project resources, it has been decided to prioritize the previous technologies on capacitive one to validate the developed testing protocols developed in Task 2.2. In capacitive sensor the receiver of the pressure measurement is the diaphragm. When pressure is applied to the surface of the diaphragm, the deformation changes the distance between two capacitances, via a filling liquid. This change in capacitance can be measured and converted into a digital signal.

Although not selected in the preliminary testing plan, the testing protocol developed in Task 2.2 can be implemented regardless of the pressure sensor technology. So, capacitive sensors could be evaluated in the final testing plan in case of unavailability of the prioritized models indicated in Table 4.

Table 4. Selection of pressure transducers to be tested.

Technology	Model
DPHARP Digital Sensor	Yokowaga EJA310A
Piezoresistive	Aplisens APC-2000/APR-2000
	Rosemount 3051C
	Rosemount 3051T
Resonant	Yokowaga EJA310E
	Yokogawa EJA430E

4.3. QUALITY ANALYSERS

It is known that mostly of the existing gas chromatographs installed in the gas grid used for analysing the composition of natural gas are not able to work correctly even with low concentrations of hydrogen. For the transport and distribution of H2NG blending new devices will be installed by both TSOs and DSOs. Therefore, the project focuses on testing water dew point analysers used in the gas grid taking advantage of the consortium capabilities.

The selected water dew point analysers are indicated in Table 5:

- Aluminum oxide sensor works by measuring the capacitance between the aluminum core and a gold film deposited on the oxide layer. The capacitance varies according to the water vapor content in the pores of the oxide layer.
- Ceramic metal-oxide moisture sensor works by adsorbing water vapor in equilibrium with the fluid being measured into its porous active layer, sandwiched between two conductive plates.
- The measuring principle of Tunable Diode Laser Absorption Spectrometers (TDLAS) is based on the Beer-Lambert Law. The Beer-Lambert principle states that when light energy at certain wavelengths travel through gas a certain amount of the energy is absorbed by the water within the path. The amount of light energy lost is related to the concentration of water.

Table 5. Selection of water dew point analysers to be tested.

Technology	Model
Aluminum Oxide Sensor	Easidew PRO XP
	SHAW SDT-Ex
Ceramic Metal-Oxide Moisture Sensor	Michell PROMET EExd
	Michell Transmet I.S.
TDLAS	Endress+Hauser J22
	Michell TDL 600

4.4. FLOW COMPUTERS

Flow computers' market results very fragmented. Specifically, 100 different models are installed in the evaluated gas grids with the distribution shown in Figure 9. Due to the characteristics of this device it is agreed to evaluate the Equation of State (EoS) for compressibility factor calculation. While many of the devices could be programmed with several methods, just two are currently implemented in devices installed in evaluated gas grids, which are selected for Work Package 3:

- AGA8 (EN ISO 12213-2) [6].
- SGERG-88 (EN ISO 12213-3) [7].

Additionally, a flow computer will be tested to analyse its performance across different hydrogen concentrations (inside and outside of limits defined in standards). The selected flow computer is KROHNE SUMMIT 8800, as this model is representative of TSO partners gas grids. In addition to the methods AGA8 and SGERG8 the device has an EU-type examination certificate for a method valid for pure hydrogen (Hydrogen gas table).

The requirements and tests for the construction, performance, safety and conformity of gas-volume electronic conversion devices associated to gas meters are defined in Standard EN 12405 [8] [9] [10].

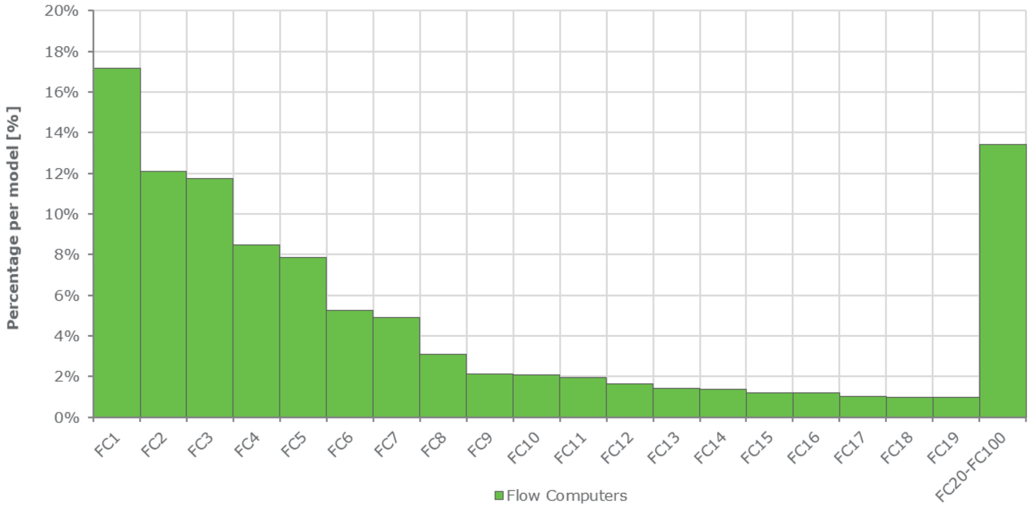

Figure 9. Representation of the flow computers (FC) models installed in the transmission gas grids of partners.

4.5. LEAK DETECTORS

60 different models are installed in the evaluated gas grids with the distribution shown in Figure 10. These models include devices used for:

- Safety during operation and maintenance.
- Emissions identification and reduction.

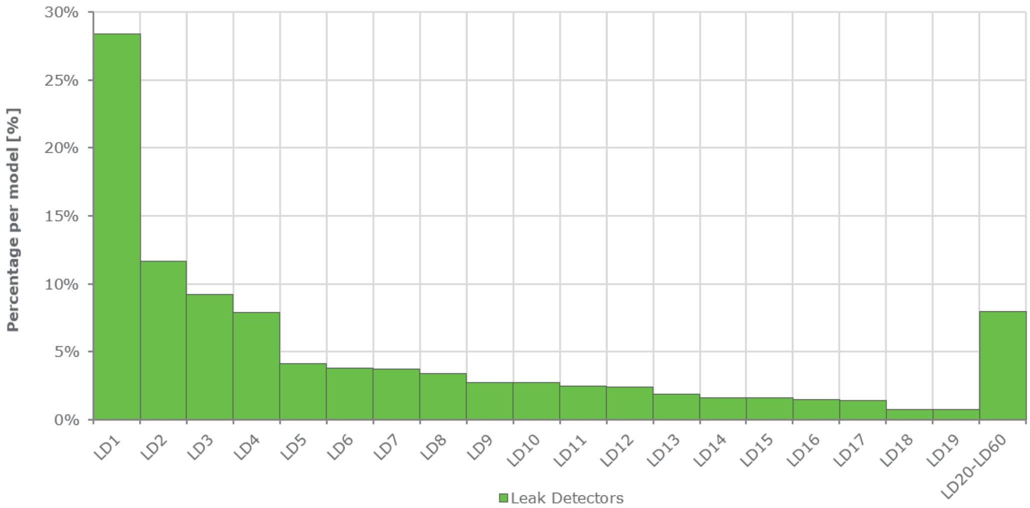

Figure 10. Representation of the leak detectors (LD) models installed in the transmission gas grids of partners.

According to previous evaluation the selected leak detectors are indicated in Table 6:

- Catalytic detector works by measuring the change in voltage produced from the catalytic combustion of the target gas in the sensor. When exposed to the gas the material oxidizes in the presence of a catalyst and the heat of combustion increases the temperature, and therefore changes sensor electrical resistance. The offset voltage caused by the increased temperature is transformed into a sensor signal.
- Infrared detector analyses atmospheric absorption in a region where the target gas absorbs and one where it does not absorb. The ratio between these absorption lines can provide accurate information of the gas concentration along an optical path.
- In the electrochemical detector, the target gas molecules react on the sensing electrode, generating a current. This current relates almost linearly to the amount of gas present.
- Semiconductor gas sensor uses a semiconductor element as a measuring unit. The gas undergoes a redox reaction on the semiconductor, which causes the resistance value to change. As the gas passes through the measuring cell, it adsorbs on its surface and reacts. Gas levels are measured through a change in conductivity of the sensing element.
- Thermal conductivity sensor is based on the principle of thermal conductivity which depends upon the composition of the gas. The sample components in the carrier gas pass into the measuring channel. A second channel serves as a reference channel where only pure carrier gas flow (e.g., zero air or N_2). The difference in thermal conductivity produces a voltage signal proportional to this difference. The signal is proportional to the concentration of the sample components.

Table 6. Selection of leak detectors to be tested.

Technology	Model
Catalytic sensor	MSA Altair 4
	Teledyne PS200
Infrared sensor	GAZOMAT INSPECTRA LASER
	Huber Günther & C. PROTHEO IR COMPACT
	SENSIT LZ-30
Infrared + Catalytic sensor	MSA Altair 5
Catalytic + Electrochemical sensors	Dräger XAM 5000 4G
Semiconductor / Catalytic / Thermal conductivity sensors	GMI GT series 40
Semiconductor + Catalytic + Thermal conductivity sensors	Huber Günther & C. METREX 2
	SENSIT HXG-3P

5. CONCLUSIONS

The selection of measuring devices for testing described in this deliverable is based on the information provided for the TSOs and DSOs with participation in the project:

- Gas meters: 25 meters selected.
  - Transmission grid: 13 meters selected.
    - Rotary pistons meters: 2 models G100 and 2 models (same as previous) G250.
    - Turbine meters: 2 models G160 and 2 models (same as previous) G650.
    - Ultrasonic meters: 2 models DN100 and 3 models (same as previous and one additional) DN300.
  - Distribution grid: 12 meters selected.
    - Diaphragm meters: 1 model G4 and G6, 1 model G10 and G16, and 1 model G40 and G65.
    - Thermal mass meters: 1 model G6 and G25.
    - Ultrasonic meters: 2 models G4 and 2 models (same than previous) G6.
- Pressure transducers: 6 transducers selected.
  - 3 models with 'piezoresistive' technology.
  - 3 models with 'resonant' technology', including 1 DPharp Digital Sensor.
- Quality analysers: 6 water dew point analysers selected.
  - 2 models with 'aluminium oxide sensor' technology.
  - 2 models with 'ceramic metal oxide moisture sensor' technology.
  - 2 models with 'TDLAS' technology.
- Flow computers:
  - 2 methods selected for compressibility factor calculation.
    - AGA8.
    - SGERG-88.
  - 1 model selected for testing with EU-type examination certificate for AGA8 and SGERG-88, and a method valid for pure hydrogen.
- Leak detectors: 10 detectors selected (more than one technology can be included in the same detector).
  - 5 models include 'catalytic' technology.
  - 4 models include 'infrared' technology.
  - 3 models include 'semiconductor' technology.
  - 2 models include 'thermal conductivity' technology.
  - 1 model includes 'electrochemical' technology.

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