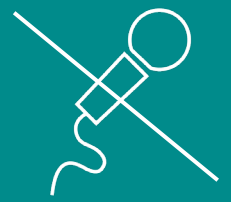
# Hydrogen quality & Grid connection

Workshop 18 January 2024



PLEASE KEEP YOUR MICROPHONE MUTED

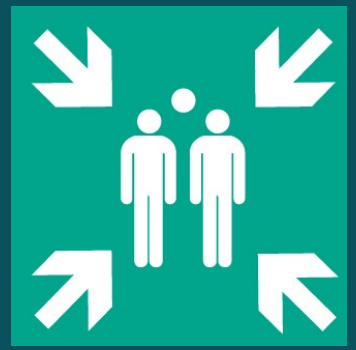
USE THE HAND MARKER OR THE CHAT FOR QUESTIONS AND COMMENTS

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<br>- Rules and Regulations (15 min)<br>- System development (15 min)<br>- 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 |

# 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 and/or 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.*

# GRID CONNECTION

System Design

# A HIGH-PRESSURE SYSTEM

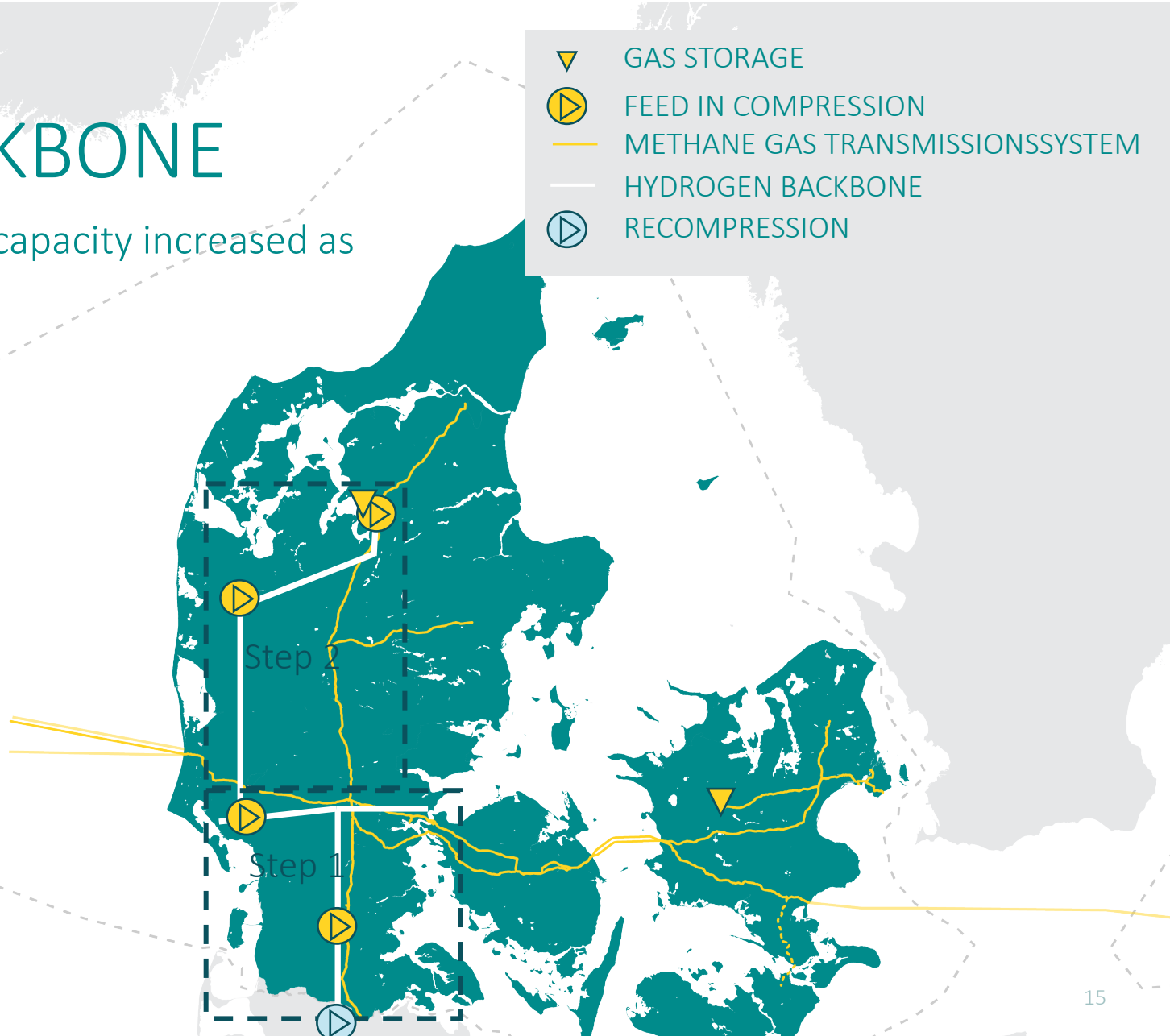
- 4-8 GW hydrogen by 2040
- 10-20 GWh of linepack flexibility
- Expected minimum pressure at the German border 50 barg

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

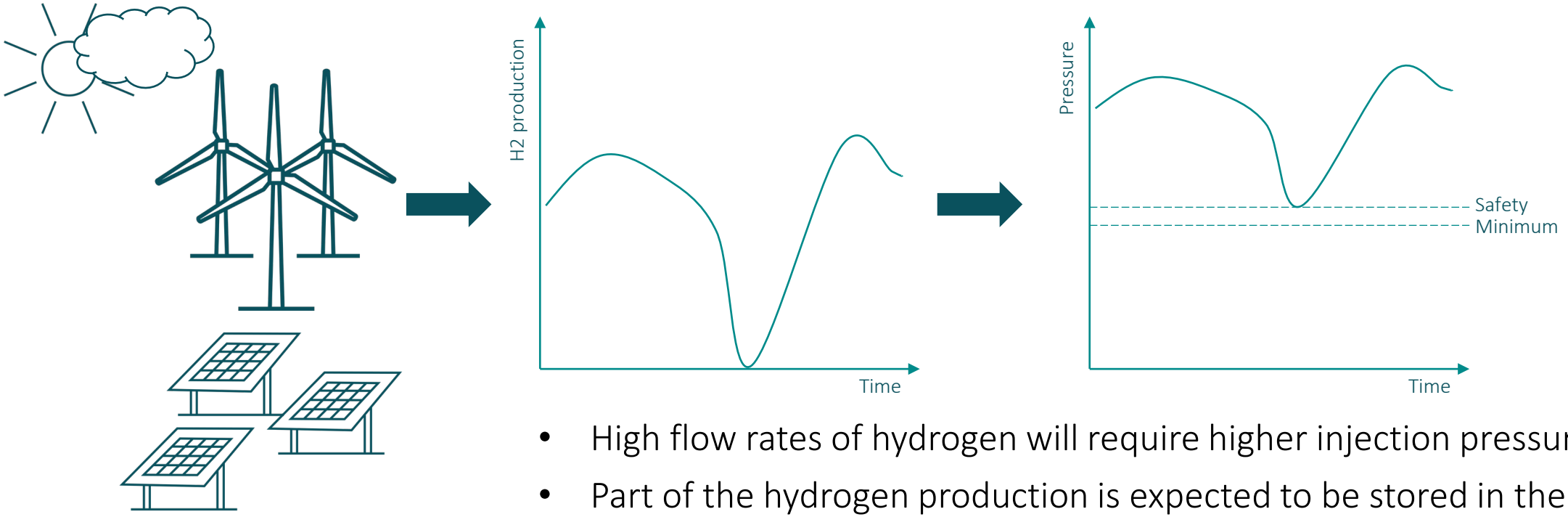
## The backbone is constructed in steps and capacity increased as needed

- 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

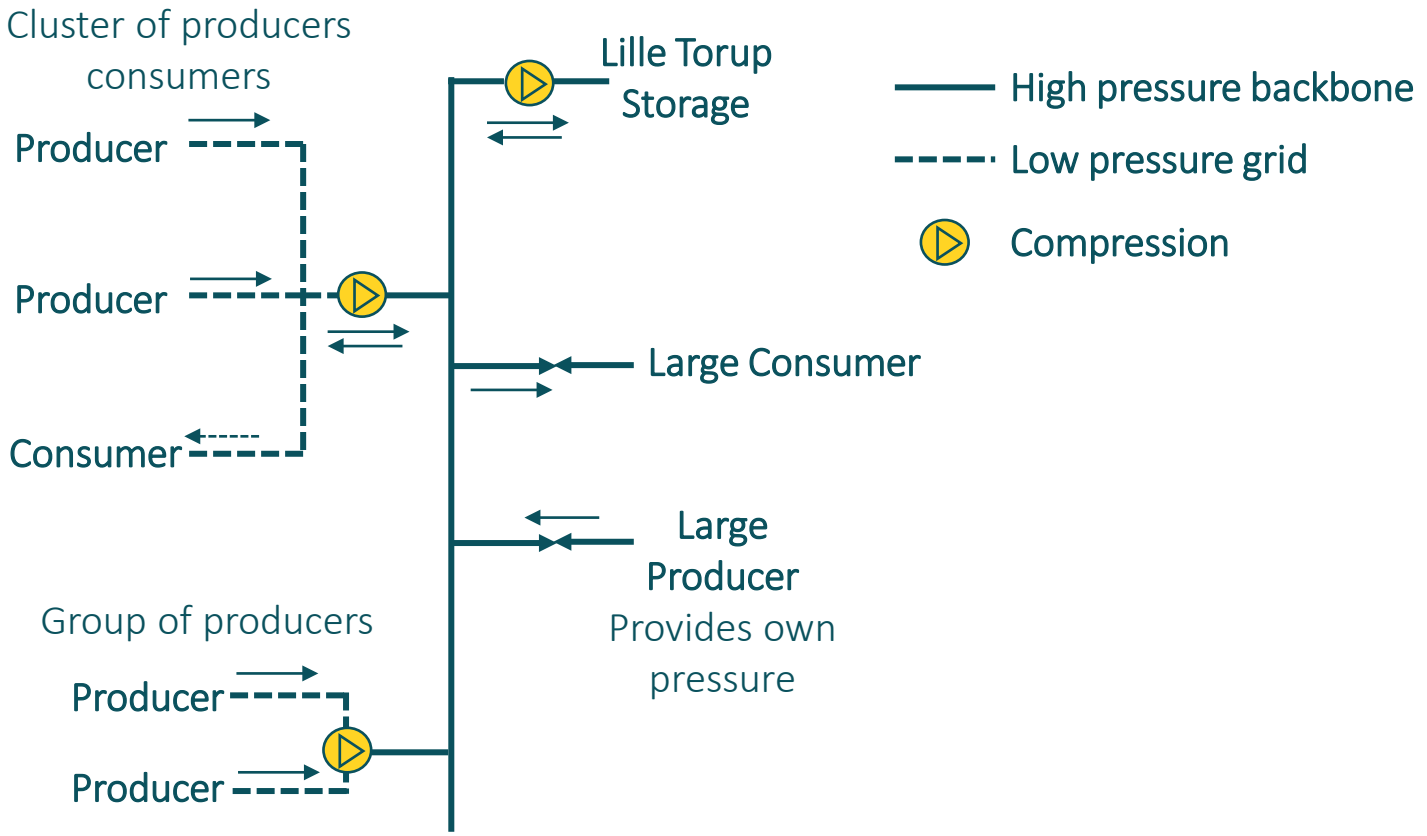



- High flow rates of hydrogen will require higher injection pressure
- Part of the hydrogen production is expected to be stored in the backbone, this will increase the pressure

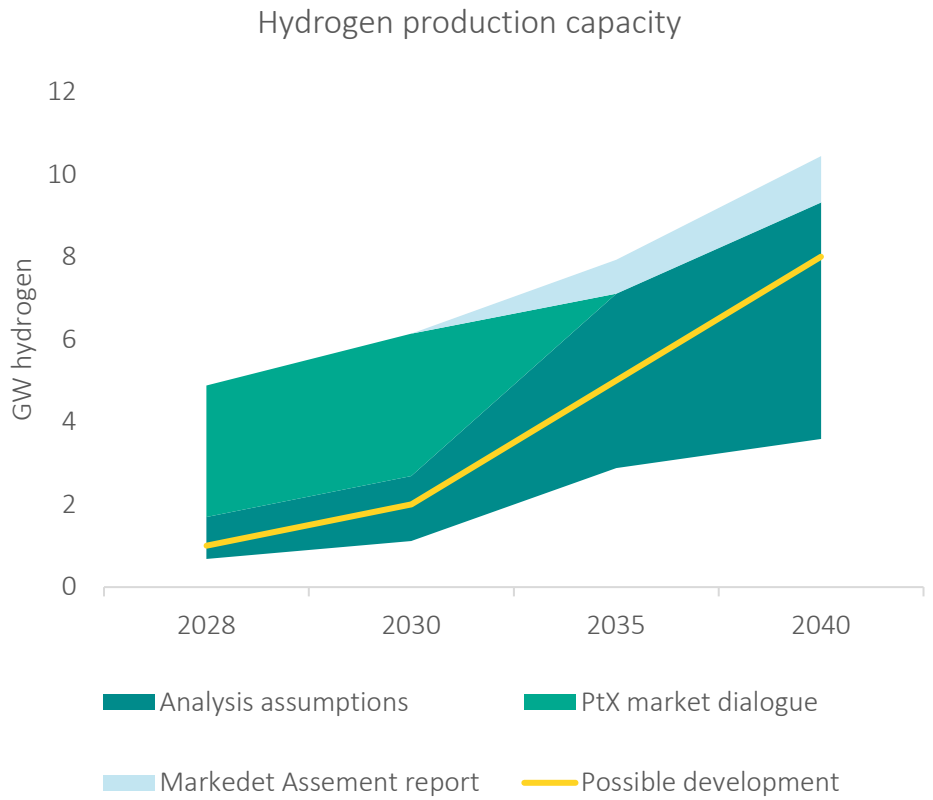
# HOW TO CONNECT TO THE BACKBONE?

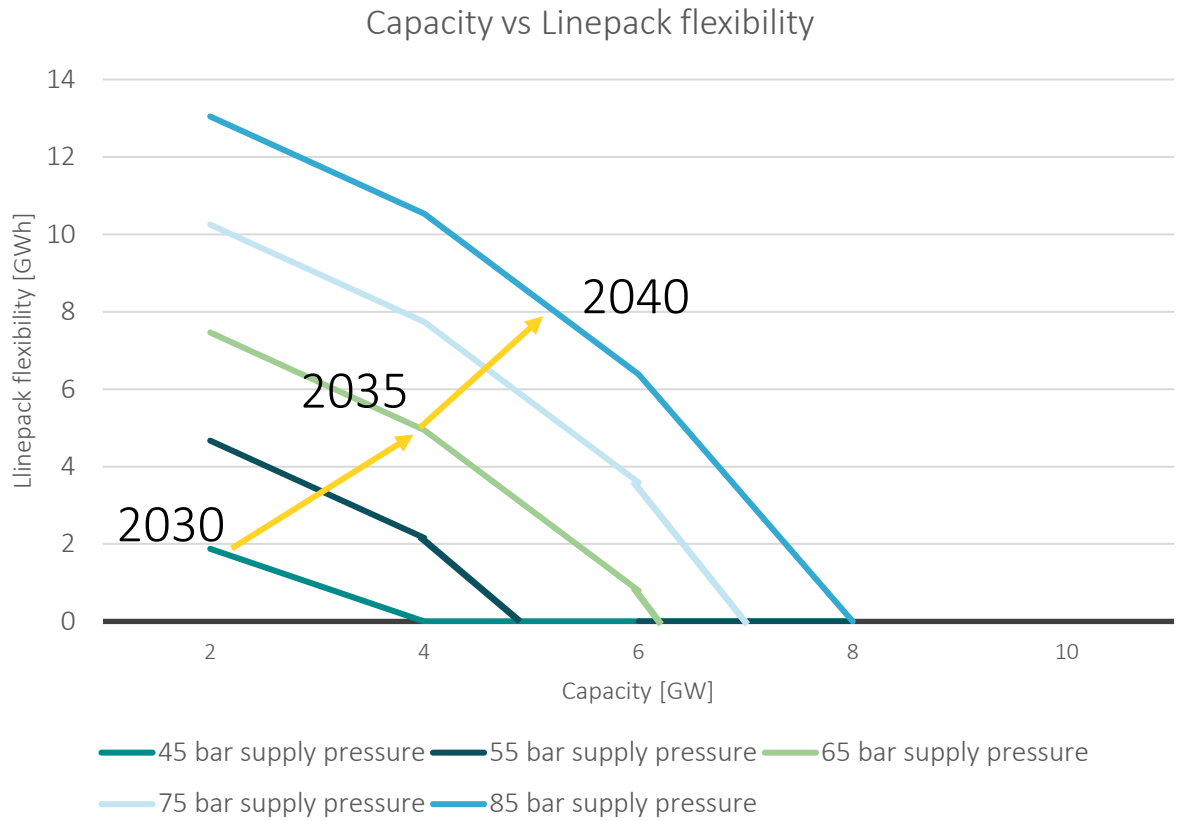
Pressure at the backbone is expected to vary between **50-90 barg**

- 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

# 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.

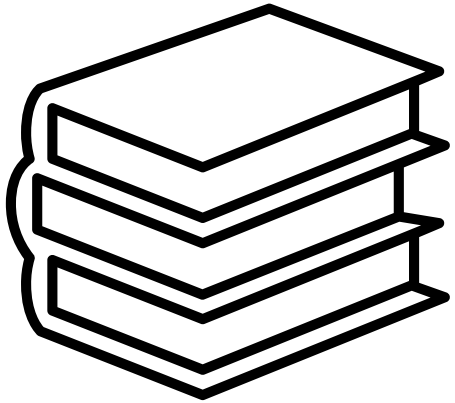
The rules and regulations are the legal framework for the terms and conditions

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**



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

**Terms & Conditions**

for hydrogen transport

**Connection Agreement**

[Consumer]/ [Producer]

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

# OVERALL TIMELINE FOR THE PROCESS

Market dialogue ”Hydrogen Quality and Grid Connection”
**18. January 2024**

Danish Energy Agency Stakeholder forum for PtX
**01. February 2024**

Danish Gas Supply Act Executive Order for hydrogen
**Ultimo of 2024**

Working Assumptions

# 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

Working Assumptions

# 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 3rd party access or future foreseeable 3rd 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*

- 3rd 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

Working Assumptions

# 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
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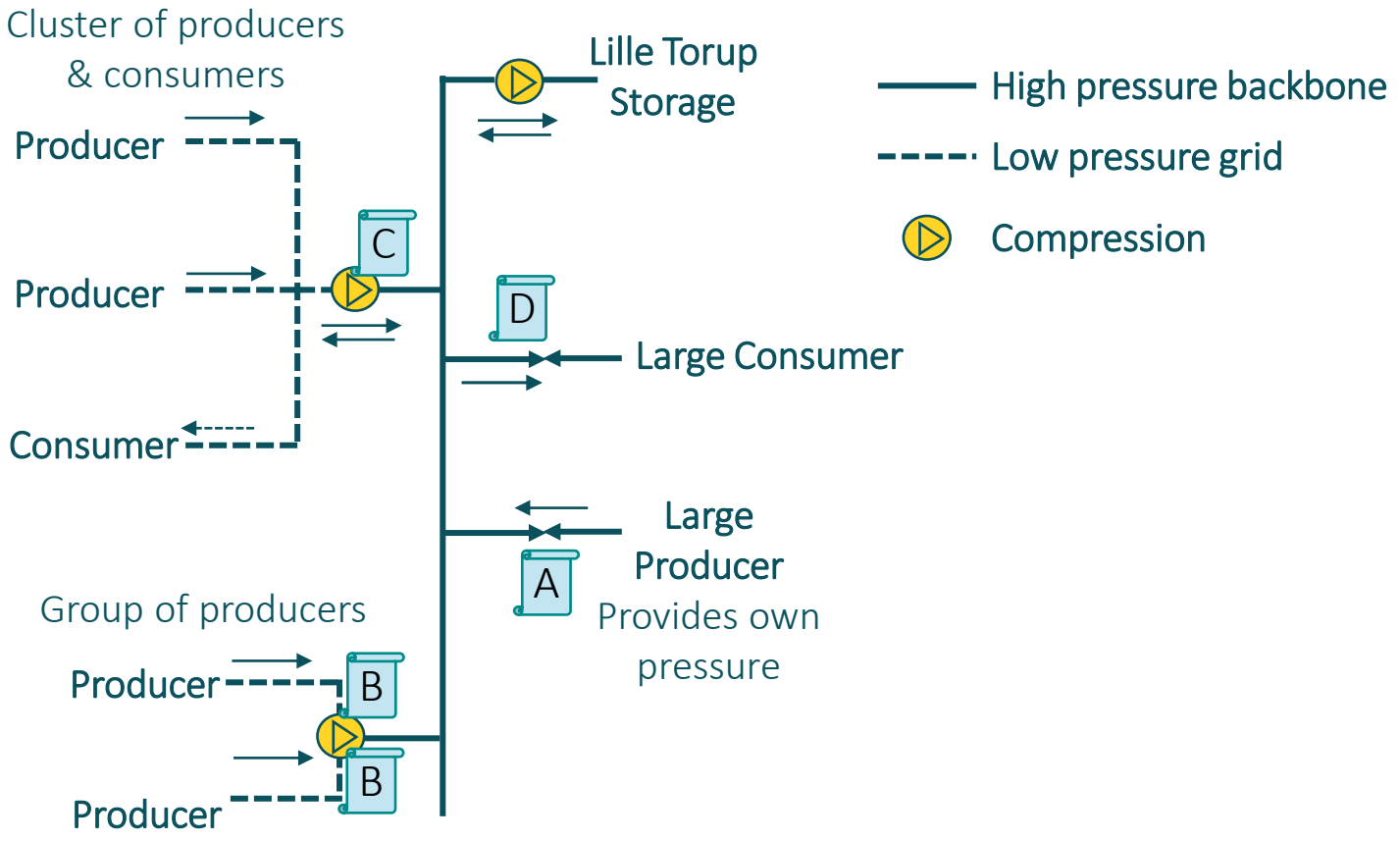


# ASSUMPTIONS FOR DISCUSSION

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

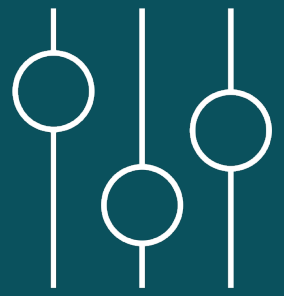
**Assumption 3:** The connection point for a System User should be decided by a common agreement between the Network Owners

**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/


# HYDROGEN QUALITY

# SCOPE

To share Energinets current position and initiate a dialogue surrounding $H_2$ qualities with future market actors.

- $H_2$ 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

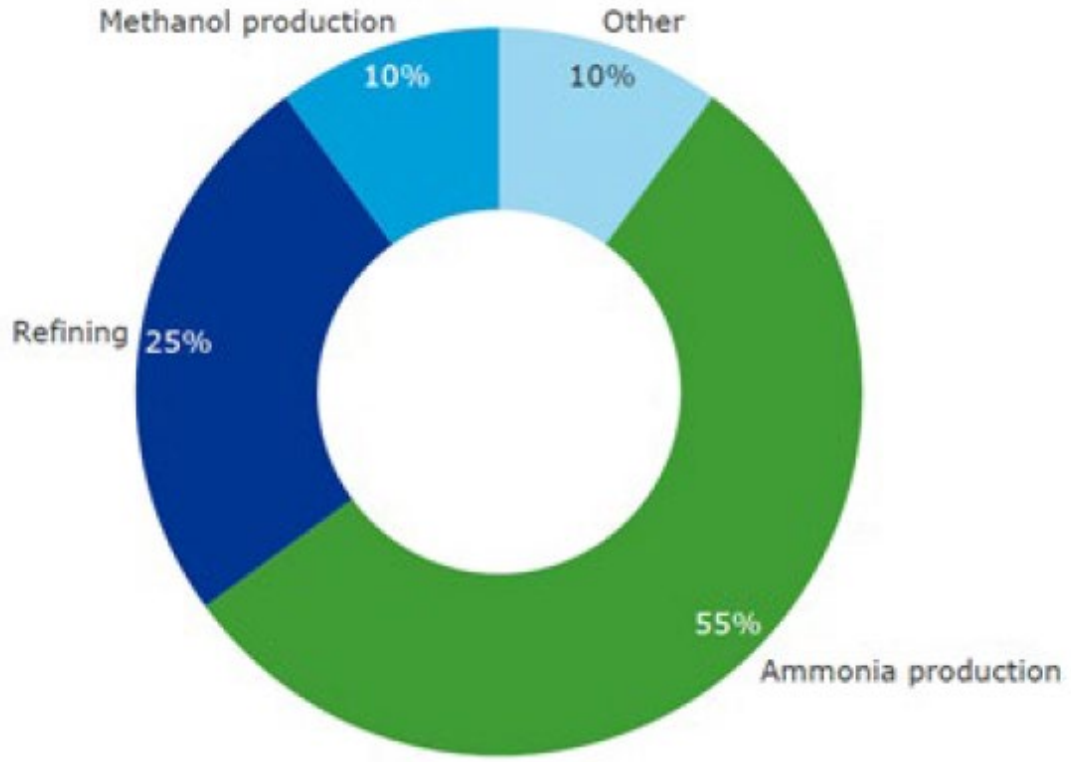



*Figure 2 Global industrial hydrogen uses per sector (in 2010). Total industrial volume ~55 Mt/year*

Source: *"Energy of the Future", Shell, 2017*

# PURITY FROM PRODUCTION

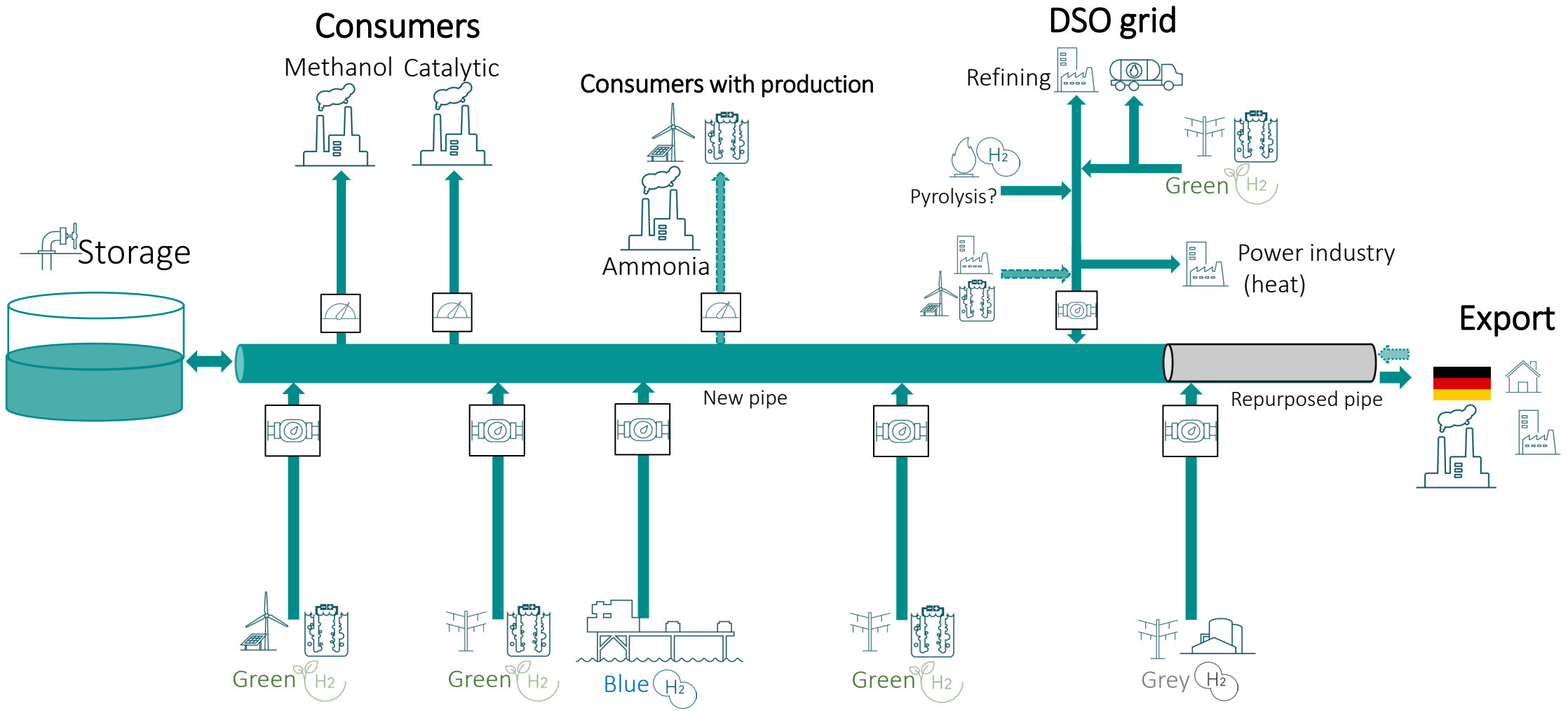
- Different production ways
- Electrolysis
  - Green hydrogen gas
  - High purity
- Water
- Oxygen

| Components | PEM(ppm) | AE(%) | AEM(%) |
|---|---|---|---|
| $H_2$ | 99,9-99,9999 | 99,5-99,9998 | 99,4 |
| $N_2$ | 1,2-4,5 | NA | NA |
| AR | <0,5 | NA | NA |
| He | <9 | NA | NA |
| $O_2$ | 18 -> 500 | <500 ppm | <500 ppm |
| $CO_2$ | 0,2-5,4 | NA | NA |
| CO | <0,02 | NA | NA |
| $CH_4$ | <0,02-0,1 | NA | NA |
| $H_2O$ | >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

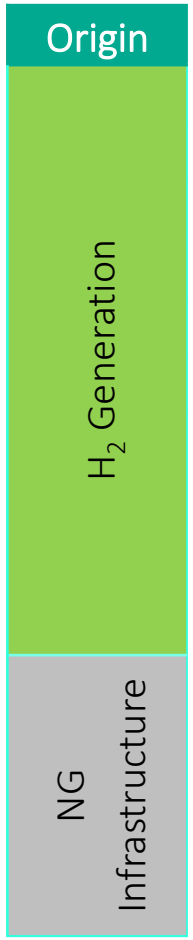
## Qualities delivered, required and guaranteed – purification for some producers and consumers?



# 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/$m^3$)



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| Origin | Name | Abbreviation | unit | CEN/TS 17977 |
|---|---|---|---|---|
| $H_2$ Generation | Hydrogen | $H_2$ | mol-% | ≥ 98 |
| | ∑ inerts | $I_{tot}$ | mol-% | ≤ 2 |
| | Carbon monoxide | CO | ppm | ≤ 20 |
| | Carbon dioxide | $CO_2$ | ppm | ≤ 20 |
| | Ammonia | $NH_3$ | ppm | ≤ 13 |
| | Halogenated compounds | R-Cl/F/Br | ppm | ≤ 0,05 |
| | Water | $H_2O$ | ppm | (≤ 250 (≤ 10 bara))<br>≤ 60 (> 10 bara) |
| | Oxygen | $O_2$ | ppm<br>ppm | (≤ 1000)<br>≤ 10 |
| NG Infrastructure | | | | |

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| | Oxygen | $O_2$ | ppm<br>ppm | (≤ 1000)<br>≤ 10 |
| NG Infrastructure | Hydrocarbons | $C_xH_y$ | mol-% | ≤ 2 |
| | Hydrocarbon DP | HCDP | °C | - 2 (@1-70 bara) |
| | Total sulphur | - | ppm | ≤ 7 |
| | Particles | - | mg/kg | Technically free |
| | Wobbe index | WI | $MJ/m^3$ | 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 |
|---|---|---|---|---|
| $H_2$ Generation | Hydrogen | mol-% | ≥ 98 | ≥ 99.5 |
| | ∑ inerts | mol-% | ≤ 2 | ≤ 0.5 |
| NG Infrastructure | Hydrocarbons | mol-% | ≤ 2 | ≤ 0.5 |

# WATER CONTENT ”DEEP DIVE”

# WATER CONTENT LIMITS

## Specification, design code and regulatory framework

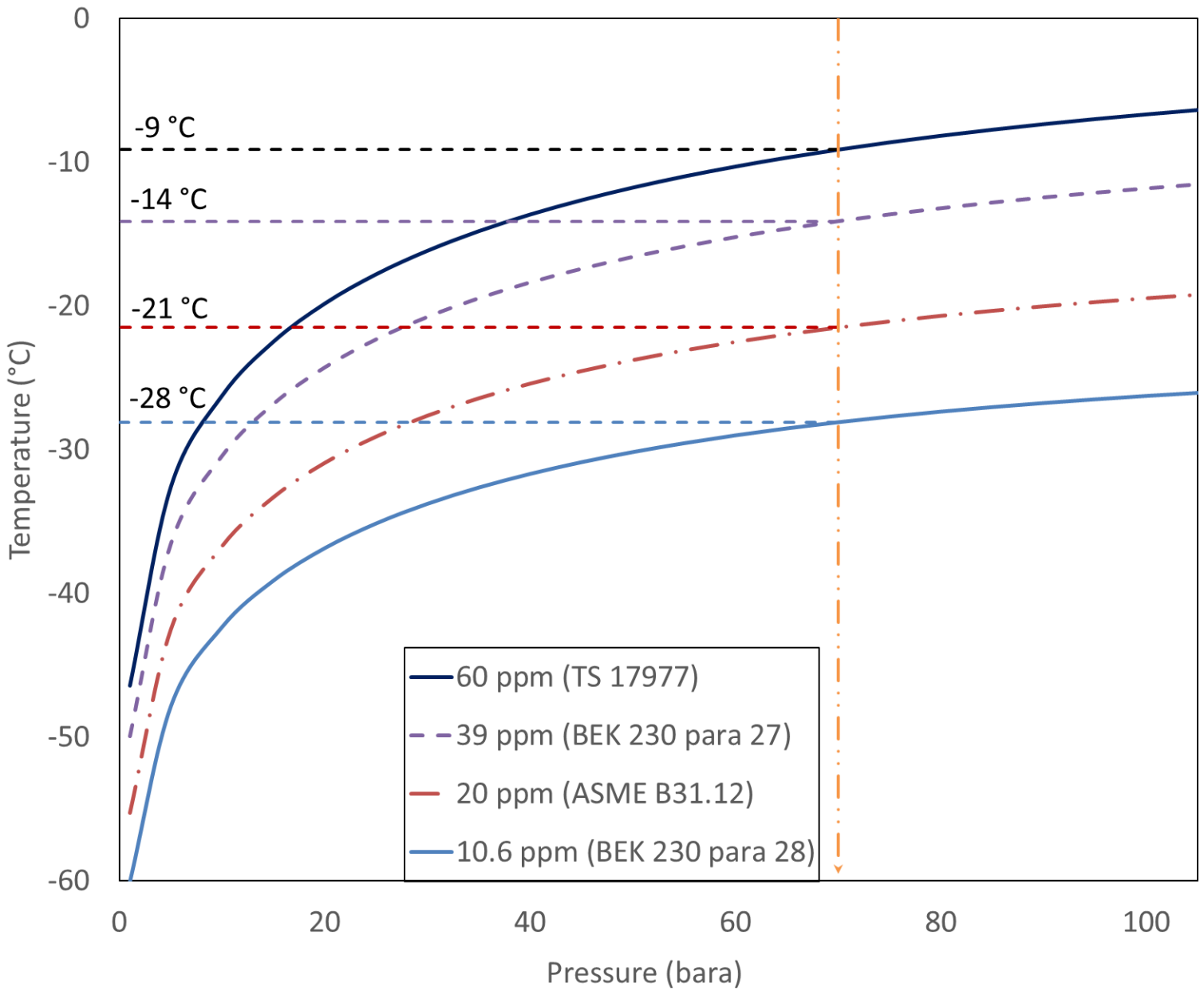
| $c(H_2O)$ (ppm) /Pressure | BEK 230, §28<br>10.6 | ASME B31.12<br>20 | BEK 230, §27<br>39 | TS 17977<br>60 |
|---|---|---|---|---|
| 1 atm | -60.0 | -55.1 | -50.0 | -46.4 |
| 70 bar | -28.1 | -21.5 | -14.1 | -9.1 |

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.

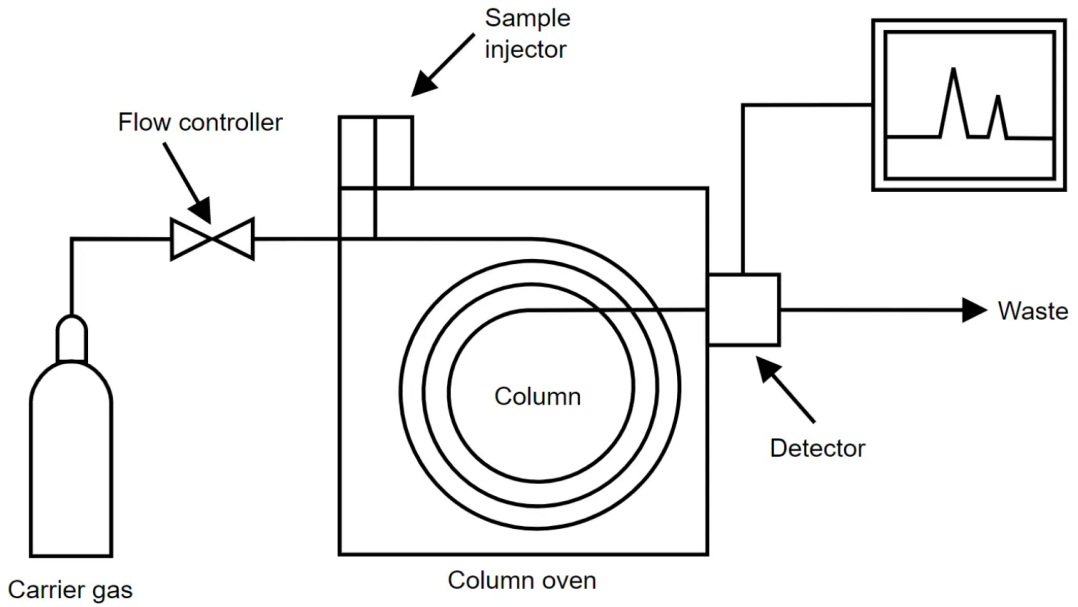


# MEASUREMENT AND ENERGY DETERMINATION

# $H_2$ MEASUREMENTS

## Assessing the quantity and quality of H2 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

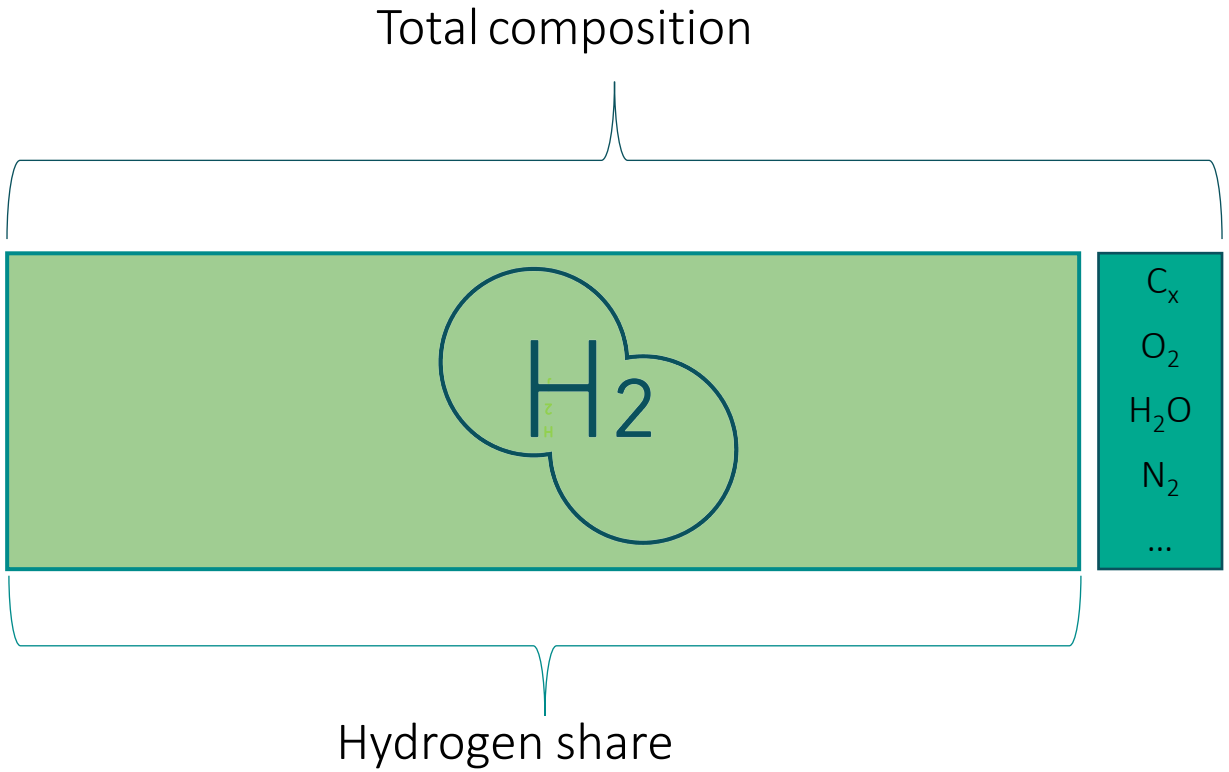
## Should hydrogen transactions be based on hydrogen purity or total energy content?

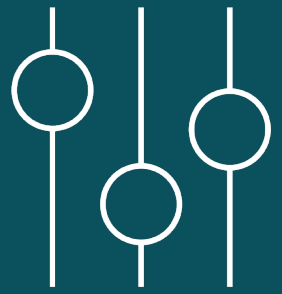
Total Composition:

- 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 |
|---|---|---|---|
| ≤ 20 ppm | ASME B31.12 | | |
| ≤ 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 $H_2$ 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/

# THANK YOU!