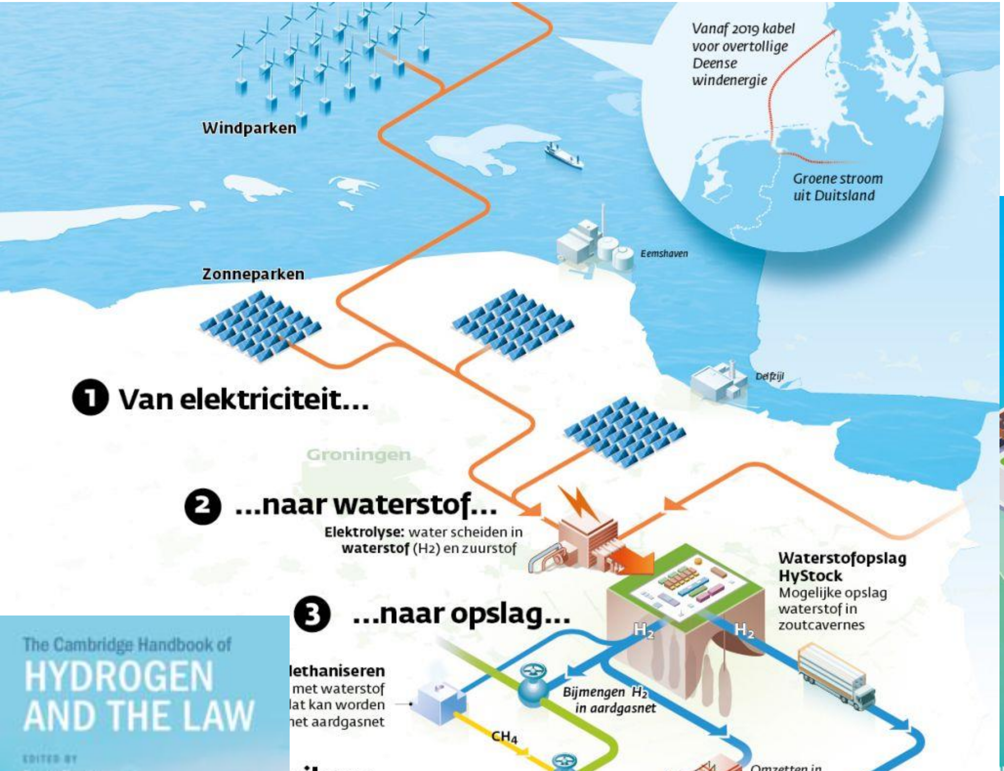
groen vermogen nl | Innovation engine for the green hydrogen economy

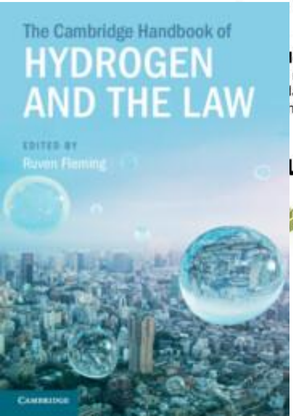
GVNL WP7 Hy-SUCCES

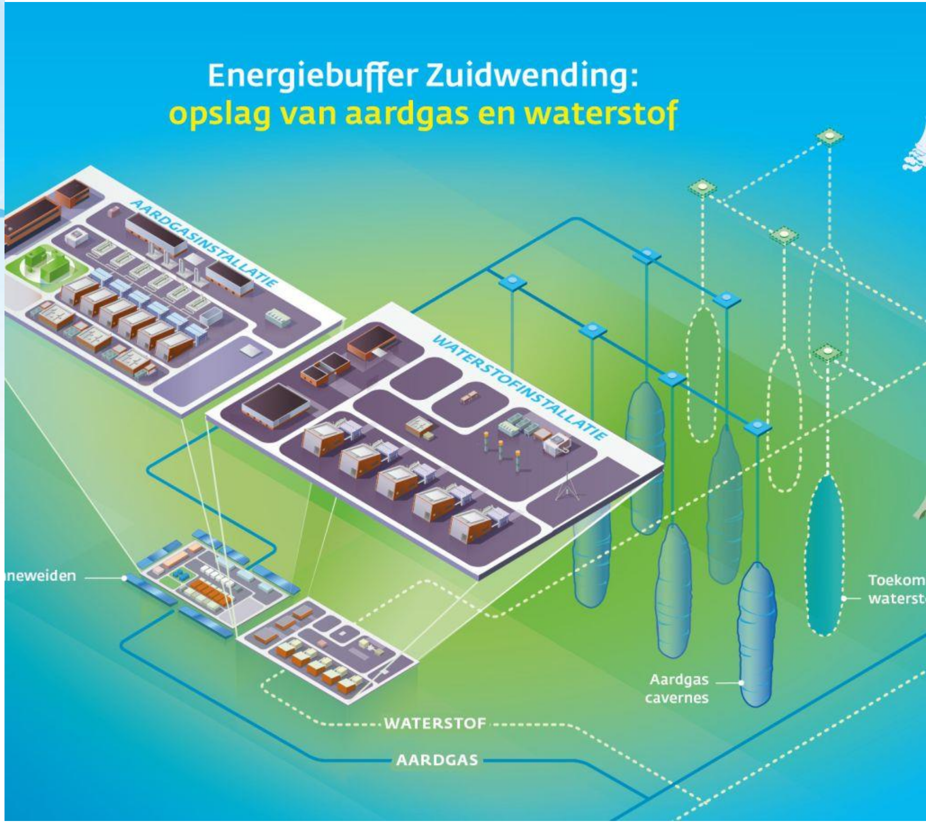
Social, **U**ser a**CC**eptable, **E**conomically **S**ustainable **S**ystems for hydrogen

Prof. Dr. Lorenzo Squintani
University of Groningen

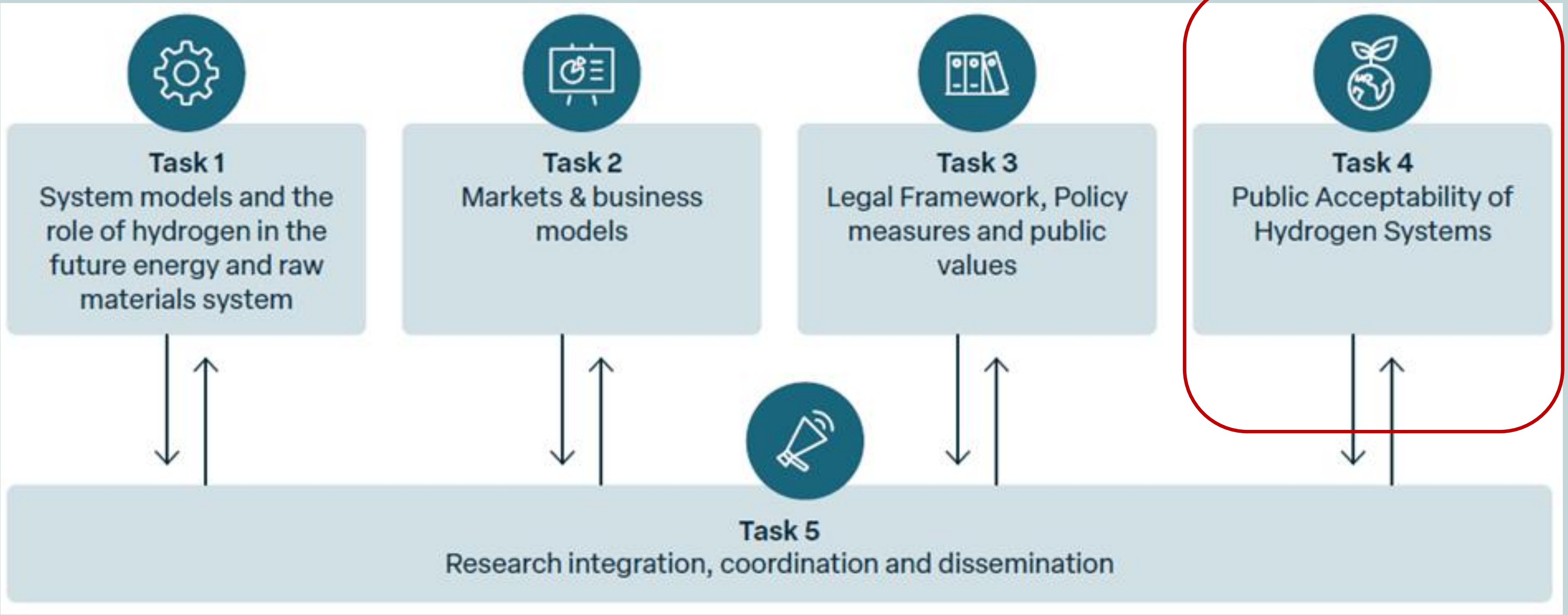
Innovation engine for the green hydrogen economy







The work in Hy-SUCCES is structured around five Tasks



What influences sustainable behaviour?

- 1) Psychological factors:
  - Altruistic values;
  - Egoistic values;
  - Environmental values;
  - Hedonic Values.

	Opposed to my values	Not important			Important			Very important	Of supreme importance
EQUALITY: equal opportunity for all	-1	0	1	2	3	4	5	6	7
RESPECTING THE EARTH: harmony with other species	-1	0	1	2	3	4	5	6	7
SOCIAL POWER: control over others, dominance	-1	0	1	2	3	4	5	6	7
PLEASURE: joy, gratification of desires	-1	0	1	2	3	4	5	6	7
UNITY WITH NATURE: fitting into nature	-1	0	1	2	3	4	5	6	7
A WORLD AT PEACE: free of war and conflict	-1	0	1	2	3	4	5	6	7
WEALTH: material possessions, money	-1	0	1	2	3	4	5	6	7
AUTHORITY: the right to lead or command	-1	0	1	2	3	4	5	6	7
SOCIAL JUSTICE: correcting injustice, care for the weak	-1	0	1	2	3	4	5	6	7
ENJOYING LIFE: enjoying food, sex, leisure, etc.	-1	0	1	2	3	4	5	6	7
PROTECTING THE ENVIRONMENT: preserving nature	-1	0	1	2	3	4	5	6	7

What influences sustainable behaviour?

- 1) Psychological factors:
  - Altruistic values;
  - Egoistic values;
  - Environmental values;
  - Hedonic Values.
- 2) Demographic factors:
  - Age;
  - Gender;
  - Studies;
  - Incomes;
  - Etc....
- 3) Contextual factors:
  - History of the community

What we know about acceptability of hydrogen projects?

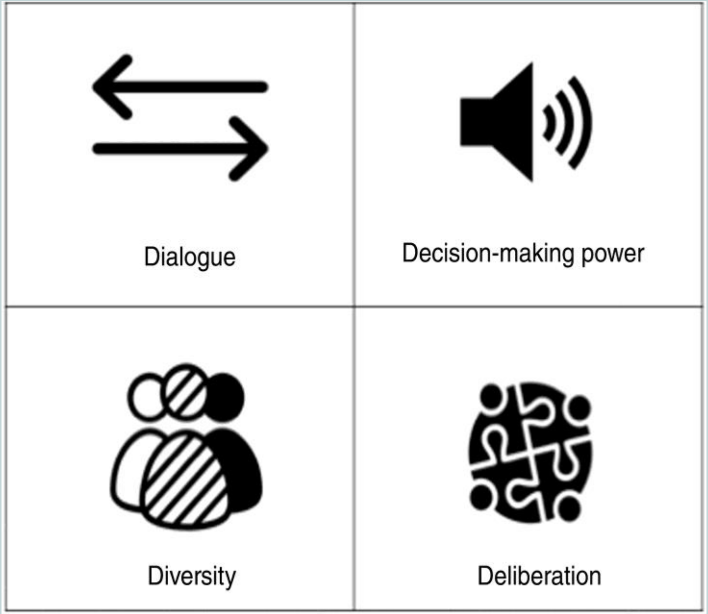
- Only few quantitative studies on acceptability of hydrogen in general:
  - Percentage agreement: The Netherlands (3), Germany (3), Taiwan (1)
  - Means agreement: Australia (1); part of UK (1)
    - IMP: support mostly for green hydrogen
- Even fewer quantitative studies with 'the public' about pipelines and storage:
  - Germany, Japan, France

Factors influencing acceptability:

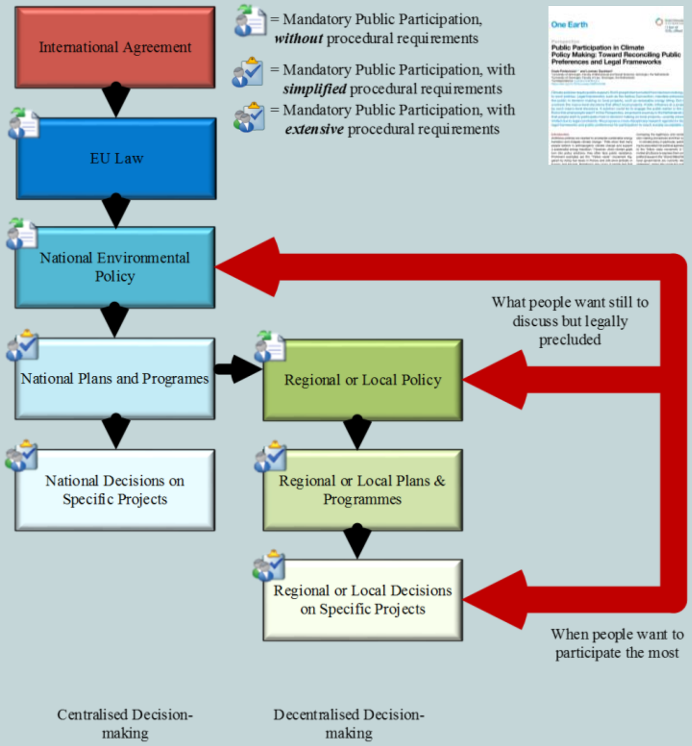
- Limited overview!
- So far, six different factors:
  - 1) safety,
  - 2) climate change mitigation,
  - 3) affordability,
  - 4) reliability,
  - 5) accessibility, and
  - 6) job creation.
- trust in government beneficial for acceptability of green hydrogen Häußermann et al (2023).
- perceived utility of hydrogen correlated with acceptability of hydrogen in salt caverns (France).
- **NONE OF THE ABOVE IS CONCLUSIVE!**

The role of public participation

- Public participation can improve acceptability



WIREs Climate Change, Volume: 13, Issue: 1, First published: 16 November 2021, DOI: (10.1002/wcc.749)



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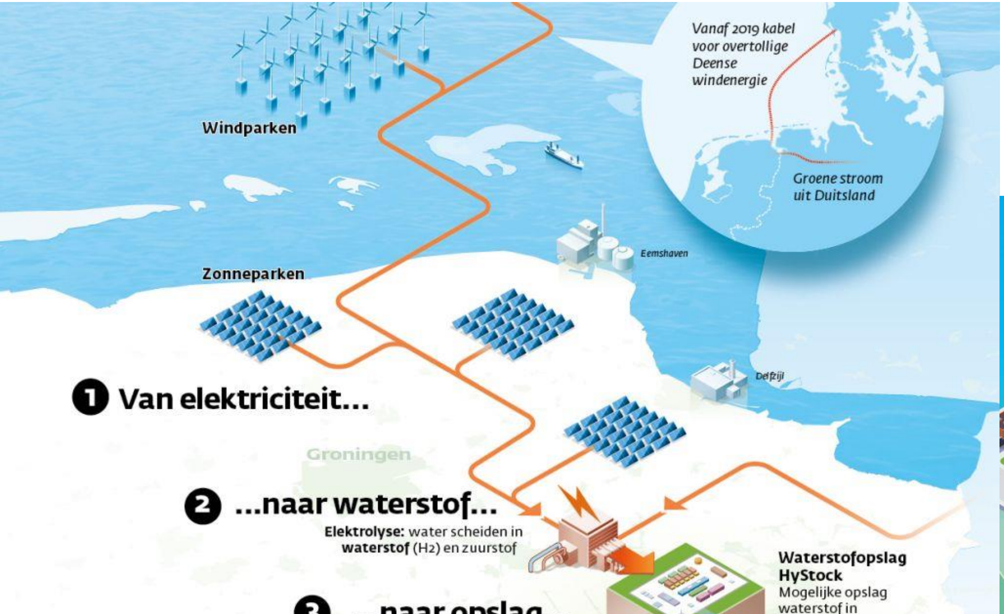
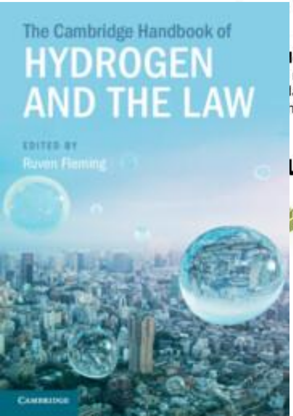
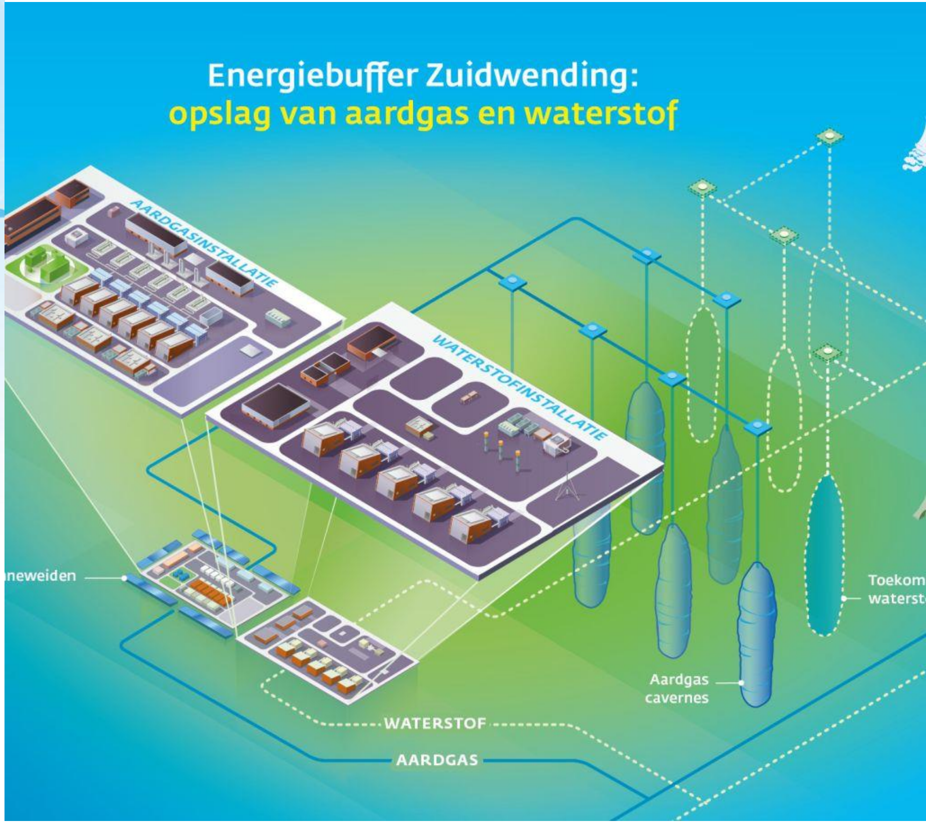






How did the public participated?

- National level:
  - Dutch National Hydrogen Programme 2022-2025 — **No PP**
  - Dutch Hydrogen Roadmap — **No PP**
    - Zuidwending location mentioned
  - Dutch Programme for the Energy Infrastructure
    - Preference for storage is depleted salt cavers — **PP**
    - In portance of PP due to Groningen earthquakes
- Regional level:
  - Climate Agenda of the Province of Groningen 2030 — **No PP**
  - Regional Energy Strategy 1.0 and 2.0 — **No PP**
  - Investment Plan on Hydrogen 2020 — **No PP**
- Project level:
  - Permitting for Zuidwending Energy Buffer — **PP**
  - Participatieplan EnergyStork — **PP, but not for location!**

Task 4 – Public Acceptability of Hydrogen Systems:

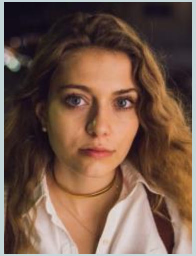
- Mapping and assessing the socio-cultural factors that influence the social acceptance and thus possibly the feasibility of various hydrogen applications.

- Research into various decision-making processes and how they can contribute to a fair direction of the Dutch hydrogen transition and influence the social acceptance of the hydrogen transition.

Marit Sprenkeling

Adelaida Patrasc-Lungu

Goda Perlaviciute



Alba Forns

Ruben Rehage

WP2 HyTROS

THERESA

Innovation engine for the green hydrogen economy

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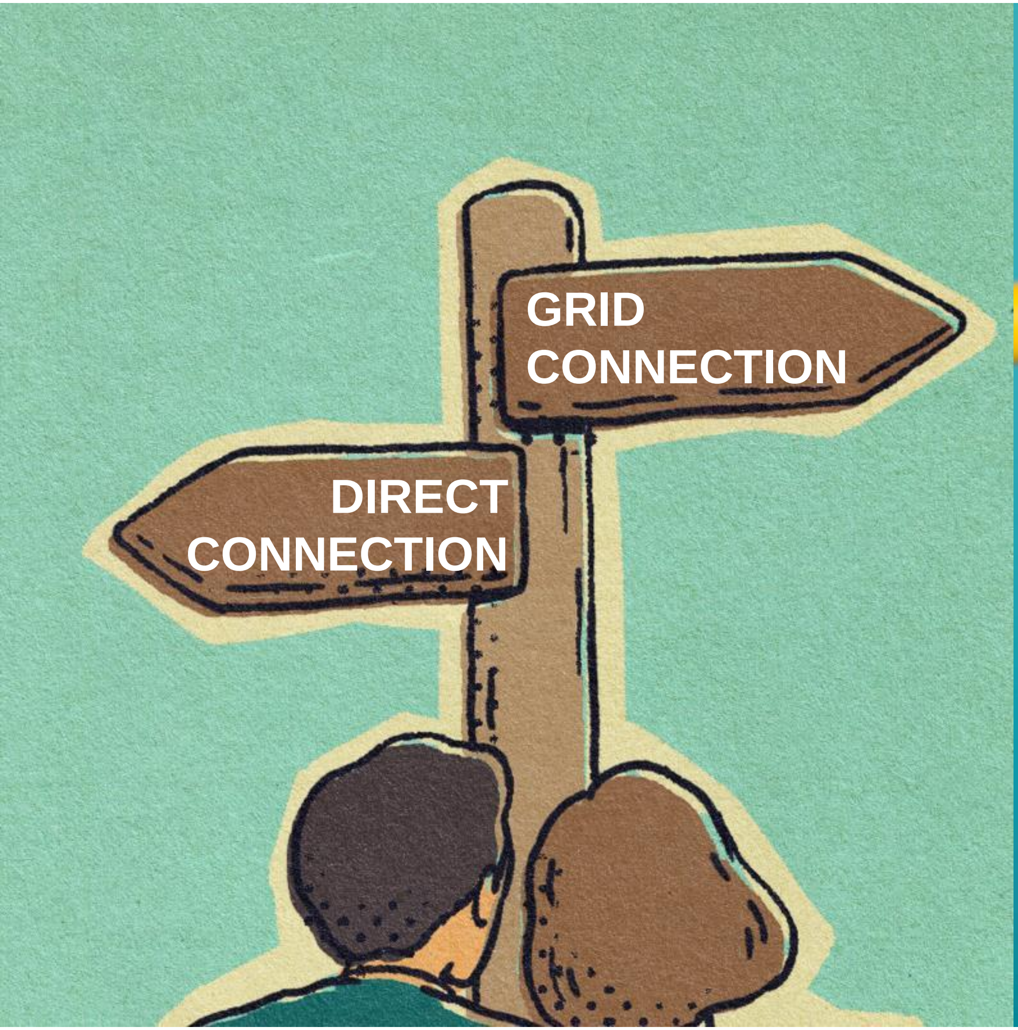
HOW TO GET THE POWER?

MR. DIRK KUIKEN 13-03-2025


GRID CONNECTION
DIRECT CONNECTION



NON-
RENEWABLE
RENEWABLE

WHAT IS RENEWABLE POWER?

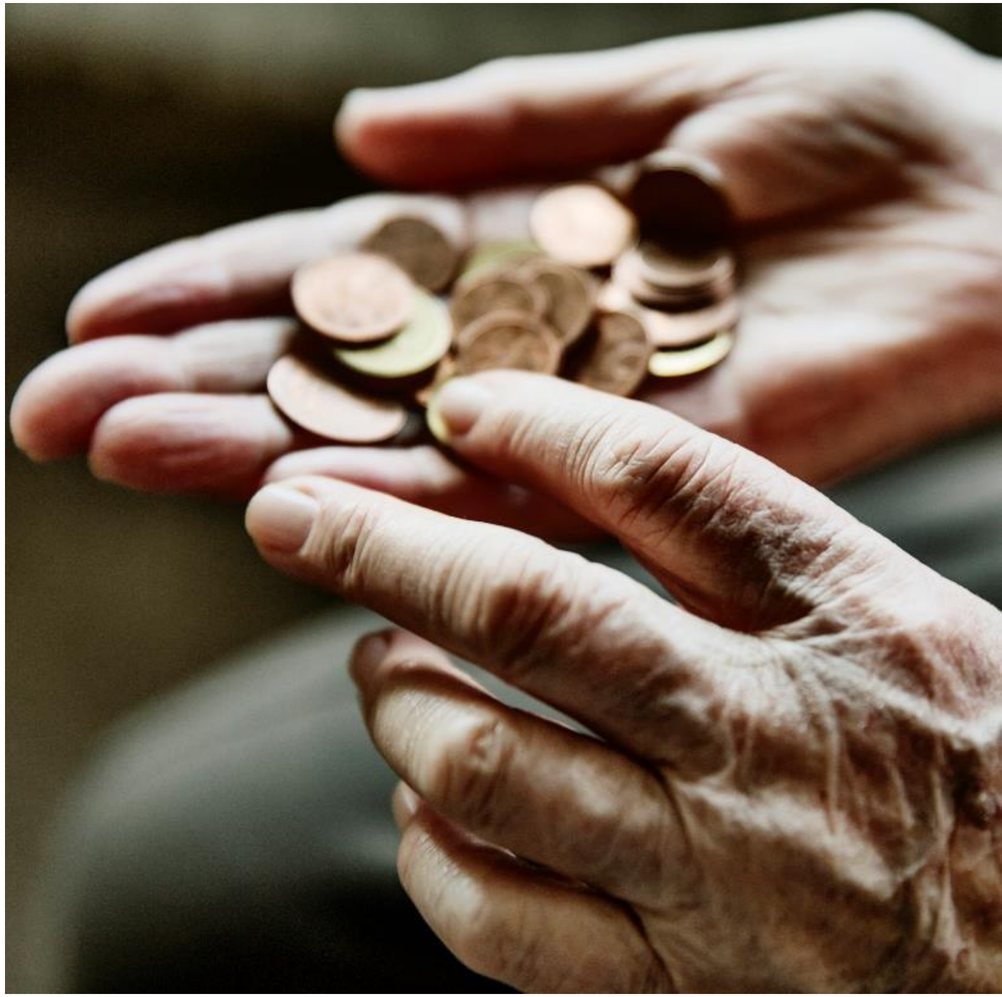
<u>Wind</u>
<u>Solar (thermal/PV)</u>
geothermal
osmotic
ambient
Tide, wave and other ocean
hydropower
biogas

WHEN DOES IT COUNT?

- **Direct connection: only using renewable installation**
- **Grid connection**: (also) using renewable electricity 'from the grid', e.g.
  - If there is (almost) 'nothing but' renewable electricity in the grid
  - Temporal correlation
    - Produced within the same hour
  - Geographical correlation
    - Within the same bidding zone

WHEN DOES IT MATTER?

- **Always, but…**
- Subsidy requirements…
  - Subsidieregeling grootschalige productie volledig hernieuwbare waterstof via elektrolyse (OWE)
  - Delegated Act (EU): Commission Delegated Regulation (EU) 2023/1184

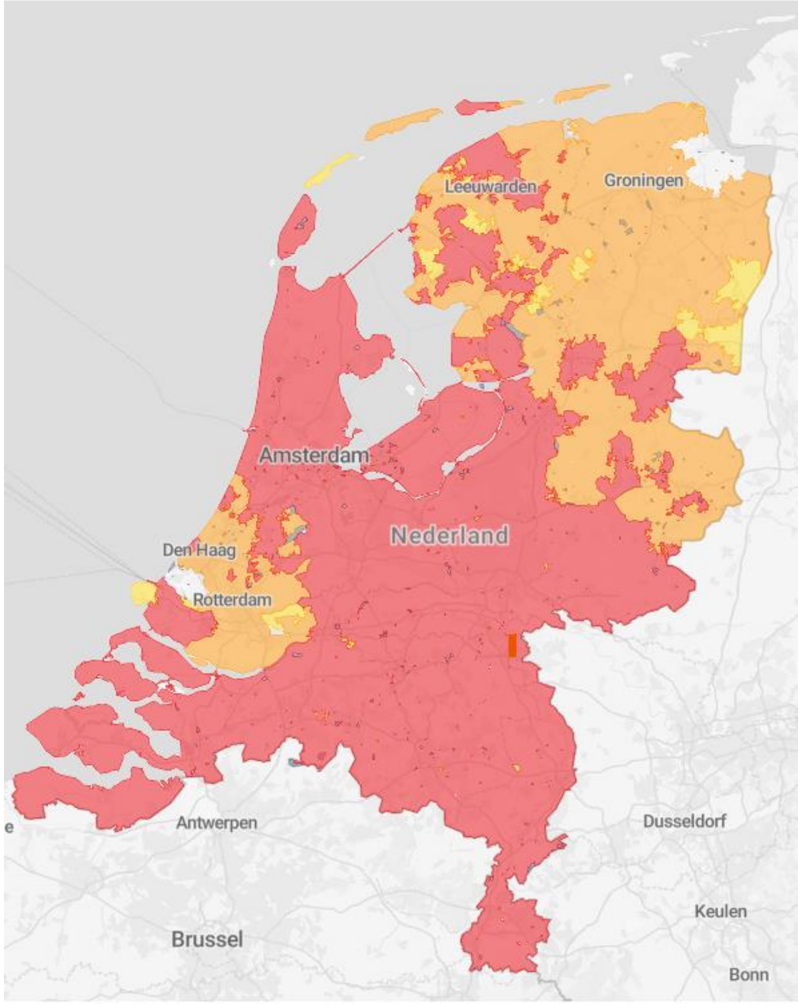


HOW TO GET A GRID CONNECTION?

- **(EU) right to access the electricity system**
  - **Not always. No capacity, no access.**
- **(NL) right to grid connection, right to transport capacity.**

However…

- Creating connections takes longer
- Expanding grid capacity is an immense task, many dependencies



CAN I GET TRANSPORT CAPACITY?

- Only when it is available…
- What if it is not?
  - *‘direct connection’…*
  - Congestion management
  - Social priority(?)
  - Cable pooling
  - Limited transport capacity (non-firm transport agreement)
  - Group transport agreement?

CONGESTION MANAGEMENT

- Capacity reduction agreement (only works *if* you have capacity)
- Redispatching (only works *if* you can dispatch)

= dependency on current users of the grid, they should reduce their use

CABLE POOLING

- Sharing a connection (and transport capacity)
  - Under conditions, 01/01/2026 also possible for ‘conversion’
    - >100kVA connections
    - Maximum of four ‘assets’
    - No grid-formation(!)

SAMEN WERKEN WE AAN EEN **BETROUWBARE EN DUURZAME ENERGIEVOORZIENING** VOOR VANDAAG ÉN VOOR DE TOEKOMST.

ENEXIS GROEP

EXPERIENCE FROM AN OPERATING PLANT

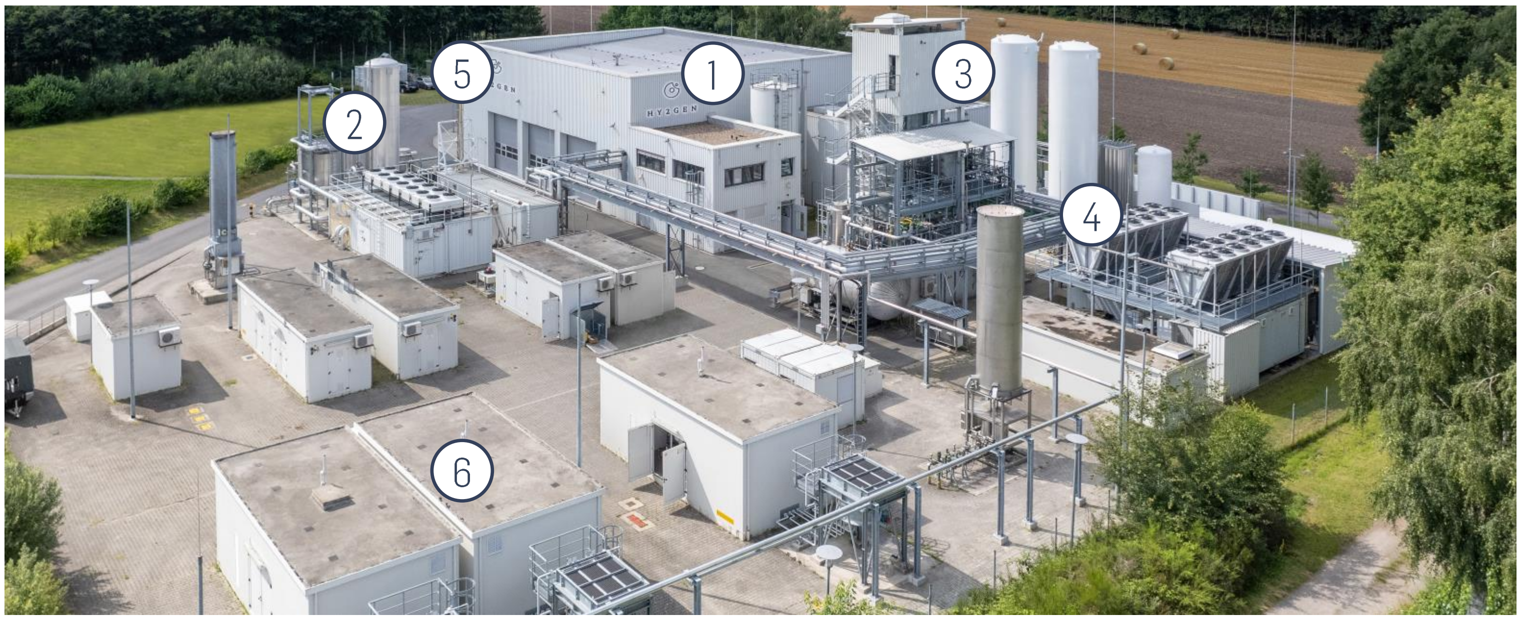
HY2GEN DEUTSCHLAND GMBH / HYDROGEN CROSS BORDER CONFERENCE

13.03.2025

HY2GEN

HY2GEN ATLANTIS

E-RNG POWER-TO-FUTURE PLANT



- The Werlte plant is the biggest industrial plant to convert green hydrogen from electrolysis combined with green CO2 into Renewable Natural Gas (e RNG).
- Research capabilities include more than 1,000 sensors in the plant, allowing continuous monitoring and evaluation of the 10 years operation

1


Three electrolyzers

2

Amine scrubber

3

Methanisation tower

4

Liquefier and e-LNG filling station

5

Hydrogen filling station

6

Grid injection plant

HY2GEN ATLANTIS

E-RNG POWER-TO-FUTURE PLANT

PRODUCT SOLD 100%

- 100% of the plant's capacity is commercially sold
- Flushing of new hydrogen trailers possible
- Injection of e-RNG into regional gas-pipeline

GREEN TECHNOLOGY CAMPUS WERLTE

- Largest e-RNG plant in operation in the world
- Supply of renewable hydrogen for first commercial SAF plant in Germany
- Biogas plant to deliver CO_2 for Methanisation

FUTURE EXTENSIONS

- Production capacity will be doubled until 2026

ATLANTIS HEAT-MANAGEMENT SYSTEM ALLOWS

- > 90% Heat Recovery from Methanisation, covering 100% use of the Carbon Capture Amine Plant
- Thus increase efficiency of Methanisation to over 90%!

HY2GEN ATLANTIS

THREE ELECTROLYSERS

1

TECHNICAL DATA

- **In operation since 2013**
- Type: alkaline, non-pressurized
- Electrolyte: Potassium Hydroxide (KOH)
- Number of stacks: three
- Total capacity: 1,300 Nm^3/h[1] hydrogen
- Power: 2 MW each, six MW total
- Current: max. 9,600 Ampere (A)
- Voltage: 220 Volt (V)
- Operation temperature: 75°C
- Heat: 500 kilowatt (kW) at 65°C

USAGE

- production of renewable hyrogen by use of water and renewable green energy

Notes: 1) Abbreviation for Normal Meter Cubes per Hour

HY2GEN ATLANTIS

METHANISATION TOWER

3

TECHNICAL DATA

- Reactor type: tube & shell
- Process: catalytic methanation Capacity: 1,300 Nm^3/h hydrogen
- Output: 350 Nm^3/h e-RNG
- Product quality: 94% CH4 (methane), 3% hydrogen, 3% CO2
- Cooling system: molten salt
- Heat recovery: max. 600 kW at 170°C

USAGE

- The produced green hydrogen can be further processed to methane by adding CO2 and a process called catalytic methanisation

HY2GEN ATLANTIS

HYDROGEN FILLING STATION

5

TECHNICAL DATA

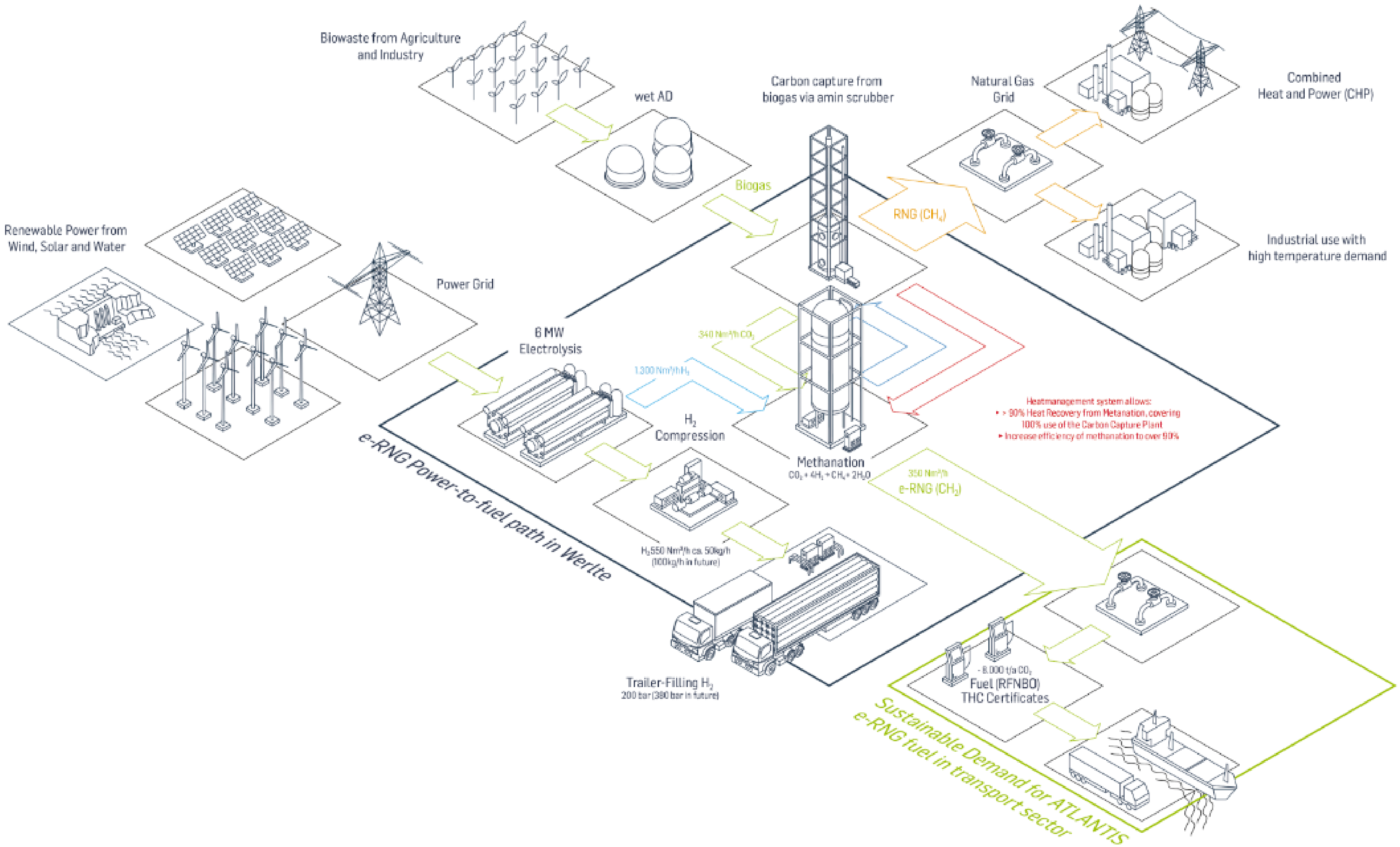
- Type: ionic compressors
- Start: August 2018
- Pressure: 200 up to 700 bar after compression
- Pressure at trailer: 200-300 bar
- Capacity: 50 kg/h
- Hydrogen quality: 5.0 / 99.999% purity

USAGE

- Delivery of renewable hydrogen to industrial customers/partners

HY2GEN ATLANTIS -. THE WORLD'S LARGEST GREEN POWER-TO-METHANE PLANT

E-RNG POWER-TO-FUEL PATH IN WERLTE



SUMMARY

HYDROGEN & E-FUELS

CERTAIN DEMAND FOR HYDROGEN

- Material Use: Refineries, steel industry
  - >630.000 t / a in Germany only (>7GW electrolyzer capacity)
- Feedstock for e-Fuels in hard to abate sectors (aviation, shipping)

POTENTIAL DEMAND FOR HYDROGEN

- Public transport as alternative to e-Mobility
- Decarbonization of additional industrial sectors
- Power Supply & Storage

E-FUELS WILL SUBSTITUTE FOSSIL EQUIVALENTS

- Aviation: SAF will replace fossil kerosine, especially on long-distance flights (starting 2025!)
- Shipping: eNH3, eMeOH, eLNG (e-RNG)
- Chemical Industry: eNH3, eMeOH
- Agriculture: eNH3

HYDROGEN LOCATION GERMANY

- First hydrogen pipeline network in the world
- Diverse EU, national and regional subsidies
- Hydrogen friendly legislation (acceleration of permitting process)
- Largest industrial market in Europe and very likely also largest offtake market in Europe for hydrogen

GERMANY WILL REMAIN AN ENERGY IMPORTING COUNTRY, BUT…

- A certain percentage of needs will be produced in Germany
- until pipeline connections from Denmark, Norway, Spain or the Netherlands are in place, national production is needed to cover first hydrogen needs
- eFuels can already today be shipped from international locations, produced with best LCOE in the world

POWER PURCHASE AGREEMENTS

PPA FOR ELECTROLYSIS TO PRODUCE RFNBO-COMPLIANT PRODUCTS

1. **Introduction to PPAs & RFNBO**
    - Importance of PPAs – Securing renewable power for electrolysis, differences from standard PPAs
    - RFNBO & Regulations – Key EU criteria, impact on project viability

2. **Challenges in Securing PPAs**
    - Availability & Duration – Long-term supply constraints, limited market options
    - Price Volatility – Impact on costs, strategies for risk mitigation

3. **Commercial & Pricing Considerations**
    - Electricity Costs – Fixed vs. market-based pricing, grid fees impact
    - Cost Optimization – Hybrid models, demand-side flexibility

POWER PURCHASE AGREEMENTS

PPA FOR ELECTROLYSIS TO PRODUCE RFNBO-COMPLIANT PRODUCTS

4. Regulatory Compliance & RFNBO Criteria

- Key Criteria – Additionality, temporal & geographic correlation
- EU Regulations – Legal & financial impact, certification requirements

5. PPA Negotiation & Structuring

- Key Terms – Contract length, pricing, off-take volumes
- Risk Allocation – Managing surplus energy

6. Future Outlook

- Market Trends – PPA price evolution, policy impact (bidding zone split)
- Innovative Models – Storage integration, flexible electrolysis

THANK YOU.

Statkraft

Agenda

Hydrogen Cross Border Conference | 13-03-2025 | Yusuf Kilic - Statkraft


Our Vision
Renew the way the world is powered
We act responsibly
We grow together
We make an impact

Statkraft: Europa’s grootste producent van duurzame stroom

Climate-friendly power generation

62 TWh

97%

Renewable energy

More than

3 million

energy related contracts traded per year*

More than

6 000

employees in over 20 countries

372

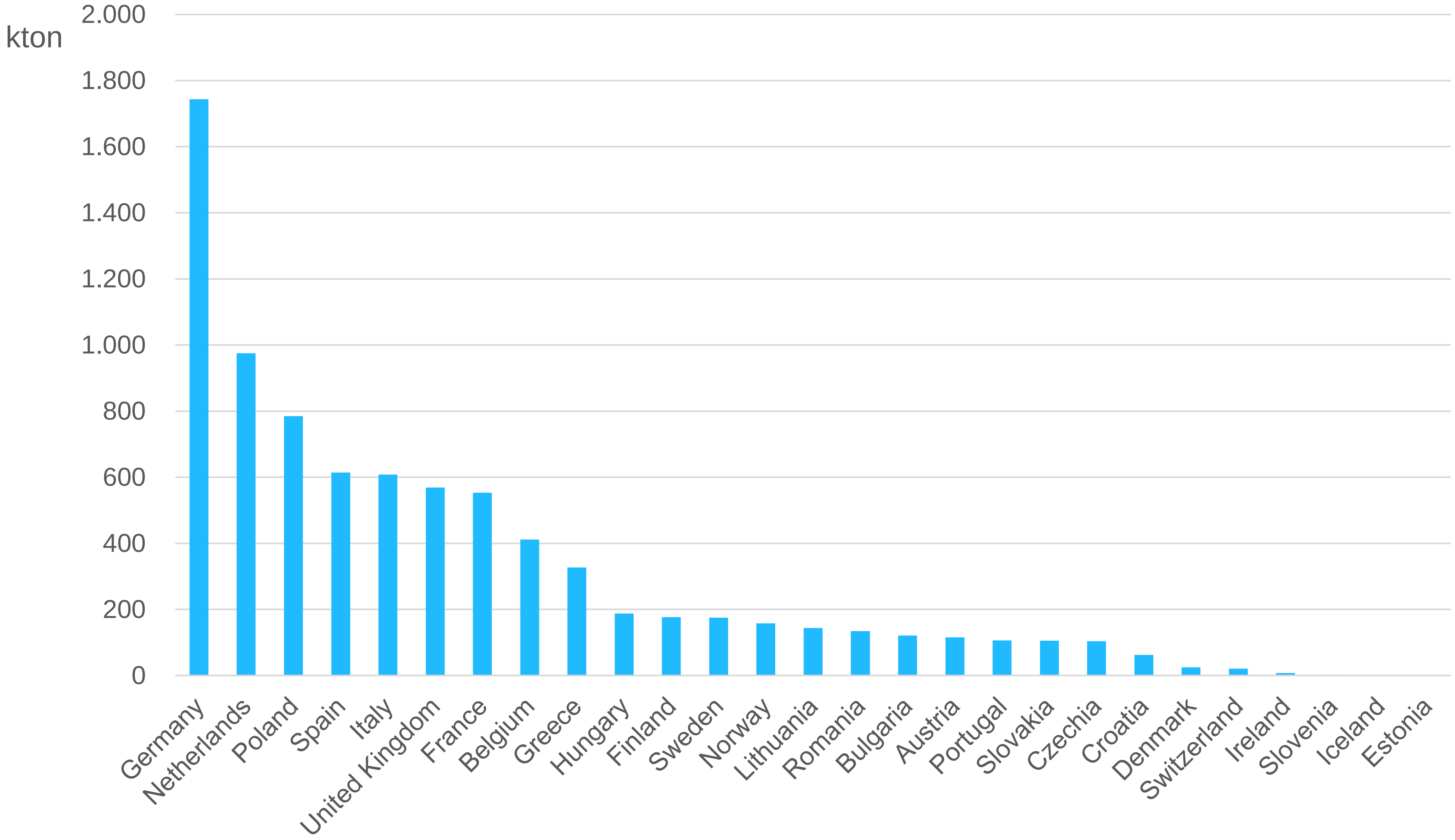
power plants around the world

100%

Norwegian state-owned

*Based on 2021 figures

HCBC: Combineert Europa's twee grootste producenten van waterstof



Source: European Hydrogen Observatory, 2022

Wat is waterstof?

Wat is waterstof?

Overvloedig, maar komt niet veel voor in de natuur

Waterstof is het meest voorkomende element in het heelal, maar niet in zijn pure vorm beschikbaar op aarde

Komt voor in water en aardgas

Er zijn chemische processen nodig om waterstof in zuivere vorm te extraheren, waarbij CO2 of O2 als bijproduct wordt uitgestoten

Schoon alternatief

Geen CO2-uitstoot bij verbranding of gebruik in een brandstofcel, er wordt alleen water geproduceerd

Licht

Waterstof is 8 keer lichter dan aardgas en 14 keer lichter dan lucht

Veelzijdig

Het kan worden gebruikt voor transport, warmte- en elektriciteitsopwekking of als grondstof voor chemicaliën, staal en synthetische brandstoffen

Ontvlambaar

Waterstof heeft een veel groter ontvlambaarheidsbereik dan andere brandstoffen en heeft slechts een kleine hoeveelheid energie nodig om te ontbranden

Hoge energiedichtheid per kilo…

Waterstof heeft 3 keer meer energie-inhoud per kg dan benzine en 2,5 keer meer dan aardgas

… maar zeer lage energiedichtheid per m3

H2 heeft 4 keer minder energie-inhoud per volume-eenheid dan benzine en 3 keer minder dan aardgas

Waterstof waardeketen

H2 te duur ← → Geen echte alternatieven voor H2

Inputs | **Productie** | **Transport, Opslag en Conversie** | **Toepassing**

Inputs

- H2O – Water + Duurzame energie
- Fossiele brandstoffen (kool, gas)

Productie

- **'Groene H2'** – Electrolyse
- **'Grijze H2'** – SMR or Coal gasification
- **'Blauwe H2'** – SMR or ATR with carbon capture

Transport, Opslag en Conversie

Pure H2
- Compressie (CH2)
- Liquefactie (LH2)

Transformatie
- Ammoniak (NH3)
- Synthetische brandstoffen (e-methanol, e-kerosine)

Distributie
- Scheepvaart
- Vrachtwagens
- Pijpleiding

Opslag
- Tanks (LH2, CH2, NH3 or fuels)
- Ondergronds (H2 in caves, wells)
- Metal Hydrides

Toepassing

Grondstoffen
- Meststoffen
- Olie raffinage*
- Chemische grondstof
- IJzer en staal

Stroom / Warmte
- Industriële Hi-temp Heat
- Huishoudelijke verwarming
- Stroomproductie / Balanceren

Transport
- Schepen
- Luchtvaart
- Langeafstands wegtransport
- Wegtransport over korte afstanden

Statkraft

*Wat kan Nederland van Duitsland leren? Waarom is er een verschil in de correctiefactor?

Source: based on Hydrogen Ladder 5.0 by Liebreich

Technologische Keuze

Wat is nodig om een juiste technologie te kiezen?

Feiten

- Oppervlakte ≈ 2,3 hectare
- Verwacht vermogen: Fase 1 ~ 6 MW | Fase 2 ~ 150 MW
- Verwachte duurzame bron: Offshore wind + wellicht zon
- Productie: Fase 1 ~ 400-600 t/jr | Fase 2 ~ 15.000 t/jr
    - Fase 1 is vergelijkbaar met het jaarlijks verbruik van 10-20 binnenvaartschepen
    - Bij fase 2 gaat het ongeveer om 450 schepen
    - Fase 2 draagt bij aan 3,75% van het landelijk doel
- Start bouwfase: Fase 1 = Q4 2027 | Fase 2 = Q2 2028

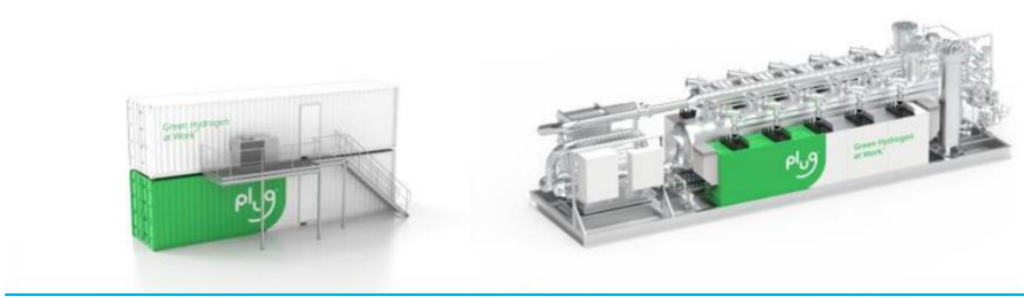
Opmerkingen

- Fase 1 is een relatief klein project;
- Als input wordt gebruik gemaakt van fluctuerende energiebronnen;
- Fase 1 richt zich op zwaar transport en maritieme sector als afzet, dit heeft impact op de puurheid en druk van de waterstof.

Welke technologie is de betere voor deze toepassing?

Proton Exchange Membrane Elektrolyse

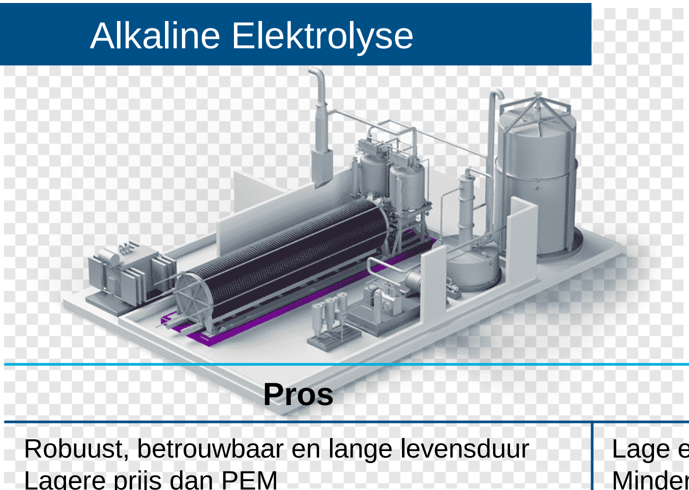
Image Source: Plug



Pros	Cons
Hoge efficiëntie Snelle respons op fluctuaties in de input	Hoge prijs Schaarste Iridium verwacht rond 2035

Alkaline Elektrolyse

Image source: Nel



Pros	Cons
Robuust, betrouwbaar en lange levensduur Lagere prijs dan PEM	Lage efficiëntie Minder flexibel en minder geschikt fluctuaties

Solid Oxide Elektrolyse

Image Source: Mitsubishi Heavy Industries

Pros	Cons
Zeer hoge efficiëntie Kans om te combineren met HT processen	Zeer lage TRL Zeer hoge prijs

Anion Exchange Membrane

Image source: Enapter

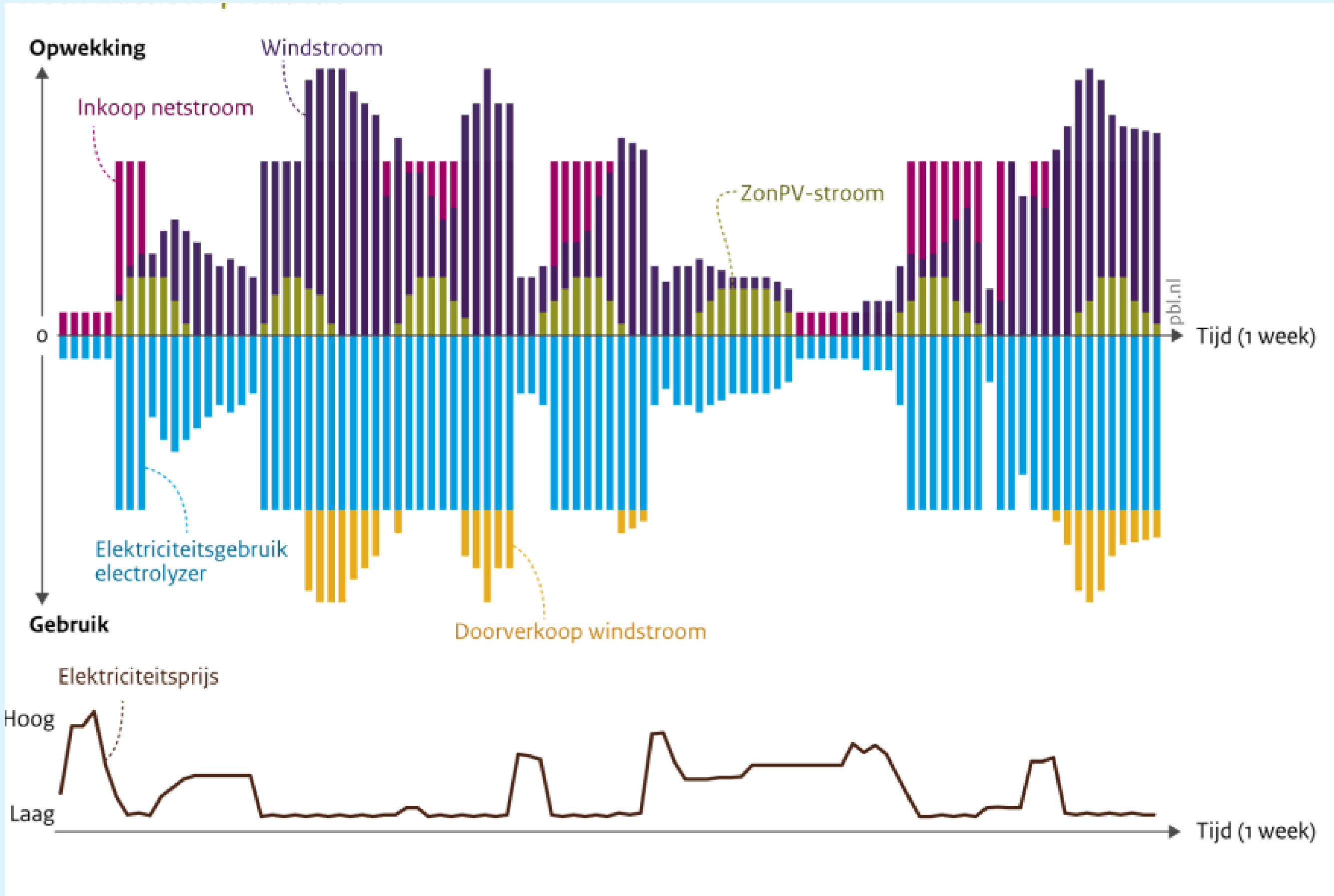
Pros	Cons
Hoge efficiëntie, lagere kosten Snelle respons op fluctuaties in de input	Lage TRL Minder stabiel → hogere Opex

Statkraft

Markt ontwikkelingen

Wat is nodig om competitief groene waterstof te kunnen produceren?

- Lagere Capex en economy of scale
- Beschikbaarheid van voldoende groene stroom
- Aansluitkosten elektriciteitsnet
- Beschikbaarheid van offtake/opslag om (kosten) efficiënt te kunnen produceren
- H2 puurheid en leveringsdruk
- Transport en distributie
- Financiële instrumenten om het gat tussen fossiel en groen te dichten



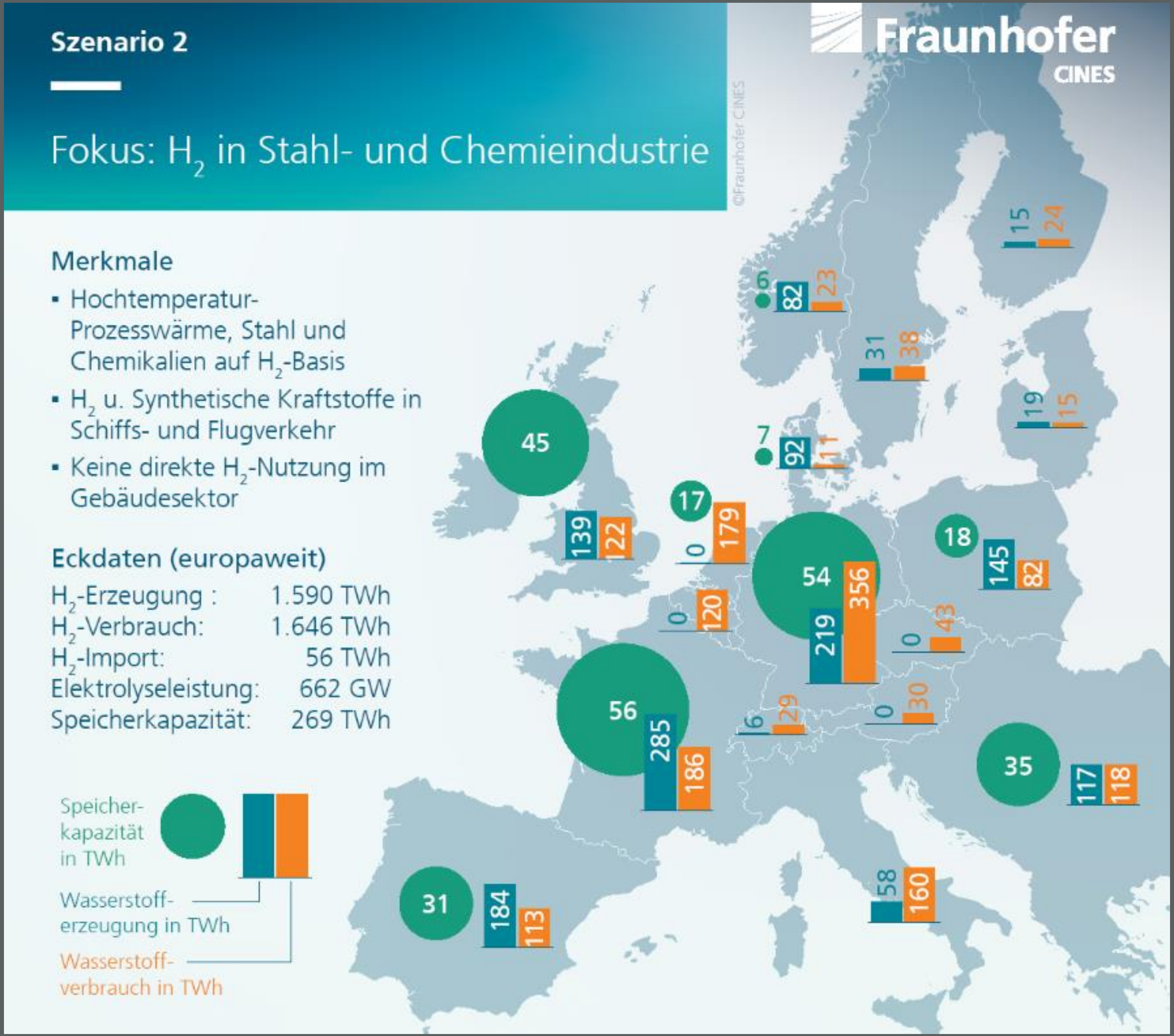
Bron: pbl rapport: pbl-2025-groene-waterstof-de-praktische-uitdagingen-tussen-droom-en-werkelijkheid

Bedankt!

Large scale hydrogen storage:

Why? Where? When?

Zuidbroek, 13.03.2025



EWE

key takeaways:

1. domestic upstream (Europe!) can dominate in supply
2. storage capacities will be essential
3. systemic costs will be crucial

Clean Hydrogen Coastline

a project by EWE

North-West Germany: becoming a central pillar of the EU hydrogen economy

1 Renewable Energies

vast capacities of wind (offshore & onshore) and enormous further potential

2 Initial Pipelines

free capacities in transport and distribution networks due to market reconsolidation

3 Established Import Infrastructures

current relevance and future-proof

4 Cavern Storages

most important gas storage sites inside EU

5 Central EU Region

infrastructural connection to regional as well as national offtaker hotspots

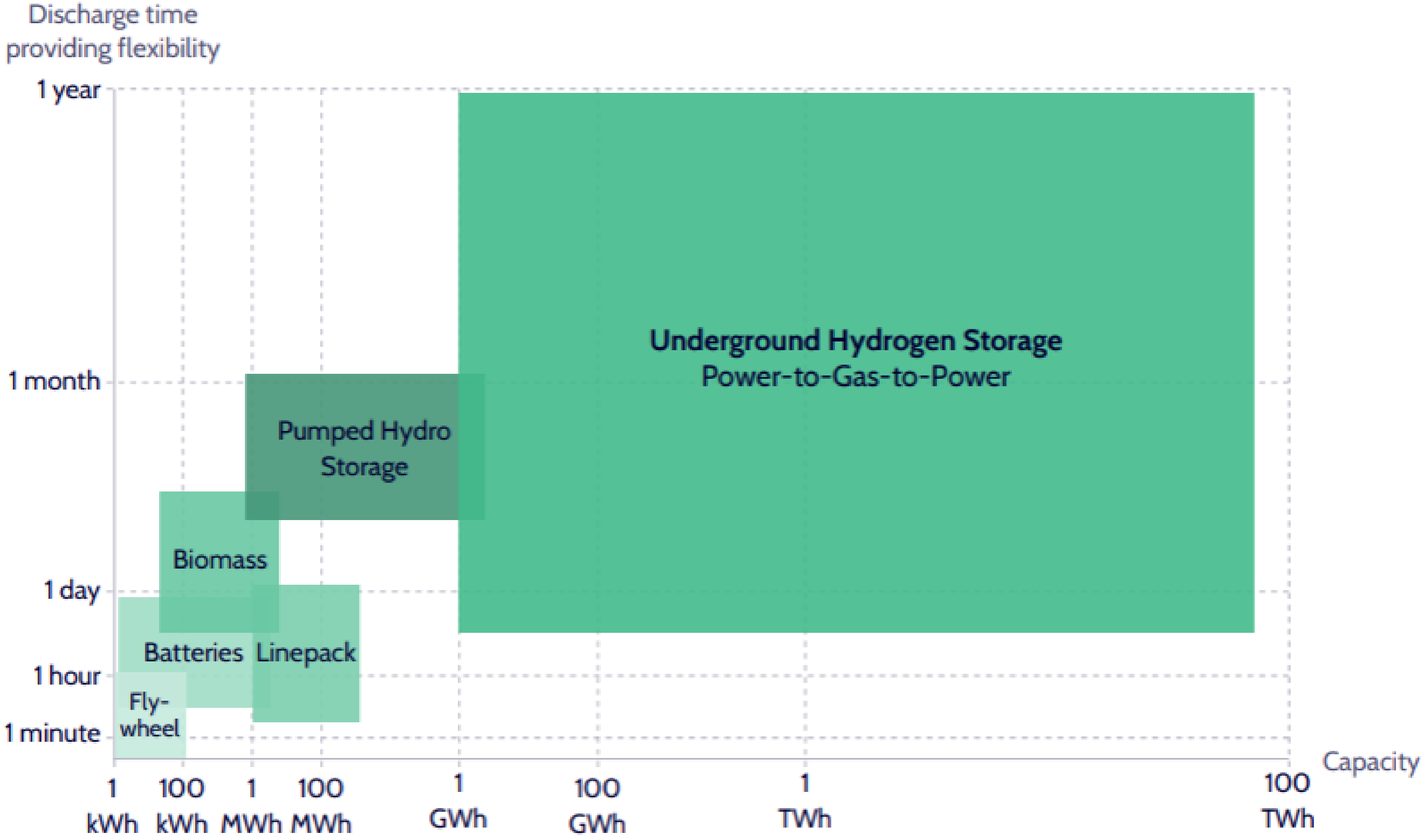
6 Investment Focus

above average investment opportunieties in the region

source: NDR

pictures: EWE AG / swb AG / IMAGO

Comparison of flexibility solutions in terms of discharge time in which they provide the according capacity[17,18,19]



Attention: Intervals on the capacity axis are exponential i.e. UHS can have almost 1 million times the capacity of a battery.

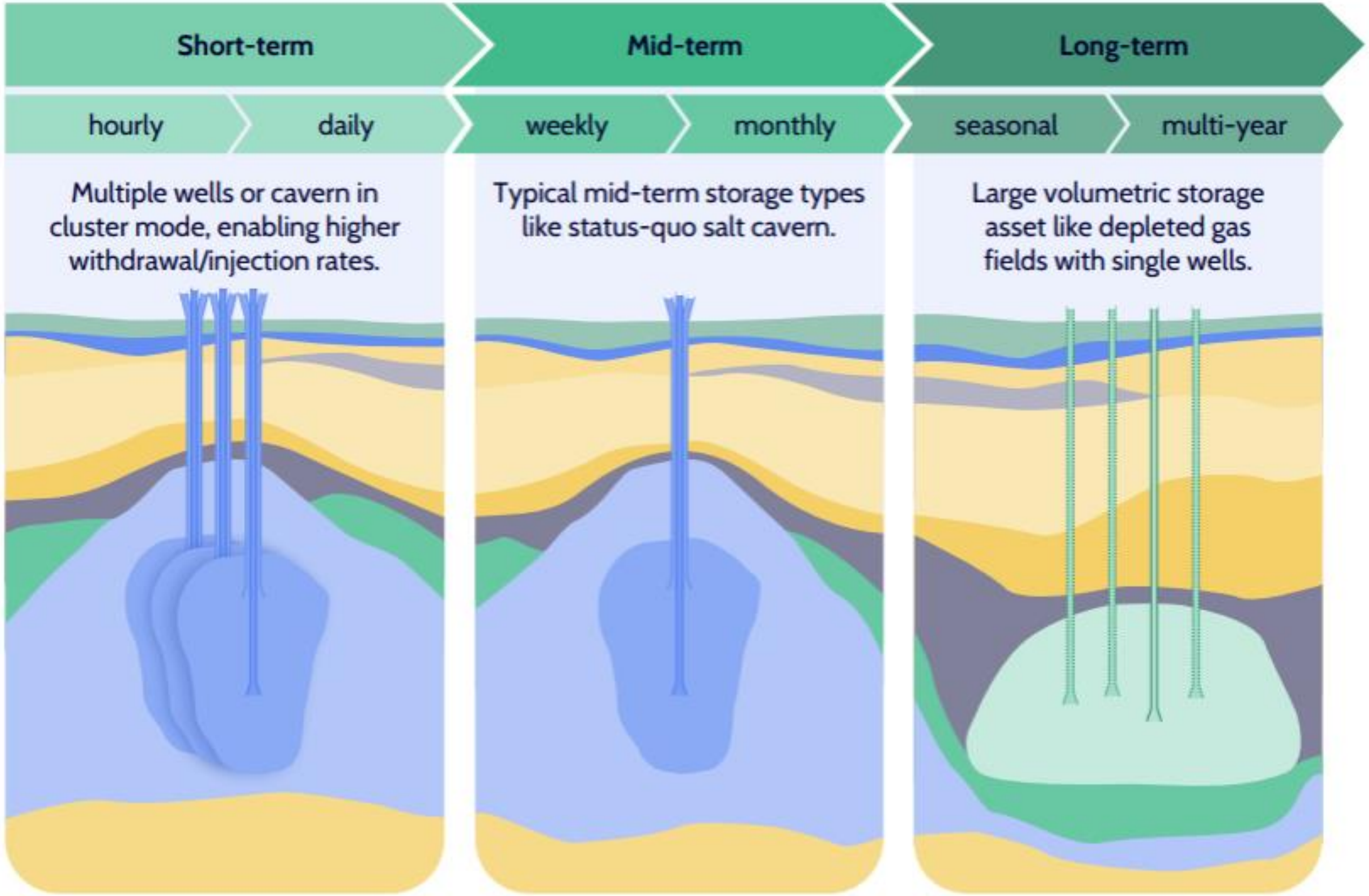
EWE

key takeaways:

1. vast capacities only provided by UHS
2. flexibility in time and capacity unrivaled
3. building on existing assets brings significant advantages

Potential setup of UHS to serve the full flexibility range by efficient well placement to increase withdrawal and injection rates

Note: All technologies can be utilised for various flexibility ranges (e.g. salt caverns can provide long-term storage). Drawings are not representative of true size, depleted gas fields are significantly larger.



key takeaways:

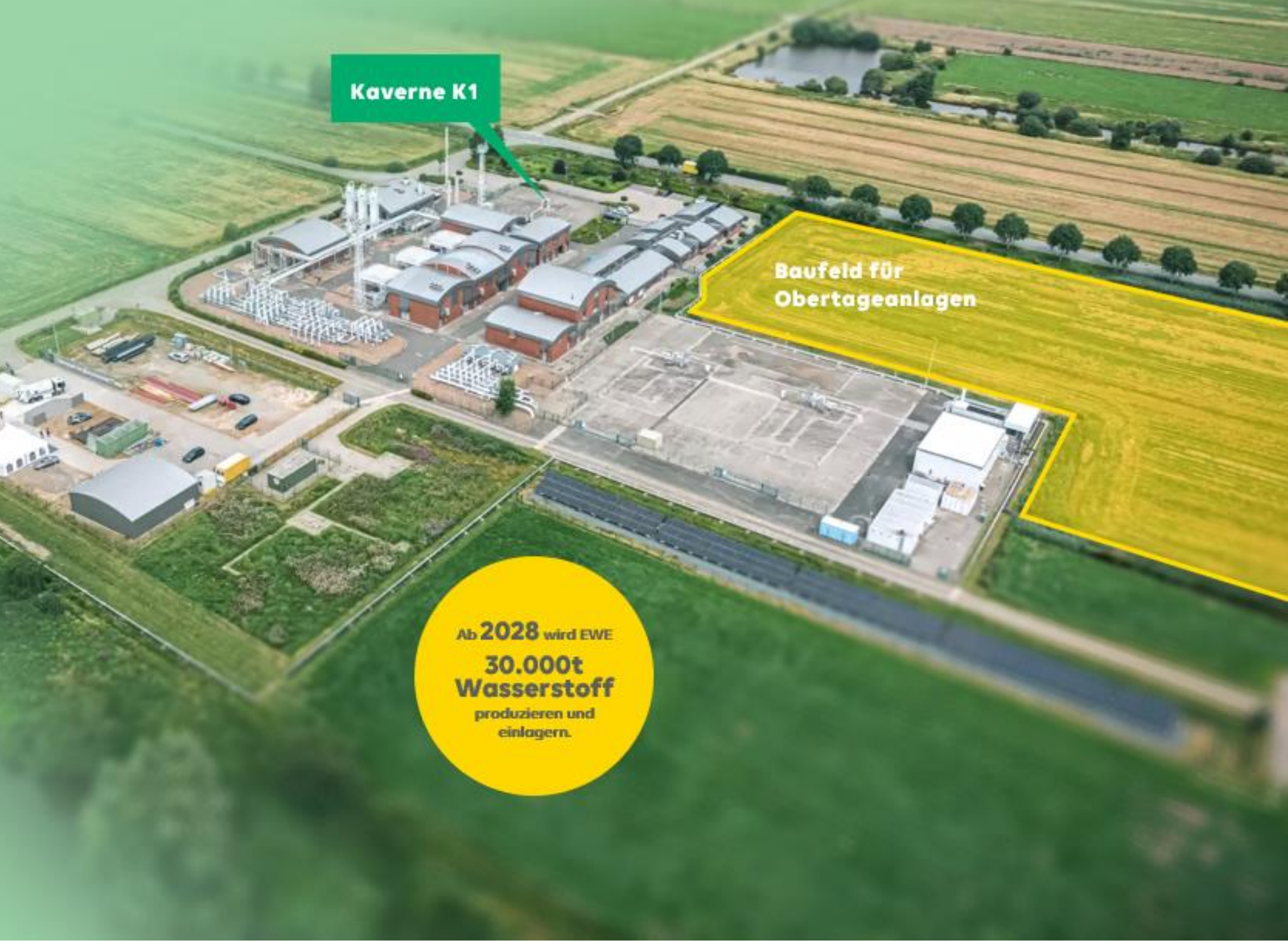
1. UHS can provide any market requirements
2. hydrogen fired power plants would demand peak rates
3. substanatial capacities and experiences in Northwest-Europe

Clean Hydrogen Coastline

Ein Projekt von EWE

CHC Speicher Huntorf

- **Erster kommerziell** genutzter **H2 Speicher** in **Deutschland** am **Standort Huntorf**
- **Projektziel: Umwidmung** einer **Erdgas Speicherkaverne** zur **Nutzung** mit **H2**
- Projekt in **08.2022** gestartet



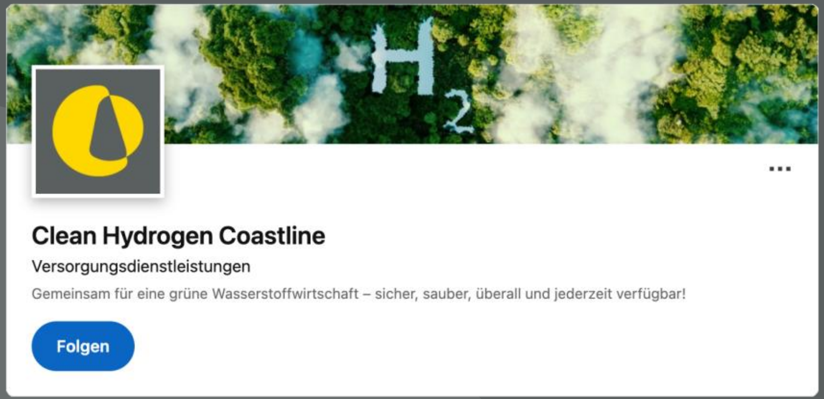
Aktueller Stand

- **Baufeld** wurde **festgelegt**
- **Genehmigungsprozess** ist mit der **Bergbehörde** abgestimmt
- **Kaverne K1** ist geflutet und auf **Wasserstoff** getestet

Clean Hydrogen Coastline

Ein Projekt von EWE

Wir informieren fortlaufend über die Projekte:



crossing borders in energy

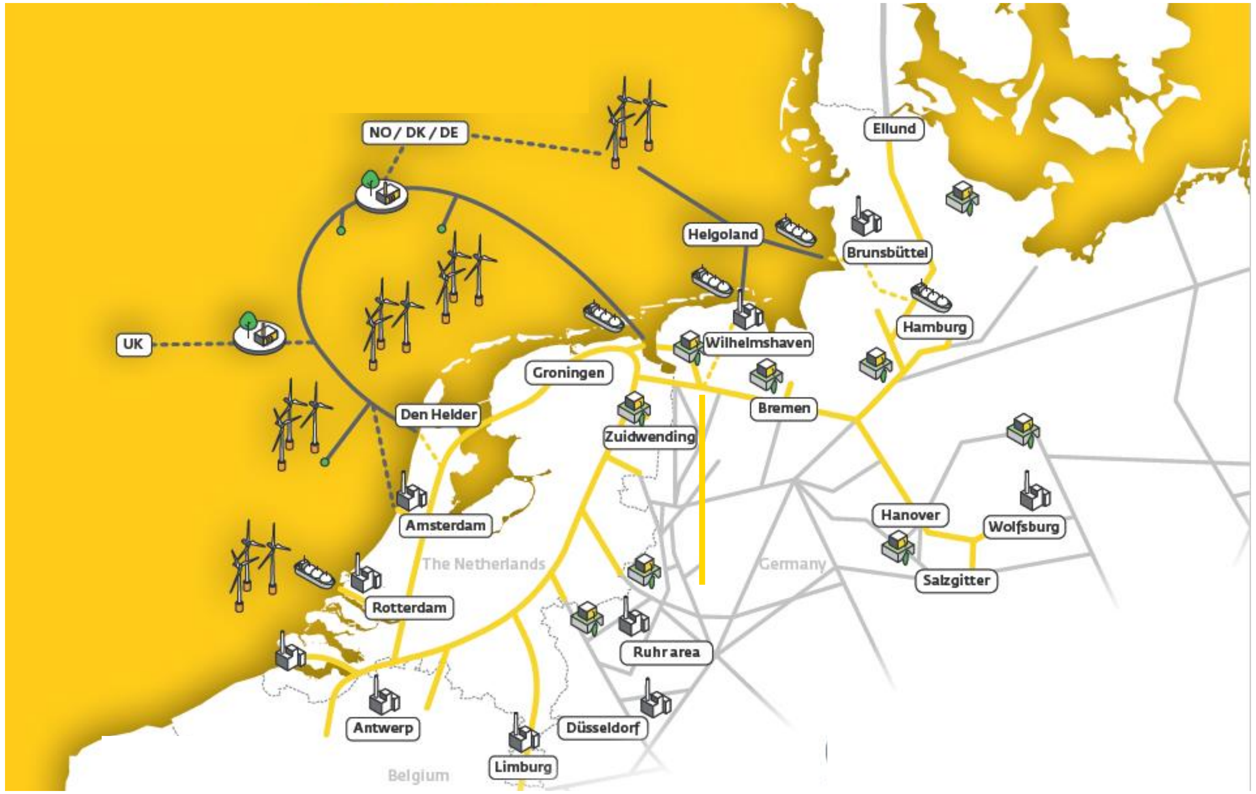
Hydrogen transport & storage

Hydrogen Cross Border Conference

13-03-2024 Bert Kiewiet

Hydrogen Infrastructure – Gasunie's Focus

Gasunie helps developing the hydrogen market by connecting supply to demand and realizing the required infrastructure early in The Netherlands and part of Germany.



What is Gasunie's contribution?

- Open Access infrastructure
- Cooperation of electrons and molecules
- Cooperation with partners

Gasunie's hydrogen scope:

- **Transport onshore/offshore**
- **Import**
- **Storage**

Hydrogen transport


NO / DK / DE
UK
Helgoland
Ellund
Brunsbüttel
Hamburg
Wilhelmshaven
Groningen
Bremen
Den Helder
Zuidwending
Amsterdam
The Netherlands
Germany
Hanover
Wolfsburg
Salzgitter
Rotterdam
Ruhr area
Antwerp
Düsseldorf
Limburg
Belgium

gasunie
crossing borders in energy

Hydrogen infrastructure - Repurposing of Existing Assets

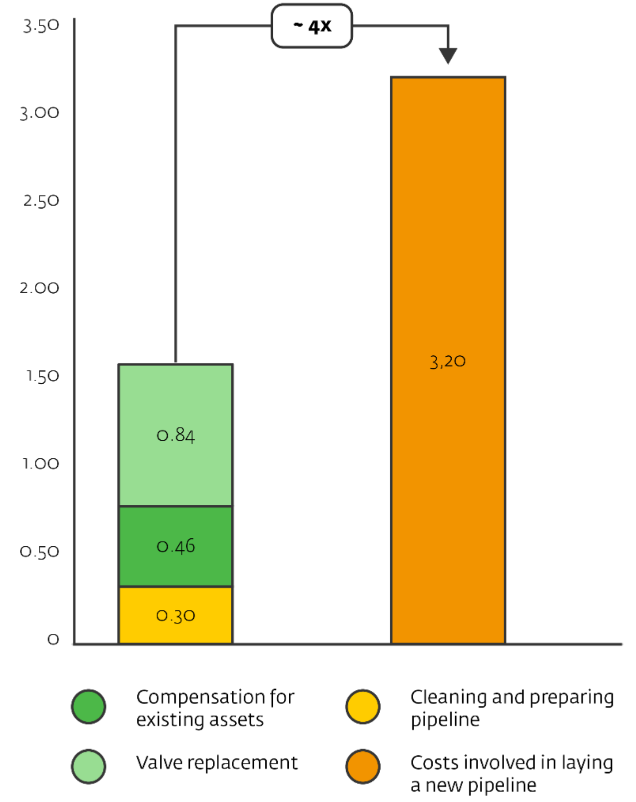
Repurposing existing natural gas assets: cost efficient and timely solution.

The rationale for repurposing of existing assets:

1 **Costs**
Investments for refurbishing lower compared to new built.

2 **Time**
Project turnaround faster.

3 **Impact**
Repurposing existing pipelines minimizes societal/environmental impact



Source: HyWay27 report - www.hyway27.nl

Fase 1: Rotterdam (2026)

Fase 2: Industrieclusters aan de kust (in of voor 2030)

hynetwork

Fase 3: Verbinden (2031-2033)

Waterstofnetwerk Nederland
Mogelijke uitbreiding van het waterstofnetwerk
Industrie
Import
Waterstofopslag (zoutcaverne)
Grensovergang

Waterstofnetwerk Nederland

Waterstofnetwerk Nederland

Mogelijke uitbreiding van het waterstofnetwerk

Industrie

Import

Waterstofopslag (zoutcaverne)

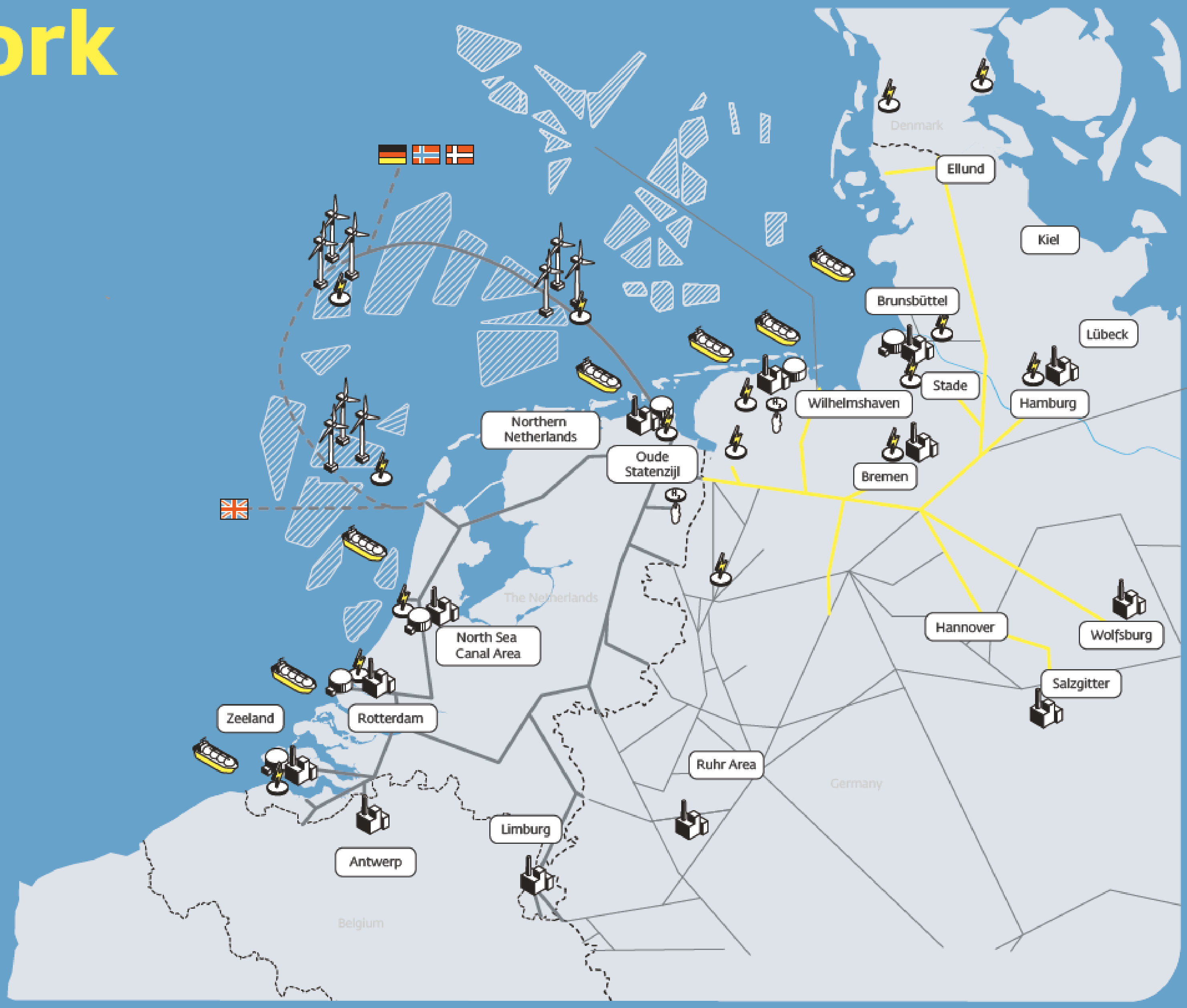
Grensovergang

hynetwork

Hydrogen network Hyperlink

Legend

- Dutch Hydrogen Network
- German Hydrogen Network (part of Kernnetz)
- Possible hydrogen pipelines
- Industry cluster
- Import
- Wind region
- Offshore wind farm
- Electrolyser
- Storage (salt cavern)
- Import terminal



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gasunie

Hydrogen infrastructure - Repurposing of Existing Assets

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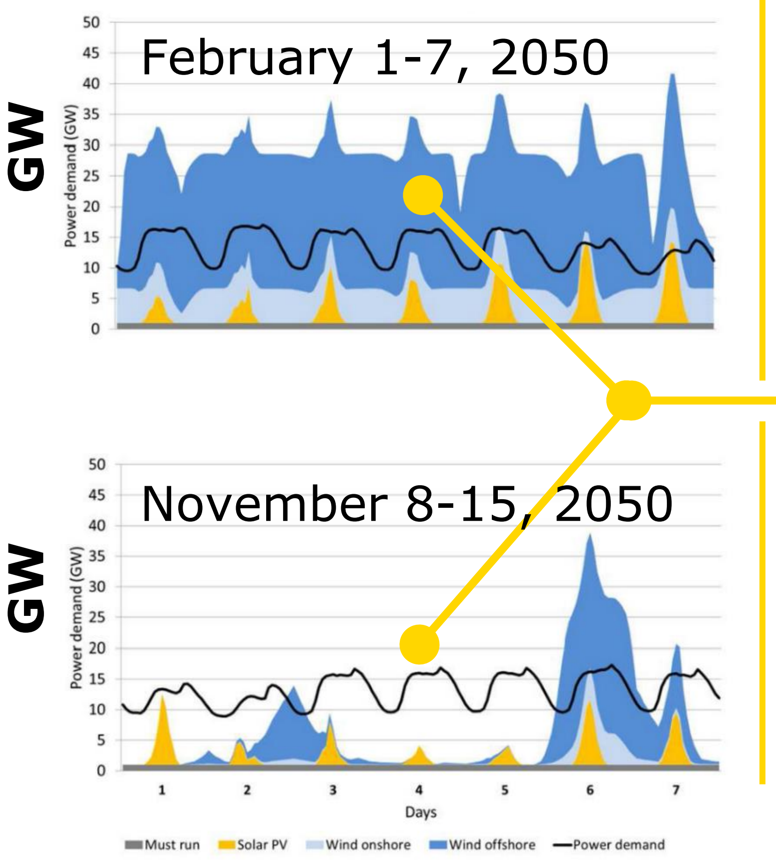
UPDATE:

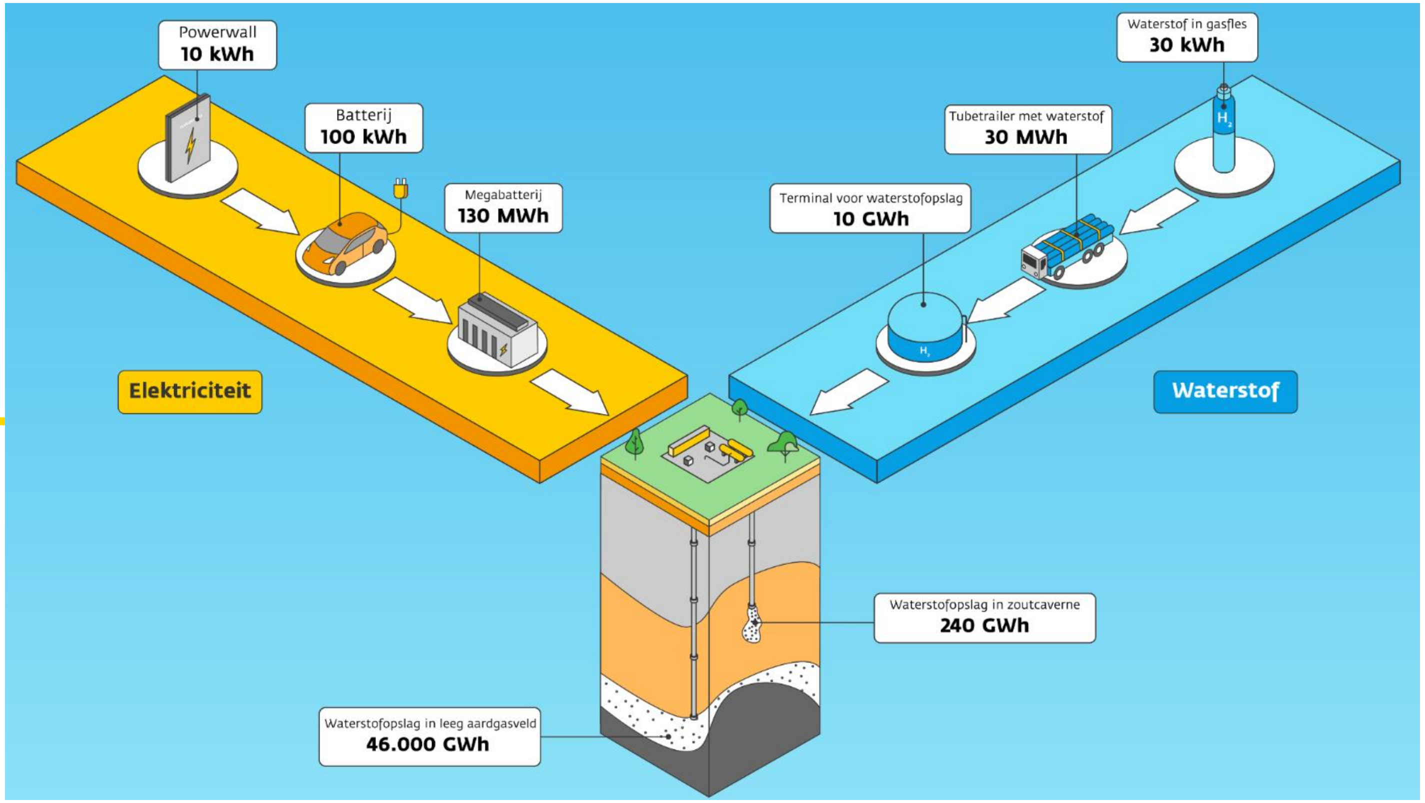
- Also **offshore** we are actively pursuing **repurposing**.
- For the first offshore electrolyser project we are currently assessing the use of an existing offshore pipeline.
- **Gasunie** and **Petrogas** signed an **LoI** towards this end.

Storage

Energy Transition – Jointly Balancing the System

The future energy system needs multiple sources of flexibility to balance the networks. Underground storage in salt caverns is an essential, cost-effective option.



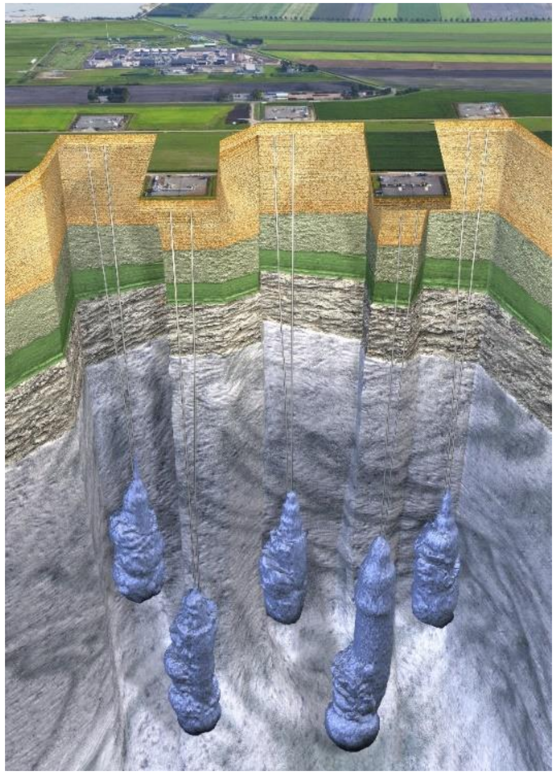


Energy Transition – Jointly Balancing the System

The future energy system needs multiple sources of flexibility to balance the networks. Underground storage in salt caverns is an essential, cost-effective option.

Gasunie's **HyStock** project:

- 4 salt caverns, 22-25 kton
- Technical testing completed
- Restart of commercial process.
- First cavern operational 2030/2031.



H2 Cast - Etzel:

- **H2 CA**vern **S**torage **T**ransition: conversion of existing caverns and facilities in Etzel.
- Extensive material/safety tests
- Gasunie as project partner focusses on **gas treatment** / **gas quality** aspects
- Project ongoing, caverns currently filled with H2.

crossing borders in energy

Implementation

From PowerPoint to Pipelines

October 2024 our King marked the official start of construction work NL

- We have **started** building!
- **Gasunie** in **Germany** has already made about **150 km** of natural gas pipeline **hydrogen-ready**.
- **Storage** pilot project H2CAST is under way. The first **hydrogen** has already been **injected**, and the **pilot installation** is expected to be ready for start-up by January **2026**.

From PowerPoint to Pipelines

When the going gets tough, the tough get going

- We are running a **marathon**, not a sprint.
- Yet, we have **no time to waste**.
- **Industry** benefits from reliability and predictability.
- Ways need to be found to **unlock demand**.
- **Pragmatism** needed.

Contact

Bert Kiewiet

Manager Business Development International

Bert.Kiewiet@Gasunie.nl

Using H_2 in Industry and SMEs: Barriers & Best Practices

Jelle Blekxtoon (FME), Tim Husmann (H2-Region Emsland)

FME POWERED BY DUTCH TECHNOLOGY

H2 REGION EMSLAND

Barriers: Renewable Hydrogen in Industry and SME

	Barriers & Obstacles
Production Capacity	- Only 5% of the targeted 4 GW electrolysis capacity for 2030 is under construction in Netherland, ~ 15 % of targeted 10 GW in Germany - Investment decisions are delayed due to uncertainty about demand and costs → available amounts of hydrogen still low
Demand Creation	- Future demand is uncertain, especially due to the competitive position of industries. - Weak incentives for transitioning from grey to green hydrogen. - Technological uncertainties: direct electrification vs. green hydrogen (options, energy savings, …)
Infrastructure	- Delay in the construction of the national hydrogen network and Delta Rhine Corridor. - No direct connections between storage locations and industrial clusters. - German Hydrogen Core-Network only slightly delayed, but connection towards non-industrial demand sites (distribution grids) challenging (no regulatory basis, high invests for single-site connections)
Costs Operation	- Green hydrogen production costs are 5 to 6 times higher than grey/blue hydrogen. - Rising investment and network costs increase uncertainty.
Costs Invest	- Fuel switch requires large investments in on-side infrastructure, components etc. - Large investments for connections to transport infrastucture
Import & International competition	- Import contracts lag behind ambitions; only one major project confirmed. - Delays in Pipelines from e.g. Spain & Africa
Legislation & Regulation	- Uncertainty about future European hydrogen obligations. - No uniform certification for green hydrogen imports

Hydrogen for Industry and SMEs: Demand creation

Source Study Deloitte Mobilising consumer demand for green hydrogen based products 2025

Policy measures & regulations

- Mandatory Blending
- CO2 pricing
- Certification & Standards

Financing

- Expanding SDE++
- EU subsidy utilisation
- Investing in Infrastructure

Demand Creation:

- Support industry clusters
- Government as Launching customer
- Long-term Hydrogen contracts (PPA)

Promoting Hydrogen in Transport & Mobility

- HRF expansion
- Synthetic fuels for shipping & aviation
- Hydrogen in heavy transport

26. Potential price increase and CO_2 decrease of selected green hydrogen-based end-products for – ILLUSTRATIVE EXAMPLES

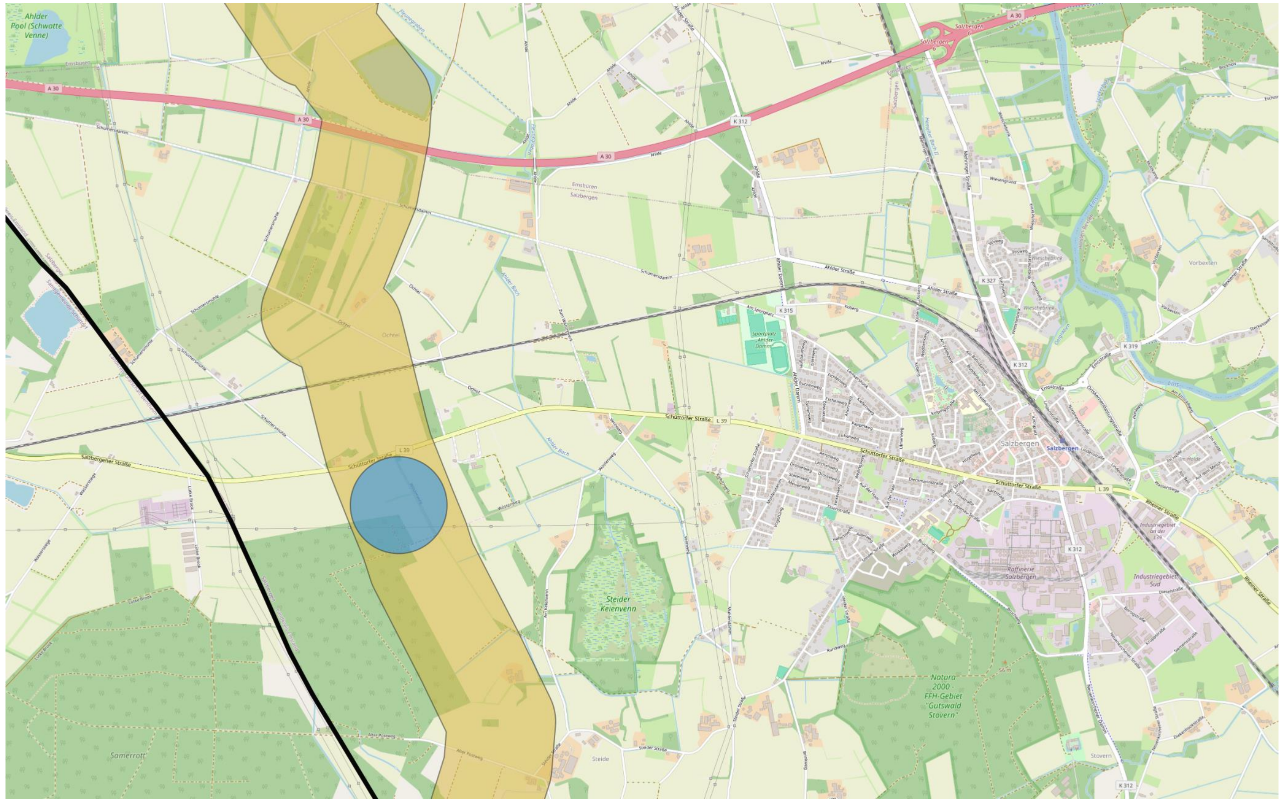
End-markets	End-products	Cost[1] increase 100% green H_2-based product	Production CO_2 abated[2]	% production CO_2 reduction from 1% cost increase[3]
Steel				
Construction	House	0.6%	26%	37
	Wind turbine (offshore)	1.1%	36%	33
Automotive	Car (ICE)	1.0%	25%	25
	Car (BEV)	1.0%	16%	16
	Truck	3.0%	42%	14
Metalware	Tomatoes (can only)	7.6%	17%	2
Domestic applian.	White goods	1.0%	23%	23
Others	Container ship	10.0%	73%	7
Fertilizers				
Wheat	Bread	0.6%	20.2%	34
Fruits and vegetables	Tomatoes (excl. can)	<0.1%	2.0%	35
	Fries	0.5%	<0.1%	<1

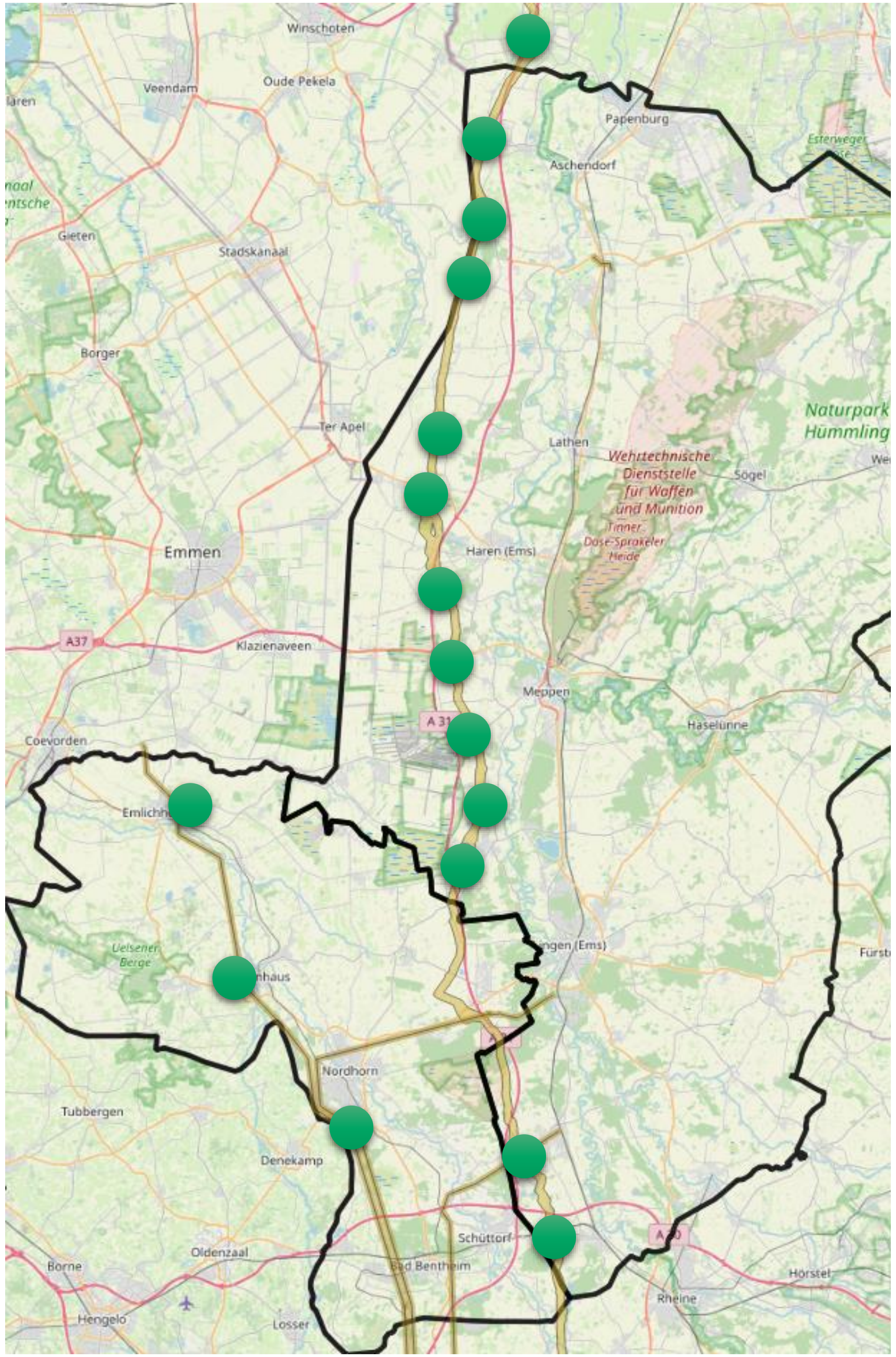
Product deep-dive next page

Demand obligations most effective as far down the value chain

Hydrogen for Industry and SMEs: Infrastructure

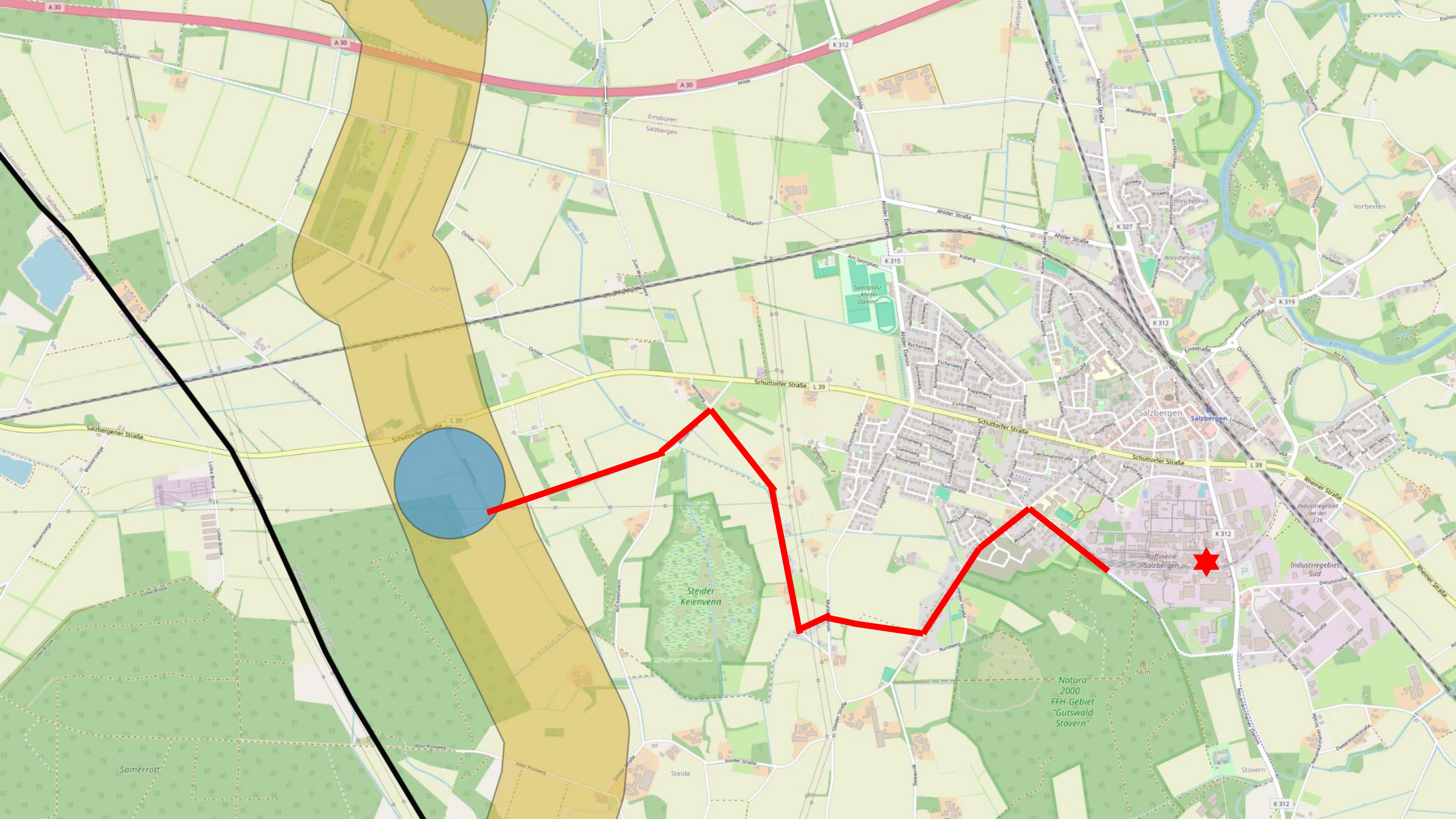
- From Core to Company: Only large industries are currently in focus!
- SMEs and (smaller) demand sites have to invest in own infrastructure!





Best Practice

H_2 Cluster
SALZBERGEN



A 30
K 312
Emsbüren
Salzbergen
Schümersdamm
Ahlder Straße
K 327
Wieschebrink
Vorbexten
Am Sportplatz
K 315
Sportplatz "Ahlder Damm"
Ochtel
K 319
K 312
Emsstraße
Schüttorfer Straße
L 39
Salzbergener Straße
Salzbergen
Industriegebiet an der L39
Rheiner Straße
Raffinerie Salzbergen
K 312
Industriegebiet Süd
Dieselstraße
Steider Keienvenn
Natura 2000 - FFH-Gebiet "Gutswald Stovern"
Samerrott
Alter Postweg
Steide
Steider Straße
Stovern
K 312

Hydrogen for Industry and SMEs: Pricing

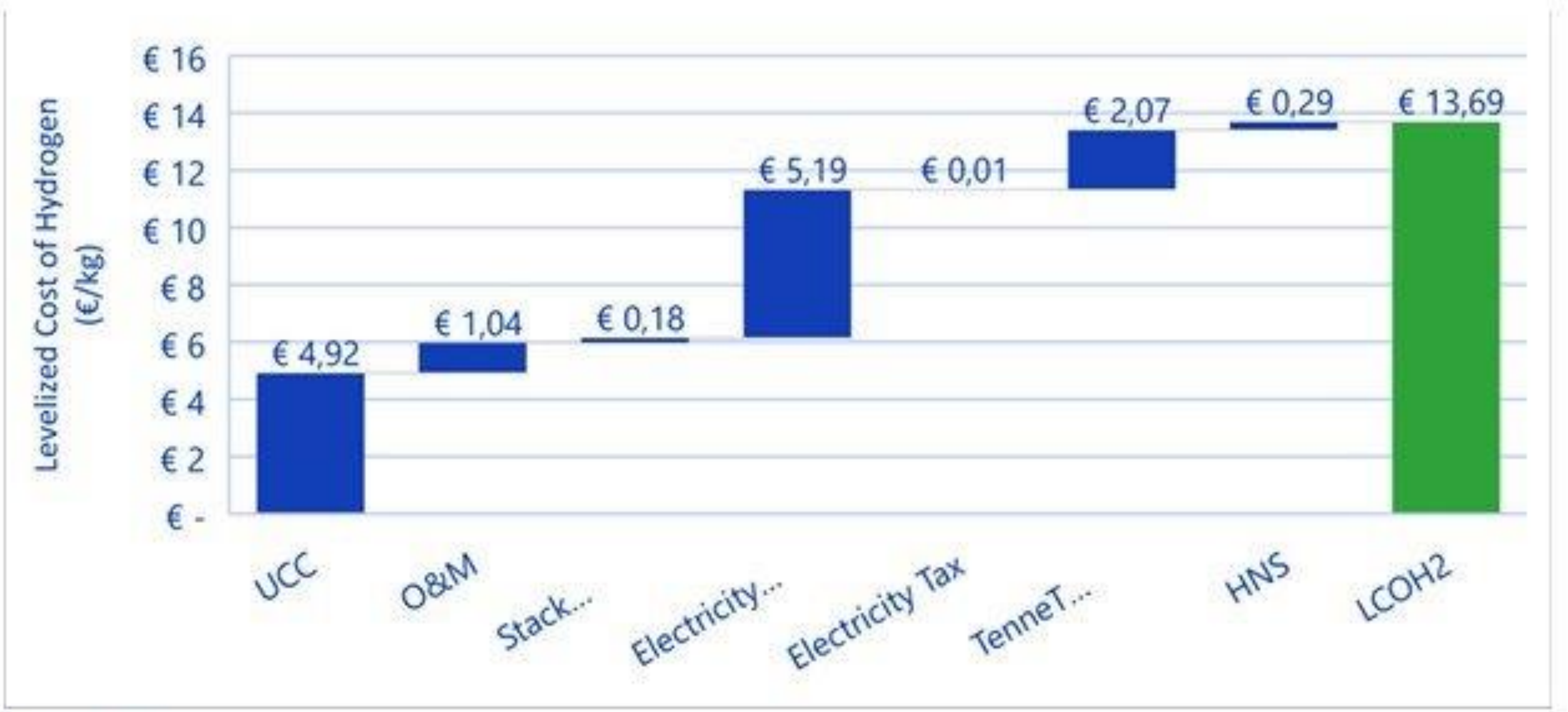
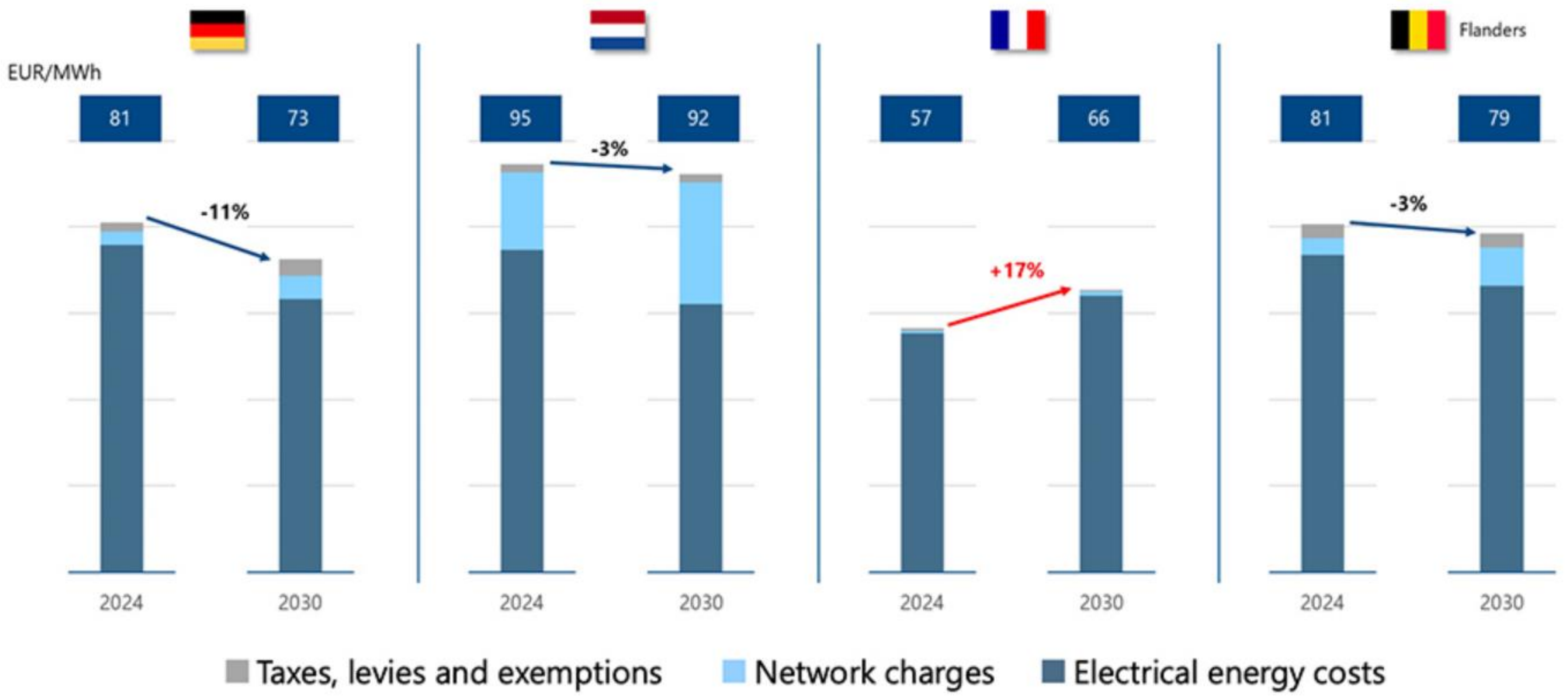


Figure 3.5: Nominal levelised cost of hydrogen production for the base case.

Source: TNO study RHyCEET may 2024

Hydrogen for Industry and SMEs: Electricity Pricing 2024 --> 2030



Bron: E-Bridge, Electricity cost assessment for large industry

Hydrogen for Industry and SMEs: Thinking out of the box!

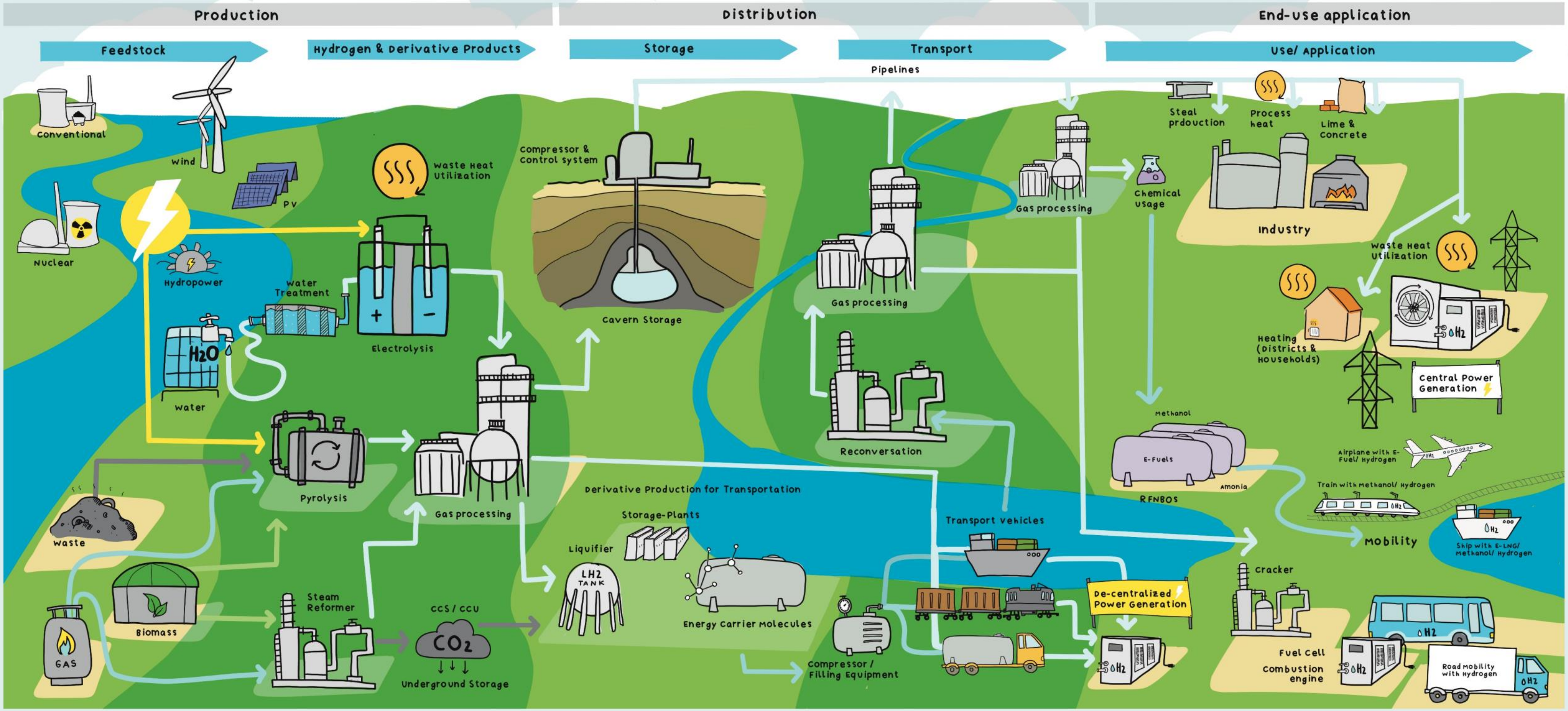
Best Practice

Fire prevention via fuel cell

- Usage of O2-depleted air from fuel cells to reduce amount of O2 in e.g. storage centers
- FC triggered NOT by electricity or heat demand but by O2-depletion demand!
- Production of electricity and heat on-site

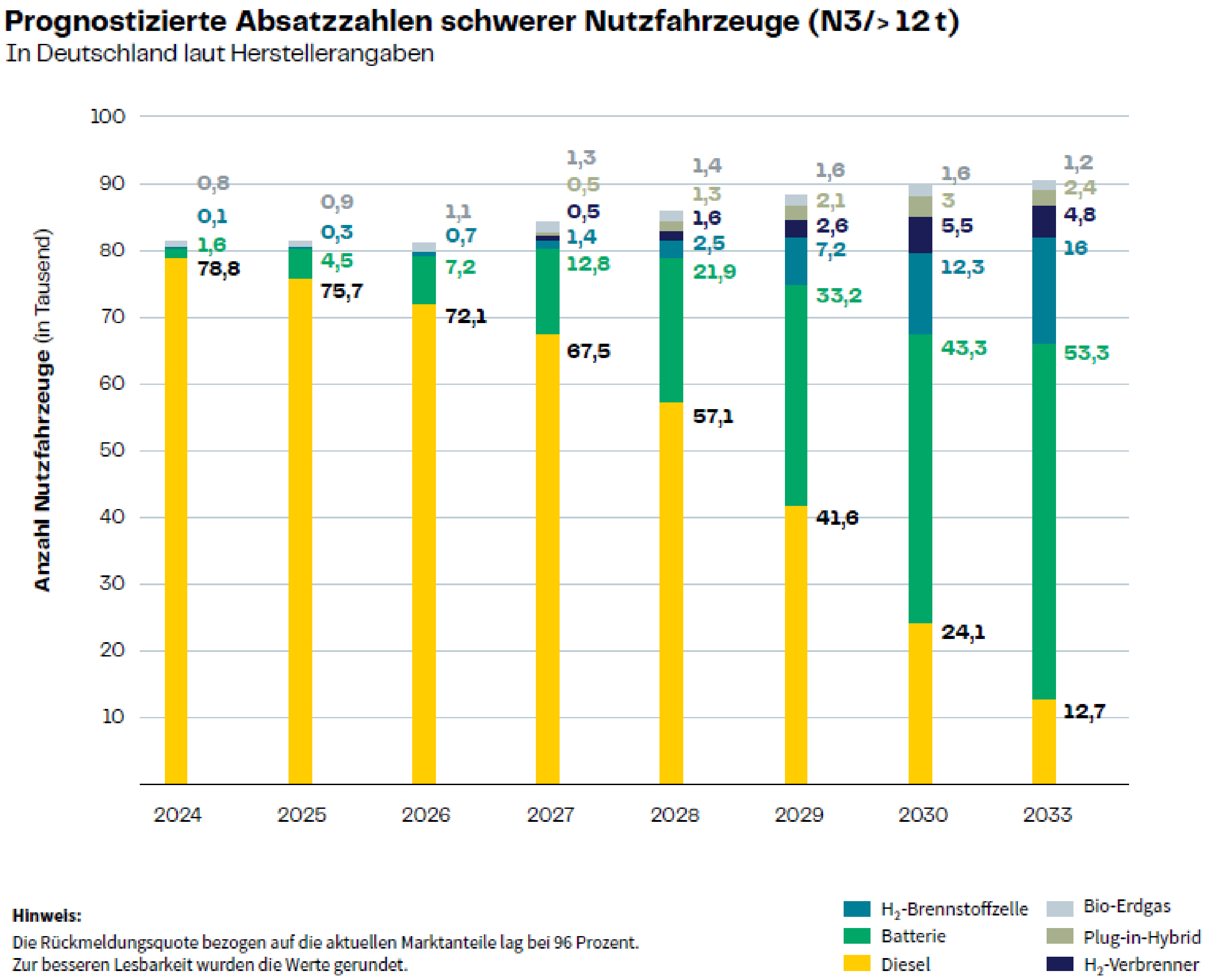
HYDROGEN CROSS BORDER CONFERENCE

HOW DO WE ACHIEVE COMPLETE VALUE CHAINS?



Hydrogen for heavy-duty vehicles

- Ambitious reduction targets of European heavy-duty vehicles' CO_2 standards for the year 2030
- A range of drive technology options is required
- Use of hydrogen in the conventional combustion engine is the most striking addition
- Which drive technology for which use case?
  - Costs
  - Technological maturity
  - Regulatory aspects
  - Effects on/of the regional value chain (synergy effects vs. competition?)



Quelle: NOW (2024): Marktentwicklung klimafreundlicher Technologien im schweren Straßengüterverkehr

Hydrogen filling station infrastructure

- Rapid expansion of the public refueling infrastructure is the most important framework
- Financing the expansion of infrastructure (Government funding, private sector initiatives, through additional revenue from the CO2 components of the truck toll?)
- Regular evaluation of AFIR target achievement and comparison with vehicle ramp-up
- “Pipeline-Studie” investigates supply of H2 filling stations via pipelines (H2 hubs can reduce transportation and processing costs)
- Variety of hydrogen storage options being pursued by manufacturers as a challenge for infrastructure development (350 bar, 700 bar or in liquid form)

Interreg
North Sea

Co-funded by
the European Union

LIHYP

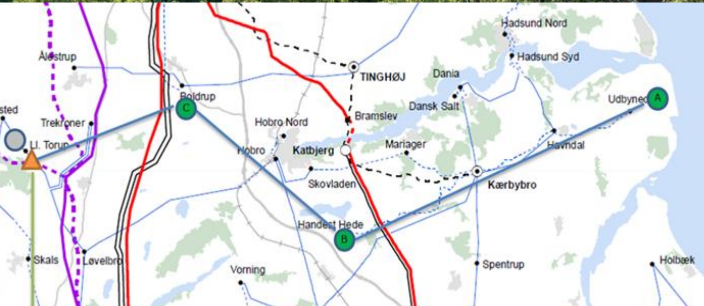
Linking Hydrogen Power Potentials

Uniting Stakeholders to build a regional hydrogen economy in the North Sea Region!

Why LIHYP?

Interreg North Sea
Co-funded by the European Union
LIHYP

LIHYP Pilots as showcases for solutions



- H2 driven freight train in the cross-border region GER/NL
- Living Lab Belgium – vessel in Ghent
- Hydrogen Valley Airport Goningen Airport Eelde
- Development of a local H2-HUB for city cargo
- H2 refueling station connected directly to a wind-/pv-site
- H2 driven coach in the region of Normandy

Questions for the discussion

- What role can hydrogen play in the commercial vehicle sector compared to the high demand in the industry?
- Is there a future for hydrogen in the mobility sector in general?
- Would the creation of hubs be a solution to support the ramp-up of regional hydrogen applications?

New Energy Coalition

Drivers of Change

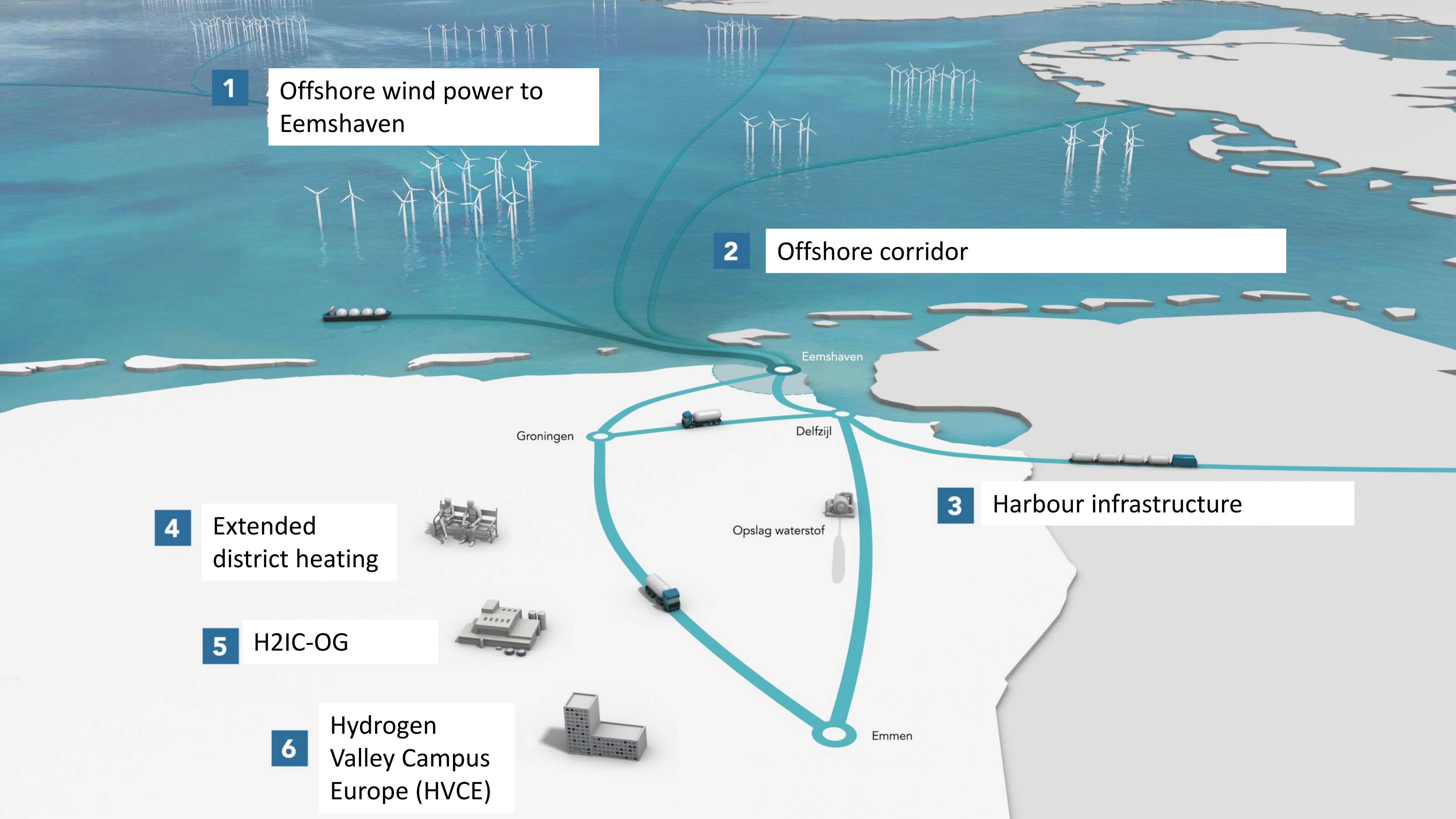
H2IC-OG

Hydrogen for Cluster 6 industrial companies in East-Groningen

Catrinus Jepma, New Energy Coalition

Hydrogen Cross Border Conference

Scheemda, 13 March 2025

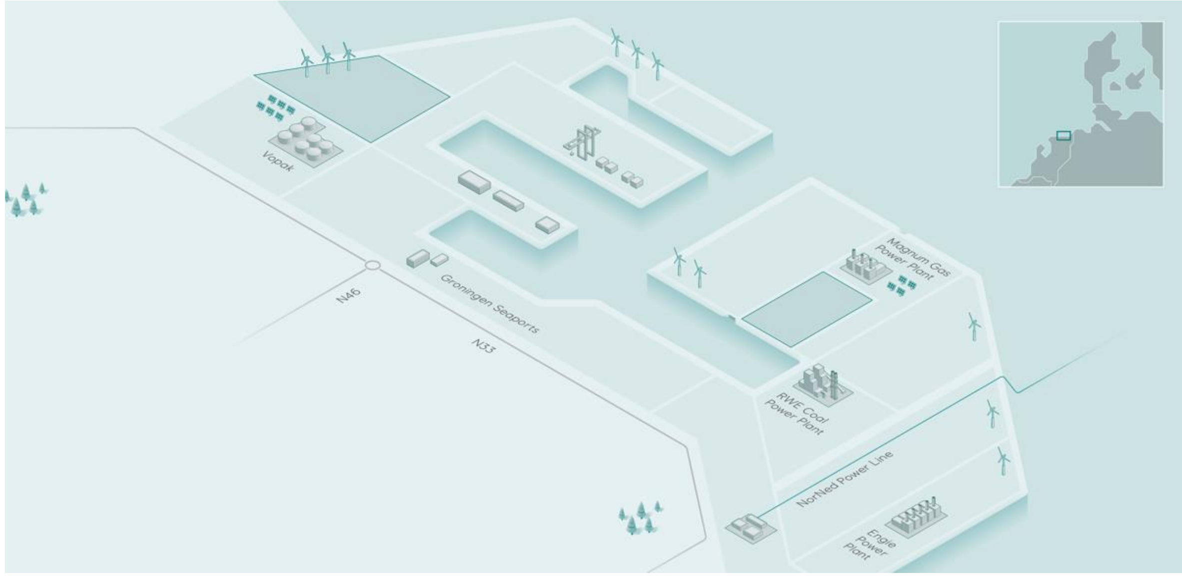

1
Offshore wind power to Eemshaven
2
Offshore corridor
Eemshaven
Groningen
Delfzijl
3
Harbour infrastructure
4
Extended district heating
Opslag waterstof
5
H2IC-OG
6
Hydrogen Valley Campus Europe (HVCE)
Emmen

Value chain parties

- Supply side: Equinor, RWE and Engie
- Demand side: IC-OG-cluster
- Infrastructure: Enexis, Northgrid, Gasunie
- Aggregator: EBN
- Public authorities: Province of Groningen, Groningen Seaports, NOM
- Coordinator: New Energy Coalition

The IC-OG cluster: Avebe, Eska, Kisuma, Nedmag, PQ, SmurfitKappa, Solidus, Strating and Wellnesspet. Together they consume 215.000.000 Nm3 natural gas = ca. 56.000t hydrogen (ref. 2023). Related employment some 10.000 fte.

H2M Eemshaven



Project goals:

- **H_2 production volume:** **210 kton per year**
- **CO_2 emission reduction:** **1,7 Mton per year (>95% capture rate)**
- **FID:** **2026**
- **Start up:** **2030**

Large-scale use of hydrogen for energy-intensive industry and back-up electricity production.

Switching raw materials and fuels from coal and natural gas to hydrogen.

Maximum use of existing assets: natural gas infrastructure, CCGTs, pipelines and storage

Close to large industrial clusters in NW Europe, using hydrogen backbone

Start-up of large-scale hydrogen value chain

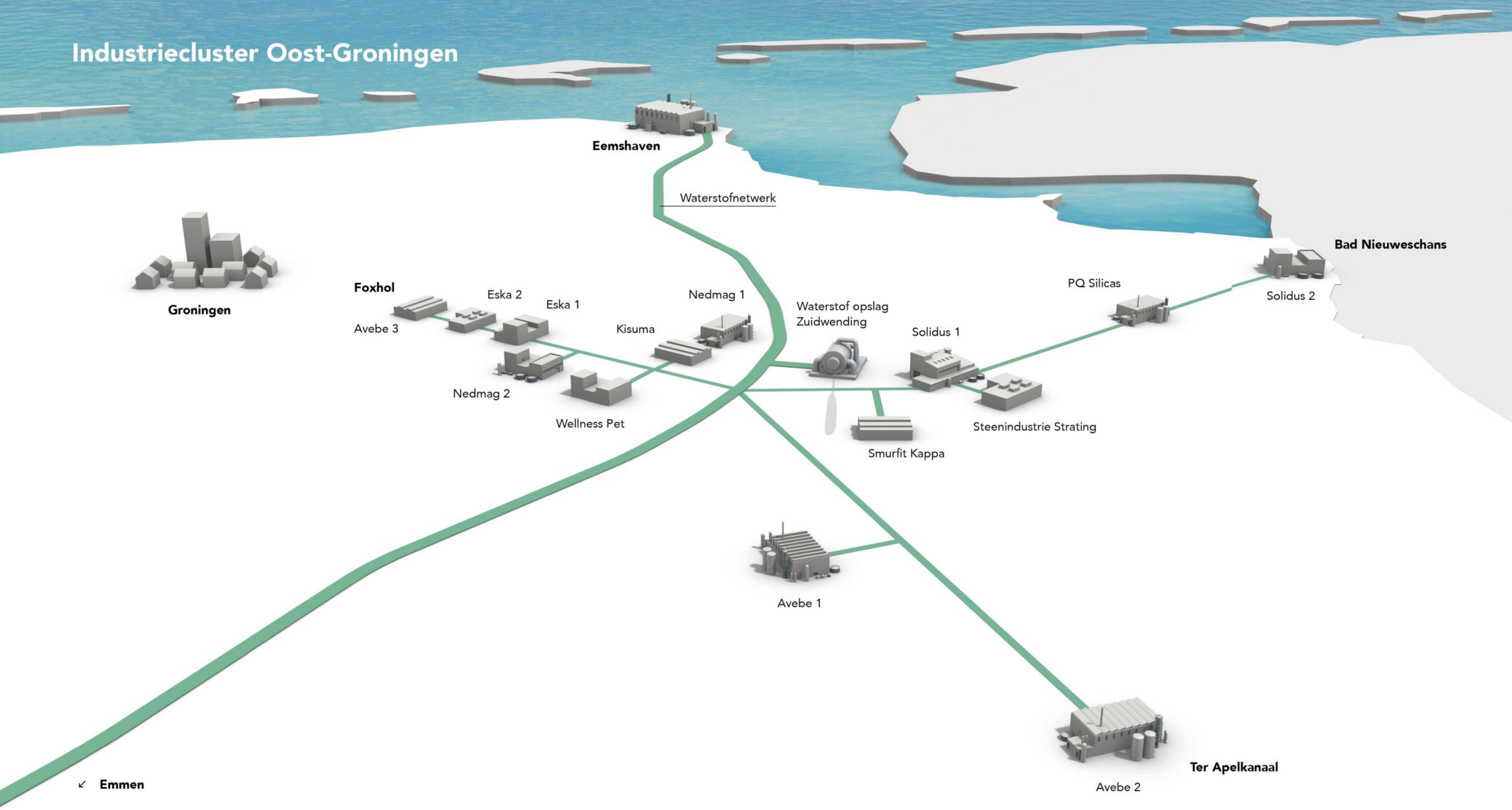
Linde partner in H2M Eemshaven as of April 2024.

Pre-feasibility H2 value chain development between Eemshaven/HNS and East-Groningen

- Based on blue hydrogen, possibly combined with green hydrogen
- Costs of some 90 km H2 distribution grid: about EUR 60 mln
- Companies face adjustment costs and time: EUR 20-60 mln (estimate)
- Compensating unprofitable top is key: base case estimate EUR 250-330 mln (present value) if all natural gas is replaced by H2
- Role of aggregator and organizer is crucial
- Timing: if 2030 it would be a first serious regional pilot with H2 backbone connection

Why H2?

- CO_2 penalties natural gas
- Without greening no future
- Electrification increasingly problematic (supply/demand congestion)
- Green gas increasingly no option
- Connection to backbone maybe feasible


Industriecluster Oost-Groningen
Eemshaven
Waterstofnetwerk
Bad Nieuweschans
Groningen
Foxhol
Eska 2
Eska 1
Nedmag 1
Waterstof opslag
Zuidwending
PQ Silicas
Solidus 2
Avebe 3
Kisuma
Solidus 1
Nedmag 2
Wellness Pet
Steenindustrie Strating
Smurfit Kappa
Avebe 1
Ter Apelkanaal
Avebe 2
Emmen

New Energy Coalition

Drivers of Change

Key conditions

- Infrastructure: backbone H2 connection point Veendam distribution grid
- Regional supply blue and green hydrogen
- Functioning aggregator
- Unprofitable top covered
- Organisation of value chain

H2M Eemshaven to unlock Dutch and German hydrogen value-chain development

210.000

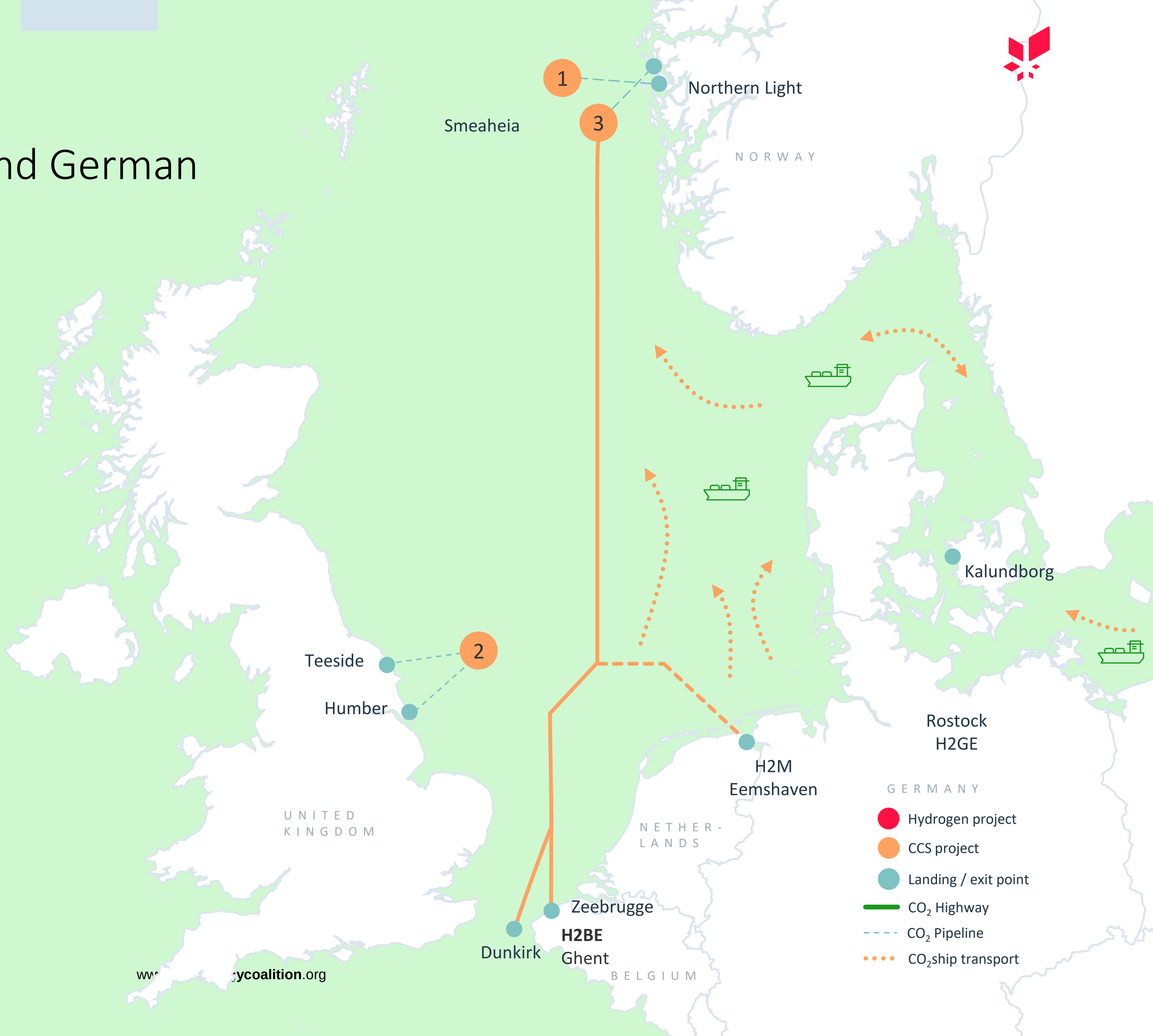
TONNES PER YEAR

Low carbon hydrogen

1.8

MILLION TONNES CO_2

Transported and stored yearly



Drivers of Change

The pre-feasibility study IC-OG by Catrinus Jepma and Jeffrey Paays

- https://www.newenergycoalition.org/kennisbank/waterstofperspectieven-voor-het-industriecluster-oost-groningen/