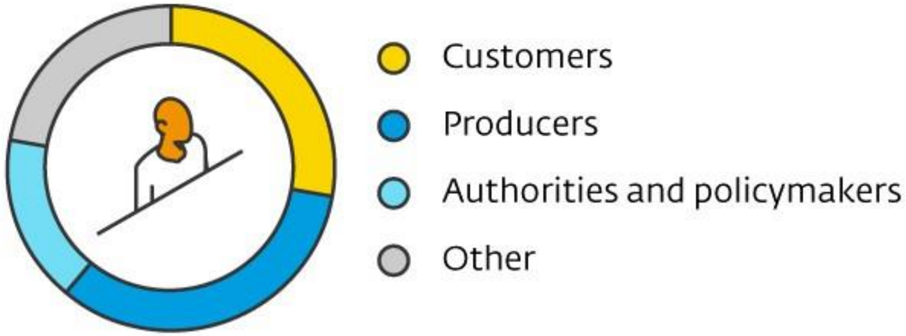
HyWay27

Audience



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

Opening 11:00 – 11:10

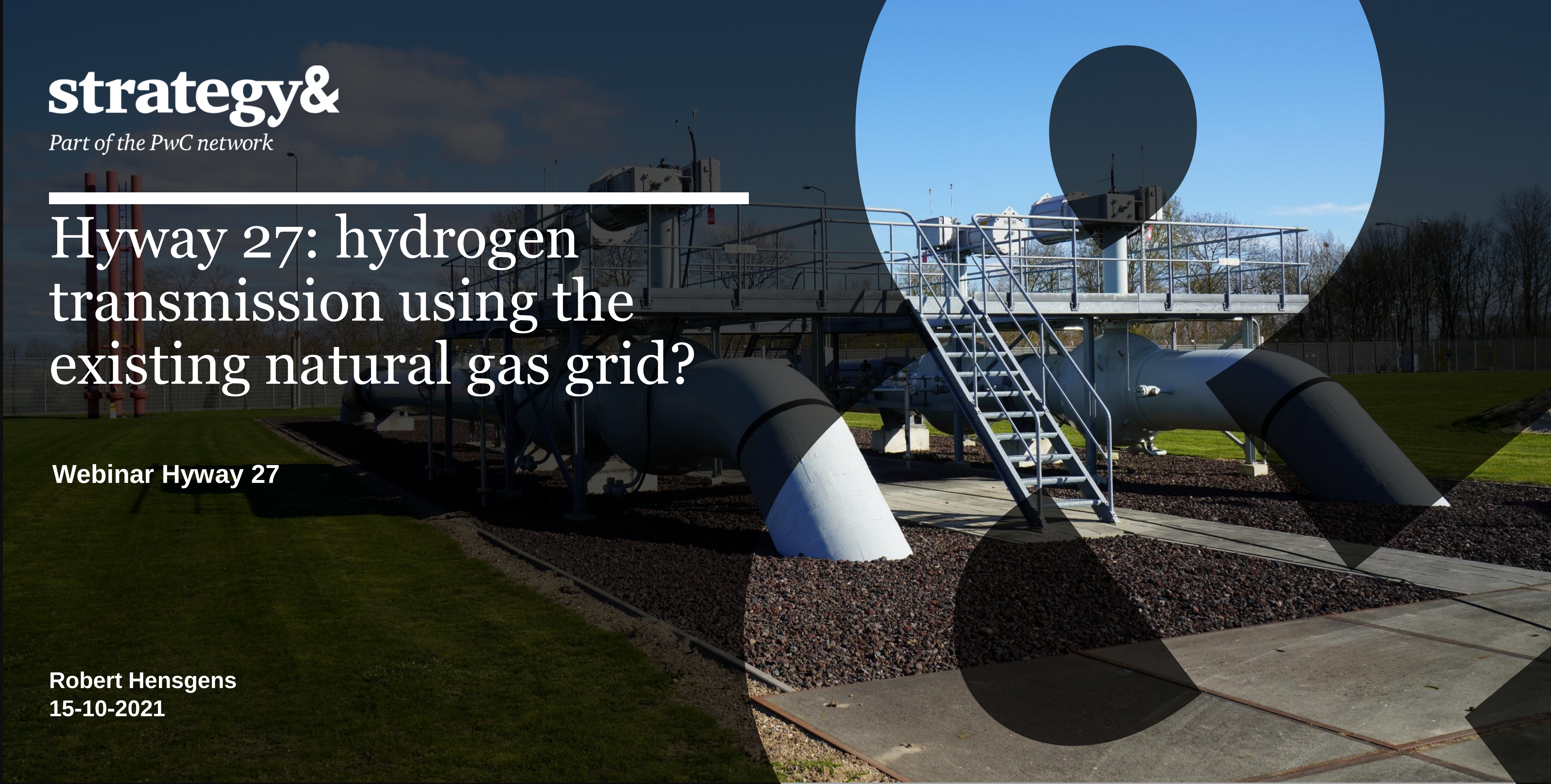
Part 1: HyWay27

11:10 – 11:35	Conclusions HyWay27	Robert Hensgens	Director PWC
11:35 – 11:50	Follow-up HyWay27	Gijs Postma	Member MT of Electricity Directorate Ministry of Economic Affairs and Climate Policy

Part 2: Market development

11:50 – 12:05	Market consultation	Janet Heida	Business Developer HNS
12:05 – 12:20	Project outlook & scope	Eddie Lycklama	Programme Manager HNS
12:20 – 12:35	Business development	Wilfred Wilting	Business Development Manager HNS

Closing 12:35 – 12:50



strategy&
Part of the PwC network

Hyway 27: hydrogen transmission using the existing natural gas grid?

Webinar Hyway 27

Robert Hensgens
15-10-2021

We investigated if, and under what conditions, the Dutch natural gas networks can be repurposed for transmission of hydrogen

Key research questions

1

Is a transmission network for hydrogen **needed**, and **if so, when**?

2

Is it possible to use the existing natural gas for hydrogen transmission, and **if so**, **would that be desirable**?

3

What **government intervention** will be required to create a transmission network for hydrogen?

Findings

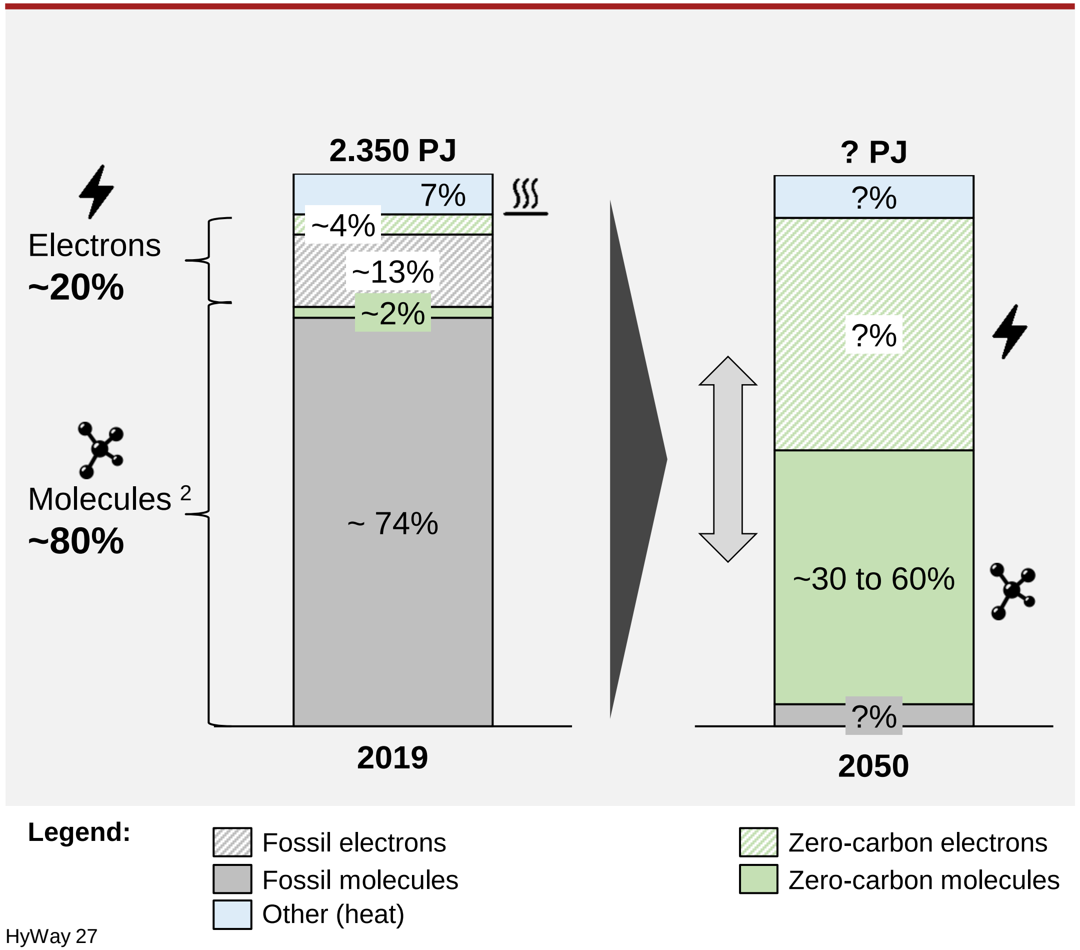
In a climate-neutral economy, pipelines for hydrogen are necessary to connect producers and users of hydrogen cost effectively. **Towards 2030** a transport network is needed to meet ambition of 3-4GW electrolysis

Existing natural gas infrastructure offers enough capacity for future hydrogen volumes and **can technically be modified**/repurposed. The **cost** per km investment is **4 times lower than new-build**

Government intervention should be aimed at financially supporting both **transport and production/usage** of hydrogen **in parallel**. Advice is to **initiate next steps** in repurposing existing natural gas grid

Hydrogen is an essential building block for a climate-neutral economy in 2050

Total energy usage in the Netherlands by end users by energy carrier and source *(as a percentage of total usage)*

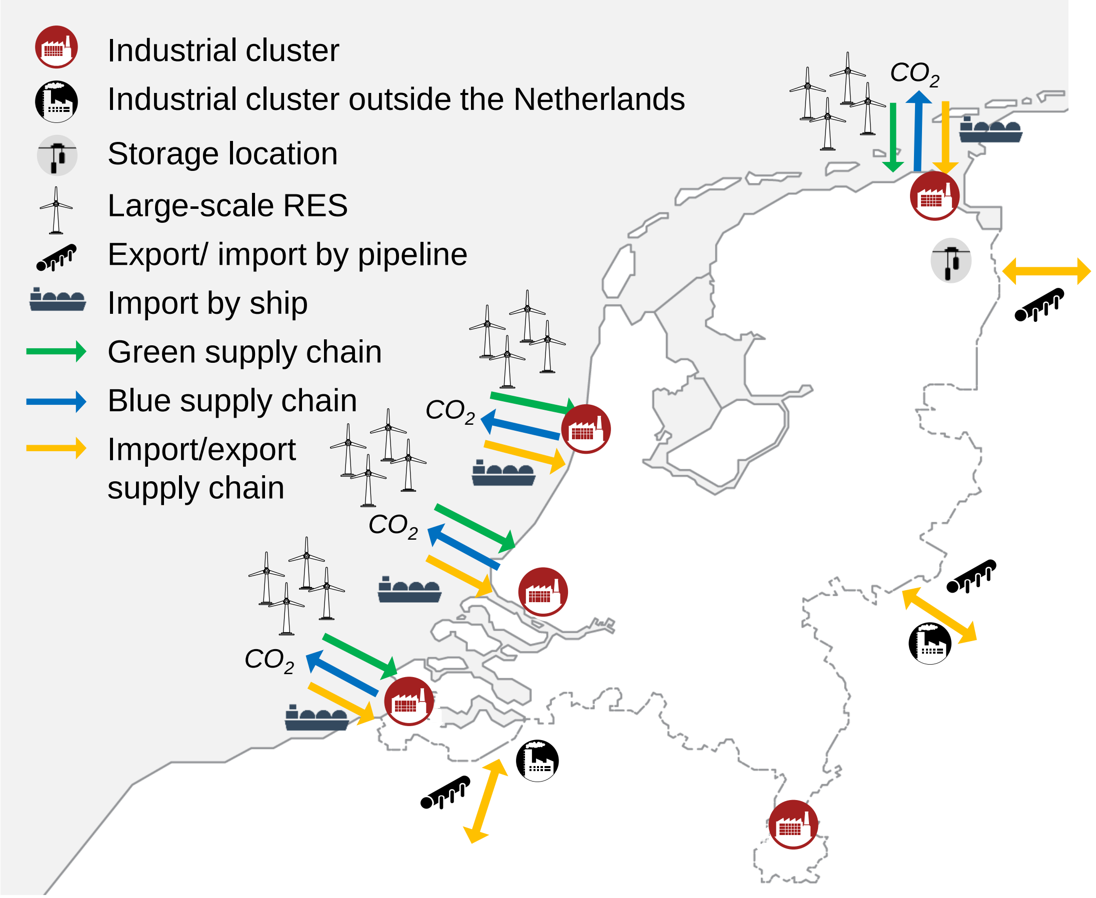


- **Molecules** currently **make up ~80%** of the energy usage and are largely fossil based
- In a climate-neutral economy, **molecules will still be needed** (estimated ~30-60% of energy usage):
  - As a fuel
  - As feedstock
  - For storage
- However, such molecules need to be carbon-free: due to its scalability **clean hydrogen is essential building bock** in addition to biofuels

For graph sources we refer to Strategy& (2021) *Hyway 27: waterstoftransport via het bestaande gasnetwerk?* Final report

A climate-neutral economy requires new transport supply routes to connect hydrogen suppliers to hydrogen users

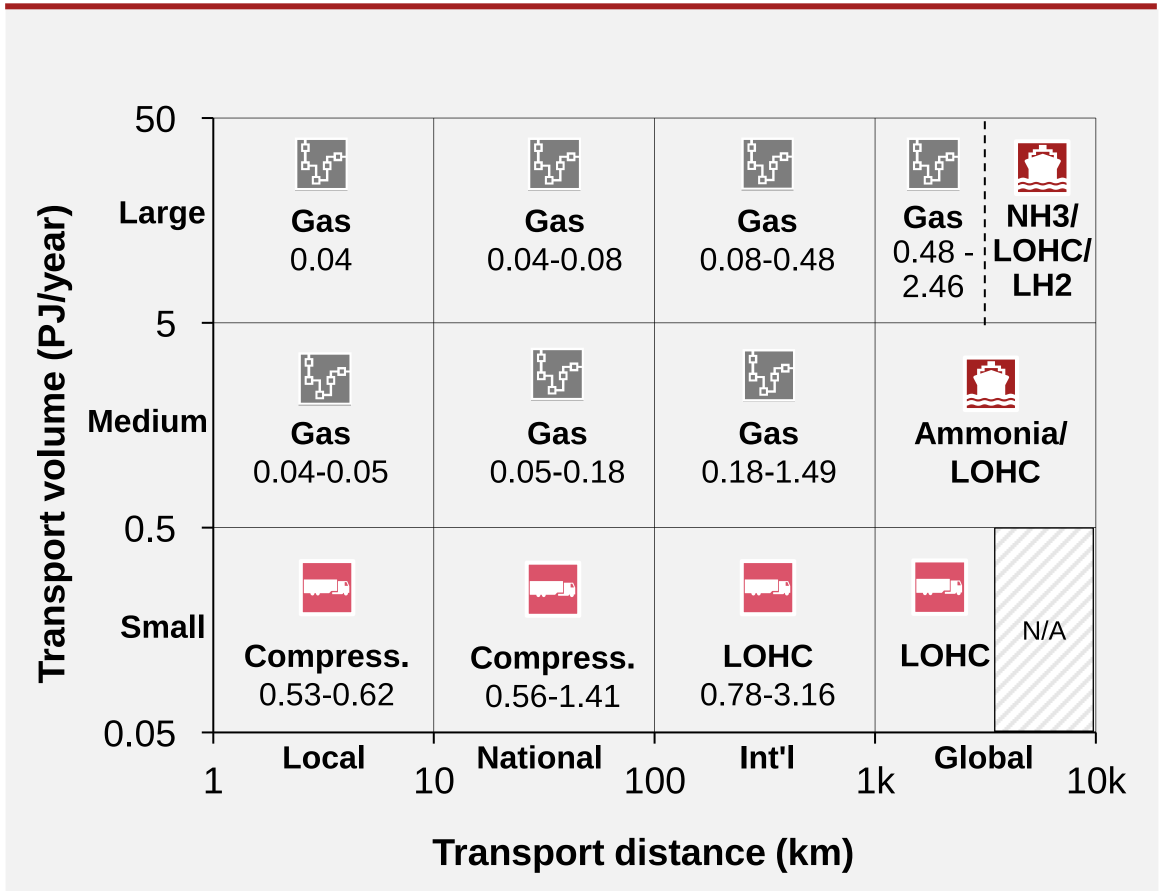
Future supply and demand clusters for hydrogen require new transport routes



- Large **demand centers in industrial clusters** in Netherlands and across the border
- Need for transport routes depends on **type of supply:**
  - Green: Connecting renewable electricity production with hydrogen users (H_2 or electron transport)
  - Blue: Connecting blue hydrogen production sites with hydrogen users and offshore wells (H_2 or CO_2 transport)
  - Import: Connecting import chains to demand users and export locations (H_2 transport)
- Furthermore, supply chains require **connection to natural storage locations** (salt caverns) to address seasonal and weather related variations

Pipelines can accommodate hydrogen demand in a cost effective way for high-volume demand

Costs of conversion and transport mode based on distance and volume *(PJ/year, km, €/kg H2)*

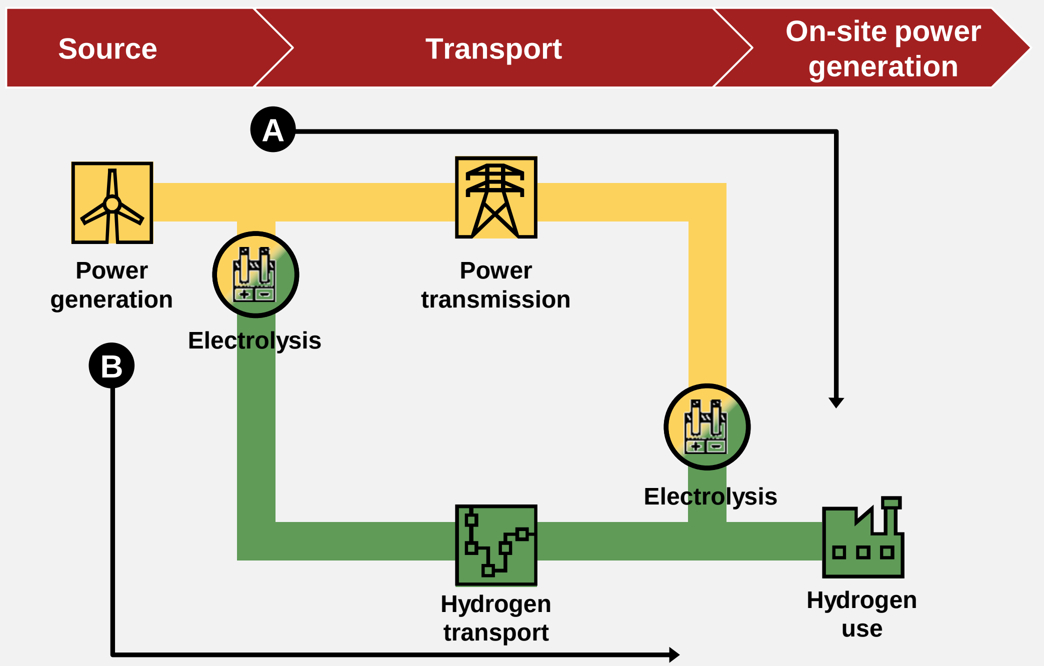


Pipeline   Tank lorry   Ship

- Various options to transport hydrogen:
  - Pipelines / lorry / ship
  - Gas / ammonia / LOHC
- What option is cost effective primarily driven by volumes and distance
- **For large volumes of hydrogen** (~>0,5PJ per year) transport by **pipeline is cost effective option**

A pipeline transmission network can help limit total transport costs in the supply chain

Electrolysis close to renewable electricity supply is more cost efficient than close to industrial usage



For hydrogen end-use applications, total cost route B are estimated x10 lower than total cost route A

- Two options for green hydrogen production:
  - Electrolysis near hydrogen user after transport of power from power generation (A)
  - Electrolysis near power generation followed by transport of hydrogen to hydrogen user (B)
- **Transporting hydrogen** to a hydrogen end user (option B) will typically be **more cost effective than transporting power** to the user (option A)
- Pipeline network enables cost efficient locational choices for electrolysis

In the short run, government's actions to support large hydrogen projects will drive where and when pipelines are needed

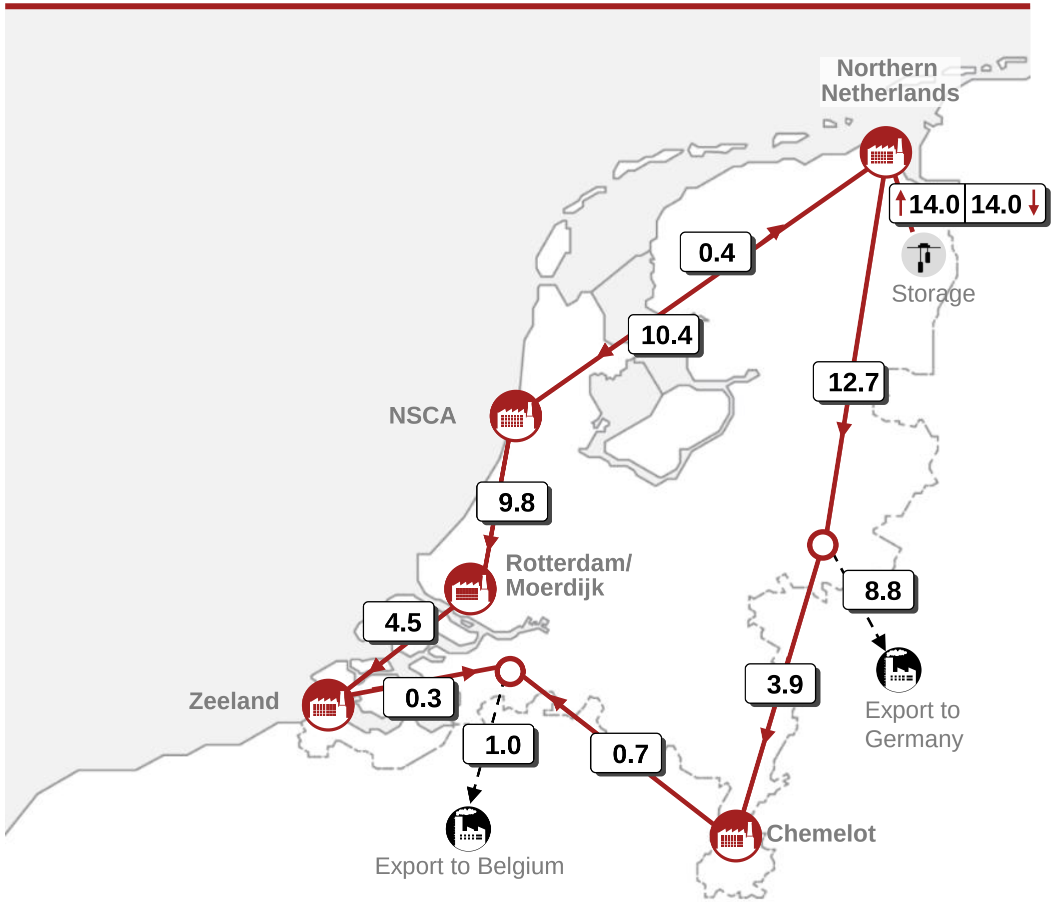
Possible roll-out path to ramp up to 3-4 GW electrolysis capacity in 2030

Year	Cumulative installed cap.	Capacity per unit	Output efficiency	Production per unit	Number of tank lorries
	MW	*MW*	*%*	*PJ per year*	*# per year*
2018	20	10	>70%	0.1-0.1	~ 700
2021	60	20	75%	0.1-0.2	~ 1,000
2023	160-200	100	75%	**0.5 -1.2**	~ 6,000
2025	500-600	250	80%	**1.4-3.2**	~ 16,000
2027	1,300-1,500	500	80%	**2.9-6.5**	~ 33,000
2030	3,500 – 4,000	1,000	>80%	**5.8-13.0**	~ 66,000

- Government's 2030 ambition is to have 3-4GW of electrolysis capacity. Meeting this ambition requires an **ambitious roll-out path** of green hydrogen projects
- In the years up to 2030, **hydrogen projects will require transport to connect producers, users and storage facilities**, driving demand for transport in the short run

Stylized model of hydrogen volumes in 2030 illustrates need for network connecting producers and industrial users in short run

Illustrative 2030 hydrogen transport volumes per route given 3-4GW ambition *(Hourly cumulative annual volume in PJ)*



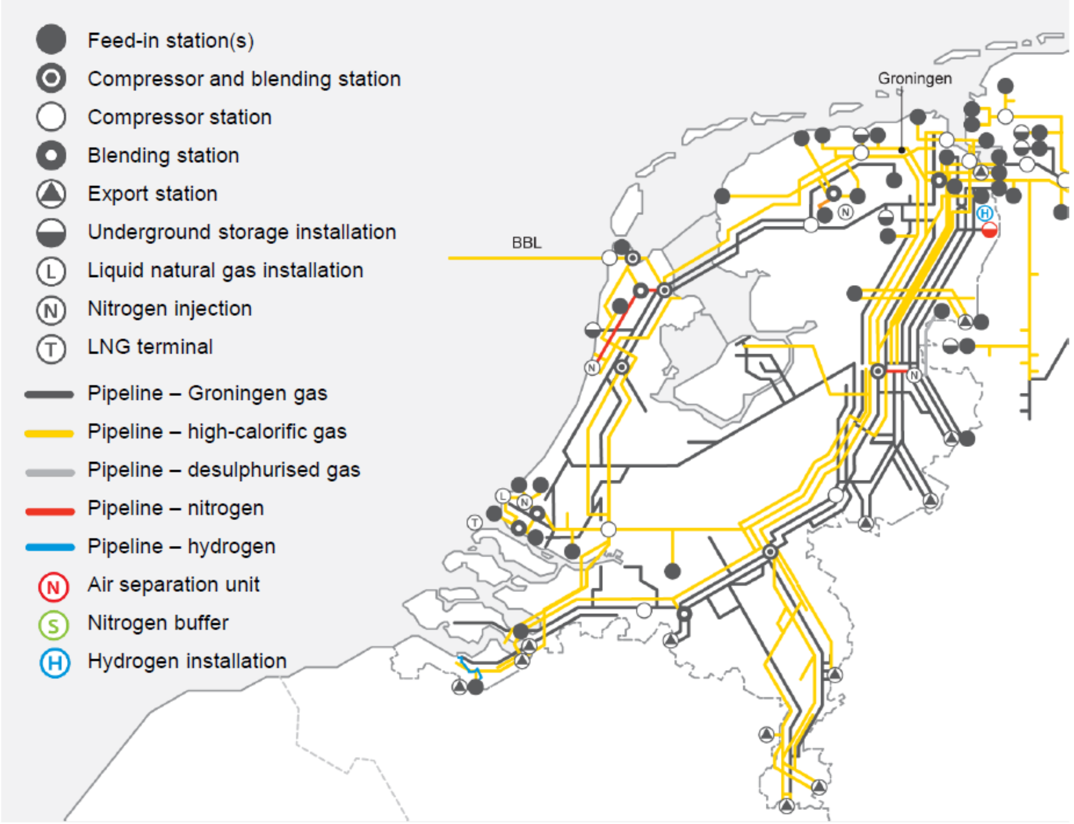
- Average transport **volume per route is 9 PJ/ year** (15 PJ/Y in climate agreement scenario)
  - ~60% of transported volume is related to regional imbalances (e.g. from coast to Germany/ Chemelot)
  - ~40% of transported volume is related to storing (or releasing) hydrogen in (/from) salt caverns
- Annual transport volumes **justify pipeline infrastructure** as cost effective connection

Assumptions

- 3.5 GW electrolysis capacity distributed according to announced projects – hourly load factors aligned with offshore wind profiles
- Geographical distribution of demand in line with existing hydrogen demand across clusters
- Scenario show left: grey hydrogen flows disregarded, no imports, no blue hydrogen production, conservative export volumes

Gasunie can free up existing natural gas transmission due to declining gas extraction and energy transition

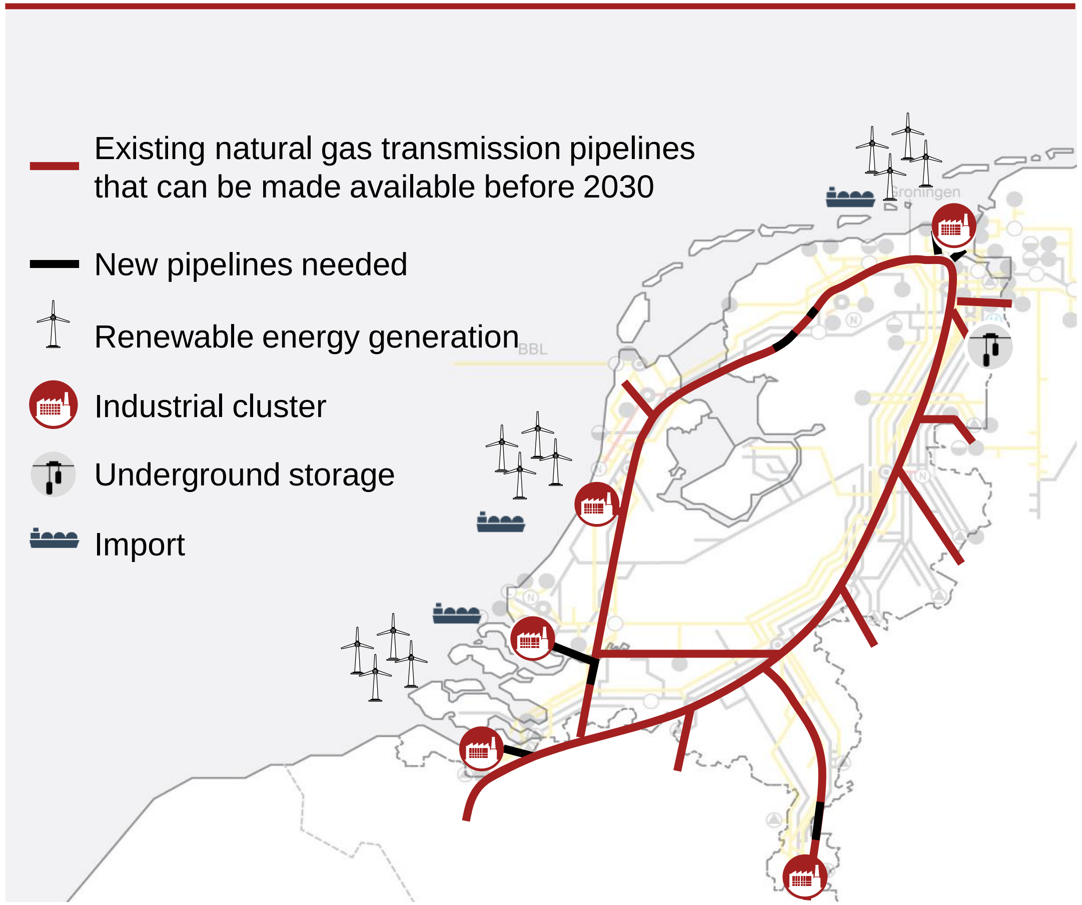
Illustration of extensive nature of Gasunie's existing gas grid



- Existing gas grid consists of two separate networks, one for high-caloric gas and one for low-caloric gas (Groningen gas), with **extensive network of parallel pipelines**
- With the phase out of Groningen gas production, demand for natural gas transmission will decrease in low-caloric gas system (incl. export routes)
- Volumes of natural gas can be re-routed such that **capacity is freed up for hydrogen**

Capacity of existing natural gas pipelines is expected to be sufficient to meet hydrogen transport needs by 2030

Gasunie can free up existing gas pipelines on routes between the five clusters and neighboring countries



- By constructing **~200km new pipeline**, possible to leverage **~1000km existing natural gas pipeline** into a ~1200km national hydrogen pipeline system connecting industrial clusters, import/expert routes and storage facilities
- The resulting capacity is future proof as it can **cover** the hydrogen **transport needs for 2030** and beyond. Illustration: average maximum capacity per pipeline is ~100PJ whereas average transport volume in 2030 is ~10PJ

To repurpose safely, changes will have to be made to existing grid and procedures

Summary of measures needed to ensure safe hydrogen transmission

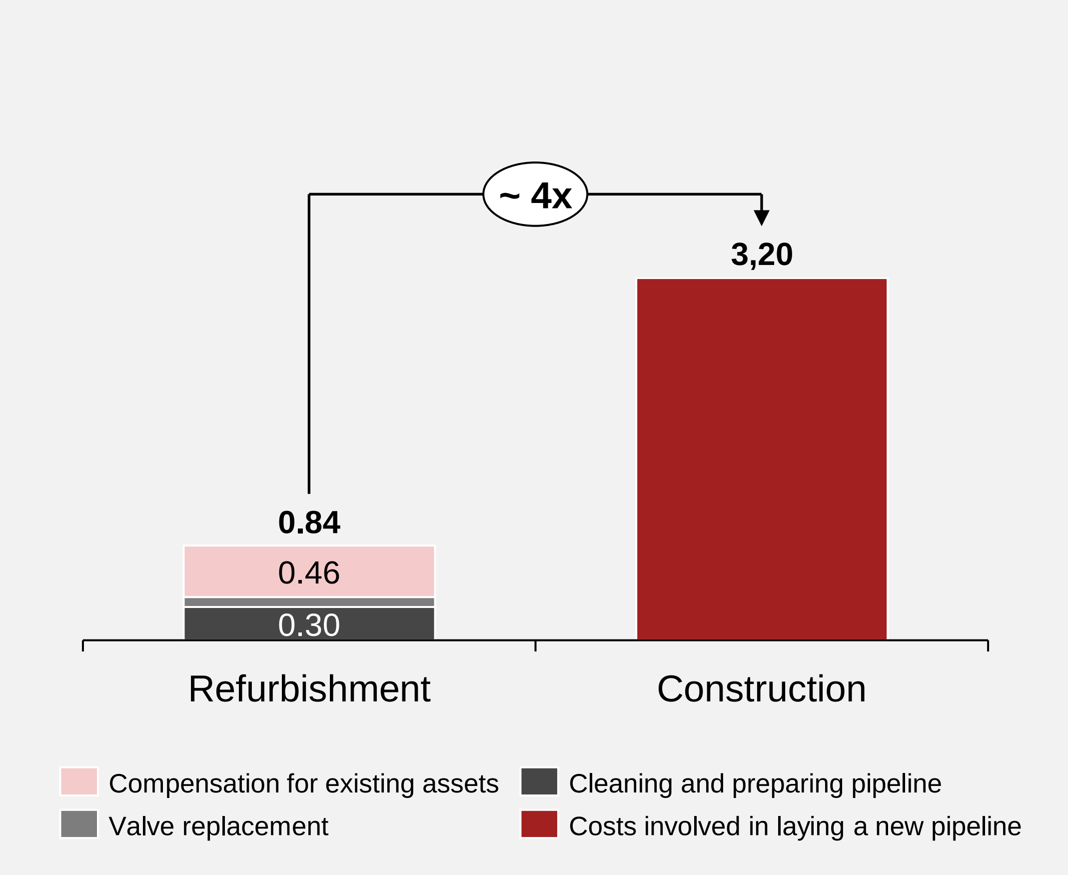
Focus point		Measure	Type
1. Leak susceptibility	1A	Replacing and/or reconditioning valves on account of possible leakage	Adjustments to existing network
	1B	Replacing other leak-prone parts (except for valves)	Adjustments to existing network
2. Contaminations	2A	Cleaning existing pipelines	Adjustments to existing network
3. Lower (energy) density	3A	Configuring or replacing metering equipment to bring it into line with flow speed and gas composition	Adjustments to existing network
	3B	Adding compressors (in the long term) on account of the incompatibility of existing compressors	Adjustments to existing network
4. Defect growth	4A	Mapping maximum operating pressures, changing operational procedures, and creating pipeline files	Adjustments to procedures
	4B	Developing and changing procedures for inline inspections	Adjustments to procedures
5. Ignition risk	5A	Training technicians to handle hydrogen	Adjustments to procedures
	5B	Changing pipeline modification procedures	Adjustments to procedures
	5C	Procuring safe electronic metering equipment for management and maintenance	Adjustments to procedures

= Adjustments to existing network *= Adjustments to procedures*

- Natural gas and hydrogen have **different physical properties**
- Using existing natural gas pipelines for hydrogen transport **requires modifications**, after which transport is safely possible**:**
  - To the existing network (e.g. replace valves, clean pipelines)
  - To the existing procedures (e.g. maintenance, training)
- **Replacing valves** and **cleaning the pipelines** are key capital expenditures driving the costs of modification

Pipelines can be repurposed with relatively little modification costs – per-km investment is four times lower than new-build

Comparison of per-km investment required for reuse and new-build *(millions of € per km, based on 36-inch pipeline)*



- Investments for refurbishing of existing grid is expected to be **~4 times lower than new built** of similar capacity
- Cost off refurbishment consists of:
  - ~55% is compensation for taking over existing assets from GTS, at regulated asset value (GAV)
  - ~45% is actual modification costs, i.e. cleaning and preparation of the pipelines, also depending on the desired purity of hydrogen
  - Gasunie assumes opex for refurbishment the same as for new build (1% of investment value)
- In order to connect all industrial demand centers, main export routes and gas storage fields in 2030, Gasunie estimates **total capex** to be **~€1,5 billion**

Government intervention should be aimed at both hydrogen production/usage and transport

Financial support is needed at several points of the green hydrogen chain

	Production/usage	Transport
Challenges	Production costs for zero-carbon hydrogen are greater than for fossil alternatives	Slow uptake of full network capacity with large measure of uncertainty
Required government interventions	1 Financial support for gradual scaling up of production/utilisation	2 Financial support for a long-term dimensioned transmission network

Coordinated simultaneous support for production/utilisation and transmission that, independently, have different paths or timelines

- Across the value chain, hydrogen investments currently **lack a financially viable business case**:
  - Production/usage: costs of low carbon hydrogen still higher than fossil alternative
  - Transport: transport demand will arises very gradually, but transport is needed now
- **Financial support is needed for both production/usage and transport**, in a coordinated way:
  - Production/usage without transport infrastructure = not possible
  - Transport infrastructure without production/usage = inefficient or redundant network

Advice is to decide in principle to use part of the existing natural gas networks for the transmission of hydrogen

Report recommendations

1. Decide in principle to **reuse existing natural gas network** for hydrogen transport
2. Decide **where and when to roll out** the network ('what')
3. Define the required **market regulation** for transmission ('who')
4. Make a plan to kick-start the **integrated supply chain** ('how' and 'how much')

- HyWay 27's conclusions **justify a decision in principle to re-purpose** parts of the existing natural gas networks for hydrogen transmission
- Further decision making needs to be initiated:
  - Where and when will network be rolled out?
  - Who will roll-out the network?
  - How will hydrogen supply chain be kick-started?
- To achieve the hydrogen ambitions for 2030 (i.e. 3-4GW of electrolysis capacity), it is **necessary to initiate next steps** now

Ministerie van Economische Zaken en Klimaat

Development of a hydrogen backbone

Gijs Postma

Electricity Directorate

Ministry of Economic Affairs and Climate Policy

Hyway27 letter to Parliament

1. Principle decision

2. Network development plan

3. Regulations

Network development plan

- Aims
  - Clarity on where and when the network will be developed;
  - Balance between clarity and posibility to incorporate new insights and developments.
- Criteria
  - Development of supply and demand
  - System perspective
  - Positioning Netherlands as hydrogen hub

Regulations

- Gasunie is asked to develop the backbone. Arguments:
  - Grid being a natural monopoly, risk of abuse of market power
  - Secure public interests
  - Evolution to vital infrastructure, involvement needed state as shareholder
  - Gasunie experienced in management of gasgrids

Expression of interest

From letter to Parliament: "Gasunie kan al snel starten met de voorbereidingen voor de ontwikkeling van het transportnet, zoals het nader in kaart brengen van vraag en aanbod en het commitment bij de vraagkant ophalen en verder door suggesties te leveren voor een fasering van de uitrol van het waterstofnet."

Timing

- Network development plan: first half 2022

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RESULTS QUESTIONNIARE

Janet Heida

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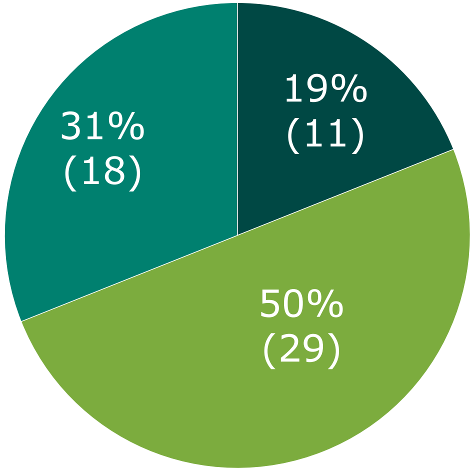
The questionnaire has 58 respondents, of which the majority are (future) hydrogen users

With regard to hydrogen, would you describe your company (now or in future) as a:

n=58

Producer & user

Industries:
- Storage
- Import
- Port operator
- Trading
- Chemicals
- Refineries
- Steel
- Oil & gas



Producer

Industries:
- Offshore wind
- Offshore gas transport
- Power
- Energy

User

Industries:
- Steel
- Glass
- Aluminum
- Manufacturing
- Food
- Chemicals
- Paper

Source: HNS questionnaire hydrogen infrastructure responses; Monitor Deloitte analysis

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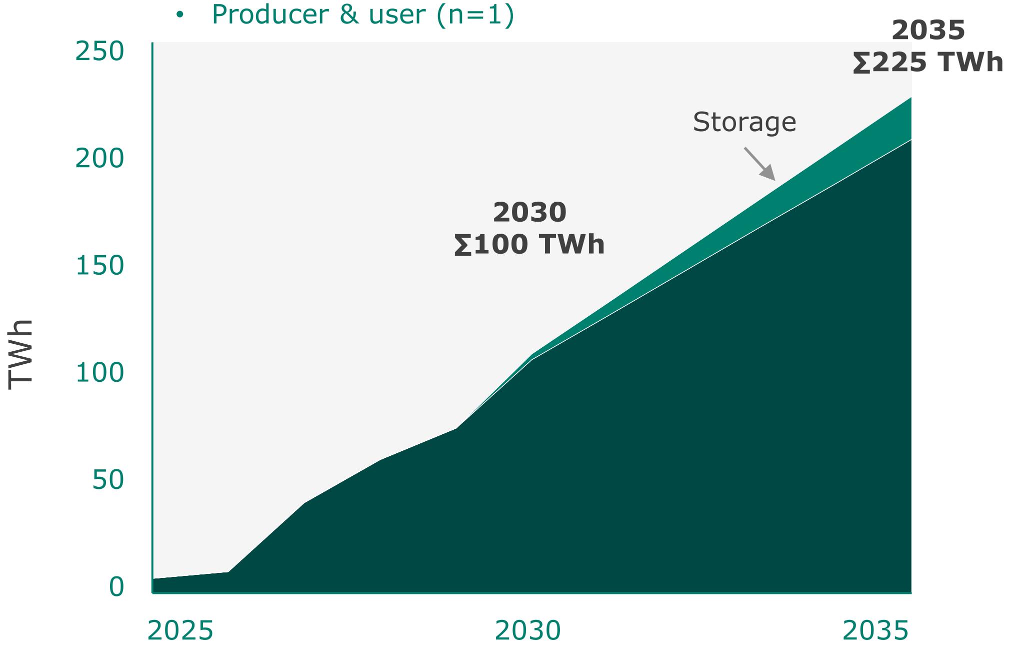
National Results

In 2030, producers expect to produce and transport roughly 100 TWh hydrogen, users expect to use roughly 20 TWh; in 2035 this increases to 225 and 80 TWh

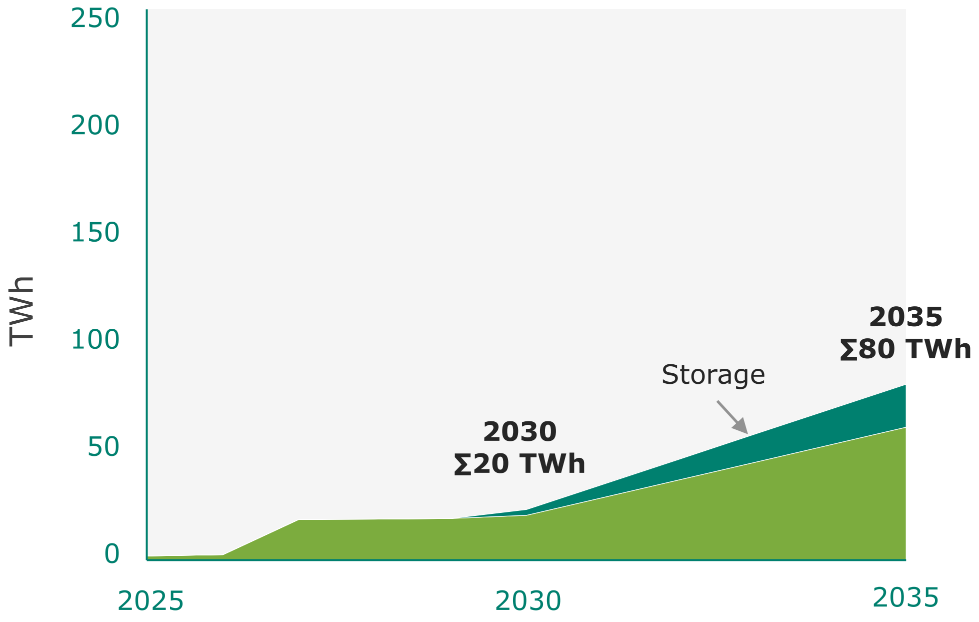
Can you give a (non-binding) indication of the volume you expect to transport in the period 2026-2035?

n=43

Supply:
- Producer (n=19)
- Producer & user (n=1)



Demand:
- User (n=23)
- Producer & user (n=1)



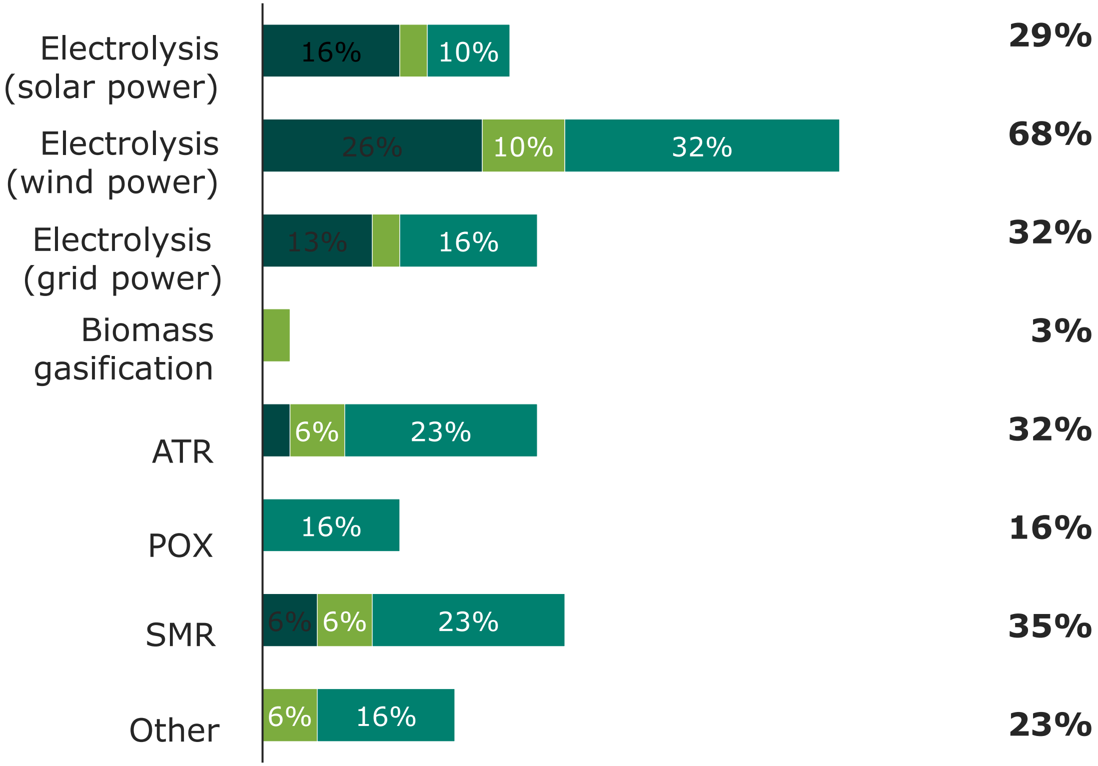
Note: Respondents in 'producer & user' segment have been manually assigned to 'producer' or 'user' for this questions based on their hydrogen plans, to avoid double counting of volumes; Producer includes import

Source: HNS questionnaire hydrogen infrastructure responses; Monitor Deloitte analysis

Heating, direct and indirect, is the most-mentioned use for hydrogen; electrolysis with electricity from offshore wind is the most-mentioned production method

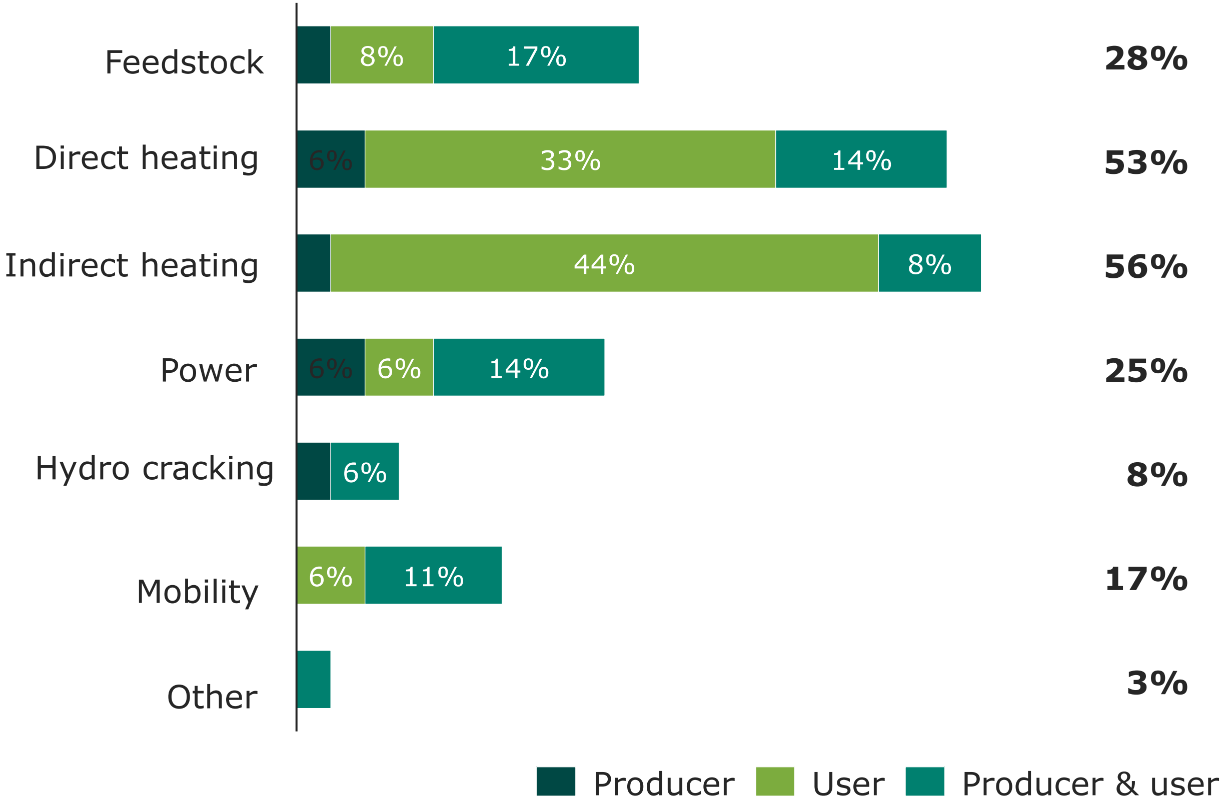
Can you describe how you plan to produce hydrogen?

n=31, multiple answers possible



Can you describe hydrogen's role in your process(es)?

n=36, multiple answers possible



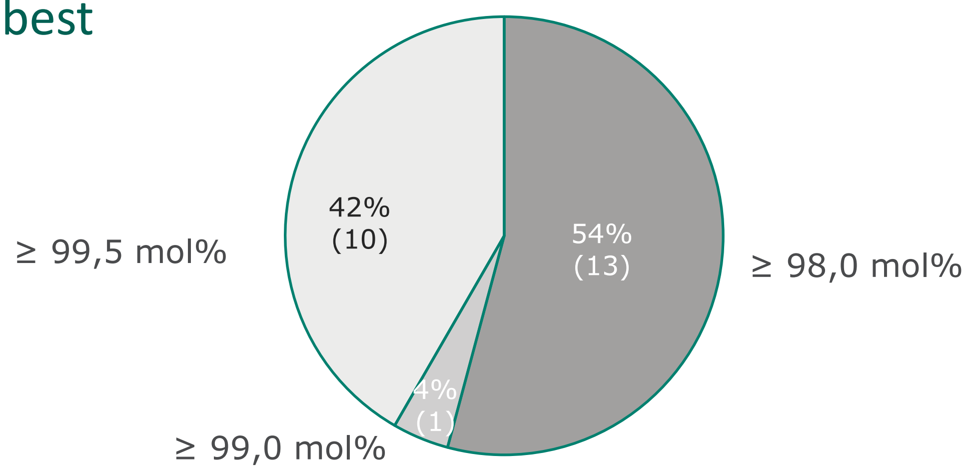
Source: HNS questionnaire hydrogen infrastructure responses; Monitor Deloitte analysis

National Results

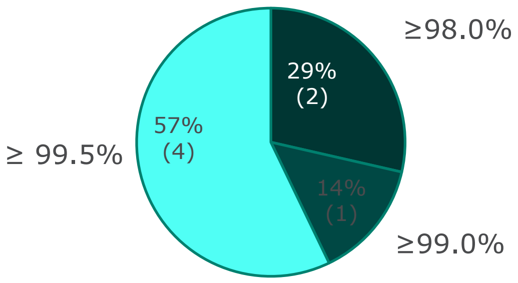
Producers see the highest quality specification as best suited for their process, users the lowest

Which of quality specifications is suited for your process?

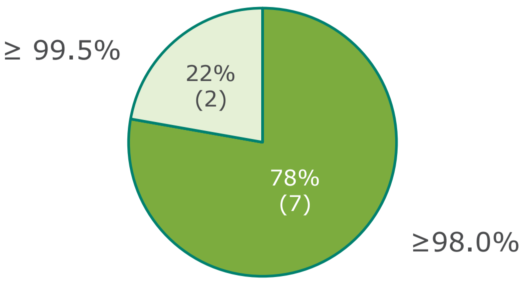
n=24



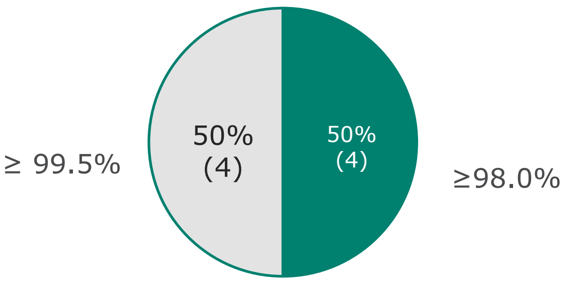
Producer



User



Producer & user



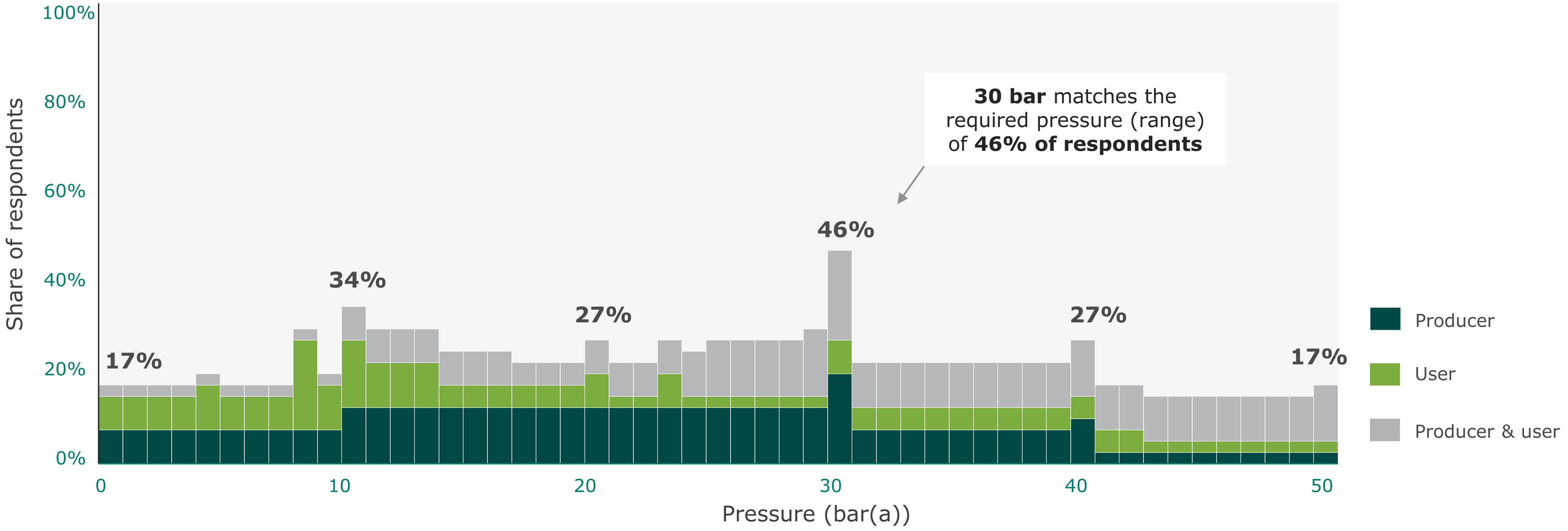
Source: **HNS** questionnaire hydrogen infrastructure responses; Monitor Deloitte analysis

National Results

Based on the submissions a 30 bar(a) delivery pressure will meet the requirements of the majority of users whilst maintaining an accessible entry pressure for the producers.

- What are the required delivery/feed-in pressures?

n=39



Source: HNS questionnaire hydrogen infrastructure responses; Monitor Deloitte analysis

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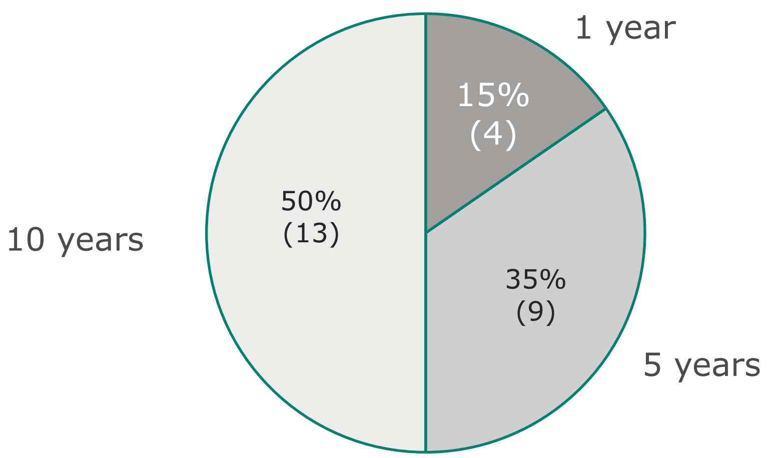
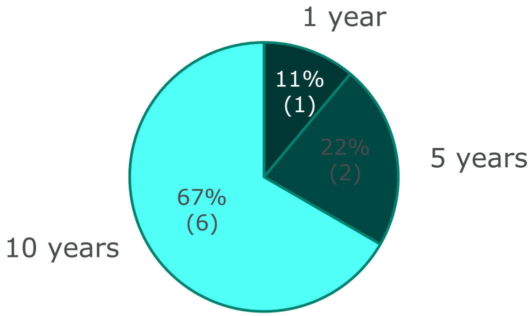
National Results

Most producers prefer 10 years contract term, users 5 years

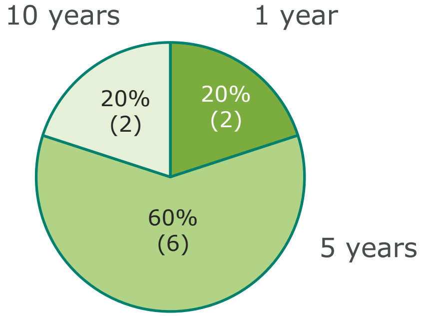
What would be your preferred contract term?
n=26



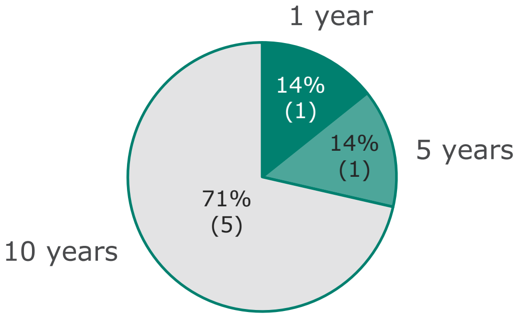
Producer



User



Producer & user



Source: HNS questionnaire hydrogen infrastructure responses; Monitor Deloitte analysis

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PROJECT OUTLOOK & SCOPE

Eddie Lycklama à Nijeholt

HYNETWORK
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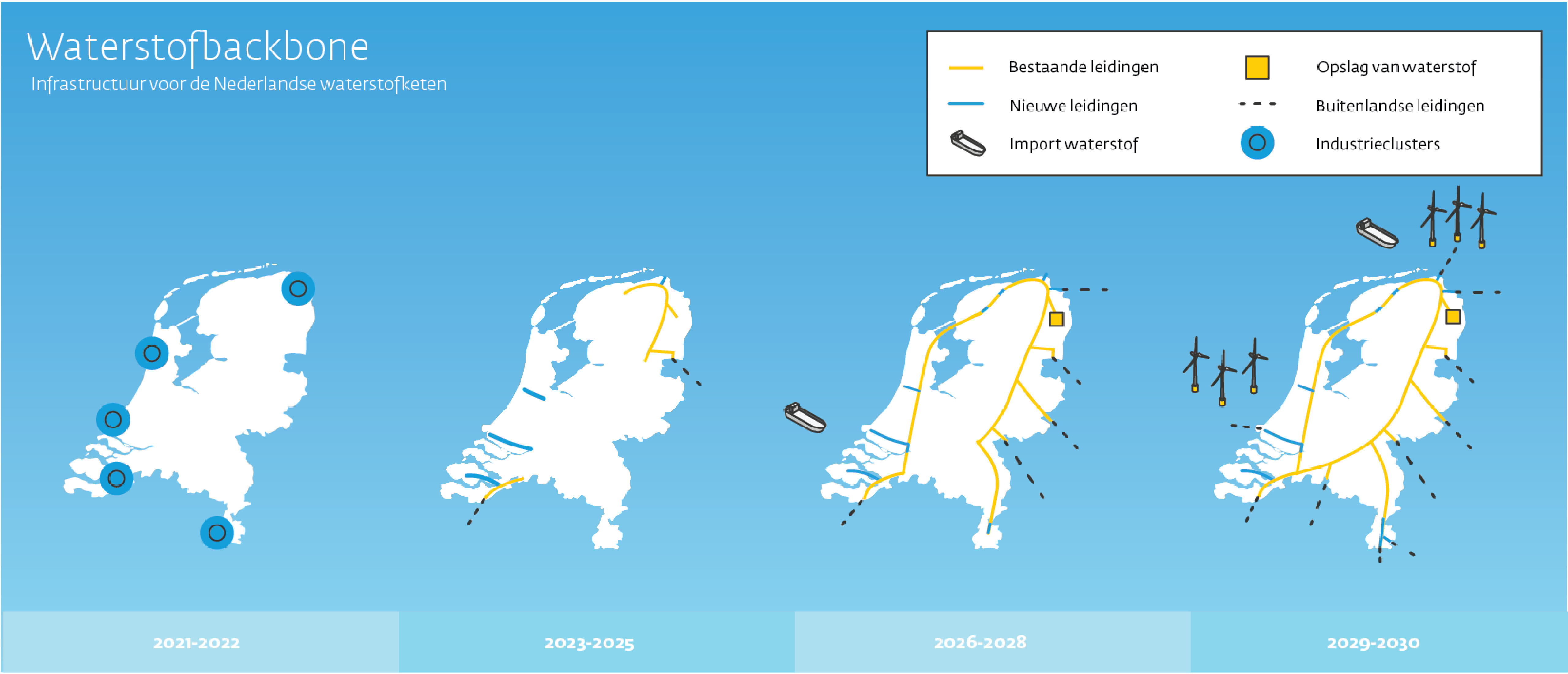

System pressure regime

As part of the consultation HyNetwork Services has interviewed potential producers as well as industrial users. Aiming for optimum specifications for the hydrogen backbone, suiting most connected parties.

For the time being we assume a bandwidth of 50 bar entry and 30 bar exit

Weighing pro’s and con’s of high versus low pressure:

- Minimizing entry production compression (H_2 pressure not for free)
- But taking a higher pressure bandwidth to maximise available capacity to clients
- For international transport, a reasonable entry pressure is required at the border
- Several industrial users (feedstock, turbine) require a minimum delivery pressure
- Finally, serving the system as a whole (balancing, storage), a higher pressure is desirable
- We will investigate local optimisations with clients during coming dialogue phase

Indicative hydrogen quality specification

As part of the consultation HyNetwork Services has interviewed potential producers as well as industrial users. Aiming for optimum specifications for the hydrogen backbone, suiting most connected parties.

For the national backbone a hydrogen purity >= 98% maximises the access for clients

- 98% is likely to become the international standard (UK, GE, BE, CEN, EASEE-gas)
- For blue hydrogen production 98,0% purity is doable
- For future industrial hydrogen users 98,0% purity seems widely acceptable

On a regional level the specification can deviate from the national backbone requirements

- We will investigate local optimisations with clients during coming dialogue phase

For feedstock we foresee strict requirements regarding impurities O_2, CO, CO_2, S, metals

- For handling impurities local cleaning measures can be required and installed

The mobility market demands a very high purity $H_2 \geq 99{,}97\%$

- This market is considered minor in volume the first decade, other supply means are in place to cover these volumes

The 98%+ standard allows HyNetwork Services to accommodate different H_2 "colours and qualities"

- Next step is to design an efficient quality management system that suits suppliers and users
- Considering in time increasing production of green H_2, adaptation to higher grade can be expected

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INVITATION TO EXPRESSION OF INTEREST

Wilfred Wilting

HYNETWORK
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The business development process

Project Process steps

Initiation	Assessment/ Feasibility	Plan/ Concept-select	Project: Develop Business Case	Project: Investment Proposal	

BD Milestones

1. Initial Market Consultation
2. Feedback and kick-off EoI
3. Signed EoI & NDA
4. Signed TA, CA & JDA "Conditional"
5. TA & JDA "Binding"

Activities

Initiation:
- Project definition
- Assessment potential clients
- Docs/materials Market consultation

Assessment/ Feasibility:
- Initial product definition
- Draft "Term Sheet"
- Draft "EoI + NDA"
- Presentation (webinar):
  - Results market consultation
  - Termsheet EoI & NDA
- Publication (website):
  - Results market consultation
  - Termsheet EoI & NDA

Project:
- Development detailed Joint Dev't Agreement (JDA)
- Development detailed Transport Agrmt. (TA)
- Development detailed Connection Agrmt (CA)
- Development additional services (balancing, purification etc.)

Multilateral and 1-2-1 dialogue with potential shippers

Final subsidy applications GU & clients

We invite Expressions of Interest in the following service

Indicative starting Date (RFO)
- Rib North Q2 2025
- Rib Rotterdam 2024
- Rib Amsterdam 2026
- Rib Zeeland 2026
- Rib Limburg

Entry Conditions
- Maximum 50 bar (a) operational min. 30 bar(a)
- Purity minimum 98% H_2 + additional impurity specs

Delivery conditions
- Minimum 30 bar (a) (operational max. 50 bar(a)
- Quality equal to minimum entry quality

Services considered to be included in tariff
- Transport from client's nominated entry point and delivery to clients' nominated delivery point
- Management of system balance

Mandatory services subject to additional cost/fee
- Connection
- Correction of imbalance

Additional optional services (subject of separate cost plus based fee) to be developed during dialogue
- Linepack Flexibility Service
- Purification
- Compression

Your Expression of Interest will contain the following information:

Annual Expected (Non-binding) Volume to be transported
Peak capacity required in transport system
Operating hours per annum
Maintenance schedule
Description of daily usage profile
Description of annual usage profile
Expected entry and exit point
Desired purity/purities
Non-desired impurities
Required pressure at entry and/or exit point pressure grid
Subsidies to be applied for
Tentative planning of production project or of energy demand / feedstock project

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Summary

- There remains substantial market uncertainty but some 50+ parties have shown early interest.
- We have perspective for a viable network with a market potential exceeding 10GW.
- We invite shippers to identify themselves as potential launching customers to participate in the next phase of project refinement.
- Completed Expression of Interest can be sent to info@hynetwork.nl

Closing

Next steps

Constituents	Unit	Minimum	Maximum
Hydrogen (H_2)	mol/mol	98 %	
Total sum of hydrocarbons including CH_4 (C_XH_Y)	mol/mol		1,5 %
Oxygen (O_2)	µmol/mol (ppm)		10
Total sum of inerts (N_2, He, Ar)	mol/mol		2,0 %
Carbon dioxide (CO_2)	µmol/mol (ppm)		20
Carbon monoxide (CO)	µmol/mol (ppm)		20
Total sulphur including H_2S (S)	µmol/mol (ppm)		5
Formic acid (CH_3OOH)	µmol/mol (ppm)		10
Formaldehyde (CH_2O)	µmol/mol (ppm)		10
Ammonia (NH_3)	µmol/mol (ppm)		10
Halogenated compounds	µmol/mol (ppm)		0,05
Water dewpoint (H_2O)	ºC @ 70 bara		-8
All other impurities	Shall not contain solid, liquid or gaseous material that might interfere with the integrity or operation of pipes or any gas appliance		

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