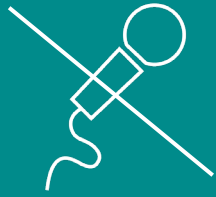




# Hydrogen quality & Grid connection

Workshop 18 January 2024





PLEASE KEEP YOUR  
MICROPHONE MUTED



USE THE HAND MARKER OR THE  
CHAT FOR QUESTIONS AND  
COMMENTS



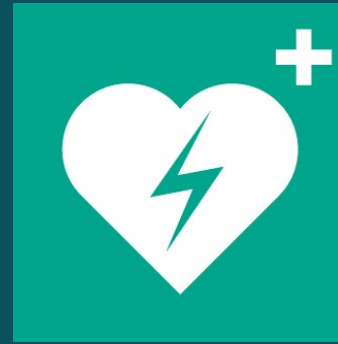
THE WEBINAR IS NOT BEING  
RECORDED



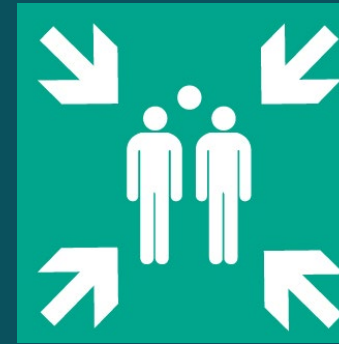
THE PRESENTATION WILL BE  
SENT OUT AFTERWARDS



Emergency exits



Defibrillator



Assembly point

# OBJECTIVES OF TODAY



- To share Energinet's status on hydrogen quality and grid connection terms and conditions with stakeholders



- To receive perspectives from stakeholders on the presented material



- To ignite invaluable discussions on the outlined topics/themes in the group sessions



- To emphasize that the shown connection terms and conditions and hydrogen quality specifications are work in progress and not finalised yet.



# TODAY'S PROGRAMME

- 10:00 - 10:10 Welcome
- 10:10 - 10:20 New year's message
- 10:20 - 11:20 Subject 1: Grid connection  
- Rules and Regulations (15 min)  
- System development (15 min)  
- Grid connection terms and conditions (30 min)
- 11:20 - 11:30 Break
- 11:30 - 11:55 Subject 1 – Group Session
- 11:55 - 12:20 Presentation in plenum
- 12:20 - 13:00 Lunch break
- 13:00 - 13:30 Subject 2: Hydrogen quality and specifications
- 13:30 - 14:00 Subject 2 – Group Session (+ **Cake & Coffee** )
- 14:00 - 14:30 Presentation in plenum
- 14:30 - 14:45 Wrap-up, summary and next steps



## H<sub>2</sub> Network Germany & Denmark





# NEW YEAR'S MESSAGE

- A key milestone for 2024 will be a political agreement about the financing of Danish hydrogen infrastructure.
- In preparation for a scenario in which this financing is contingent on some level of user commitment, Energinet is preparing a model and timeline for collecting such commitments before the offshore wind tenders end-2024.
- Our first step will be publishing a concept paper end-January, which we invite you to provide feedback on.
- Contact [CRU@energinet.dk](mailto:CRU@energinet.dk) and/or [KKN@energinet.dk](mailto:KKN@energinet.dk) to book bilateral meetings.







# RULES AND REGULATIONS

Grid Connection - Terms and Conditions

# EU- LEGISLATION

## New Gas Market Regulation

- Third party access
- Capacity and balancing rules
- Tariffs
- Rules for TSO/DSO
- Legal basis for Network Codes and Guidelines
- Etc.

## New Gas Market Directive

# NATIONAL LEGISLATION

## Danish Gas Supply Act

New national legislation on grid connection

## Implementation of new Gas Market Directive

- Unbundling
- Technical rules
- Third party access
- Approval of methodologies
- Etc.

# ENERGINET TERMS

## Methodologies

- Tariffs
- Access requirements
- Balance
- Etc.

Terms and conditions for hydrogen transport (expected)

## Connection Agreement



# LEGAL FRAMEWORK TO ESTABLISH TECHNICAL REQUIREMENTS

- Hydrogen has been included as a gas in the Danish Gas Supply Act
- Limited experience with grid connection requirements due to few facilities connected to the methane transmission system
- Use of the comprehensive experience with stipulating technical requirements on electricity in a hydrogen setting
- Legal framework may be amended with the new gas market regulation and directive



# CURRENTLY APPLICABLE LEGAL BASIS TO DEVELOP AND USE METHODOLOGIES

Section 36 a in the Danish Gas Supply Act (indicative translation)

*“1. Prices and conditions for use of transmission systems or distribution systems and LNG-facilities are determined by transmission companies, transmission system owners, system operators and distribution- and LNG companies under public methodologies which are approved by the Danish Utility Regulator.*

*[...]”*

# CURRENTLY APPLICABLE LEGAL BASIS TO ESTABLISH TECHNICAL REQUIREMENTS

Section 23 in the Danish Gas Supply Act (indicative translation)

*“1. In order to gain access to use the system, the users must comply with the stipulated requirements, cf. subsection 3.*

*2. In order to be connected to the system, facilities and installations must comply with stipulated technical requirements and standards.*

*3. The Danish Minister of Climate, Energy and Utilities may establish detailed rules regarding the listed conditions in subsection 1 and 2, including to decide that certain technical requirements and standards for connection to and requirements for use of the system must be established by transmission companies or transmission system owners and system operators.”*



# CURRENTLY APPLICABLE LEGAL BASIS TO ESTABLISH TECHNICAL REQUIREMENTS

Section 5 in the Danish Executive Order on Gas System Responsibility (indicative translation)

*“1. The transmission companies must, after dialogue with distribution-, storage- and LNG-companies and other relevant market actors develop terms and conditions for use of the gas system which are necessary for that the transmission companies can handle their tasks, cf. section 12 a(1)-(2) in the Danish Gas Supply Act. The terms and conditions must include the following:*

- 1) Terms and conditions for access to and use of the gas system (conditions for gas transport)*
- 2) Terms and conditions for the actor’s obligations which secure maintenance of the technical quality, security of supply, gas quality and balance in the gas system.*

A photograph of an industrial facility, likely a power plant or refinery, featuring large machinery, pipes, and a worker in a high-visibility vest. A teal semi-transparent overlay is positioned on the left side of the image, containing the text 'GRID CONNECTION' and 'System Design'.

# GRID CONNECTION

System Design



# A HIGH-PRESSURE SYSTEM

- 4-8 GW hydrogen by 2040
- 10-20 GWh of linepack flexibility
- Expected minimum pressure at the German border 50 barg

To provide this, the system will have to operate at very high pressure – connections to the system must meet the pressure in the system

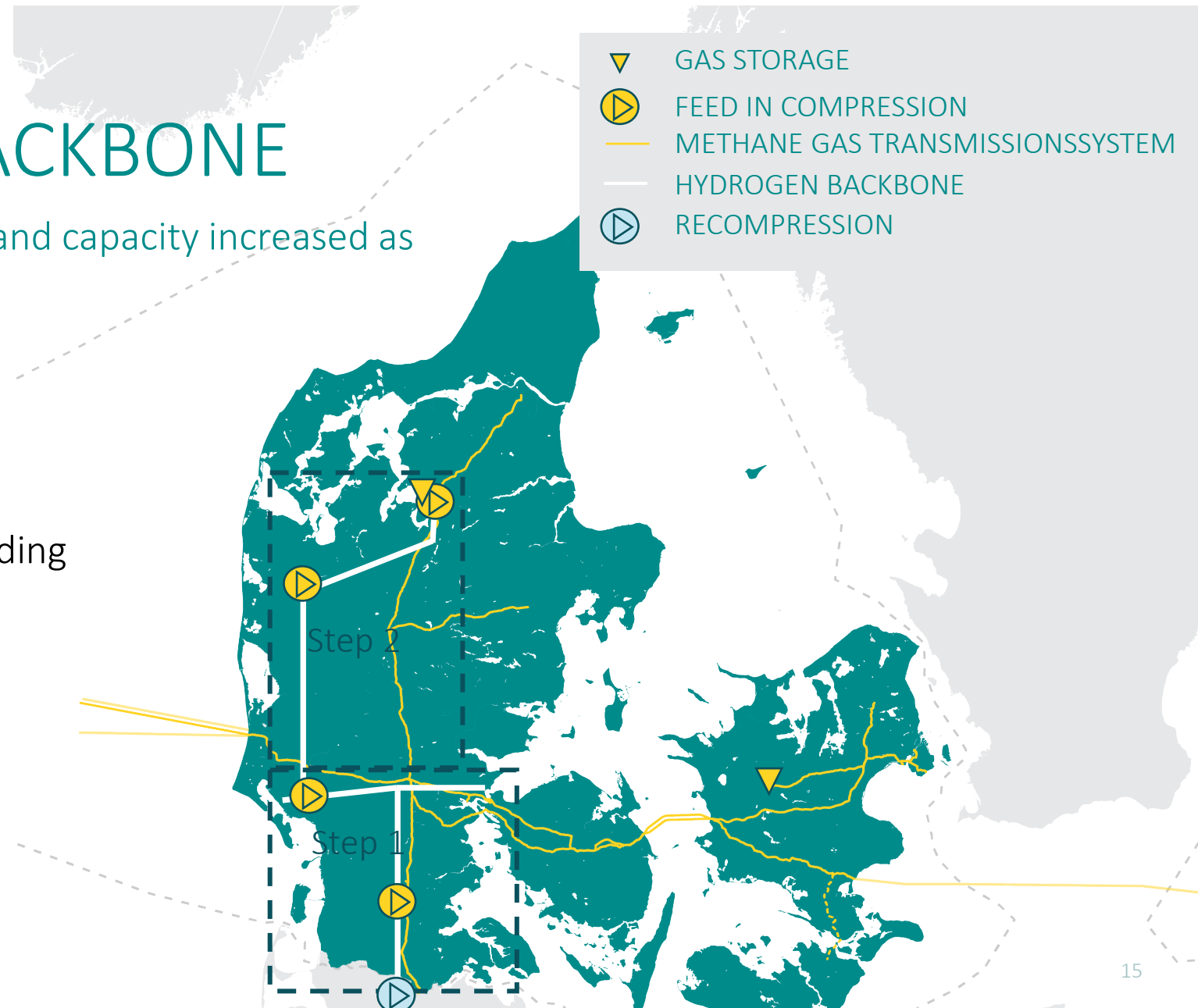




# THE HYDROGEN BACKBONE

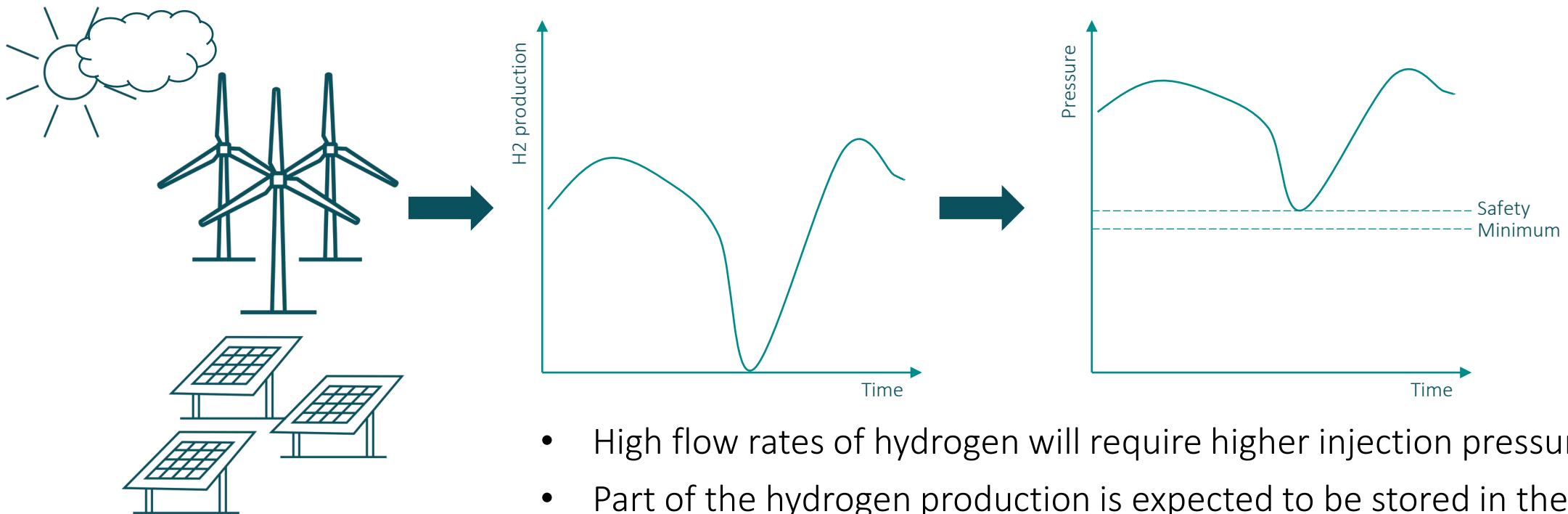
The backbone is constructed in steps and capacity increased as needed

- Backbone constructed in steps – starting from the German border
- Gradual increase in pressure according to the need for capacity
- Feed in compression – possible compression towards Germany to provide sufficient capacity



## PRESSURE IN THE BACKBONE IS EXPECTED TO FLUCTUATE

We expect the production of hydrogen to vary with the availability of wind and solar - as a result, the pressure will fluctuate

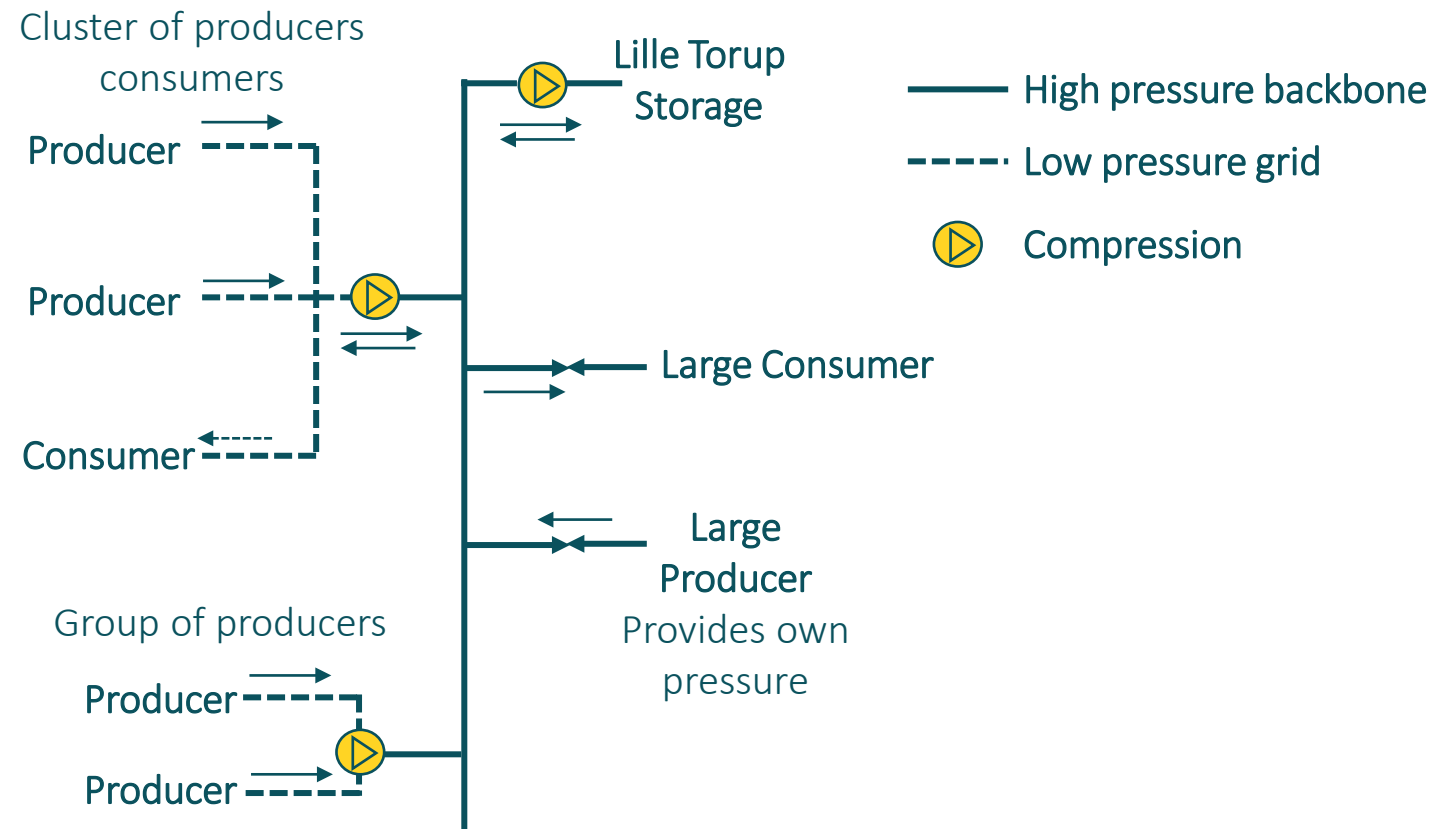


- High flow rates of hydrogen will require higher injection pressure
- Part of the hydrogen production is expected to be stored in the backbone, this will increase the pressure

# HOW TO CONNECT TO THE BACKBONE?

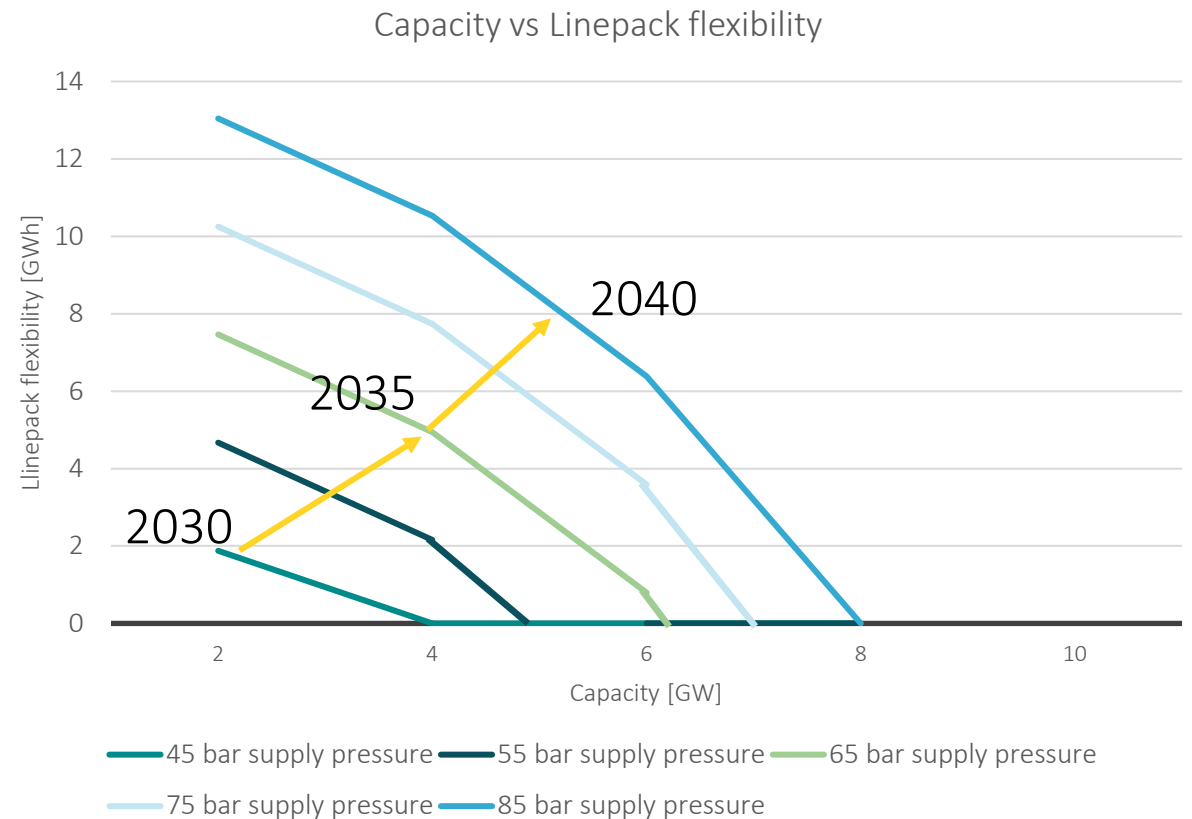
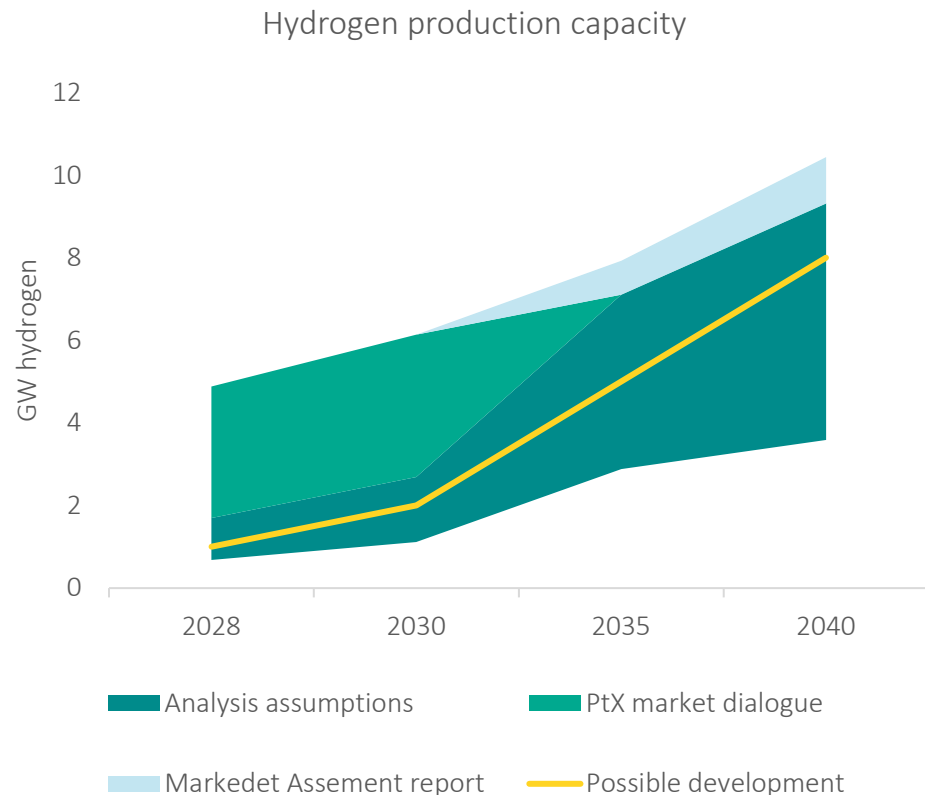
Pressure at the backbone is expected to vary between **50-90 barg**

- Smaller producers may be clustered via a low-pressure system or share a connection point
- Larger producers may connect directly to the backbone – providing own pressure
- Lille Torup storage requires even higher pressure





# OPERATING PRESSURE MAY INCREASE OVER TIME



# PHYSICAL REQUIREMENTS FOR CONNECTION

- High pressure transmission system up to 90 barg
- Fluctuating pressure
- Pressure may start low and increase over time
- Hydrogen producers/consumers can be connected individually, in groups or through clusters





A photograph of an industrial facility, likely a power plant or refinery, featuring large machinery, pipes, and a worker in a high-visibility vest. A teal semi-transparent banner is overlaid on the left side of the image, containing the text 'GRID CONNECTION' and 'Grid Connection Terms and Conditions'.

# GRID CONNECTION

Grid Connection Terms and Conditions





## SCOPE

The rules and regulations for system users to be connected to the hydrogen grid are currently being developed by the Danish Energy Agency in dialogue with Energinet and Evida.

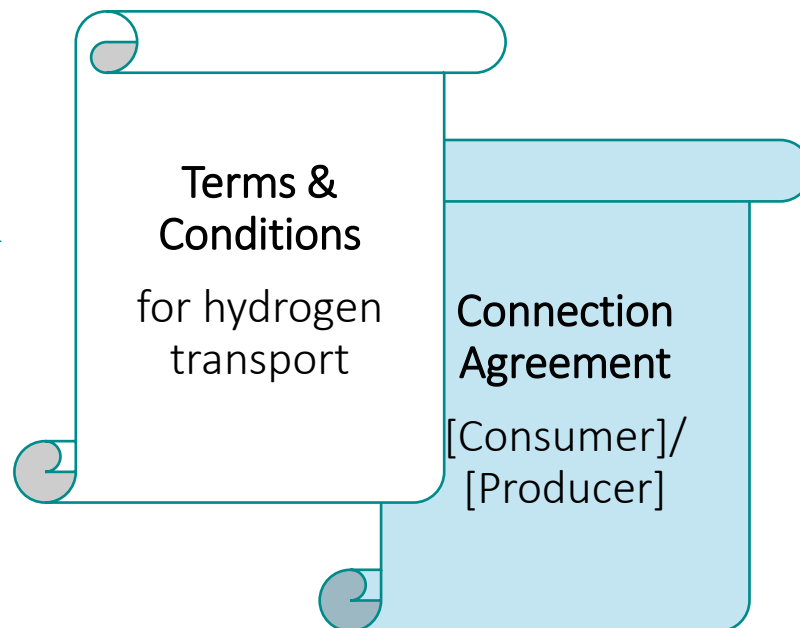
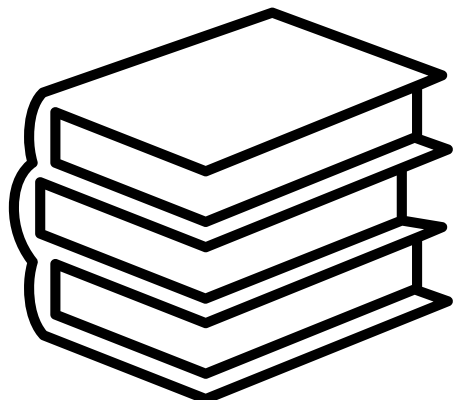
The rules and regulations are the legal framework for the terms and conditions

Today, we would like to hear your thoughts on Energinet's working assumptions in this matter

# THE VALUE CHAIN PROCESS FOR SETTING TERMS AND CONDITIONS IN A CONNECTION AGREEMENT

Regulatory framework for making a connection agreement with Energinet

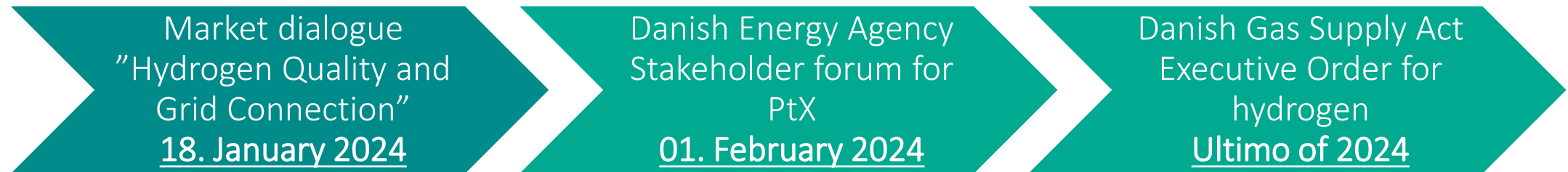
Rules and Regulations



Operational Parameters
Capacity (Max)
Flow
Pressure Range
Temperature
Data Exchange
Ramp Up/Down

- Connection Point
- Own, Operate and Construct
- Cost Allocation

# OVERALL TIMELINE FOR THE PROCESS





# TERMS AND CONDITIONS FOR CONNECTING TO THE HYDROGEN SYSTEM

The terms and conditions must aim for being transparent, non-discriminatory and without cross-subsidization

## Connection Point (Property limit)

The Network Operator must direct the System User or adjacent Hydrogen Cluster System to the most long-term cost-efficient connection point with available technical capacity.

The connection point is decided in the common Network Development Group of network operators.

## Definitions

- Network Operator: Energinet and Evida
- System Users: Projects for hydrogen production and consumer
- Hydrogen Cluster System: local system
- Long-term cost-efficient: best long-term solution for the collective system including System Users
- Technical capacity: transport capacity with defined maximum-minimum operational pressure and design supply-demand scenario
- Network Development Group: planning group for the development of the Danish hydrogen system

# TERMS AND CONDITIONS FOR CONNECTING TO THE HYDROGEN SYSTEM

The terms and conditions must aim for being transparent, non-discriminatory and without cross-subsidization

## Own, Operate and Construct

Network Operators should only construct, operate and own systems (e.g. pipeline and compressor) with 3<sup>rd</sup> party access or future foreseeable 3<sup>rd</sup> party access in the long-term cost-efficient System Development Plan.

Exceptions to that rule are possible in specific cases of security, market or operational needs stipulated in terms and conditions.

### Definitions

- 3<sup>rd</sup> party access: all system users can be connected on transparent and non-discriminatory terms and conditions without cross-subsidization to the collective system
- Security, market or operational needs: benefits should overweight the general rules of the collective system of being transparent, non-discriminatory and without cross-subsidization
- System Development Plan: Long-term cost-efficient future development plan of the Danish hydrogen system

# TERMS AND CONDITIONS FOR CONNECTING TO THE HYDROGEN SYSTEM

The terms and conditions must aim for being transparent, non-discriminatory and without cross-subsidization

## Cost allocation

All costs related to the hydrogen system connection of a System User must be paid by the System User.

Relatable costs of a System Users' connection in the *System Development Plan* must be paid by the System User via a connection tariff.

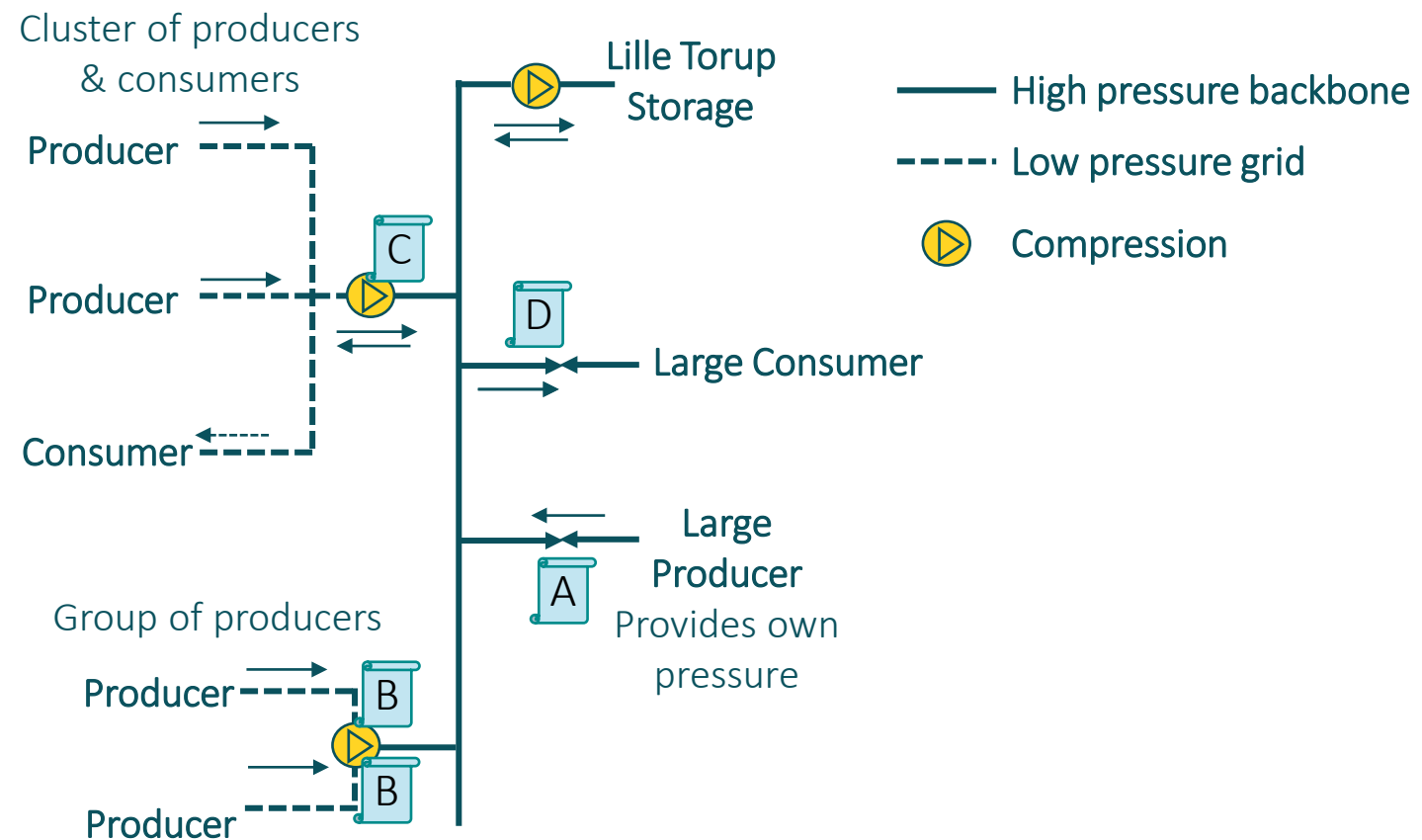
## Definitions

- Relatable costs: cost-benefit analysis for the System Users in the long-term cost-efficient development of the collective system

## THE TERMS AND CONDITIONS MUST AIM FOR BEING TRANSPARENT, NON-DISCRIMINATORY AND WITHOUT CROSS-SUBSIDIZATION

Pressure at the backbone is expected to vary between **50-90 barg**

- Smaller producers may be clustered via a low-pressure system or share a connection point
- Larger producers may connect directly to the backbone – providing own pressure
- Lille Torup storage requires even higher pressure





# ASSUMPTIONS FOR DISCUSSION

**Assumption 1:** Energinet should construct, operate and own the part of the connection facility that could be develop into a collective hydrogen system with 3<sup>rd</sup> party access

**Assumption 2:** The location of hydrogen system connection points should be decided from the collective hydrogen perspective and not the specific System User

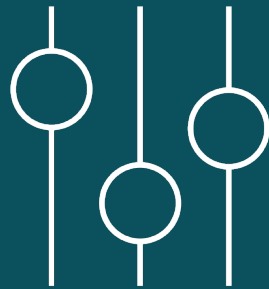
**Assumption 3:** The connection point for a System User should be decided by a common agreement between the Network Owners

**Assumption 4:** All costs related to specific connection should be paid by the System User (including cost share of possible expansion of the collective system for future development)

**Assumption 5:** Operational coordination between electrolysis and connection/feed-in compressor unit are more sensitive than system balancing due to low local storage

**Assumption 6:** Long-term cost-efficient analysis of the system development could result in parts of the connection facility being developed into the collective system

**Assumption 7:** Large pressure range in the system with high linepack flexibility is more essential for a business case than cost saving for a compressor unit with less pressure range



# GROUP SESSION 1

Grid connection – Terms and Conditions





Lunch

**LUNCH 12.20 -13.00**



**ENERGINET**



**HAVE YOU SIGNED  
UP TO RECEIVE OUR  
NEWSLETTER YET?**

[www.en.energinet.dk/hydrogen/](http://www.en.energinet.dk/hydrogen/)





# HYDROGEN QUALITY





# H

## SCOPE

To share Energinets current position and initiate a dialogue surrounding H<sub>2</sub> qualities with future market actors.

- H<sub>2</sub> quality
- Measurements
- Billing

# WHAT IS HYDROGEN QUALITY?

Purity

Contaminants

Physical properties

# WHY DO WE NEED REQUIREMENTS?

Protection of assets

Safety

Usage

Billing

# NEEDS FOR INDUSTRIAL USERS

- Varying industrial needs
  - 60-99,99% hydrogen
  - Feed
  - Refining
  - Combustion

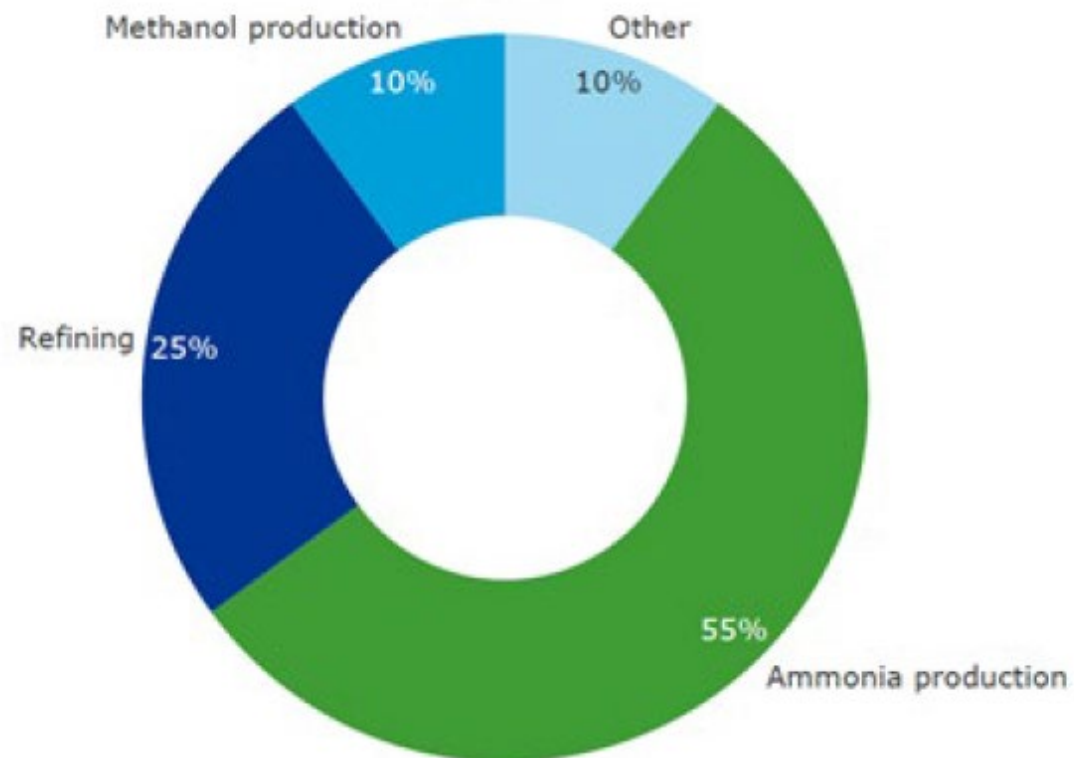


Figure 2 Global industrial hydrogen uses per sector (in 2010). Total industrial volume ~55 Mt/year  
Source: "Energy of the Future", Shell, 2017



# PURITY FROM PRODUCTION

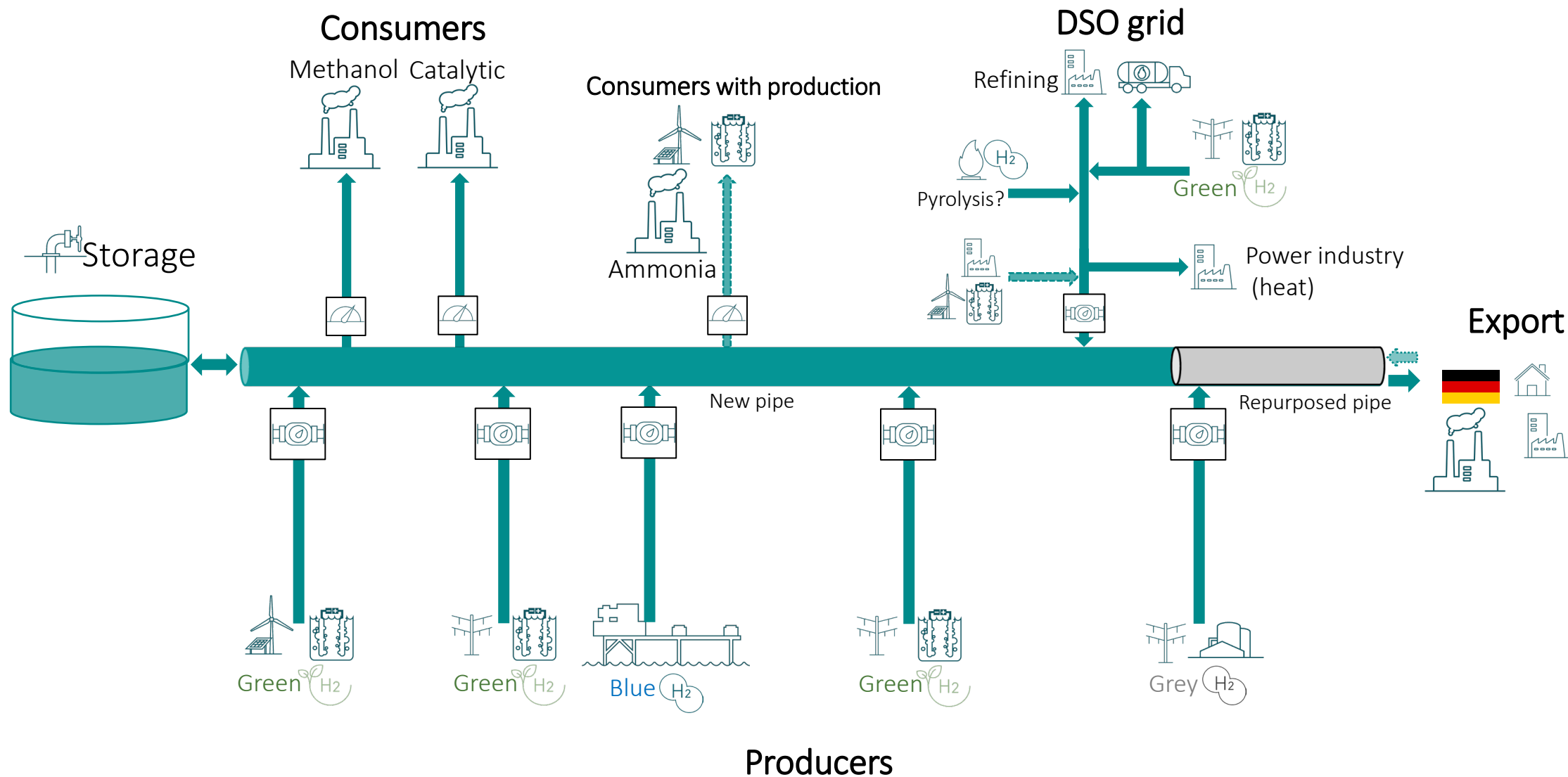
- Different production ways
- Electrolysis
  - Green hydrogen gas
  - High purity
- Water
- Oxygen

Components	PEM(ppm)	AE(%)	AEM(%)
H <sub>2</sub>	99,9-99,9999	99,5-99,9998	99,4
N <sub>2</sub>	1,2-4,5	NA	NA
AR	<0,5	NA	NA
He	<9	NA	NA
O <sub>2</sub>	18 -> 500	<500 ppm	<500 ppm
CO <sub>2</sub>	0,2-5,4	NA	NA
CO	<0,02	NA	NA
CH <sub>4</sub>	<0,02-0,1	NA	NA
H <sub>2</sub> O	>100	>100 ppm	<100 ppm
Total sulphur compounds	<0,0036	NA	NA
Hydrocarbon compounds	<1	NA	NA
Halogenated compounds	<0,005	NA	NA

Source: Bacquart- Hydrogen fuel quality from two main production processes: Steam methane reforming and proton exchange membrane water electrolysis, 2019

# QUALITY IN A HYDROGEN SYSTEM

Qualities delivered, required and guaranteed – purification for some producers and consumers?



# PRELIMINARY SPECIFICATION FOR HYDROGEN

CEN/TS 17977 with possible supplementary expected national amendments and departures.

- ❖ Harmonization across system borders.
- ❖ Revisions stricter with parameters in the future.
- ❖ Additional components that might be included.
  - Formic acid (<10 ppm).
  - Formaldehyde (< 10 ppm).
  - Mercury (<0.004 ppm)
  - Si-components (1mg/m<sup>3</sup>)





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Origin	Name	Abbreviation	unit	CEN/TS 17977
H <sub>2</sub> Generation	Hydrogen	H <sub>2</sub>	mol-%	≥ 98
	∑ inerts	I <sub>tot</sub>	mol-%	≤ 2
	Carbon monoxide	CO	ppm	≤ 20
	Carbon dioxide	CO <sub>2</sub>	ppm	≤ 20
	Ammonia	NH <sub>3</sub>	ppm	≤ 13
	Halogenated compounds	R-Cl/F/Br	ppm	≤ 0,05
	Water	H <sub>2</sub> O	ppm	(≤ 250 (≤ 10 bara)) ≤ 60 (> 10 bara)
	Oxygen	O <sub>2</sub>	ppm	(≤ 1000) ≤ 10
NG Infrastructure				

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	Ammonia	NH <sub>3</sub>	ppm	≤ 13
	Halogenated compounds	R-Cl/F/Br	ppm	≤ 0,05
	Water	H <sub>2</sub> O	ppm	(≤ 250 (≤ 10 bara)) ≤ 60 (> 10 bara)
NG Infrastructure	Oxygen	O <sub>2</sub>	ppm	(≤ 1000) ≤ 10
	Hydrocarbons	C <sub>x</sub> H <sub>y</sub>	mol-%	≤ 2
	Hydrocarbon DP	HCDP	°C	- 2 (@1-70 bara)
	Total sulphur	-	ppm	≤ 7
	Particles	-	mg/kg	Technically free
	Wobbe index	WI	MJ/m <sup>3</sup>	42,0-46,0 (15/15)

# POSSIBLE FUTURE EUROPEAN STANDARD

- CEN is awaiting a standardization request from the European Commission.
- The Technical Specification may be revised and elevated to an EN standard in the future.
- Possible adjustments:
  - Higher hydrogen purity (e.g. 99.5%)
  - Stricter requirements for hydrocarbons and inerts (2 % → 0.5 %)

Origin	Name	unit	TS 17977	Possible future revision
H <sub>2</sub> Generation	Hydrogen	mol-%	≥ 98	≥ 99.5
	∑ inerts	mol-%	≤ 2	≤ 0.5
NG Infrastructure	Hydrocarbons	mol-%	≤ 2	≤ 0.5

A close-up photograph of numerous water droplets of various sizes scattered across a dark, textured surface. The droplets are in sharp focus in the foreground, while those in the background are blurred. A semi-transparent teal rectangular box is centered over the image, containing white text.

# WATER CONTENT "DEEP DIVE"



# WATER CONTENT LIMITS

Specification, design code and regulatory framework

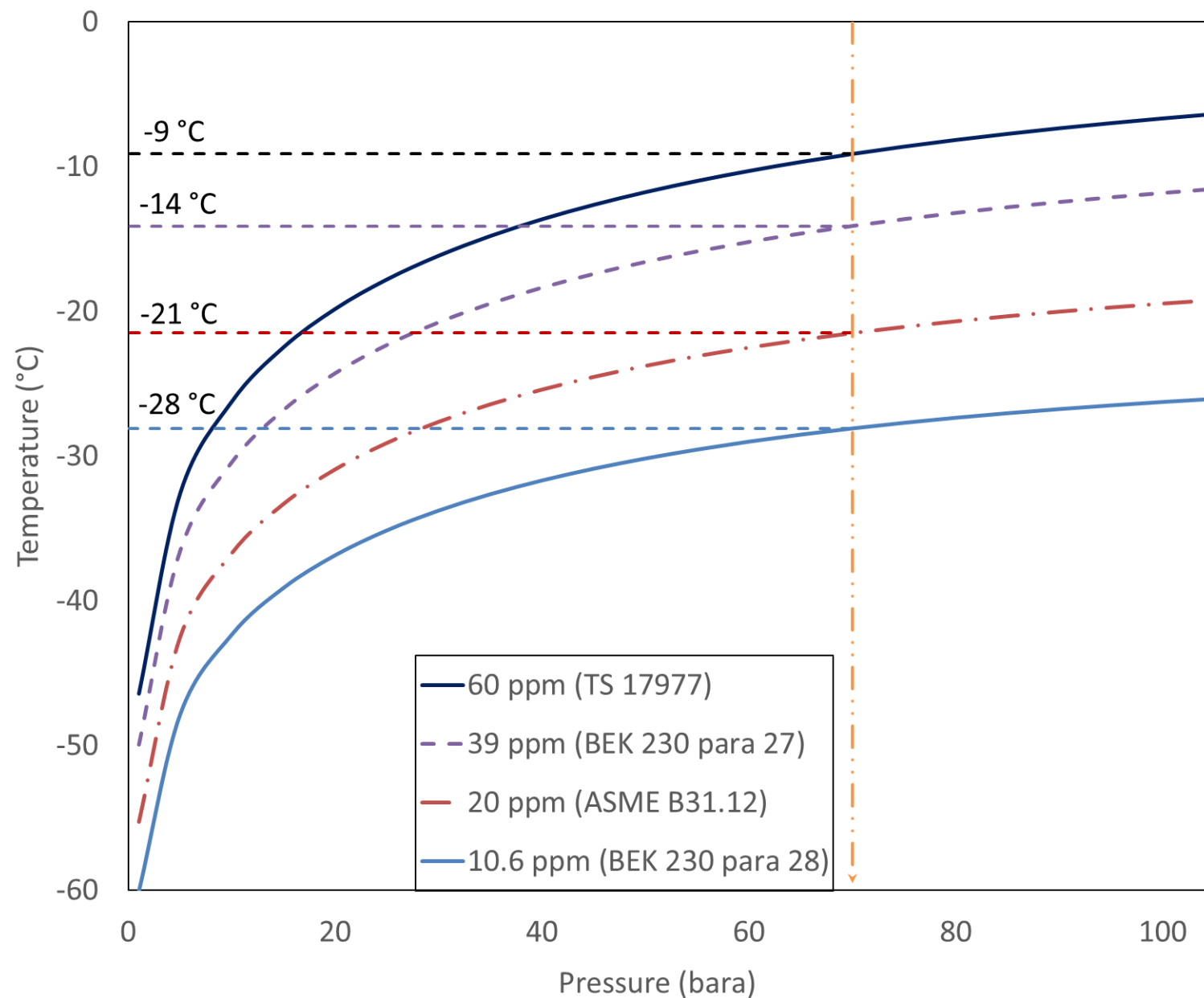
	BEK 230, §28	ASME B31.12	BEK 230, §27	TS 17977
c(H <sub>2</sub> O) (ppm) /Pressure	10.6	<b>20</b>	39	<b>60</b>
1 atm	<b>-60.0</b>	<b>-55.1</b>	<b>-50.0</b>	-46.4
70 bar	-28.1	-21.5	-14.1	-9.1

The **Red** font indicates the specified limit in each document: A water dew point temperature at a given pressure and/or a water content. Other values are calculated.

# WATER DEW POINT T/P CURVES

- Dew Temp indicated at 70 bara.
- Different “plateau” values at higher pressures.
- Steep drop in dew Temp below 10 bar.

Calculated with ISO 18453 for natural gas.





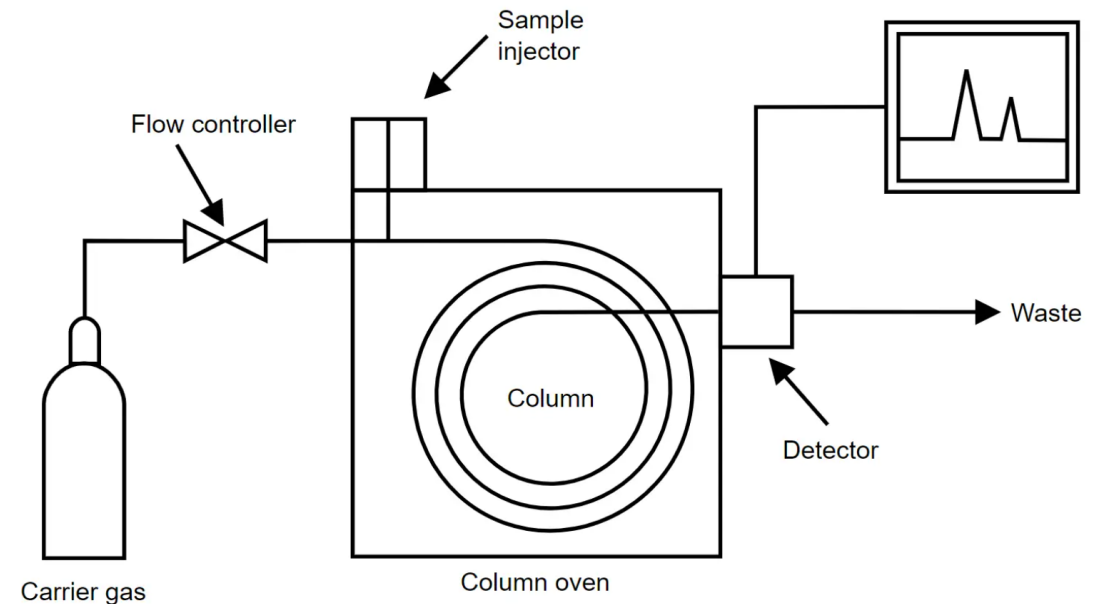
# MEASUREMENT AND ENERGY DETERMINATION



# H<sub>2</sub> MEASUREMENTS

Assessing the quantity and quality of H<sub>2</sub> is essential for efficient system operation.

- Hydrogen, water, oxygen
- Impurities
  - Different factors
  - Risk assessment
- Billing purposes
- Periodic or continuous measurements





# BILLING OF HYDROGEN – QUALITY PERSPECTIVE

Which units of measure are suitable?

## Natural gas

- ❖ Traditionally mainly used as an energy source.
- ❖ Billing and market transactions based on energy content.
- ❖ Energy takes all combustible components into account.

## Hydrogen

- Traditionally used primarily as a feedstock secondly as an energy source.
- End-users mainly interested in the hydrogen.
- Combustible components are impurities.

# ENERGY DETERMINATION OF HYDROGEN

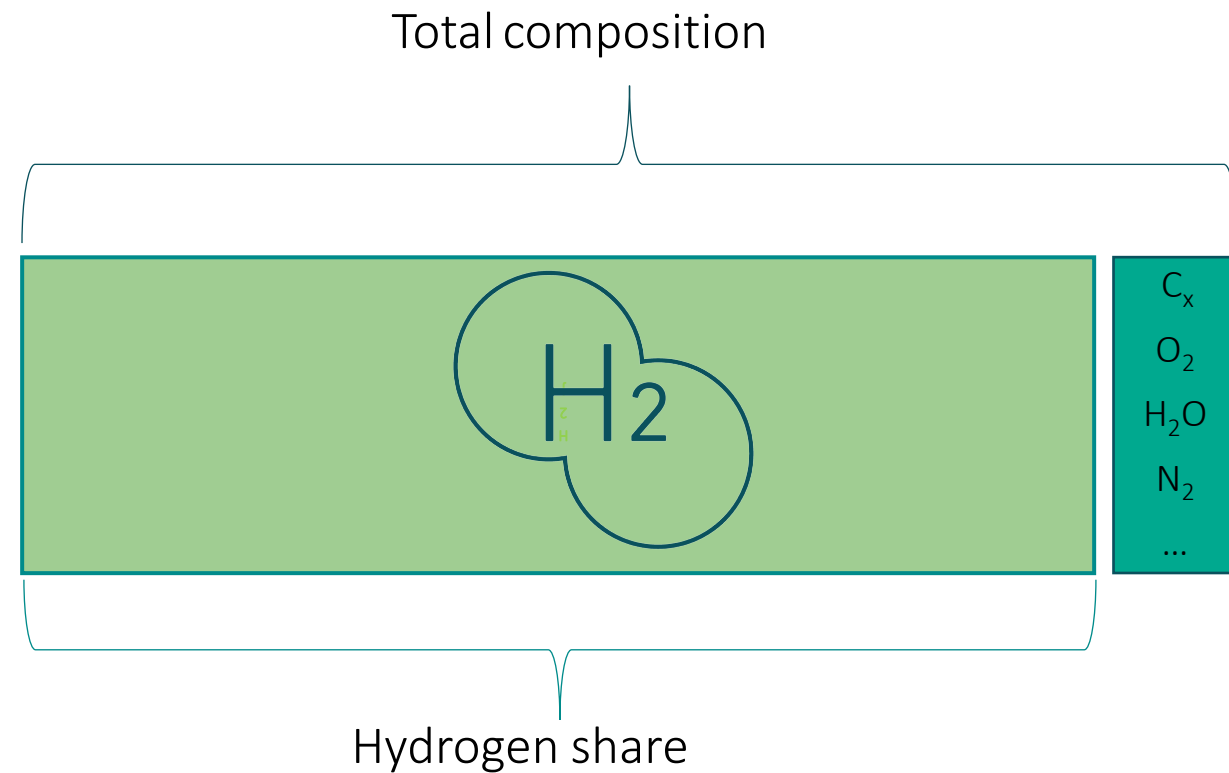
Should hydrogen transactions be based on hydrogen purity or total energy content?

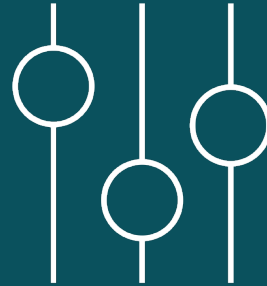
## Total Composition:

- ❑ Takes all combustible components into account when determining energy content.

## Hydrogen share:

- ❑ Only the energy from the hydrogen molecule is taken into account.





# GROUP SESSION 2

Hydrogen quality



# WHAT SHOULD THE WATER CONTENT LIMIT BE IN THE HYDROGEN SYSTEM?

Discuss the pros and cons of different water content limits

Water content	Compliant with	Pros	Cons
$\leq 20$ ppm	ASME B31.12		
$\leq 60$ ppm	CEN TS 17977		

# WHAT SHOULD BE THE MINIMUM HYDROGEN PURITY IN THE HYDROGEN SYSTEM?

Discuss the pros and cons of different minimum hydrogen purity requirements

Hydrogen purity	Pros	Cons
≥ 98 mol%		
≥ 99.5 mol%		

# QUESTIONS



Were you surprised by the presence/lack of any impurities in the presented specifications? Which components in the H<sub>2</sub> quality is most important to you and why?

Answer:



Hydrogen gas can be billed, either in the form of the energy content from hydrogen or the overall energy content of the gas. Which type of billing do you prefer? Would the final purity affect your preference?

Answer:



Repurposing previous natural gas systems will likely lead to more impurities in the hydrogen gas. What is your opinion on the possibility of different exit and entry specifications?

Answer:





QUESTIONS OR  
REFLECTIONS?



# WRAP-UP AND NEXT STEPS

**ENERGINET**



**HAVE YOU SIGNED  
UP TO RECEIVE OUR  
NEWSLETTER YET?**

[www.en.energinet.dk/hydrogen/](http://www.en.energinet.dk/hydrogen/)





THANK YOU!