ENTSOG Gas Quality workshop

15 November 2023

Lorella Palluotto, Interoperabilty – Gas Quality & Hydrogen Adviser

Hybrid event

1. Introduction session: recent developments on Gas Quality standard and Guarantees of Origin

Revision of EN 16726 – Wobbe Index, hydrogen and other challenges

Presentation by CEN

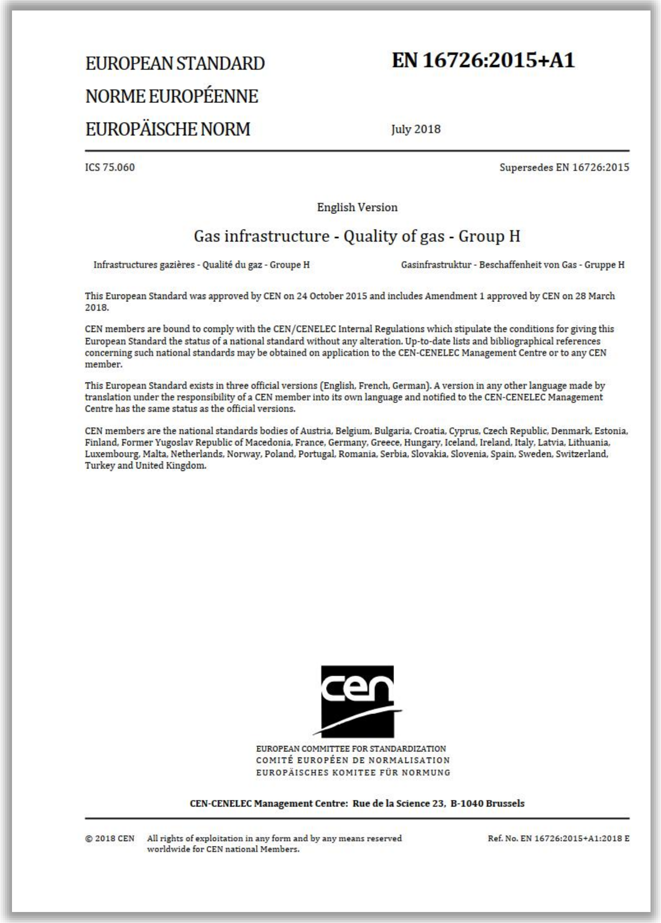
Hiltrud Schülken, CEN/TC 234 Secretary

ENTSOG Gas quality workshop, 15 November 2023

Revision of EN 16726 – Quality of gas – Group H

Public enquiry:
2023-12-21 – 2024-02-21

- **Current document came into force in 2015:**
  - without Wobbe-Index - despite mandate M/400
  - with (only) information for green gases (e.g. Hydrogen)
- **Study phase on possible Wobbe-Index requirements took place in the CEN Sector Forum Gas from 2016-2022**
- **Revision process 2022 – 2025 for:**
  All parameters were investigated for revision need; the following are subject to changes:
  1. Wobbe Index (EC Mandate M/400, CEN SFGas GQS)
  2. Hydrogen content and adapted minimum value for relative density
  3. Oxygen (facilitate renewables)
  4. Sulfur
  5. Methane Number


EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 16726:2015+A1

July 2018

ICS 75.060

Supersedes EN 16726:2015

English Version

Gas infrastructure - Quality of gas - Group H

Infrastructures gazières - Qualité du gaz - Groupe H

Gasinfrastruktur - Beschaffenheit von Gas - Gruppe H

This European Standard was approved by CEN on 24 October 2015 and includes Amendment 1 approved by CEN on 28 March 2018.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. EN 16726:2015+A1:2018 E

1. Wobbe Index classification (1)

❖ **CEN SFGas GQS normative recommendation for a Wobbe Index Entry Range:**

46,44 to 54,00 MJ/m³ [15°C/15°C] (13,59 kWh/m³ to 15,8 kWh/m³[25°C/0°C])

❖ **CEN SFGas GQS normative requirement of a Wobbe Index Exit Classification, based on the distributed gas**

- **Class specified:** bandwidth within a specified WI range: **3,7 within 46,44 to 53,00** [MJ/m³; 15°C/15°] (bandwith 1,08 kWh/m3 within 13,59 kWh/m³ to 15,51 kWh/m³[25°C/0°C])
- **Class extended:** any other situation of WI bandwidth and/or of the WI range;

Obligation for network operators

- assign the WI classes and inform end-user of the class including the upper and lower WI limits
- keep the exceedance of the classes at a minimum regarding time duration, extent, frequency and impact
- be aware that a WI variations over the whole indicated entry range of 46,44 to 54,00 MJ/m³ are not acceptable for the majority of nowaday's applications (including residential and commercial)
- provide information on historical WI data, incl. actual highest and lowest values and class range of the exit point for individual end-users' analysis (on request)
- *Additionally for class extended:* carry out an unbiased assessment of the presence of sensitive users at the concerned (cluster of) exit point and – if any – implementation of appropriate mitigation measures in cooperation with the all involved parties.

1. Wobbe Index classification (2)

❖ **Explanative informative annexes**

- Annex H - Limitations of the end-use gas applications to cope with the broad Wobbe Index entry range;
- Annex I - General considerations on adjustment and re-adjustment of residential and commercial appliances;
- Annex J - Onside adjustment of end-use applications

1. Wobbe Index classification (3)

Public enquiry:
2023-12-21 – 2024-02-21

Controversial expectations on the following issues from the different stakeholder groups could not be solved:

- permissible **deviation** of the indicated classification WI values (extent, intensity, time distribution)
- **lead time** for switch of class and
- time **duration** of a classification

- ➢ **a dynamic and information based approach is now in the draft standard**
- ➢ approach is seen as a huge benefit, also by many end-users;
- ➢ however, end-users seek **certainties, reliable limit values and measurable requirements**

- ➢ **Since the Secretariats of CEN/TC 234 and WG 11 have not seen any possibility to develop the topic further in the internal CEN/TC 234 WG 11 discussions, it was decided together with the CEN-CENELEC Management Center (CCMC) to go for the public enquiry to get a broader view on the subject again.**
- ➢ The EC DG Energy is informed about it; A more detailed explanation is announced.
- ➢ All stakeholder are invited to comment on the draft standard to overcome the blocked situation!

European regulation for Wobbe Index as pre-condition for implementation of EN 16726

→**For the implementation of the Wobbe Index Exit Classification, a European legal/regulatory framework is needed (ref. to gas package regulation, art 56)**

– for responsibilities, liabilities, classification and assessment procedures (incl. CBA, costs)

Gas quality in the energy transition

The Forum confirms its support and invites CEN to finalise the process on the Wobbe Index standardisation and to continue its work in support of the use of renewable and low-carbon gases in gas infrastructure and gas applications, while considering different end-users requirements. The Forum also calls on all market participants to be constructively engaged in this process.

Following the adoption of the hydrogen and decarbonised gas market package and finalisation of the process on the Wobbe Index standardisation, the Forum encourages the Commission to initiate the revision of the Interoperability Network Code to include the regulatory framework for the Wobbe Index classification system.

37th MF conclusion, May 2023

➢ **The draft prEN 16726 foresees a transition phase until the procedures are fixed** (see WI documents of the CEN SFGas GQS and the Prime Movers‘ Group Subgroup ‘WI Framework’ gives already more detailed reflections)

2. Hydrogen and relative density in the draft prEN 16726

Hydrogen content: Determination of max. allowable hydrogen admixture of 2% , with the option to allow higher concentrations in certain grid areas based on bilateral agreements and grid assessment with respect to technical and legal restrictions for CNG and other applications

> Alignment might be needed after EU Gas/Hydrogen Package approval.

Relative density: Reduction of lower limit of relative density from 0,55 to 0,45 to allow higher H2 admixtures.

Parameter	Unit	Limits based on standard reference condition 15 °C/15 °C		Limits based on normal reference condition 25 °C/0 °C (for information)		Reference standards for test methodsf (informative)
		Min.	Max.	Min.	Max.	
Hydrogen	mol%	not applicable	2	not applicable	2	none
	A hydrogen concentration shall be accepted up to two percent by mole across the whole value chain. It may deviate nationally, regionally or locally for higher values of hydrogen concentration than 2 % in the grids provided that the requirements of the sensitive users are met (see 5.4 and Annex E)					
Relative density	no unit	0,45[a]	0,70	0,45	0,70	EN ISO 6976, EN ISO 15970

- Reference to the EC gas package §19 on H2-admixture in the cross-boarder transport
- In the trialogue 2, 3 and 5% admixture are subject to discussion

3. Oxygen in the draft prEN 16726

Oxygen: No change of the values, but addition of a case-by-case assessment process for oxygen-sensitive installations in grids influenced by actual oxygen content.

> continuation of discussions in the Joint Task Force CEN SFGas GQS /TC 234 and in the GERG study on oxygen (procedures for desulfuration of oxygen)

Parameter	Unit	Limits based on standard reference condition 15 °C/15 °C		Limits based on normal reference condition 25 °C/0 °C (for information)		Reference standards for test methodsf (informative)
		Min.	Max.	Min.	Max.	
Oxygen	mol/mol	not applicable	1 % or 0,001 % for sensitive users (see below)	not applicable	1 % or 0,001 % for sensitive users (see below)	EN ISO 6974-3, EN ISO 6974-6, EN ISO 6975
	In the gas infrastructure the mole fraction of oxygen shall be no more than 1 %. However, if it can be demonstrated that a gas with oxygen content can flow to installations sensitive to oxygen, e.g. underground gas storage, a maximum limit down to 0,001 %, expressed as a moving 24 hour average, at those exit point shall be applied, unless there is no technical need (for most applications a level of e.g. 0,01 % or higher is sufficient). The evaluation of the applicable level shall be done by an assessment process. If the technical need for a low oxygen limit is not confirmed within the required assessment process, then higher oxygen concentrations can be agreed on. The evaluation of the applicable level shall be done by a case-by-case analysis for the grid that is influenced by the oxygen content based on concrete input e.g. from requester for gas injection, gas infrastructure operators and relevant end-users. NOTE 2 0,01 % is equal to 100 ppm and 0,001 % is equal to 10 ppm.					

4. Sulfur in the draft prEN 16726

Total sulfur: reduction of total sulfur constituents to 11 mg/m³, with the possiblity to have

- up to 20 mg/m³ if other sulfur components can be proven in the grid.
- up to 30 mg/m³ in case of transmission of odorised gas between high pressure neworks

Parameter	Unit	Limits based on standard reference condition 15 °C/15 °C		Limits based on normal reference condition 25 °C/0 °C (for information)		Reference standards for test methodsf (informative)
		Min.	Max.	Min.	Max.	
Total sulfur without odorant	mg/m³	not applicable	11[b]	not applicable	11[b]	EN ISO 19739
	A maximum total sulfur concentration of 20 mg/m³ may apply provided that sulfur components other than those mentioned in this table are experienced in the grid. For existing practices with respect to transmission of odorized gas between high pressure networks higher sulfur content value up to 30 mg/m³ may be accepted. NOTE Odorization is considered as a safety issue, dealt with at national level. Some information about sulfur odorant content is given in Annex B.					
Hydrogen sulphide + Carbonyl sulphide (as sulfur)	mg/m³	not applicable	5[b]	not applicable	5[b]	EN ISO 6326-1, EN ISO 6326-3, EN ISO 19739
Mercaptan sulfur without odorant (as sulfur)	mg/m³	not applicable	6[b]	not applicable	6[b]	EN ISO 6326-3, EN ISO 19739

[b] Figures are indicated without post-comma digits due to analytical uncertainty.

5. Methane number in the draft prEN 16726

Methane Number: Confirmation of the minimum MN value of 65;

Addition of a clarifying note that th 65 is not the design value, which is generally higher. This is explained in a new Annex F.

Confirmation of the normative Annex A *Calculation of methane number of gaseous fuels for engines*

Parameter	Unit	Limits based on standard reference condition 15 °C/15 °C		Limits based on normal reference condition 25 °C/0 °C (for information)		Reference standards for test methods[f] (informative)
		Min.	Max.	Min.	Max.	
Methane number	no unit	65[g] (see normative Annex A, Annex F)	not applicable	65[g]	not applicable	none

[g] This limit value does not imply that gas engines should be designed for the minimum *MN* of 65. The gas engines should be designed for the expected gas quality. They are generally designed for a minimum *MN* of 70 or above. (see Annex F).

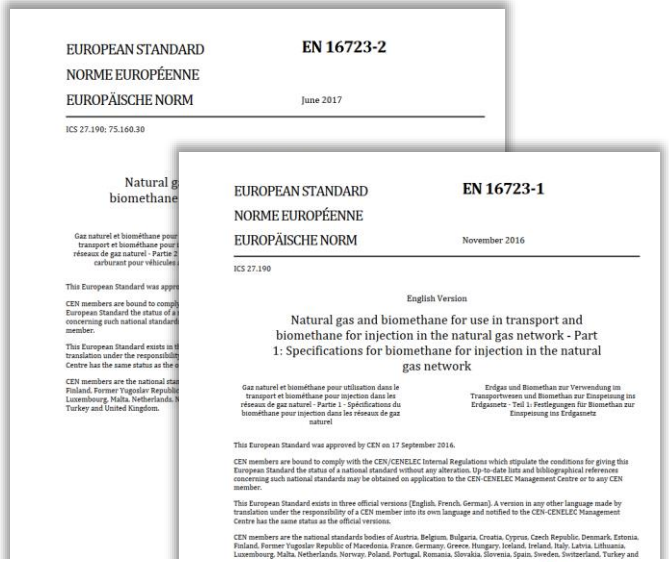
Note: development of calculation methods for methane number are taking place in CEN/TC 408 in cooperation with ISO (EN ISO 17507-1 and EN ISO 17507-2)

Revision of biomethane quality standards

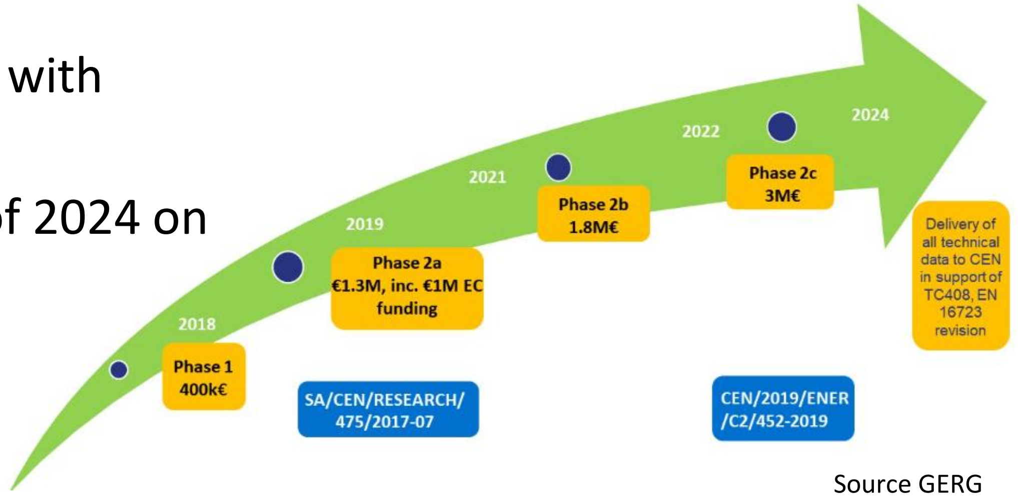
EN 16723-1/-2 Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network

1. Specifications for biomethane for injection in the natural gas network
2. Automotive fuels specification

- ➢ developed by CEN/TC 408 under Mandate M/475, interlinked with M/400 for gas quality
- ➢ revision in preparation including EU funded research by end of 2024 on
  - – impact of oxygen in UGS and on pipes
  - – impact of sulfur on engines
  - – impact of hydrogen on H2 tanks (for 2%, 4%, 6%; 2023)


EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM
EN 16723-2
June 2017
ICS 27.190; 75.160.30

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM
EN 16723-1
November 2016
ICS 27.190
English Version
Natural gas and biomethane for use in transport and biomethane in the natural gas network - Part 1: Specifications for biomethane for injection in the natural gas network



Source GERG

Additionally, development of analysis methods for components not found in natural gas but found in biomethane (silicon, terpenes, amines, ammonia, compressor oil, halogenated compounds…) in cooperation with ISO.

Timeline until finalisation of EN 16726

2023-12-21 to 2024-03-14	Public consultation (Public Enquiry) ➢ **All interested parties have the possibility to comment on the document** • by adressing comments to the national standardisation body • by adressing the comments to a CEN partner organisations - (the organisation will send it to the CEN/TC 234 Secretariat or to CEN-CENELEC Management Center) • CEN comments template shall be used: Link
2024-10-01	Deadline for TC 234 finalisation of final draft
2024-12-10	planned start of final voting (Formal Vote)
2025-04	planned publication of the revised EN 16726

Contact

Hiltrud Schülken,
CEN/TC 234 Gas infrastructure

hiltrud.schuelken@dvgw.de

Tobias van Almsick
CEN/TC 234 WG 11 Gas quality

tobias.vanalmsick@oge.net

Christophe Erhel
CEN/TC 408 Biomethane for use in transport and injection in natural gas pipelines
christophe.erhel@francegaz.fr

ENSTOG Gas Quality Workshop
Gases classification
from an EU policy perspective

15 November 2023

Victor Bernabeu, Director

Eurogas

Eurogas is an association representing the European gas wholesale, retail, distribution and mobility sectors towards the EU institutions. Founded in 1990, Eurogas currently comprises 77 companies and associations from 25 countries

Which EU policies are classifying gases?

- Numerous processes to produce biogas, hydrogen and synthetic methane.
- EU policies regulating these gases does not classify them by their process pathways.
- Usually: Look at the feedstock and define a set of sustainability criteria/production requirements & a GHG emissions savings threshold.
- In fact, there are no definition of hydrogen per colour, or biogas per production pathway:

Examples of what does not exist in the EU policy framework:

~~Biogas from anaerobic digestion~~

~~Renewable hydrogen~~

~~Blue hydrogen~~

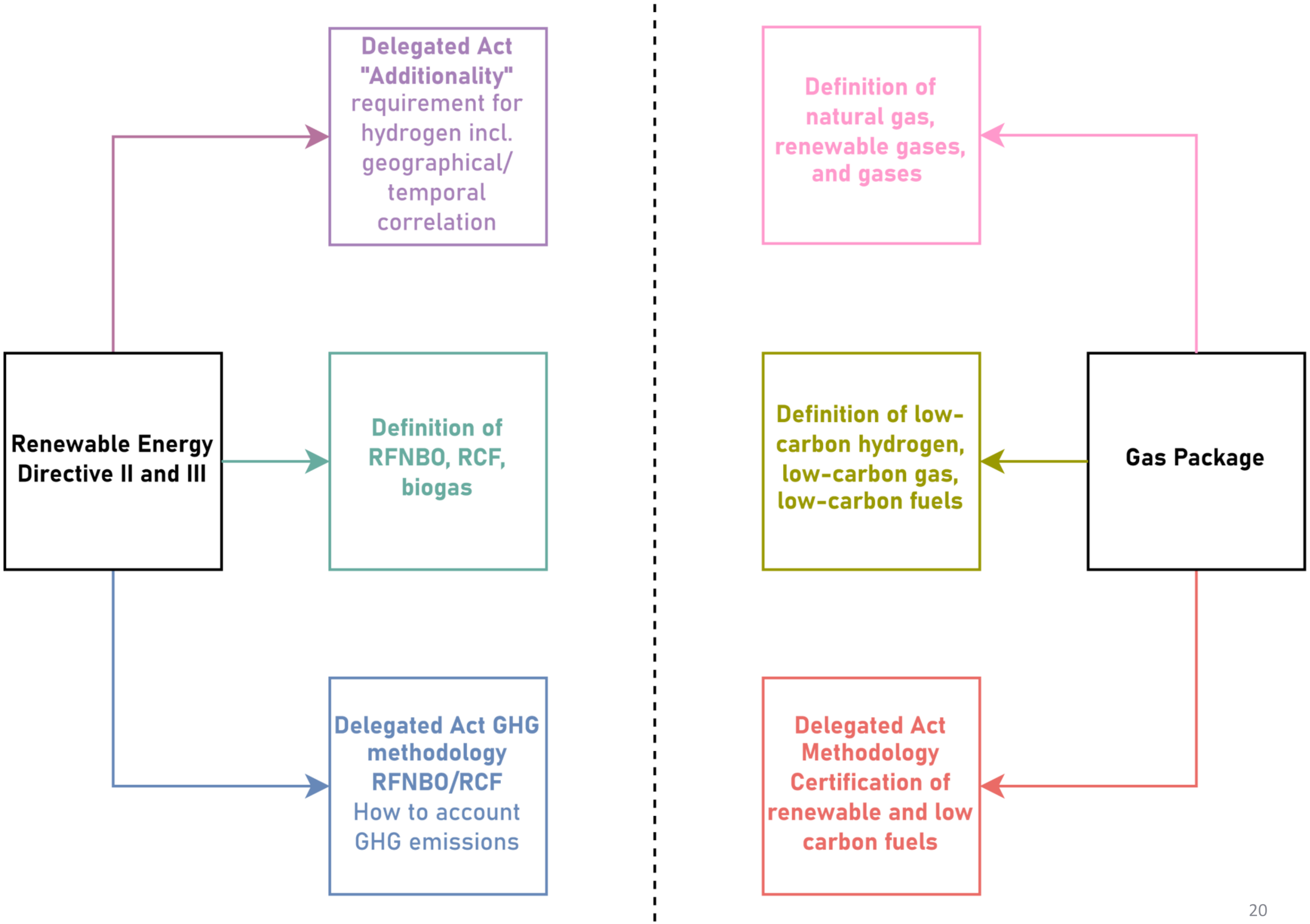
~~Synthetic methane~~

4 main definition “baskets”

	RFNBO *for Renewable Fuels of Non-Biological Origin*	**RCF** *for Recycled Carbon Fuels*	**Biogas**	**Low-carbon fuels** *Depend on final agreement on the Gas Directive*
Definition	Liquid or gas; energy from renewable sources other than biomass	Liquid or gas; produced from non-renewable feedstock: • liquid/solid waste streams not suitable for material recovery • unavoidable & unintentional waste processing (exhaust) gas from industrial installations’ production process	Gas from biomass	Include RCF & low-carbon hydrogen (i.e. from non-renewable sources) incl. derivatives
Sustainability	Set of requirements incl. additionality and -70% GHG vs. fossil reference	-70% GHG vs. fossil reference	Set of sustainability requirements and -50 to -70% GHG vs. fossil reference (depends on end uses and installation’s starting date)	-70% GHG vs. fossil reference
What could qualify there?	Some electrolytic hydrogen and derivatives incl. e-methane & e-fuels	Fischer-Tropsch hydrocarbons or methanol, ethanol from (microbial) fermentation	Biogas	Blue/turquoise hydrogen, other electrolytic hydrogen not qualifying as RFNBO
Fro definition	Renewable Energy Directive			Upcoming Gas Directive

Interactions between EU policies

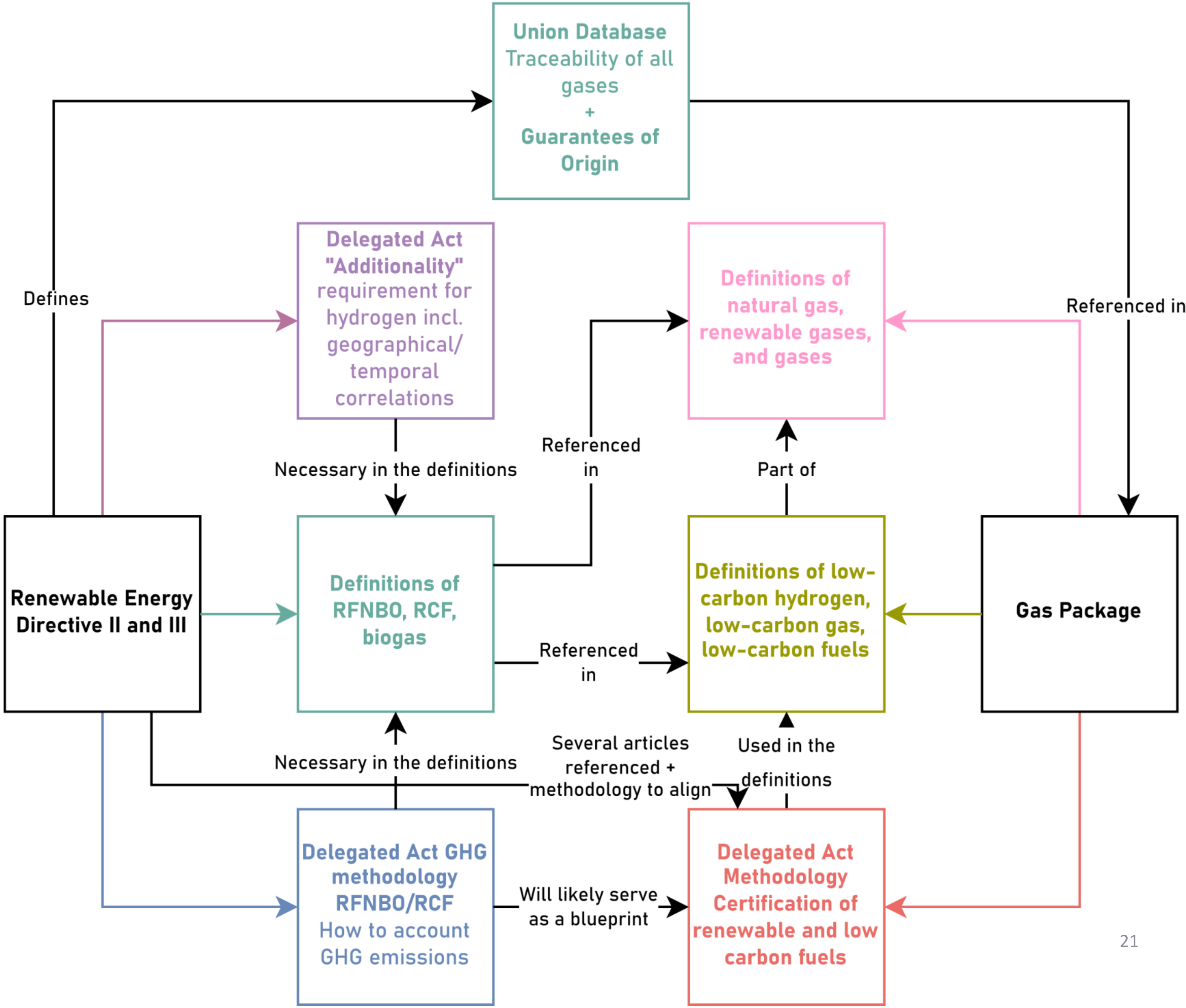
2 separate policies?



eurogas

Interactions between EU policies

- Numerous interlinkages, cross-references.
- Two policies **defined in parallel**. Do we have everything covered? **No.**
- Low carbon gases definition is rather open, other definitions (RFNBO/biogas) do not properly capture all cases: ex. **biohydrogen**.



Thank you!

- eurogas.org
- @Eurogas_Eu
- Rue d’Arlon 80, 1040 Brussels

eurogas

Recent developments on Guarantees of Origin and GO Standard

Guarantees of Origin for different kinds of gas

Katrien Verwimp

Strategy Coordinator – European Energy Certificate System

AIB and its Member Countries / Regions

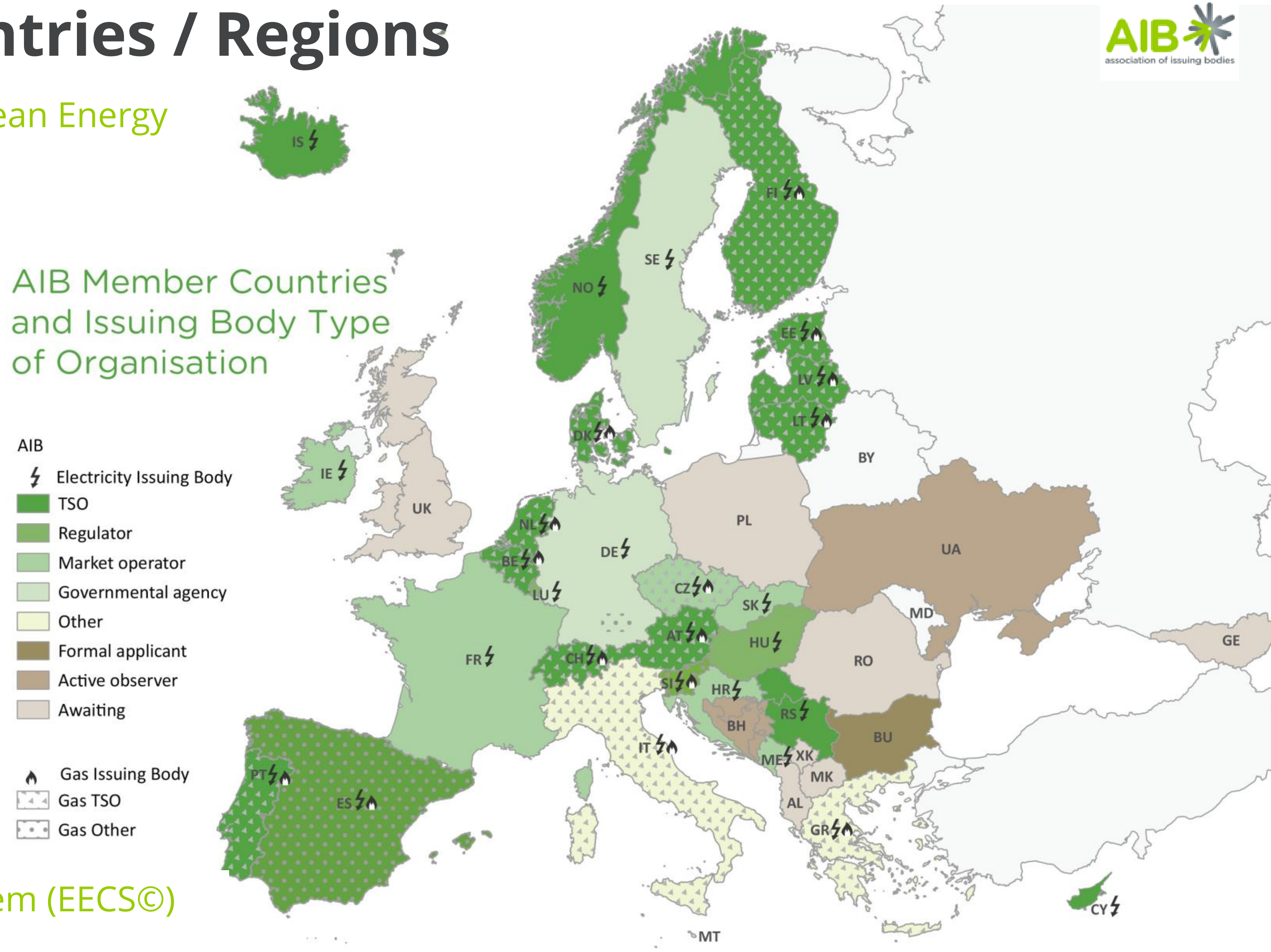
AIB mission: Guaranteeing the origin of European Energy

→ AIB is founded in 2002, international non-profit association

→ 28 countries connected (35 members)

- Geographical scope: EU - EFTA – Energy Community
- All governmentally appointed issuing bodies for Guarantees of Origin
  - Diverse: regulator, market operator, TSO, ministry, power exchange etc.
- 20 AIB members assigned by their government for issuing gas GO
  - Austria (E-Control), Belgium Brussels (Brugel), Belgium Flanders (VREG), Belgium Wallonia (SPW), Czech Republic (OTE), Croatia (HROTE), Denmark (Energinet), Estonia (Elering), Finland (Gasgrid Finland), France (EEX), Greece (DAPEEP), Italy (GSE), Latvia (Conexus Baltic Grid), Lithuania (Amber Grid), Luxembourg (ILR), Netherlands (VertiCer), Portugal (REN), Slovenia (AGEN-RS), Spain (Enagas GTS), Switzerland (Pronovo), more to follow

→ Developer and custodian of the EECS standard

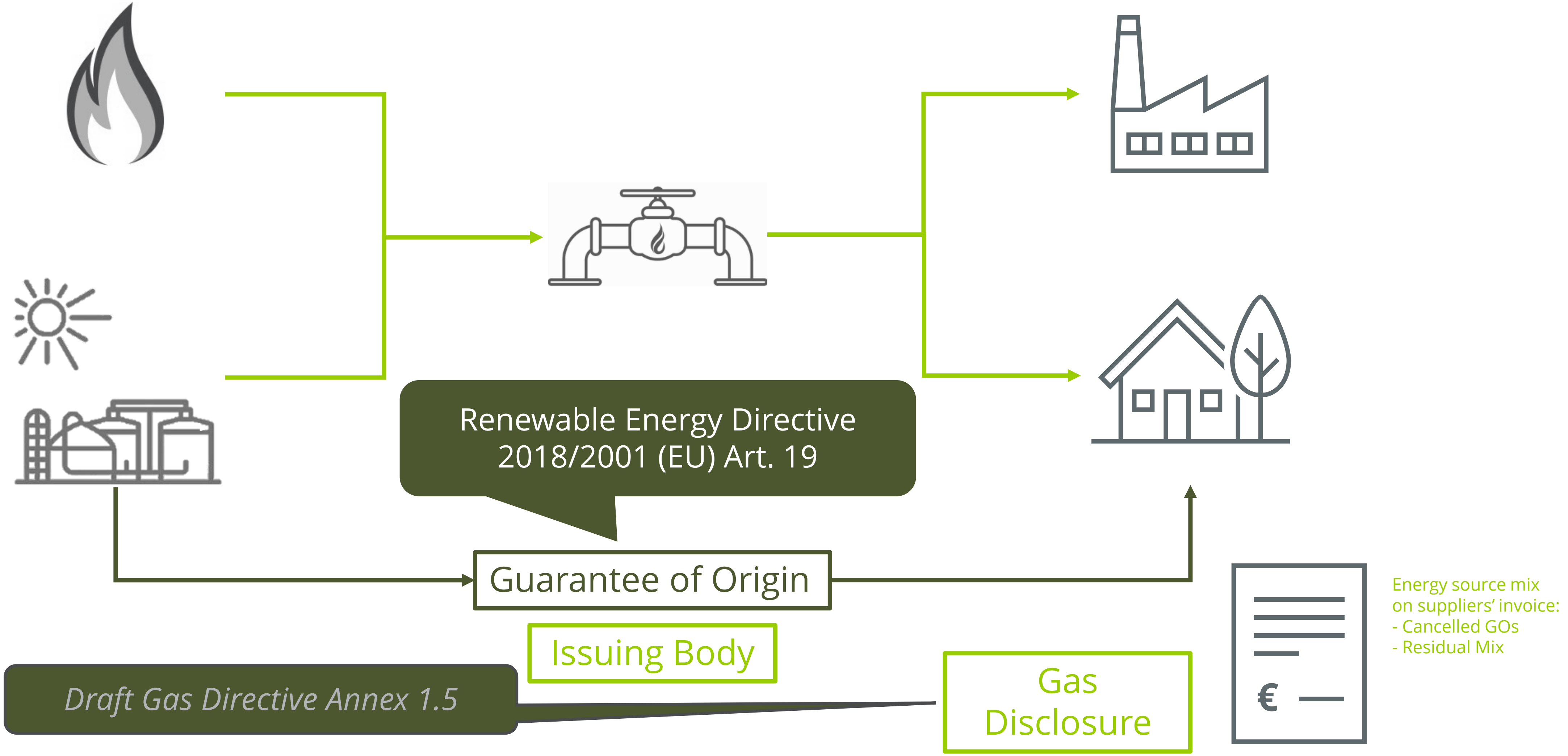


Pillars of the European Energy Certificate System (EECS©)

I. **EECS Rules**: engaging into quality and harmonisation
II. **IT hub**: enables GO transfer between national/regional Domain registries
III. Peer reviews and **audits**

Guarantees of Origin

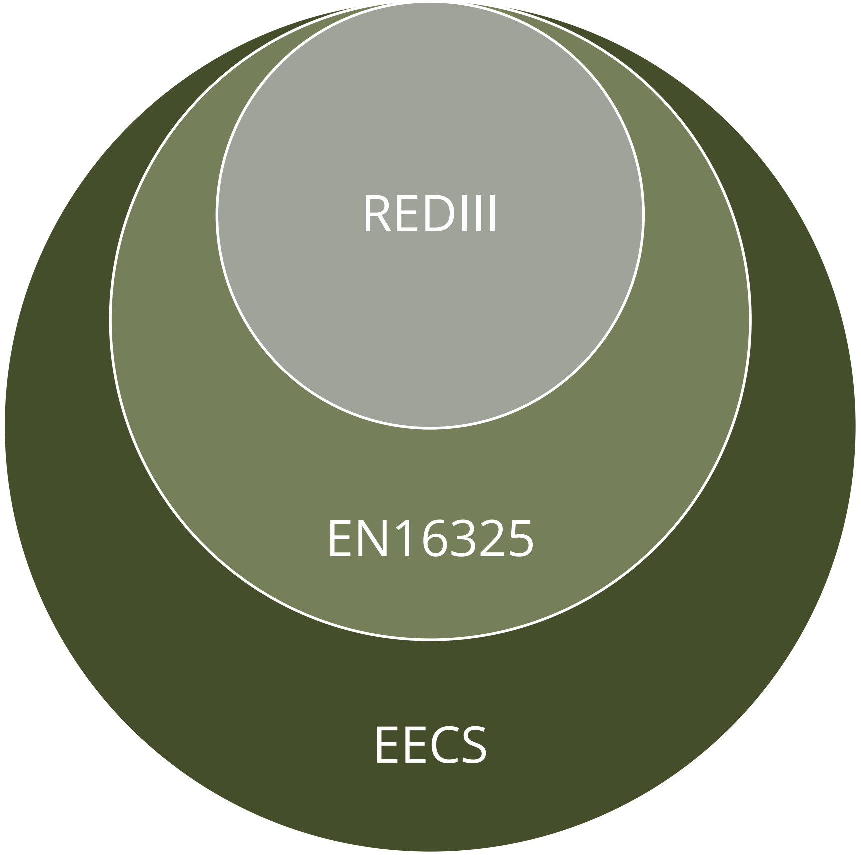
European Legislation



Guarantees of origin

Framework

1. GOs are for disclosure – legislation
2. Reliable GO system – mandatory standard
3. Efficient and reliable GO system – voluntary standard



Why do we have standards?

Framework

Try plugging that in!

Complementary GO standards

Relationship EN16325 (CEN) and EECS™

EN16325
Principles for reliable GOs

- Under discussion in CEN, in addition to EECS today:
  - ✓Optional Data fields on the GO post-conversion*
  - ✓GOs for heating and cooling
  - ✓Discussion on categorisation of gases – usage of gas GOs
  - ✓Export & Import – maintain same perimeter as in residual mix or ensure imports/exports of GOs don't exceed total direct import of that energy carrier in that year

EECS
Reliable and efficient operation

- EECS going beyond CEN
  - ✓Operational details, needing flexible adaptation
  - ✓IT facilitation of international transfers and joint needs
  - ✓Platform for sharing experiences
  - ✓Co-creation by issuing bodies
  - ✓Standard procedures for robust decision- making

* EECS will update to (at least) synchronise with CEN latest after final EN16325 is published

Transparency enhances empowered consumer choices

Data on generic EECS Certificates

- Energy Carrier
  - Electricity / Energy Gas / Hydrogen
- Product
  - GO / Support Certificate / Target Certificate / Independent Criteria Scheme
  - Product name
- Unique certificate number
- Production period (start and end dates)
- Energy source
- Type of installation
- Production device info
- Identity and country of originating member
- Issue date
- Identity and country of relevant competent body
- Purpose
  - Disclosure, Support and/or Target
- Support received by type
- Dissemination level
- Face Value
- Conversion Tag & Storage Tag
- Label(s) *
- Carbon Footprint *
- Timestamp *
- Production Device Module *
- Radioactive waste *

Additional on Electricity certificate

High-Efficiency Cogeneration

- *High Efficiency Cogeneration Criterion Met?*
  - *Y/N*
  - *If Yes, then also following fields are mandatory*
- Lower Calorific Value
- Use of Heat
- Primary Energy Savings
  - *% PES*
  - *Absolute PES*
- GHG Emissions
  - %
  - Absolute

Fossil energy sources

- GHG Emissions

Nuclear energy sources

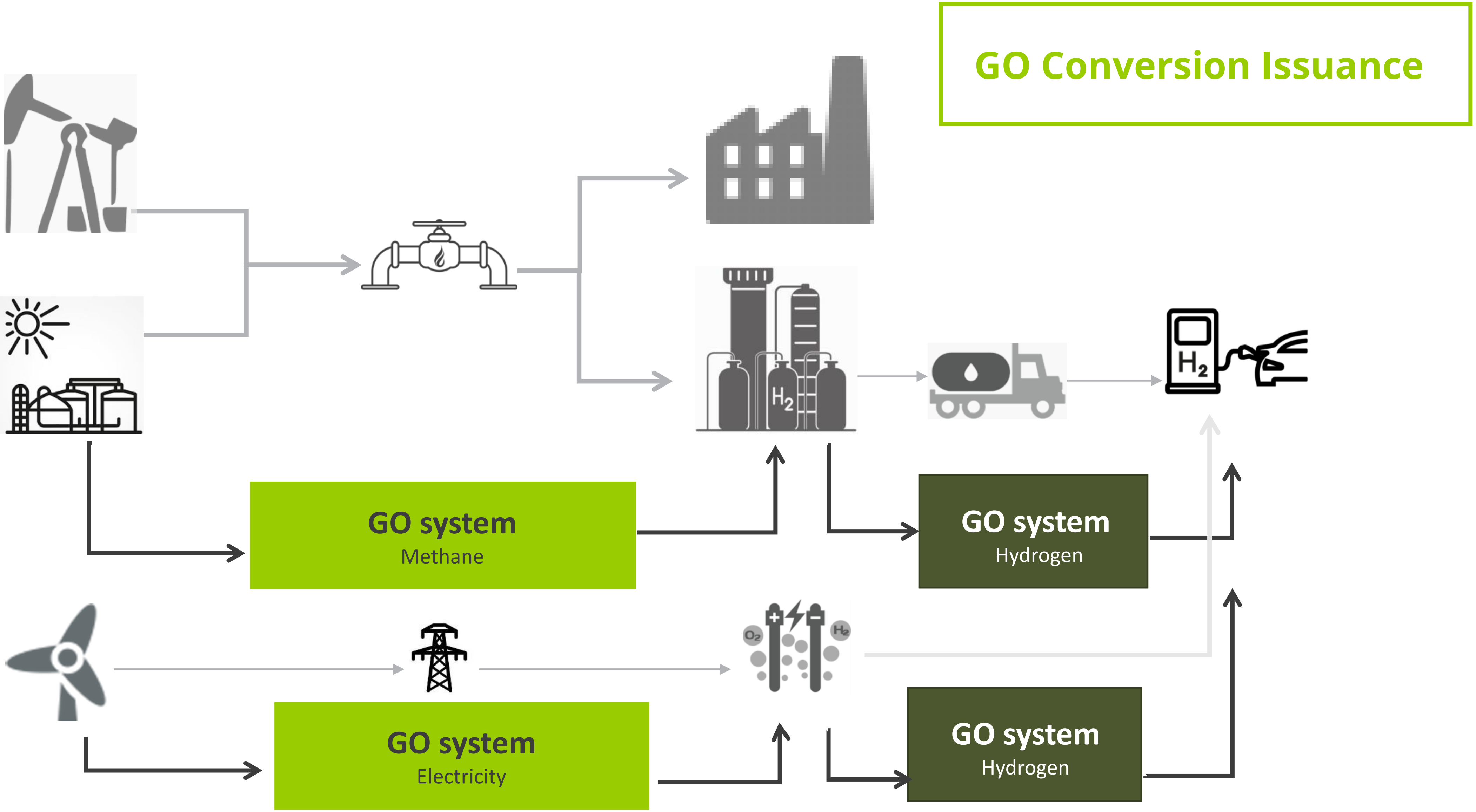
- Radioactive Waste

Additional on Gas certificate

- Type of Gas
  - *See Fact Sheet*
- Whether Higher or Lower Calorific Value
- GHG Emissions Saved & Produced *
  - + Methodology reference
- Sustainability Criteria met?*
  - *Y/N; requirements, scheme, name Certification Body, reference to report*
- GHG saving criteria met?*
- Calorific value *
- End-Use of gas category*
- Source-Shares *
- Production Device Module(s) *
  - Description, capacity, date operational
- Pre-Conversion support info *
- PurityOfGas *
- CompositionCriteriaReference *
- Advanced Biofuel Criteria Met? *

Legend:
- Mandatory information field
- *Optional information field

Why a generic GO system for all energy carriers?



CEN EN16325 revision – Categorisation of gases

Draft standard refining ongoing

Generic GO Rules and Rules per Energy Type: Electricity / Gas / Heating and Cooling

Data on GO: objectivity, transparency, immutability

- Energy Source,
- Technology, production location, capacity, commissioning date, …
- Public support type
- Type of Gaseous Energy Carrier:
  - Methane, Ethane, Propane, Butane, Dimethylether, Hydrogen, Ammonia, Unspecified Gas.
- Dissemination level:
  - Injected in Distribution or Transmission System / Consumed by the operator of the production device / Transported by vehicle / …
- Sustainability Criteria met: Y/N (optional)
- Under debate:
  - Proportion of gas in the mixture?
  - Multiple GOs for separate components of a mixture?
  - Where is the Gas?

Which Gas GOs to use for which gaseous energy consumption?

Harmonisation opportunities versus opinions on quality & market organisation

Transparent info on **issued GO**: CEN

Which GO to **use** for which gas consumption

- REDIII: gas GO used shall correspond with "the relevant network characteristics"
- Interpret & refine GO usage rules : CEN or National legislation ?

(The only) Legal GO import criteria (REDIII art 19.9):

Accuracy, reliability, veracity

Potential Risk: Different national interpretations
=> Diverse national import restrictions

Liquidity of gas GO market?

Welcoming interaction!

www.aib-net.org

+32 (0)486 55 83 01

info@aib-net.org

katrien@aib-net.org

2. Biomethane, the implication of the 35 bcm target from a Gas Quality point of view

Technical challenges concerning gas quality from the biomethane production side

Mieke Decorte – Technical and Project Manager

ENTSTOG Gas Quality Workshop – 15 November 2023

The whole biogases value chain

290

MEMBERS

243

COMPANIES

47

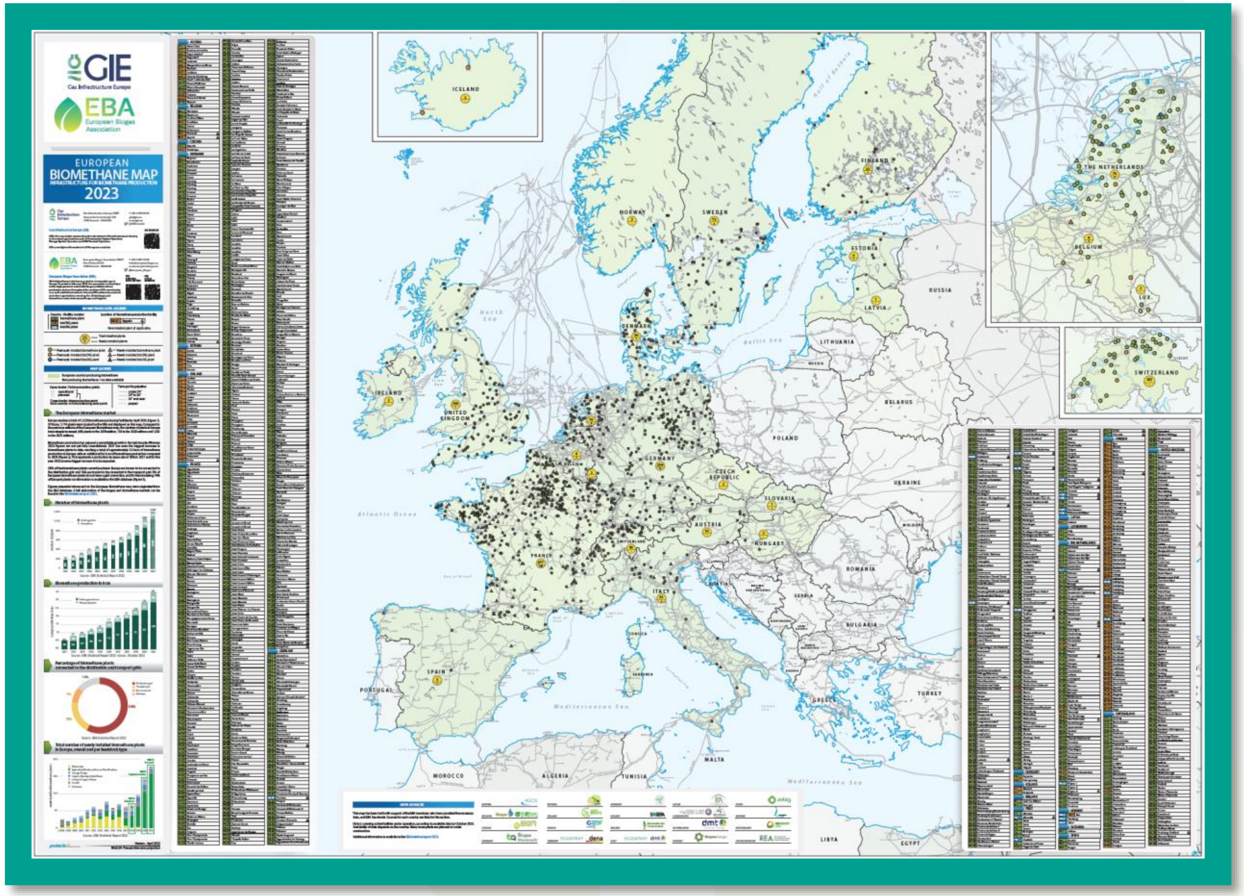
NATIONAL ASSOCIATION

35

COUNTRIES

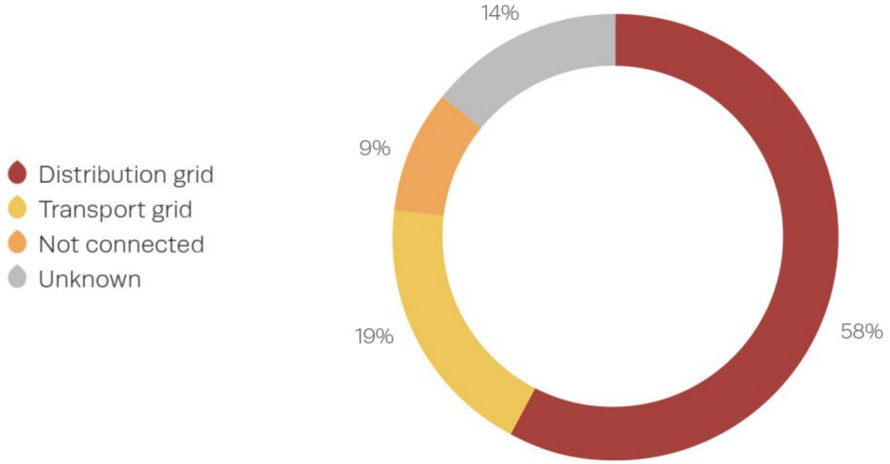
Why a EU Gas Quality Standard?

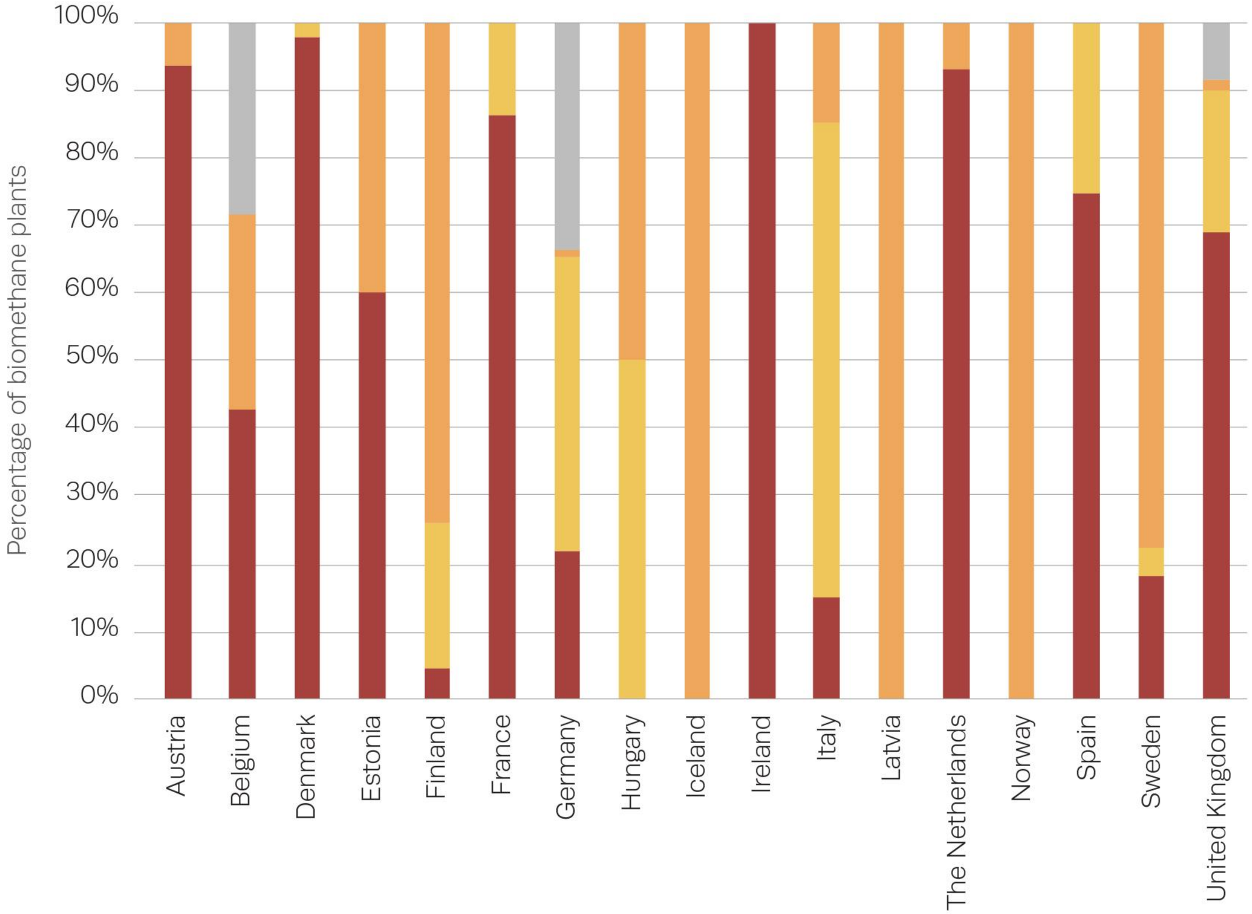
- There are > 1,300 biomethane production facilities in Europe.
- 24 European countries are producing biomethane
  - 2018: Belgium and Estonia
  - 2019: Czech Republic
  - 2020: Ireland, Latvia
  - 2022: Slovakia
  - 2023: Ukraine and Lithuania
- **To reach the 35 bcm target, around 5,000 new plants would need** to be built by 2030



Why a EU Gas Quality Standard?

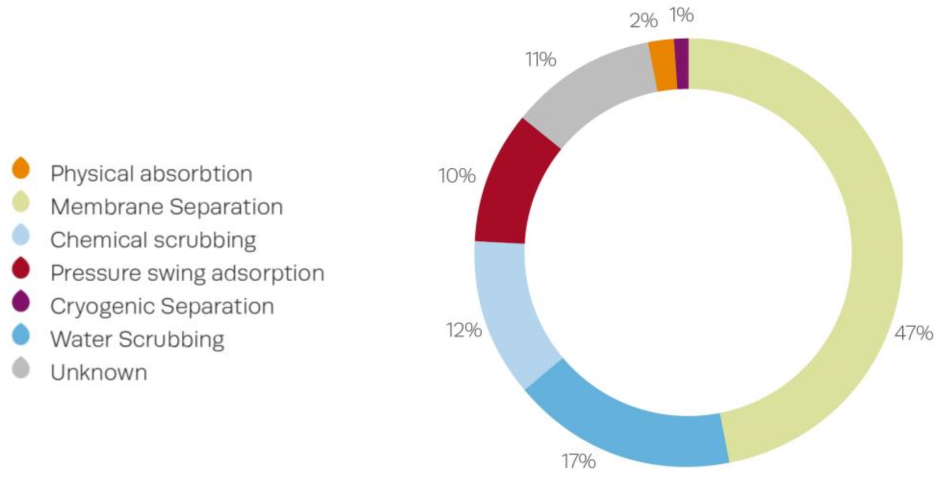
- Plants are connected both to the distribution (58%) and transmission grids (19%).
- Large differences in type of connection per country.

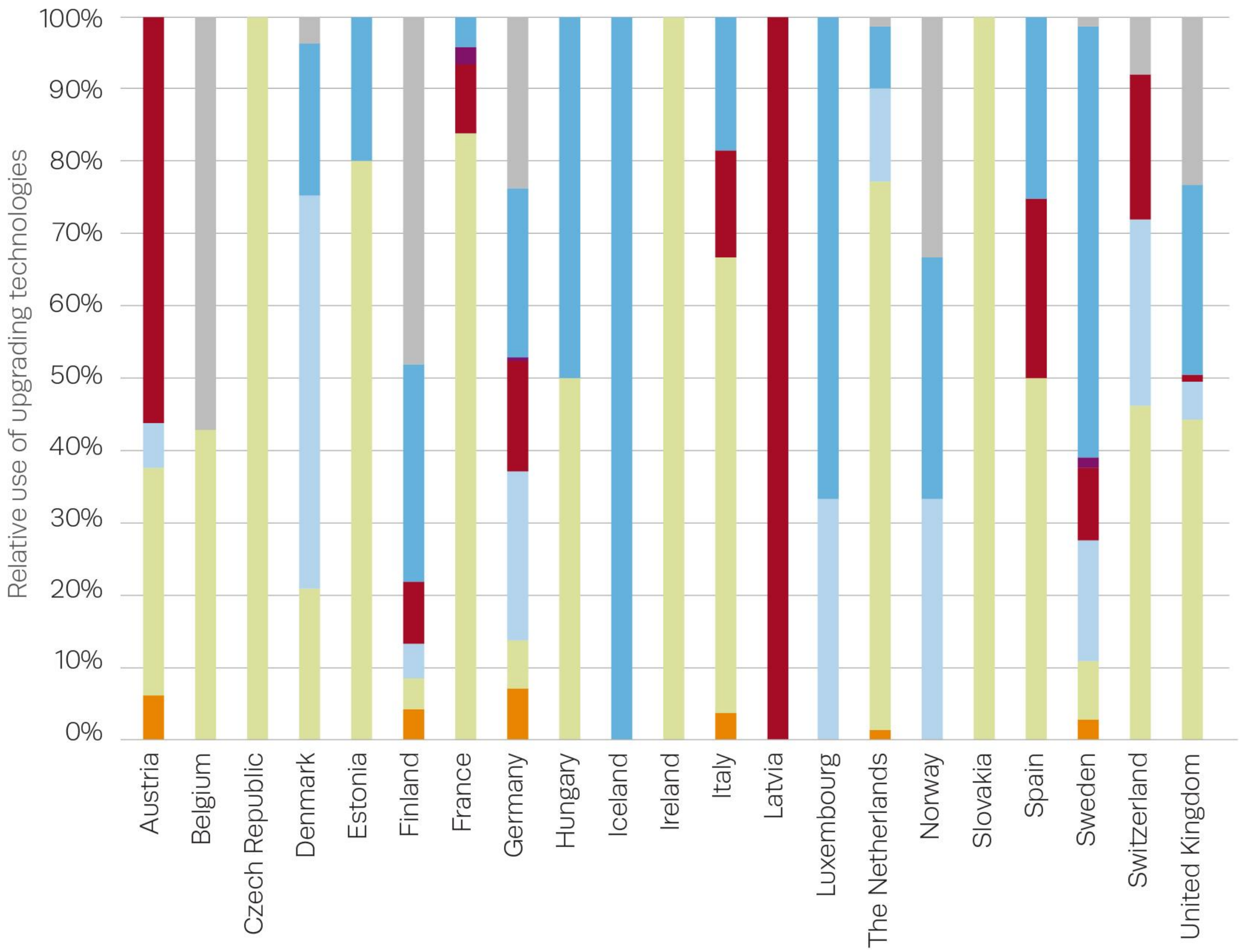




Why a EU Gas Quality Standard?

- There are a range of different upgrading technologies in place, resulting in different properties of the biomethane.





Why a EU Gas Quality Standard?

1. Decarbonising the gas grid comes with a diversification of gas supplies and thus diversification of gas properties.
2. Different oxygen requirements between Members States are in place.
3. Differences in gas quality should not hamper the free trade of gas cross borders.
4. To ensure smooth handling of the gas mix by storage facilities and chemical industry.

A EU Gas Quality standard is key to the REPowerEU ambition of 35 bcm biomethane by 2030

Sources of oxygen in biomethane

Accidently

Through leaks or unintended air from vacuum-valves

Air pockets in biomass

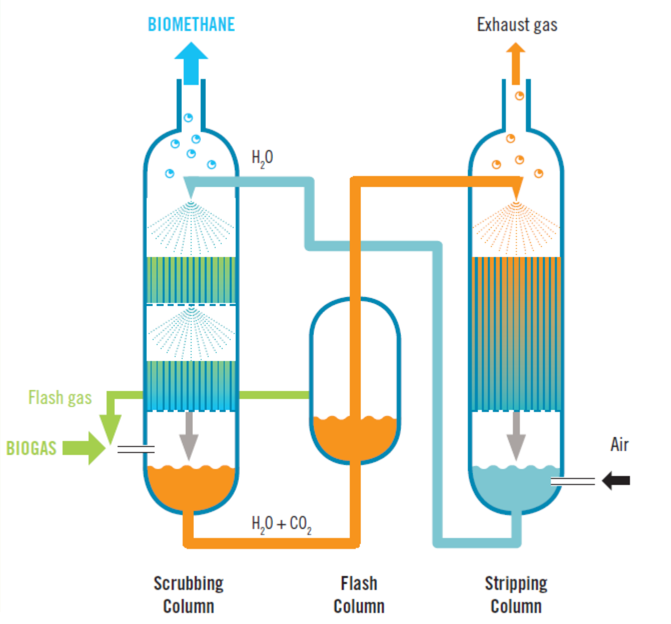
De-sulphuration process of biogas

Biological sulphur cleaning with in-situ oxygen or air injection in the biogas reactor.

Before acitivated carbon oxygen is added to improve the H2S adsoprtion.

From the biogas upgrading process

Where air is added as part of the upgrading process (e.g. water scrubbing)



A durable solution, allowing for a 100% green gas grid

Reducing oxygen level in the biomethane at the point of injection

- Removing oxygen is technically possible but can increase the cost of decarbonising the gas system.
- Costs of oxygen removal highly depends on plant size, upgrading technology and applied H2S content of the biogas before cleaning.
- Low oxygen limits for biomethane will be challenging for small-scale biomethane plants.

Removing it at gas storage facilities

- Gas storage facilities have limited experience with oxygen in the gas.
- Research needs to clarify the amount of oxygen gas storage facilities can contain.
- Cost for handling oxygen at the gas storage facilities will decrease if higher oxygen volumes can be handled.
- Costs depend on the number of gas storage facilities, which differs between countries.

Reaching the 35 bcm target: relevant standards for biomethane

Report on the importance of standards for the biomethane industry

1. CEN/CLC/JTC14/WG5 "**Guarantees of Origin related to energy**"
2. SECT/SF GAS I/JWG GQS "**Qas Quality Standards**"
   - TF3 "Oxygen"
3. CEN/TC 223 "**Soil improvers and growing media**"
4. CEN/TC 408 "**Natural gas and biomethane for use in transport and biomethane for injection in the natural gas grid**"

GREENMEUP

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decorte@europeanbiogas.eu

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DANISH EXPERIENCE OF BIOMETHANE AND ITS IMPURITIES

Solutions and challenges

Jesper Bruun, Energinet

CONTENT

Biomethane development in Denmark

Odorization

Biomethane trace components:

- Oxygen
- Terpenes
- Hydrogen
- Other

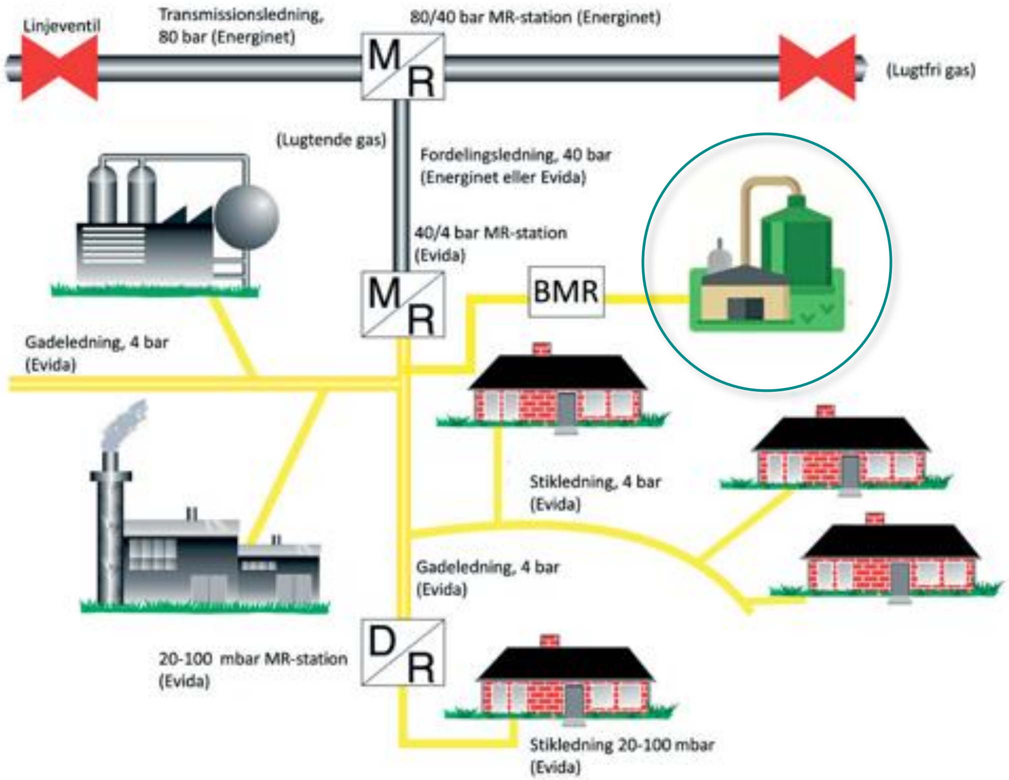
Summary

PRODUCTION OF BIOMETHANE

Biomethane is upgraded biogas

Biogas is produced from biowaste and biomethane is thus a renewable gas

Biomethane is injected into the distribution grid and – up until recently – consumed there



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SHARE OF BIOMETHANE

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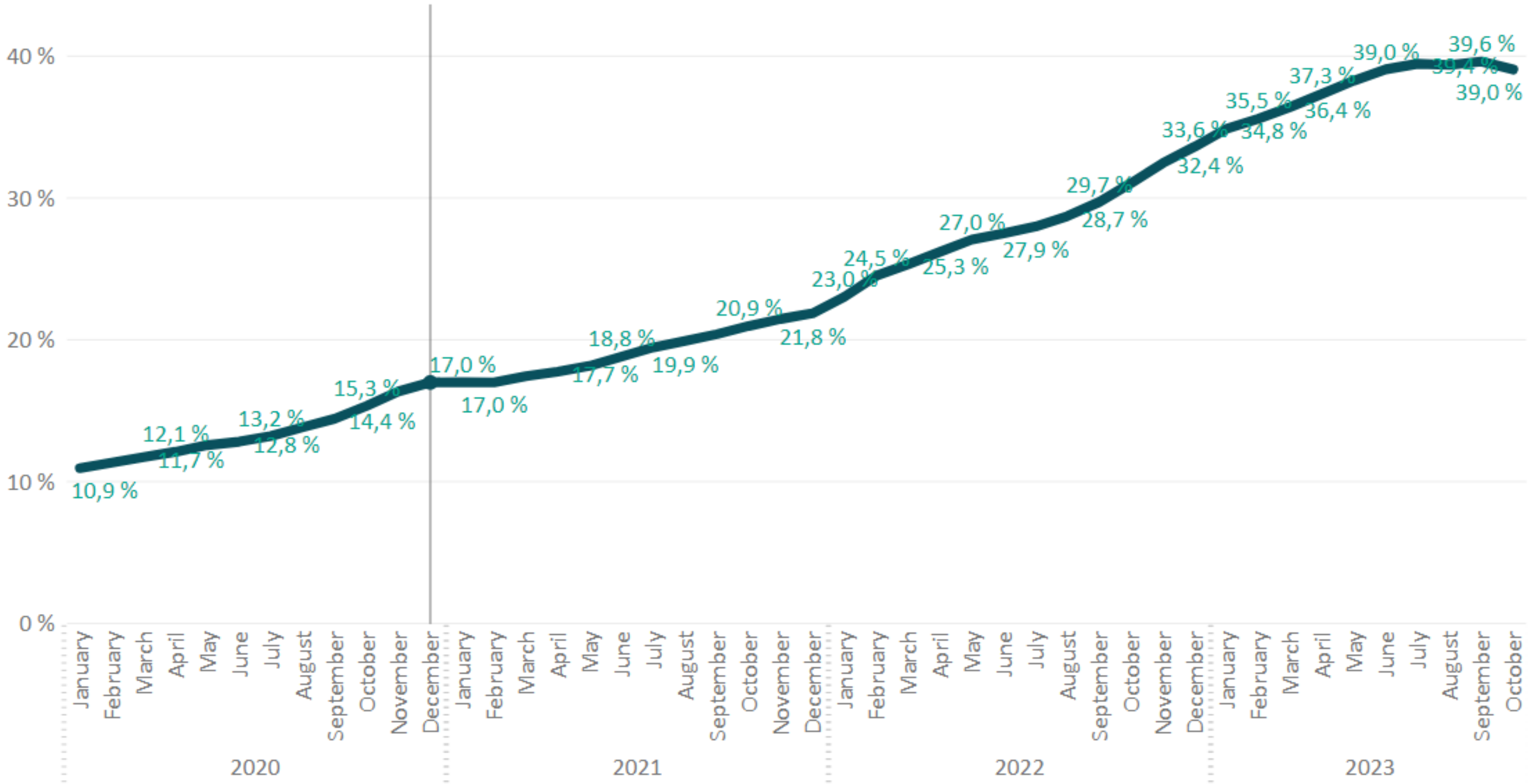
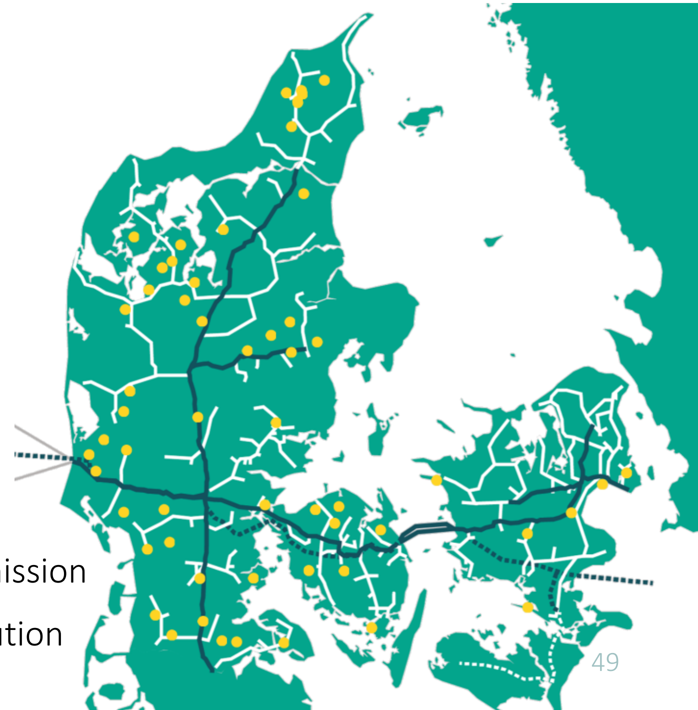
In relation to the last 12 months of production and Danish gas consumption



Source: https://en.energinet.dk/gas/biomethane/



Biomethane production

High pressure gas transmission

Low pressure gas distribution

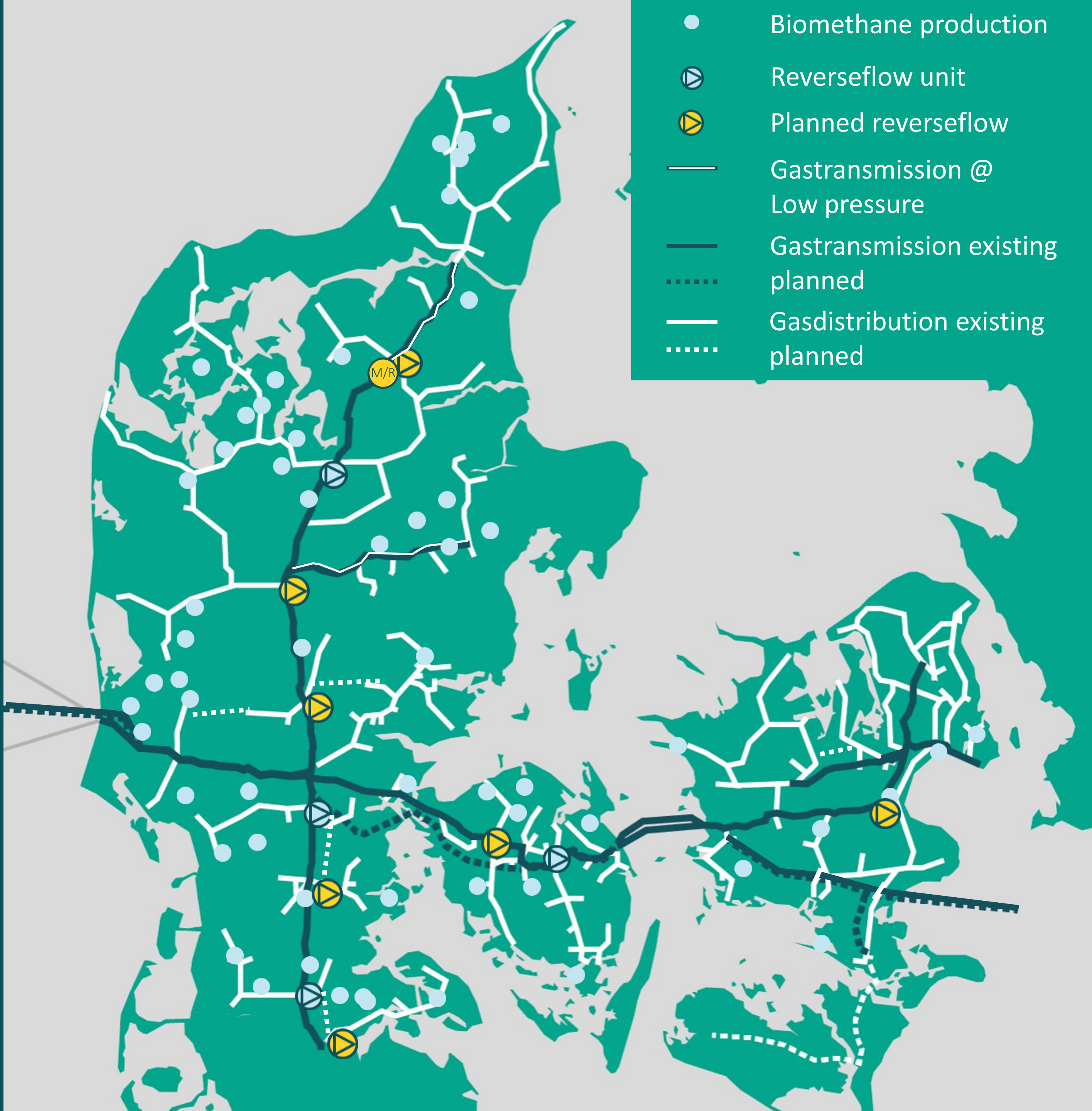
REVERSE BIOMETHANE FLOW

Compression of biomethane – injection into transmission grid

Six reverse flow facilities

Increased biogas production – more reverse facilities to come

First E-methane plant in operation November 2023 – deliver to the distribution grid

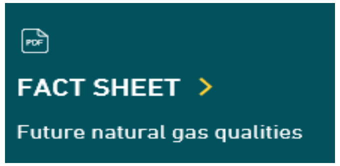


GAS QUALITY REQUIREMENTS IN DENMARK

Gas quality at the end-user is regulated in the Danish Gas Legislation called "Bekendtgørelse om gaskvalitet" under the authority of the Danish Safety Technical Authority (www.sik.dk).

Gas in the transmission system must meet the requirements in Energinet's General Terms and Conditions for Gas Transport (www.energinet.dk).

Future Natural Gas Qualities - Fact sheet
https://en.energinet.dk/Gas/Gas-Quality



Specific for biomethane
Ammonia (NH_3): max 3 mg/Nm3
Siloxanes: max 1 mg/Nm3

Parameter (unit)	Minimum value	Maximal value
Wobbe index (MJ/Nm3) - note 1	50.76	55.8
Wobbe index (kWh/Nm3)	14.1	15.5
Relative density (-)	0.555	0.700
CO_2 content (mole-%)	-	2.5
O_2 content (mole-%) - note 2	-	0.1
H_2S and COS content (mg/Nm3 as sulphur) - note 3	-	5
Mercaptans (mg/Nm3 as sulphur)	-	6
Total S content (mg/Nm3 as sulphur)	-	30
Water dew point at 70 bara (°C)	-	- 8
Hydrate formation at 70 bara (°C)	-	- 8
Hydrocarbon dew point at any pressure up to 70 bara (°C)	-	- 2

Note 1: A special preparedness plan for Ellund Border has been approved by the Danish Safety Technology Authority allowing gas with Wobbe index between 50.04 MJ/Nm3 to ~~55.8 MJ/Nm3 to be imported.~~
Note 2: Upgraded biogas is allowed with an oxygen content up to 0.5 mole-%.
~~Note 3: Peaks up to 10 mg/Nm3 are allowed in up to 2 hours if the daily average value is~~ below 5 mg/Nm3.

GAS QUALITY OF GREEN GASES

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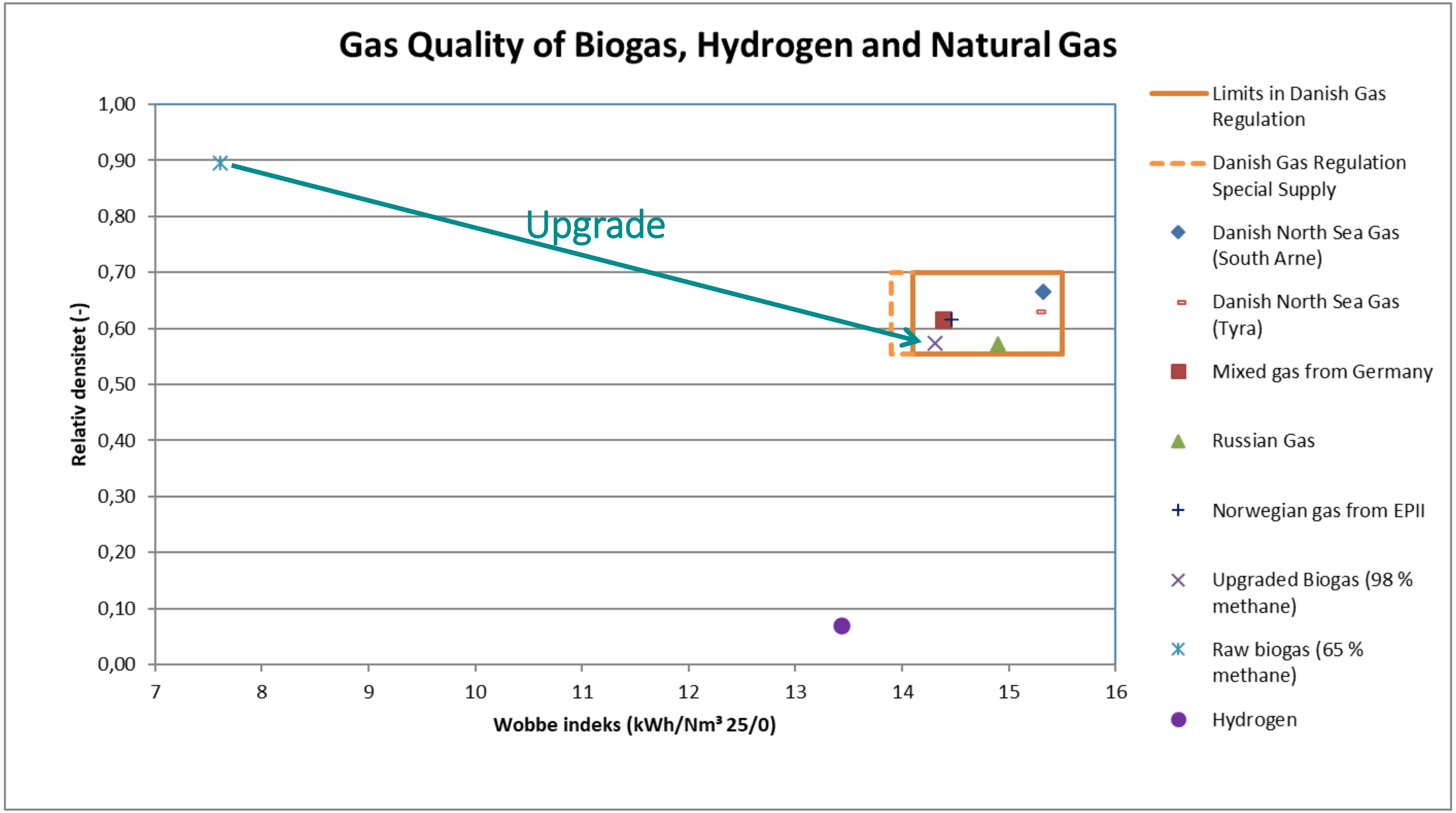


Source: 20/09059-9

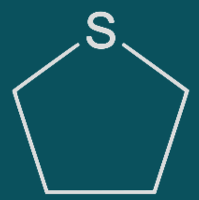
ODORANTS AND DEORDORIZATION

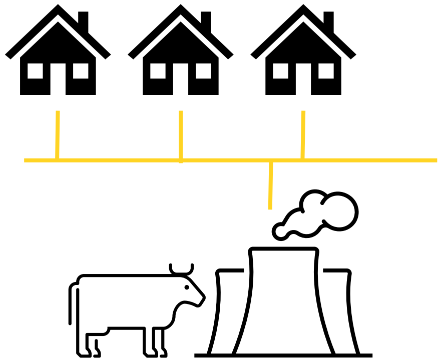
Injection of odorized gas from the distribution grid into the transmission grid requires **deordorization** due to requirements

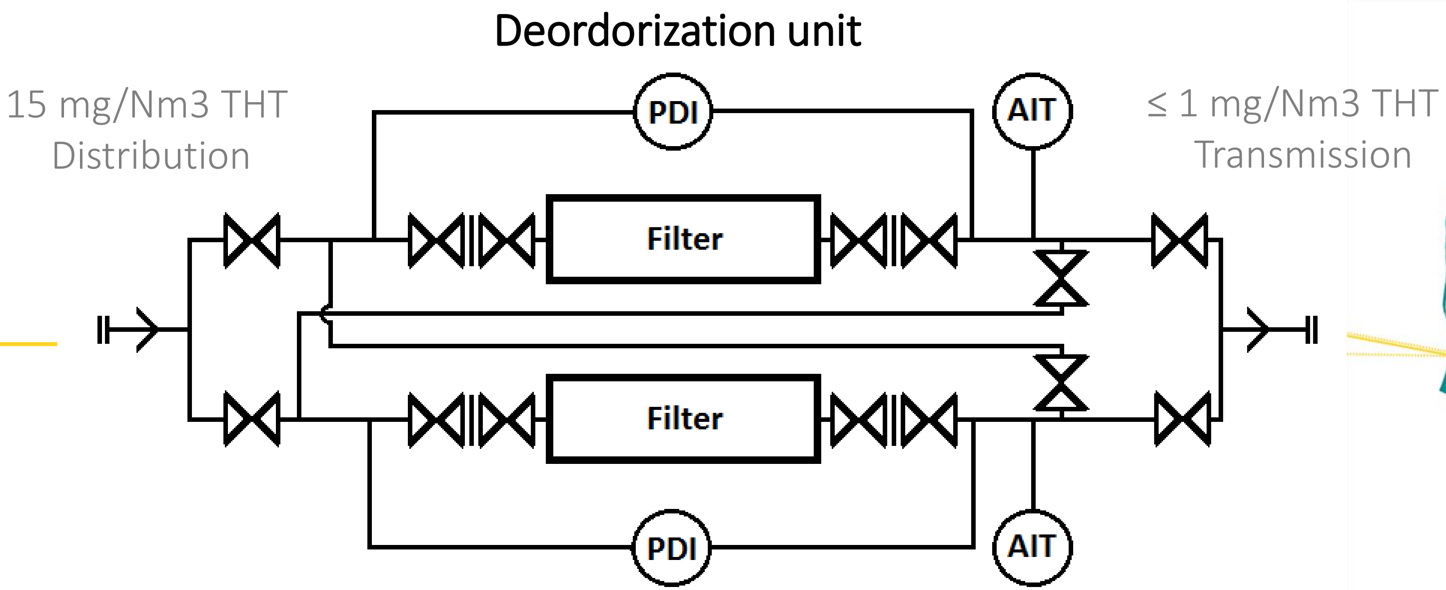
Deodorization units consist of filters operated in both series (maintenance) and parallel (redundancy)

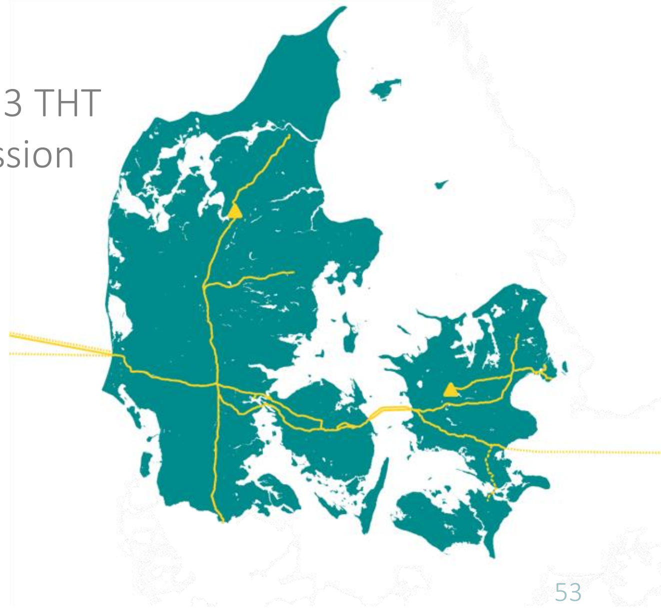
Solid, porous filter material for example active coal or others

Tetrahydro-thiophene (THT)









OXYGEN IN BIOMETHANE

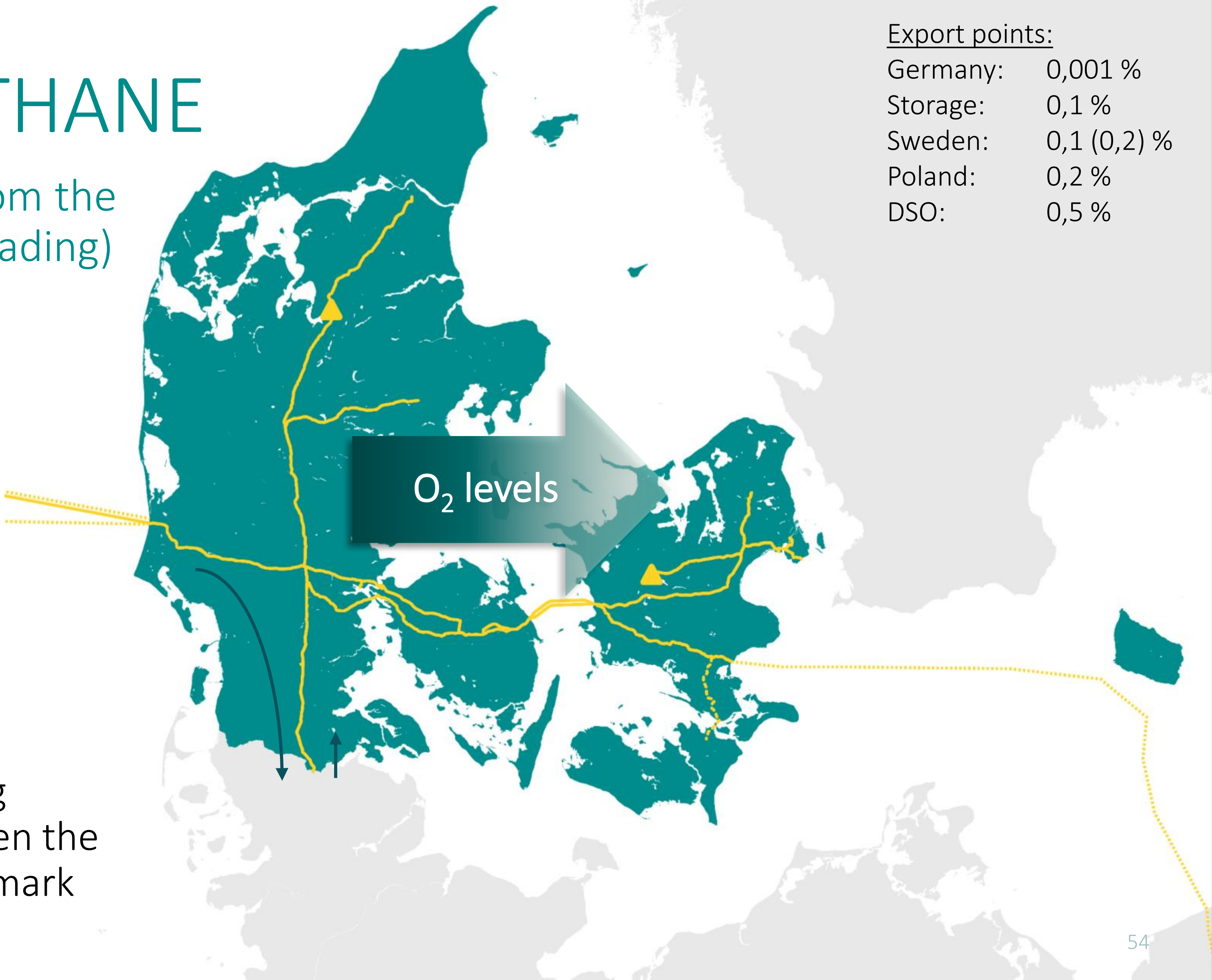
Surplus oxygen is in biomethane from the de-sulphurisation process (i.e. upgrading) of the biogas

Asymmetry in oxygen requirements demands different handling

Germany: Infrastructure development; sectioning of pipes for export/import. Reconfiguration of Egtved

Sweden and Poland: Dialogue and operational tools. Dilution

Storage: Oxygen levels monitored using SIMONE – ongoing cooperation between the System Operator and Gas Storage Denmark



<u>Entry points:</u>

Import:	0,1 %
Biomethane:	0,5 %

<u>Export points:</u>

Germany:	0,001 %
Storage:	0,1 %
Sweden:	0,1 (0,2) %
Poland:	0,2 %
DSO:	0,5 %

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TRACE ANALYSIS

Trace components in biomethane

Biomethane contains additional impurities, some of which we are only now becoming aware of.

Periodic samples (yearly) are used to track these components

Aromatics (BTEX): Measured but not directly regulated

Periodic gas analysis at a upgrading facility

		Februar 2021	Juni 2022	Maj 2023
Terpener				
tricylene	mg/Nm^3	-	-	-
α-pinen	mg/Nm^3	-	-	-
β-pinen	mg/Nm^3	0,02	0,03	-
camphene	mg/Nm^3	-	-	-
3-caren	mg/Nm^3	-	0,02	-
2-caren	mg/Nm^3	-	-	-
o-cymen	mg/Nm^3	0,01	0,02	0,07
d-limonen	mg/Nm^3	0,05	0,03	-
γ-terpinen	mg/Nm^3	-	0,01	-
terpinolen	mg/Nm^3	-	-	-
p-cymenen	mg/Nm^3	-	-	-
Aromatiske forbindelser				
benzen	mg/Nm^3	0,02	0,02	0,13
toluen	mg/Nm^3	-	-	0,04
ethylbenzen	mg/Nm^3	-	-	-
xylen	mg/Nm^3	-	-	-
Odorant				
THT	mg/Nm^3	15,00	15,00	15,0
Hydrogen	ppm			110

EXPERIENCES WITH TERPENES

Terpenes masks the smell of THT.

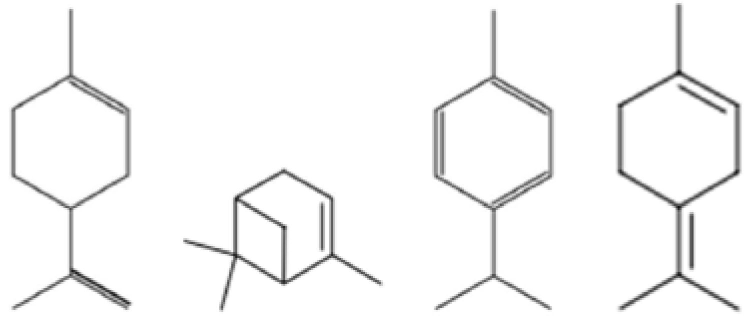
A number of challenges are related to the presence of terpenes:

- Terpenes may mask the smell of THT
- Possibly linked to the formation of black dust in compressors.
- Reduces lifetime of deodorisation units (early saturation of adsorbent).

The allowable content of terpenes are not regulated in Denmark.

- A limit of 13 mg/Nm^3 (2 ppm) has been suggested (KIWA study), but rejected by safety authority.
- If the limit is above 13 mg/Nm^3 they receive a letter with suggestions for reduction, e.g. change carbon filter, but no demands. (10/58 facilities)
- DSO responsibility to ensure that the gas can be still be smelled. Potential cut-off if the gas cannot be smelled.

Large seasonal variation
(linked to citrus fruit consumption).

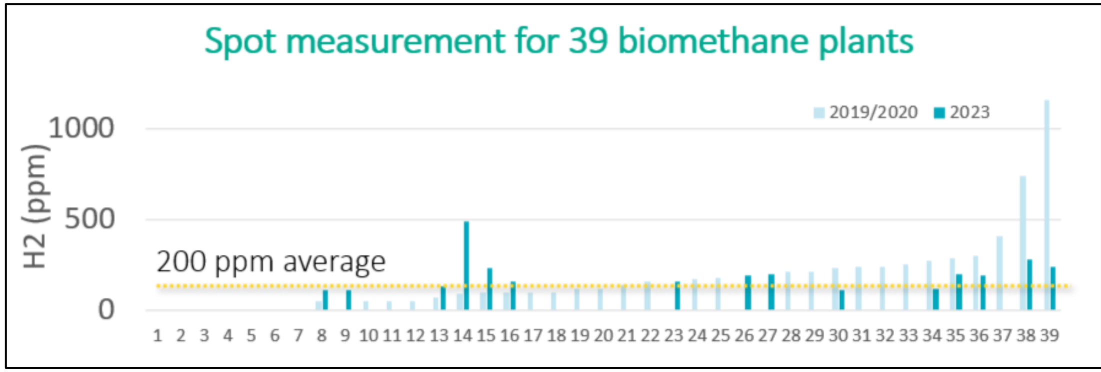


d-limonen α-pinen p-cymen terpinolen

Examples of terpenes naturally occurring in biomass.
Partly removed in carbon filters during upgrading.

HYDROGEN IN BIOMETHANE

Biomethane contains trace amounts of hydrogen



It was recently found, that most biomethane injected into the natural gas system contains small amounts of hydrogen.

This means that hydrogen is already present in the gas

DGC has made measurements of approx. 40 biogas facilities.

- Average hydrogen content: 200 ppm (0,02 %).
- Peak values up to 1200 ppm (0,12 %).
- <10 facilities below detection limit.

Glansager Biogas – delivers E-methane to the Danish system

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OTHER COMPONENTS

SILOXANES

Siloxanes are silicon-containing compounds.

Very dependent on the used substrate for biogas production.

The siloxanes have a bad habit to form solid silica (SiO_2) during combustion.

Limit in Demark is max 1 mg/Nm3

AMMONIA

Ammonia, NH_3, is most probable from the biogas, but may come from degradation of amine in an amine scrubber.

The limit in Denmark is 3 mg/Nm3.

Values above the limit have been observed, but with short peaks.

Is continuous measurement required?

UNKNOWNS…

The inert gas argon have been seen up-concentrated in biogas upgrading facilities, but not to significant levels.

Carbon mono-oxide, CO, could be an issue for e-methane but is not seen in biomethane.

Other?

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SUMMARY

New gasses => new contaminations => new challenges => new solutions

Odorisation:

- Odorant have to be removed when gas is back-flown from distribution to transmission
- a trace limit of max 1 mg THT/Nm3 have been formulated for transmission (earlier it was just "unodorised").

Oxygen is in the biomethane. Levels dependent on technology. Very different requirements in countries. Harmonisation of limits in EU would help the integration of biomethane in the system.

Terpenes comes from certain substrates. Very smelly and may interfere with the smell of odorant. The link between black dust and terpenes is so far non-conclusive.

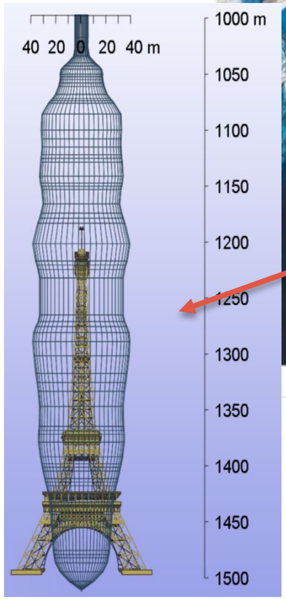
Hydrogen is in the biomethane as a trace component (levels about 200 ppm).

New contaminants will most probably occur in the future. This will have to be handled as well!

EXPERIENCE AND POTENTIAL ISSUES WITH BIOMETHANE IN UNDERGROUND STORAGE IN DENMARK

ENTSOG GAS QUALITY WORKSHOP - 15/11/2023

MIKAEL LÜTHJE - GAS STORAGE DENMARK



GAS STORAGE DENMARK

Lille Torup cavern storage
Capacity: 300 million m^3
Operating caverns: 5
Total caverns: 7

Stenlille Aquifer storage
Capacity: 580 million m^3
Total wells: 20
Wells for operation: 14
Observation wells: 6

The two storage facilities are operated as one virtual gas storage

Gas Storage Denmark can store 10 TWh and can deliver 7.5 GW for around 60 days

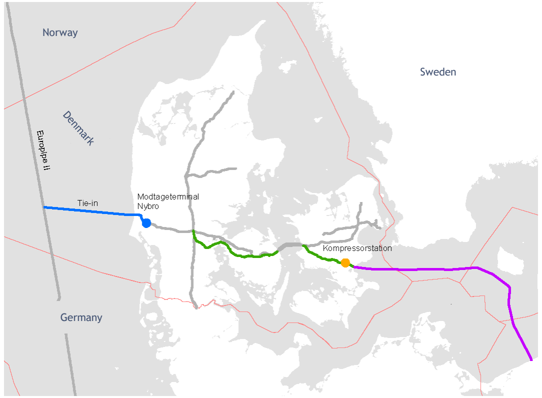
Denmark and Sweden uses around 30 to 35 TWh (gas) per year.

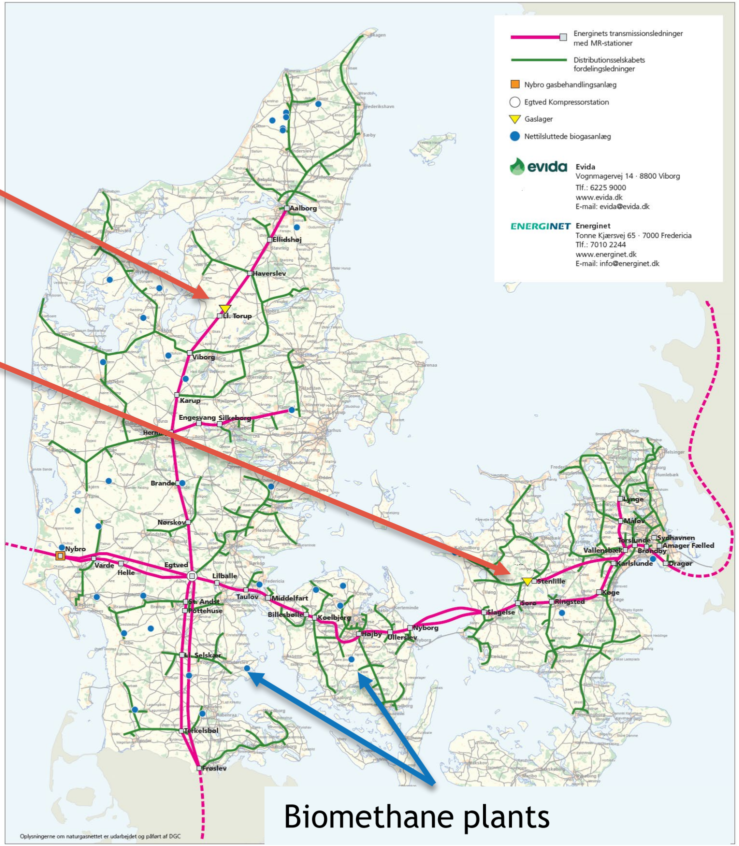
Denmark has an installed wind power capacity of 7 GW and produced 16 TWh in 2021

GREEN GASSES IN STORAGE

Lille Torup cavern storage in Northern Jutland

Stenlille aquifer storage, in central Zealand.

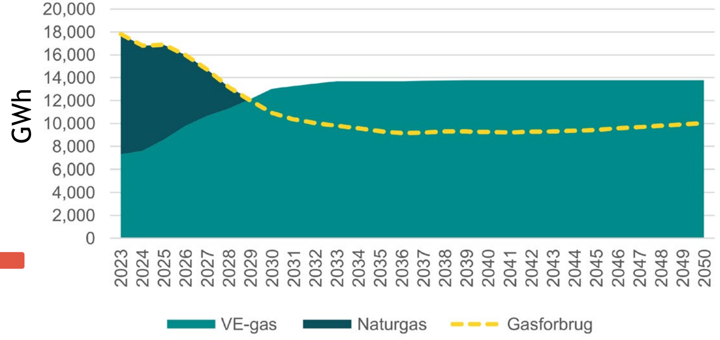


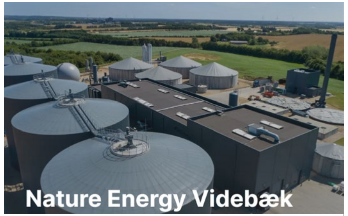


GREEN GASSES IN STORAGE

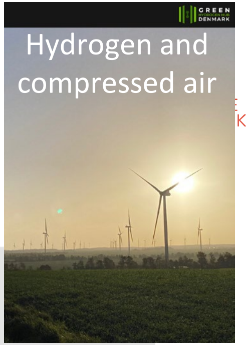
Gas Storage Denmark has a clear vision for green gases:

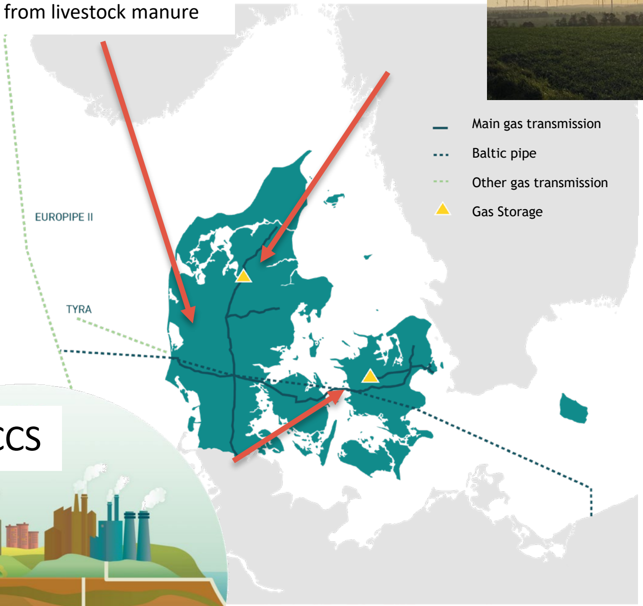
- Green gasses are going to dominate the grid in the coming decades.
- Gas Storage Denmark wants to play a significant role in offering solutions for the green transition.
- Currently, Gas Storage Denmark is developing Europe's first large-scale commercial on-shore CCS project (CO_2rylus).
- Additionally, Gas Storage Denmark is also working on converting two caverns for hydrogen and compressed air storage.

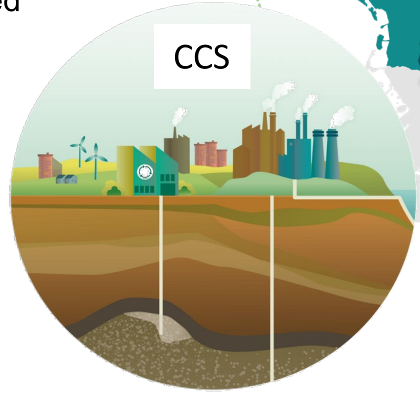




27.5 Mio. m^3 biomethane produced from livestock manure







BIOMETHANE IN LILLE TORUP CAVERNS

GSD GAS STORAGE DENMARK

Odorant (THT) in the caverns:

- Concerns about sulfur deposition (surface facilities).
- Concerns about interaction with other (future) gases.

Oxygen in the caverns:

- (Slight) concern about increased corrosion rates (surface facilities, wells).
- Less concern for the subsurface due to a small reactive surface area.
- Corrosion has always been an issue and has continuously been monitored. A slight increase in the corrosion rates poses no significant threat to the storage.

Strategy:

- Rapid filling of the caverns during the injection season of 2023 to avoid operation during the summer period when the risk of odorant in the system is highest.
- Studies on potential consequences for methane with traces of THT, O2, and H2 are ongoing.
- In conclusion, there are no significant worries regarding green gases in Ll. Torup cavern storage.

TO-X1

Differences in sonar measurements between January 2016 and November 2020.

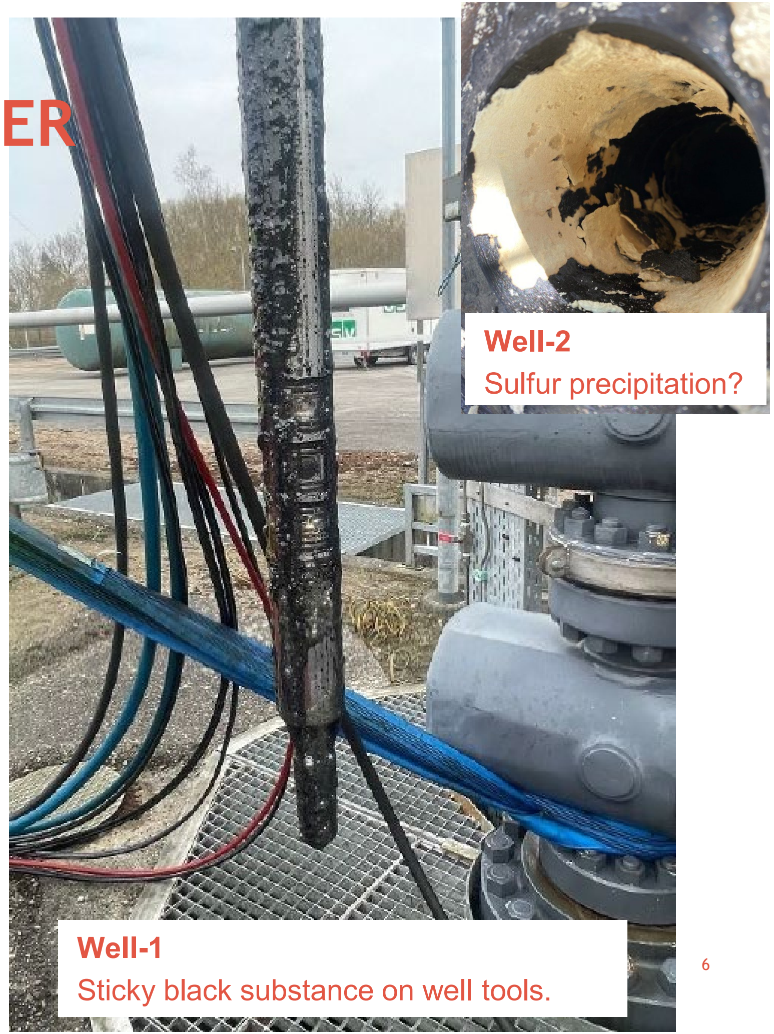
BIOMETHANE IN STENLILLE AQUIFER

Injection of oxygen-containing gas:

- Oxygen can create growth conditions for bacteria that can form biofilms and clog the pores in the reservoir.
- Oxygen can react with minerals in the subsurface.
- -Oxygen can participate in reactions with hydrogen sulfide (H_2S), forming elemental sulfur (S8).
- The highest risk occurs during periods of limited flow through Baltic Pipe.
- Possible risk of souring of the reservoir.

Experience:

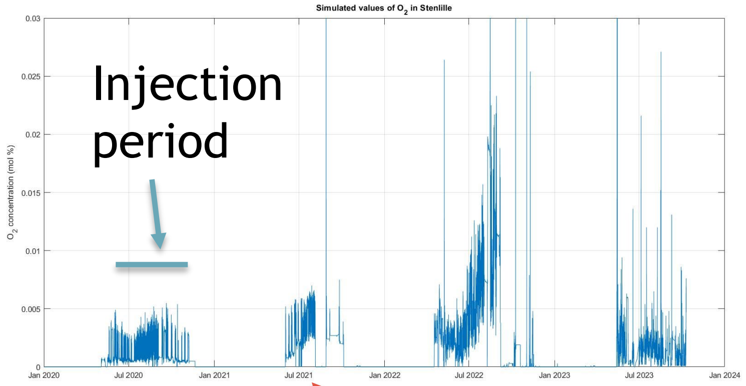
- Blockage of Well-1 in December 2022. Cause unknown
- Possible sulfur precipitation in the FC valve in Well-2 in December 2022.



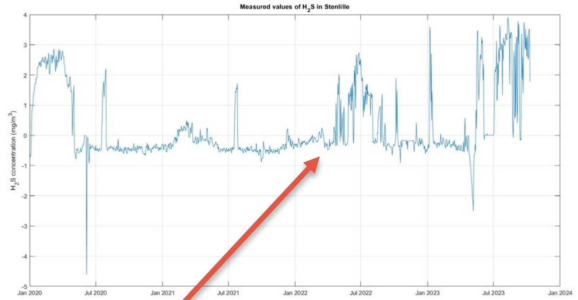
Well-1
Sticky black substance on well tools.

Well-2
Sulfur precipitation?

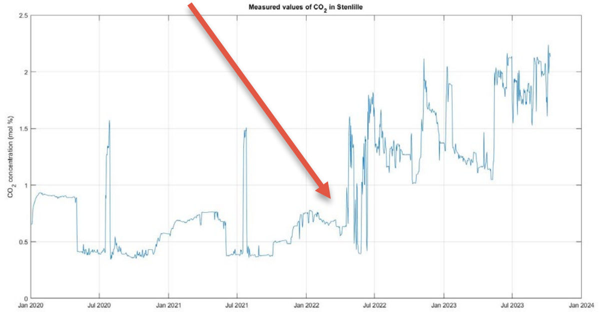
BIOMETHANE IN STENLILLE AQUIFER



Increase in O2 =? increase in biomethane



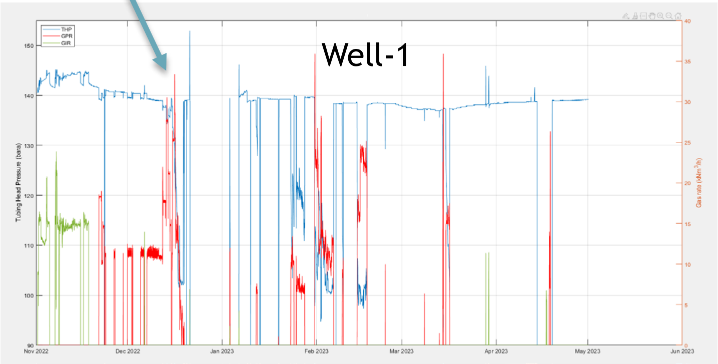
Change in gas composition (Baltic pipe / invasion of Ukraine)

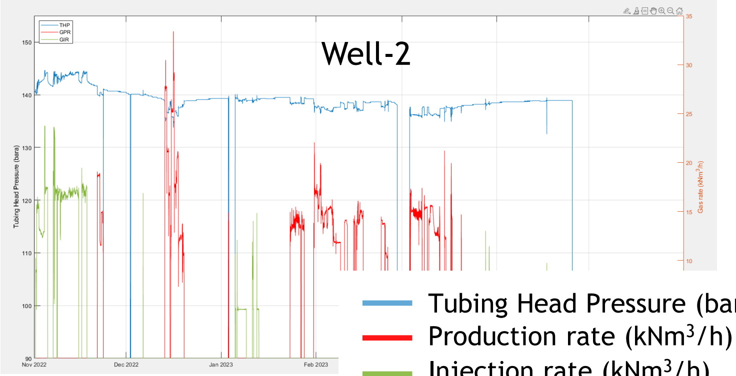


GSD GAS STORAGE DENMARK

Drop in pressure and production

8 g/kg Sulfur
78 g/kg Iron

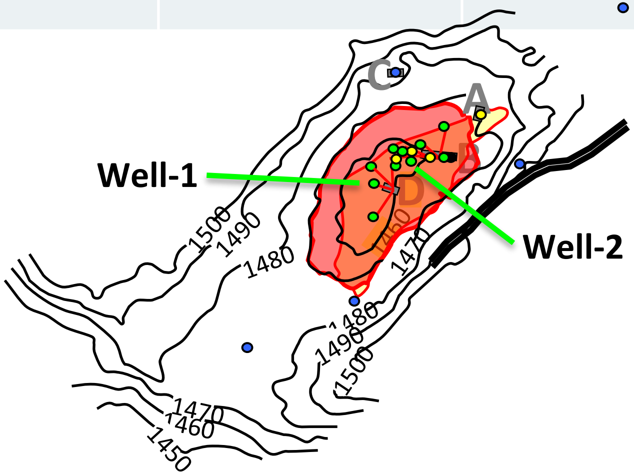




Tubing Head Pressure (bar)
Production rate (kNm^3/h)
Injection rate (kNm^3/h)

POTENTIAL EXPLANATIONS

Corrosion type	Pre-requisite	Effect
Corrosion/oxidation with oxygen – formation of rust	Water	Increased corrosion
Formation of black dust (iron sulfide) and free sulfur	Existing rust (see top left) as well as H_2S in the gas	Increased corrosion



Impact of biomethane injection on sulfur precipitation – Surface condition

→ Elemental sulfur (or S_8) forms from iron sulfides (FeS, FeS_2 or pyrite, etc.),
→ S_8 can precipitate where temperature and pressure drop below its condensation point,
→ The consequences: malfunction of valves, blocking of screens, enhanced corrosion of pipelines, etc.
The consequences are strongly depending on O_2 concentration.

For example, S_8 can precipitate from H_2S and O_2 in the presence of:

- iron hydroxides: $2Fe(OH)_3 + 3H_2S \rightarrow 2FeS + 6H_2O + \frac{1}{8}S_8$
- iron oxides: $4FeS + 6H_2O + 3O_2 \rightarrow 4Fe(OH)_3 + \frac{1}{2}S_8$

→ It is an autocatalytic process: the catalyst is one of the products of the reaction.
→ The formation of elemental sulfur can occur even in dry pipelines because the water necessary for the 2nd reaction is produced by the 1st reaction.

The successful prevention of sulfur formation, therefore, depends on the removal of hydrogen sulfide and/or oxygen from the system.

- Water (formation water) can potentially accumulate at the lowest points in the pipelines.
- The wells closest to the manifold will typically see the most fluid. This is the case for both Well-1 and Well-2.
- The presence of oxygen will increase the risk of corrosion and the formation of iron oxides. Any by-products from the corrosion processes could be injected into the reservoir.

BIOMETHANE - CONCLUSIONS

In conclusion:

- There may be issues regarding green gases in Stenlille aquifer storage.
- Possible solutions include a temporary halt to injection when O_2 content is above threshold and O_2 removal from gas before injection.
- Risk is difficult to quantify in advance. Logging from inspections and spikes must be followed to see a development in the corrosion rate over time.
- Problems can potentially occur anywhere in the plant and at different speeds due to different combinations of gas composition and different pressures and temperatures.
- More knowledge is needed to quantify risks.

Strategy for now:

- Avoid operation during periods of high oxygen concentrations.
- Oxygen meter purchased.
- Laboratory studies of reservoir samples.

GAS STORAGE DENMARK

O_2 level management : towards convergence at interfaces to meet European biomethane targets

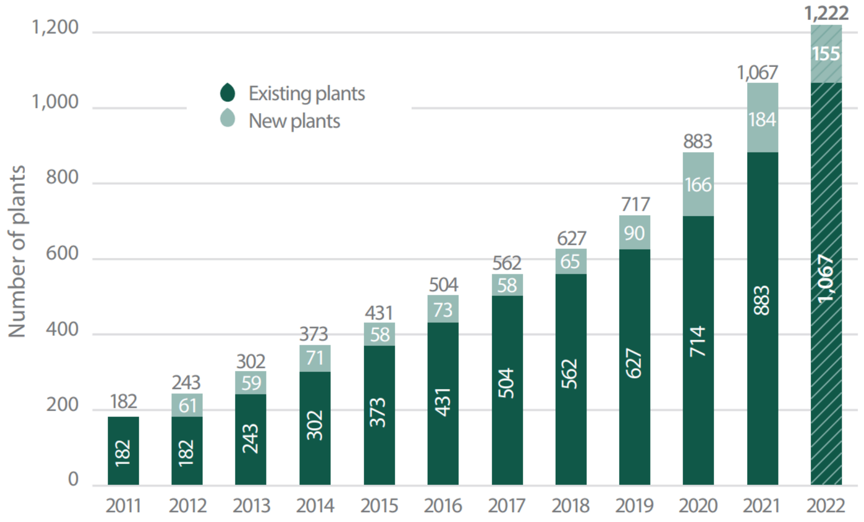
GRTgaz experience

ENTSOG Gas Quality Workshop

15 november 2023

Repower EU : from 4 to 35 bcm biomethane injected in 8 years

2022 : 4 bcm of biomethane injected into gas networks



Source : EBA Statistical Report 2022

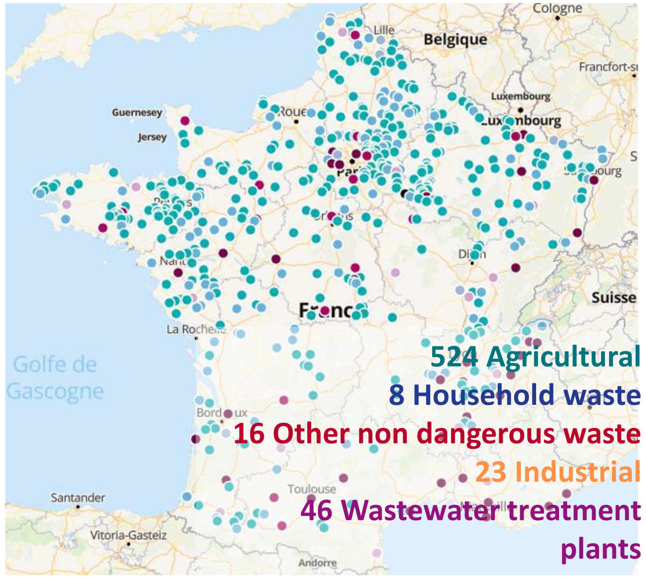
2030 : an ambitious target of 35 bcm of biomethane

- **Renewable gases** (mainly from agricultural waste and residues) will play a key role in achieving RepowerEU's objectives
- This target is consistent with the **biogas potential** in EU countries (estimated at 41 bcm in 2030)
- To achieve this objective, several levers have been identified :
  - Upgrading **biogas facilities** (potential of 17 bcm)
  - Implement favorable **market framework and incentives**
  - Investment **in biomethane production** (estimated at 80 billion €)

To achieve these ambitious biomethane production targets in Europe, the restrictions linked to gas quality in the networks must evolve, particularly regarding O_2.

A rapid development of biomethane in France

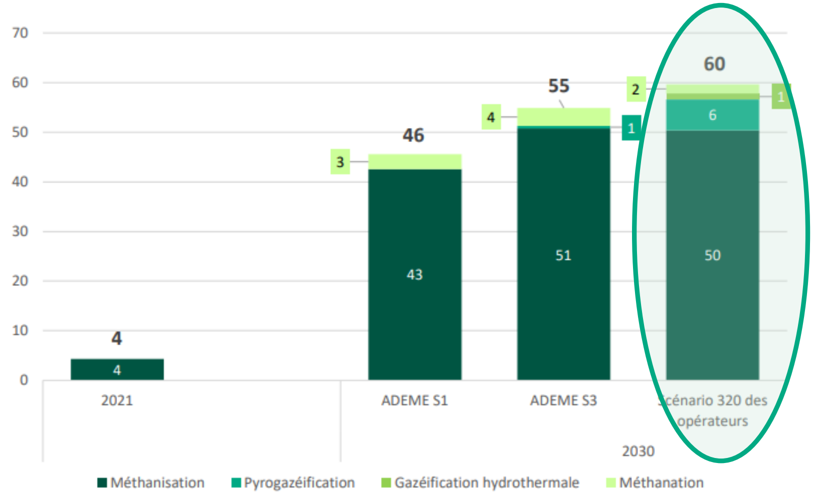
September 2023 : 1 bcm of biomethane injected into the network



- **617 units** in service
- **13%** of these units inject directly into the **transmission grid =20%** total biomethane

2030 : Target of 5 bcm (50 TWh) of biomethane injected

Projection of renewable and low-carbon methane production to 2030 (in TWh PCS)



Sources : Perspectives Gaz 2022, GRTgaz, Teréga, GRDF

Current O_2 constraints for GRTgaz

Regulations and standards

European Standards / Texts

- CBP EASEE GAS (2005) : **O_2 < 10 ppm daily average with up to 100 ppm** if UGS using activated carbon desulphurization
- NF EN 16726 **(under revision)** : at network entry points and interconnection points, the O_2 content shall not exceed **10 ppm expressed as a daily average**, up to 1% if no sensitive customers

French Regulations

- **O_2 not defined** in the decrees of 16/09/1977; 28/03/1980; 28/01/1981
- Decree of 08/12/2017 relating to the characteristics of CNG and (LNG) intended for fuelization : **O_2 < 1% (10.000 ppm)**

GRTgaz technical specifications

- **O_2 < 100 ppm** at network entry points, **derogations are possible up to 4.000 ppm** for injection contracts with biomethane producers
- **Not defined for gas delivered** : no mention of O_2 in consumer contracts

O_2 levels at network interfaces

French UGS

15 locations with a sensitivity related to the total quantity of oxygen (level + duration) :

- Level of derogation to date : relaxed position from 10 ppm/day in the IOAs in coherence with GRTgaz technical prescriptions
- R&D work in progress to further ease the constraints

Adjacent TSOs

Acceptable **O_2 levels are defined in the IOAs** :

- Some adjacent TSOs use the 10 ppm/day in the EN16726 as a strong reference for O_2 levels at IPs
- Other TSOs have more relaxed position on O_2

Biomethane producers

Derogations from the technical requirements are granted to producers in their injection contracts :

- To date, these derogations can be **up to 4.000 ppm**
- At the launch of the biomethane injections, some projects were granted derogations of up to 7.000 ppm

Consumers

19 sensitive industrial units identified (mainly SMR). Sensitivity identified to date at 1.000 ppm. No specification in the contract.

Observations to date: a need to rapidly reassess O_2 constraints

O_2 derogations for producers

- Historically, **producers have been granted derogations from technical requirements** concerning the O_2 content of biomethane injected into the network. This choice was made to **enable the biomethane sector to launch**, as a strong constraint on O_2 could weigh heavily on the viability of a project

Multiplication of O_2 peaks at sensitive interfaces

- With the growing number of biomethane and reverse-flow units, the proportion of biomethane in the transmission system is becoming ever greater, leading to a **multiplication of O_2 "pockets"**
- Once biomethane reaches the transmission system, it can be delivered to any point on the network. **"Pockets" of O_2 can reach sensitive interfaces** (sensitive consumers, UGS, adjacent TSOs)

O_2 must be managed differently to meet biomethane targets

- **Gas blending solutions** have been implemented to manage the first appearances of O_2 pockets, but **these solutions are reaching their limits**, either because the network configuration does not allow it, or because they represent a significant cost (both economic and environmental)
- The **situation will continue to deteriorate** in the future if no action is taken, as the **share of biomethane in the gas mix must continue to grow**

The development of biomethane is leading to an increase in O_2 peaks at sensitive interfaces (sensitive customers and adjacent operators such as TSOs or UGS), which can no longer be managed by specific network management actions

Long-term outlook : define O_2 level management consistent with biomethane objectives

A dedicated Task Force has been set up at GRTgaz to define a target O_2 level, acceptable to biomethane producers, sensitive customers and adjacent operators (TSOs and USGs)

The Task Force carries out various actions (R&D, standards revision, network studies, partnerships etc.), in consultation with all the French operators concerned (UGS, TSOs, DSOs)

Upstream (gas injection)

- **Study** of different **O_2 regulation and treatment solutions**, on-site **tests**
- **Identify best practices** of producers, draft **recommendations for manufacturers**

*A large number of production sites, distributed across the network, with strong growth perspectives : **difficult to address***

Network

- **Network studies** (flow trends, trajectories)
- **Study of deoxygenation solutions** at critical points in the network

Downstream (gas supply)

Sensitive customers

- Assessment of O_2 levels acceptable to sensitive customers, ongoing exchanges
- Study of the possibility of upgrading industrial processes or on-site O_2 treatment

UGS

- Ongoing study of the impact of O_2 on storages
- Easing of O_2 constraints in inter-operator agreements (in progress)

TSO

- Revision of EN16726 standard
- Exchanges with adjacent TSOs to ease O_2 constraints

*A very limited number of interfaces, stable over time: **actions to prioritize***

Conclusions on O_2 management to reach the European target of 35 bcm of biomethane

- Oxygen is already a concern for GRTgaz in terms of flow management, and with strong expectations for biomethane in Europe, there is an **urgent need to address this O_2 issue**.
- It is necessary to **define a target O_2 level that is compatible with all interfaces** and that does not restrict the development of the biomethane sector. A **joint effort by producers, TSOs and UGSs** is needed to ensure the future of gas infrastructures.
- In France, a **dedicated inter-operator program** was launched several years ago and is already **showing significant results**, with the easing of constraints on many interfaces (UGS, sensitive customers, some TSOs).
- GRTgaz and the French operators are **available to share the studies carried out and the results obtained**, in order to act rapidly and uniformly on a European scale.
- The **evolution of the standard would already be a first step in facilitating the development of biomethane**, revised EN16726 should not stick to 10 ppm in our point of view.

Thank you

3. Synthetic methane: projects and first injections in Europe

Synthetic methane: projects in France, gas quality and R&D

ENSTOG Gas Quality Workshop
15/11/2023

Claudia Paijens – Research engineer in gas quality
Dairo Ballestas Castro – NewCH4 R&D program coordinator

Table of contents

Introduction

Renewable and low carbon gases in France

- **Renewable gas:** biomethane and some synthetic methanes

→ Definition from the French **Energy Code**:

Gas coming from biomass

- **Low carbon gas:** some synthetic methanes

→ Definition from the French **law n° 2023-175 of the 10th March 2023** concerning the **acceleration of the production of renewable energy:**

A *gas mainly composed of methane, which can be safely injected and transported in the natural gas grid and coming from a production process that generates emissions lower than or equal to the threshold value targeted by the government.*

OBJECTIVE IN FRANCE

To reach

20%

of reneweable gases in the national mix in

2030

French gas consumption in 2021: 466 TWh

Introduction

New methanes – Current state of the development of the different sectors

R&D & demonstration units → Starting under preparation → Industrialized

Hydrothermal gasification

Power-to-Methane

Short demonstration of production and injection in 2022
Operational injections into the French grid expected for 2024

Methanization

> 600 injection sites

Pyrogasification

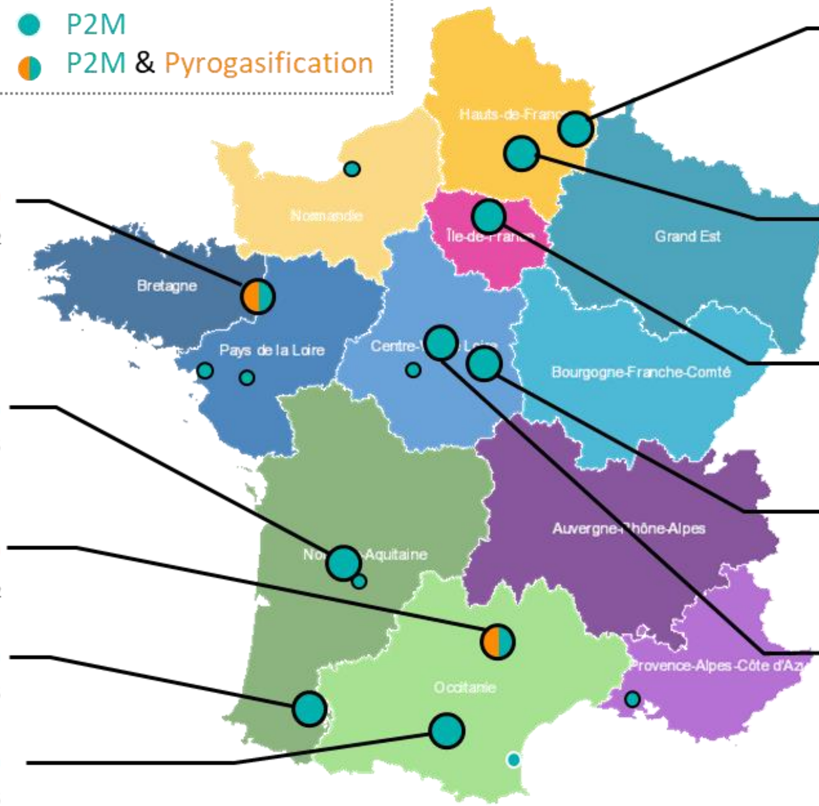
49 identified projects

Call for expression of interest in 2022
First injections into the French grid expected for 2026

Projects in France

Power-to-methane

- P2M
- P2M & Pyrogasification



HYMOOV Châteaubourg (35)
1200 Nm^3/h – Wood waste + H_2

CUMA Saint-Pierre d'Eyraud (24)
130 Nm^3/h – $H_2 + CO_2$ from agricultural biogas

HYMOOV Onet-le-Château (12)
1200 Nm^3/h (2025) – Wood waste + H_2

Pau'wer-Two-Gas Lescar (64)
60 Nm^3/h – $H_2 + CO_2$ from sewage sludge biogas

OCCI-BIOME Saint-Amadou (09)
120 Nm^3/h – $H_2 + CO_2$ from agricultural biogas

DENOBIO Lesquielles-Saint-Germain (02)
50 Nm^3/h – $H_2 + CO_2$/agricultural biogas

ENERGO Sempigny (60)
2,5 Nm^3/h (july 2022) – $H_2 + CO_2$ from agricultural biogas

STEP de Bonneuil Bonneuil-en-France (95)
50 Nm^3/h – $H_2 + CO_2$ from sewage sludge biogas

MarHySol Marmagne (18)
150 Nm^3/h – $H_2 + CO_2$ from agricultural biogas

Méthycentre Angé (41)
13 Nm^3/h – $H_2 + CO_2$ from agri

Sources: *Open Data Réseaux-Energies*

Non-exhaustive map

(Only public projects with exepcted injection in the French distribution gas grid)

Projects in France

Pyrogasification – Call for expression of interest

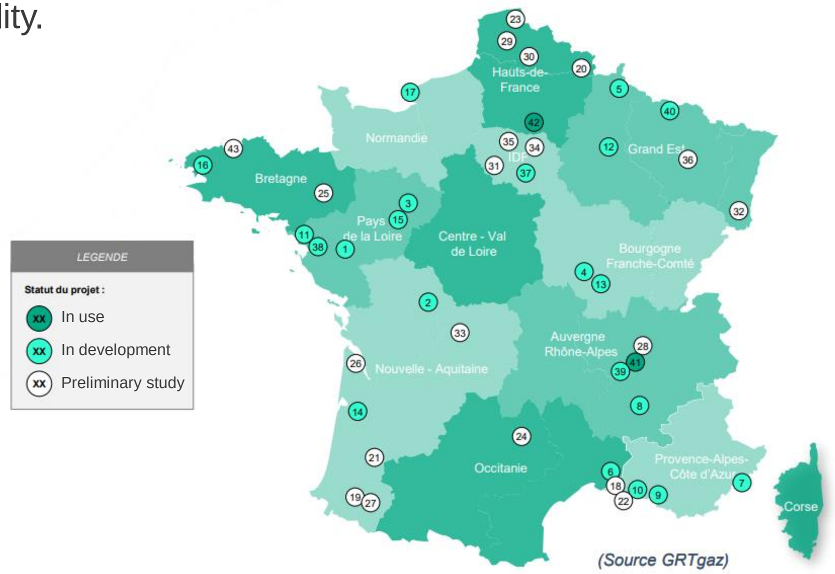
Call organized in 2022 ***CSF NSE***
and managed by ***GRTgaz***

49 projects were identified

- **Aims of the call for expression of interest**
  - Draw up the **current state of this sector / identify the projects** for the further establishment of the experiment contracts
  - **Support the projects**: proposal structuring, access conditions to the gas grid, gas quality.

- **Sector with an important development potential** (up to 90 TWh/year in 2050), the results of this call confirm the interest of this sector for methane production
  - Mainly biomass and slightly treated wood, but a few projects with solid recovered fuel
  - Up to 1,3 Mt of **residual waste** treated per year

- **A launching of a call for projects is expected next year** by public authorities in France – **Injection** of gases from **pyrogasification** from **non fermentiscible biomass / waste**



(Source GRTgaz)

Projects in France

R&D projects – Raw synthetic methane

SYNTHANE

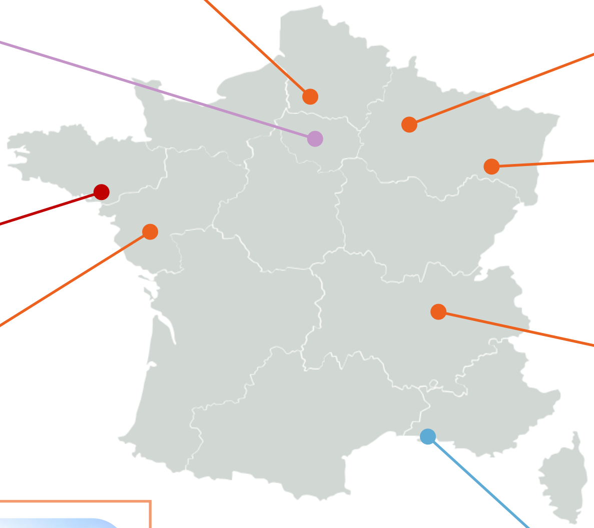
Pyrolyse + methanation

METHAGRID 2

Biological methanation

COMETHA

Methanization + gasification + methanation



PLAINÉNERGIE
Phase 2
Pyrogasification + methanation

Potential injectable quality

GHAMa
Hydrothermal gasification + methanation

GAYA

Pyrogasification + methanation

TITAN 5

Pyrogasification + methanation

JUPITER 1000

Power-to-Methane + H_2

Gas quality specifications for synthetic methane

New methanes – R&D issues concerning gas quality

Emergence of new sectors: obtain compatible gas with the value chain of natural gas

New gas matrices: Deep knowledge of these gases

Potential impacts: Assess and control them

Injection: Reduce the costs and make reliable the control of the injected gas quality

Gas quality specifications for synthetic methane

New methanes – 4 complementary sectors

Methanization → **Biomethane**

CH_4 + CO_2
(+ traces including O_2)

Power-to-Methane (P2M) → **Synthetic methane**

CH_4 + CO_2, H_2
(+ traces)

Pyrogasification → **Synthetic methane**

CH_4 + CO_2, H_2, CO, $C2^+$
(+ traces)

Hydrothermal gasification (HG) → **Synthetic methane**

CH_4 + CO_2, H_2, CO, $C2^+$
(+ traces)

Injection

Gas quality specifications for synthetic methane

Specifications for biomethane & evolution for synthetic methanes

Towards the modification of the threshold values of 3 parameters in France

- H_2: < 2%
- CO: < 0.1%
- Density : 0.500 à 0.700

Compatibility with most of **uses**

In **accordance** with the **revision of EN 16726**

The targeted composition of produced gas is **technically achievable**

Current monitoring strategy for biomethane

- Online measurements: CH_4, CO_2, O_2, N_2
- Regular sampling and analyses in laboratories: NH_3, Hg, total Cl & F, sulfur compounds, H_2 & CO, siloxanes for some operators

Monitoring strategy for synthetic methane

- Online measurements : CH_4, CO_2, O_2, N_2, **H_2 & CO**

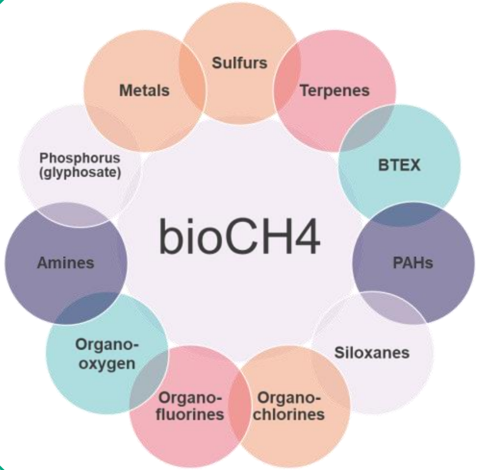
→ Scientific watch on analyzers & assessments

- Regular sampling and analyses in laboratories : NH_3, Hg, total Cl & F, sulfur compounds, siloxanes for some operators

→ Other trace compounds to consider?
Analysis of raw gases

Strategy to deepen our knowledge on synthetic methane quality

The CARABIO project & extrapolation to synthetic methane



CARABIO

Deep characterization of biomethane to **allay the doubts**

80 Analysis campaigns of biomethane

TERĒGA storengy GRTgaz GRDF

- **> 600** measured compounds & impact assessement
- Input for **biomethane acceptation** in storage facilities
- **Methodology that can be extrapolated** to synthetic methanes

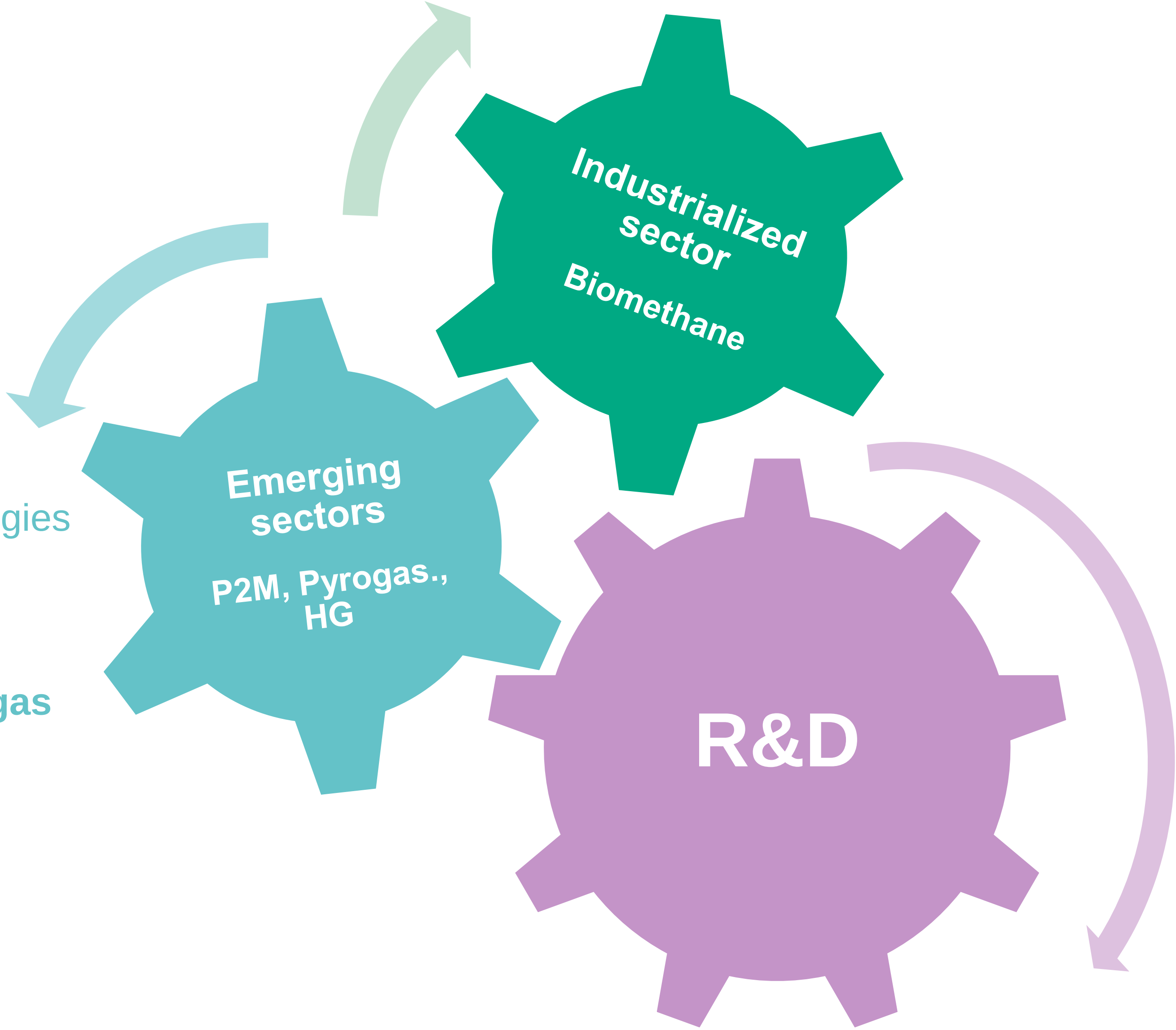
Useful knowledge for the emerging sectors

Successfully applied to gas produce by a few demonstrators (GoBiGas, BioCat or ENERGO)

Deep analysis strategy with sampling and analysis campaigns on raw gases to anticipate further monitoring of the synthetic methane quality, i.e., the parameters to follow (VOCs, inorganic halogens, etc.) and the needed method developments

Conclusion

- Optimization of injection



- Increase maturity of production technologies
- Knowledge on gas composition
- Evaluation on potential risks

→ **Ensure the obtention of the required gas quality**

Thank you !

For more information: claudia.paijens@grtgaz.com & dairo.ballestas@grtgaz.com

METHAREN project: an innovative pathway to produce renewable methane

José A. Lana

Enagás Transporte SAU

ENTSOG Gas Quality Workshop, 15th November 2023

This project has received funding from the European Union's Horizon Europe Research and Innovation programme under Grant Agreement No. 101084288.

REPowerEU

➢ A 300-billion-euro plan of the European Commission to help secure energy supply and accelerate the ecological transition

DOUBLING THE EU AMBITION FOR BIO METHANE AND PRODUCE 35 BILLION CUBIC METERS PER YEAR BY 2030

R&I in innovative technologies are needed to boost the bio methane and renewable fuels production.

- Twenty R&I projects in Horizon 2020 (€120 million) focused on innovative technologies for production of sustainable bio methane. The results will be integrated on bio methane grid access.
- Two additional R&I projects were awarded on bio methane barriers and enablers deployment (€30 million).

Research effort in Europe for innovative biomethane

HYDROGEN EUROPE

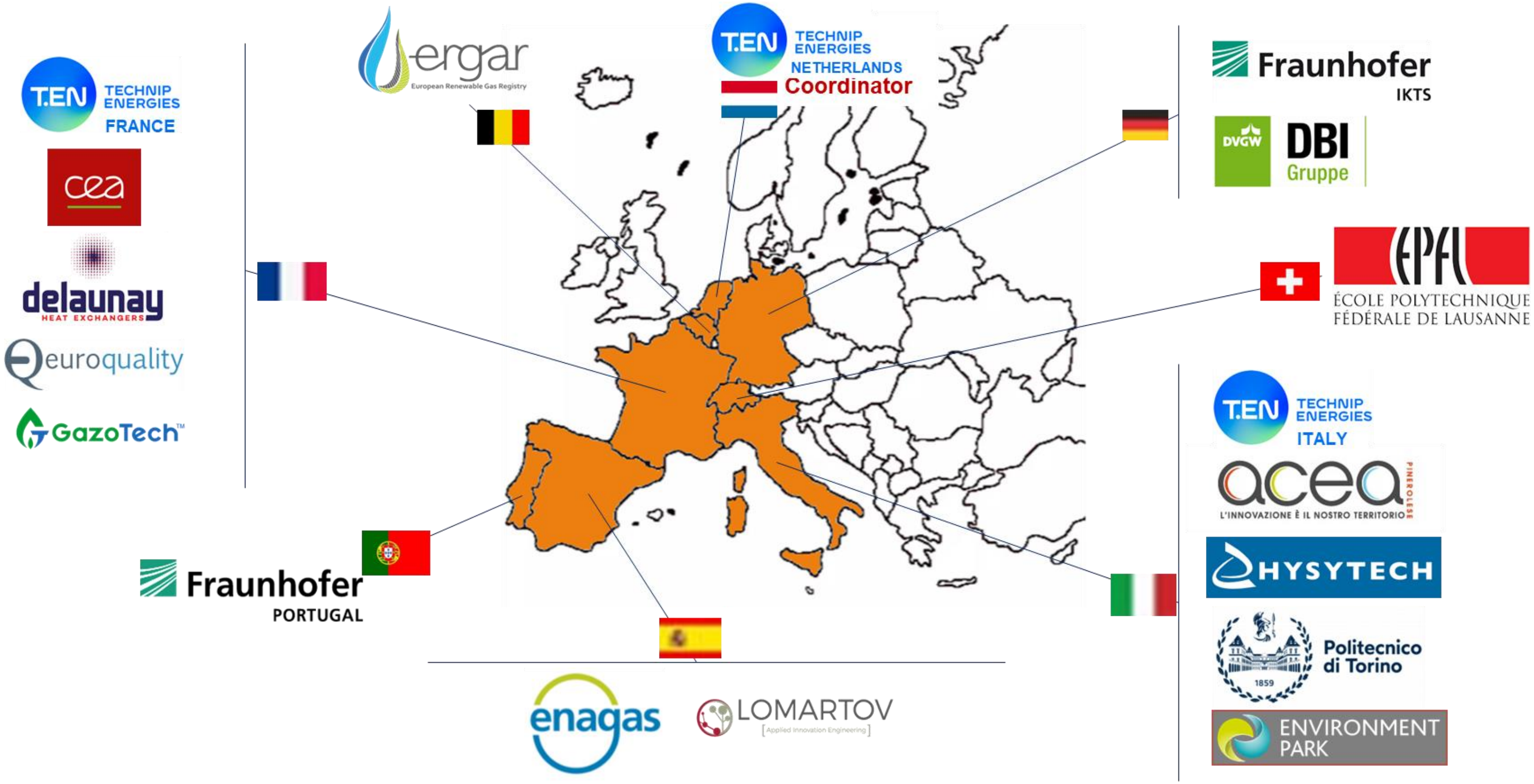
- Call: Sustainable, secure and competitive energy supply
  - HORIZON-CL5-2021-D3-03
- Topic: *Innovative biomethane production as an energy carrier and a fuel*
  - HORIZON-CL5-2021-D3-03-16

Four projects selected:

- *BIOMETHAVERSE*
- *HYFUELUP*
- *SEMPRE-BIO*
- *METHAREN*
  - *5 years duration: 1/11/2022 – 31/10/2027*
  - *Budget, 13.76 k€ (funded by EC 10.36 k€)*

METHAREN Consortium

- 8 countries, 18 partners



Objectives of METHAREN

Optimizing biomethane production

- Extraction of value from biogenic-CO2 and discarded residues, to increase by 150% the overall production capacity of biomethane while reducing the overall production costs

Transforming biomethane into a flexible renewable energy carrier

- Demonstrate the system efficiency to manage the RES intermittency by transforming continuously any electron in biomethane as a flexible renewable energy carrier, minimizing use of electric storage devices

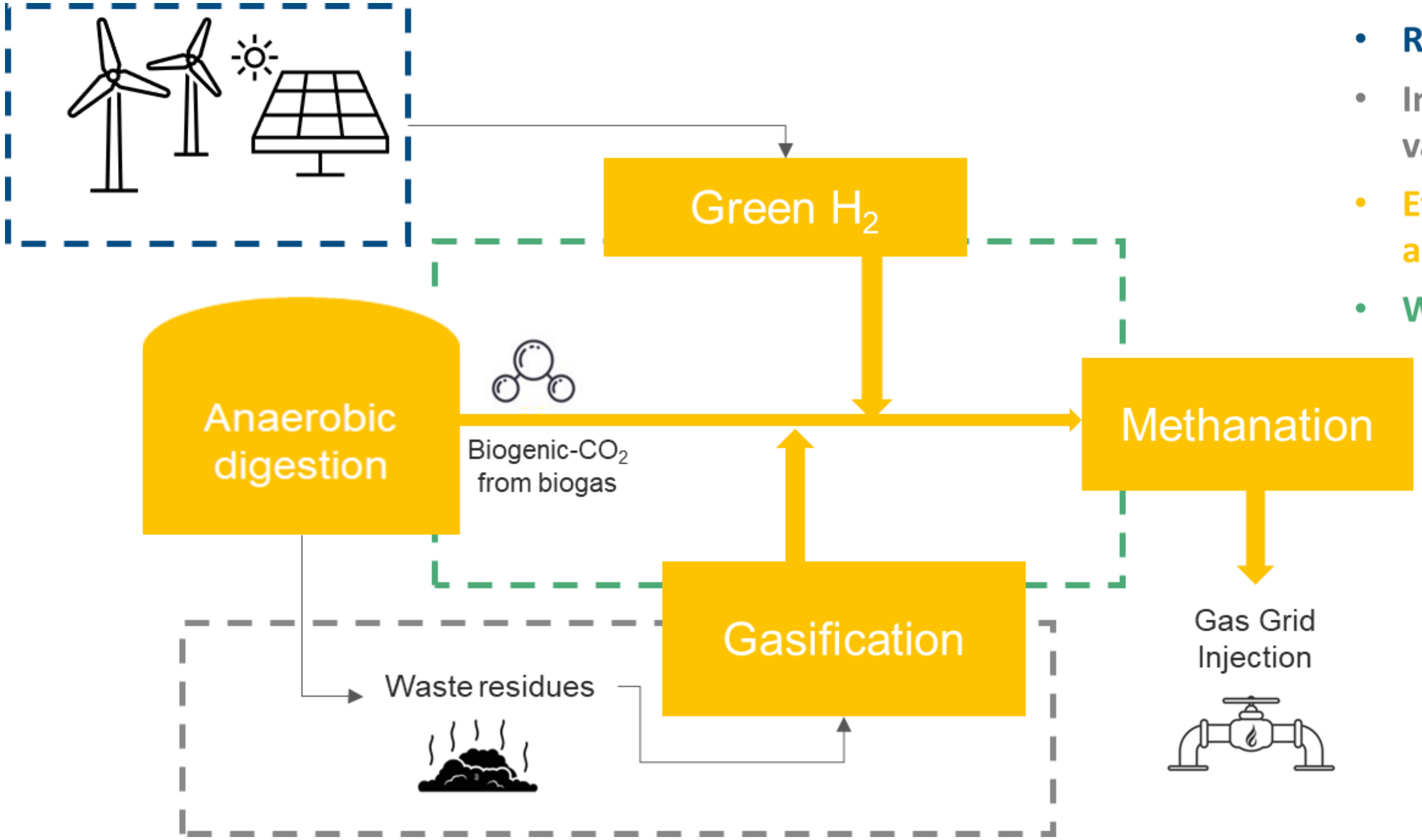
Maximizing circular and sustainable biomethane production with reduced GHG emissions

- Enhance circularity and sustainability with heat recovery and power integration playing a great role in the system with different process intensification schemes representing a significant innovation and contributing to minimize overall energy consumption

Developing an Optimized biomethane production system with market potential

- Develop an integrated and optimized biomethane production system with a strong market uptake and upscaling potential. METHAREN plans to demonstrate an innovative system relying on its integration facing different technological challenges

METHAREN proposal
an innovative concept to efficiently convert electricity into gas



- **REN storage thanks to methane production**
- **Intermittency management with effluent valorisation**
- **Efficient system thanks to smart integration and best state of the art bricks**
- **Water & Carbon circularity**

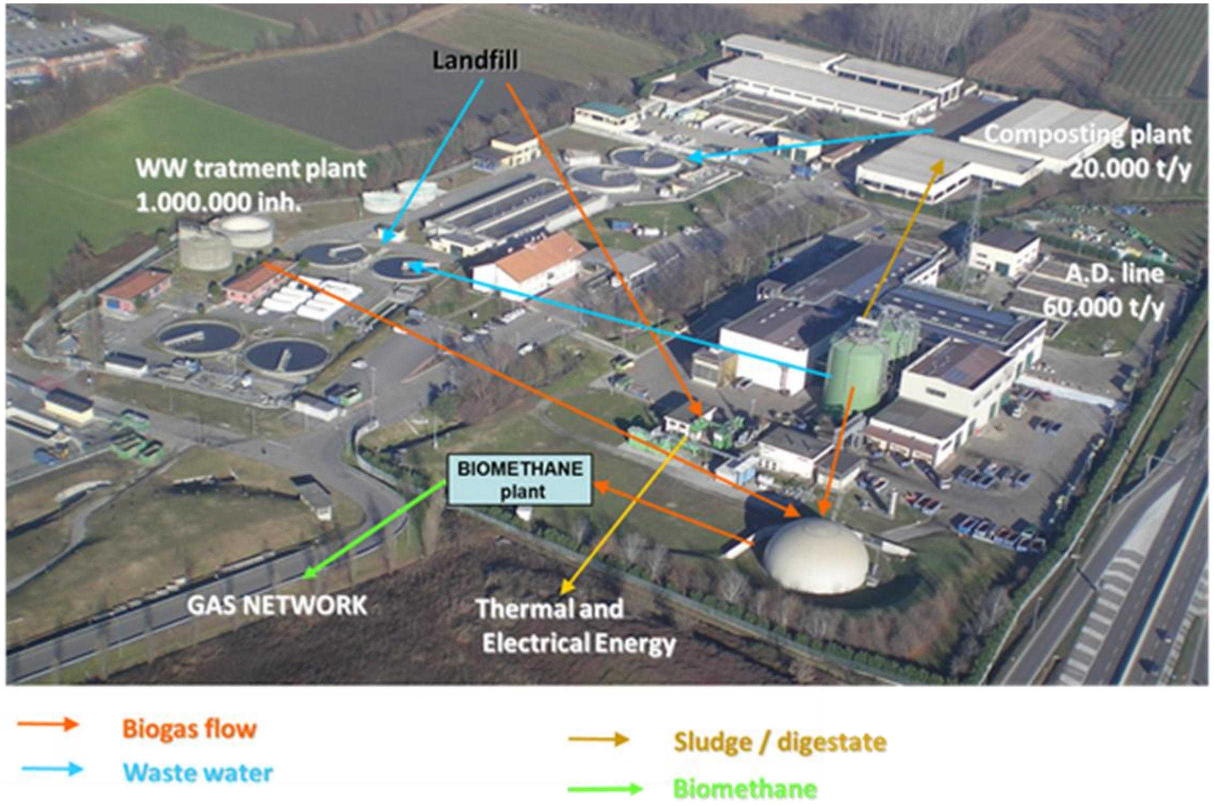
Methanation reactions:

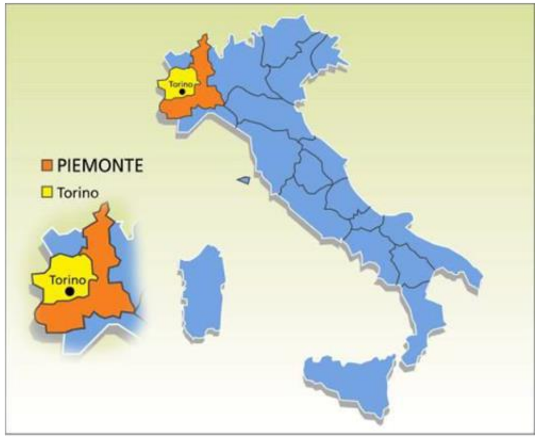
$CO + 3\,H_2 \longrightarrow CH_4 + H_2O$; $\Delta H = -206$ kJ/mol

$CO_2 + 4\,H_2 \longrightarrow CH_4 + 2\,H_2O$; $\Delta H = -165$ kJ/mol

➢ *Integrated process* adaptable to existing biogas plants

Location of the pilot plant: *ACEA*, Piemonte, Italy

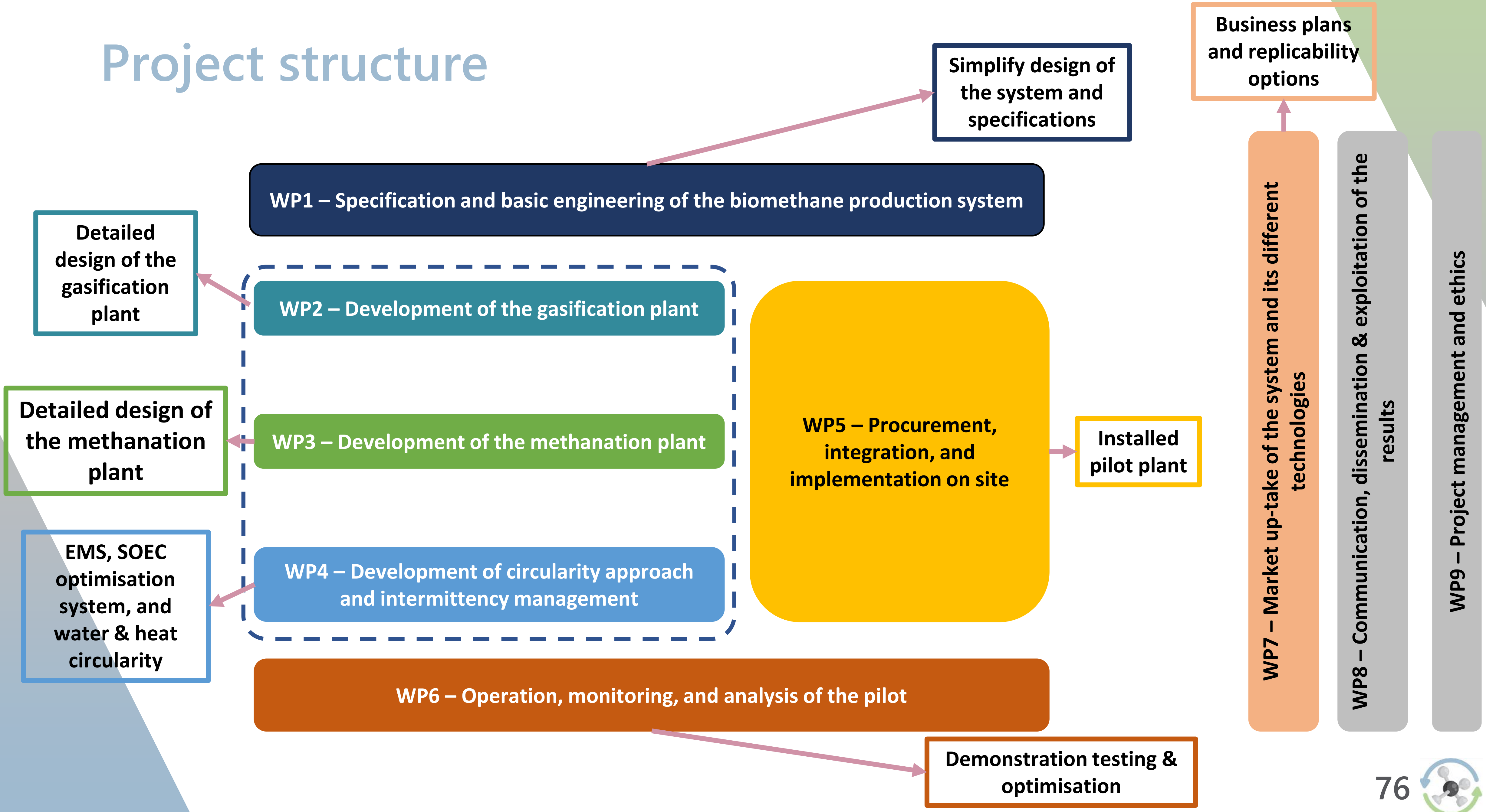




ACEA Waste Treatment Plant

- ✓ Capacity: 60.000 t / year (serving roughly 1.000.000 inhabitants)
- ✓ Biogas flow: 950 Nm3/h from anaerobic digestion and WWT
- ✓ Biomethane flow injected into the natural gas grid: 560 Nm3/h

Project structure



Synthetic natural gas quality

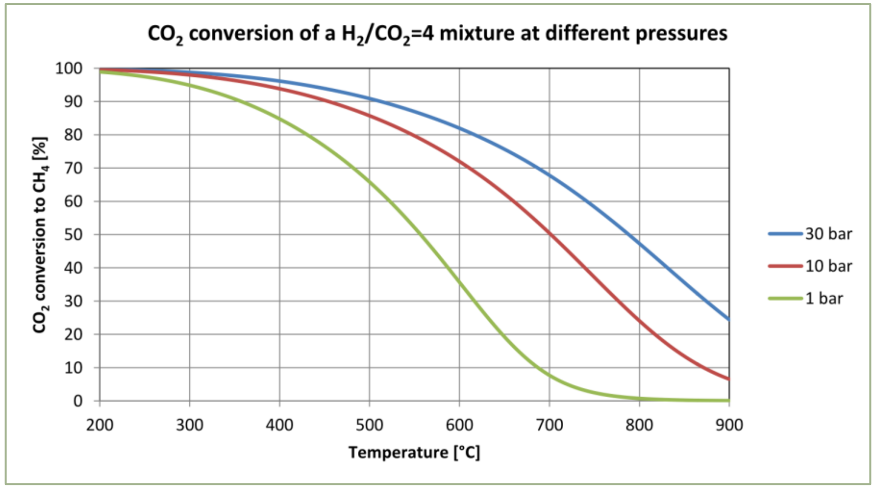
Methanation reaction of syngas produces a mixture of components

$$CH_4 + CO_2 + CO + H_2 \rightarrow CH_4 + H_2 + CO_2 + H_2O$$

Syngas from gasification + biogenic CO2 + H2 — *Synthetic natural gas*

Quality of SNG depends on

- *Methanation reactor design:*
  - *Pressure & temperature conditions*
  - *Management of heat produced in the reaction*
- *Selectivity of catalyst*
- *Deactivation/ageing of catalyst*



http://www.helmeth.eu/index.php/technologies/methanation-process

Synthetic natural gas quality: *METHAREN approach* for the desired gas quality

Reactor architecture

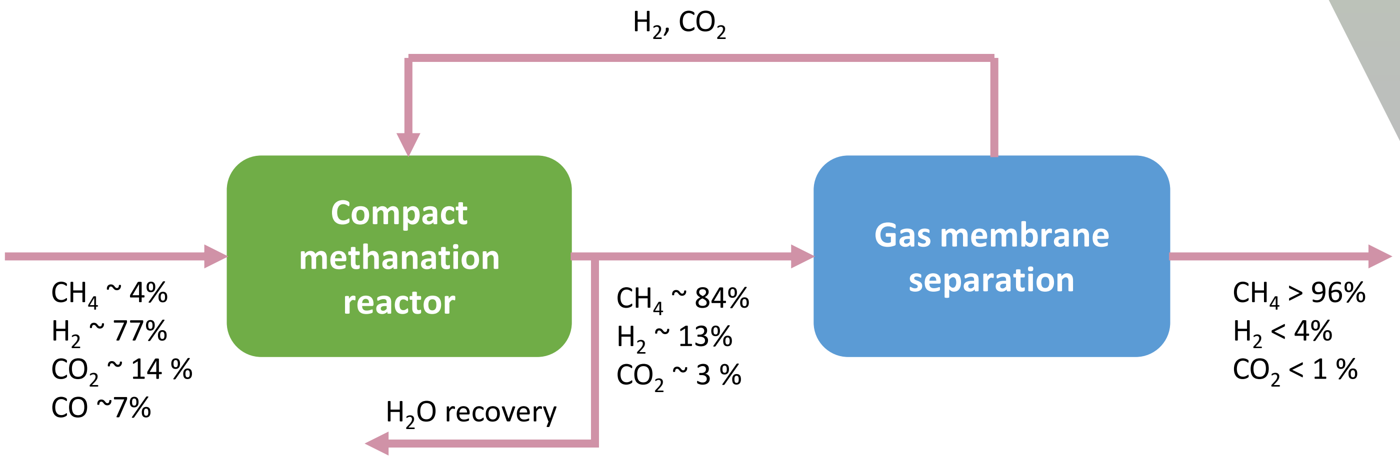
- *Shell and tube reactor with an innovative design that allows gas flow through catalyst bed to optimize reaction heat management*

Post treatment of reaction products to fit the required network gas specification

- *Utilisation of an innovative carbon membrane separation system*

Recirculation of recovered unwanted stream to the inlet of methanation reactor

- *This allows full conversion of carbon products to methane*



Methanation reactions:

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Gas quality consideration

Synthetic natural composition can be adjusted to "almost" the desired one

- *This implies to improve purification/recycling stage*
- *To use more selective catalyst and/or specific reaction condition*

But some consideration should be taken into account

- *Gas specification is a National issue*
  - *What it is acceptable in one country could not be in another*
- *Minimum relative density or GCV can be difficult to reach*
  - *Current draft of revised EN16726 is proposing 0.45 as lower limit for relative density, not mention to GCV*

%mol	***SNG 1***	***SNG 2***	***Italian Spec requirements***	***Spanish Spec requirement***	***French Spec requirement***	***Belgium Spec requirement***
CO_2	*1*	*1*	*≤ 2.5*	*< 2.5*	*< 2.5 TSO grid* *< 3.5 DSO grid*	*< 2.5 TSO grid* *< 4.0 DSO grid*
CH_4	*95*	*96*		*≥ 90*		
H_2	***4***	***3***	*≤ 2.0*	*< 5.0*	*< 6.0*	*< 2.0*
Gas properties (15/15), ISO6976:2016						
GCV	***36.37***	***36.63***	*35.0 - 45.3*	*34.4 - 45.1*	***36.5 - 43.7***	***36.9 - 43.7***
Rel. Density	***0.54***	*0.58*	***0.555 - 0.7***	***0.555 - 0.7***	***0.555 - 0.7***	***0.555 - 0.7***
Wobbe in.	*49.27*	*48.23*	*47.3 - 52.3*	*45.5 - 54.5*	*46.6 - 53.6*	*46.6 - 53.9*

SNG composition are only an example, not necessarily the ones produced in METHAREN

Conclusions

Quality of SNG depends on

- *Methanation reactor design and operation condition*
- *Catalyst: selectivity and ageing*

Post reaction quality adjustment is possible

Acceptance of SNG for grid injection depends on National gas specification, different from country to country

The METHAREN process, including the reactor, the membranes separation and the recycling will allow to provide quality required for direct injection to the grid.

- *Both reactor and membranes will be designed to fulfill gas specifications*

METHAREN

Thank you for your attention

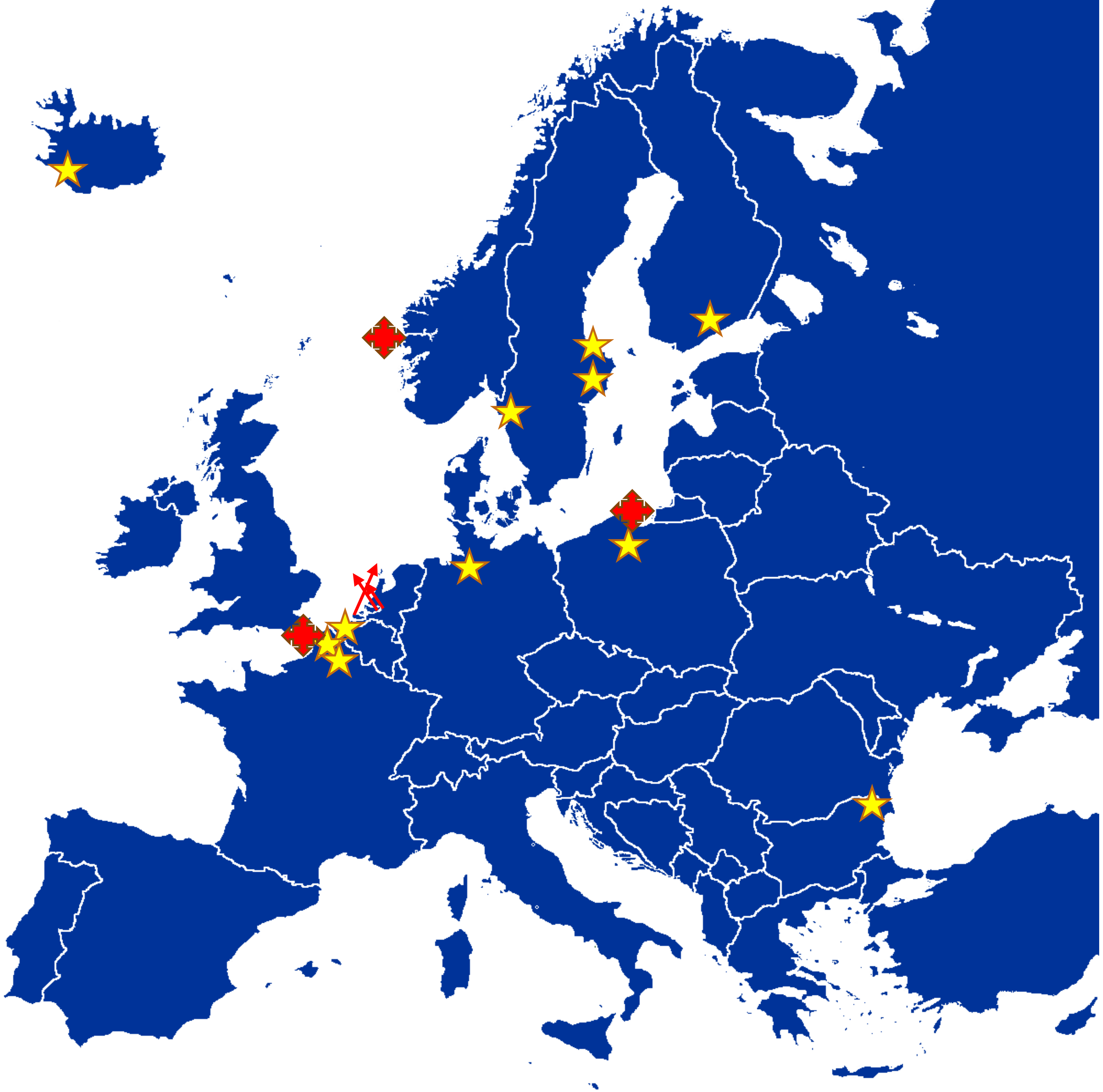
https://metharen.eu/

4. Advancing CO2 specifications for a European CO2 infrastructure

Towards EU-wide CO_2 transport infrastructure

Chris Bolesta, CCUS Team Leader
Directorate-General for Energy
European Commission

EU sponsored projects



11 Innovation Fund projects
6 TEN-E projects

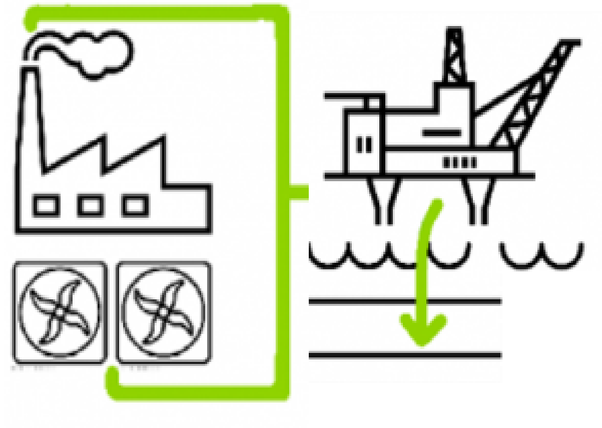
+12 further candidate capture projects under IF
18 candidate transport projects to replace 6 TEN-E projects

Total storage needed ca. 12 Mt CO_2 p/a

European Commission

CO_2 storage obligation

- Net Zero Industry Act
- EU-wide objective to achieve an annual CO_2 storage capacity of **50 million tonnes by 2030**
- Once NZIA becomes EEA relevant – target revised
- Associated transport infrastructure likely to be added



Industrial carbon management strategy

CCS

CCU

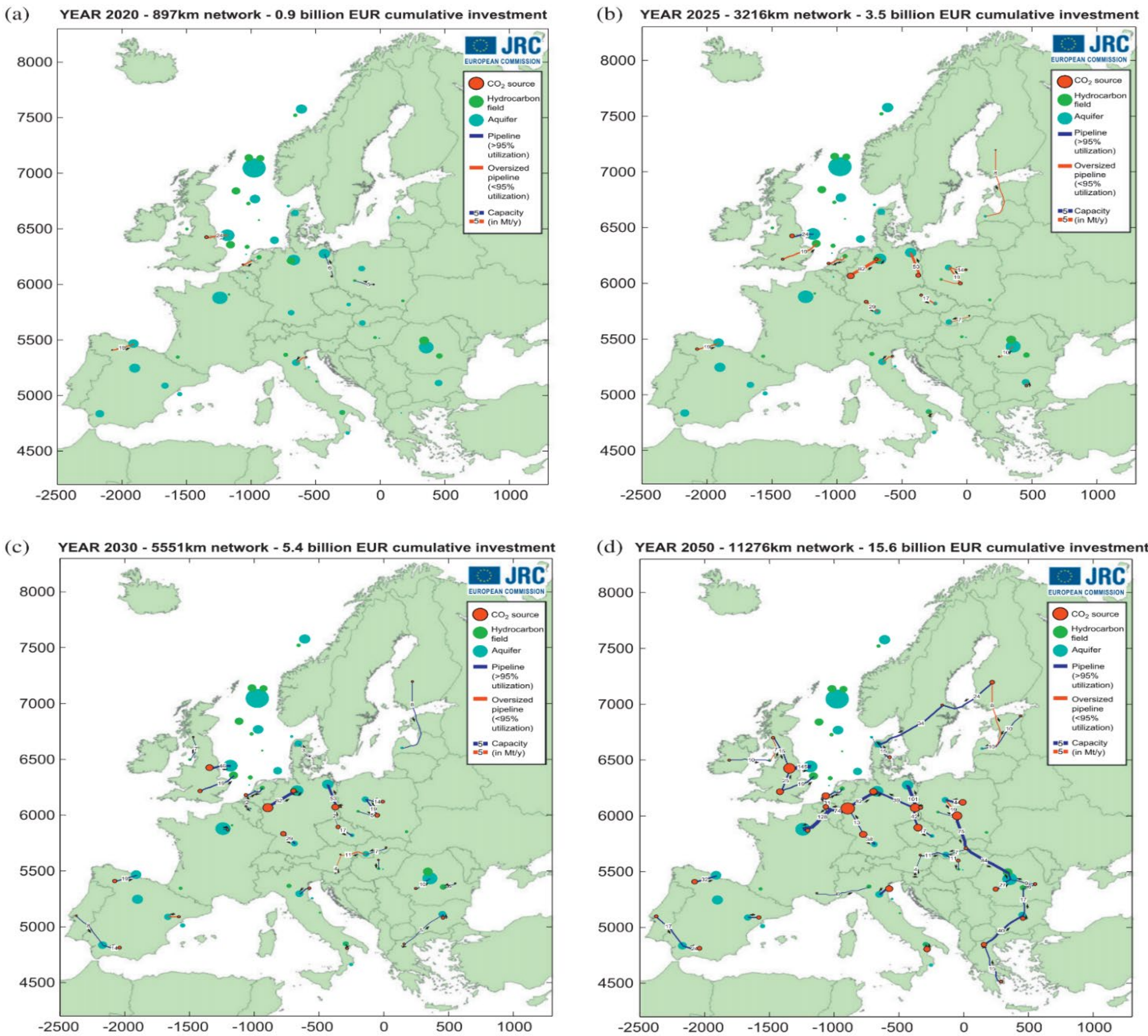
Industrial Carbon Removals

CO_2 transport infrastructure

European Commission

Some sources of wisdom

- JRC - connecting sources and sinks
- ENTEC - Future regulatory environment
- CCUS Forum – CO_2 standards
- Open public consultation



Takeaways

- First CO_2 hubs will be built around IF projects and PCIs/PMIs with multimodal transport means
- Some EU-wide standards should be agreed as soon as possible
- Open access transport network key for market development
- Market set-up and regulatory set-up could come after 2024
- Catering to our climate and energy needs we might need CO_2 transport network possibly exceeding 100,000 km in 2050
- To start well, well designed EU-coordination and planning necessary

Thank you!

European Commission

Steps towards an interoperable European CO_2 transportation network

Harald Tlatlik, Wintershall Dea AG

November 15th, 2023

Zero Emissions Platform

CCS needs a European framework!

CCS will only be successful on a European scale

➔ Need for a harmonized European (transport) system at hand

- No value-based international concept and only few regulations available
- *But* some member states already setting own rules and standards
- Industries have started projects; some long lead items are already ordered
- Knowledge and concept gaps exist
- Field experience hardly available
- Value chain is not optimized

Setting the CO_2 specification on a European level is key to make CCS fly!

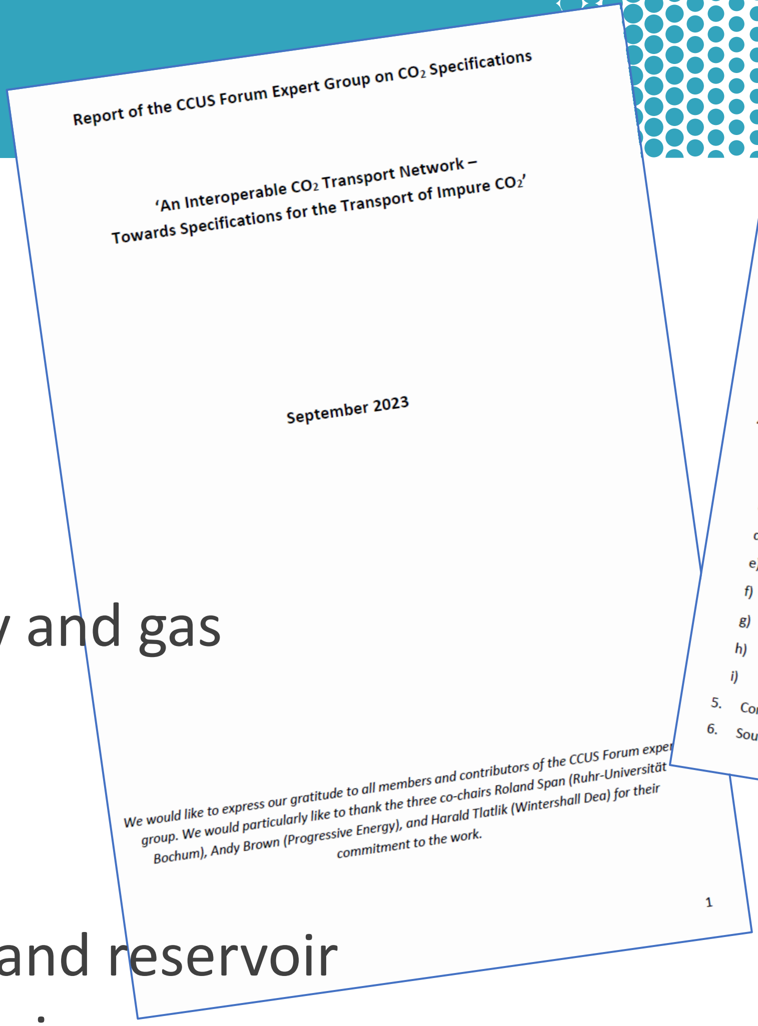
CCUS Forum expert group on CO2 specifications

Objective and process

- Objective is to identify challenges associated with CO_2 transport in Europe in terms of specifications and issue clear recommendations
- 3 co-chairs Roland Span (Ruhr-University Bochum), Andy Brown (Progressive Energy) and Harald Tlatlik (Wintershall Dea)
- Large group of experts specialised in CO_2 specifications
- Report finalised and issued
- Report complements the CCUS Forum report on CO_2 infrastructure

Structure of the paper

- Assumptions
- Impurities
- Specific considerations
  - Pipeline transport high density and gas
  - Buffer storage
  - Ship transport
  - Rail & truck transport
  - Geological storage – injection and reservoir
  - Relevance of capture technologies
  - CO_2 captured on board of ships

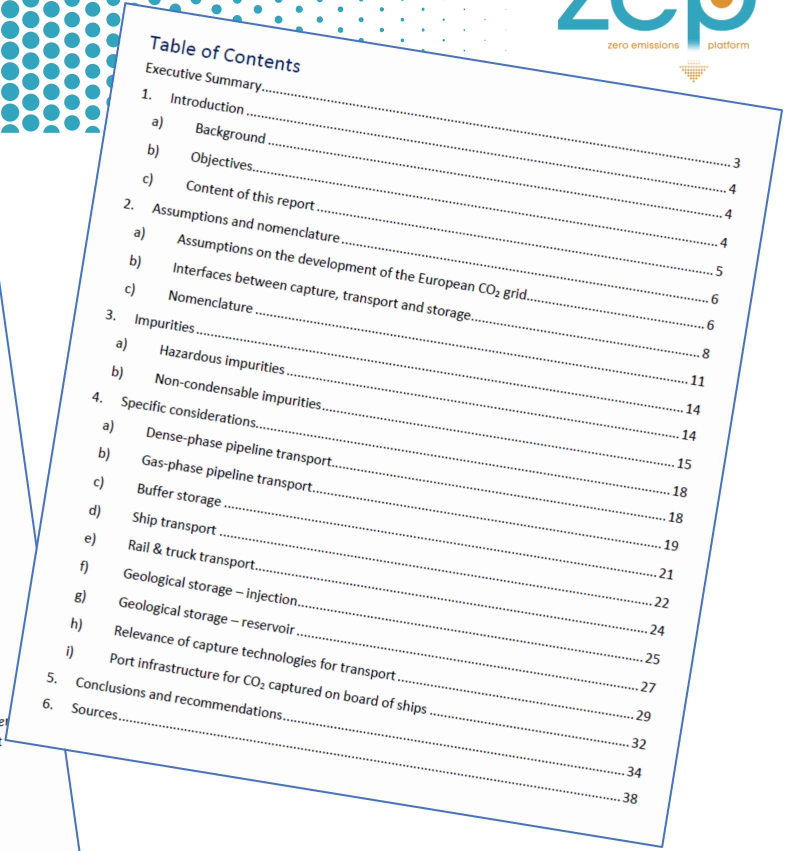


Report of the CCUS Forum Expert Group on CO_2 Specifications

'An Interoperable CO_2 Transport Network –
Towards Specifications for the Transport of Impure CO_2'

September 2023

We would like to express our gratitude to all members and contributors of the CCUS Forum expert group. We would particularly like to thank the three co-chairs Roland Span (Ruhr-Universität Bochum), Andy Brown (Progressive Energy), and Harald Tlatlik (Wintershall Dea) for their commitment to the work.



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Please find it on https://circabc.europa.eu/

Link: Circabc (europa.eu)

CCUS Forum expert group on CO2 specifications

Key recommandations & messages

- Safe transport of impure CO_2 streams is possible today
- Develop as rapidly as possible a network code and standards for a multimodal CO_2 transport network in the EU/EEA
- Determining standards and a network code will require the development of scenarios
  - Need fundamental assumptions on the future European CO_2 transport network
  - Develop a strategy and clear targets for a common European CO_2 transport network
- Support and prioritise research in identified fields
- Improved theoretical understanding alone does not result in better transport networks
- Theory must go together with experience from practical implementation, which must start now!

That’s it, thanks!

Questions, comments, ideas?

Backup – draft a vision

To From	Gas phase pipeline	Dense phase pipeline	MP shipping (14-17.5 bara)	LP shipping (6.5-8 bara)	Rail and truck
Gas phase		Fully compatible[3]	Purification	Purification	Not likely
Dense phase	Exceptional		Purification	Purification	Not likely
MP shipping	Not likely	Fully compatible		Unexplored	Fully compatible
LP shipping	Not likely	Fully compatible	Unexplored		Fully compatible
HP shipping	Unexplored	Unexplored	Unexplored	Unexplored	Unexplored

[contributed by Adriaan Kodde]

Considerations for the transport of carbon dioxide

Gas Quality Workshop ENTSOG - 15/11/2023

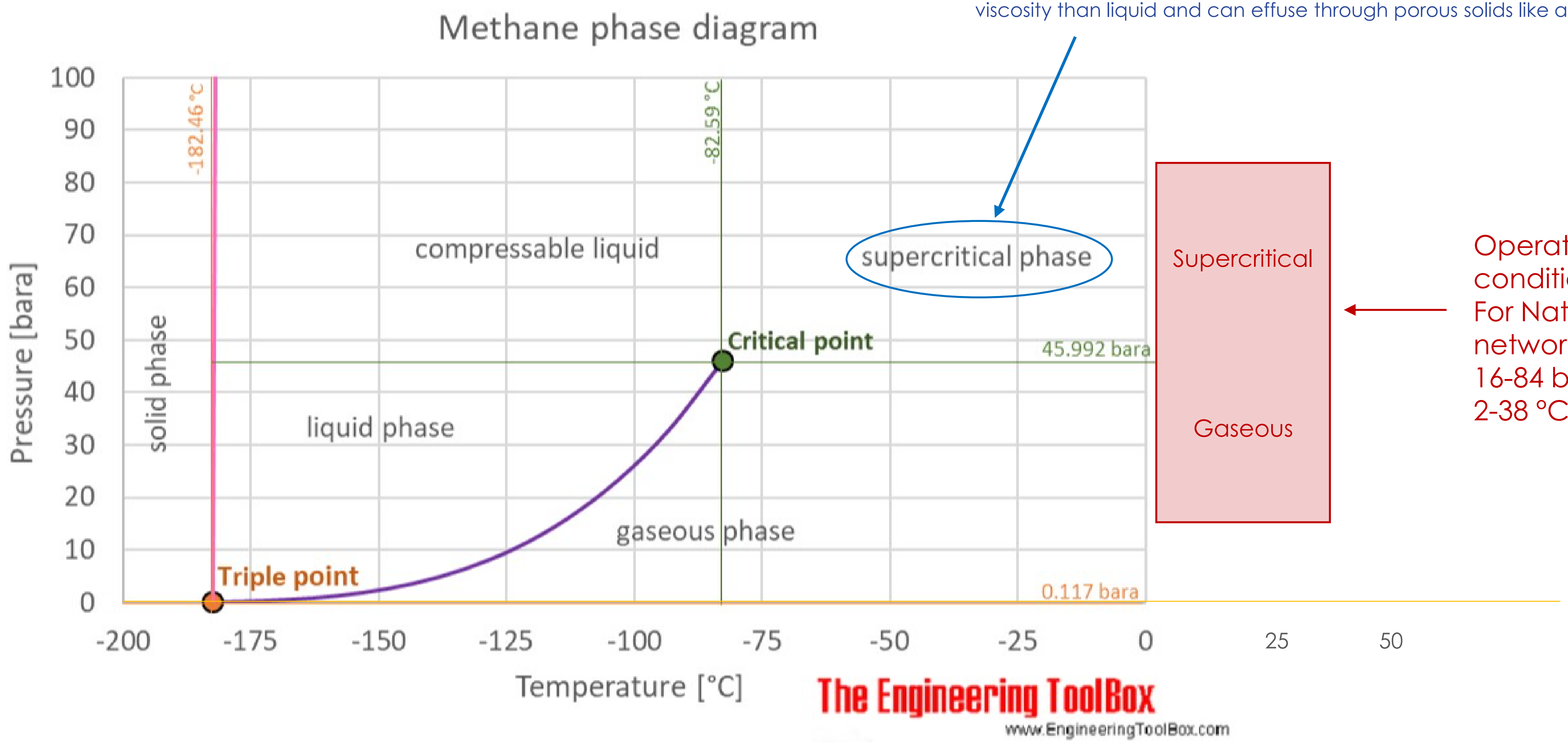
Summary

- Phase diagrams
- Schematic : phases in carbon dioxide value chain
- Impact of gas composition
- Fluxys carbon dioxide quality specifications

Please note that the charts and tables that are provided in this presentation are provided for illustrative purpose only (and might not be accurate).

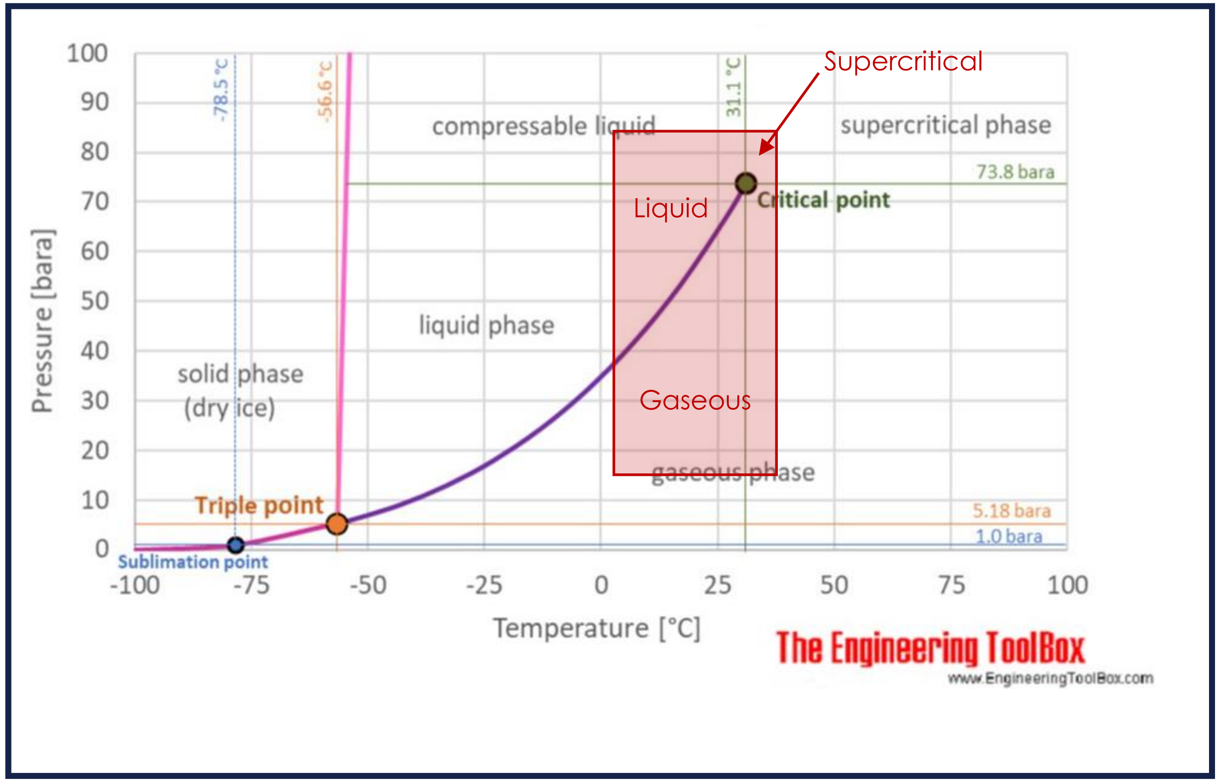
PHASE DIAGRAM : CH_4

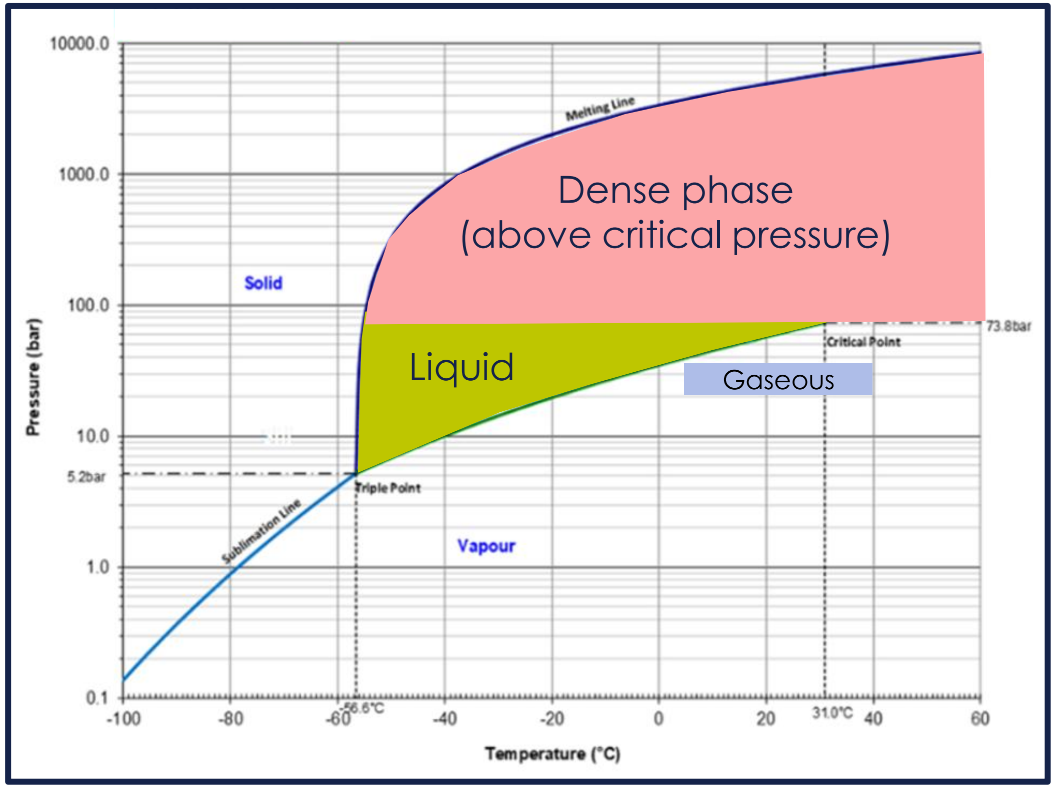
Substance at a temperature and pressure above its critical point, where distinct liquid and gas phases do not exist, and which has very specific characteristics. For example, it has a density close to the one of liquid phase and dissolve materials like liquids or solids, but it also has a much lower viscosity than liquid and can effuse through porous solids like a gas



Operating conditions Fluxys For Natural Gas network
16-84 bar
2-38 °C

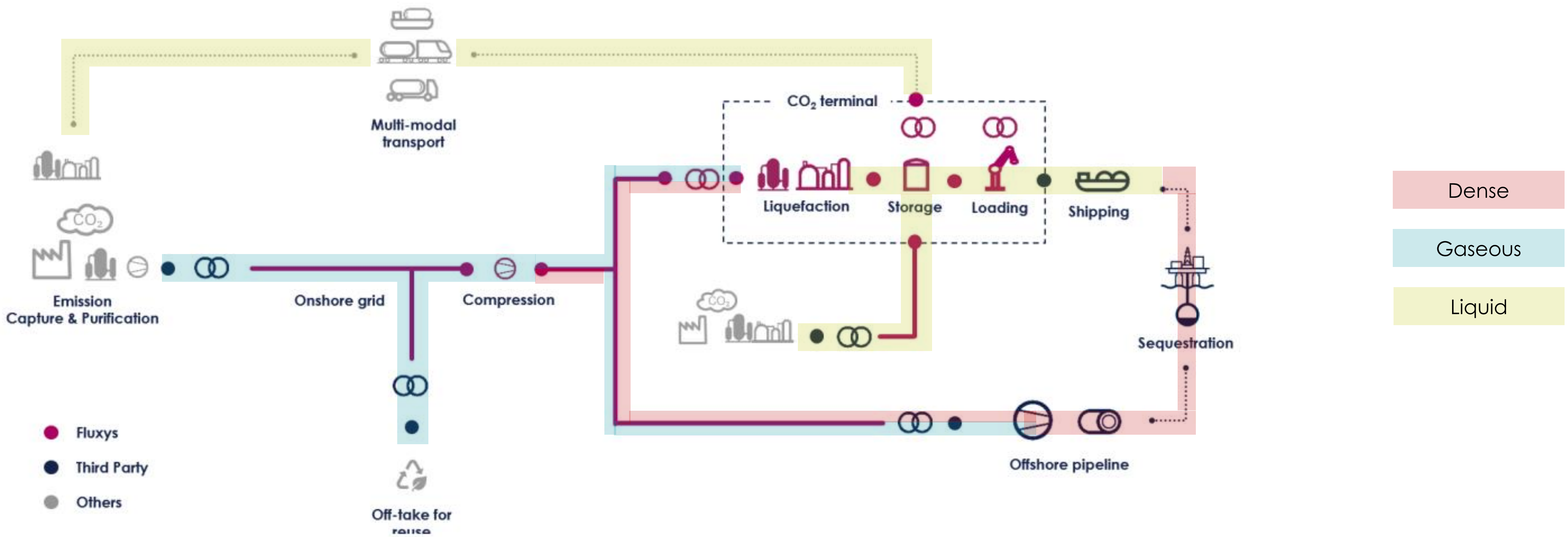
PHASE DIAGRAM : CO_2





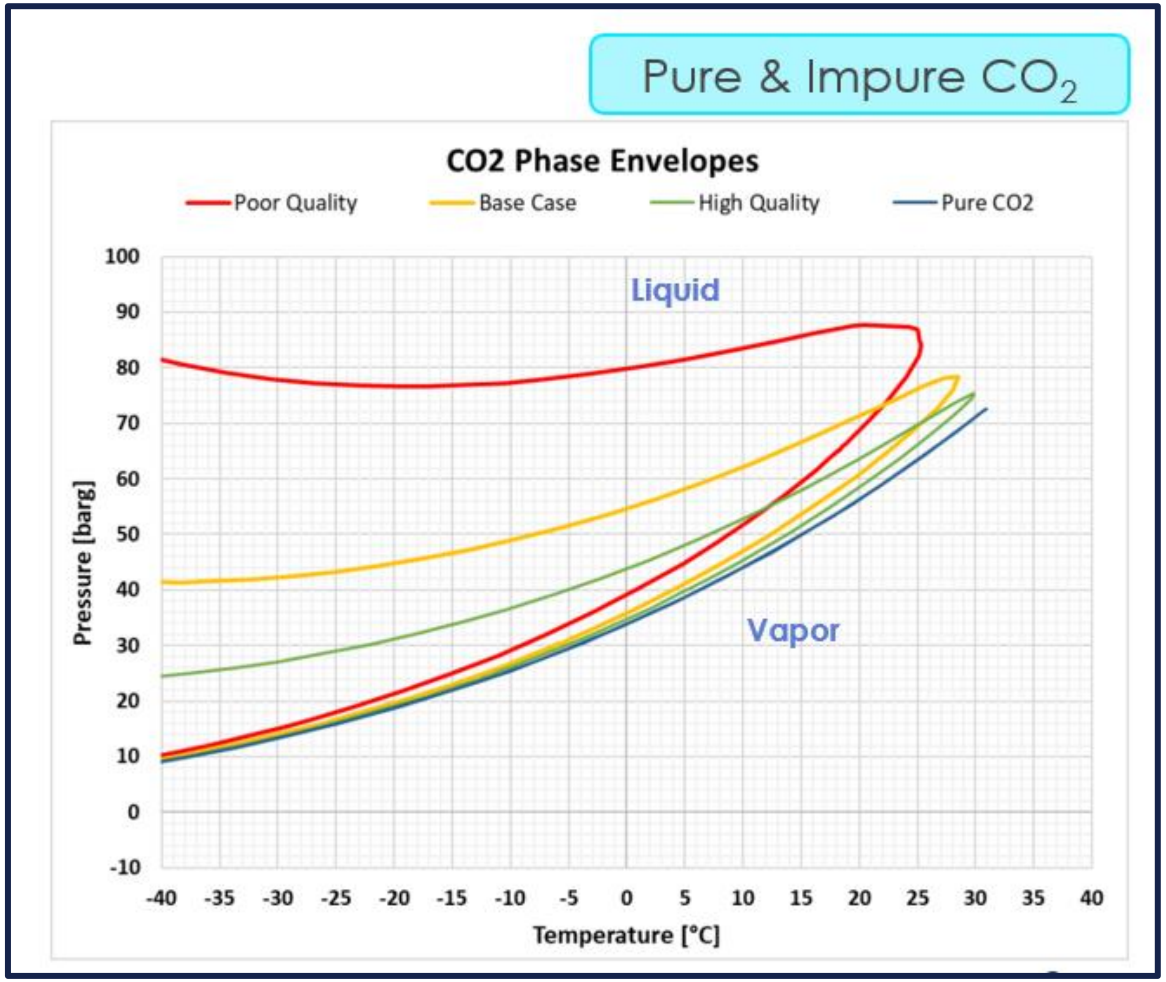
- With current operating conditions from natural gas, pure **CO_2 could change between three phases : gas, liquid and supercritical**
- **Pipeline transport on long distance** is expected to develop under **dense phase** (above critical pressure)
- Fluxys' pipelines available for repurposing do not offer a sufficient MOP for efficient dense phase transport
- In Belgium, repurposed pipelines will be used for transport under gaseous phase

SCHEMATIC : PHASES IN CARBON DIOXIDE VALUE CHAIN

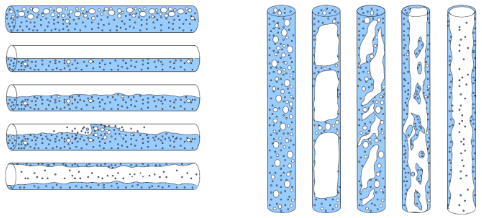


- No purification unit between gaseous and dense phases → **same quality specifications for dense/gaseous phases**
- Liquefaction units between dense/gaseous and liquid phases → allow to introduce **stricter quality specifications for liquid phase**

IMPACT OF THE COMPOSITION



- Non condensable gases like H_2, CH_4, N_2, Ar, O_2 turn the saturation curve (line between vapour and liquid phases) into a **phase envelope wherein both phases coexist**
- Some impurities like H_2S, NH_3 or amine also adversely influence the form and the position of the CO_2 phase envelope and should therefore be limited
- **Infrastructures are usually not designed for biphasic fluids**



Examples of Two-Phase flow
Blue is the liquid, white is the vapor

- **The larger the phase envelop, the higher the pressure needed to go to liquid and dense phase**
  - This increase sharply the operating costs or even endanger the feasibility of some options

Pipeline and ship transport in dense/liquid phases require higher purity than pipeline transport in gaseous phase

IMPACT OF THE COMPOSITION

1. $H_2S + 3NO_2 \rightarrow SO_2 + H_2O + 3NO$
2. $2NO + O_2 \rightarrow 2NO_2$

Chemical reactions (1–2)

3. $SO_2 + H_2O + NO_2 \rightarrow NO + H_2SO_4$
4. $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$
   $2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$

Acid formation, aqueous phase (corrosive phase) (3–4)

5. $8H_2S + 4O_2 = 8H_2O + S_8\ (s)$
6. $CO_2 + 2\ NH_3 = NH_4CO_2NH_2\ (s)$

Solids, particulate matter (5–6)

Table 1 Limits for the formation of a separate phase in CO_2 [ppm Mole][16,19,23] periods of validation typically cover around 50 hours exposure.

Conditions	phase	Test	Impurity H_2O	SO_2	H_2S	O_2	NO_2	Comments
25 °C 100 bar CO_2 [16] Pipe transport	dense	1	2500					No water drop-out, no corrosion
		2	1900	80		240		Some corrosion > 1900 ppm H_2O
		3	200	1000		100		Slight corrosion
		4	100	35	35	60		No liquid drop-out
		5	300	100	350	100		Non-reactive experiment, but no visual confirmation
		6	50	35		80	30	No liquid drop-out
		7	250				70	At 670 ppm H_2O corrosion in dense phase
		8	200	20	20	20	10	No liquid drop-out
4 °C 100 bar CO_2 [23] Pipe transport	dense	9	70	10	5	40	2.5	Some reactions, but no liquid drop-out observed. At 5 ppm NO_2 an acidic phase dropped out as a separate phase.
-25 °C 20 bar CO_2 [19] Ship transport	liquid	10	10	Total 60		10		No reactions or acid formation was observed with H_2S + SO_2 at a total of 60 ppm
-23°C 20 bar CO_2 [23] Ship transport	liquid	11	30	10	5	10	1.5	Some reactions, but no liquid drop-out observed. At 2.5 ppm NO_2 acids were formed and reaction product drop-out has been observed.
25 °C 30 bar CO_2 [23] Pipe transport	gas	12	70	10	5	40	5	Reactions take place ($NO_2 + H_2S \rightarrow NO$) but no drop out of liquids has been observed (refer figure 2)

From Sonke *et.al. CO2 transport and injection, Effect of impurities, Understanding of Reactions and Consequences, Paper 18756 AMPP annual conference March 19-23 2023 Denver Colorado*

- In certain operating conditions, some elements typically present in a carbon dioxide stream like **NOx, SOx, H_2S, O_2, H_2O,… can react chemically in the pipeline**
- Such reactions may produce additional water which could lead to **an aqueous phase forming into the CO_2 stream**
- **Other impurities like glycol, amines and methanol** can also enable the formation of an aqueous phase, even if the water content is sufficiently low to be normally fully dissolved in CO_2
- **Acidic water drop-out** may develop with an aqueous phase which **increases sharply the corrosion rates**
- In addition, certain elements like CO, NH_3, … are **limited due to their toxicity**

➡ These components should be removed prior to their injection into the network (**purification at capture**)

CARBON DIOXIDE QUALITY SPECIFICATION

Methane

Constituents
Gross Calorific Value
Wobbe Index
Relative density
Hydrocarbon dewpoint
H_2O dewpoint
O_2
CO_2
H_2S + COS (as S)
Mercaptan (as S)
Stot
Methane number
Contaminants

12 parameters

Hydrogen

Constituents
H_2
Wobbe Index
Sum of inerts (N_2, He, Ar)
Gaseous hydrocarbons
Hydrocarbon dewpoint
H_2O
O_2
CO
CO_2
Stot
NH_3
Halogenated compounds
Contaminants

13 parameters

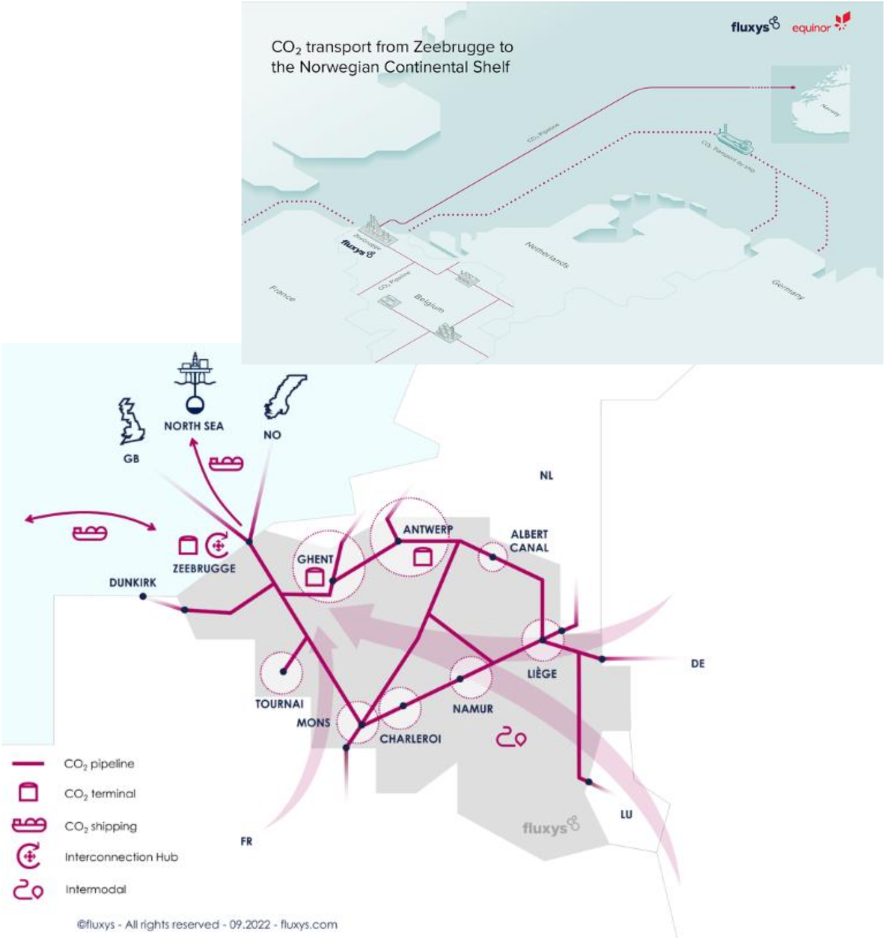
Carbon dioxide

Constituents
CO_2
H_2O
H_2
N_2
Ar
CH_4
CO
O_2
$H_2+N_2+Ar+CH_4+CO+O_2$
Total aliphatic hydrocarbons (C2-10)
Total aromatic hydrocarbons (C6-10, incl. BTEX)
H_2S
SO_3
SO_X
S_{TOT} (COS, DMS, H_2S, SO_X, Mercaptan)
NO_X
Dewpoint (for all liquids)
NH_3
Total volatile organic compounds (excl. methane, total aliphatic, HC C_2 to C_{10}, methanol, ethanol, and aldehydes)
Total aldehyde compounds
Ethanol
Methanol
Total carboxylic acid and amide compounds
Total phosphorus - contained compounds
Hydrogen cyanide (HCN)
Mercury (Hg)
Cadmium (Cd) + Thallium (Tl)
Total amine compounds

28 parameters

Carbon dioxide quality specification is much more complex than what we were used to until now

CARBON DIOXIDE QUALITY SPECIFICATION : FLUXYS



- **Drivers** for developing a carbon dioxide quality specifications are :
  - **Network integrity**
  - **Operational safety**
  - **Operational feasibility and efficiency**
  - **Interoperability** with adjacent systems (gas networks, liquid networks, liquefaction terminals, underground storages, …)

- Fluxys follows or participates to multiple studies, JIPs, … to help **filling the knowledge gaps and identify the margins** we have on the quality specifications

- Fluxys is also actively engaged in finding a **common (optimum) quality specification** for
  - Emitters and end users that will be connected to its network
  - Upstream dense and gaseous phases pipelines
  - Downstream dense phase pipelines
  - Downstream liquefaction terminals

Our intention is to publish a **second version of our carbon dioxide quality specification early 2024**

THANK YOU !

shaping together
a bright energy
future

fluxys

CEN/TC on CCUS

CO_2 capture, transportation, utilization, storage and carbon accounting

Adriaan den Herder & Koen Kobes

November 15, 2023

CCUS projects in Europe

Source: IOGP

Overview of existing and planned CCUS facilities

AUSTRIA

1. Vienna Green CO_2*

BELGIUM

1. Leilac 1
2. Antwerp@C*
3. Carbon Connect Delta
4. Steelanol
5. C4U
6. North-CCU-Hub
7. Power-to-Methanol Antwerp BV
8. Kairos@C€
9. H2BE*

BULGARIA

1. ANRAV€

CROATIA

1. Petrokemija Kutina*
2. Bio-Refinery Project*
3. CCGeo€

DENMARK

1. Greensand*
2. C4: Carbon Capture Cluster Copenhagen
3. Bifrost*

FINLAND

1. SHARC€

FRANCE

1. DMX Demonstration in Dunkirk*
2. Pycasso*
3. K6€
4. CalCC€
5. **Cryocap**
6. D'Artagnan

GERMANY

1. H2morrow*
2. Leilac 2
3. BlueHyNow*
4. OXYFUEL100 (subproject of Westkuste100)
5. H2GE Rostock*

GREECE

1. Prinos CCS
2. RECODE

ICELAND

1. **Orca**
2. **Silverstone**€
3. Coda Terminal€

ITALY

1. CCS Ravenna Hub*
2. Cleankerk

THE NETHERLANDS

1. Porthos*
2. Aramis*
3. H2M*
4. H-Vision*
5. Twence*
6. **AVR-Duiven**
7. AZUR*
8. L10 CCS

NORWAY

1. **Sleipner CO_2 Storage***
2. Longship (including Northern Lights)*
3. Barents Blue*
4. Norsk e-fuel
5. Borg CO_2*
6. **Snøhvit CO_2 Storage***
7. Smeaheia*

POLAND

1. Poland EU CCS Interconnector
2. Go4ECOPlanet€

REPUBLIC OF IRELAND

1. Ervia Cork CCS

SPAIN

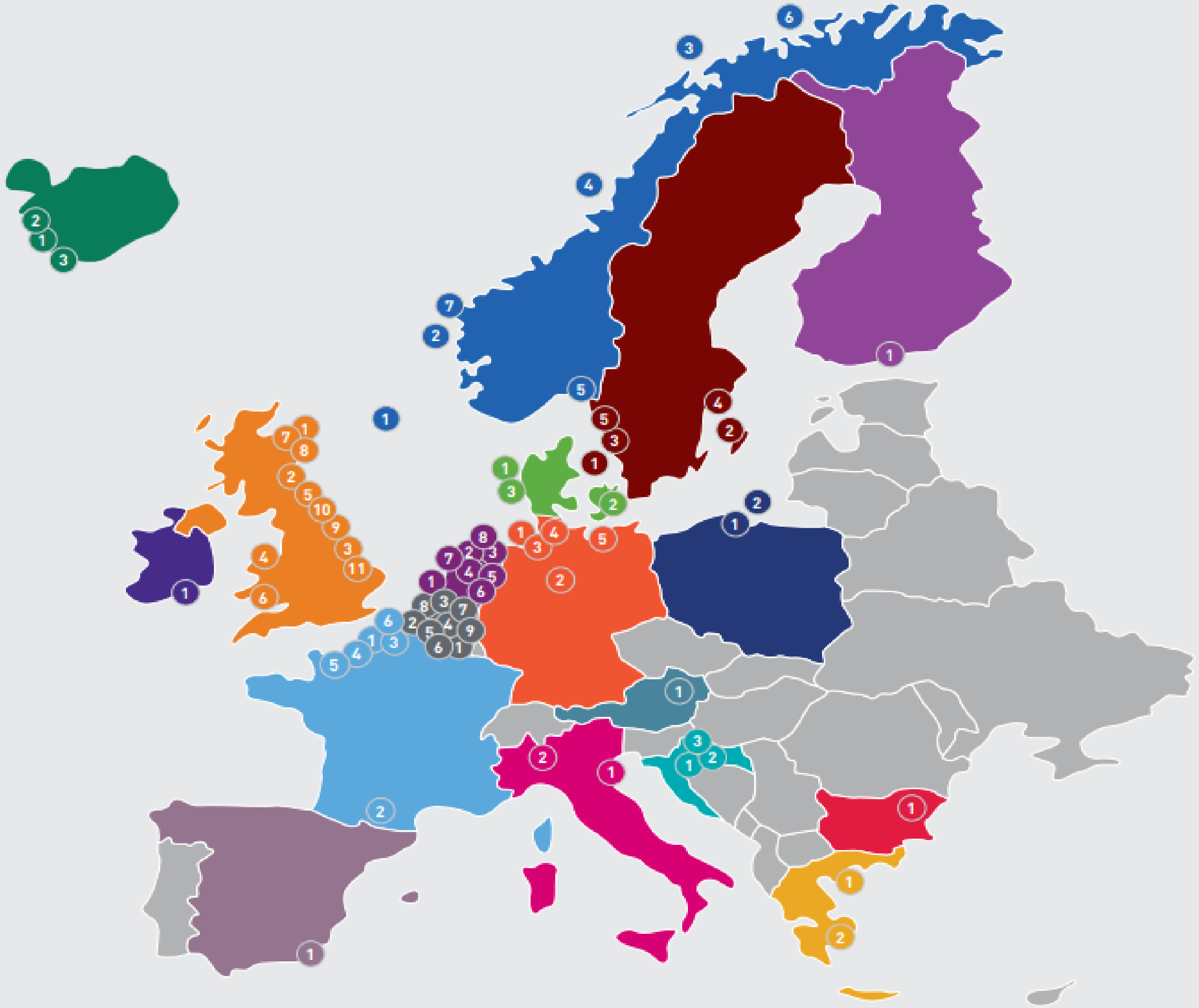
1. ECCO2

SWEDEN

1. Preem CCS*
2. Slite CCS
3. CinfraCap
4. BECCS@STHLM€
5. Project AIR€

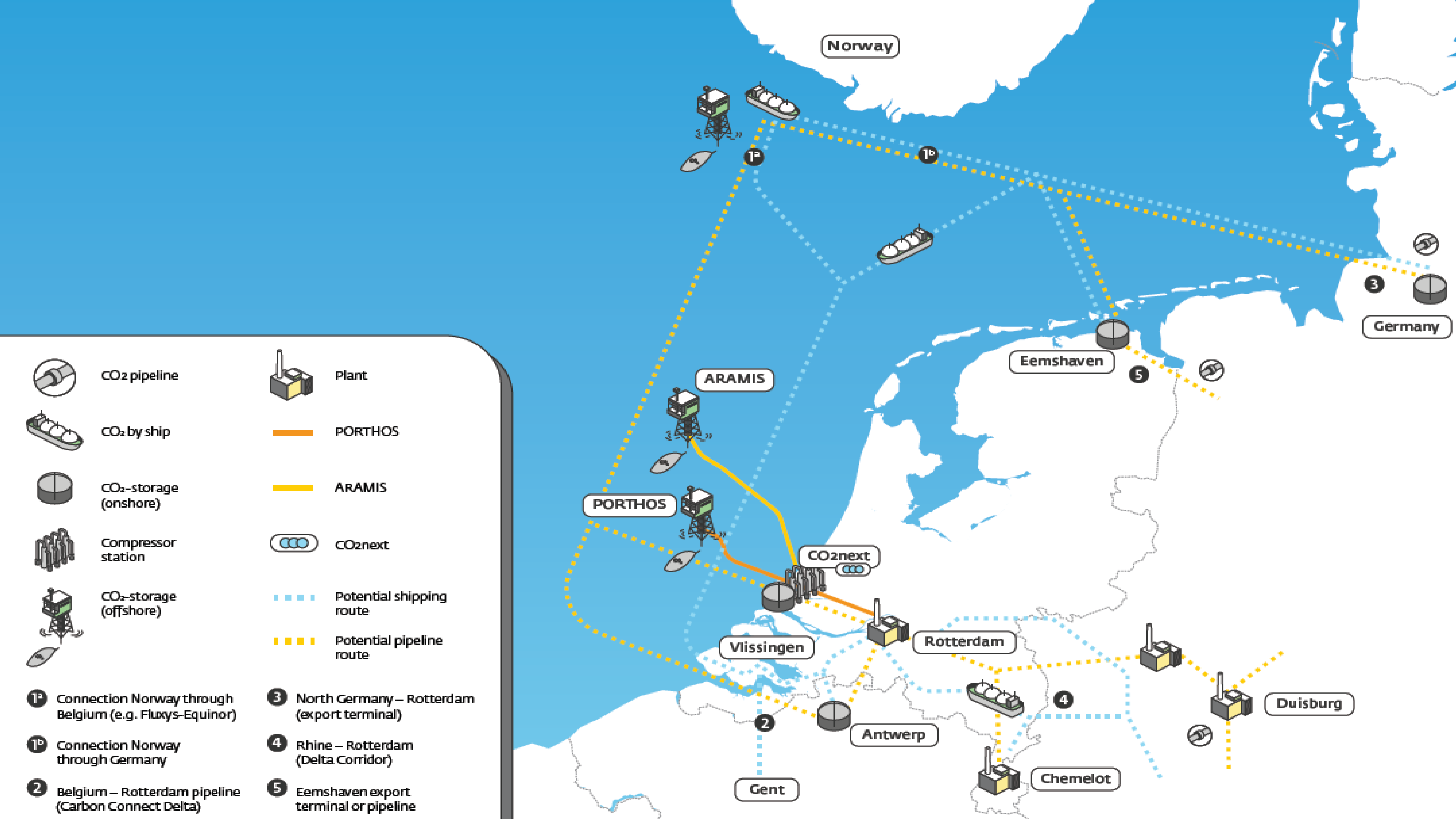
UK

1. Acorn*
2. Caledonia Clean Energy
3. Zero Carbon Humber*
4. HyNet*
5. Net Zero Teesside*
6. South Wales Industrial Cluster
7. Peterhead CCS Power Station*
8. Acorn CO_2 SAPLING*
9. Northern Endurance Partnership*
10. H2Teeside*
11. H2H Saltend*



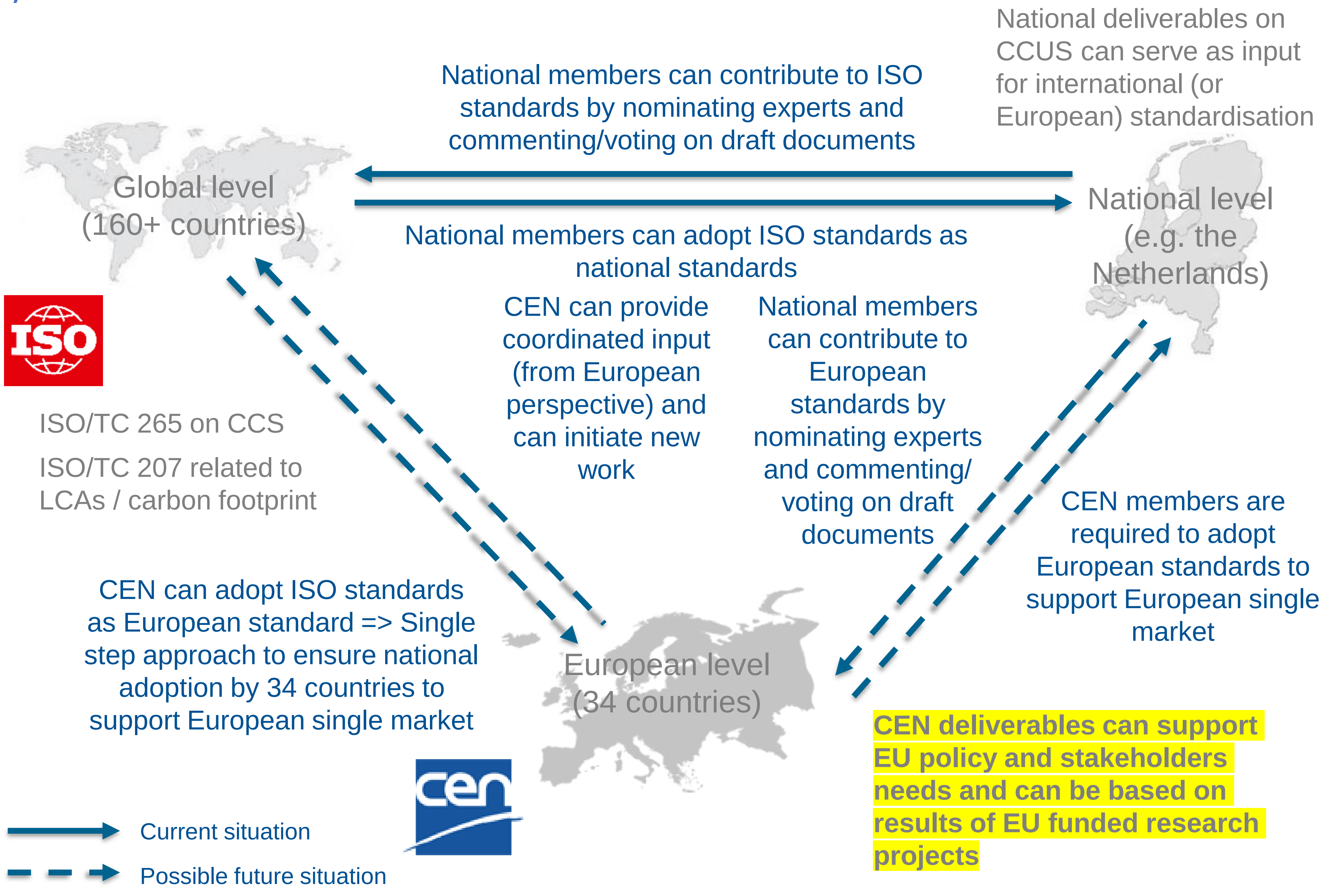
* Project where IOGP Members are involved
€ EU Innovation Fund (11 selected, **4 awarded**)
Projects listed in **bold** are in operation

Total number of projects: **71**
Around 80 $MtCO_2$/yr stored by 2030



Norway
1a
1b
ARAMIS
PORTHOS
CO2next
Eemshaven
Germany
3
5
Vlissingen
Rotterdam
Antwerp
Gent
2
4
Duisburg
Chemelot
CO2 pipeline
Plant
CO2 by ship
PORTHOS
CO2-storage (onshore)
ARAMIS
Compressor station
CO2next
CO2-storage (offshore)
Potential shipping route
Potential pipeline route
1a Connection Norway through Belgium (e.g. Fluxys-Equinor)
1b Connection Norway through Germany
2 Belgium – Rotterdam pipeline (Carbon Connect Delta)
3 North Germany – Rotterdam (export terminal)
4 Rhine – Rotterdam (Delta Corridor)
5 Eemshaven export terminal or pipeline

Proposal new CEN/TC on CCUS



Proposal new CEN/TC on CCUS

ISO/TC 265 standards portfolio

Carbon capture

ISO/TR 27912 CO_2 capture systems, technologies and processes

ISO 27919-1 Performance evaluation methods for post-combustion CO_2 capture integrated with a power plant

ISO 27919-2 Evaluation procedure to assure and maintain stable performance of post-combustion CO_2 capture plant integrated with a power plant

ISO/TR 27922 Overview of CO_2 capture technologies in the cement industry

ISO 27927 Carbon dioxide capture - Absorbent performance

ISO 27928 Carbon dioxide intensive industries

Transportation

ISO 27913 Pipeline transportation systems [revision]

ISO/TR 27929 transportation of CO_2 by ship

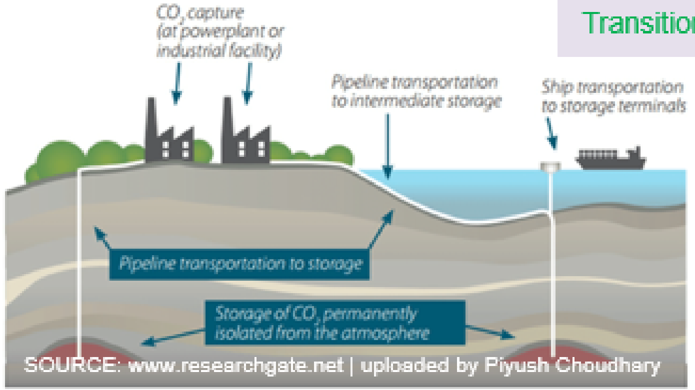
Underground storage

ISO 27914 Geological storage [revision to include quantification and verification]

ISO 27916 CO_2 storage using enhanced oil recovery (CO_2-EOR)

ISO/TR 27923 Geologic storage of CO_2 injection operations and infrastructure

ISO/TR 27926 CO_2-EOR - Transitioning from EOR to storage



Key
Black: Published document
Green: Document under preparation
Grey: New proposed project
Red: Project cancelled

Status: September 2021

Overarching aspects

ISO 27917 Vocabulary — Cross cutting terms

ISO/TR 27925 Flow assurance

ISO/TR 27918 Lifecycle risk management for integrated CCS projects

ISO/TS 27924 Risk management for integrated CCS projects

ISO/TR 27915 Quantification and verification

ISO 27920 Quantification and verification

ISO/TR 27921 CO_2 stream composition

Advantages CEN/TC

- Level playing field in Europe (EU27 + 7 countries incl. NO en GB)
- Cooperation and coordination on European level
- Knowledge sharing and enrichment through both informal and formal meetings
- Stimulating innovations by means of relation with i.e. European research programs
- Building on trust and social basis for CCUS and ‘CO_2 credits’
- Cost reduction through standardization of products, materials, methods, etc.
- Prioritization & agenda-setting on European level
- ….

Identified CEN/TC work items

- CO_2 composition (purity grades) and determination methods
- CO_2 measurement, monitoring and verification (MMV) throughout the value chain
- CO_2 transport by pipeline or ship including offloading and temporary storage
- Integrity of wells for underground CO_2 storage
- Harmonisation of life cycle analysis methods for CO_2 reuse
- Tools box for carbon accounting: guarantee of origin, carbon removal mechanisms, 'carbon take back obligation', mass balance / book & claim, transparent communication including certification

Proposal new CEN/TC on CCUS

Timeline 2023/2024

- **Start July**: sending final proposal to BT CEN/CENELEC
- **July-October**: Voting by correspondence National Standardization Bodies
- **October**: Ballot result -> positive -> TC474
- First plenary meeting CEN/TC474 5/6 february 2024

5. Hydrogen Quality in dedicated networks: insights, studies, and user perspectives

Standardization of Hydrogen – holistic European approach to facilitate market ramp-up

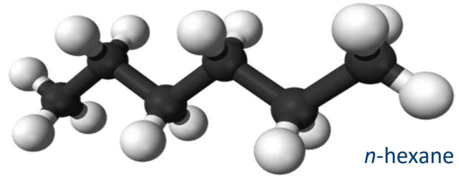
Presentation by CEN

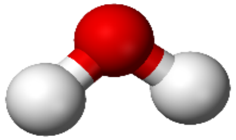
Tobias van Almsick, CEN/TC 234/WG 11 Convenor

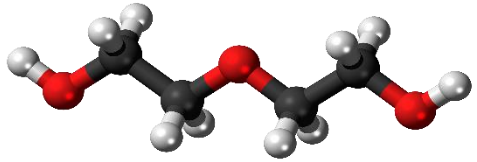
ENTSOG Gas quality workshop, 15 November 2023

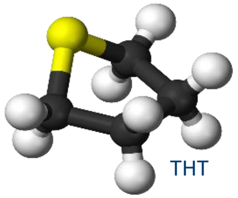
Hydrogen is not necessarily always hydrogen

H_2 sources	Possible impurities
Electrolysis	Water, oxygen, argon
Steam reformation + pressure swing adsorption (PSA)	Methane, CO, argon, nitrogen
Biogenic processes + membrane processes	Water, CO_2, methane, sulphur / chlorine / nitrogen compounds
Converted natural gas pipelines	Typical associated gas components, condensate components
Storage facilities	Water, higher hydrocarbons, glycol


n-hexane


Water


Diethylene glycol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National and international codes of practice

	DVGW G 260, Group A	Hydrogen network Netherlands SEP22-5	EASEE-Gas CBP 2022-001/01	BSI PAS 4444 (UK)	CEN TS 17977:2023
Hydrogen	≥ 98 mol %	≥ 98 mol %	≥ 98 mol %	≥ 98 mol %	≥ 98 mol %
Water	≤ 50 mg/m³	-8°C from 1 to 70 bar	-8°C from 1 to 70 bar	-10°C from 1 to 70 bar	≤ 50 mg/m³
Oxygen	≤ 1 mol % ≤ 0.001 mol %	≤ 0.001 mol %	≤ 0.001 mol %	≤ 0.2 mol %	≤ 0.1 mol % ≤ 0.001 mol %
CO	≤ 0.1 mol %	≤ 0.002 mol %	≤ 0.002 mol %	≤ 0.002 mol %	≤ 0.002 mol %
CO_2	-	≤ 0.002 mol %	≤ 0.002 mol-%	≤ 1 mol %	≤ 0.002 mol %
Sulphur	≤ 6 mg/m³	≤ 3 µmol/mol	≤ 21 mg/m³	≤ 50 mg/m³	≤ 10 mg/m³

European experts have a similar view of gas quality issues:

- 98% purity is regarded as a starting point which will be further developed towards higher degrees of purity.
- CEN TS 17977:2023 specifies the outlook in writing.

CEN Technical Specification (CEN/TS 17977)
Gas infrastructure - Quality of gas - Hydrogen used in rededicated gas systems”

Table 1 – Quality requirements for hydrogen in rededicated gas networks

Parameter	unit	value	Reference standards for test methods (informative)
Hydrogen	mol-%	≥ 98	DIN 51894
Wobbe Index	MJ/m^3 (15 °C/15 °C)	42,0 – 46,0	EN ISO 6976
The content and composition of the further quality parameter (e.g., sum of inerts) shall satisfy the Wobbe Index value above.			
Water	µmol/mol	≤ 250 ≤ 60[a]	ISO 21087
Hydrocarbon dew point (HCDP)[d]	°C	< -2 °C at 1 < p < 70 bar	ISO 21087
Sum of inerts (N_2, He, Ar)	mol-%	≤ 2	ISO 21087
Gaseous hydrocarbons[d]	mol-%	≤ 2	ISO 21087
Oxygen (O_2)[e]	mol-% µmol/mol	≤ 0,1[b] ≤10	ISO 21087
Carbon monoxide	µmol/mol	≤ 20	ISO 21087
Carbon dioxide	µmol/mol	≤ 20	ISO 21087
Total sulfur[d]	µmol/mol	≤ 7[c]	ISO 21087
Ammonia	µmol/mol	≤ 13	ISO 21087
Halogenated compounds	µmol/mol	≤ 0,05	ISO 21087
max. particulate concentration[d]	mg/kg	technically free	ISO 21087
Contaminants	The gas shall not contain constituents other than listed in this table at levels that prevent its transportation, storage and/or utilization without quality adjustment of treatment.		ISO 21087

[a] 250 µmol/mol at MOP less or equal to 10 bar, 60 µmol/mol at MOP over 10 bar
[b] max. 0,1 Mol-% in grids with no exit point to UGS or to sensitive customers, otherwise max. 10 µmol/mol
[c] non odorised hydrogen
[d] these components most likely have their source in the previous use of the pipework
[e] rolling 24 h average

In addition to the contaminants featured in Table 1, the hydrogen shall not contain any constituents that can impede safety or the integrity of the infrastructure and/or of gas appliances and operations of end-users. Appropriate measures shall be taken.

NOTE 2 Applications are sensitive towards variation of the gas quality depending on the type of application and the degree of variation.

- conservative approach – due to lack of practical experience
- transition phase – Technical Specifiation will be subject to revision in future times
- quite likely to be more strict with the parameters in future times

Rededicated infrastructure becomes dedicated infrastructure after full conversion!

Comparison of H_2 grids in Grade A and "A+" quality

Grade A grid (CEN TS 17977)

Purity of min. 98% H_2 concentration
Complex purification at exit points where higher H_2 quality is required

- Higher costs

Conversion of grids is more cost-effective.

Possible purification at import points is no longer necessary (discussion with neighbouring / export countries).

Lower risk of possible off-spec gas

Grade "A+" grid (possible future EN)

Higher purity than 98% H_2 concentration
Simple purification at H_2 sources and - where higher H_2 quality is required - at exit points

- Lower costs

Economically viable in the medium / long term

Grade "A+" grids easier to bill / billing procedure

Tail gas problem for sensitive customers no longer applicable

A

"A+"

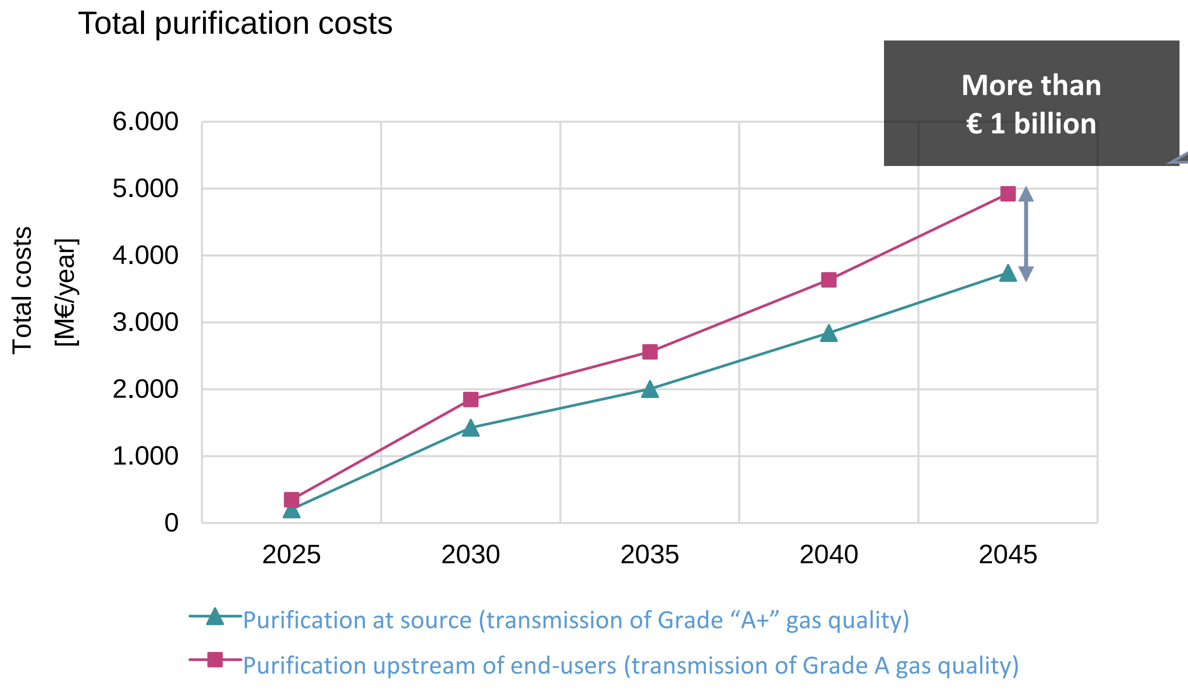
Strong arguments on both sides

Reflection: adjustment to a higher H_2 content (e.g. 99.5%)
CEN discussions are just starting!

Studies identify Grade "A+" as the economic optimum

Influenced by the following factors:

- requirements for producers vs. end-users
- location and type / costs of purification



In 2045, the difference in purification costs between a Group A grid and a Group A+ grid will be more than € 1 billion/year!

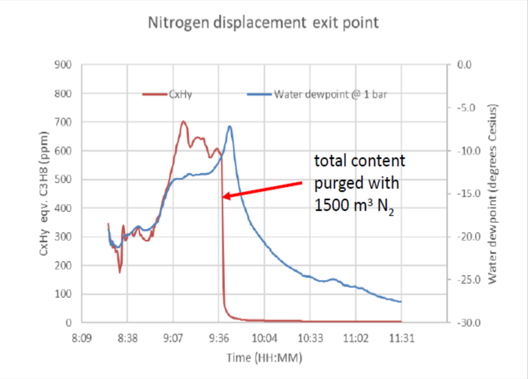
Injection and offtake quantity: 514 TWh (dena)
Injection distribution: 25% Grade A, 75% Grade "A+" (presumption OGE)
Offtake distribution: 66% Grade A, 34% Grade "A+" (dena)

Redicated pipeline and high H_2-purity?

DNV-Project: Repurposing of an existing natural gas pipeline to Hydrogen transport

BTEX and cycloalkanes in initial nitrogen samples (June 2018)

Component	Symbol	Retention time (min)	Concentration (ppm)
Benzene	C_6H_6	18.2	43.7
Cyclohexane	C_6H_8	18.8	3.5
Methylcyclohexane	C_7H_{14}	22.8	5.1
Toluene	C_7H_8	24.9	17.2
Ethylbenzene	C_8H_{10}	30.6	3.3
p/m-Xylene	C_8H_{10}	31.0	6.9
o-Xylene	C_8H_{10}	32.4	4.3



Component	2018 Exit no flow	2019 Exit flow	2020 Exit flow	2020 Entry flow	2022 Exit no flow	2022 Entry no flow	Unit
Carbon dioxide	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	ppm
Oxygen	-	<1.0	8	<1.0	3	<1	ppm
Nitrogen	-	895	1444	1423	601	804	ppm
Cyclohexane	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	ppm
BTEX	0.5	<0.1	<0.1	<0.1	<0.1	<0.1	ppm
Other saturated hydrocarbons	0.2	<0.1	<0.1	<0.1	<0.1	0.2	ppm
Chlorine and organochlorides	*	*	*	*	*	*	ppm
Fluoride and organofluorides	*	*	*	*	*	*	ppm
Total sulphur (inorganic and organic)	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	mg S/Nm³
Total silicon (including siloxanes)	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	mg Si/Nm³

**no organic chloride and -fluoride components detected*

- Pigging of the pipeline under natural gas
- Purge the line with N_2 (several dead volumes) under atmospheric pressure
- Pigging of the pipeline under N_2
- Final switch to hydrogen
  - Hydrogen quality **> 99.5 mol-%**
  - Concentration of trace components strikingly low
- Engineering calculation from OGE dovetail with experimental data: dilution process finished after approx. 4 weeks

Theory = Practice

Discussions in the broader European context

- **The Dutch Ministry of Economics is aiming at 99.5% H_2 purity in the backbone**
  - Presentation at Madrid Forum May 2023 and subsequent discussion
  - (meeting between NEN and EZK held on April 3rd).
  - Discussion between BMWK and EZK held on October 6th.

Ministerie van Economische Zaken en Klimaat

- The EC will mandate CEN with further standardisation on hydrogen quality taking into account economic aspects on purification cost and cost allocation

Europäische Kommission

- Current discussion: billing model for H_2
  - Only the H_2 content in gas is billed in kWh.
  - The value of other fuel gases is disregarded.
  - Incentive to inject H_2 with maximum purity

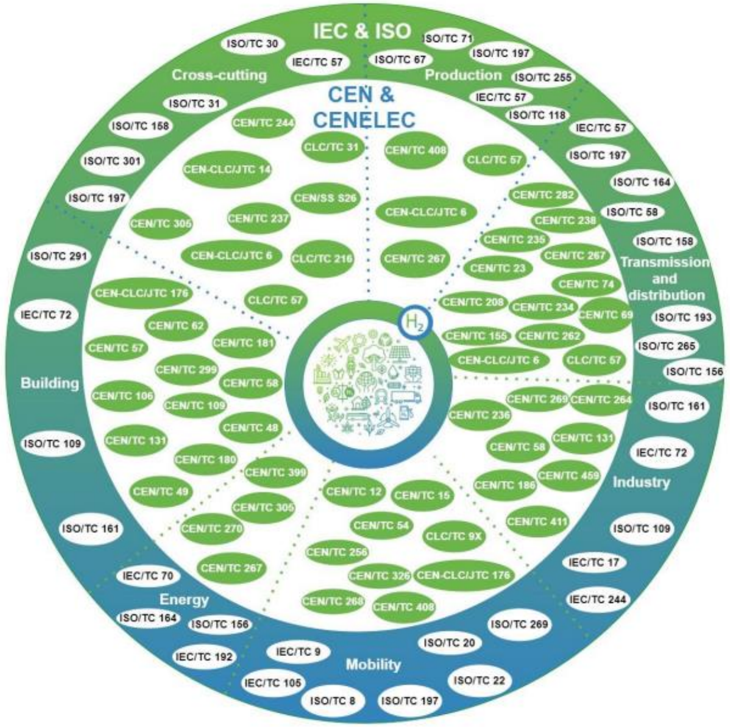
Continuation of European standardization on Hydrogen

- Finalization of report to CEN SF JTF’s questionnaire on H_2 quality ('Hydrogen quality needs for industrial uses’)

- CEN is avaiting a standardization request from EC
  - Discussion ongoing, start only after completion of the EU gas/hydrogen package (1st Q 2024?)

- EISMEA project opportunity for pre-normative action:
  - Proposal for a project on mapping and evaluation of available research findings and identification of gaps related to quality aspects in dedicated gaseous hydrogen networks

EISMEA



Contact

Tobias van Almsick
CEN/TC 234 WG 11 Gas quality

tobias.vanalmsick@oge.net

Uwe Klaas
CEN/TC 234 WG 11 Gas quality

uwe.klaas@dvgw.de

Hiltrud Schülken,
CEN/TC 234 Gas infrastructure

hiltrud.schuelken@dvgw.de

Optimal gas quality parameters for the Dutch hydrogen backbone

Maurits Doelman (Kiwa) & Jan Willem Turkstra (DNV)

DNV

kiwa

15 November 2023

Partner for Progress

Incentive

Legislative framework is being formed

Purity issue is complex:

- Suppliers produce varying qualities
- End-users demand varying qualities
- Purification methods
- European hydrogen market uncertain

What is the lowest societal cost?

Source: Gasunie

Commissioned by the Ministry of Economic Affairs and Climate Policy

Ministerie van Economische Zaken en Klimaat

Scenarios

- Follow-up focused on 2035 and 2050
  - Dutch situation

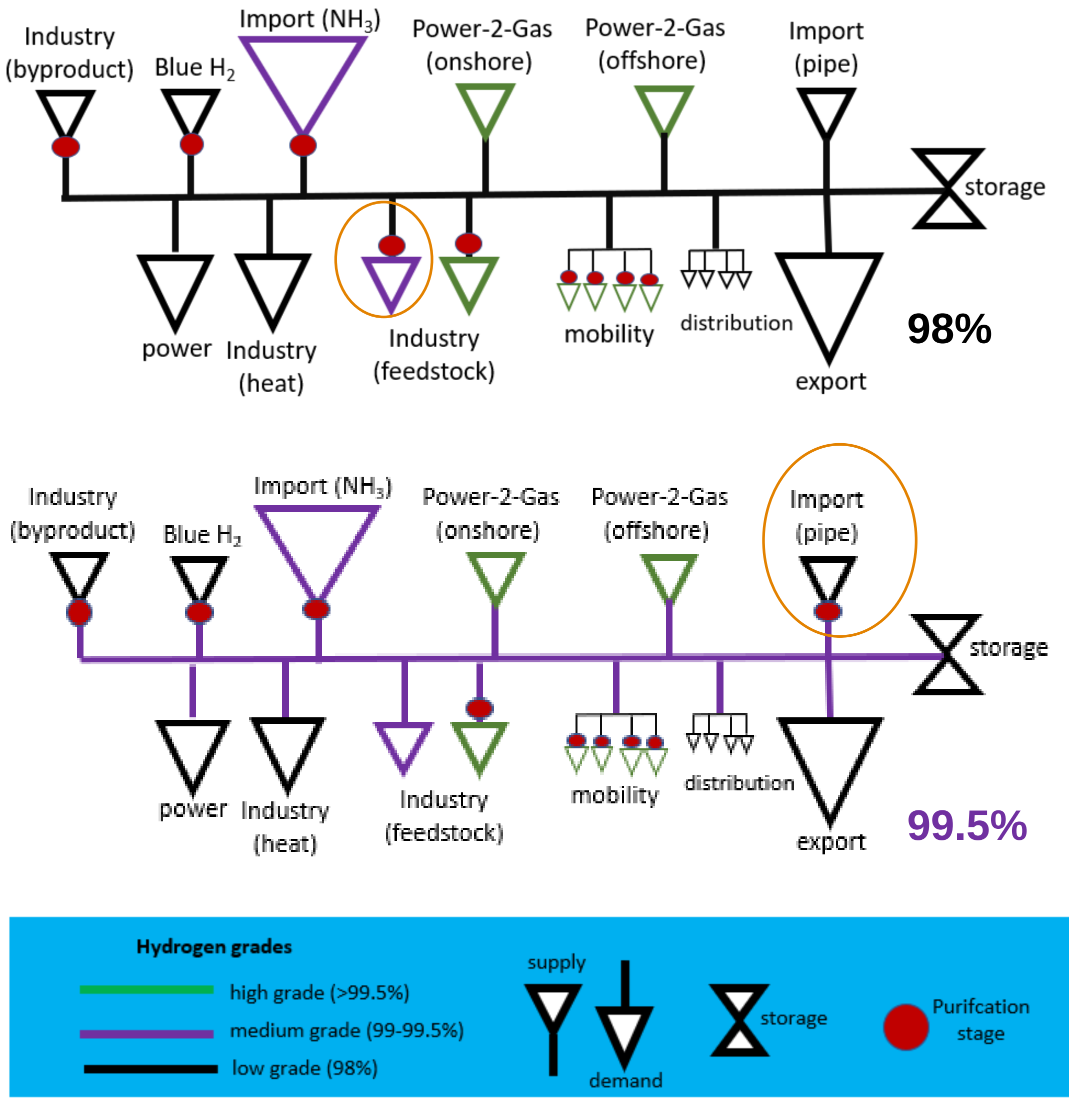
- Seven scenarios
  - Hydrogen market scenarios for 2035 and 2050 based on II3050-scenarios (2023)[1]
  - Key assumptions checked by stakeholders

- Cost of blue and green hydrogen assumed to be equal

[1] *Het energiesysteem van de toekomst: de II3050-scenario's*, Netbeheer Nederland, Gasunie & Tennet, 2023

Model

- Excel "Bookkeeping" model
- Determine required PSA stages[1]
- Model the "tailgas" impact
  - Higher purity means more tailgas
  - Remaining value as local heat source
- Determine the total cost



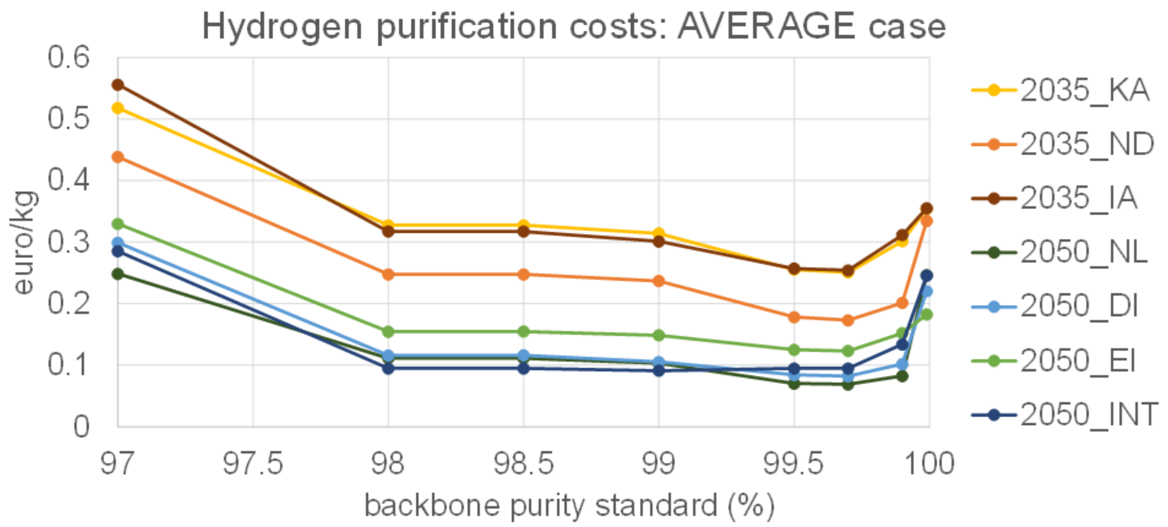
1) Pressure Swing Adsorption

Results of the model

- Hydrogen purification costs dominated (85-95%) by tailgas

- Relative cost differentials 98% v 99.5% small in all scenarios
  - Bulk producers >99.5%
  - Bulk demand <98%

- Impact of costs decreases towards 2050

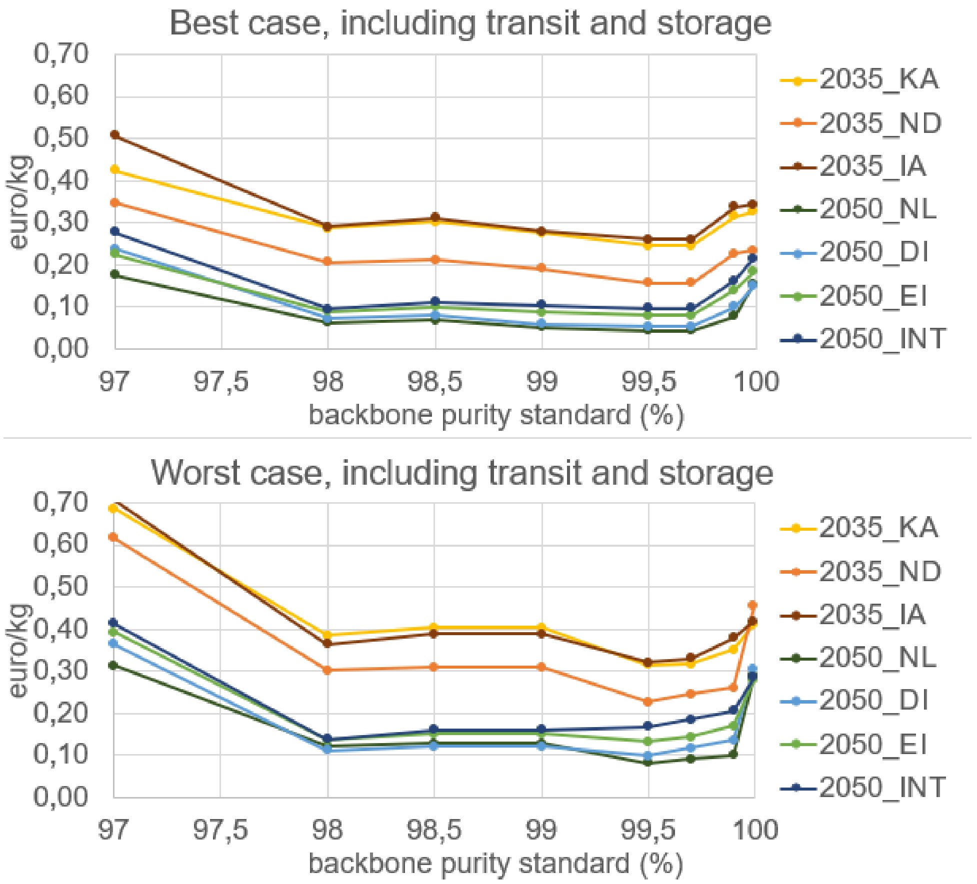


Sensitivity

Scenarios:

- Transit not included
  - All scenarios annually net export
  - Transit in favour of 98% purity
- Storage not included
  - Including storage >99.7% becomes less favourable

In summary, main findings are considered robust.



Best and worst case cover the uncertainty in all underlying technical assumptions

Advised specifications

- Hydrogen purity requirement at 99.5%
  - Inerts & hydrocarbons change to <0.5%
- Total sulphur content at most 3 ppm
- Temperature between 5 – 30 °C

Parameter	Unit	Value
Wobbe number	MJ/m³(n)	45.99-48.35 [A]
Hydrogen	mol%	≥ 99.5
Inerts	mol%	≤ 0.5 inert N_2, Ar, He
Hydrocarbons	mol%	< 0.5 incl. CH_4
Hydrocarbon dewpoint	°C	≤ -2 at 1 – 70 bar(a)
Water dewpoint	°C	-8 at 70 bar(g)
Oxygen	mol ppm	≤ 10
Carbon dioxide	mol ppm	≤ 20
Total S content (incl. H_2S)	mol ppm	≤ 3
Halogen compounds	mol ppb	≤ 50
Carbon monoxide	mol ppm	≤ 20
Formic acid	mol ppm	≤ 10
Ammonia	mol ppm	≤ 10
Formaldehyde	mol ppm	≤ 10
Dust particles (> 5 μm)	-	B
Temperature (entry)	°C	5 - 30 [C]
Temperature (exit)	°C	5 - 30 [C]

A. The volume in m^3(n) is defined at 0°C (measurement conditions) and 1013.25 mbar. The energy in MJ is derived from the thermodynamic values between 25°C (combustion conditions) and 0°C and at 1013.25 mbar according to ISO 6976.
B. The hydrogen may not contain any solid particles, liquids or gaseous components which could affect the integrity of the gas network or gas application.
C. The maximum temperature may be deviated from depending on the situation on site (types of materials, requirements of customers).

EASEE-gas

Common Business Practice on units used in Hydrogen market processes

Peter van Wesenbeeck (N.V. Nederlandse Gasunie)

Chair EASEE-gas Gas Quality Harmonisation Working Group (GQHWG)

EASEE-gas
European Association for the Streamlining of Energy Exchange – gas

Founded in 2002

85 companies in EU gas market

Three working groups

- Technology Standards
- Message & Workflow Design
- Gas Quality Harmonisation

Solutions

- Edig@s
- Gas Role Model
- Security Certificates
- Common Business Practices (CBP's)

CBP on Hydrogen Units
Introduction

Natural gas

- Traditionally used as an energy source
- Market transactions, i.e. nominating, allocating, balancing, based on energy flow
- Energy content takes the contributions of all combustible components into account
- Units used: kWh/h (energy flow), kWh (energy)

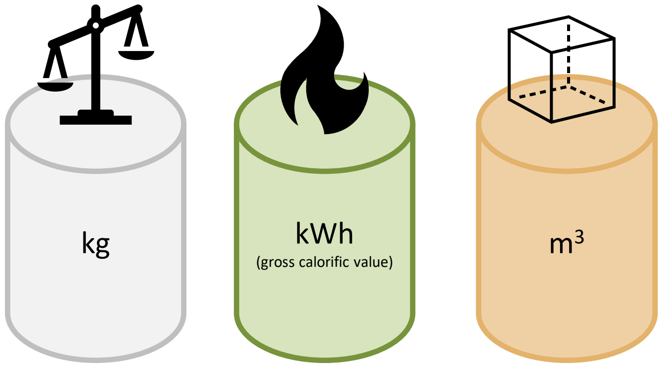
Hydrogen

- Traditionally used as a feedstock and as an energy source
- Transactions in industry based on mass with a certain quality specification (grade)
- End users are only interested in the amount of hydrogen (feedstock, carbon free)
- **Question what units need to be used?**

Units for hydrogen
Options

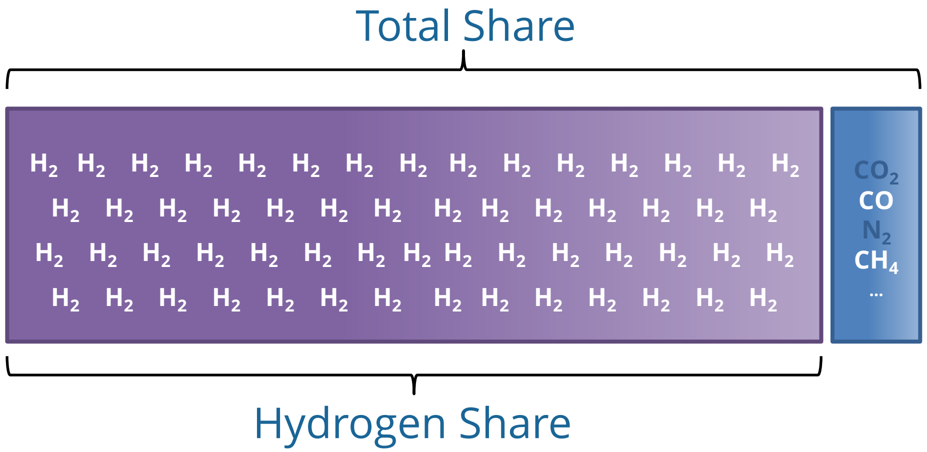
Base unit used for hydrogen market processes

- Mass (kg)
- Energy (kWh)
- Volume (m^3)



Energy determination of hydrogen stream

- All combustible components (total share)
- Only the hydrogen molecules (hydrogen share)



EASEE-gas

Base unit for hydrogen

Ranking the various options

Basis	End user acceptance	Future proof
Mass (kg)	The market for chemicals mostly uses mass but gas and electricity are traded on energy basis	Not desirable for the integration of electricity and gas market.
Energy (kWh)	Hydrogen energy (option hydrogen share) could confuse end users and result in questions and / or measurement complaints. (Risk can be mitigated by information provision)	The hydrogen market is expected to be closely integrated with the electricity market. The current gas market messages can be used without modifications
Volume (m^3)	Volume units are not relevant for hydrogen customers.	Volumes depend on chosen pressure and temperature conditions Not desirable for the integration of electricity and gas market

Green	++ / no risk
Purple	0
Orange	- / high risk

EASEE-gas

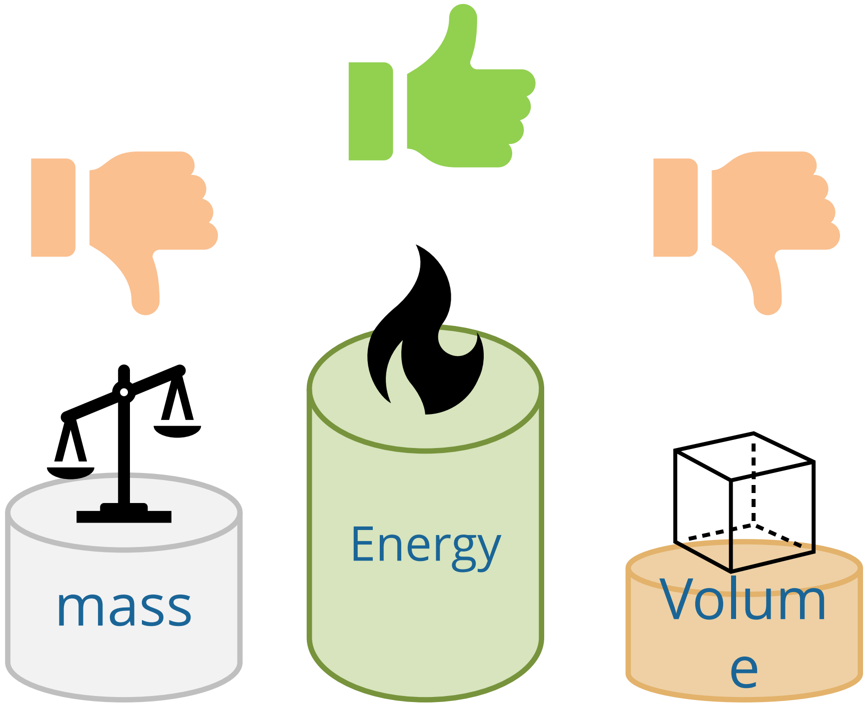
Energy determination
Ranking total share and hydrogen share options

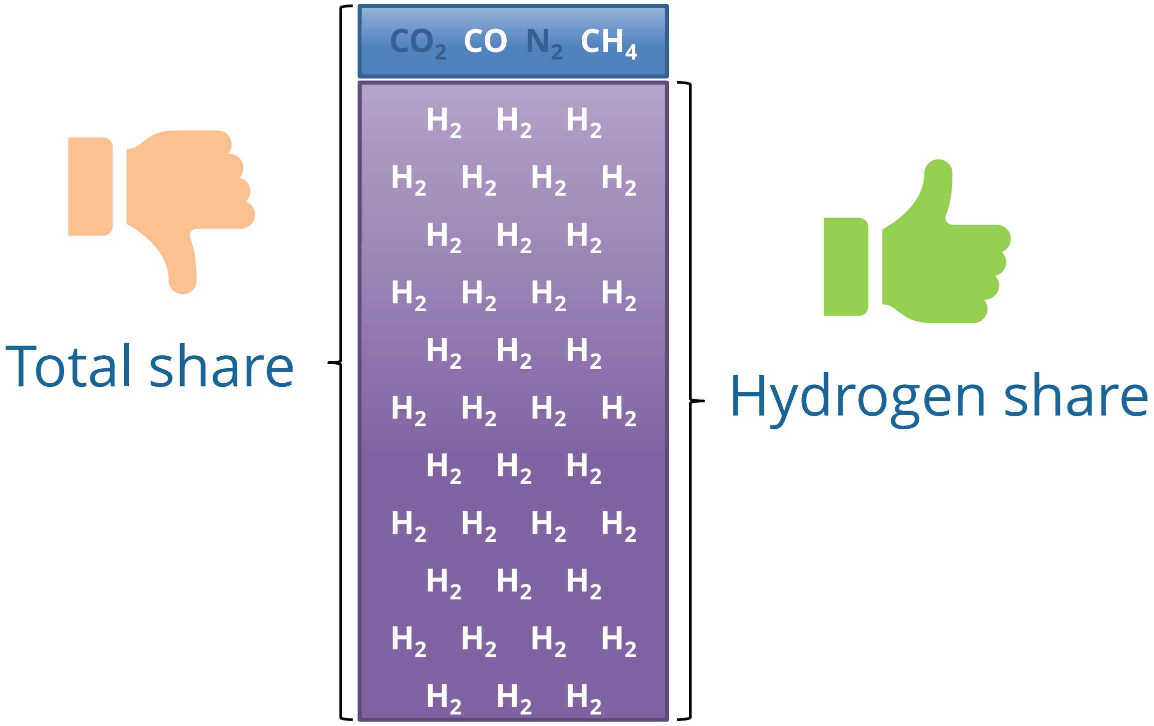
Property	Total share	Hydrogen share
end user acceptance	Match between end user and TSO measurements (all components)	Mismatch between end user and TSO measurement (only hydrogen)
Future-proof	No incentive for producing hydrogen with higher purity and even a risk for adding additional combustible components	An incentive for producing hydrogen with higher purity and no risk on adding additional combustible components
Transmission fees	All combustible products are settled (allocation)	Only hydrogen quantities are settled (allocation).
	Transmission fees based on all combustible products (like for natural gas).	Transmission fee only based on hydrogen (Allocating of transmission costs based on the total amount of hydrogen transmitted).
Facilitating certification	The amount of all combustible components are taken into account	Only the amount of hydrogen present in the gas is taken into account

++ / no risk | 0 | - / high risk

EASEE-gas

Units for hydrogen
Conclusions





CBP on Hydrogen Units
Outlook

Units to be used in market processes

- Based on energy content of hydrogen i.e. only based on the hydrogen molecules present. The energy content of all other combustible components is not taken into account.
- Based on gross calorific value of hydrogen calculated at a reference combustion condition of 15 °C, a volume reference temperature of 15 °C and a volume reference pressure of 1,01325 bar

Note

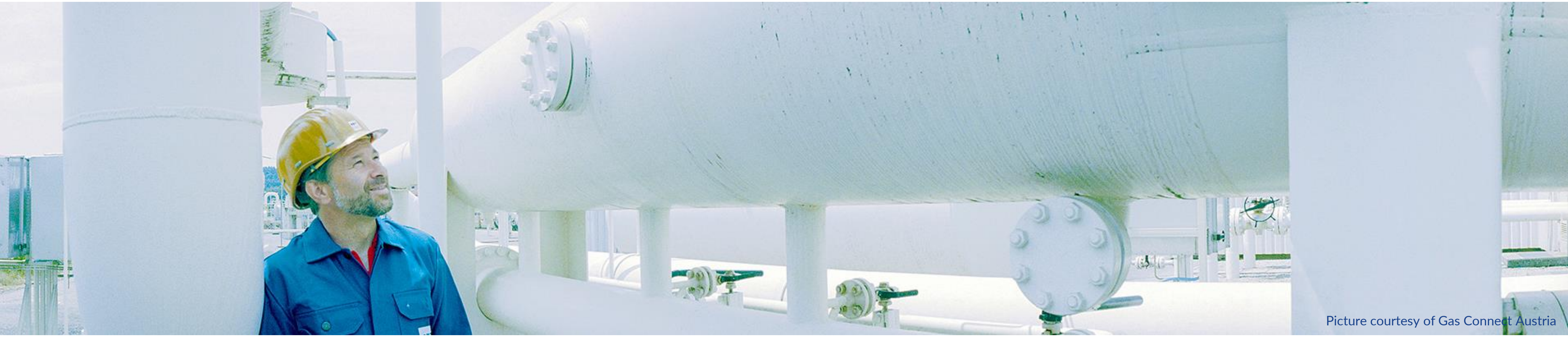
- In some countries a formal approval is required from the legal metrology authorities before implementation of the in the CBP proposed method is allowed.

CBP is expected to become available before the end of this year

6. Learnings on LNG post imports increase

15 November

INT2604-23_Rev_0



Gas Flow Changes and Impact on Gas Quality

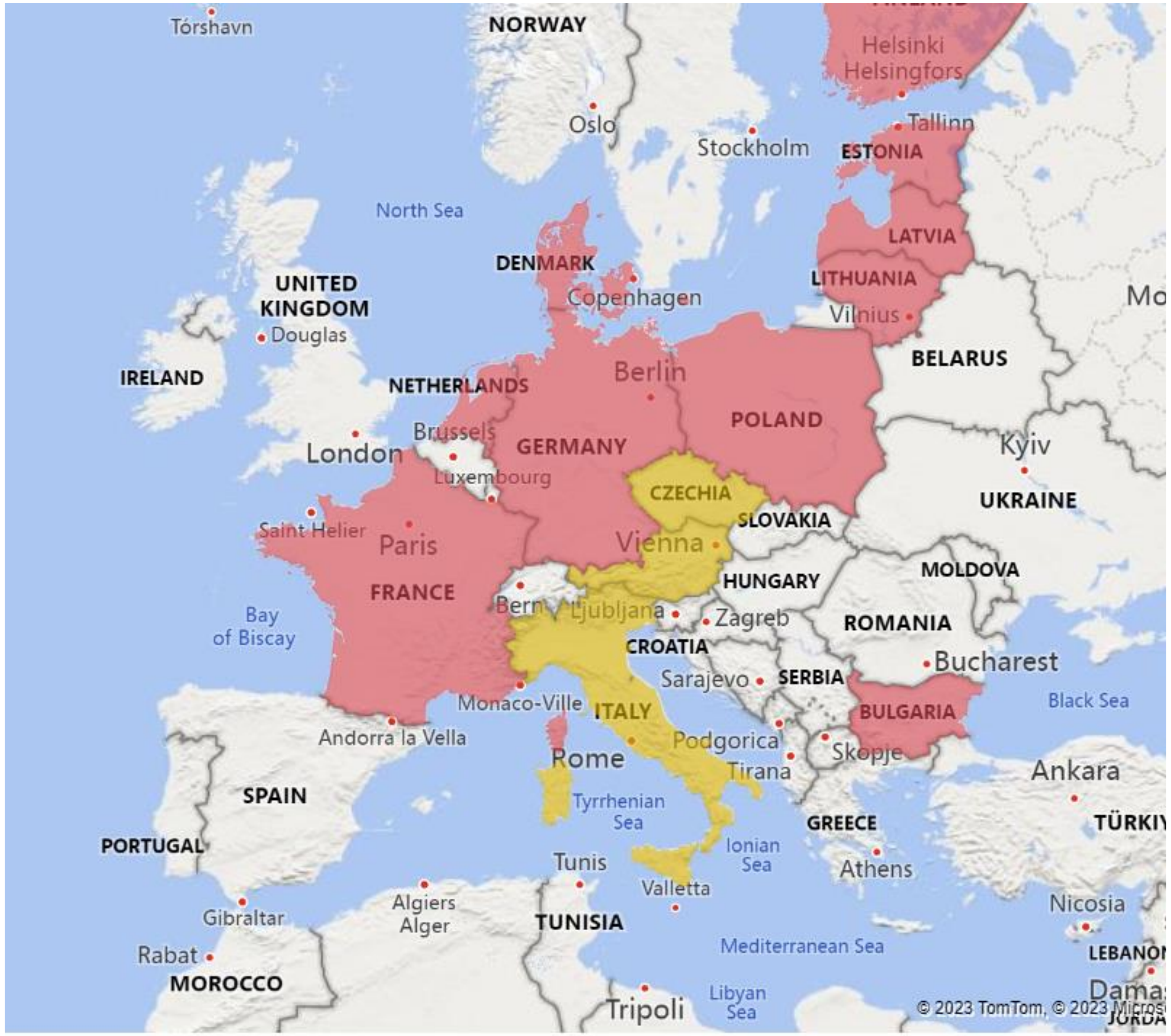
ENTSOG GQ Workshop – 15 November 2023

Hendrik Pollex, Director, System Operation

Reduction of Russian Pipeline Gas Supply in 2022

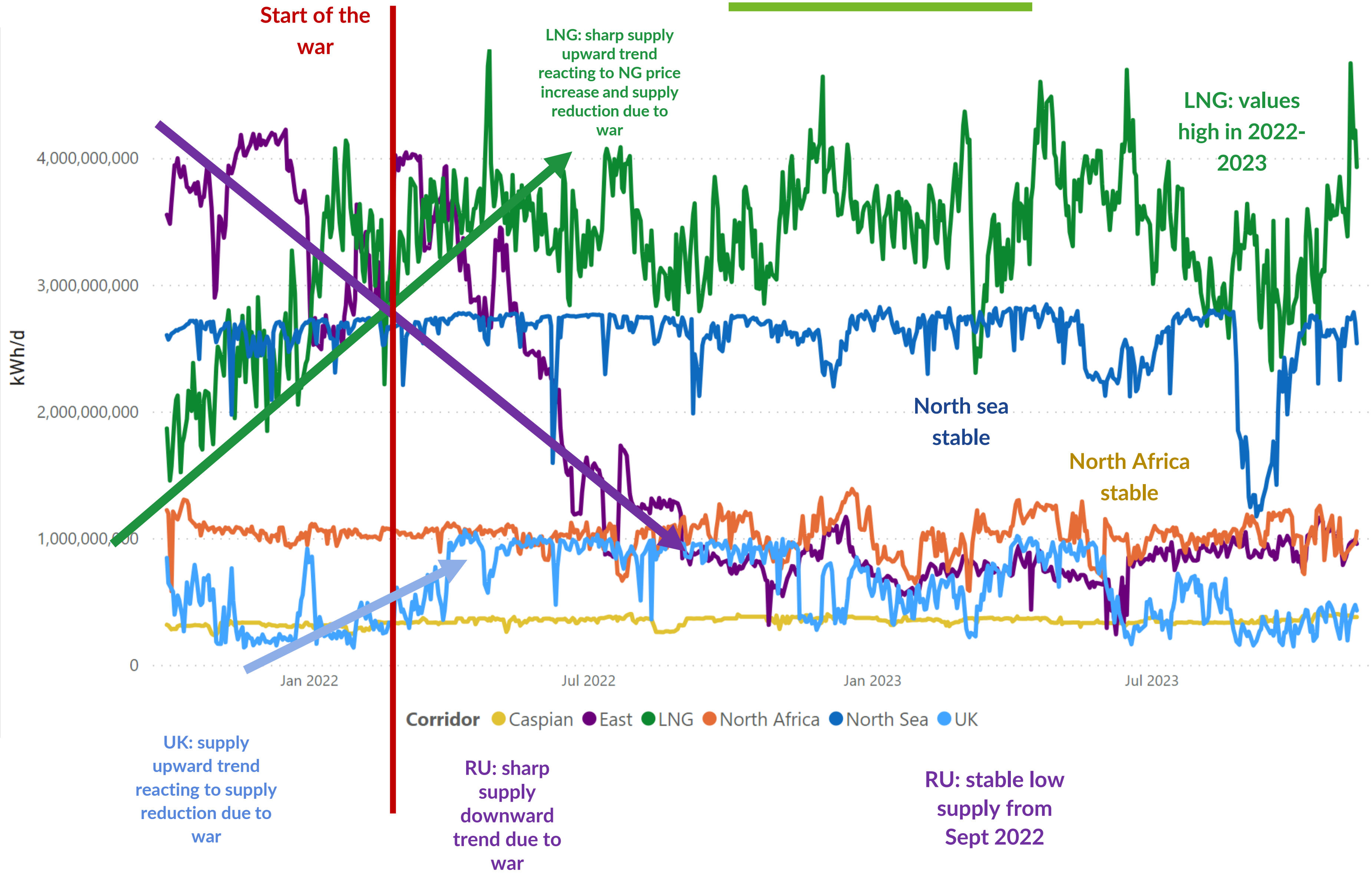
- **2022**
  - Stepwise reduction of Russian gas supply to the EU
  - Around 25 BCM left compared to around 150 BCM in 2021

- **2023**
  - Situation remains stable
  - Share of around 8-12 % of total supply of pipeline gas to the EU



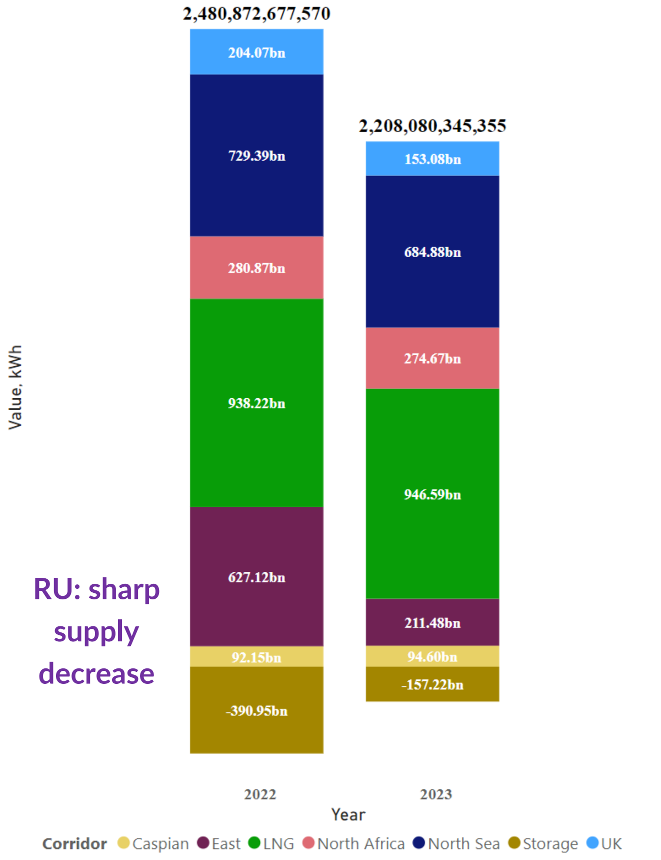
Rusian gas supply in 2023 ● reduced ● stopped

Overall EU Gas Supply Flows Trends Since October 2021



EU supply picture of Q1-3 2022 vs Q1-3 2023

Reduction in supply was compensated by demand reduction by EU effort



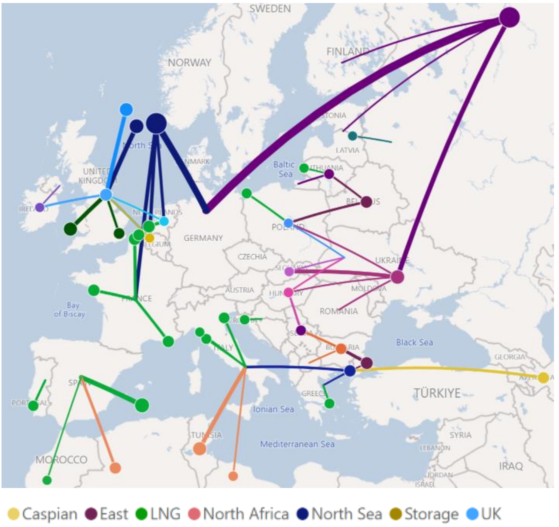
Gas Supply Flows in 2021 vs 2022 (and 2023) and Gas Quality

Main findings at country level:

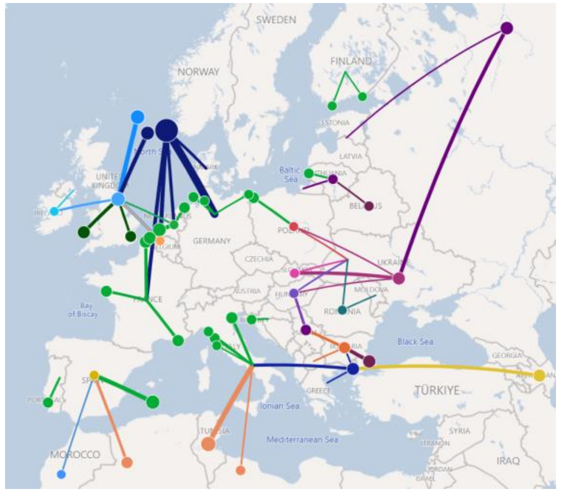
- DE: nearly no flows from RU from Sept 2022; flows from FR; lower flows to CZ and AT; new flows from LNG; much higher flows from BE
- PL: no flows from RU from May 2022; more LNG (incl. from LT) and more gas from NO via DK; flows to UA

Consequences for Gas Quality:

- Weighted average of GQ parameters (GCV, WI) in the EU is different
- Central east EU MSs affected by flows changes – methane content differs from previous situation (IAs under discussion)
- Odorized gas from FR to DE
- More LNG and more diversified sources led to GQ changes
- GQ parameters fluctuations – no complains from consumers



2021

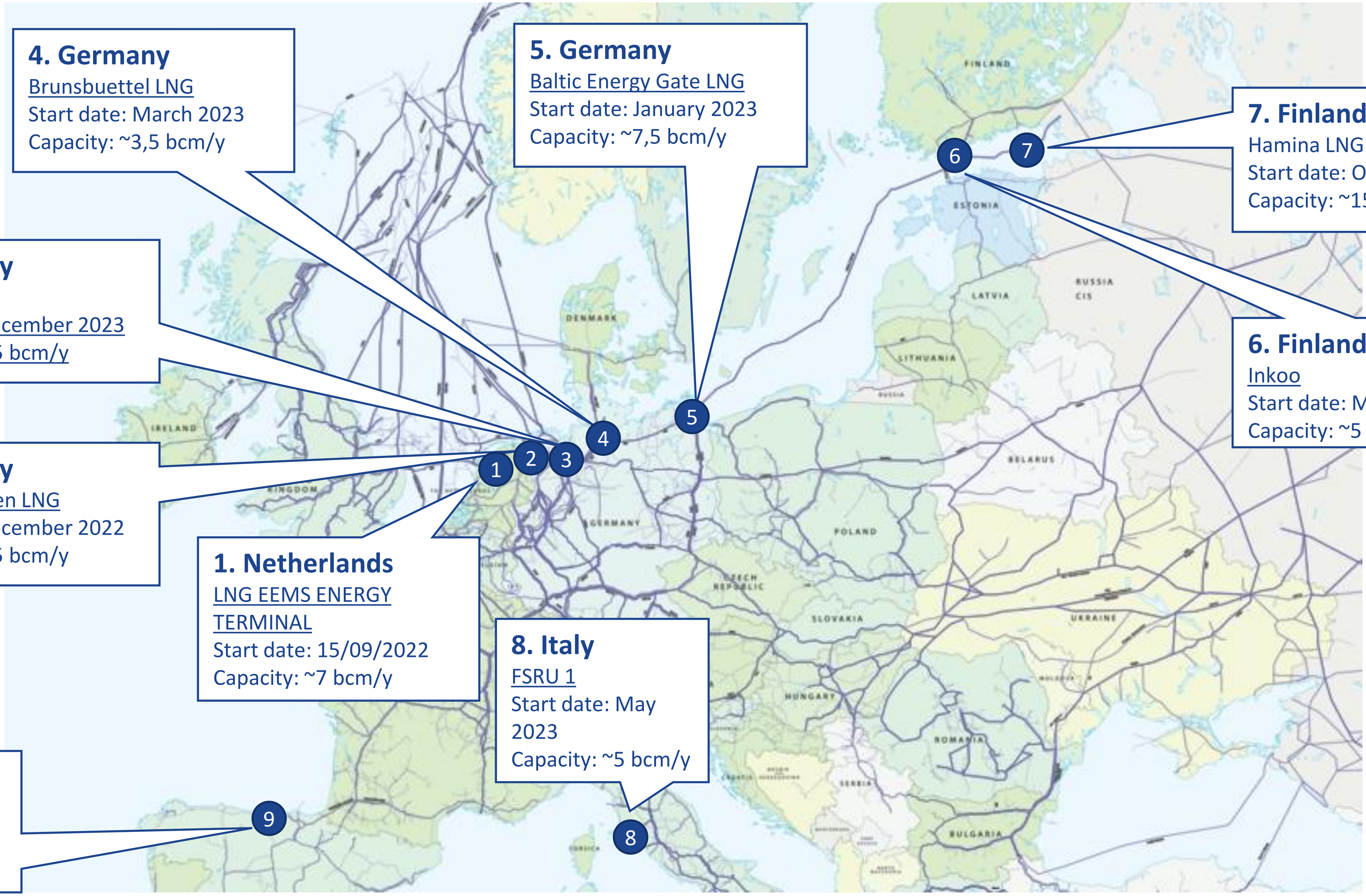


Q4 2022

and 2023

TSOs have successfully managed their networks after flows patterns and GQ changes

New Main LNG & FSRU Projects 2022 & 2023



4. Germany
Brunsbuettel LNG
Start date: March 2023
Capacity: ~3,5 bcm/y

5. Germany
Baltic Energy Gate LNG
Start date: January 2023
Capacity: ~7,5 bcm/y

7. Finland
Hamina LNG
Start date: October 2022
Capacity: ~150 Mcm/y

3. Germany
Stade LNG
Start date: December 2023
Capacity: ~7,5 bcm/y

6. Finland / Estonia
Inkoo
Start date: March 2023
Capacity: ~5 bcm/y

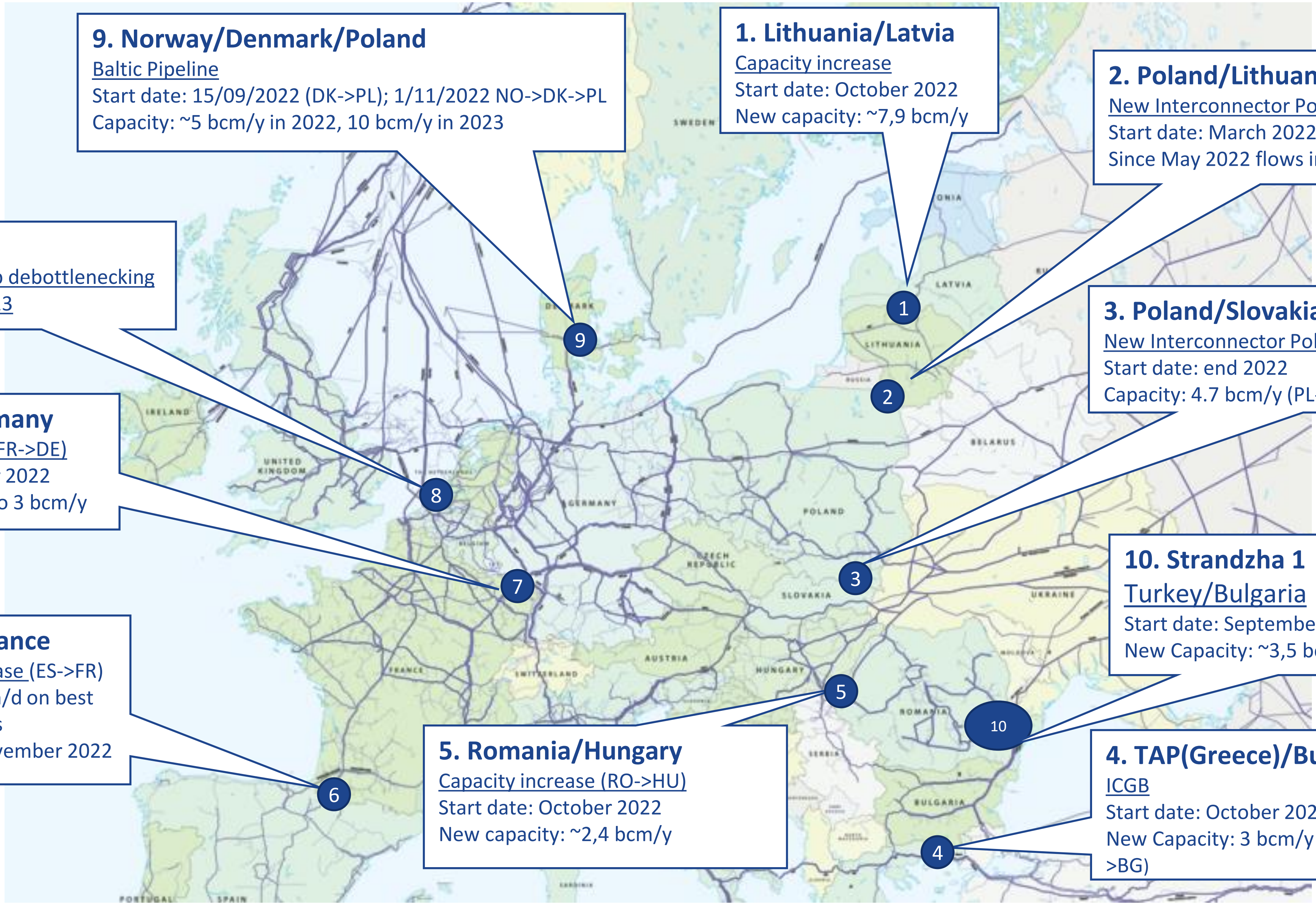
2. Germany
Wilhelmshaven LNG
Start date: December 2022
Capacity: ~7,5 bcm/y

1. Netherlands
LNG EEMS ENERGY TERMINAL
Start date: 15/09/2022
Capacity: ~7 bcm/y

8. Italy
FSRU 1
Start date: May 2023
Capacity: ~5 bcm/y

9. Spain
LNG Musel
Start date: 1/07/2023
Capacity: ~8 bcm/y

New Main Infrastructure Projects 2022 & 2023



9. Norway/Denmark/Poland
Baltic Pipeline
Start date: 15/09/2022 (DK->PL); 1/11/2022 NO->DK->PL
Capacity: ~5 bcm/y in 2022, 10 bcm/y in 2023

1. Lithuania/Latvia
Capacity increase
Start date: October 2022
New capacity: ~7,9 bcm/y

2. Poland/Lithuania
New Interconnector Poland Lithuania
Start date: March 2022
Since May 2022 flows in both directions

8. Belgium
Zeebrugge hub debottlenecking
Start date: 2023

3. Poland/Slovakia
New Interconnector Poland-Slovakia
Start date: end 2022
Capacity: 4.7 bcm/y (PL->SK); 5.7 bcm/y (SK->PL)

7. France/Germany
Capacity increase (FR->DE)
Start date: October 2022
New Capacity: up to 3 bcm/y

10. Strandzha 1
Turkey/Bulgaria
Start date: September 2023
New Capacity: ~3,5 bcm/y

6. Spain/France
Capacity increase (ES->FR)
Around 4 Mcm/d on best endavour basis
Start date: November 2022

5. Romania/Hungary
Capacity increase (RO->HU)
Start date: October 2022
New capacity: ~2,4 bcm/y

4. TAP(Greece)/Bulgaria
ICGB
Start date: October 2022
New Capacity: 3 bcm/y in 2022 (TAP->BG)

LNG supply to Spain in 2022, is there an impact on natural gas quality delivers to the market?

José A. Lana

Enagás Transporte S.A.U.

15th November 2023/*ENTSOG Gas Quality Workshop*

enagas

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Leader in energy infrastructures

Over 50 years of experience

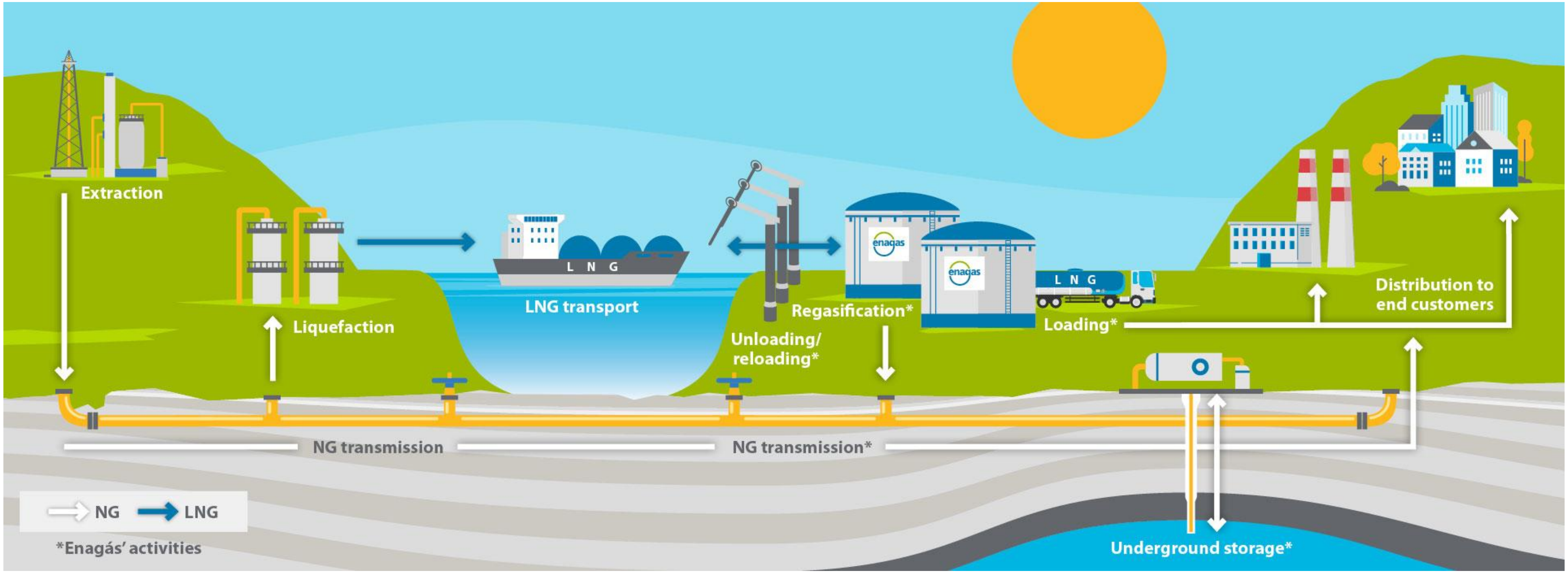
A **midstream company**

European Union accredited **independent TSO**

Top natural gas **transmission company** in Spain

Technical Manager of Spain's Gas **System**

Committed to decarbonisation: natural gas and renewable gases



A clear purpose

To contribute to guaranteeing the **security of energy supply** in Spain and Europe and to speed up the **decarbonization** process.

2022-2030 Strategic Plan

Looking ahead to 2030, we are working towards...

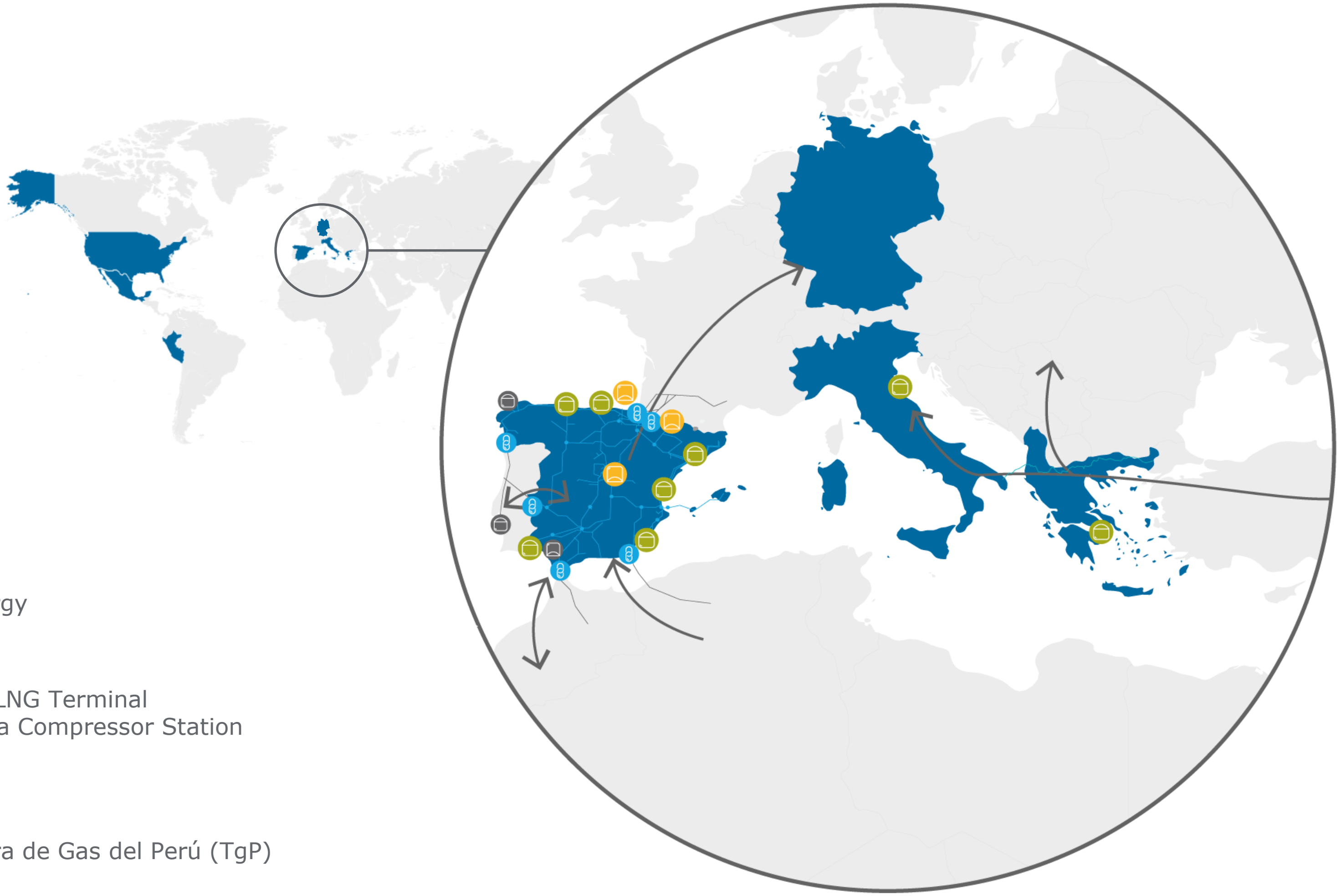
The **integration of a European energy system** through infrastructure

The promotion of a **future hydrogen network** in Europe

The creation of a **market for renewable gases** through our Enagás Renovable subsidiary

A leading TSO with focus on Europe

Future HNO



USA
Tallgrass Energy

Mexico
TLA Altamira LNG Terminal
Soto La Marina Compressor Station

Peru
Transportadora de Gas del Perú (TgP)

Spain
11,000 km gas pipeline
6 LNG terminals
3 underground storage facilities

Greece
DESFA

Greece, Albania and Italy
Trans Adriatic Pipeline (TAP)

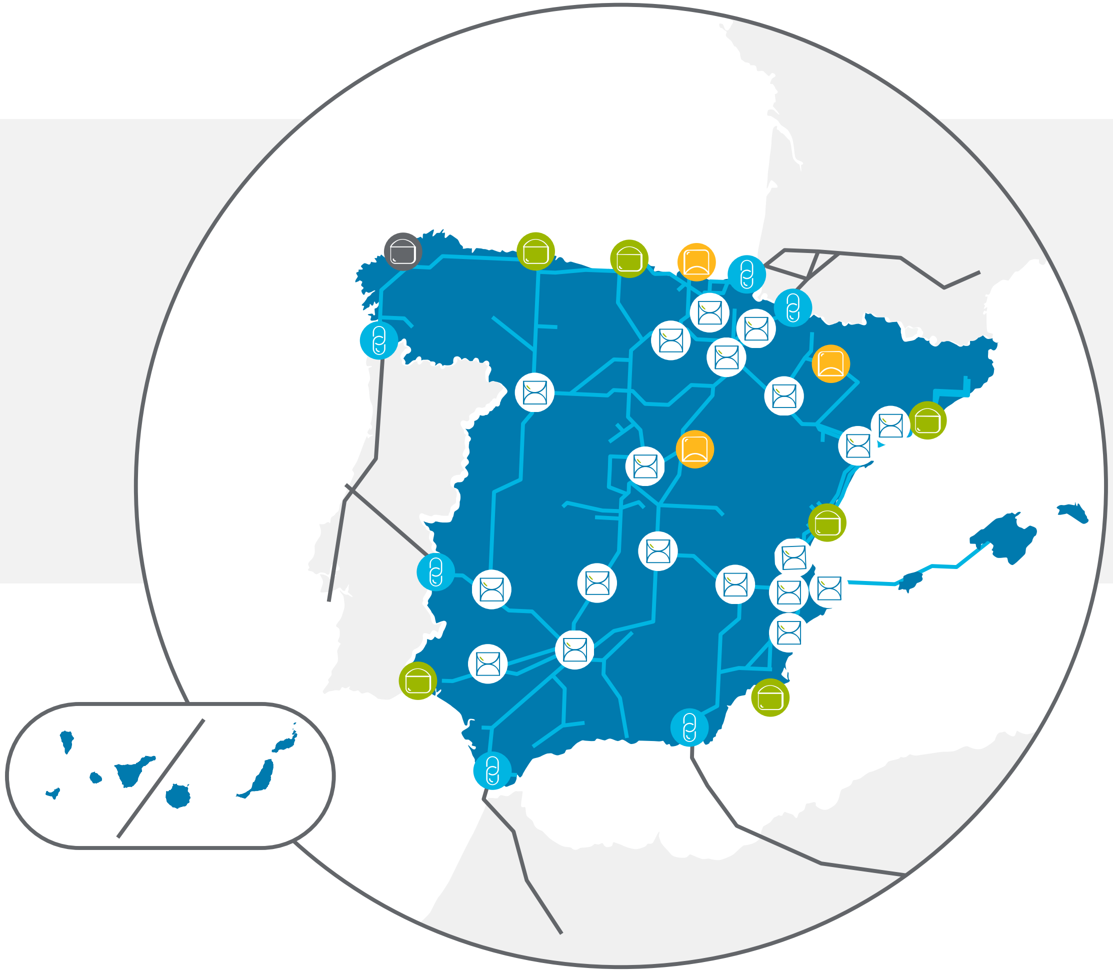
Italy
Ravenna Small Scale LNG Terminal

Germany
10% Hanseatic Energy Hub

Our infrastructure in Spain

Key to the security of supply and the decarbonisation process

Our **infrastructure network** is needed and will be complemented by new ones for the **transmission and storage of renewable gases**



Point of entry for LNG to Europe

We are the company with the most LNG terminals in Europe and third in the world

11,000 km gas pipeline

6 LNG terminals

3 underground storage facilities

19 compressor stations

6 international connections

Catalyst for an H2 market

Pioneers and leaders in the development of renewable gases as new energy solutions for decarbonisation

Enagás Hydrogen Infrastructures

Ready to be **operator of the future hydrogen network**

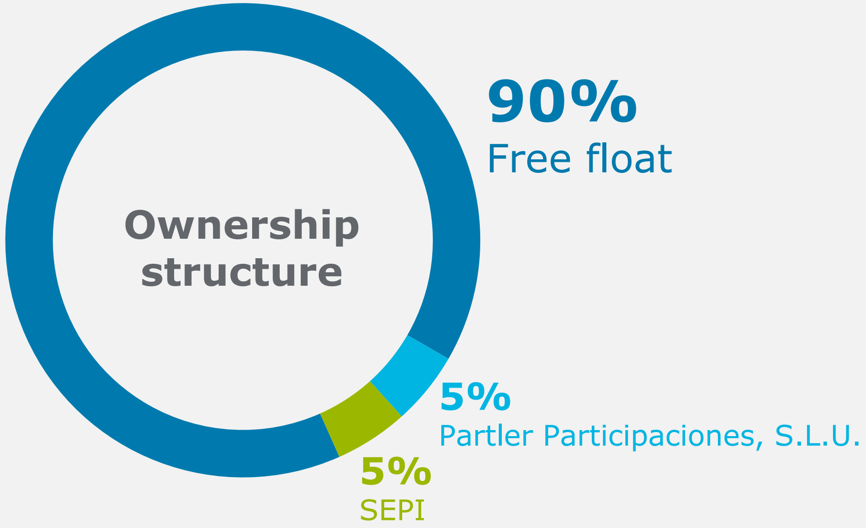
enagas renovable

60% stake in Enagás Renovable **to contribute to the creation of the renewable gas market in Europe**

Enagás GTS

Implementation of the **Guarantees of Origin System** for renewable gases

A robust and independent company



Market capitalisation

(12th April 2023) **€4,813 Mn**

STANDARD & POOR'S **BBB**

FitchRatings **BBB**

2022

€970.3 Mn
Total income

€797.4 Mn
EBITDA

€375.8 Mn
Net profit

Dec. 2022

Liquidity	Assets
€3,794 Mn	**€9,398 Mn**

Sustainability and ESG principles, the cornerstones of our strategy

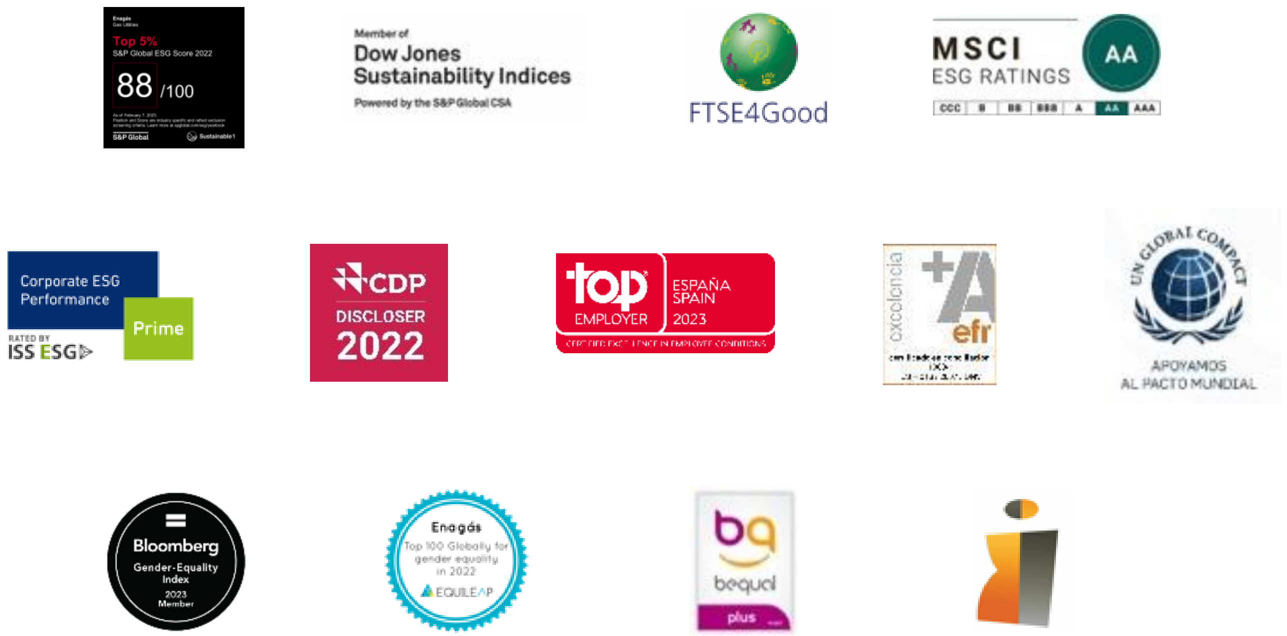
Target: carbon neutrality by 2040

+50
Energy **efficiency projects** a year

-32%
Emissions
2022 vs. 2014

+1,300
highly qualified
professionals

Leaders in sustainability



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Context

- European natural gas supplies changed abruptly in February 2022
- Traditional pipeline flow from Russia had to be replaced by LNG
  - Higher share of LNG in countries already importing
  - LNG arriving to Central Europe countries
- Spain has always had a great share of supplies from LNG, but an significant increase can be seen in 2022

Year	LNG (%)	Pipeline (%)
2021	55	45
2022	71	29

The Spanish Gas System. Report 2022, Enagás GTS

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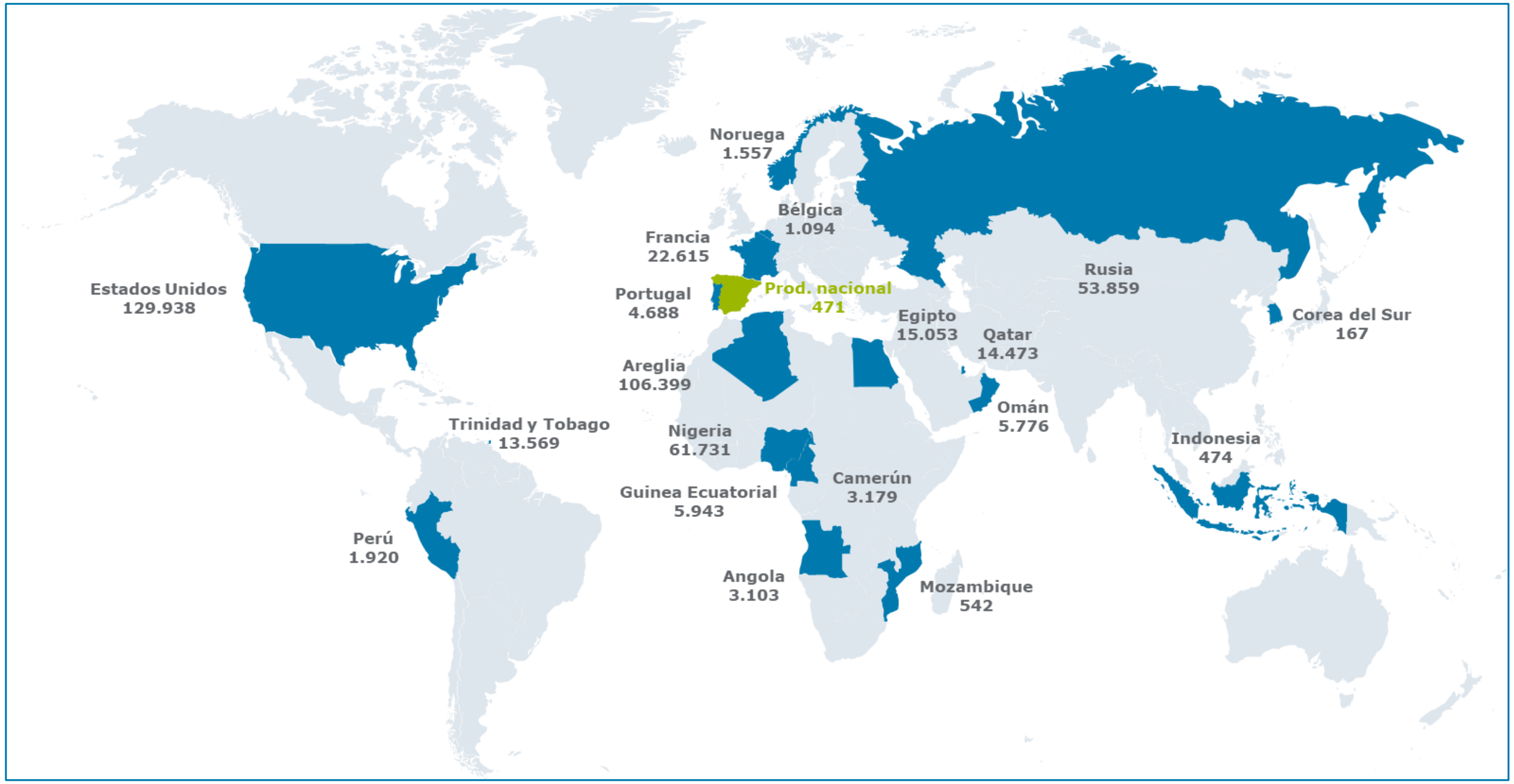
LNG supplies to Spain, 2022

Great diversification of supplies → *Security of supply*

19 countries 2022



[The Spanish Gas System. Report 2022, Enagás GTS]()

	GWh
United State of America	129 938
Algeria (NG + LNG)	106 399
Nigeria	61 731
Russia	53 859
France (NG + LNG)	22 615
Egypt	15 053
Qatar	14 473
Trinidad	13 569
Equatorial Guinea	5 943
Oman	5 776
Portugal (NG)	4 688
Cameroon	3 179
Angola	3 103
Peru	1 920
Norway	1 557
Belgiun (LNG)	1 094
Mozambique	542
Indonesia	474
National production	471
South Korea	167
Total	**446 550**

Comparison gas supply 2021 vs 2022

All Spanish LNG terminals

- 2022 saw a great increase in LNG importation in comparison with 2021
- Although more natural gas arrived to Spain in 2022 than in 2021:
  - Higher exportation of natural via pipeline to Europe and Morocco
  - Higher exportation of LNG, carrier loading, + 45%
    - 27.9 TWh in 2022 vs 17.1 TWh in 2021

TWh	2021	2022	Δ
NG	189.5	127.7	-32.6
LNG	227.2	318.9	40.4
Total	***416.7***	***446.6***	***7.2***
National consumption	*378.5*	*364.4*	*-3.7*

The Spanish Gas System. Report 2022, Enagás GTS

The Spanish Gas System. Report 2021, Enagás GTS

LNG Carrier by terminal

	2021	2022
Barcelona	47	58
Huelva	52	68
Cartagena	44	61
Bilbao	49	65
Sagunto	38	58
Mugardos	24	28
TOTAL	**254**	**338**

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1. About Enagás
2. Context
3. Gas supplies to Spain
4. **LNG quality**
5. Conclusion

LNG quality

Limited to three LNG terminals fully operated by Enagás

- Barcelona, Cartagena & Huelva LNG terminals:
  - In 2021, received 56 % LNG carriers arriving to Spain, 143
  - In 2022, received 55 % LNG carriers arriving to Spain, 187
  - Consider *representative of LNG arriving to Spain*

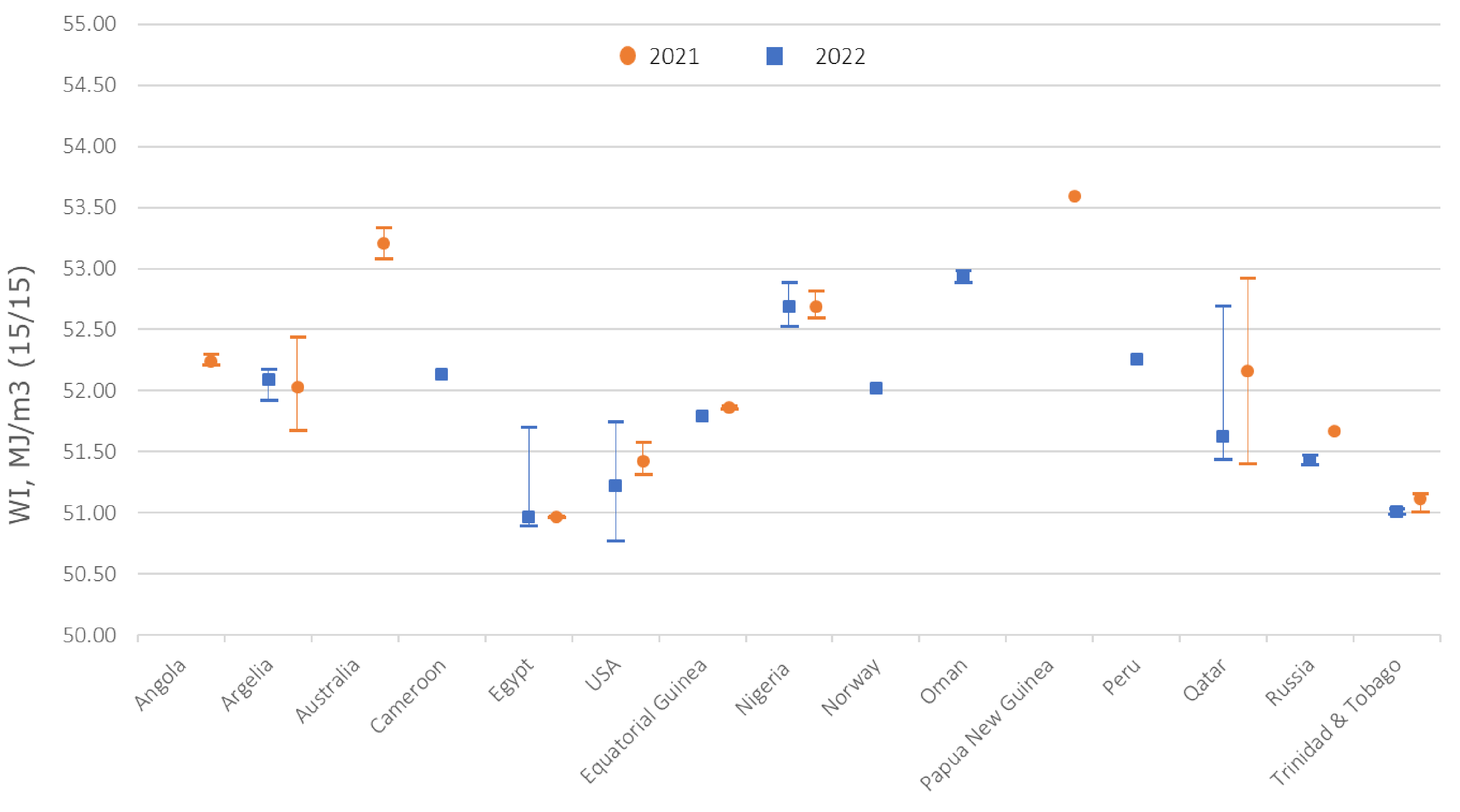
- The analysis done *does not considered the LNG coming from re-loading in other countries*, i.e., Belgium or South Korea

- Analysis for *three quality parameters*
  - *Wobbe index*
  - *Gross Calorific Value*
  - *Methane number*

- LNG by countries includes a comparison of 2021 and 2022 data

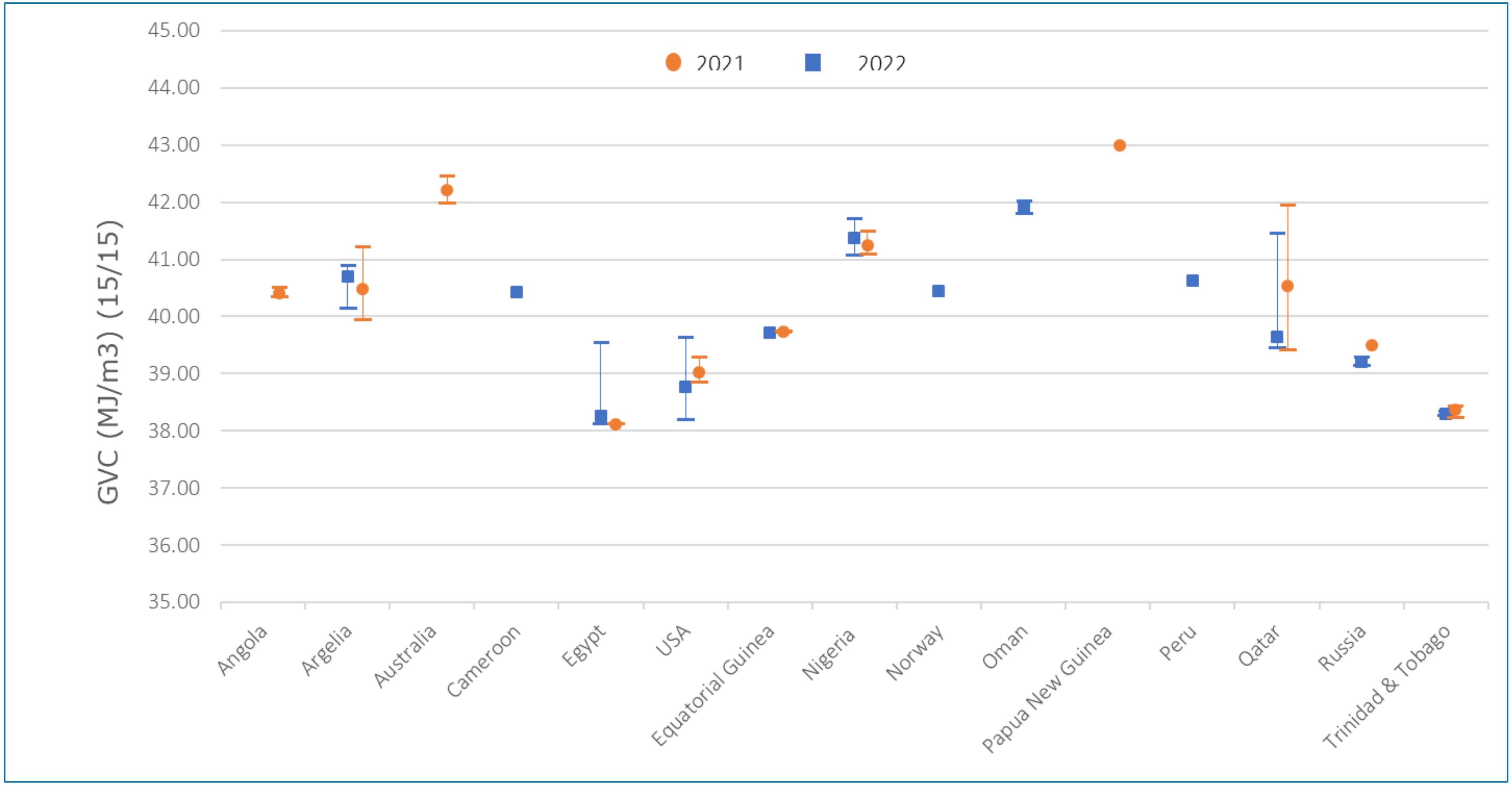
LNG quality 2021 & 2022

Wobbe index [MJ/m³ (15/15)]



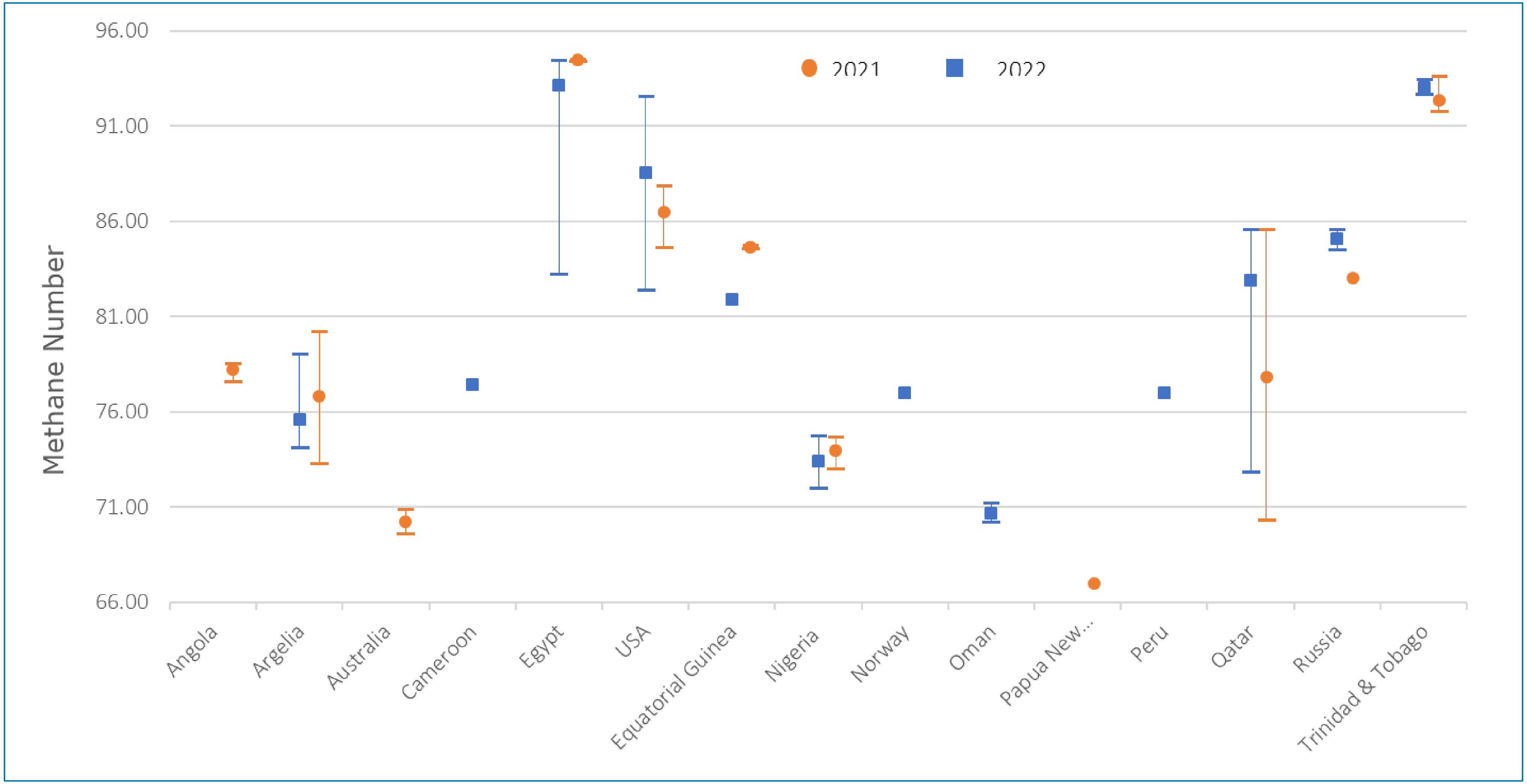
LNG quality 2021 & 2022

GCV[MJ/m³ (15/15)]



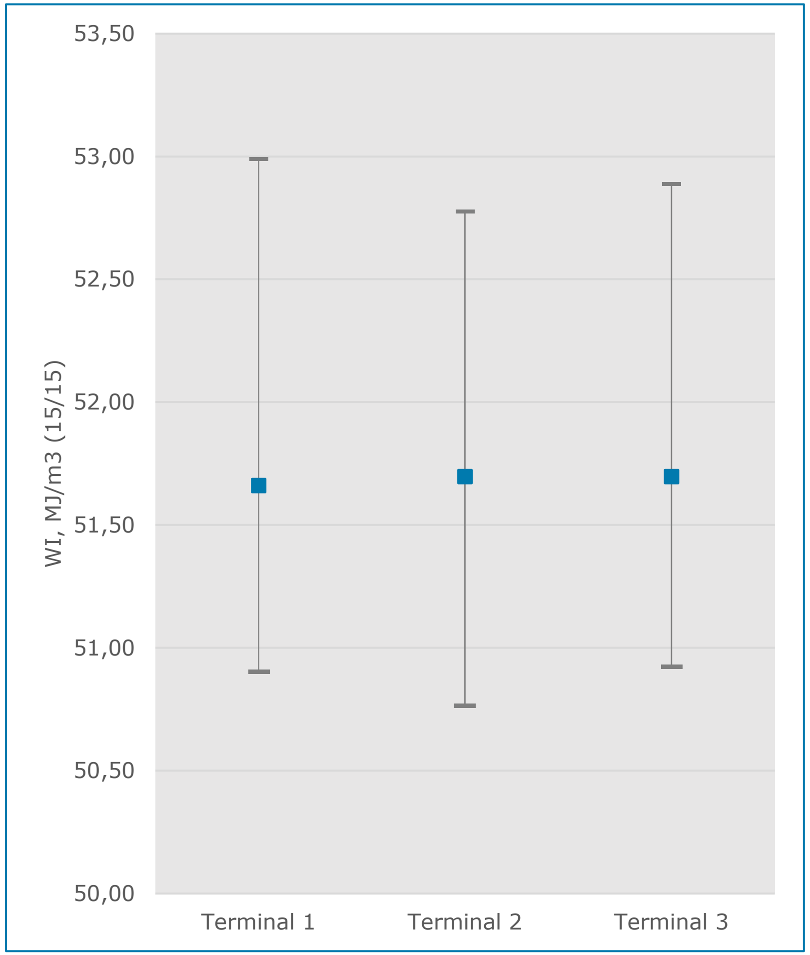
LNG quality 2021 & 2022

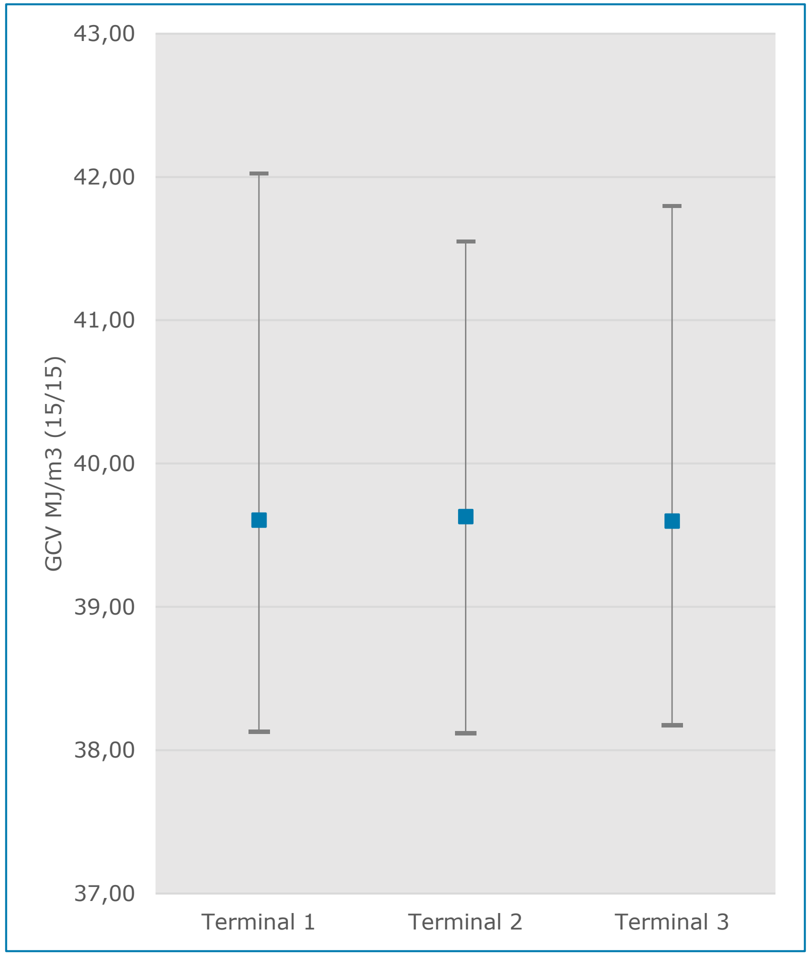
Methane number

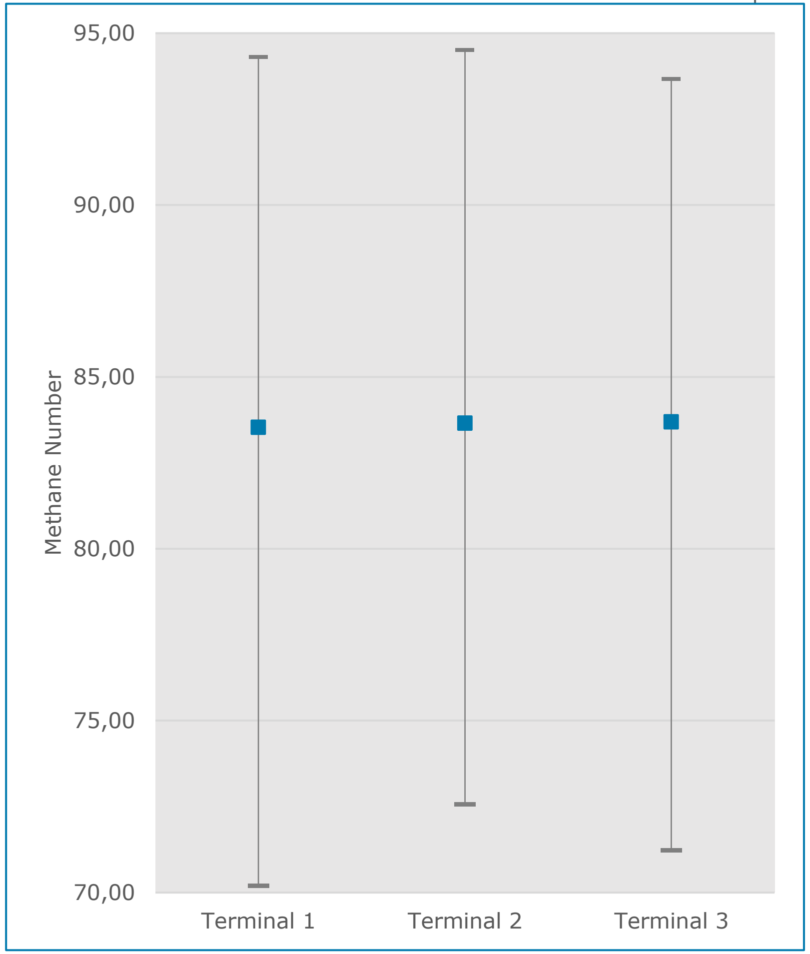


LNG quality by terminal

Wobbe index [MJ/m³ (15/15)], GCV [MJ/m³ (15/15)] and Methane number







LNG quality by terminal

What it is delivered to the pipeline network

- *Yearly average of gas quality does not change significantly between LNG received and the natural gas sent to the grid*
  - And there is not a great difference with 2021

Wobbe index [MJ/m³ (15/15)]	2022 LNG (yearly average)	2022 NG sent to grid (yearly average)	2021 NG sent to grid (yearly average)
Terminal 1	51.66	51.66	51.87
Terminal 2	51.70	51.68	51.98
Terminal 3	51.70	51.66	51.91

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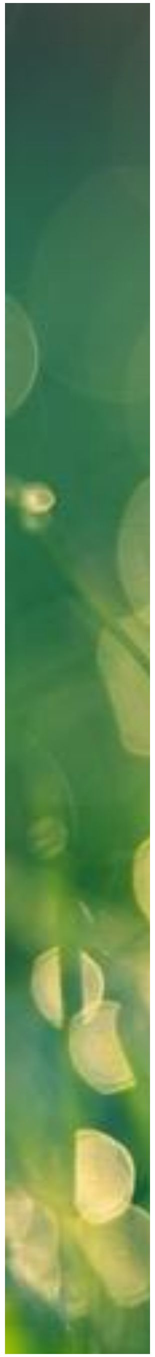
Conclusions

- Spain has very ***diversified*** natural gas supplies
  - This allows a *great Security of Supply*

- This scenario is helped by a *broad natural gas specification* for input to the National gas system (*NGTS PD01*):
  - Wobbe index: 45.6 – 54.7 MJ/m^3 (15/15)
  - Gross Calorific Value: 34.9 – 45.2 MJ/m^3 (15/15)

- From the comparison of the LNG quality in 2021 and 2022:
  - *No appreciable change in LNG quality can be seen,* in spite of a relevant increase of importation to Spain.
  - Wobbe index of *all LNG arriving Spain is inside the EU entry range proposed in the revision of the standard EN16726*
    - EN16726 Wobbe index range proposed: 46.44 – 54.00 MJ/m^3 (15/15)



Thank you

Thank you for your participation!!!

Lorella Palluotto, Interoperability & Gas Quality & Hydrogen Adviser

Lorella.palluotto@entsog.eu

ENTSOG - European Network of Transmission System Operators for Gas
Avenue de Cortenbergh 100, 1000 Bruxelles

www.entsog.eu | info@entsog.eu