gasunie
crossing borders in energy

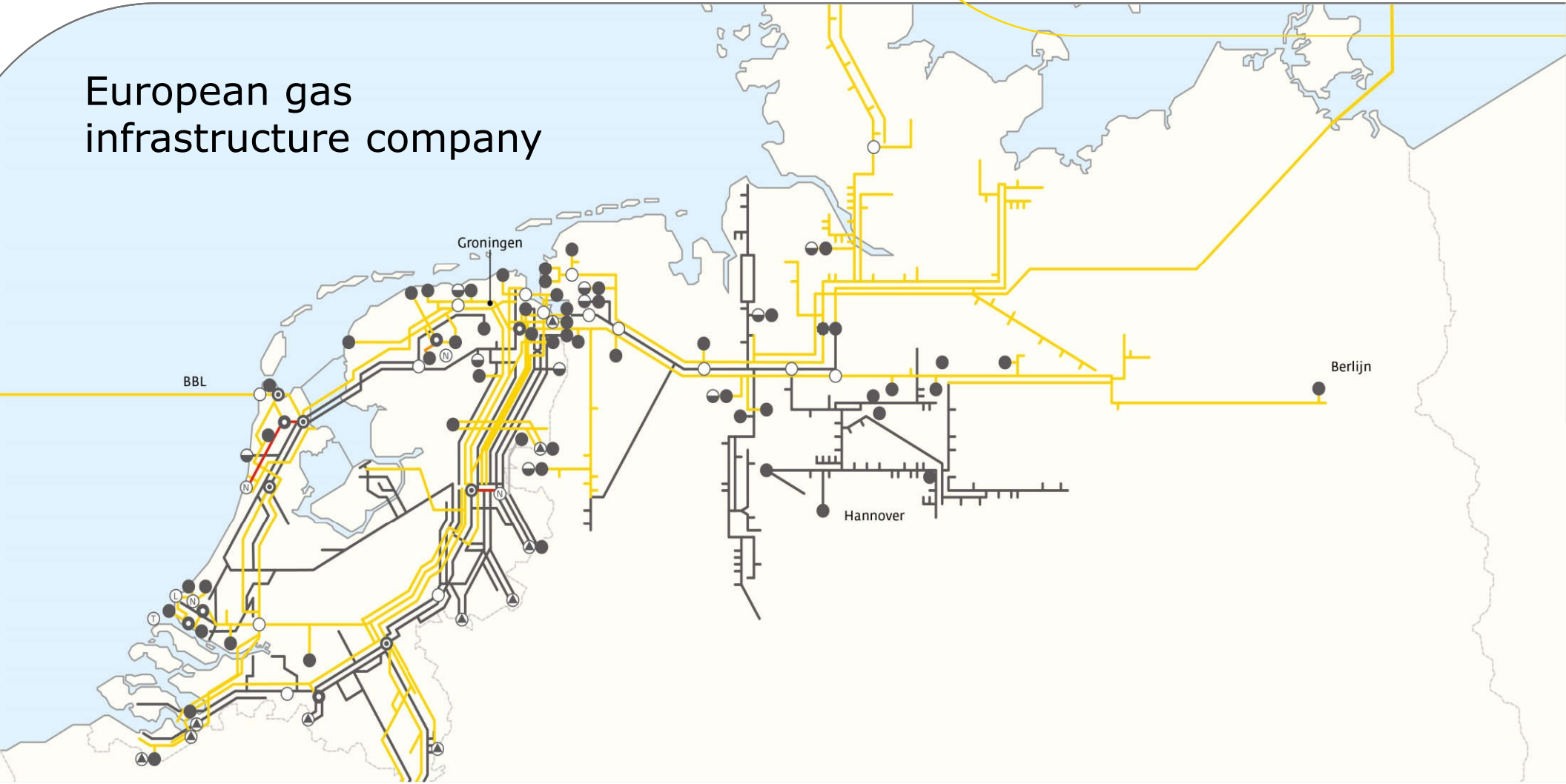
2 September 2020

Growing Hydrogen

Masterclass in Hydrogen - Israel

René Schutte

European gas infrastructure company



Strategy

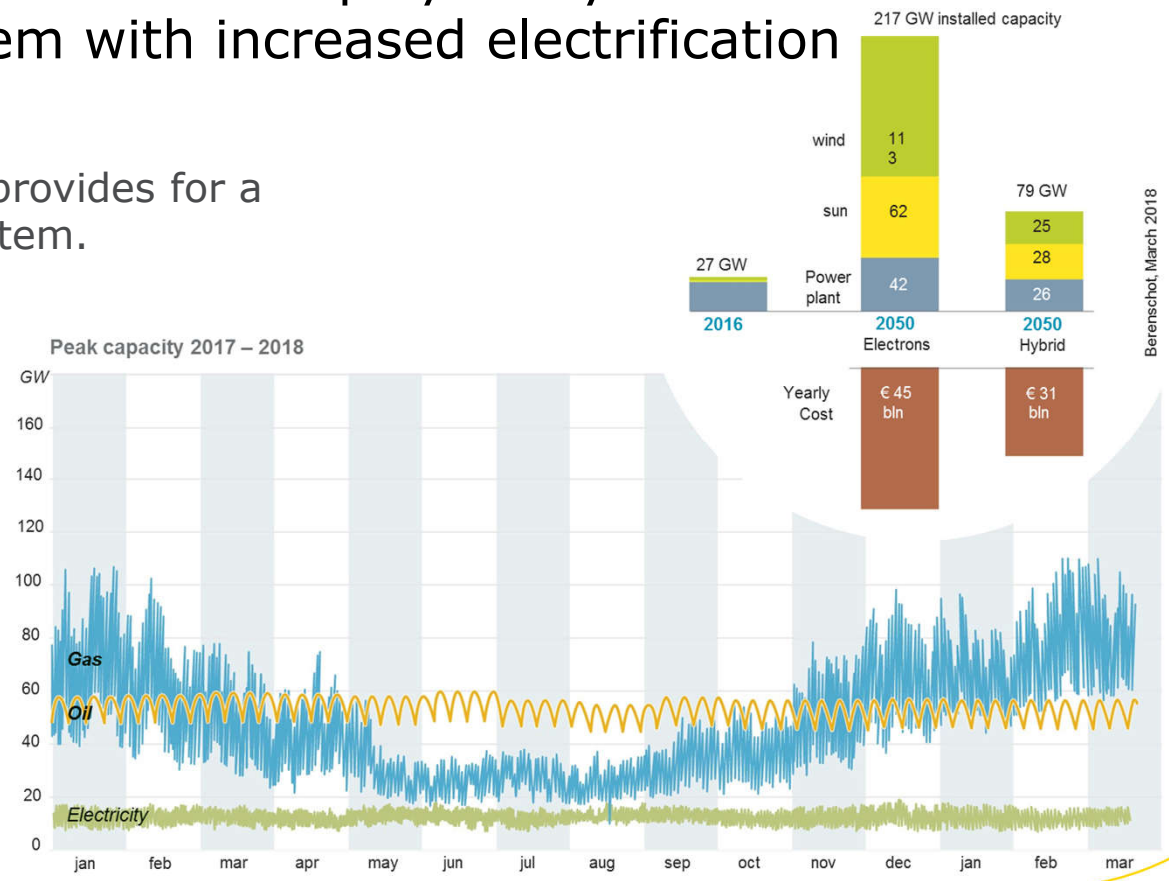
Optimising the value of our existing assets

Strengthening our leading position as cross-border gas infrastructure company in Europe

Making the transition towards more sustainable energy use possible

We foresee that gas infrastructure will play a key role in a decarbonised energy system with increased electrification

A smart role for green molecules provides for a reliable and affordable energy system.

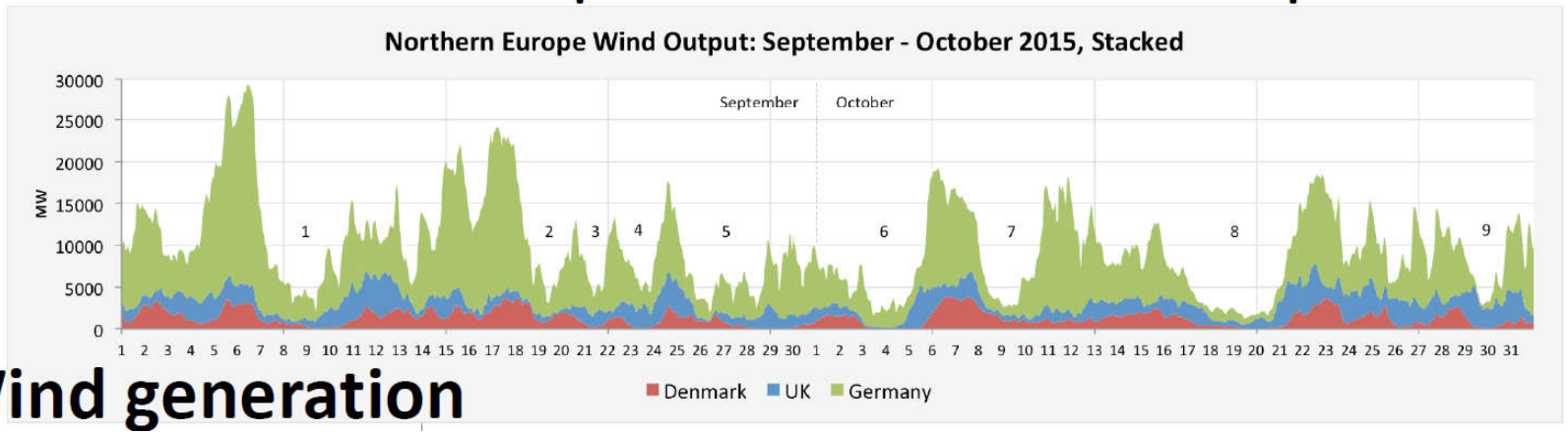


Wind production profile

Logan Energy
hydrogen technologies

Renewable Energy

DAILY electrical production and load profiles



Wind generation

Gas can be stored more efficiently than electricity

Cavern

Gas can be stored more efficiently than electricity

Volume

- 1 cavern with 1 mln m^3 of hydrogen equals 240,000 MWh (= 6,100 tons H_2)

Equivalents

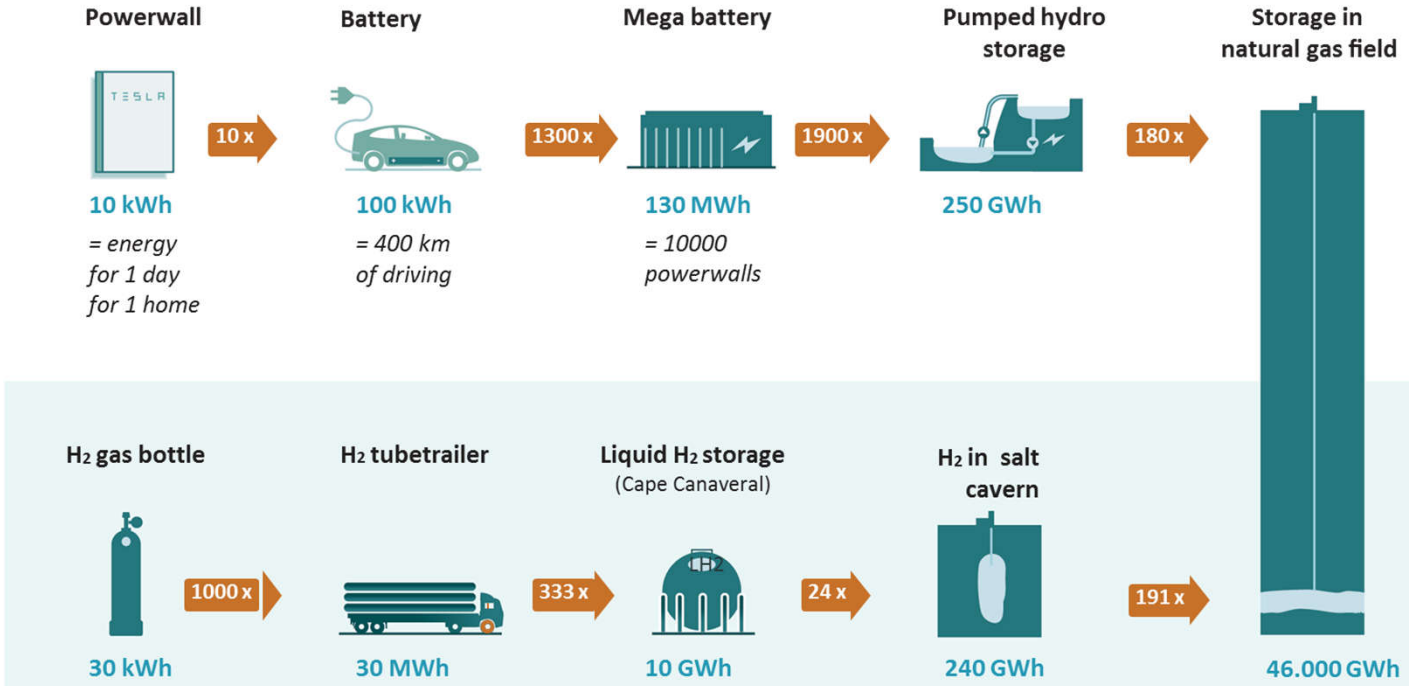
- 24 mln. power walls (10 KWh, Tesla)
- 2400 of the largest batteries in the world (100 MWh, Tesla)

Experience

- H_2 storage in caverns is an existing technology
- Many years of experience in the UK and US

Battery

Electron and Molecule Storage in perspective



Transport of gas is much cheaper and more efficient

Power

BritNed

- 260 km
- € 600 mio
- 1 GW capacity
- € 230/kW/100 km

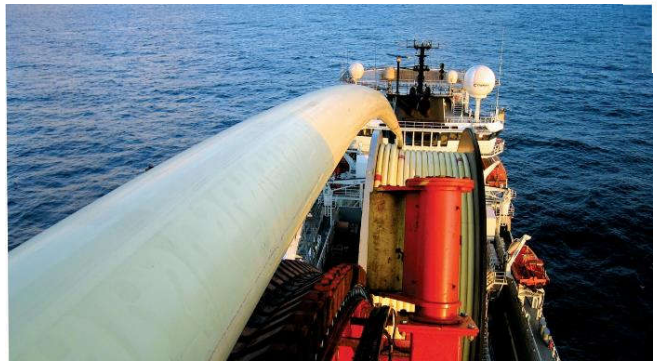
Gas

bbl company

- 230 km
- € 500 mio
- 20 GW capacity
- € 11/kW/100 km

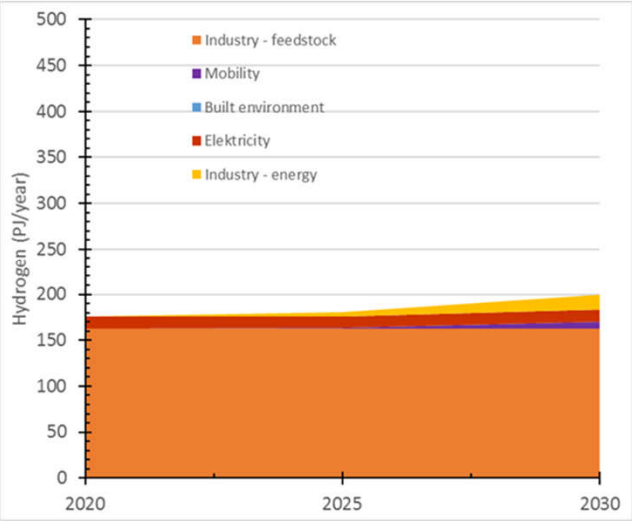
Nord Stream

- € 9/kW/100 km

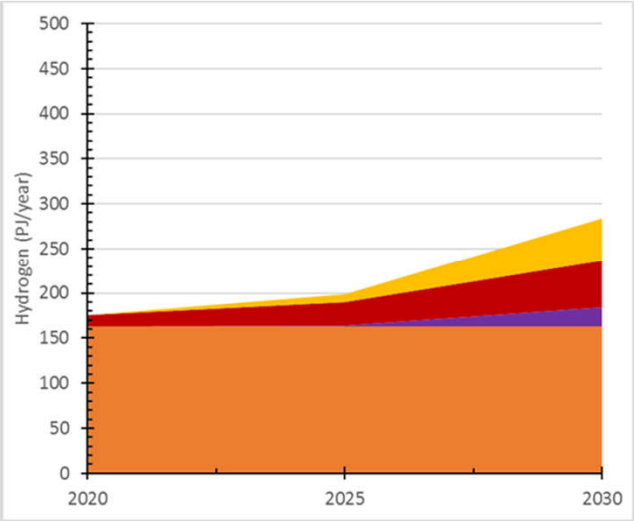


Hydrogen Demand

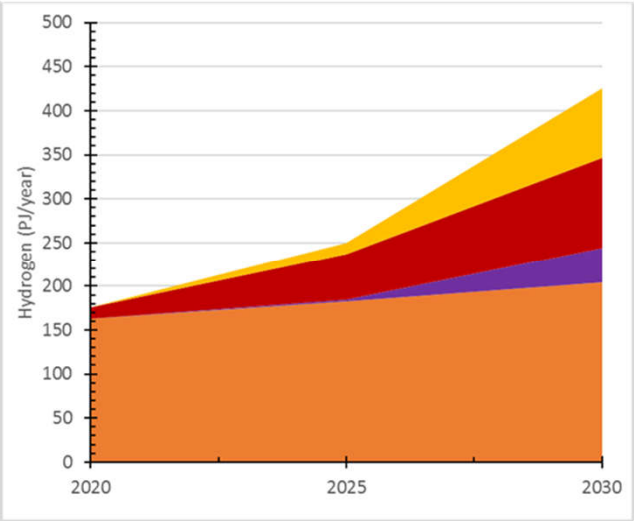
Low



Medium



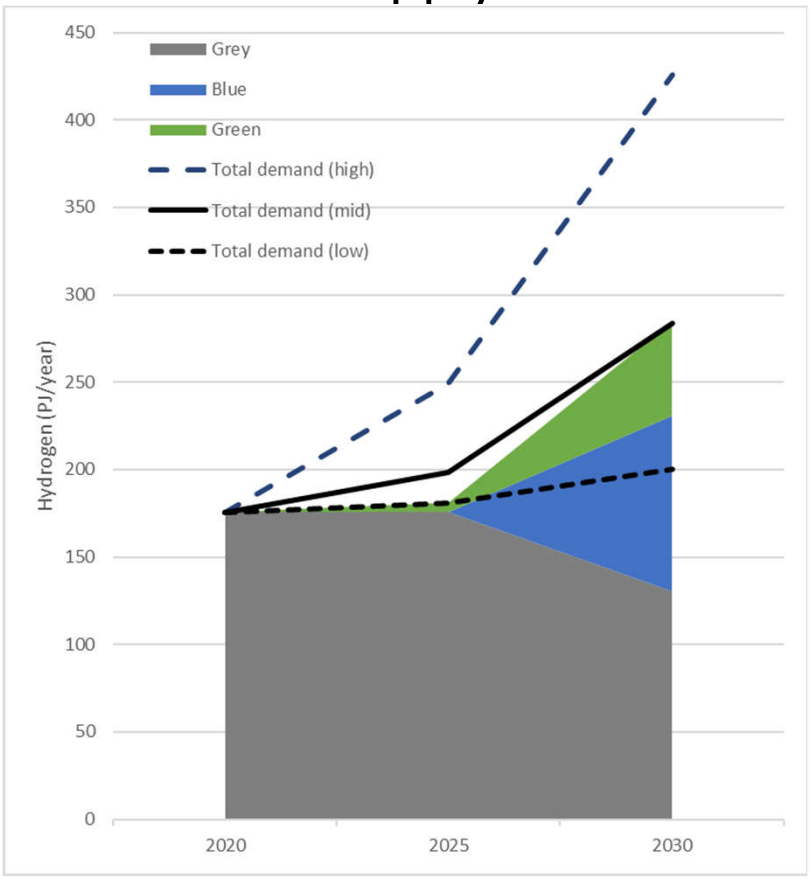
High



Towards 2030 – Hydrogen demand and supply

Dutch Climate Agreement:

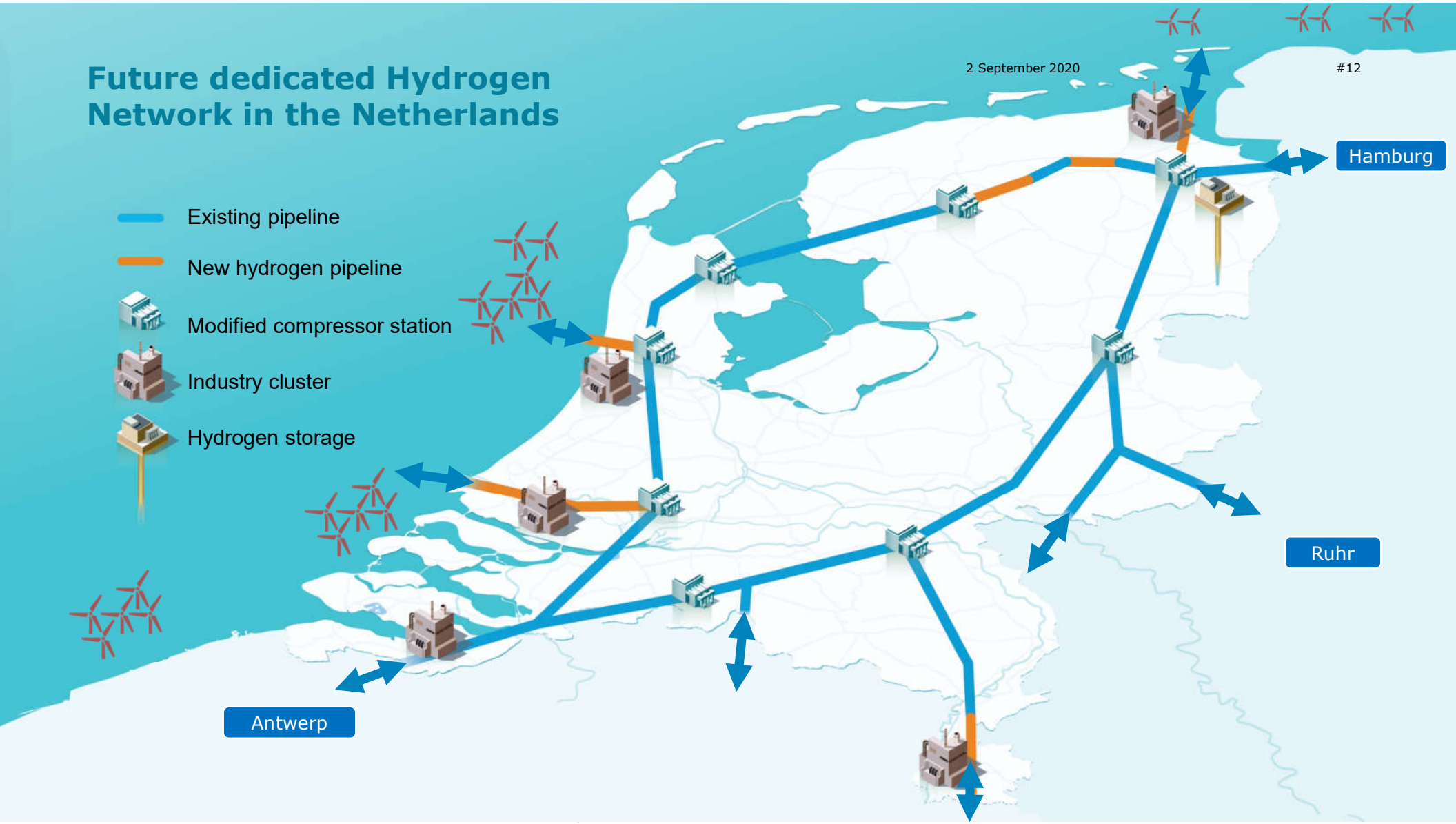
- 500 MW in 2025
- 4 GW in 2030



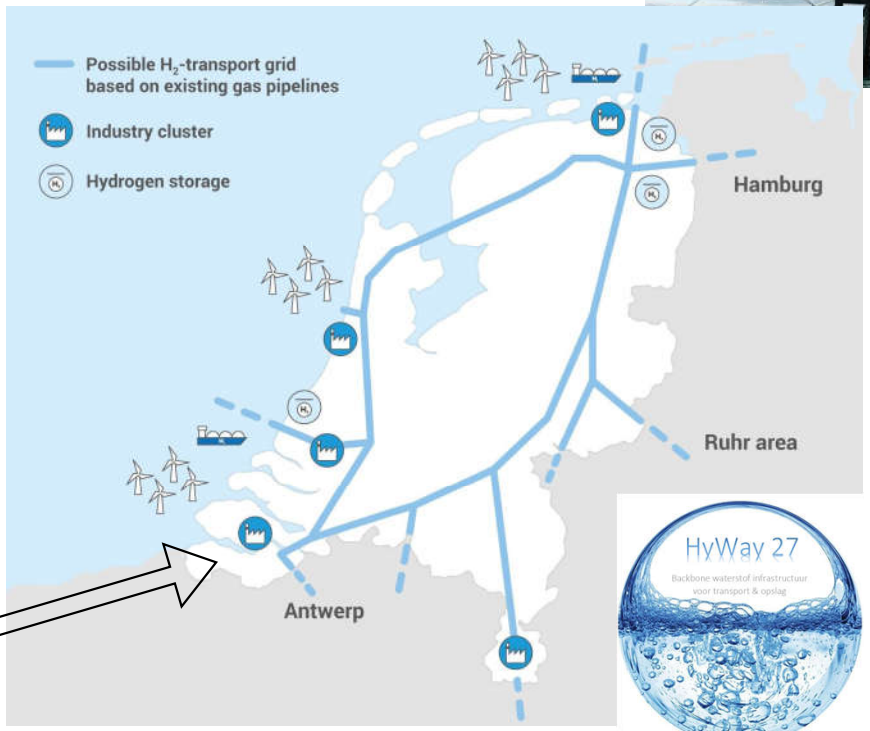
Refit from natural gas to hydrogen pipeline

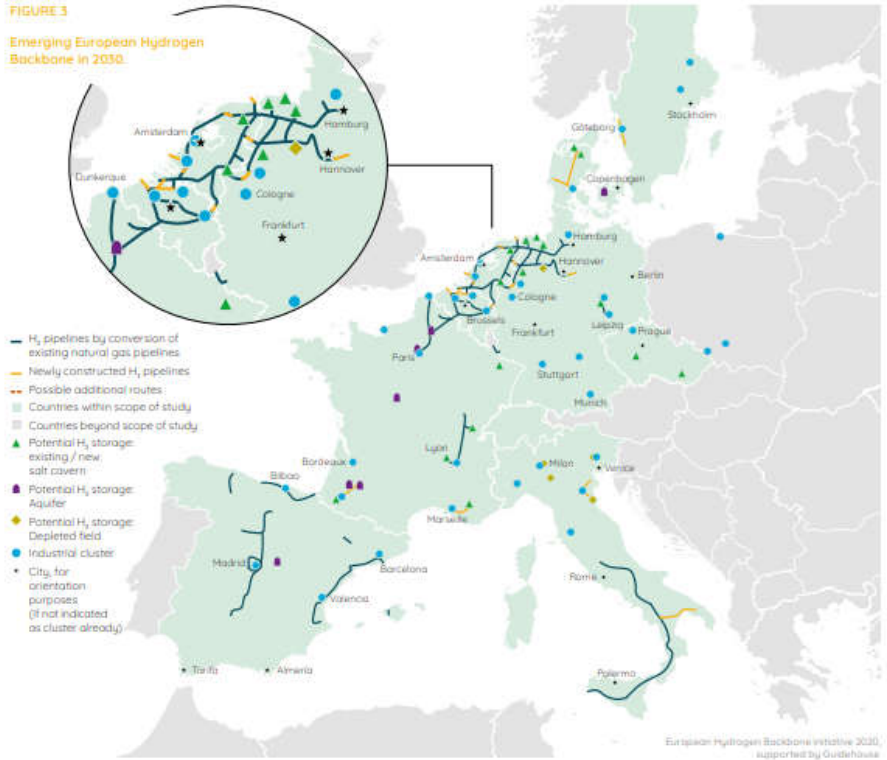
- Smart Delta Resources (Zeeland): Hydrogen for the region
- Energy savings
- Road transport savings
- CO_2 emission reduction

Future dedicated Hydrogen Network in the Netherlands



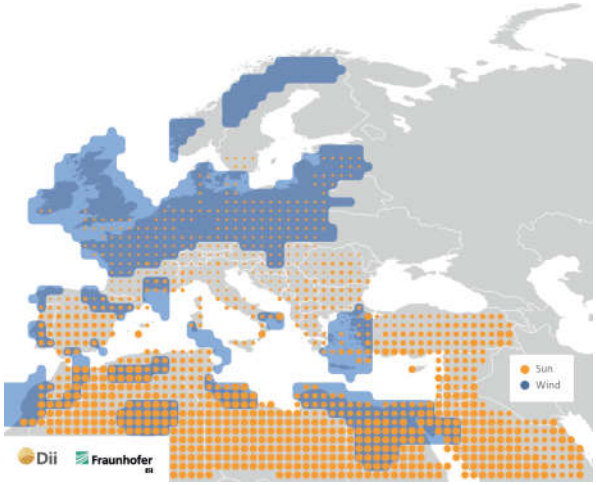
Hydrogen infrastructure





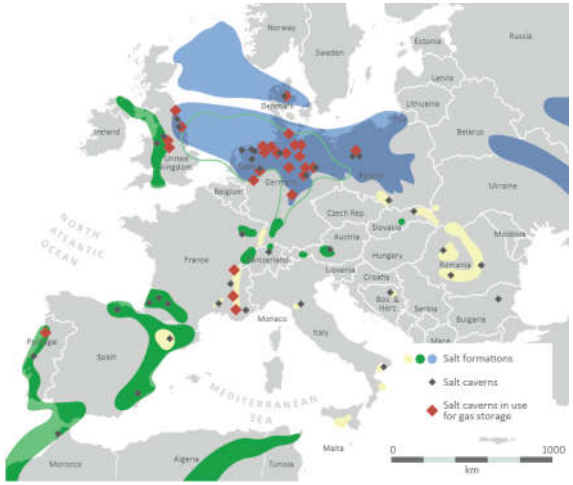
Unique opportunity to develop green hydrogen

Solar/wind resources



Hydrogen backbone

Salt Caverns

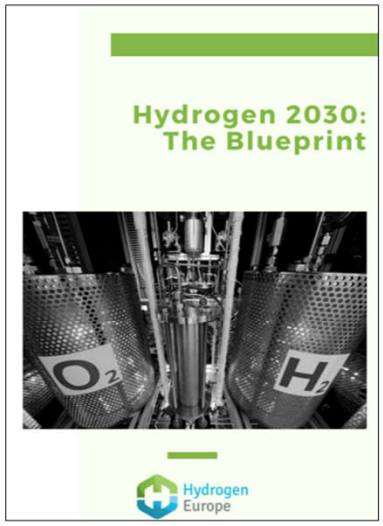


Coherent approach

VISION

Produce 40GW in Europe and 40GW in neighbouring countries by 2030.

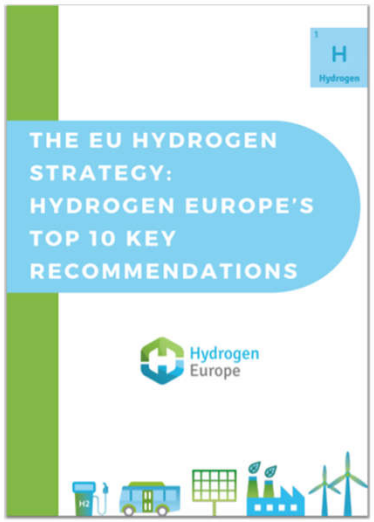
COST



€430bn in funds are needed to kick start the hydrogen economy.

COMMITMENT

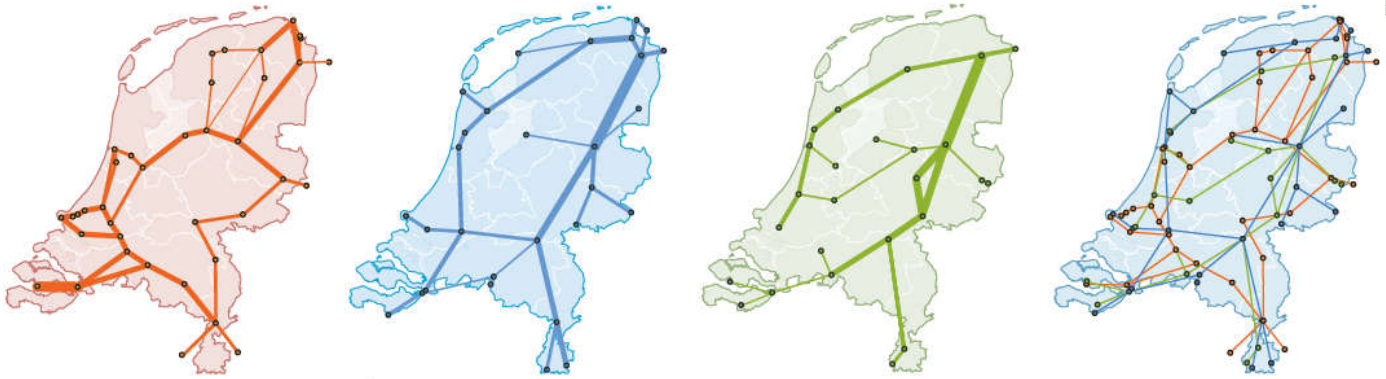
RECOMMENDATIONS



Input to the Hydrogen Strategy: providing an enabling regulatory framework at EU level.

Existing grids as starting point

Electricity Grid + **Hydrogen Grid** + **Methane Grid** = **Combined Grid**



Capacity 20 GW

Capacity 350 GW

Tennet

Electricity grid (220 & 380kV)

Investment plans:

Reinforcement exisiting grid

New connections wind at sea

Gasunie

H-gas grid (80 bar)

Hydrogen grid 2030,

To connect industrial clusters and storage

Gasunie

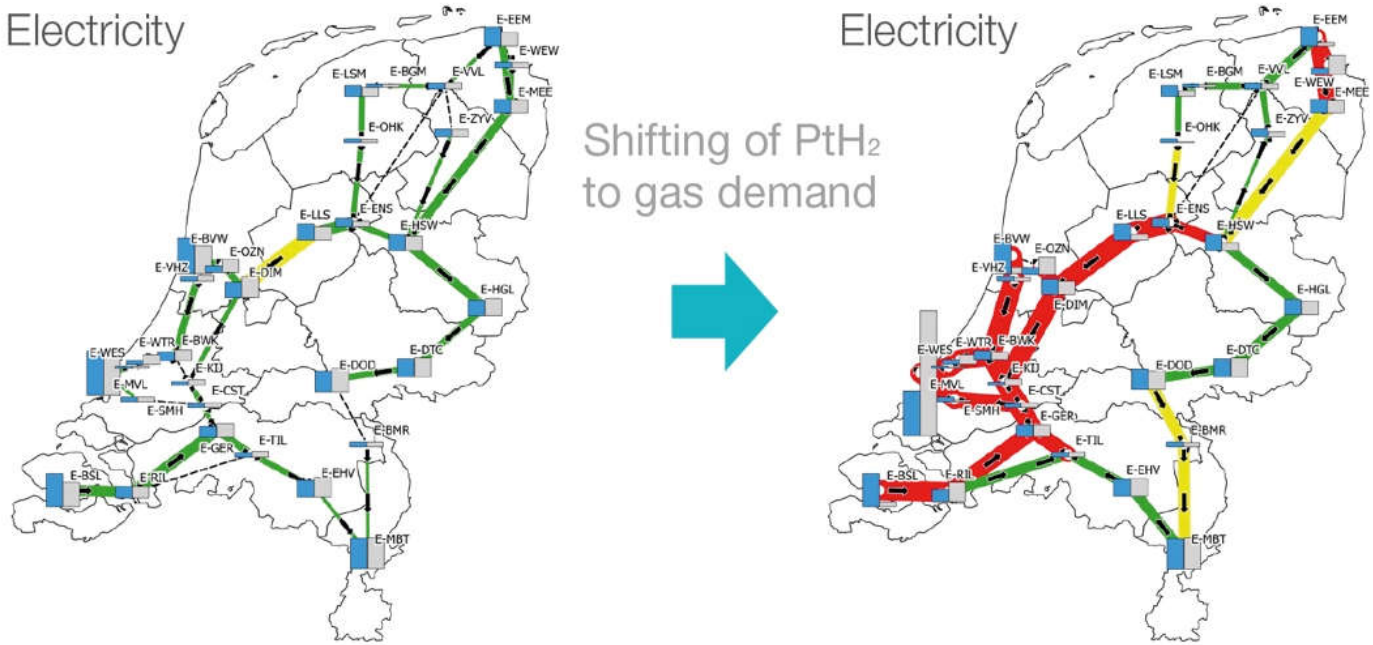
G-gas grid (67 bar)

Feed in green gas via manifold line

Connection Points

1. **Power Plants: methane of hydrogen -> electricity**
2. **Electrolysis: electricity -> hydrogen**

Location P2G



Key insights

1 An energy system based on domestic renewables will need a firm integration of gas and electricity networks.

2 Great need for hydrogen and methane storage.

Expansion of cavern storages for hydrogen in NL foreseen.

3 Need for further expansion of electricity grids after 2030 due to growing demand, but smart sector coupling can decrease it.

No major expansion of gas grids foreseen.

4 Adequate allocation of P2G sites needed to stay within the financial and spatial planning limits for investments in electricity grids.

5 Import of green gas (methane or hydrogen) can significantly reduce the need for investments in electricity infrastructure.

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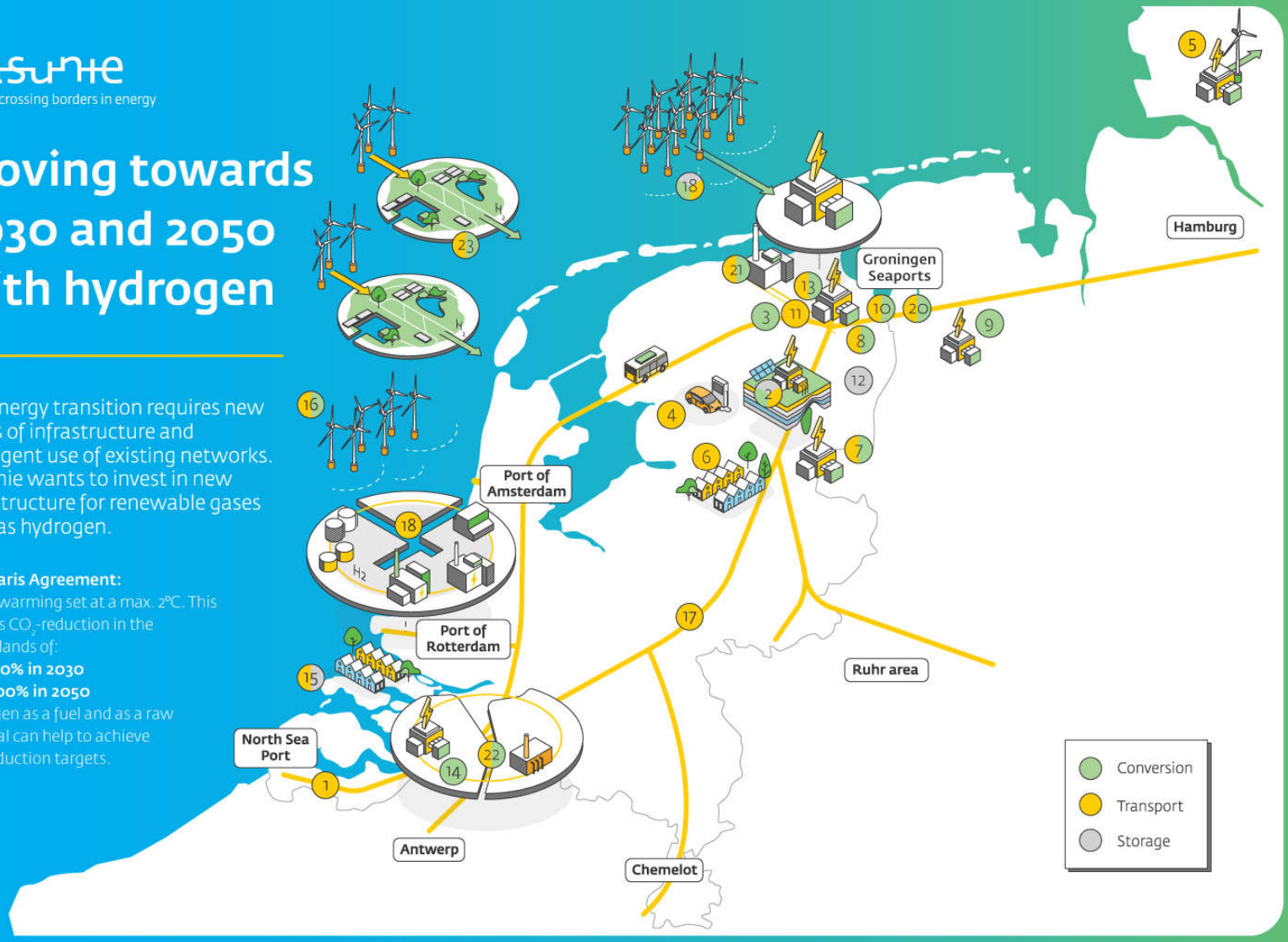
Moving towards 2030 and 2050 with hydrogen

The energy transition requires new forms of infrastructure and intelligent use of existing networks. Gasunie wants to invest in new infrastructure for renewable gases such as hydrogen.

2016 Paris Agreement:
Global warming set at a max. 2°C. This requires CO_2-reduction in the Netherlands of:

- **40-50% in 2030**
- **85-100% in 2050**

Hydrogen as a fuel and as a raw material can help to achieve CO_2-reduction targets.



2017
1 Hydrogen pipeline

2018
2 HyStock

2019
3 Hydrohub

2020
4 Hydrogen re-fuelling stations and buses

2020
5 H_2-projekt Haurup

2021
6 Hydrogen district Hoogeveen

2022
7 GZI Next
8 Djewels

2023
9 Element 1

2024
10 HyNether-lands
11 Northern H2 infra

2025
12 Hydrogen storage
13 H2M

2026
14 CUST

2027
15 Hydrogen district Stad aan 't Haringvliet
16 North Sea Wind Farm
17 Back-bone

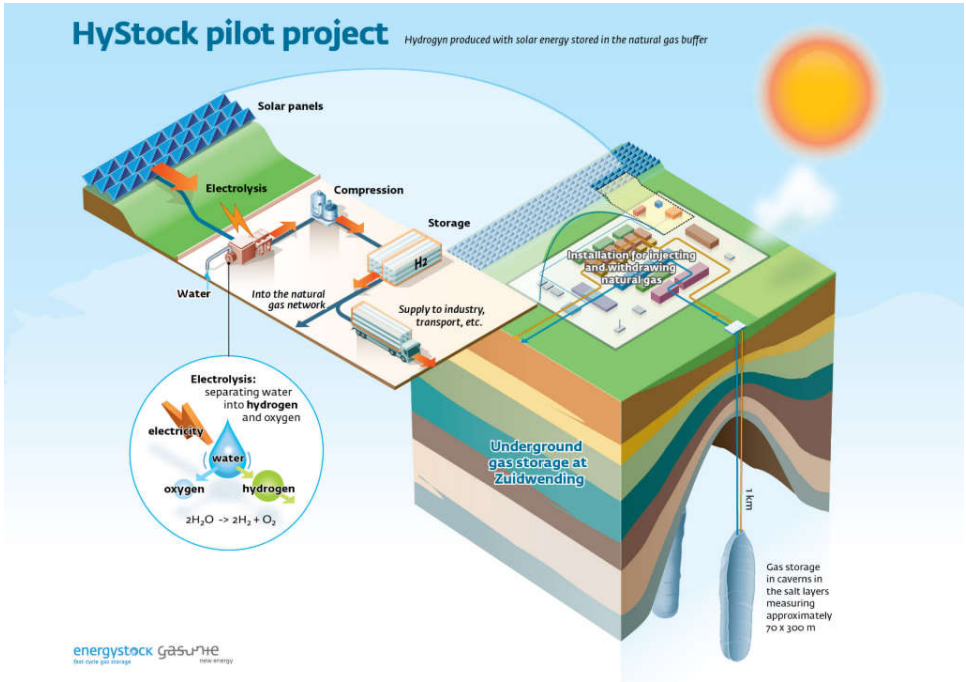
2028
18 NorthH_2
19 H-vision
20 HyNether-lands

2029
21 H2M phase 2
22 CUST

2030
23 North Sea Wind Power Hub

HyStock

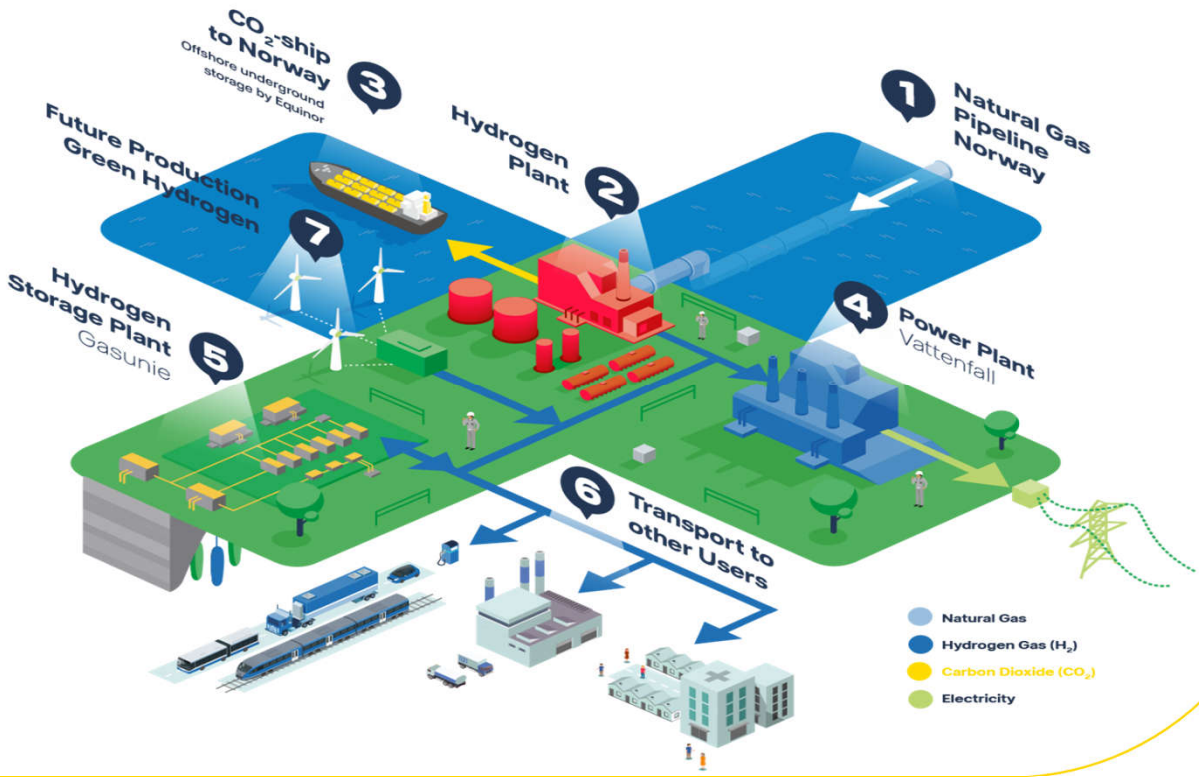
- Pilot project
- 1,1 MW
- 8500 solar panels
- Cavern storage (start with tube trailers)
- Open access facilitity



H2M Project

Development of low carbon hydrogen economy

Refit Vattenfall
Magnum power plant from
natural gas to hydrogen



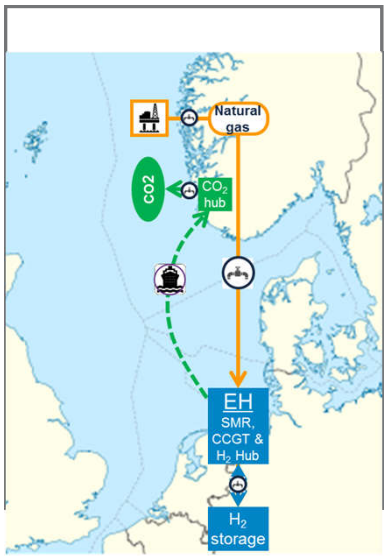
equinor

VATTENFALL

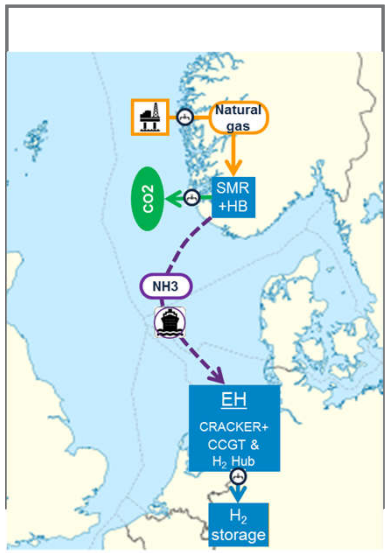
gasunie

Refit Vattenfall Magnum power plant from natural gas to hydrogen

Option 1:
H2 production in Norway



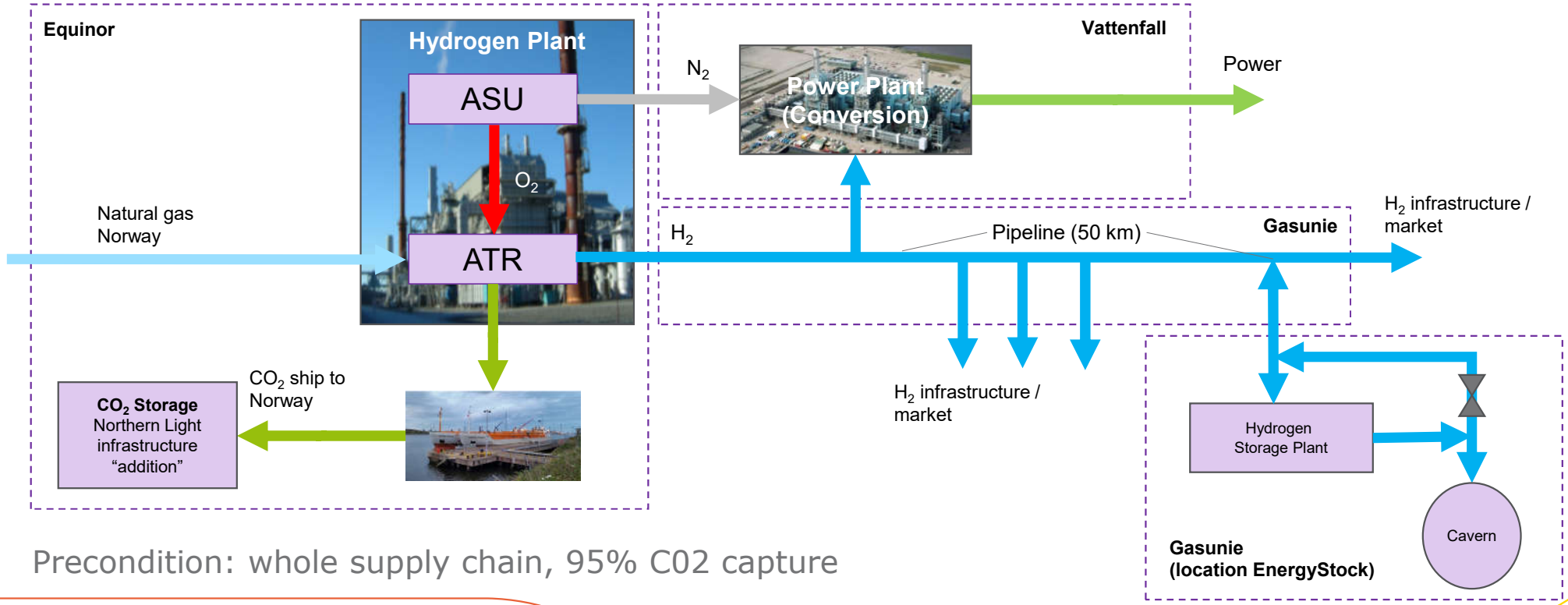
Option 2:
H2 production in NL



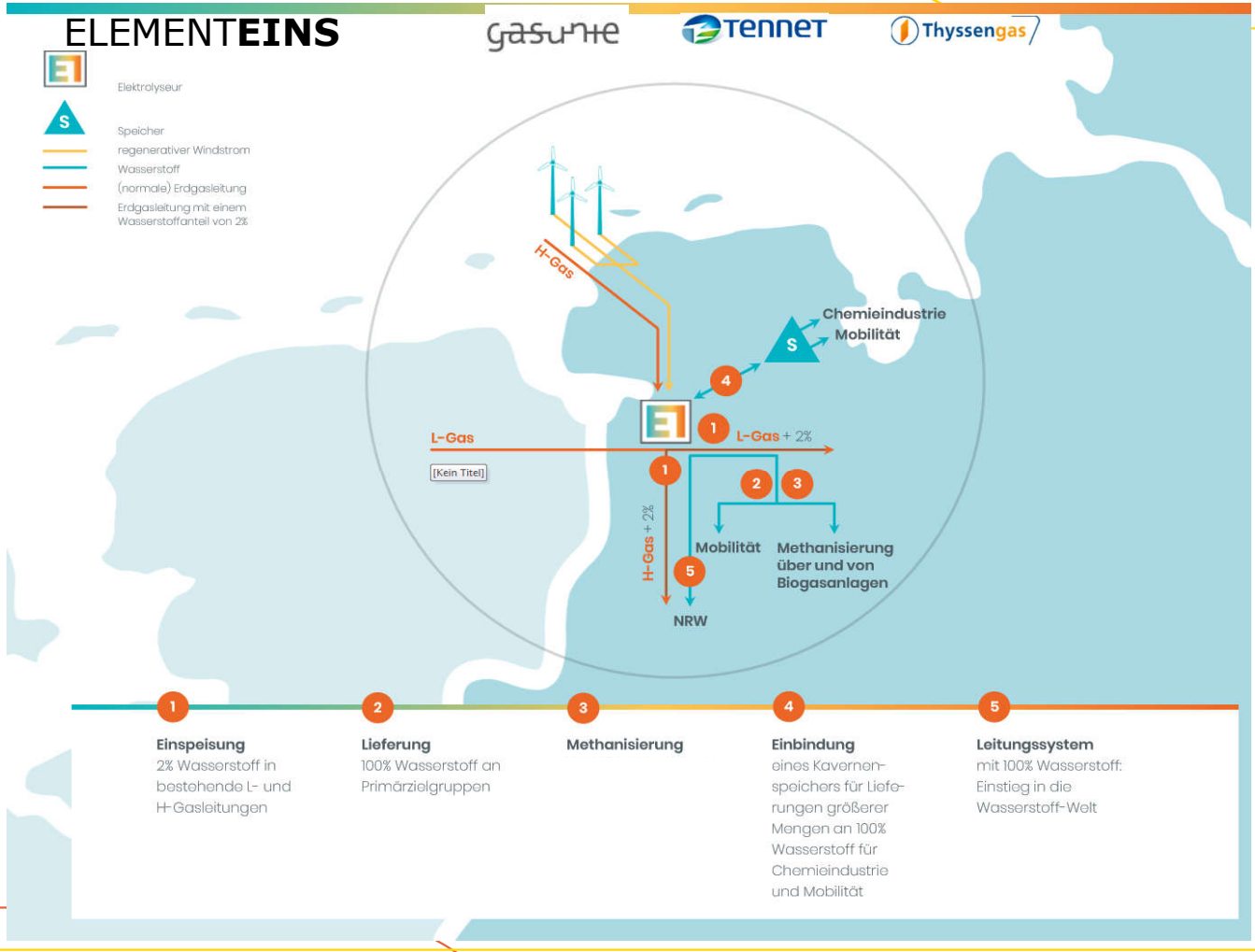
Option 3:
NH3 production in Norway

EH: Eemshaven;
CCGT = Magnum power plant;
SMR = steam methane reforming plant to split natural gas into hydrogen and CO2;
HB = Haber Bosch process to convert hydrogen into ammonia

Concept of H2M Project

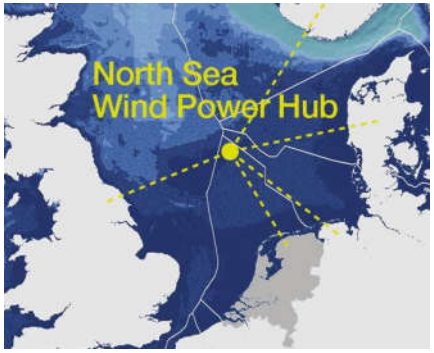


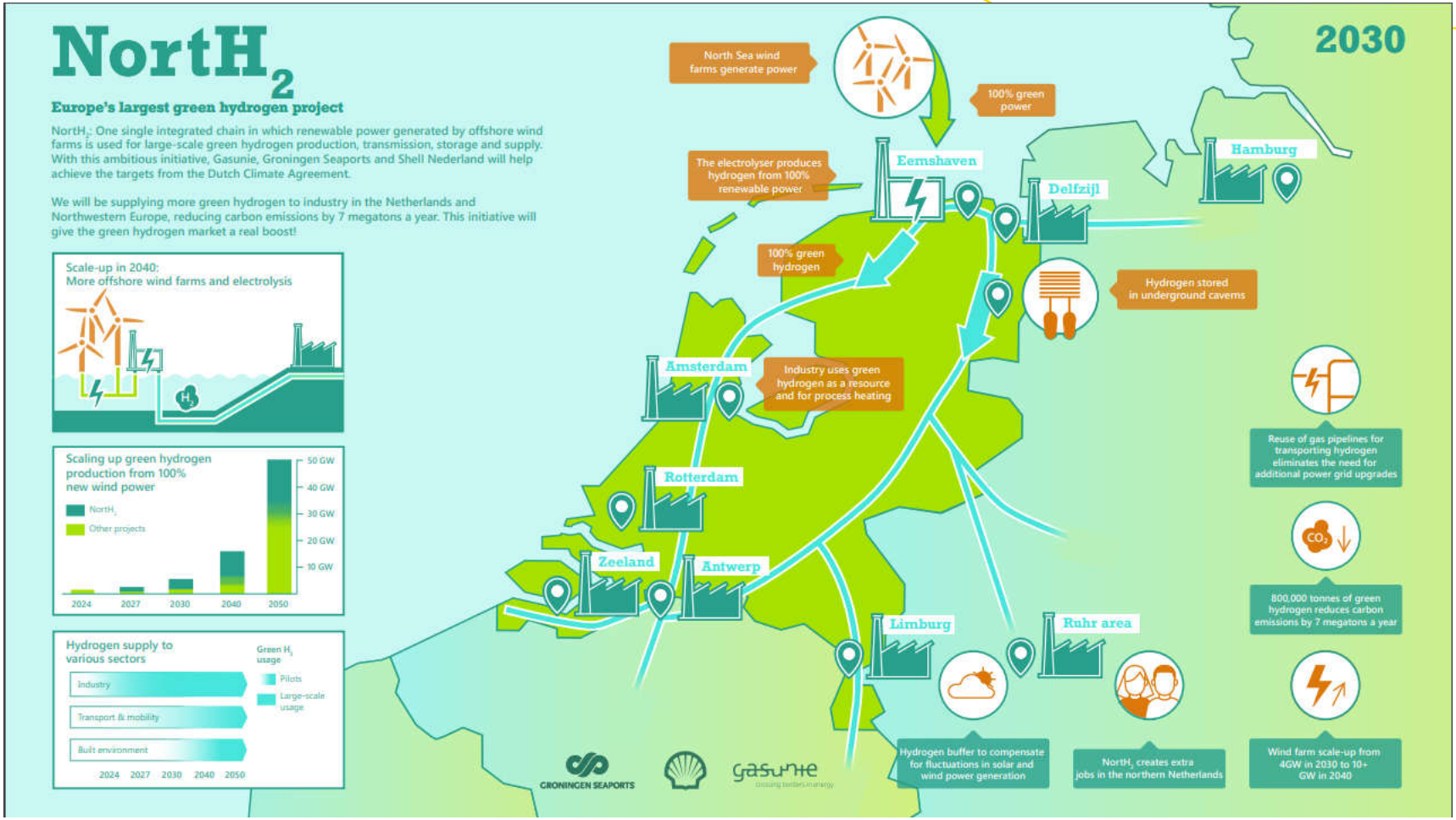
Precondition: whole supply chain, 95% C02 capture


ELEMENTEINS
gasunie
TenneT
Thyssengas
Elektrolyseur
Speicher
regenerativer Windstrom
Wasserstoff
(normale) Erdgasleitung
Erdgasleitung mit einem Wasserstoffanteil von 2%
H-Gas
Chemieindustrie
Mobilität
L-Gas
L-Gas + 2%
[Kein Titel]
H-Gas + 2%
Mobilität
Methanisierung über und von Biogasanlagen
NRW
1 Einspeisung
2% Wasserstoff in bestehende L- und H-Gasleitungen
2 Lieferung
100% Wasserstoff an Primärzielgruppen
3 Methanisierung
4 Einbindung
eines Kavernenspeichers für Lieferungen größerer Mengen an 100% Wasserstoff für Chemieindustrie und Mobilität
5 Leitungssystem
mit 100% Wasserstoff: Einstieg in die Wasserstoff-Welt

North Sea Wind Power Hub

- 180 GW offshore wind capacity in the North Sea
- Cost savings can be achieved by integrating capacity into a single offshore hub
- Contributes to the balancing of NWE electricity markets, including in the form of hydrogen conversion and transportation.
- Consortium with TenneT, Energinet, Gasunie, and Port of Rotterdam




NortH2
Europe's largest green hydrogen project
NortH2: One single integrated chain in which renewable power generated by offshore wind farms is used for large-scale green hydrogen production, transmission, storage and supply. With this ambitious initiative, Gasunie, Groningen Seaports and Shell Nederland will help achieve the targets from the Dutch Climate Agreement.
We will be supplying more green hydrogen to industry in the Netherlands and Northwestern Europe, reducing carbon emissions by 7 megatons a year. This initiative will give the green hydrogen market a real boost!
Scale-up in 2040:
More offshore wind farms and electrolysis
Scaling up green hydrogen production from 100% new wind power
NortH2
Other projects
50 GW
40 GW
30 GW
20 GW
10 GW
2024
2027
2030
2040
2050
Hydrogen supply to various sectors
Green H2 usage
Industry
Transport & mobility
Built environment
Pilots
Large-scale usage
2024 2027 2030 2040 2050
2030
North Sea wind farms generate power
100% green power
The electrolyser produces hydrogen from 100% renewable power
Eemshaven
Delfzijl
Hamburg
100% green hydrogen
Hydrogen stored in underground cavems
Amsterdam
Industry uses green hydrogen as a resource and for process heating
Rotterdam
Zeeland
Antwerp
Limburg
Ruhr area
Reuse of gas pipelines for transporting hydrogen eliminates the need for additional power grid upgrades
800,000 tonnes of green hydrogen reduces carbon emissions by 7 megatons a year
Wind farm scale-up from 4GW in 2030 to 10+ GW in 2040
Hydrogen buffer to compensate for fluctuations in solar and wind power generation
NortH2 creates extra jobs in the northern Netherlands
GRONINGEN SEAPORTS
gasunie

Green Octopus – potential group of projects for IPCEI application

Build a backbone and value chain to serve green hydrogen demand

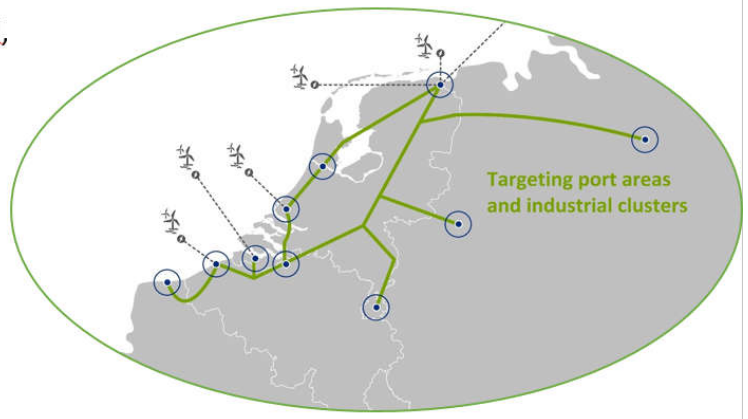
Hydrogen for Climate Action

Large amounts of clean hydrogen will be **produced** locally or abroad,

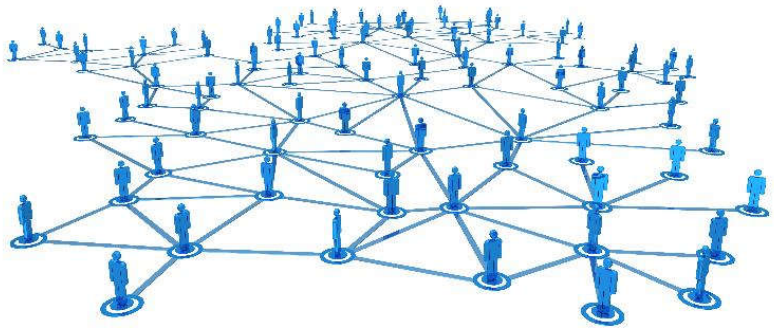
will be **imported** via the ports,

will be **transported** by converted natural gas or new infrastructure

towards large scale **endusers** of hydrogen



What is required?



- Scaling up
- Phased roll-out
- Programmatic approach
- Cooperation
- Funding


thanks
for
your
attention
questions?
arigato
gracias
merci
spasiba
danke
grazie
cheers
danki
mèsi
nkosi
wado
mahalo
talofa
shukran
saha
zikomo
sobodi
vinaka
buznyg
dėkoju
dziekuje
stuutiyi
spas
obrigada
tanmirt
matondi
gràcies
misaotra
bayarlalaa
tenki
grassie
maururu
soolong
bedankt
meharbani
shakkran
gratzias
dankewol
welalin
blagodaria
dakujem
multumesc
supas
rahmat
omol
manjuthe
kinisou
köszönöm
shukria
marahaba
saðol
miigwech
chokrane
shukriyaa
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yekeniele
modupe
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barkal
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ngiyabonga
dekuji
obrigado
waybale
tashakor
murakoze
tanemirt
dankie
salamat
akiba
menlau
aitäh
tack
skee
nuhun
paldies
trugéré
madlobt
merkzi
ahsante
sulpáy
aabar
takk
kiitos
manana
tänan
waita

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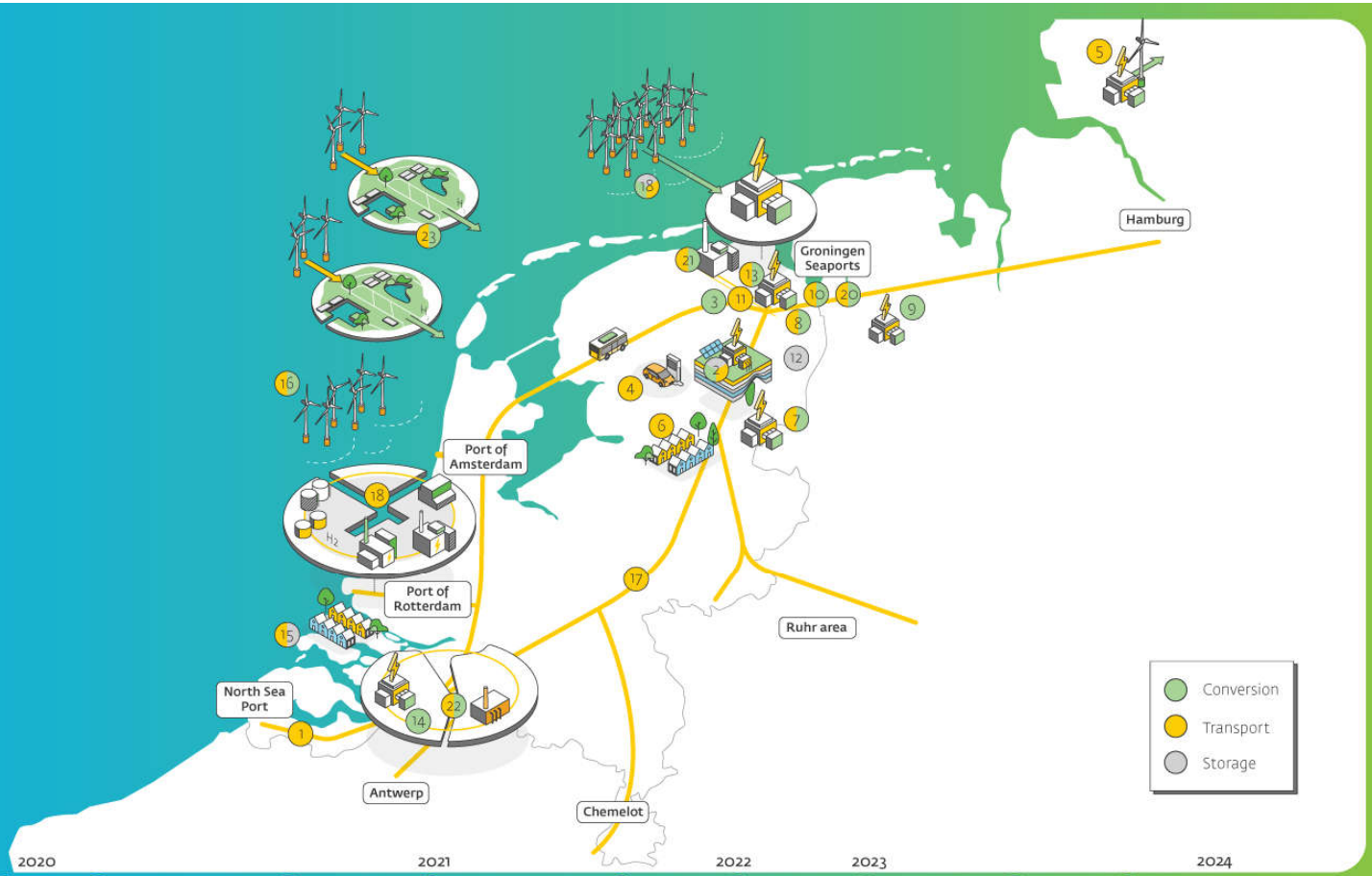
Moving towards 2030 and 2050 with hydrogen

The energy transition requires new forms of infrastructure and intelligent use of existing networks. Gasunie wants to invest in new infrastructure for renewable gases such as hydrogen.



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- **40-50% in 2030**
- **85-100% in 2050**

Hydrogen as a fuel and as a raw material can help to achieve CO_2-reduction targets.

2016 2017 2018 2019 2020 2021 2022 2023 2024

1 **Hydrogen pipeline**
Retrofit former natural gas pipeline. Linking hydrogen industries in Zeeland and the Delta region (Nov. 2018 in operation).

2 **HyStock**
Conversion of solar energy in hydrogen via 1 MW electrolysis (July 2019 in operation).

3 **Hydrohub**
1 MW electrolysis test centre.

4 **Hydrogen refuelling stations and buses**
Development mobility market in North of the Netherlands.

5 **H_2- projekt Haurup**
Hydrogen from wind energy injected in the gas grid.

6 **Hydrogen district Hoogeveen**
Construction of 80 new houses with a hydrogen boiler.

7 **GZI Next**
2-4 MW hydrogen plant and fuelling station.

8 **Djewels**
20-60 MW electrolyser, including transport.

9 **Element 1**
100 MW power-to-gas pilot from offshore wind energy.

10 **HyNetherlands**
100 MW electrolyser, including transport.

11 **Northern H2 Infra**
Start of Backbone in the Northern part of the Netherlands. Connecting Eemshaven, Delfzijl, Emmen and caverns.

2024 2025 2026 2027 2028 2029 2030

12 **Hydrogen storage**
Development of hydrogen salt caverns in Zuidwending.

13 **H2M**
Conversion of hydrogen and CCS, first turbine power plant on hydrogen.

14 **CUST**
100 MW electrolyser.

15 **Hydrogen district Stad aan 't Haringvliet**
Conversion of 600 houses with a hydrogen boiler.

16 **North Sea Wind Farm**
Possible development of onshore electrolysis, including transport.

17 **Backbone**
National hydrogen transport network connecting the main industrial clusters and other users and interconnections via existing infrastructure.

18 **NortH2**
Development of offshore wind power and on-shore electrolysis, including transport.

19 **H-vision**
Large-scale switch to hydrogen for power plants, refinery and chemical industry including CCS.

20 **HyNetherlands**
Upscaling electrolyser to 750 MW-1 GW, including transport.

21 **H2M phase 2**
All three turbines power plant on hydrogen and CCS power for >2 million homes.

22 **CUST**
Further deployment hydrogen and CO_2 net-work in the Delta region.

23 **North Sea Wind Power Hub**
Isles where power from offshore wind farms is partially converted into hydrogen connected to shore via pipelines.