strategy&
Part of the PwC network

Establishing low carbon hydrogen infrastructure

Extracts from HyWay27 project

World Hydrogen Energy Summit 2021
16-11-2021

The question of developing a hydrogen infrastructure is relevant for multiple countries, we worked it out for The Netherlands

Context of the presentation

Today we provide inside in the following challenges

1. 

How to determine **if there is a need** for a hydrogen transport infrastructure, and if so, **when and where it is required**?

2. 

Is it possible to **reuse existing natural gas infrastructure?**

3. 

What are the **barriers** for realizing a hydrogen infrastructure, and which **government interventions** could overcome those barriers?

Findings for The Netherlands

Increasing **uptake for low-carbon hydrogen** will **require transport infrastructure –** when and where depends on large-scale projects

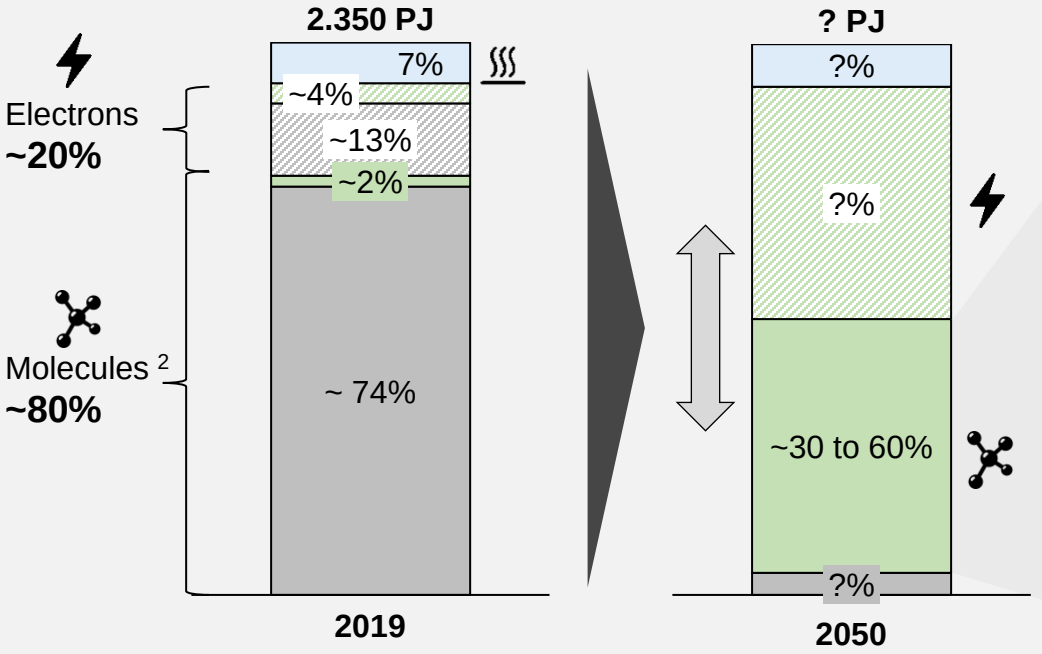
At relatively low cost, existing **gas infrastructure can be modified** for safe transport of hydrogen – **per km investment is 4 times lower than new-build**

The government should decide in principle to **start reusing the existing grid** – in parallel innervations are required to **drive development of both supply and demand**

Hydrogen is an essential building block for a climate-neutral economy in 2050 – studies estimate the demand will increase

It is expected that 30 to 60% of the total energy demand in 2050 will consist of CO_2-free molecules

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

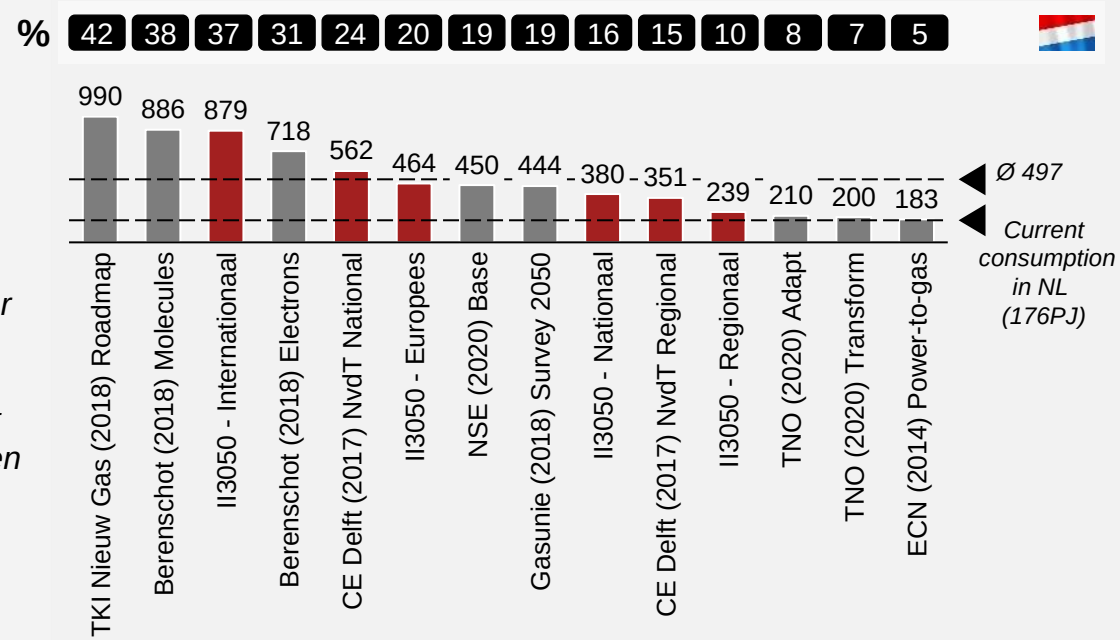


Legend:
- Fossil electrons
- Fossil molecules
- Other (heat)
- Zero-carbon electrons
- Zero-carbon molecules

Demand for CO_2-free molecules largely met by hydrogen

Scenario studies confirm need for hydrogen, but expected quantity varies

Scenario forecasts for Dutch hydrogen demand in 2050 *Excluding hydrogen for synthetic fuels (in PJ)*

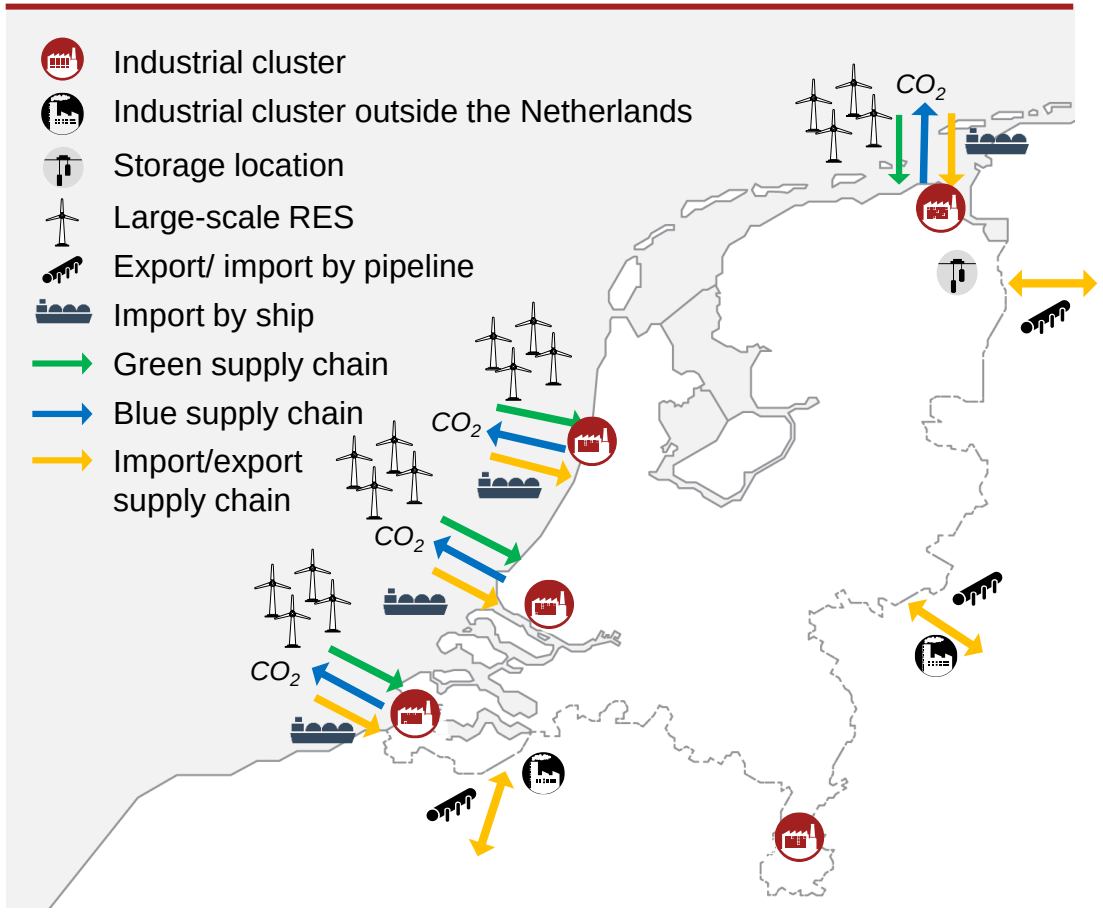


- Not climate-neutral
- Climate neutral
- % Zero-carbon hydrogen demand as a percentage of the current final energy usage in NL (2351PJ)

Sources: CBS (2020), TNO (2020), Strategy& analysis

The uptake of low-carbon hydrogen requires new transport routes to connect production, demand, and storage

Future supply and demand clusters for hydrogen require new transport routes

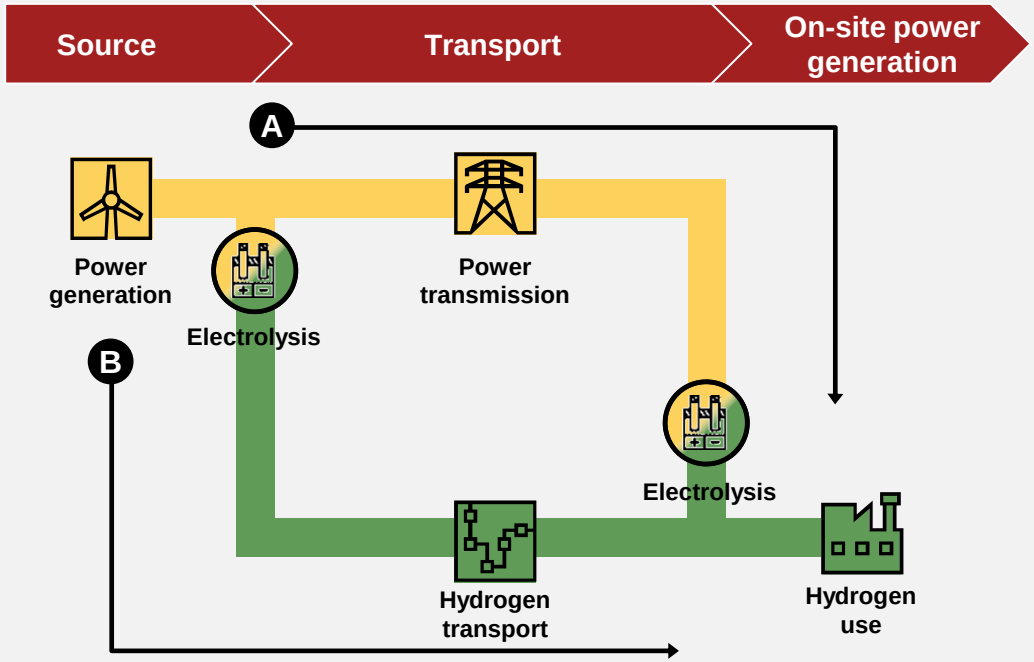


- **Hydrogen demand until 2030 is predominantly located within the 5 industrial clusters** – further demand centers located in Germany and Belgium
- **New transport routes depend on the development of the different hydrogen supply chains:**
  - **Green:** Connecting renewable electricity production with hydrogen demand centers (**H_2 or electron transport**)
  - **Blue:** Connecting blue hydrogen production sites to offshore wells (**CO_2 transport**)
  - **Import:** Connecting import chains to demand centers and export locations (**H_2 transport**)
- Furthermore, all supply chains require **connection to natural storage locations** (salt caverns) to address seasonal and weather related variations

Source: Strategy& analysis

Green hydrogen should mostly be produced close to renewable power generation and is then typically transported by pipelines

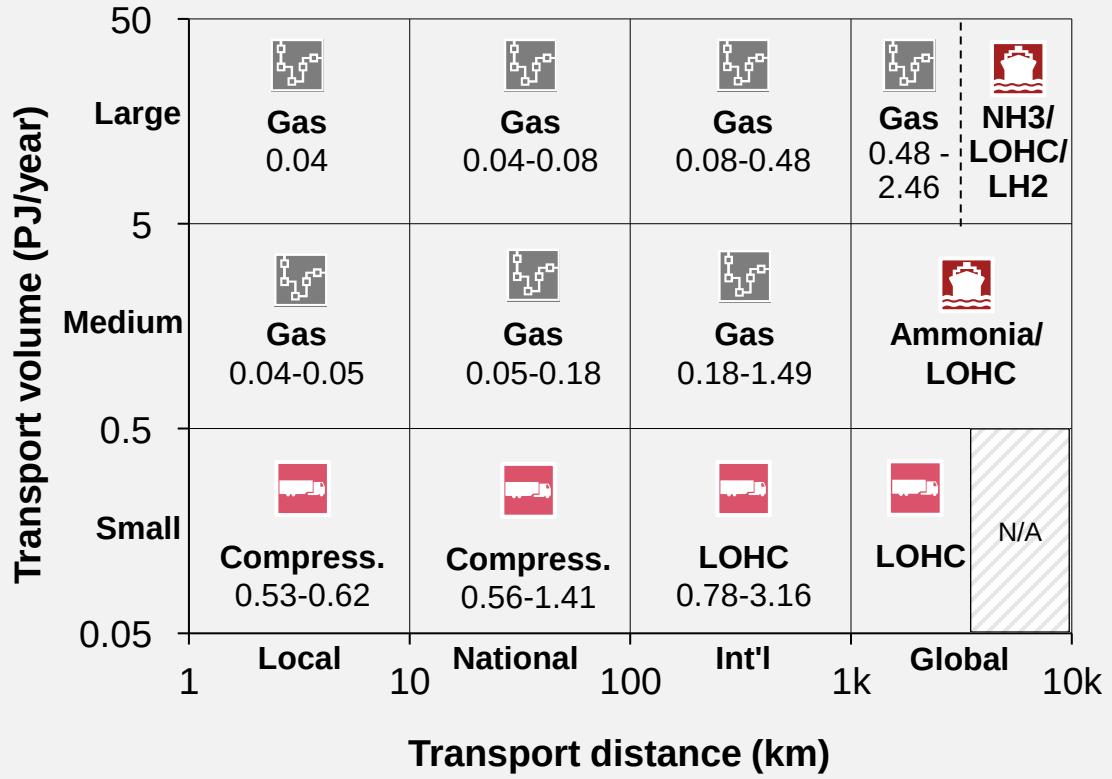
Electrolysis close to renewable electricity supply is economically more attractive than close to demand centers



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

Above transport volume of 0.5 PJ per year, pipelines are the most efficient way

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



Sources: DNV GL (2020), Bloomberg NEF (2020), Strategy& analysis

The government defined the ambition to install 3-4 GW electrolysis capacity, which drives the need for a pipeline transport network

Government has the ambition to ramp up 3-4 GW electrolysis capacity towards 2030

Possible roll-out path for hydrogen projects

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

>0.5PJ / year pipelines are the most cost efficient transport option

From 2023 onwards, pipeline transport is the most cost effective way to transport hydrogen from supply to demand

Above 100 MW electrolysis capacity, **pipelines are more cost effective than tank lorries**

To realize the 3-4 GW ambition, **hydrogen pipelines are required from 2023 onwards**

Until 2030, hydrogen transport capacity needed:

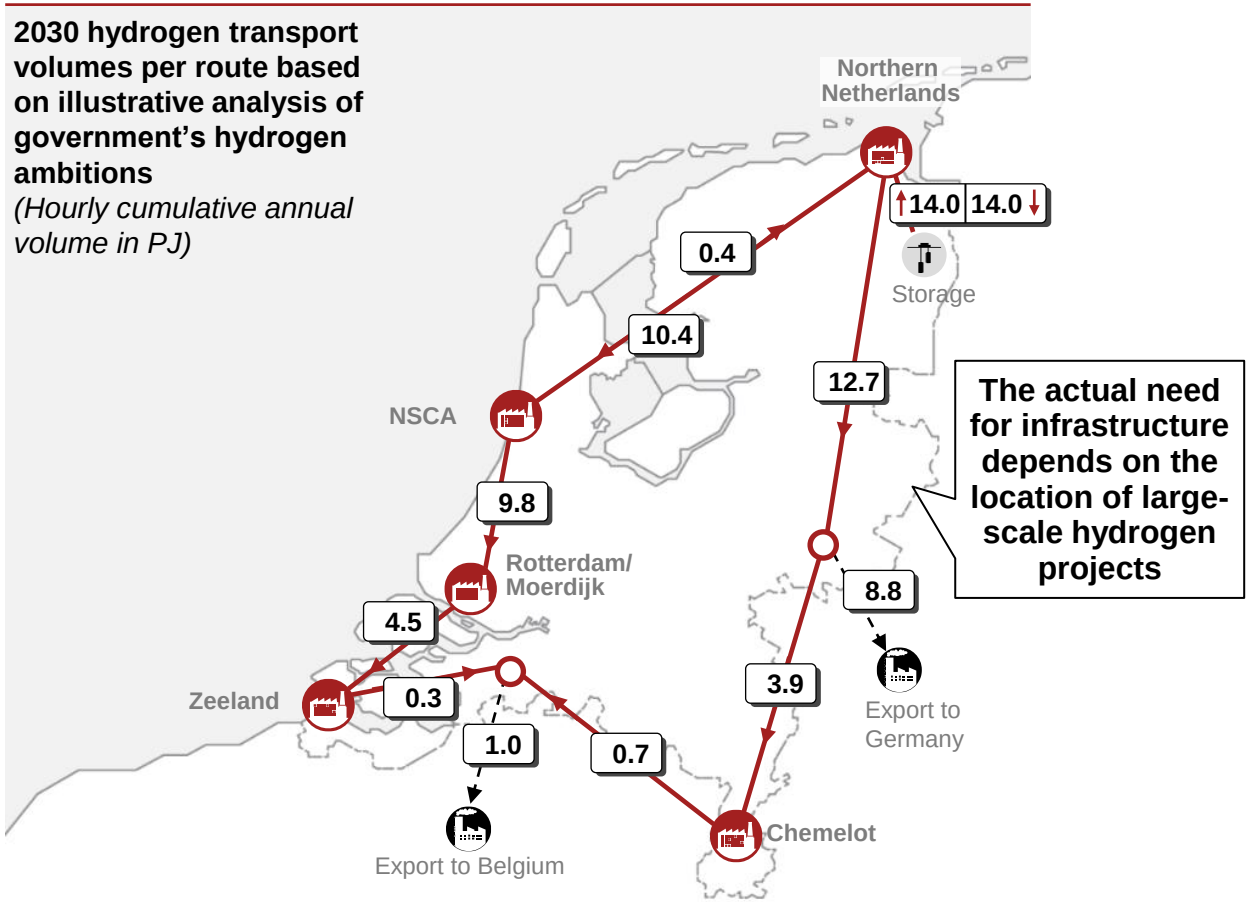
- Within industrial clusters to connect local supply and demand
- Between clusters to supply clusters with limited own supply (typically further from coast)
- To and from natural storage facilities in Groningen

Sources: Gasunie, Waterstofcoalitie (2018), Strategy& analysis

Illustrative analysis of transport volumes demonstrates the need for national infrastructure connecting industrial clusters by 2030

With 3-4 GW electrolysis capacity, hydrogen transport volumes per route are above 0.5 PJ threshold

2030 hydrogen transport volumes per route based on illustrative analysis of government's hydrogen ambitions
(Hourly cumulative annual volume in PJ)



The actual need for infrastructure depends on the location of large-scale hydrogen projects

Model 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
- Grey hydrogen flows disregarded, no imports, no blue hydrogen production, conservative export volumes
- Simplified network topology

Conclusions:

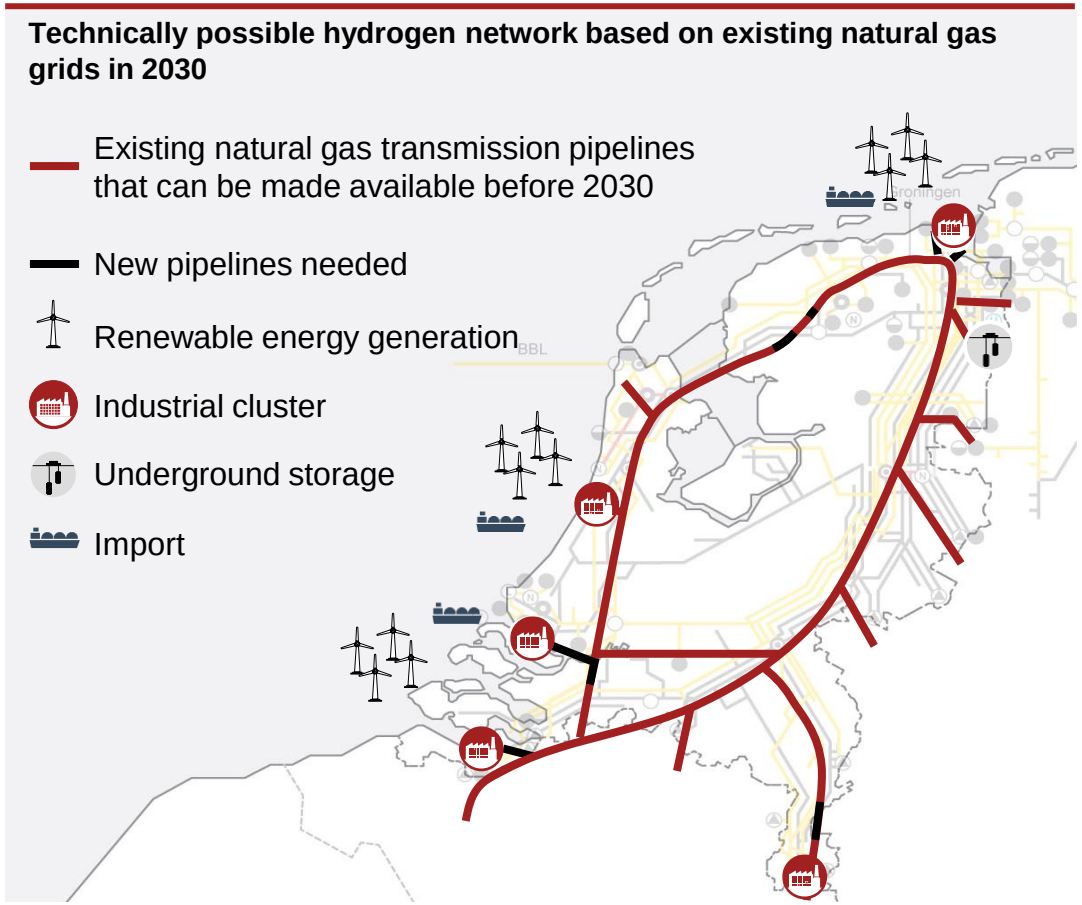
- Annual transport volumes to/from all industrial clusters justify pipeline infrastructure as most cost effective connection
- Average transport volume per route is 9 PJ/ year
- ~60% of transport volume is related to regional imbalances (e.g. from coast to Germany/ Chemelot)
- ~40% of transport volume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

Source: Gasunie, Strategy& analysis

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

Technically possible hydrogen network based on existing natural gas grids in 2030



The Dutch gas Transmission grid is unique in the world:

1. **Two almost overlapping systems exist,** one for high-caloric gas and one for low-caloric gas (Groningen gas)
2. With the phase out of Groningen gas production, **overcapacity increases in low-caloric gas system** (incl. export routes)
3. **The capacity that will be available until 2030 can cover the hydrogen transport needs for 2030**

As a result, by constructing just **~200km new pipeline**, the Netherlands could leverage ~1000km existing natural gas pipeline into a **~1200km national hydrogen pipeline system** connecting industrial clusters, import/expert routes and storage facilities

Source: Gasunie, Strategy& analysis

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

Current pipelines can be safely used for hydrogen if a number of adjustments are made

Summary of measures needed to ensure safe hydrogen transmission

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

Additional costs

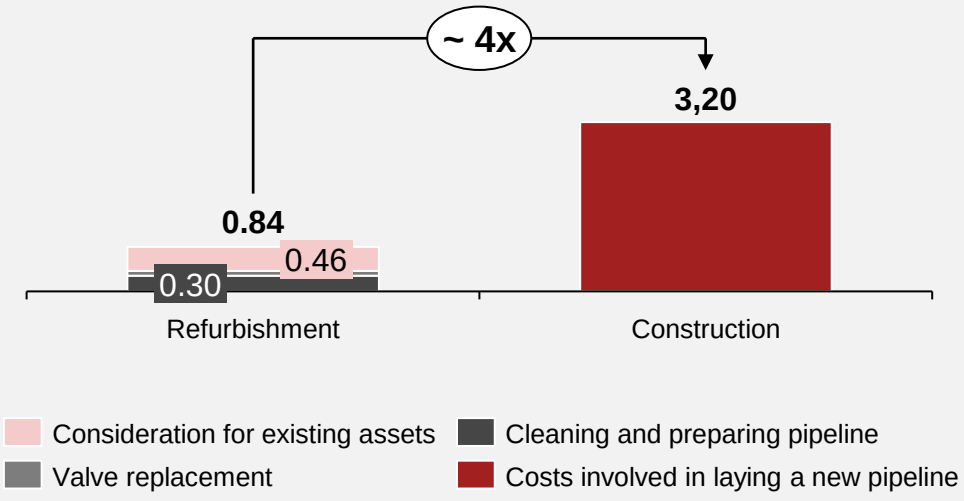
= Adjustments to existing network *= Adjustments to procedures*

Completely new construction of the transport network is four times more expensive than converting the network

Comparison of per-km investment required for reuse and new-build
(millions of € per km, based on: 36-inch pipeline and route covering 1,183km)

~55% of the investment in conversion consists of a payment for taking over existing assets from GTS, at regulated asset value (GAV)

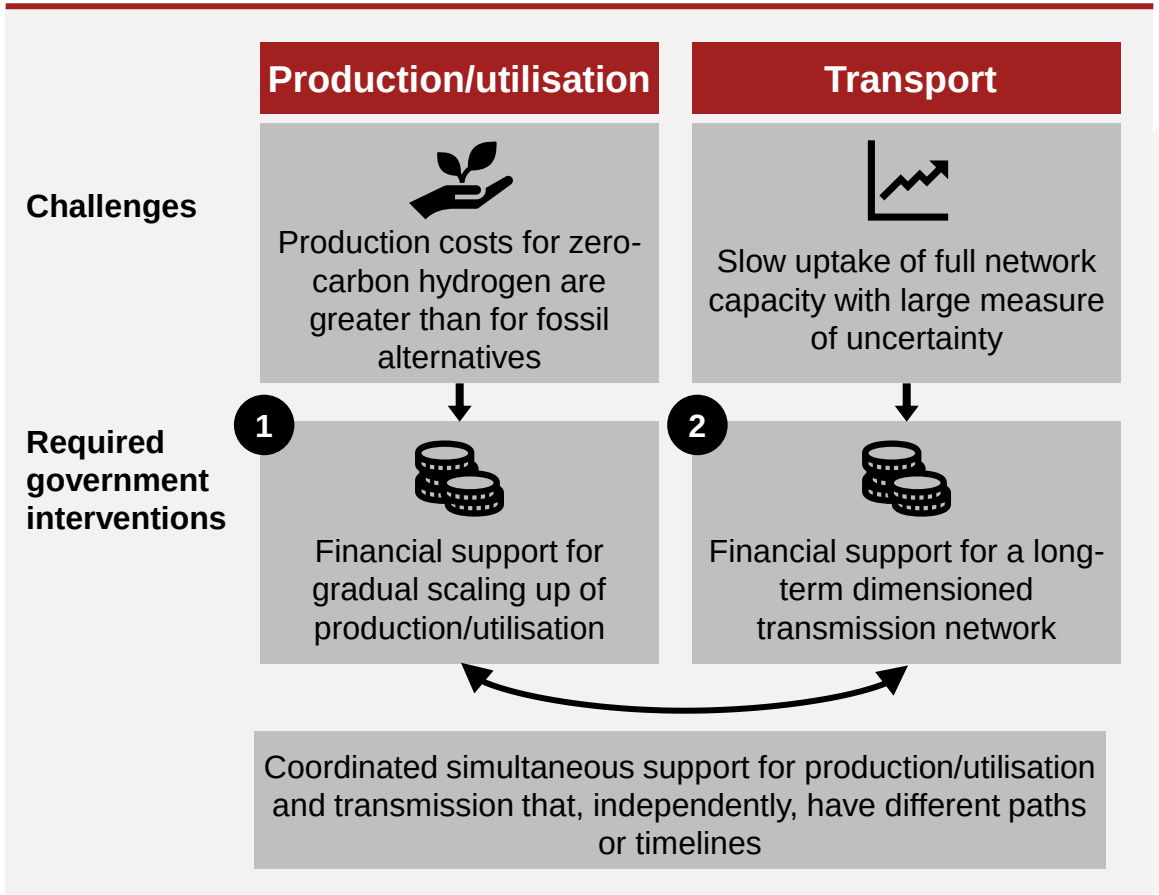
~45% consists of actual conversion costs, i.e. cleaning and preparation of the pipelines, also depending on the desired purity of hydrogen



Source: Gasunie, Strategy& analysis

Government intervention is required to address the "chicken & egg" problem of the hydrogen market and hydrogen transport

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



Firstly, **applications** for zero carbon hydrogen **are not yet profitable**, so there is **no transmission demand**

Secondly, the **transmission** grid is dimensioned for the **long term**, while **demand arises** very **gradually**

- Government intervention is needed for both transport and production and use of green hydrogen
- Support from both sides needs to be coordinated, with consideration of when what support is needed

Source: Strategy& analysis

Dutch government has started to implement our recommendations for the realization of a hydrogen infrastructure

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’)

Current status on principle decision:

- On June 30th, our recommendations to the government where put forward to second chamber
- On September 21st, the government published its draft budget for 2022 in which it allocates:
  - €750 Mn for development of the hydrogen transport system
  - €35 Mn for development of hydrogen storage

More information on the project is publicly available on:

www.HyWay27.nl