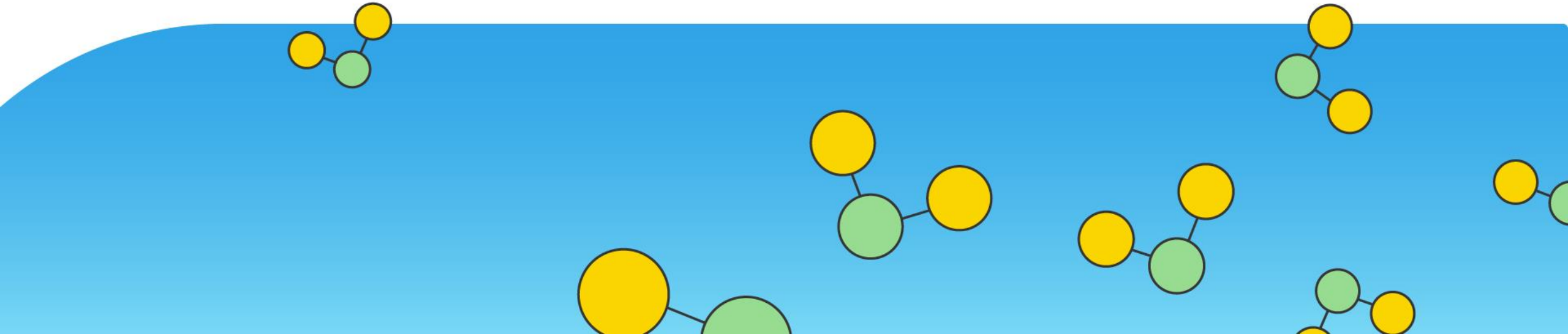
gasunie

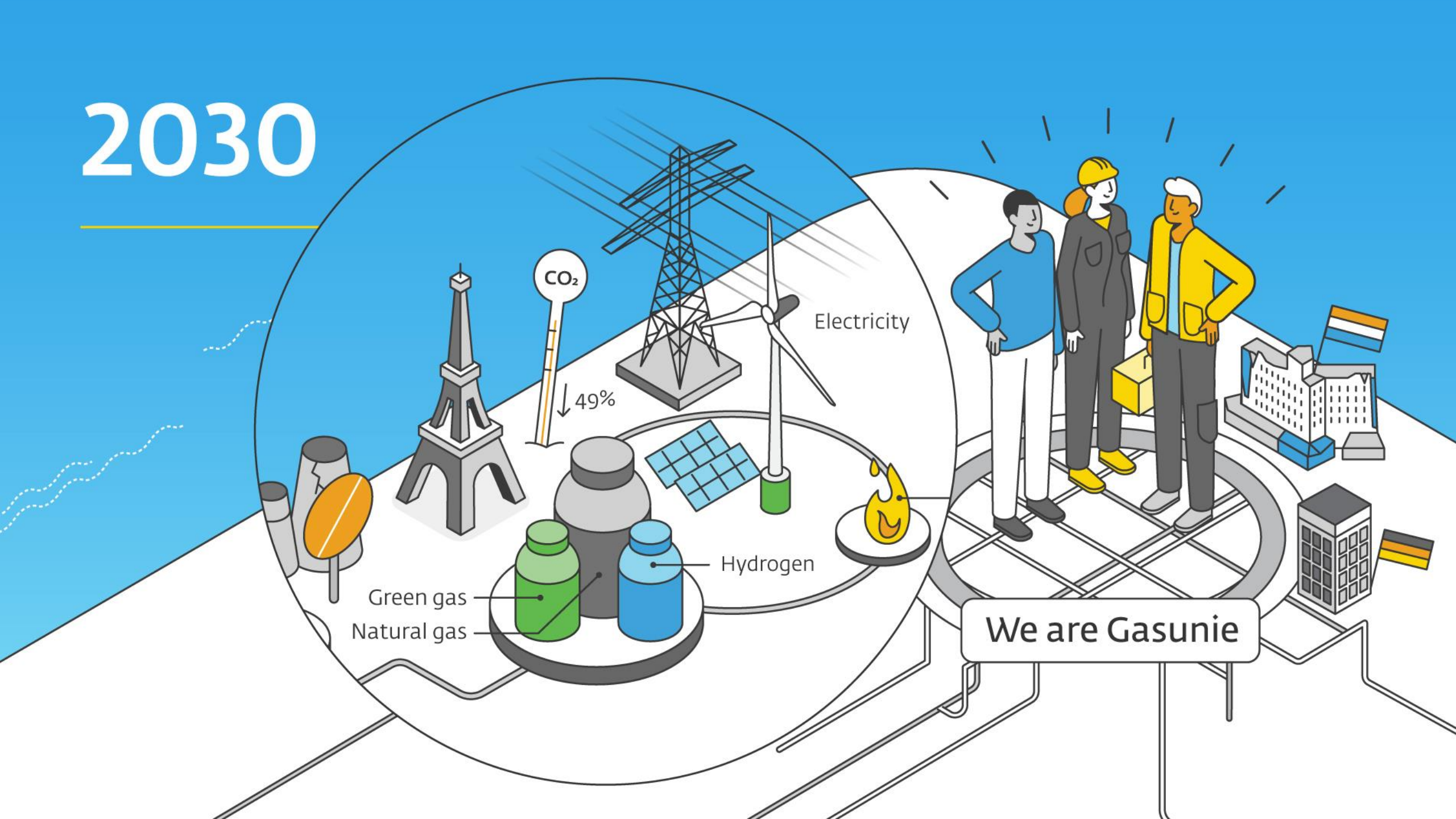
crossing borders in energy

Webinar hydrogen infrastructure

Welcome!

Gerard van Pijkeren




2030
CO_2
49%
Electricity
Hydrogen
Green gas
Natural gas
We are Gasunie

Hydrogen and Gasunie

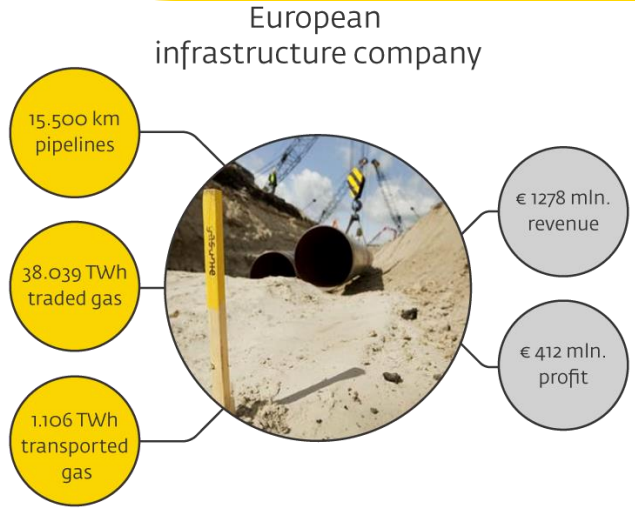
Global, European and national climate goals

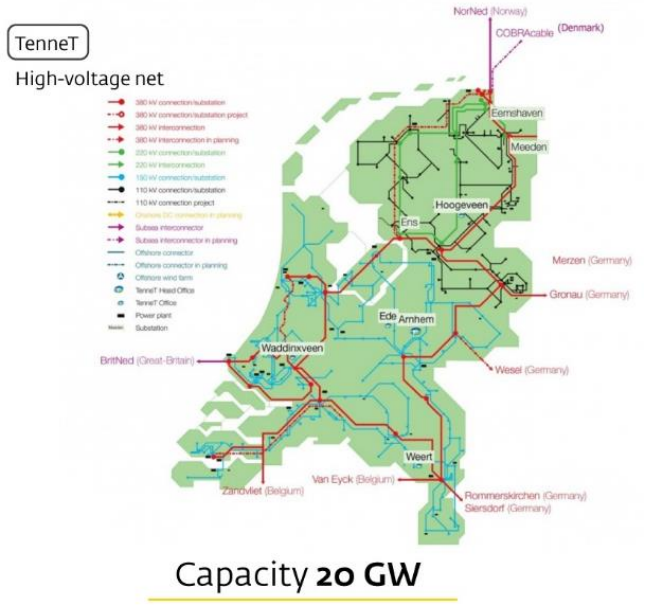
Hydrogen essential energy carrier to realize carbon neutrality in 2050

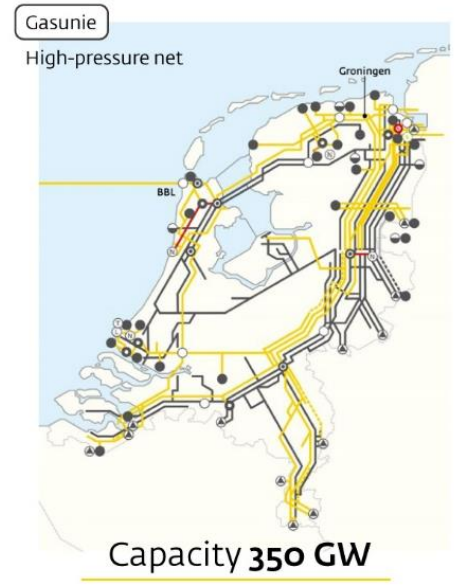
- efficient CO_2 reduction in various sectors
- fulfils the need for flexibility in a weather-dependent energy system
- integrated energy system at efficient cost
- security of supply

In 2050 hydrogen based on solar and wind

- Development and scale up of electrolysis techniques







Audience

- Customers
- Producers
- Authorities and policymakers
- Other

- IJmuiden
- Rijnmond
- Noord
- Limburg
- Zeeland
- Other

House rules

- All audience participants will be muted by default.
- Please use a head set or earplugs for the best sound.
- Please enter questions in the chatbox, the moderator will address them either in the session or afterwards via the website.

Agenda

Hydrogen backbone

- 11:10 – 11:25 General overview – Harry Smit, Project Manager
- 11:25 – 11:55 Technical information – Ronald Pieters, Technical Project Manager
- 11:55 – 12:25 Commercial information – Gareth Noble, Business Developer

Break (10 minutes)

Hydrogen storage

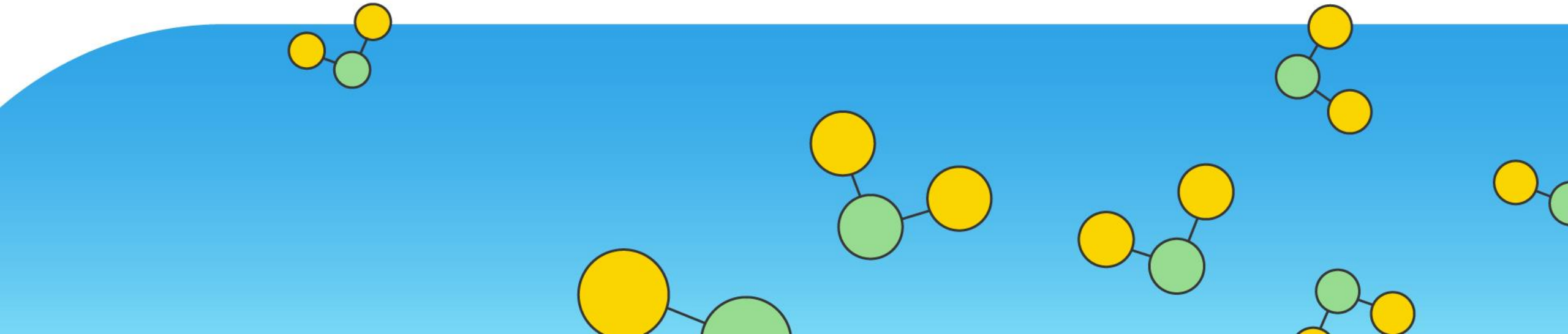
- 12:35 – 12:40 General overview – Inge de Groot, Business Developer
- 12:40 – 12:50 Technical information – Bert Stouwie, Technical Project Manager
- 12:50 – 13:00 Commercial information – Gareth Noble, Business Developer

Wrap up – Gerard van Pijkeren, Director Gasunie New Energy

Hydrogen backbone

General overview

Harry Smit

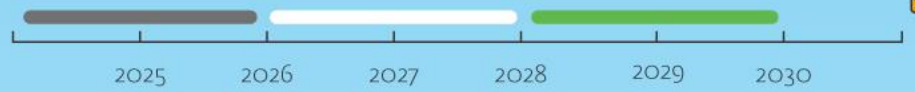


Gasunie hydrogen backbone

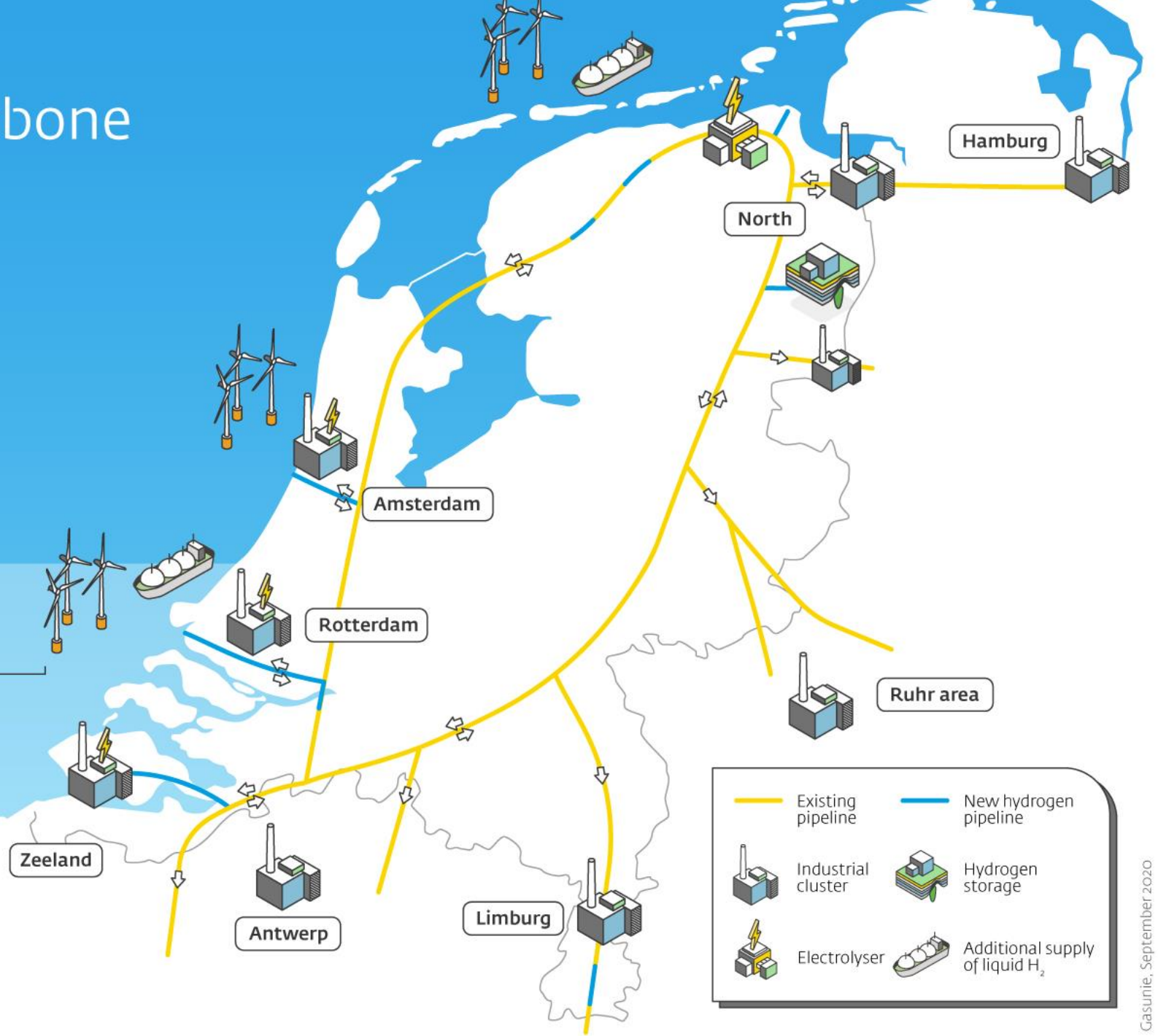
Local	backbone branches
Regional	backbone ribs
Country	main backbone
NW Europe	cross border networks

Re-use	low cost / little impact
Storage	balancing demand / supply
Large scale & capacity	1400 km, ± 42" > CO_2 red. potential

Phases



- Development of regional backbones, including connections to Germany and the northern Netherlands
- Industrial clusters interconnected and connected to hydrogen storage facilities
- Backbone connected to European hydrogen backbone



gasunie
crossing borders in energy

Gasunie, September 2020

Hydrogen backbone – starting points

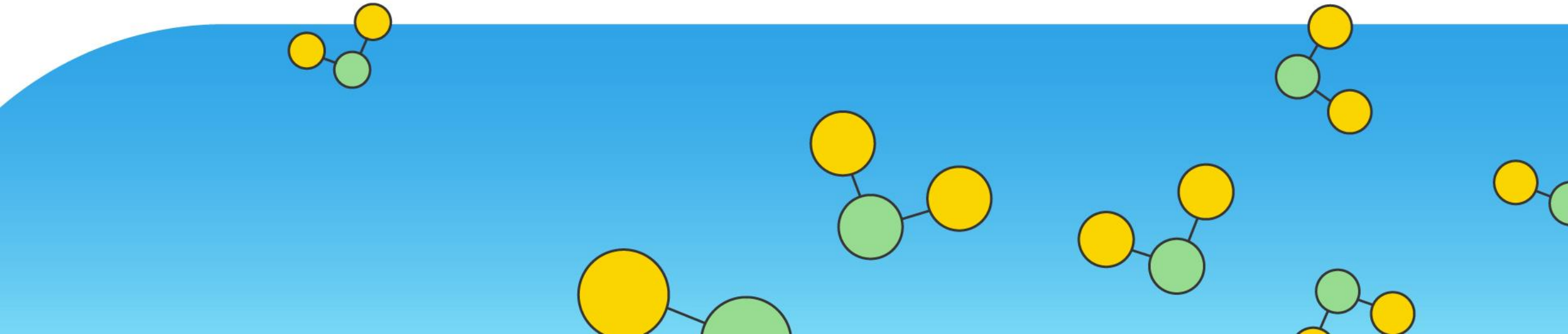
Backbone design setup

- Infra — build-up largely from existing natural gas pipelines
- Capacity — around 10 – 15 GW excluding compression
- Usage — from zero to full load 2025 –> 2040
- Costs & recovery — magnitude of investments 1,5 – 2,0 billion €
initial government funding -> commercial contracts
- Pressure & quality — physical constraints & market requirements ->
offers design bandwidth of pipeline specifications
- In order to — fulfil customer needs & minimize customer costs
tariffs should be "*minor part of H_2 cost chain*"

Hydrogen backbone

General overview

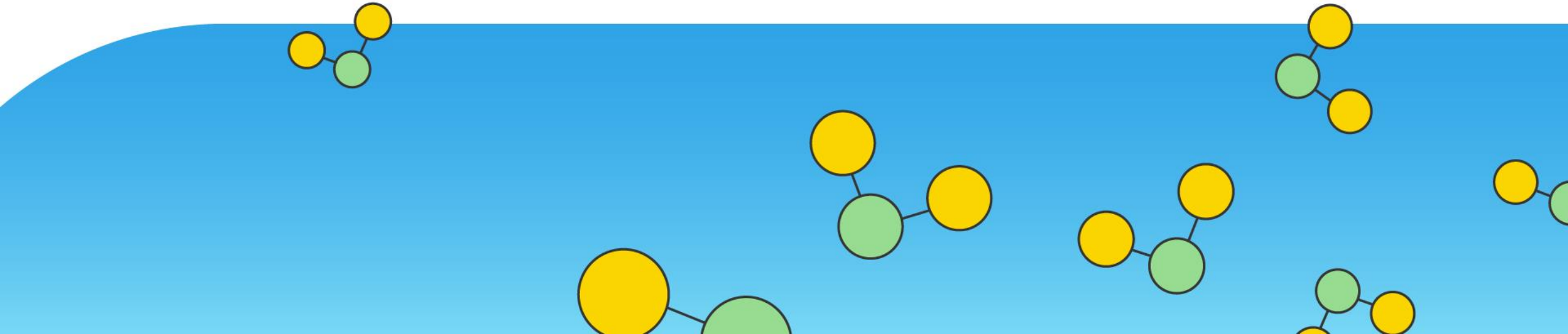
Harry Smit



Hydrogen backbone

Technical information

Ronald Pieters



Technical considerations for the H_2 backbone

For development of the H_2 backbone, we developed first concepts for the technical configuration. In this presentation, we will focus on 2 matters:

System pressure regime

Hydrogen quality specification

System pressure regime

For operating the H_2 backbone, Gasunie will have to developed a system pressure regime. Objective of our investigation is to develop a regime that is best suitable for producers, customers, and Gasunie as transmission operator.

The pressure regime will consist of 2 pressure levels:

- Upper level for producers (feed pressure)
- Lower level for consumers (supply pressure)

Gasunie investigated multiple pressure regimes, for different scenarios, based on requirements of producers, consumers, and for transportation.

- Producers: possible feed pressure for different production processes;
- Consumers: supply pressures required for different applications;
- Transporation: pressure needed to have sufficient transport capacity;

System pressure regime

Hydrogen quality specification

System pressure regime

Based on our investigations, we analysed different pressure regimes:

Our working hypothesis on the pressure regime consists of two phases:

- Start with a pressure regime of **10 – 30 bar** (first phase)
- Later to be succeeded by **30 - 50 bar** (second phase)

Currently, we see an optimal solution in a long term pressure regime of 30 - 50 bar. This regime will provide sufficient pressure for hydrogen customers, and will enable Gasunie to create sufficient transport capacity for the long term;

For the regional ribs, in the first development phases, we do see the option to start with a temporary lower pressure regime of 10 - 30 bar, in case preferred by regional parties. In case we will connect regional ribs with the national H_2 backbone, the pressure regime might be changed to a higher pressure level.

System pressure regime

Hydrogen quality specification

Hydrogen quality specification

Gasunie is searching for an optimal quality specification for the hydrogen backbone, best suitable for all connected parties;

The hydrogen quality specification will be specified in:

- Hydrogen purity (e.g. 99%),
- Impurities (e.g. oxygen, sulphur)

Hydrogen purity of 100% will not be possible, due to limitations in production and possible contamination by transmission. But what quality spec <100% is acceptable for market parties and Gasunie? For that matter, Gasunie analyses different elements that will have an impact on hydrogen quality, such as:

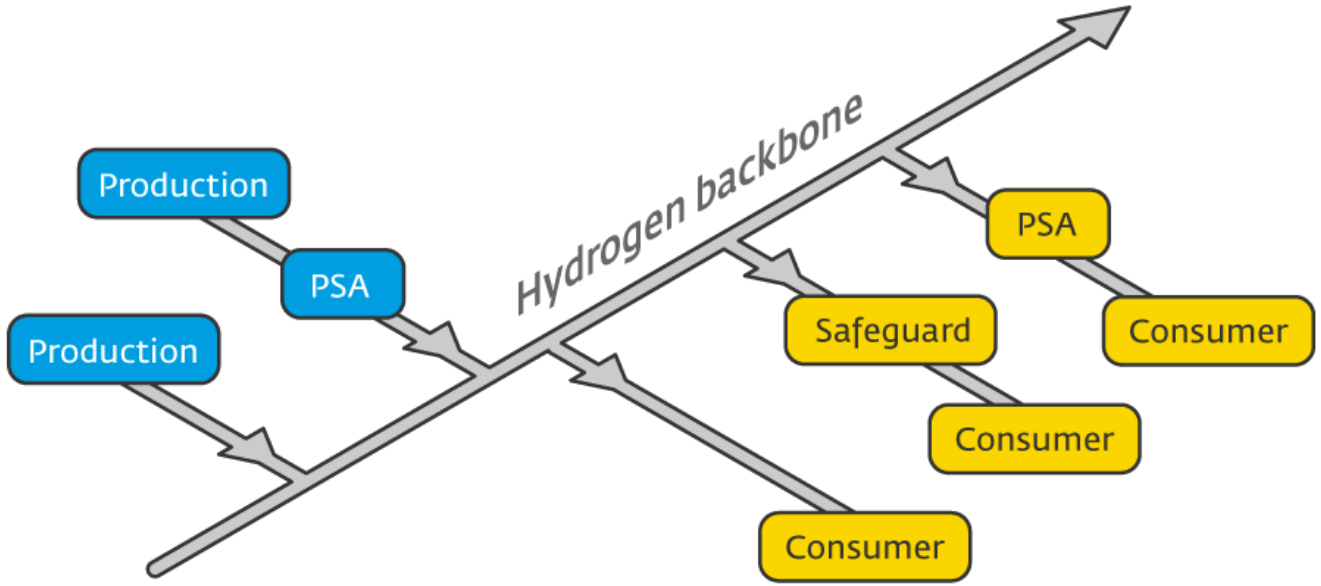
- the quality limitations for producer and consumer;
- the potential contamination by transmission;
- technical options for hydrogen quality treatment;

System pressure regime

Hydrogen quality specification

Hydrogen quality specification

Gasunie developed first technical concepts for handling hydrogen quality. In our concepts, (clusters of) suppliers or consumers can be equipped with hydrogen treatment (PSA / safeguarding) to deliver the required hydrogen specification.




System pressure regime


Hydrogen quality specification

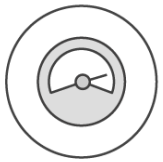
Hydrogen quality specification

Based on analysing the requirements of different hydrogen processes, we developed 3 concepts specifications:

		1	2	3
Hydrogen	[mol%]	98,0	99,0	99,5

In addition to the hydrogen purity, Gasunie developed specifications impurities, such as (but not limited to): hydrocarbons, oxygen, water, sulphur, halogenated compounds, carbon monoxide, or carbon dioxide

The detailed specifications are found in the appendix of this presentation



System pressure regime

Hydrogen quality specification

Appendix - Hydrogen quality specification

Constituents	Specification 1	Specification 2	Specification 3	Opm.
Hydrogen fuel index	≥98,0 mol%	≥99,0 mol%	≥99,5 mol%	1
Total hydrocarbons including methane	≤1000 µmol/mol	≤1000 µmol/mol	≤1000 µmol/mol	2
Oxygen (O_2)	0,1-0,2 mol%	0,1-0,2 mol%	0,1-0,2 mol%	3
Sum of Inerts	≤2 mol%	≤1,0 mol%	≤0,5 mol%	4
Carbon dioxide (CO_2)	≤20 µmol/mol	≤20 µmol/mol	≤1 µmol/mol	5
Carbon monoxide (CO)	≤20 µmol/mol	≤20 µmol/mol	≤1 µmol/mol	6
Total sulphur incl H_2S	≤5 µmol/mol	≤5 µmol/mol	≤1 µmol/mol	7
Formic acid	≤10 µmol/mol	≤10 µmol/mol	≤1 µmol/mol	8
Formaldehyde (HCOH)	≤10 µmol/mol	≤10 µmol/mol	≤1 µmol/mol	8
Ammonia (NH_3)	≤10 µmol/mol	≤10 µmol/mol	≤1 µmol/mol	8
Halogenated compounds	≤0,05 µmol/mol	≤0,05 µmol/mol	≤0,05 µmol/mol	9
Water dewpoint	-8 °C bij 70 bara	-8 °C bij 70 bara	-8 °C bij 70 bara	10
All other impurities	disclaimer	disclaimer	disclaimer	11
Temperature	5-30 °C	5-30 °C	5-30 °C	12

1. Purity hydrogen
2. Because there is no Wobbe limit a limit on hydrocarbons is necessary
3. For pipelines transporting hydrogen gas, degradation can set a limit on the fatigue loading in terms of pressure variations and/or number of cycles. The degradation can be mitigated by adding a small amount of oxygen gas to the hydrogen gas. This has the advantage that the fatigue loading does not have to be limited and monitored. (ref: VA 20.0214; minimum oxygen gas level to mitigate hydrogen-enhanced fatigue in pipelines)
4. Limitation on inerts also based on the purity of hydrogen. For fuel cells also limited.
5. CO_2 level as low as possible, aim is no CO_2 emission.
6. Because of personal safety reasons at end-users the CO level on the given value.
7. Total sulpher on low level because no sulpher is expected in the hydrogen.
8. Important for fuel cells and can be produced by electrolyser hydrogen production.
9. Adopted from ISO 14687
10. Adopted from the Ministerial Regulation Gas quality (MR gas quality) in the Netherlands
11. Disclaimer: Shall not contain solid, liquid or gaseous material that might interfere with the integrity or operation of pipes or any gas appliance.
12. Limitation on temperature because of the design temperature of the pipeline.

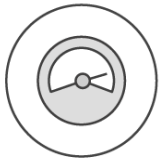
Hydrogen quality specification

Questions for market parties:

We would like to ask for your input regarding hydrogen quality:

- Which of the mentioned quality specifications would be suitable?
- For what application will the hydrogen be used?
- What are critical impurities in your process?
- Do you foresee quality treatment / safeguarding within your process?

Based on the given answers, we will improve our quality analysis, in order to develop a hydrogen quality specs that suits the market, is technically viable, and with acceptable costs for quality treatment



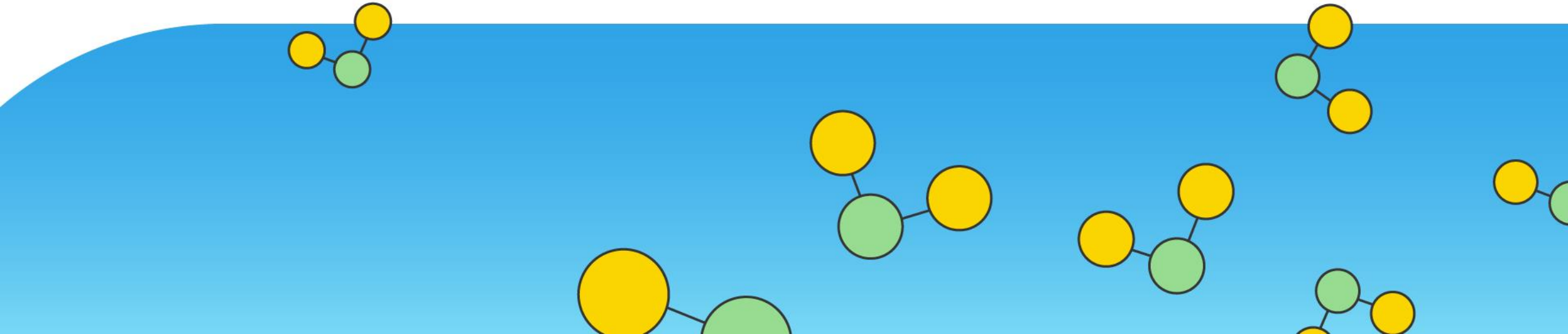
System pressure regime

Hydrogen quality specification

Hydrogen backbone

Technical information

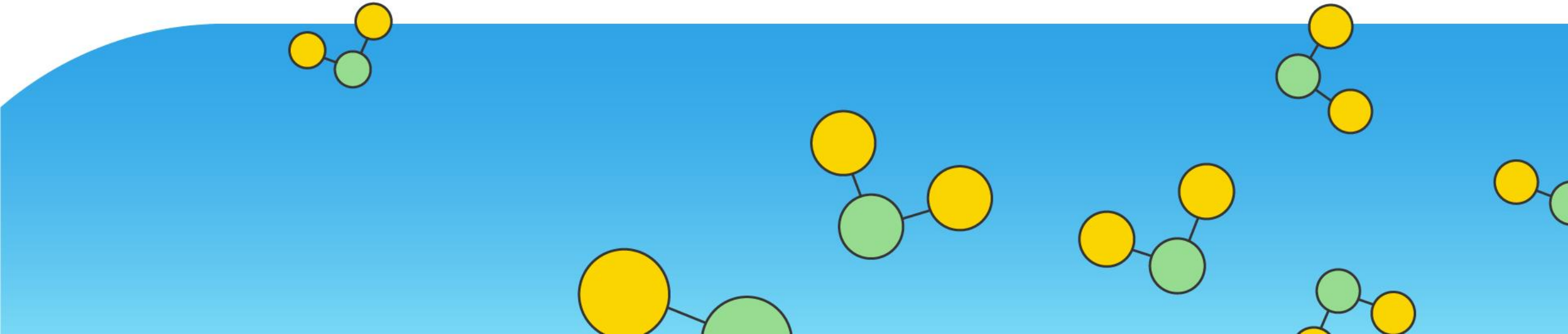
Ronald Pieters



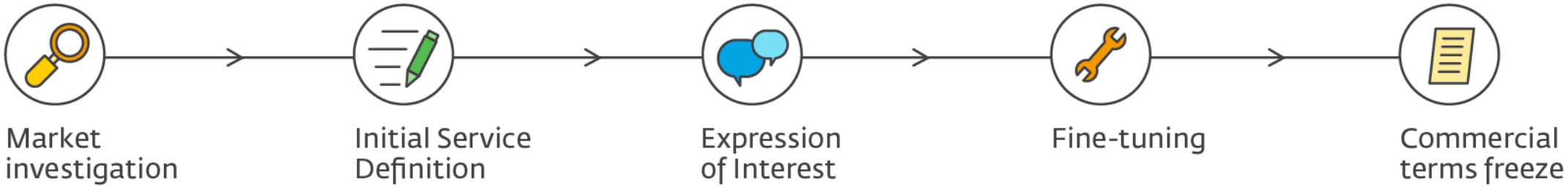
Hydrogen backbone

Commercial information

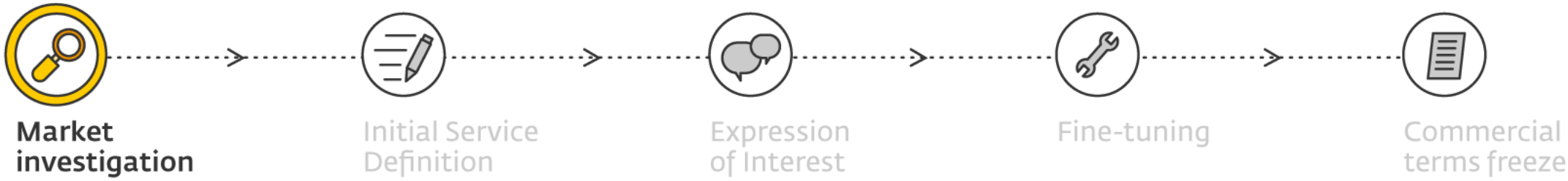
Gareth Noble



Envisaged Commercial Process - Backbone



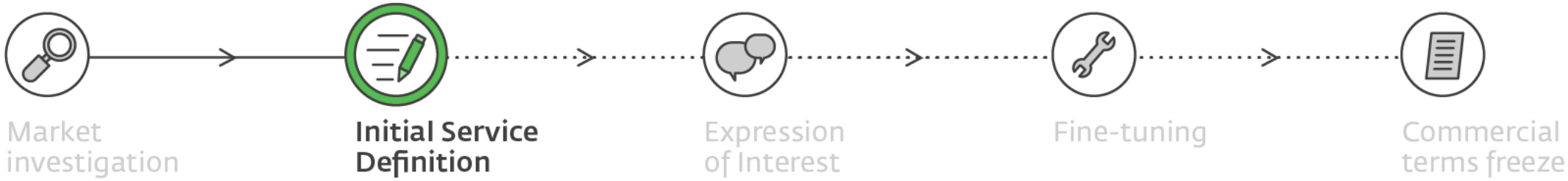
Envisaged Commercial Process - Backbone



1st October – 14th October 2020

- Based on external questionnaire
- Provides input for service definition (Tariff indication, quality, pressure regime,)
- Serves as basis for project phasing (RIBs & Backbone)

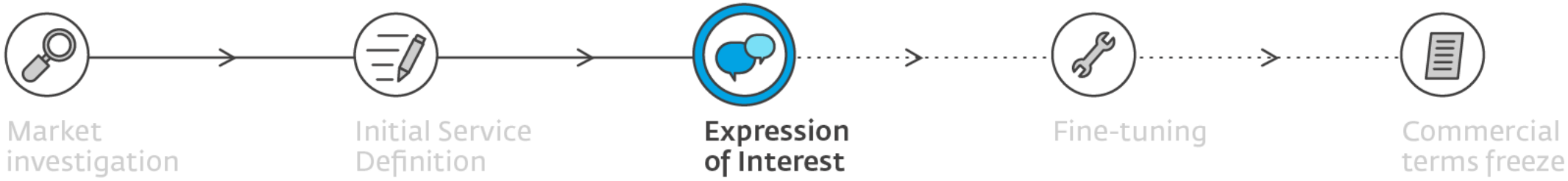
Envisaged Commercial Process - Backbone



15th October – 15th November 2020

- Detailed analysis of results questionnaire
- Some clarification discussions will be required

Envisaged Commercial Process - Backbone

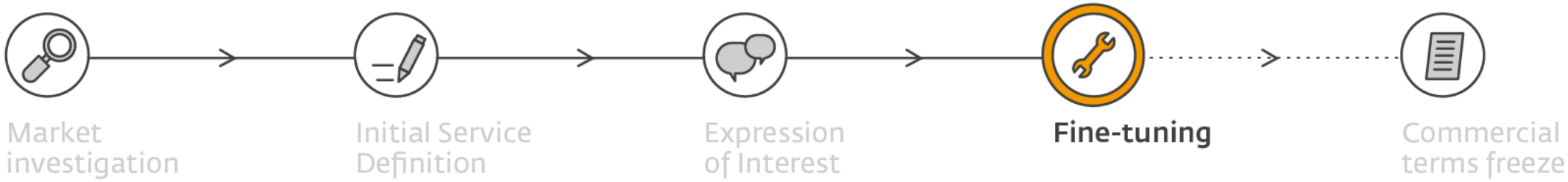


16th November - 31st December 2020

- Potential clients receive draft term sheet & product description and are asked to indicate timing, volume and capacity requirements
- We anticipate that this will initially be aimed at individual RIBs with FID's in 2021/'22*
- EoI includes reciprocal commitment to execute respective define phase projects (i.e. this is not an FID)

* Process and timing for subsequent RiBs & the backbone depend on results from Market Investigation

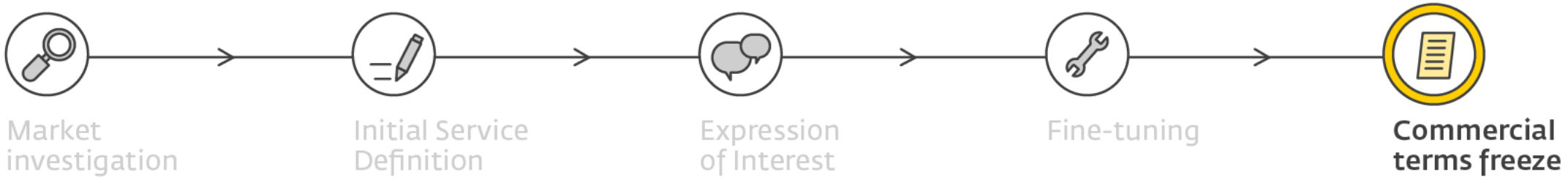
Envisaged Commercial Process - Backbone



1st January -31st December 2021

- Includes both further definition of commercial terms and detailed agreement preparation
- Depends also on the development of the government's support instruments (including coverage of pre-investments/fill risk)
- This will require iteration with the market participants

Envisaged Commercial Process - Backbone



31st December 2021

- Depends on definitive Capex estimate which is only available shortly before FID approvals process

Key aspects of questionnaire 1/2

1. Company information
   - Provides essential contact details as we are moving from the ongoing dialogue and commencing a more formal commercial process
2. Company objectives on hydrogen
   - Consumers – an indication on type of usage allows us to assess profiles, quality and pressure requirements
   - Producers – provides information similar to those of consumers and also will allow us to assess the profile (green, blue and grey hydrogen)
3. Volumes and capacities (incl. project maturity)
   - Essential for system dimensions but also for our assessment of optimal project and facilities phasing
   - Project maturity information also allows us to optimize by using a risk/opportunity-based approach and be starting point for discussion on how we can align our project processes

All data will be treated confidentially and covered by an NDA which accompanies the questionnaire.

Key aspects of questionnaire 2/2

4. Pressure regime
   - We will endeavour to develop a pressure regime that is economically efficient for the whole chain
   - We envisage a max 50 bar input and min 30 bar delivery regime but, depending on support, may offer a 30-10 system at early stages.
5. Hydrogen quality requirements
   - 3 potential regimes are being considered (98, 99 & 99,5 mol%)
   - We also will use background information to ensure consistency across common production methods.
   - We investigate whether there is additional flexibility available in the specifications as this may allow for a more efficient system
6. Ancillary services
   - Gasunie is keen to facilitate market development and is willing to identify potential barriers and where we can cooperate to alleviate them.

All data will be treated confidentially and covered by an NDA which accompanies the questionnaire.

Our objective is to mobilize

We aim to develop a flexible system that meets the needs of the customers.

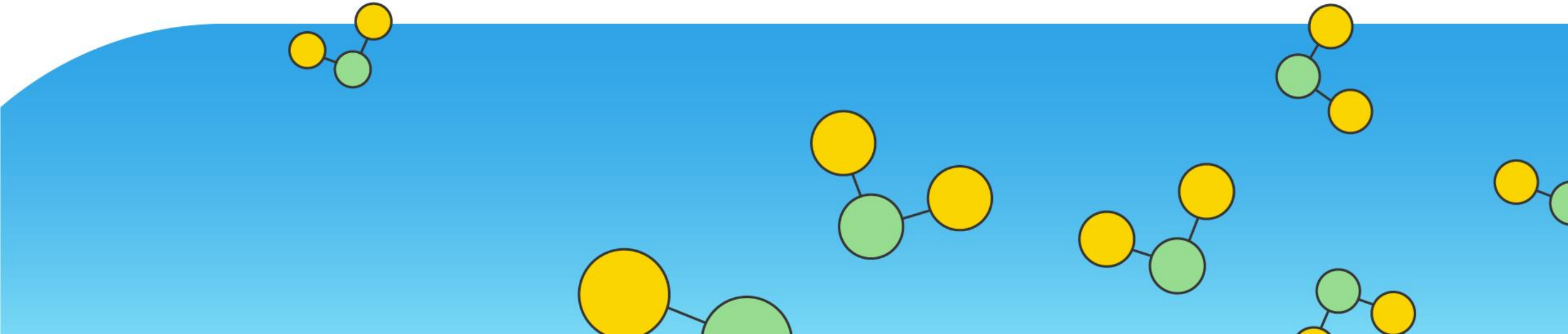
Tariff setting will be guided by the following considerations:

- Non-discriminatory
- Transparency
- Cost reflectivity / cost recovery
- Economic efficiency
  - guides system design
  - We will endeavour to secure a maximum of (European) subsidies
- Avoid cross-subsidisation between elements of the chain (e.g. hydrogen storage)

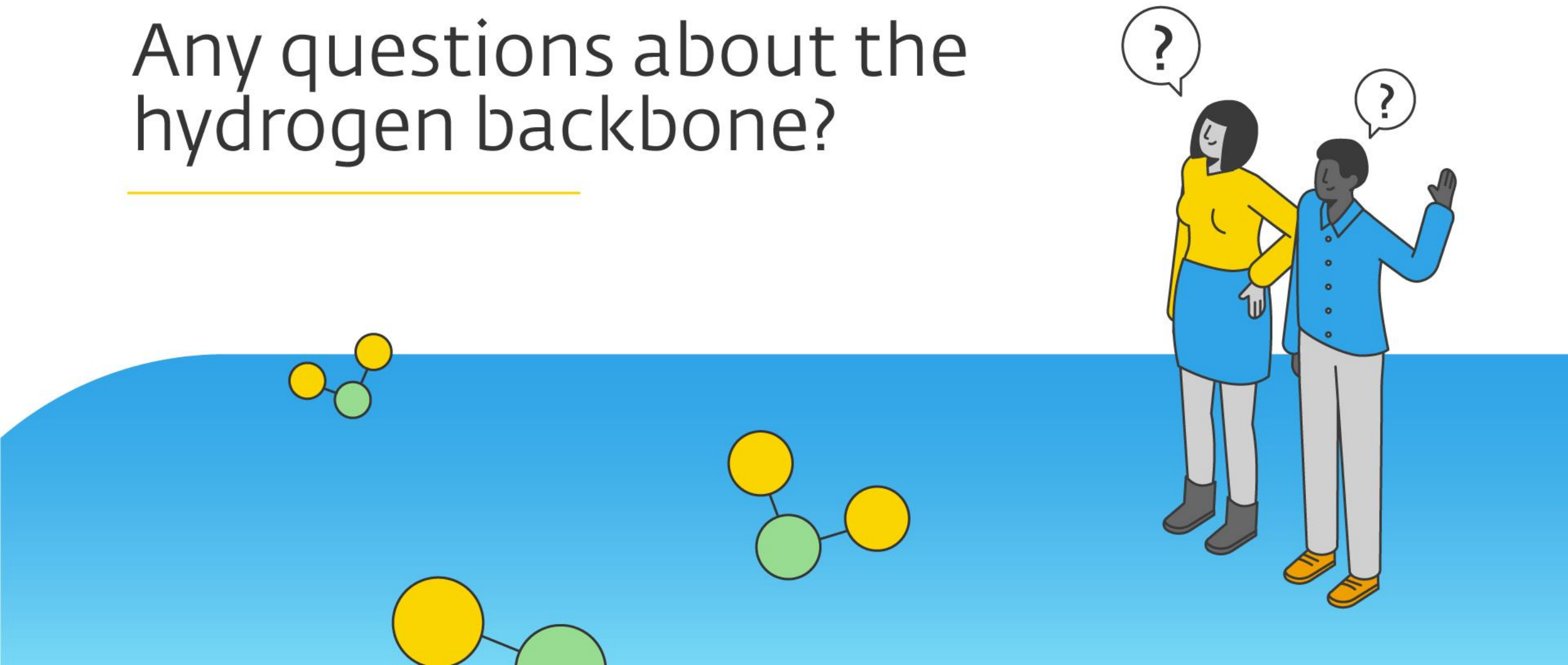
Hydrogen backbone

Commercial information

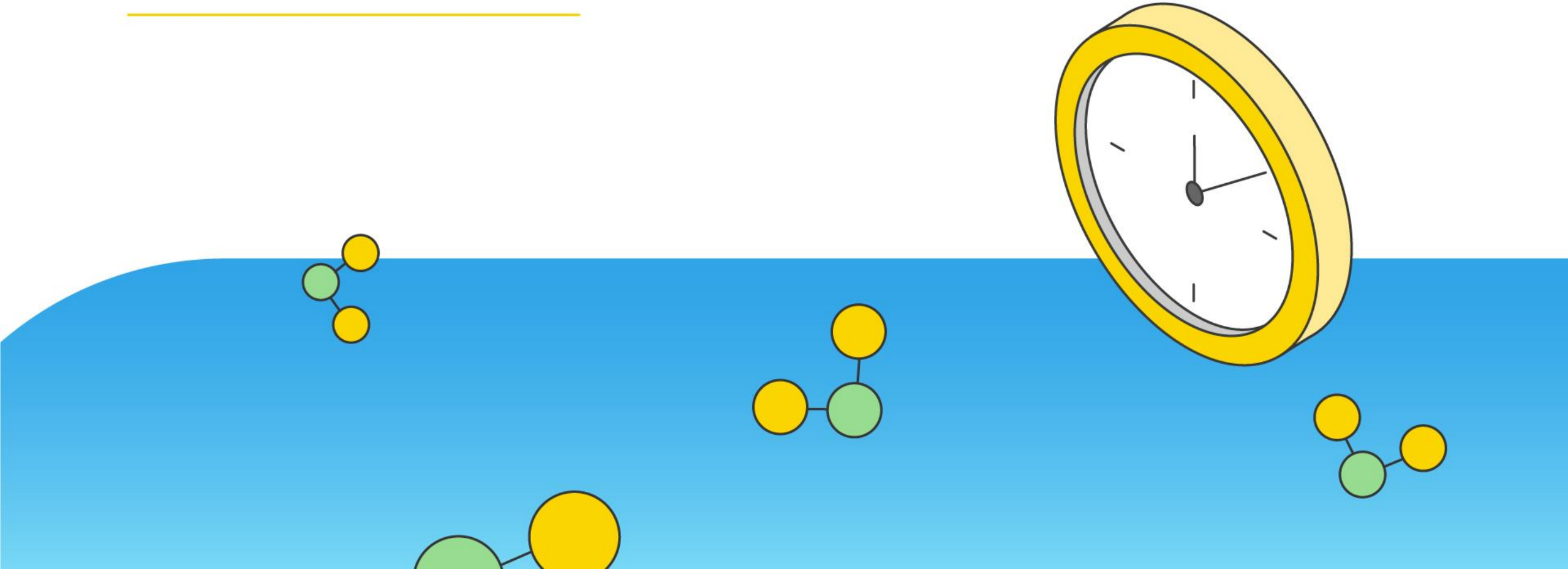
Gareth Noble



Any questions about the hydrogen backbone?



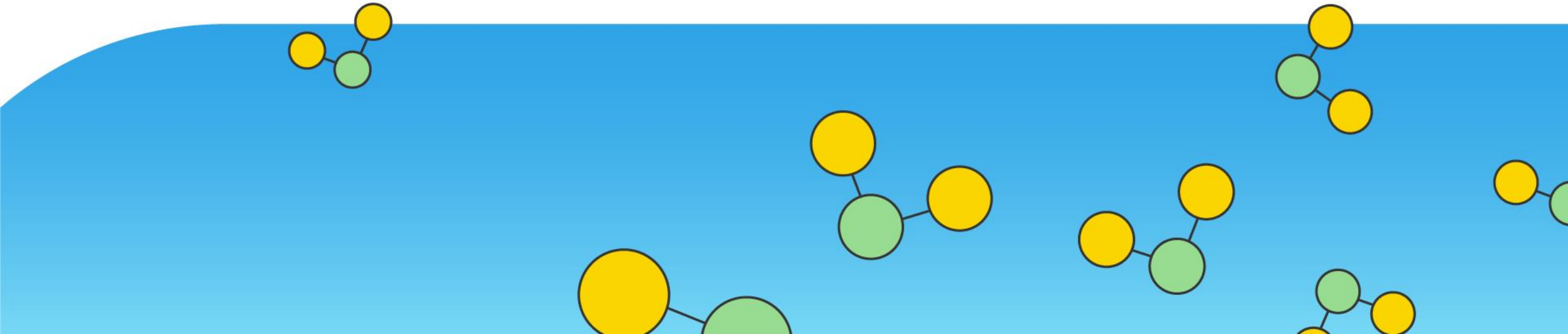
10 minute break



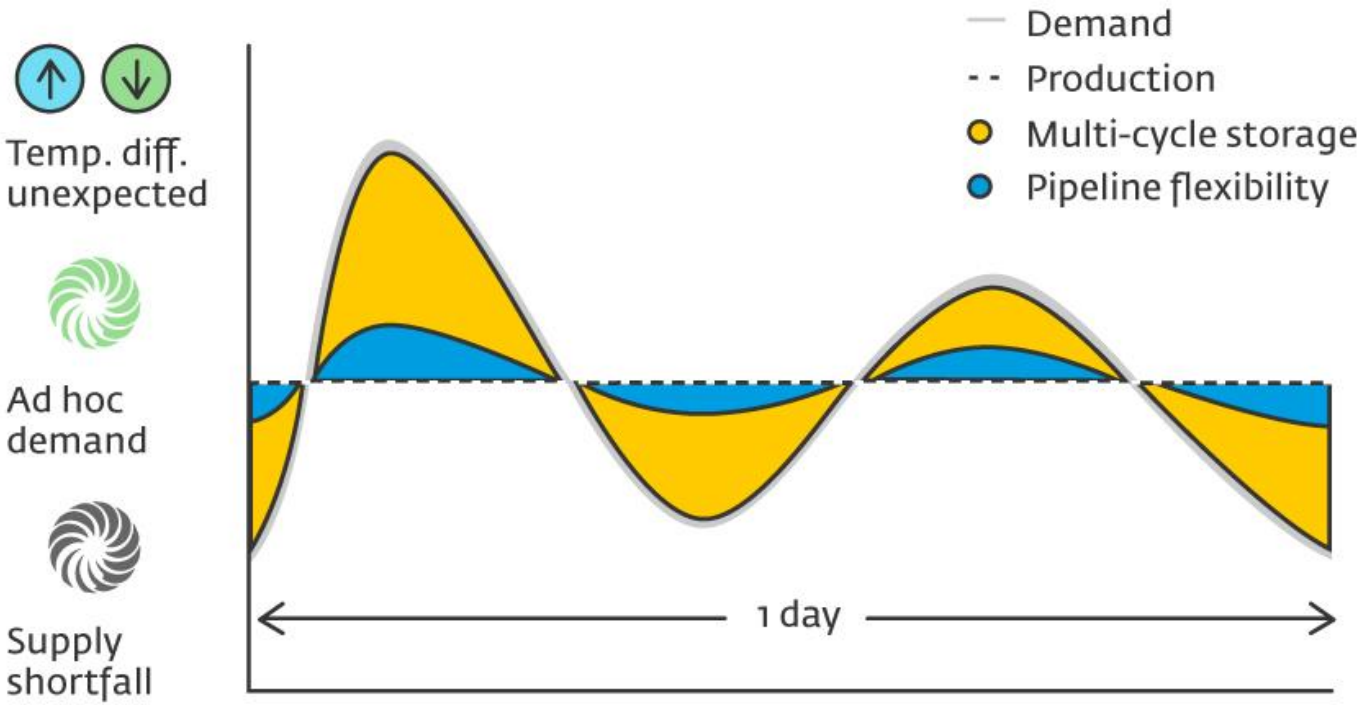
Hydrogen storage

General overview

Inge de Groot

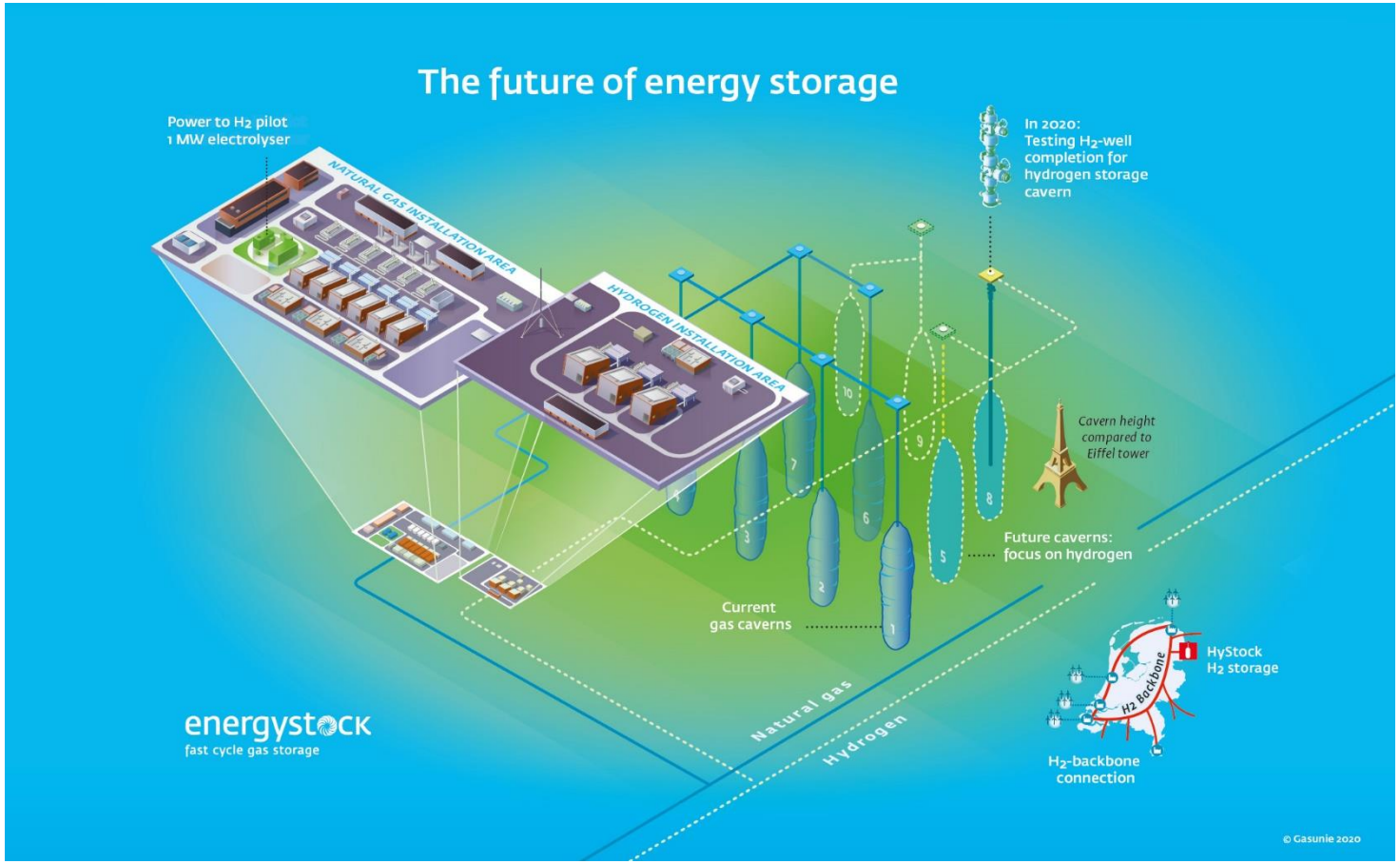


Why hydrogen storage is needed



- Essential for achieving the climate goals
- Future demand and supply will not match
- Strong volatile production of renewable energy
- Balancing is required
- Storage can act as a "lung"

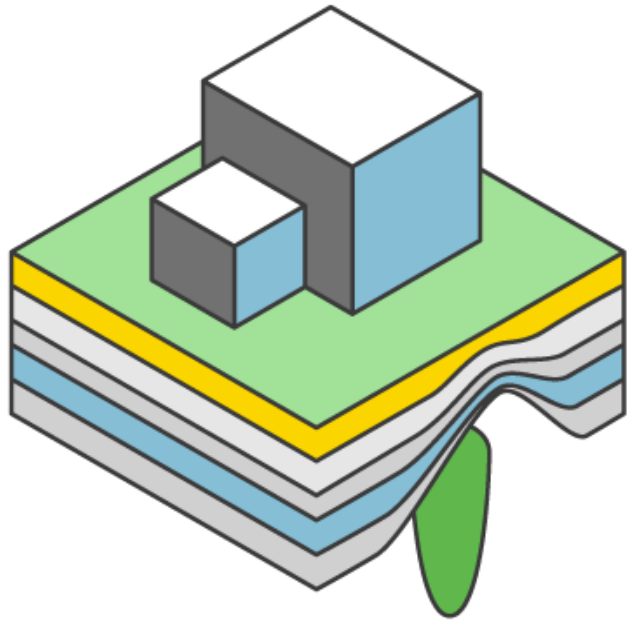
Where & when can we develop hydrogen storage?



- Located next to the current gas storage, province of Groningen
- Strategically located
- 4 additional caverns can be developed
- First phase of storage facility can be operational in 2026
- Storage volume can be developed based on market demand

Conditions to develop hydrogen storage

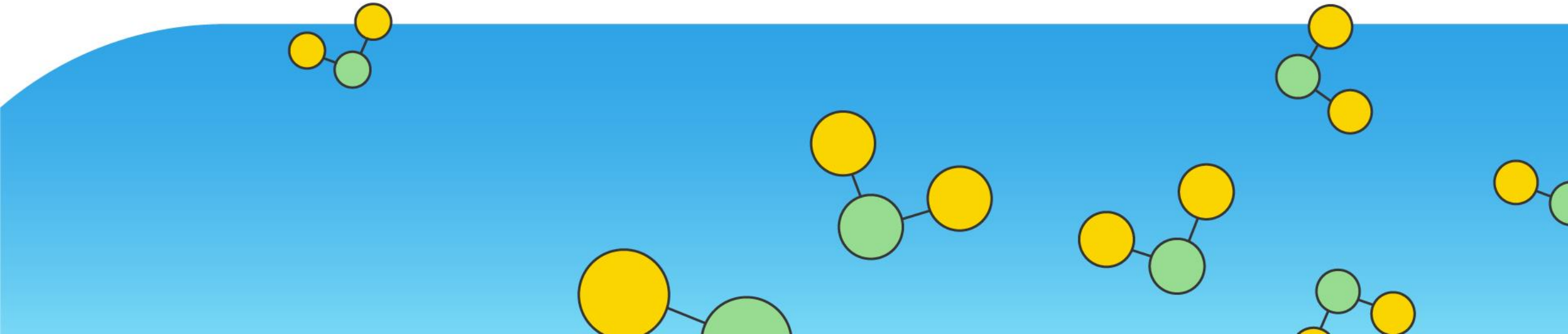
- Development of techniques and standards to store hydrogen safely based on a testing program
- Obtain (mining) permits for the development of the installation and caverns
- A feasible business case, including, where necessary, national and European grants



Hydrogen storage

General overview

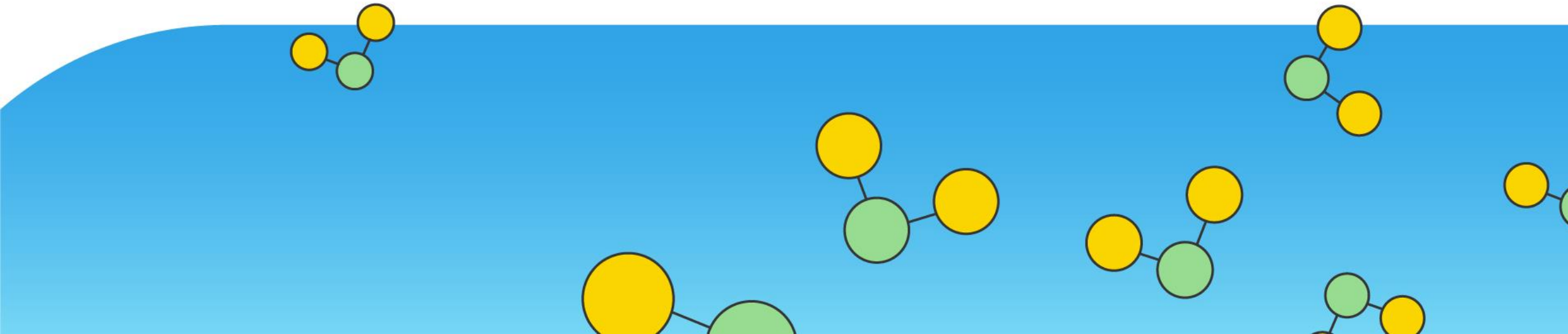
Inge de Groot



Hydrogen storage

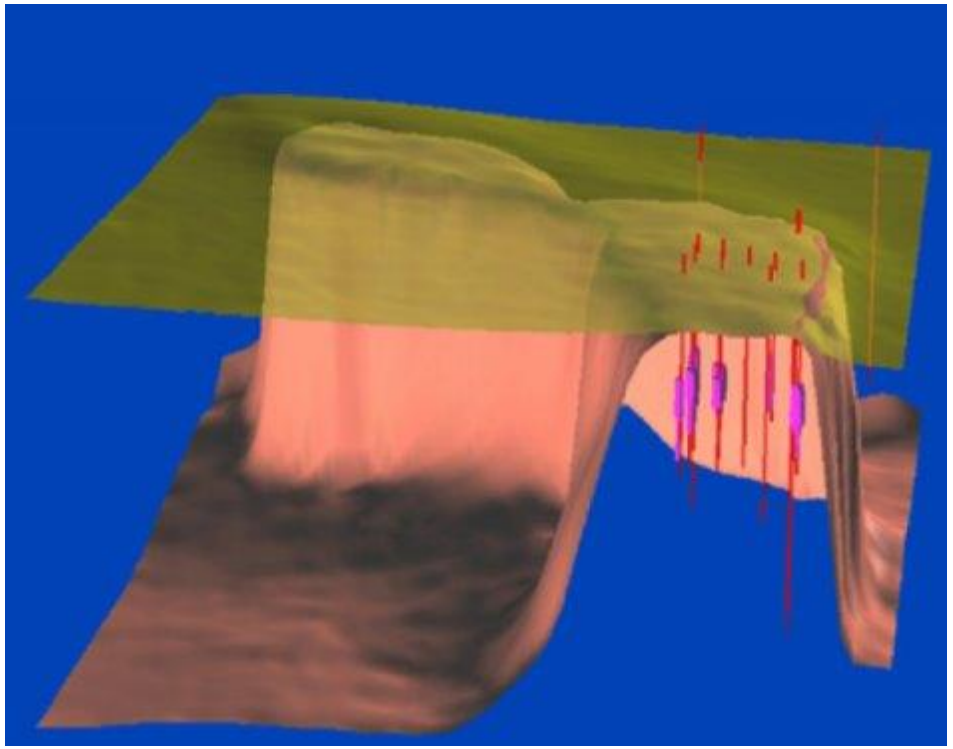
Technical information

Bert Stouwie

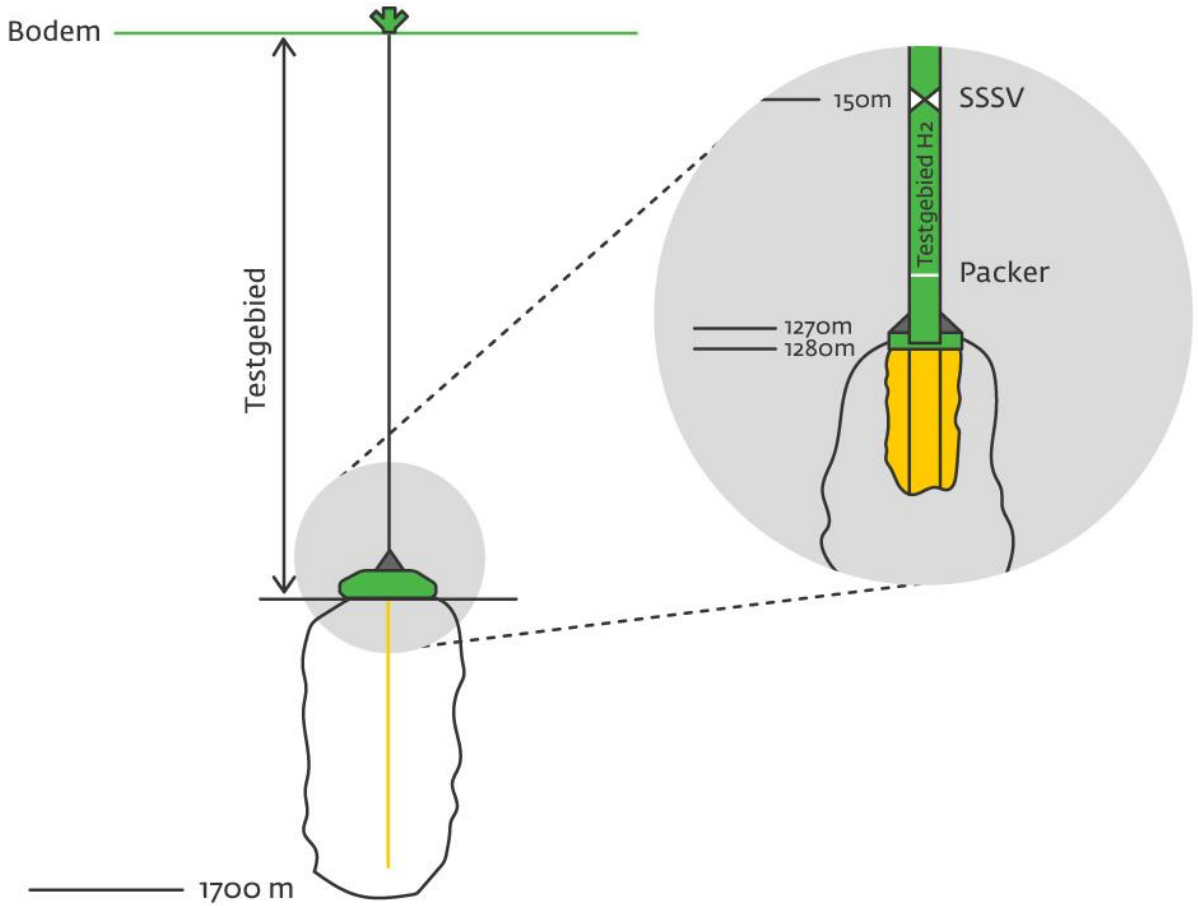


Existing fast cycle gas storage plant Zuidwending

Cavern area with 6 active gas caverns and 4 spare positions for hydrogen storage



2020-2021 : Hydrogen test of borehole A8 and equipment



2020: Feasibility study hydrogen storage plant - characteristics

- Combination of caverns and injection/production plant
- Indication: <10 tons/hr up to >40 tons/hr
- Scalable from first storage needs up to a max case with 4 caverns
- Storage per cavern more than 6.500 tons (working gas)
- Adapted to pressure regime of back bone (10-30 and/or 30-50 bar)
- Caverns contain water and therefore hydrogen needs to be dried after production
- Quality of hydrogen supplied remains within backbone specifications
- Fast switch over between injection and production

Indication of a planning schedule: depending on permitting and commercial progress

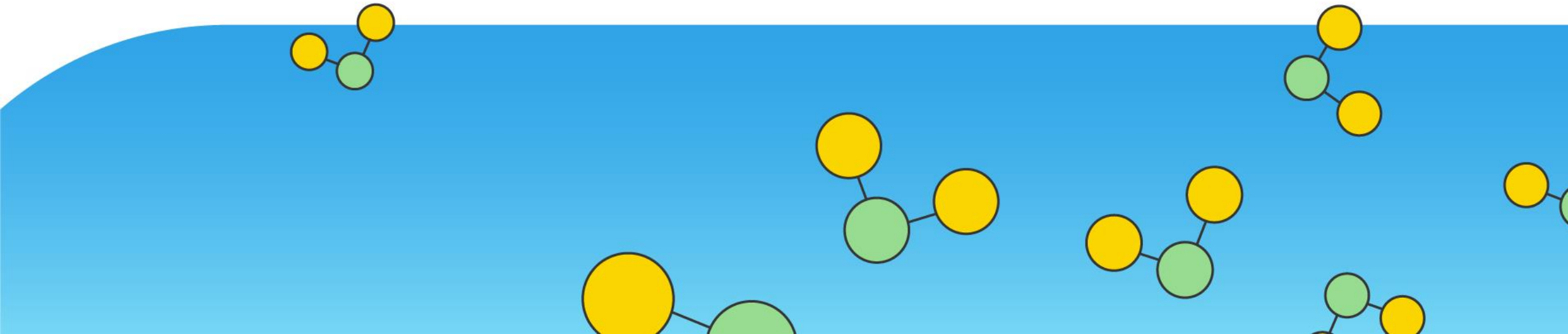
- 2020: Feasibility study
- 2021: Basic design and start permitting
- 2022: Small scale tests and detail design
- 2023: Material supply
- 2024-2025: Construction
- 2026: Commissioning, debrining with hydrogen and start up
- 2027-> Upscaling based on demand

What's real?

Hydrogen storage

Technical information

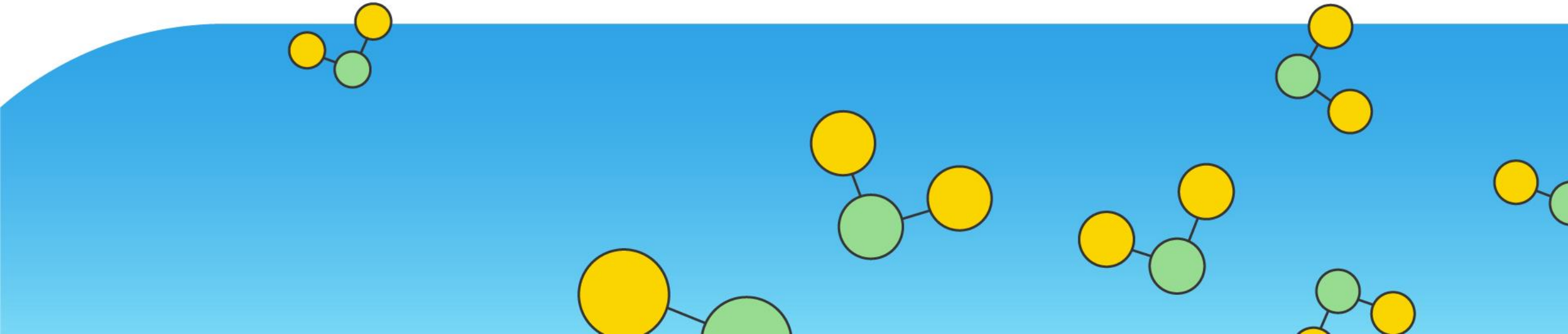
Bert Stouwie



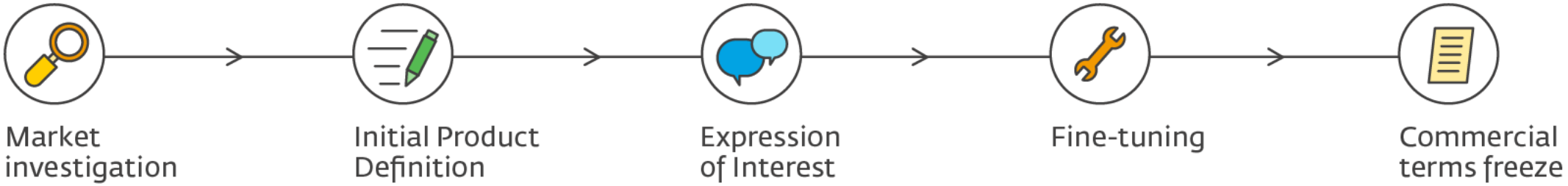
Hydrogen storage

Commercial information

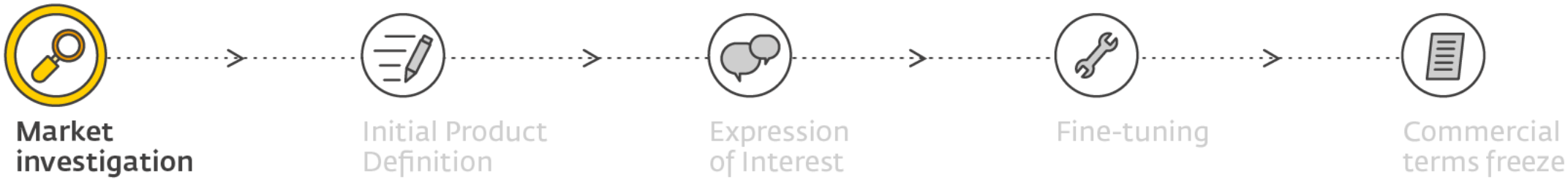
Gareth Noble



Envisaged Commercial Process – Hydrogen storage



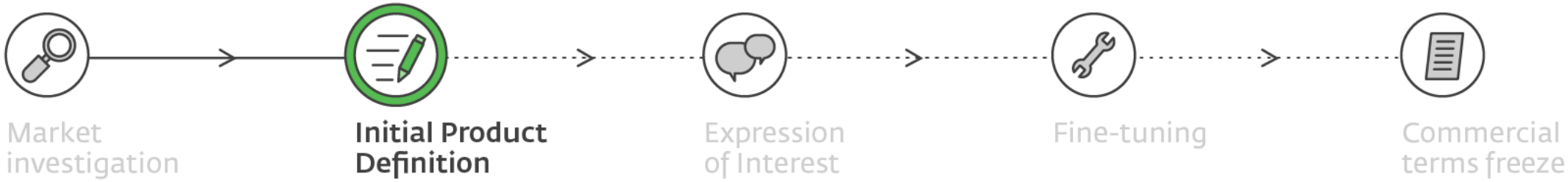
Envisaged Commercial Process – Hydrogen storage



1st October – 14th October 2020

- Based on external questionnaire
- Provides input for product definition (Price indication, injection and withdrawal rates, storage volumes)
- Basis for project phasing (Caverns #1 to 4)

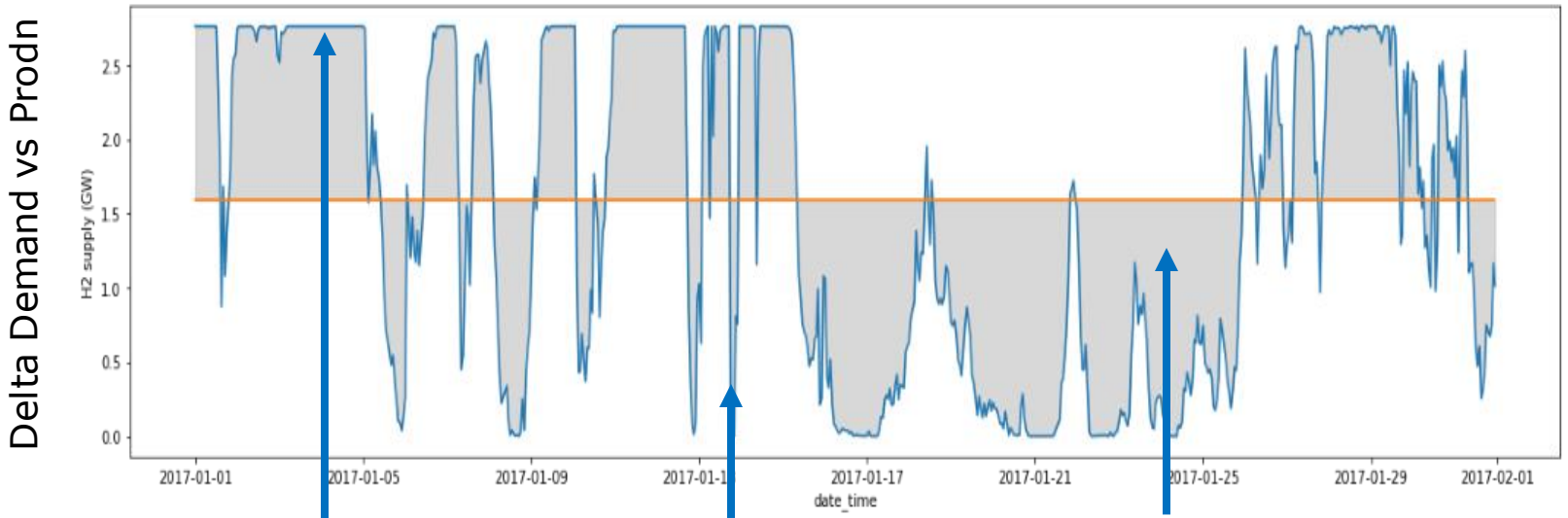
Envisaged Commercial Process – Hydrogen storage



15th October –30th November 2020

- Detailed analysis of results questionnaire defines e.g. a standard bundle (Injection and withdrawal rates and stored volume)
- Clarification discussions will be required

Assessment of Storage requires insight into composite input and offtake patterns



Peak Call-off rates

Max withdrawal rates

Max Stored Volumes

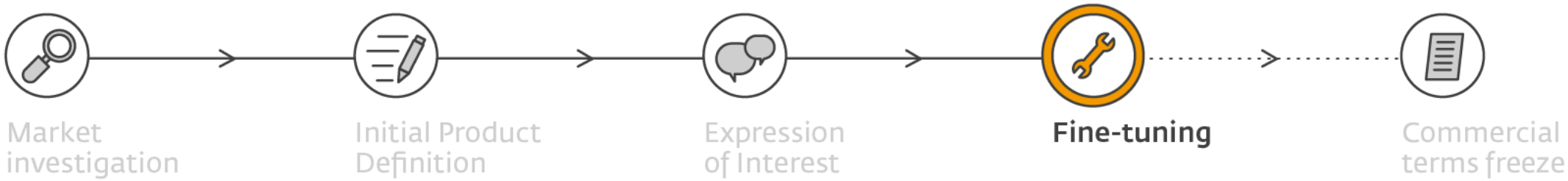
Envisaged Commercial Process – Hydrogen storage

1st December –31st January 2021

- Potential clients for Cavern #1 will receive draft term sheet & product description and are asked to indicate requirements in terms of for example number of standard bundles *
- Reciprocal commitment to execute respective define phase projects – explicitly not an FID.

* Process and timing for subsequent caverns depend on results from Market Investigation

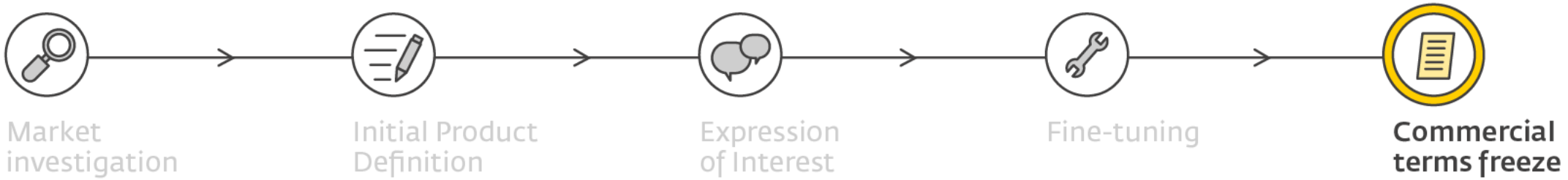
Envisaged Commercial Process – Hydrogen storage



31st January 2021 – mid 2022

- Includes both further definition of commercial terms and detailed agreement preparation
- Depends also on the development of the government's support instruments (including coverage of pre-investments/fill risk)
- This will require iteration with the market participants

Envisaged Commercial Process – Hydrogen storage



Date mid 2022

- Depends on definitive Capex estimate which is only available shortly before FID approvals process

Key aspects of questionnaire hydrogen storage 1/2

1. Company information
   - Provides essential contact details as we are moving from the ongoing dialogue and commencing a more formal commercial process
2. Project Background Information
   - What is the expected location of both the entry point and exit point of your hydrogen?
   - Why do you anticipate that you will require storage services?
3. Project Status
   - What is the intended FID and RFO date of your project(s)?
   - What is the status of your project(s)? (Feasibility/Pre-Feed/FEED)

All data will be treated confidentially and covered by an NDA which accompanies the questionnaire.

Key aspects of questionnaire hydrogen storage 2/2

4. Annual Volumes
   - Indication of the expected volume in the period 2025-2035?

5. Offtake patterns
   - If available we request an estimate of a production or offtake pattern at the highest possible level of definition (hourly, daily)
   - If a detailed profile is not available, what type of off-take/production pattern do you expect?
     - Base load with shut down (1 – 6 years)
     - Variable load with load duration factor 0,75, 0,5, less than 0,5
   - Maximum rate of entry into the transport system
   - Maximum rate of offtake from the transportation system

Allows estimation for planning purposes

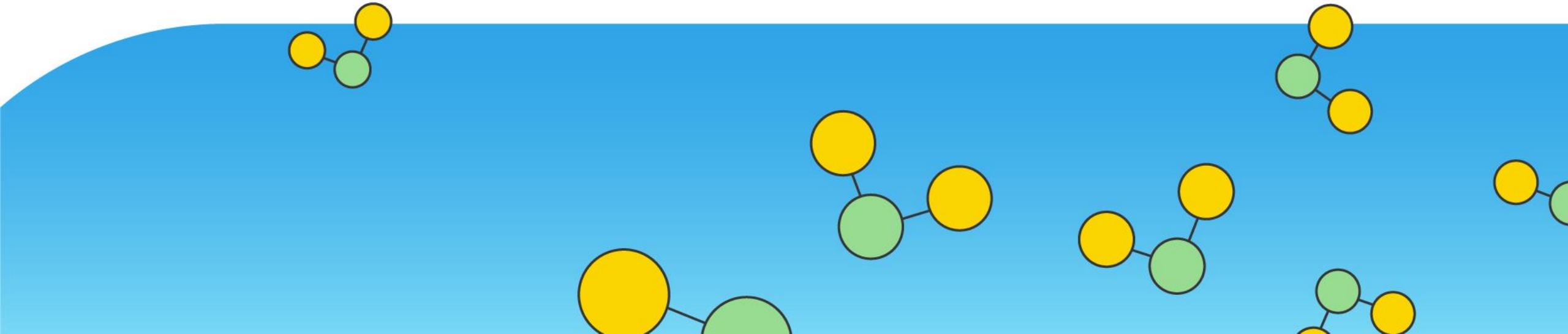
We will gather information from parties identified as producers, consumers and shippers and will cross reference the data so that we don't double count.

All data will be treated confidentially and covered by an NDA which accompanies the questionnaire.

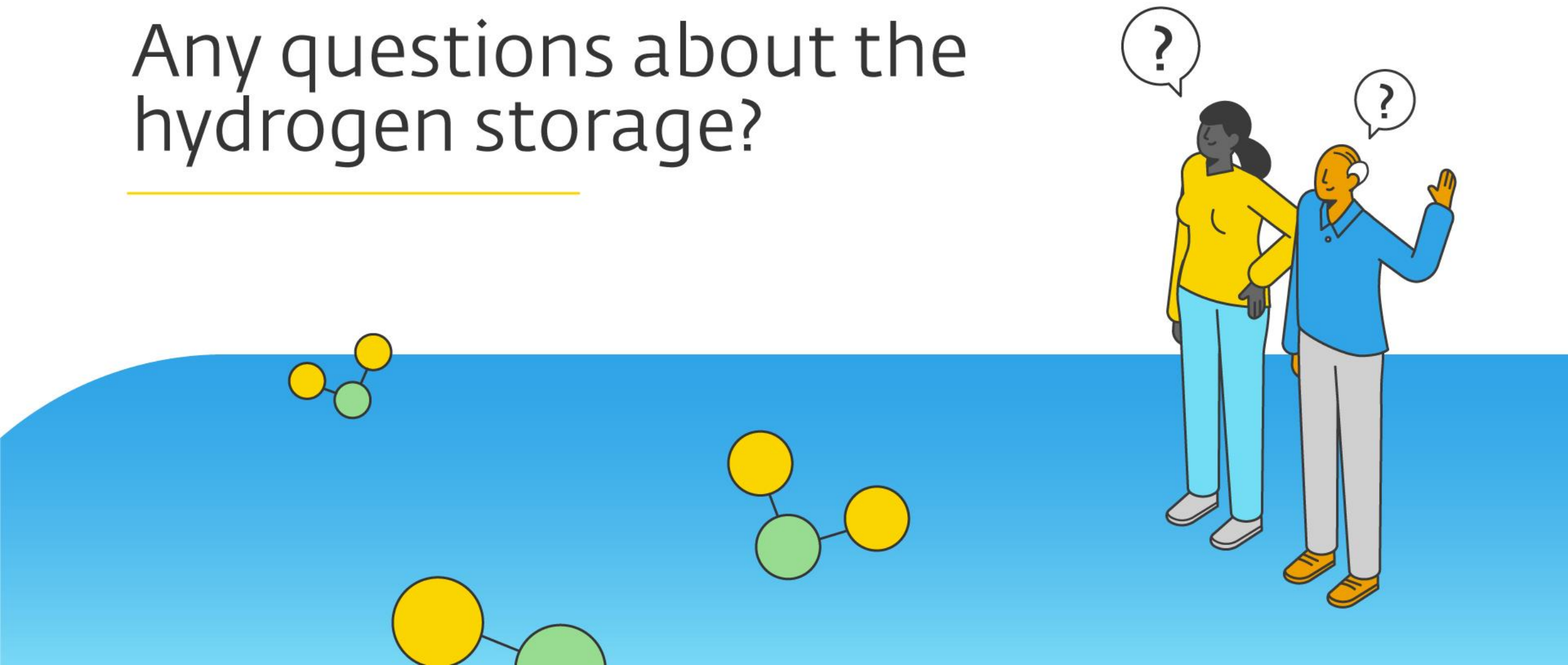
Hydrogen storage

Commercial information

Gareth Noble



Any questions about the hydrogen storage?



Webinar hydrogen infrastructure

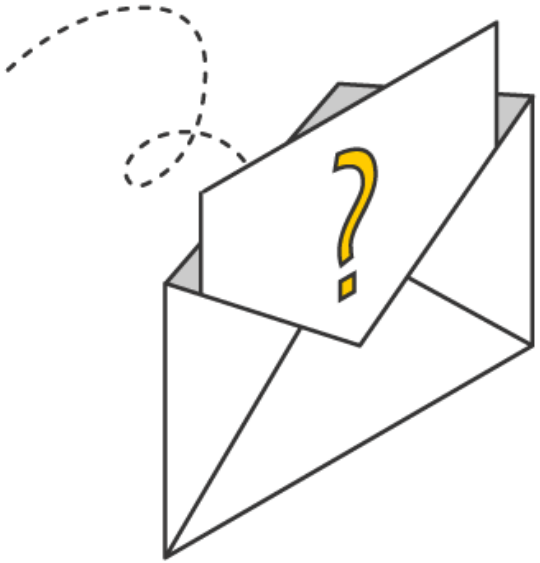
Wrap-up

Gerard van Pijkeren

Contacts for questions

Concerning Hydrogen Backbone ➡ H2backbone@gasunie.nl

Concerning Hydrogen Storage ➡ hydrogenstorage@gasunie.nl



The received data will be held confidential under the Non-Disclosure Agreements to the questionnaires.


Thanks!