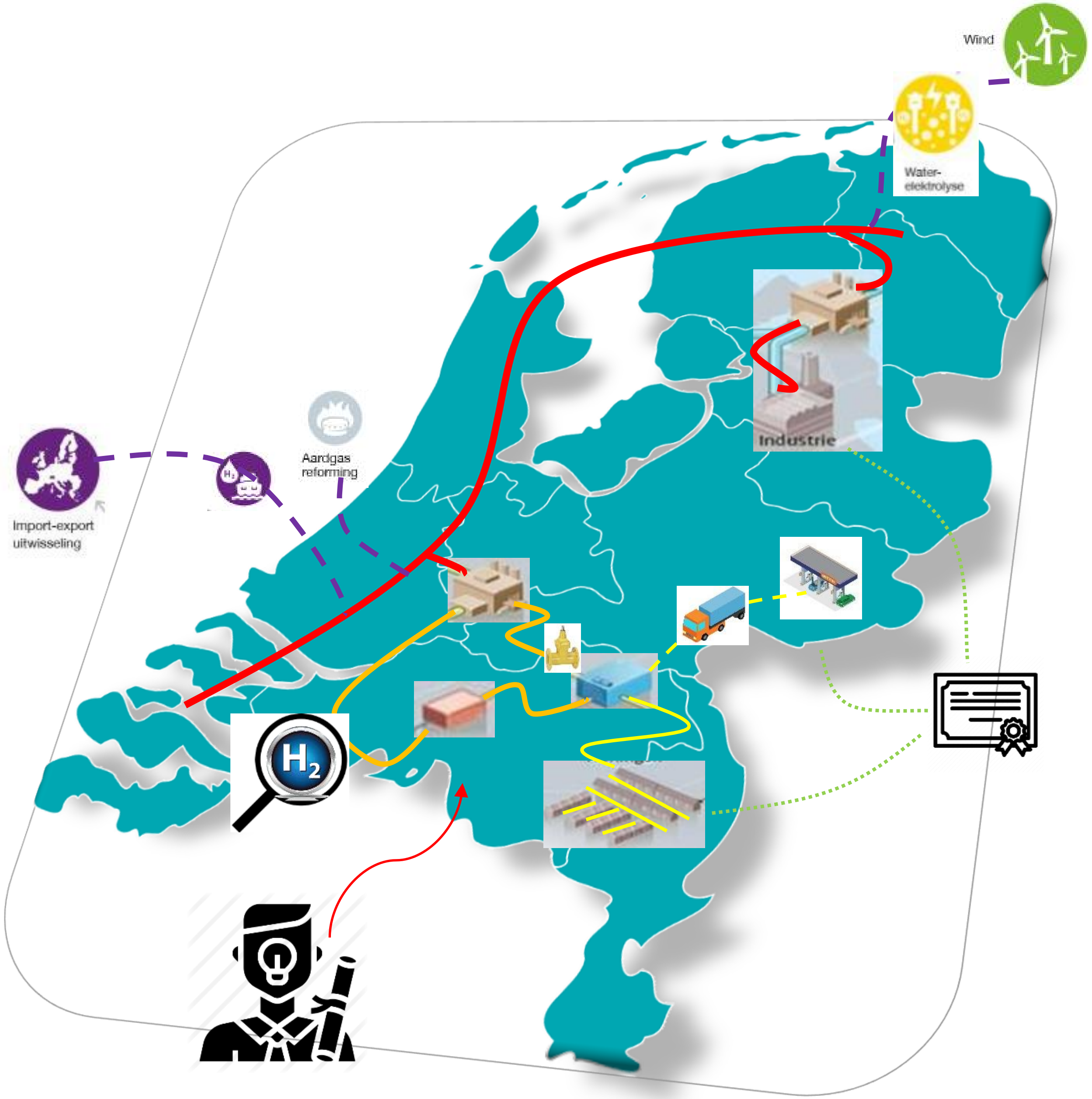
HyDelta

Plenary Progress Meeting 2 – foreword

New Energy Coalition

Julio Garcia-Navarro – project coordinator

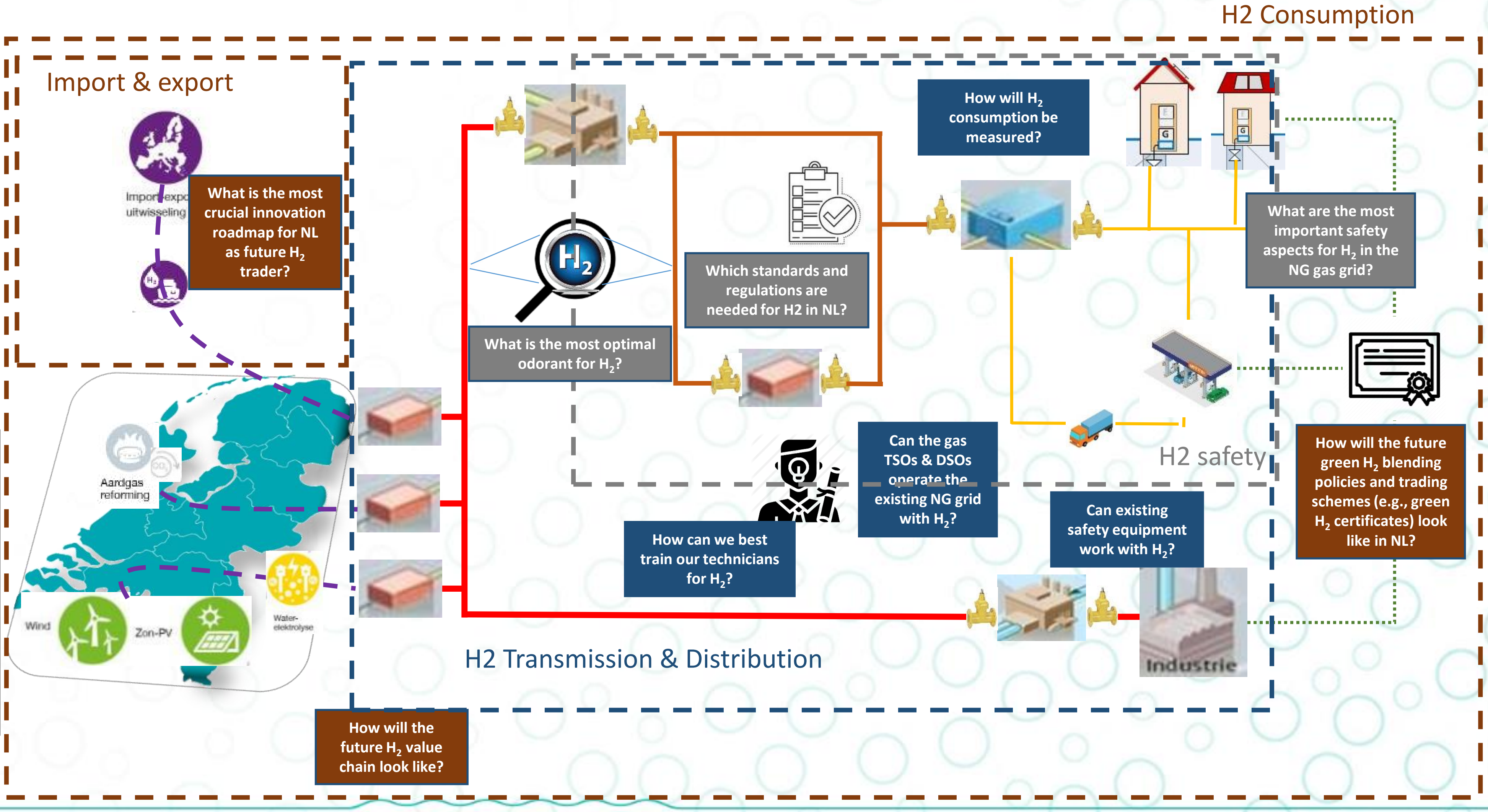
07-12-2021



HyDelta project overview – research questions

Overview of the research questions in HyDelta 1.0

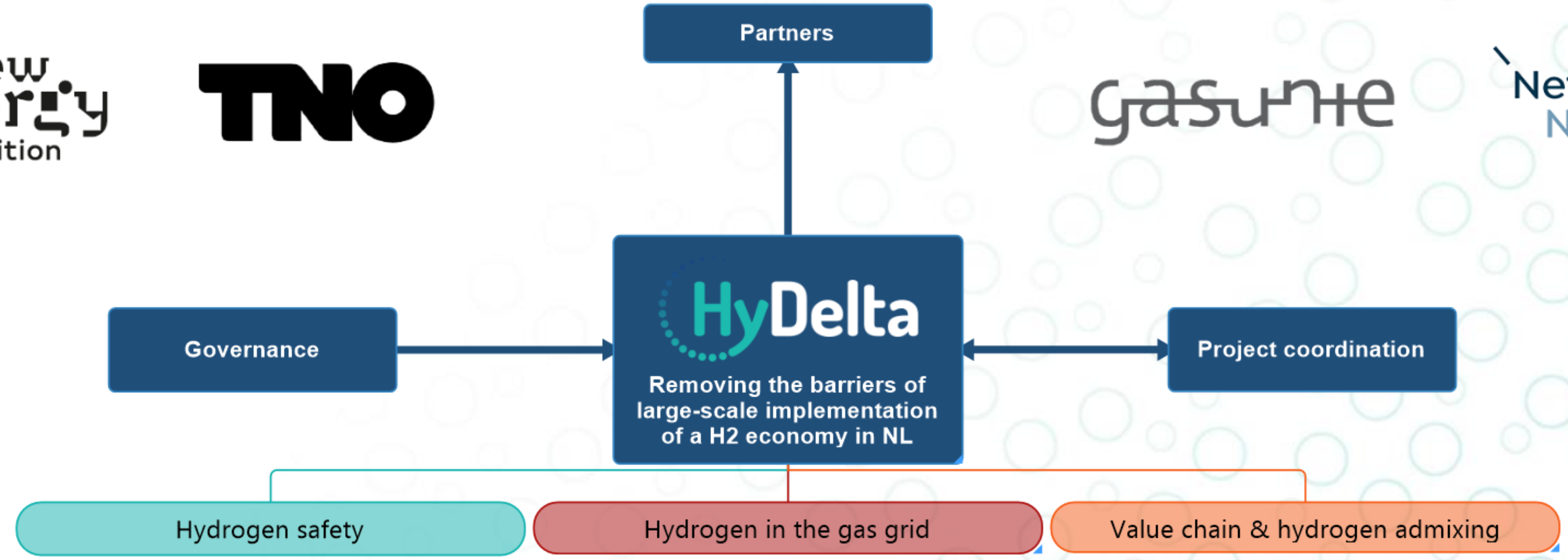
HyDelta 1.0 is a **consortium** project **aimed** at conducting **research** on the area of **transport** or **blending** of **hydrogen** in the existing **NG network** in **NL**



Legend

- Hydrogen safety
- Hydrogen in the gas grid
- Value chain & hydrogen admixing

Project consortium



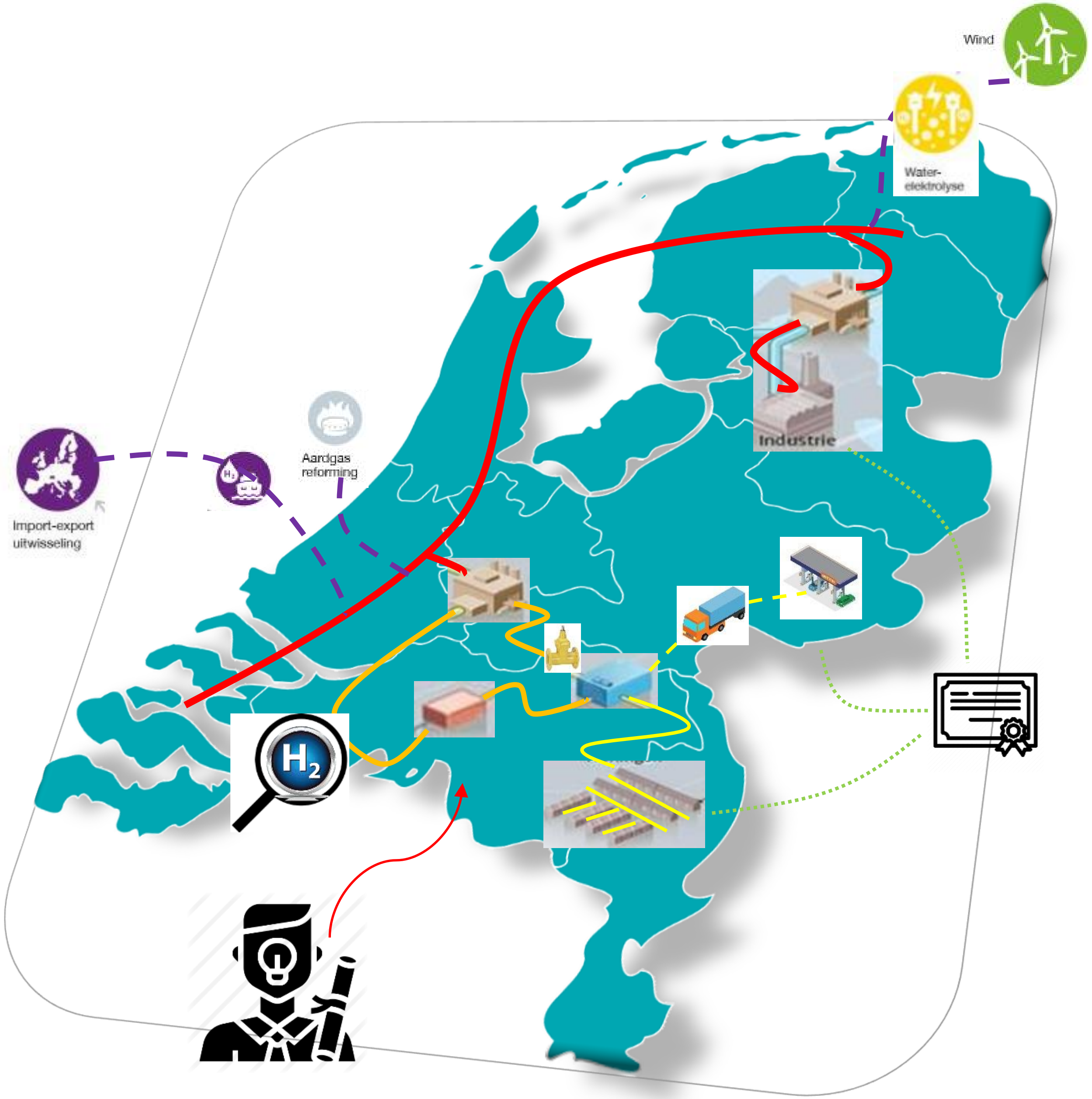
Agenda for today

- **15-min presentations** with an intermediate **break (13:00 – 13:10)**
- The **presenters** will be **reminded** when there is **1 minute left** in their time
- **Questions**? Feel free to enter them in the **chat**. The ones we **cannot** answer **live** will be **answered** in **writing** and **disseminated**
- After the meeting we will **distribute** the **recording** of the presentation alongside the **answers** to the **questions**

Timeslot	Event	Presenter
11:00 – 11:05	Welcome & intro presentation HyDelta	Julio Garcia-Navarro, NEC
11:05 – 12:00	Topic 1: Value chain & hydrogen admixing	
11:05 – 11:20	WP7A Techno-economic value chain analysis	Joris Kee, New Energy Coalition
11:20 – 11:35	WP7B Technical analysis of hydrogen supply chains	Sara Wieclawska, TNO
11:35 – 11:45	WP7C System value of hydrogen	Ekaterina Florez, DNV
11:45 – 12:00	WP8 Admixing & mandatory blending	Rob van Zoelen, New Energy Coalition
12:00 – 13:00	Topic 2: Hydrogen safety	
12:00 – 12:15	WP1A Hydrogen & safety	Albert van den Noort, DNV
12:15 – 12:30	WP1E Impact of hydrogen flow speed on safety	Néstor Gonzalez Diez, TNO
12:30 – 12:45	WP2 Odorization of hydrogen	Erik Polman, Kiwa
12:45 – 13:00	WP3 Standards for hydrogen	Hans de Laat, Kiwa
13:00 – 13:10	Intermediate break	
13:10 – 14:25	Topic 3: Hydrogen in the gas grid	
13:10 – 13:25	WP1B Gas stations	Sander van Woudenberg, Kiwa
13:25 – 13:40	WP1C Piping & indoor installations	Sander Lueb, Kiwa
13:40 – 13:55	WP1D Hydrogen flow metering	Hans de Laat, Kiwa
13:55 – 14:10	WP1F Testing of shut-off valves in the gas transportation grid	Nard Vermeltfoort, Kiwa
14:10 – 14:25	WP4 Development of educational tracks	Sjoerd Delnooz, Kiwa
14:25 – 14:30	Final remarks and closing	Julio Garcia-Navarro, NEC

HyDelta

Part 1 – value chain and hydrogen admixing



Plenary Progress Meeting

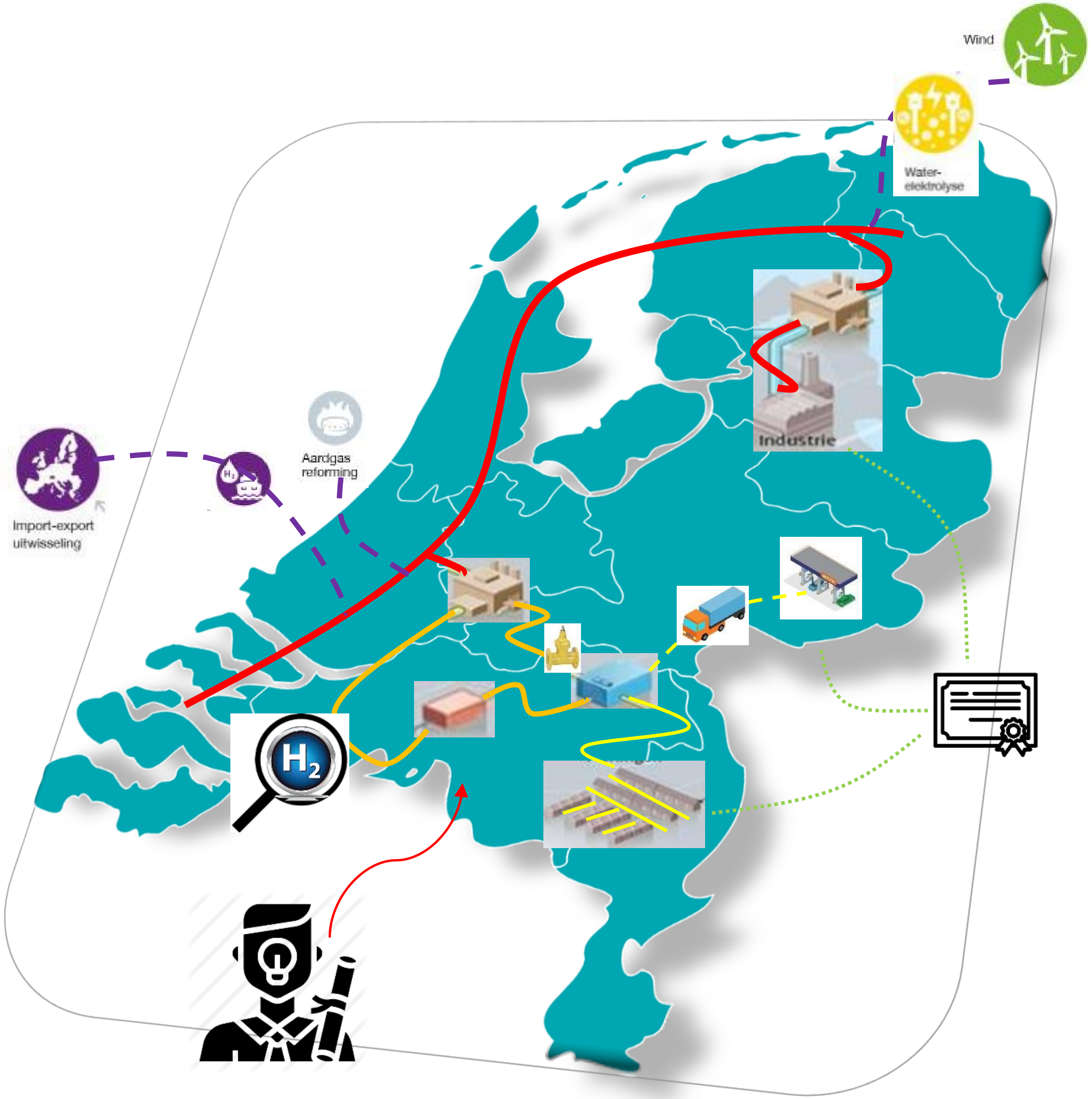
HyDelta

7A

Techno-economic value chain analysis

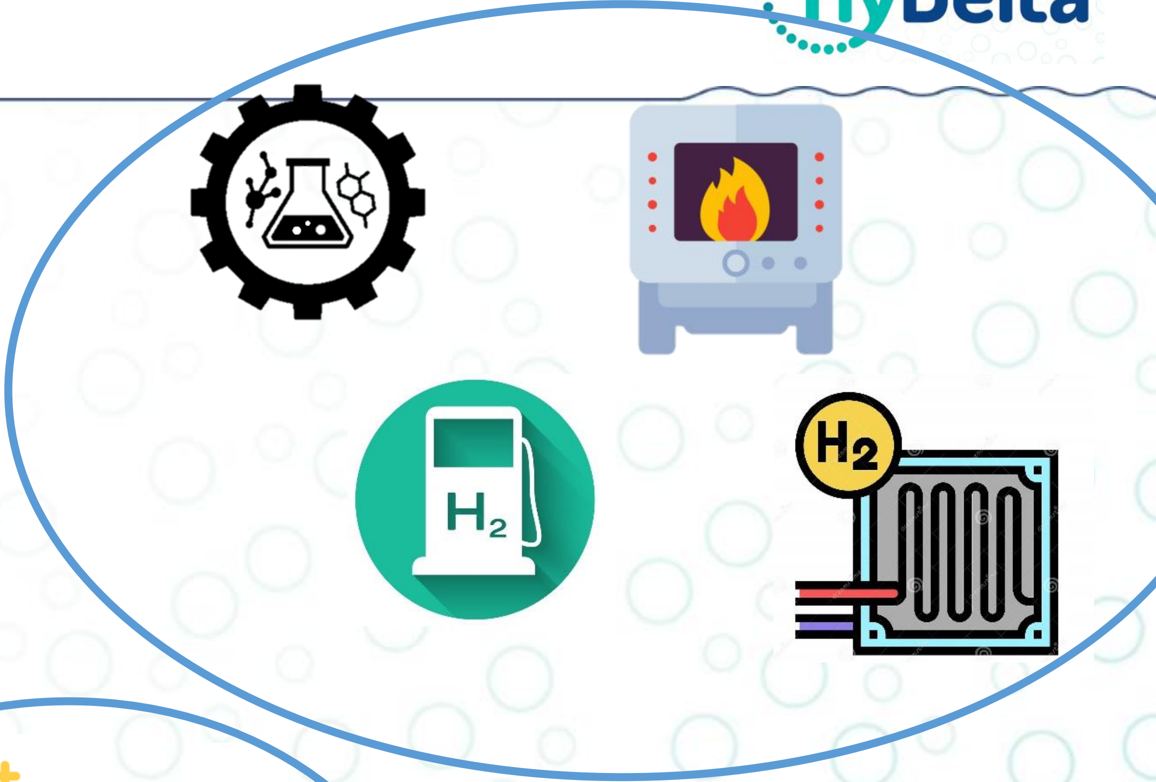
New Energy Coalition

Joris Kee



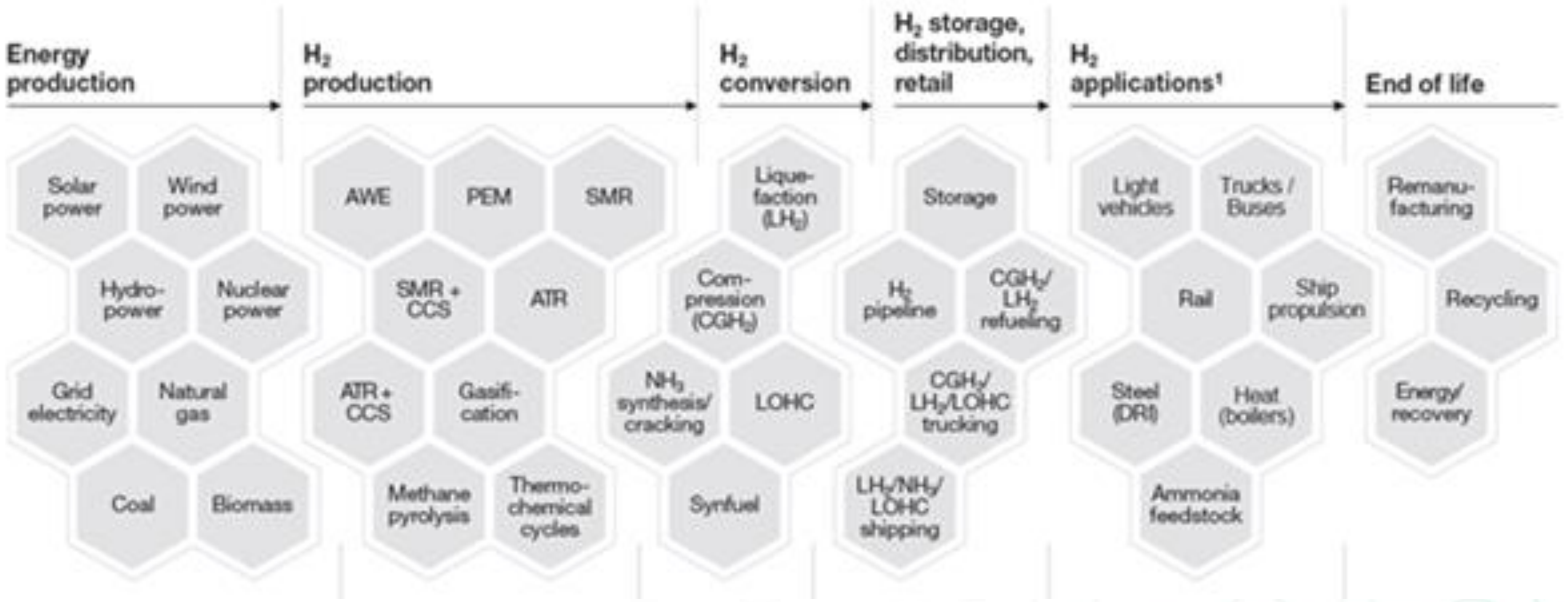
Progress of the work in the period

- Market Dynamics Analysis
- Modelling
  - Design of relevant value chains:
    - Industrial feedstock
    - Industrial heating
    - Mobility
    - Built environment
  - Deriving input-data:
    - Capex/Opex (WP7B)
    - Volumes/demand
    - Hydrogen demand pattern
    - Hydrogen quality



Market Dynamics analysis

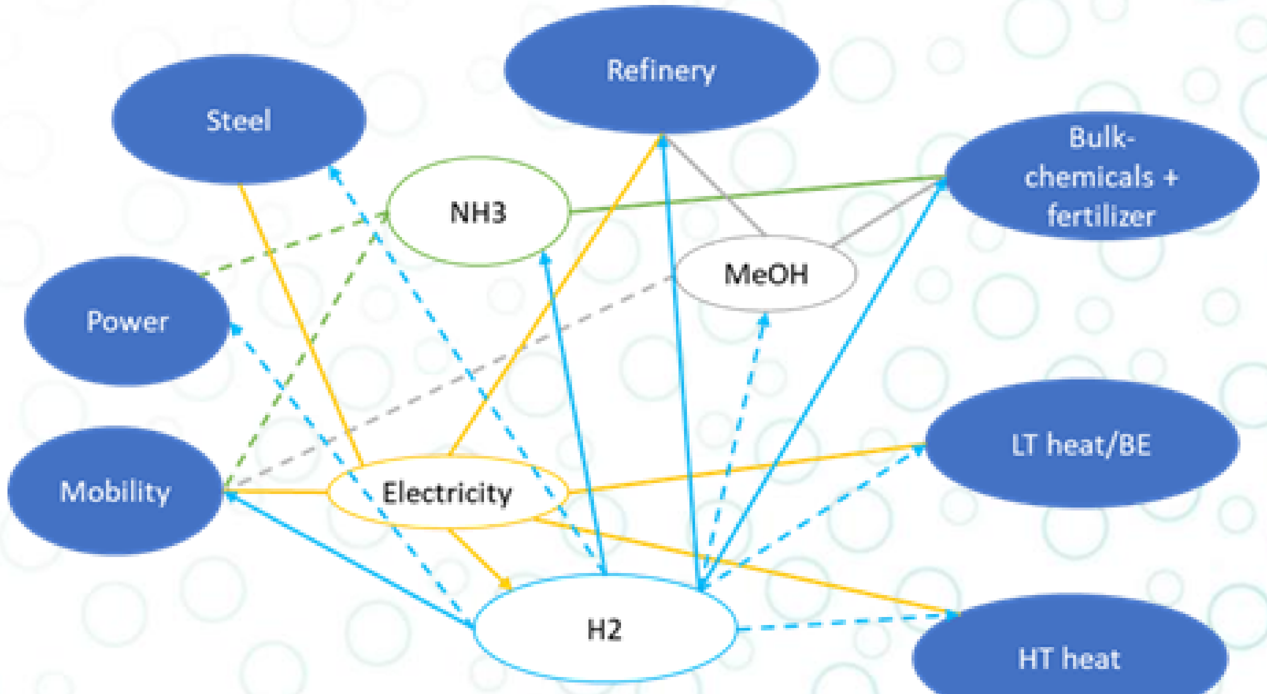
- Multiple actors develop in a future hydrogen economy



Market Dynamics analysis

- Multiple actors develop in a future hydrogen economy

- Hydrogen carriers can play a cross-sectoral role in a future hydrogen economy, where new markets (with new competitors) develop-->



Market Dynamics analysis

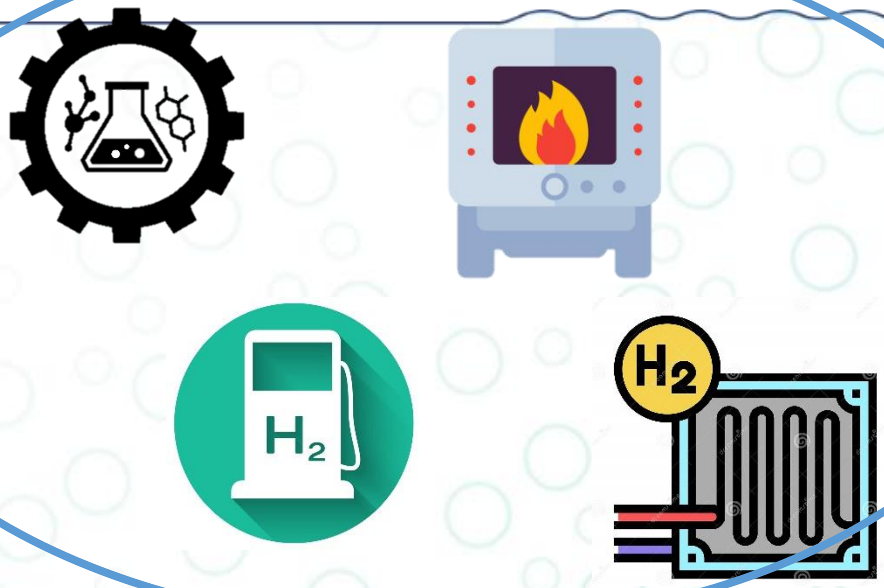
HyDelta

- Multiple actors develop in a future hydrogen economy
- Hydrogen carriers can play a cross-sectoral role in a future hydrogen economy, where new markets develop
- Therefore (in a nutshell):

Complex issues	→	Suggested ways forward
Bringing together suppliers and consumers at an immature market place is a challenging task		Facilitate the mutual commitment of supply chain actors through stakeholder governance
A just distribution of sustainable molecules amongst sectors is not trivial		Use the available hydrogen to minimize the emission of our society
Many uncertainties cloud the development of market-facilitating infrastructure		Create infrastructure to facilitate a functioning open market place

Progress of the work in the period

- Techno-economic modelling:
- Design of relevant value chains
  - **Industrial feedstock**
  - Industrial heating
  - Mobility
  - Built environment



- Deriving input-data
  - Capex/Opex (WP7B)
  - Volumes/demand
  - Hydrogen demand pattern
  - Hydrogen quality

Progress of the work in the period

Example: Industrial Feedstock: NH3

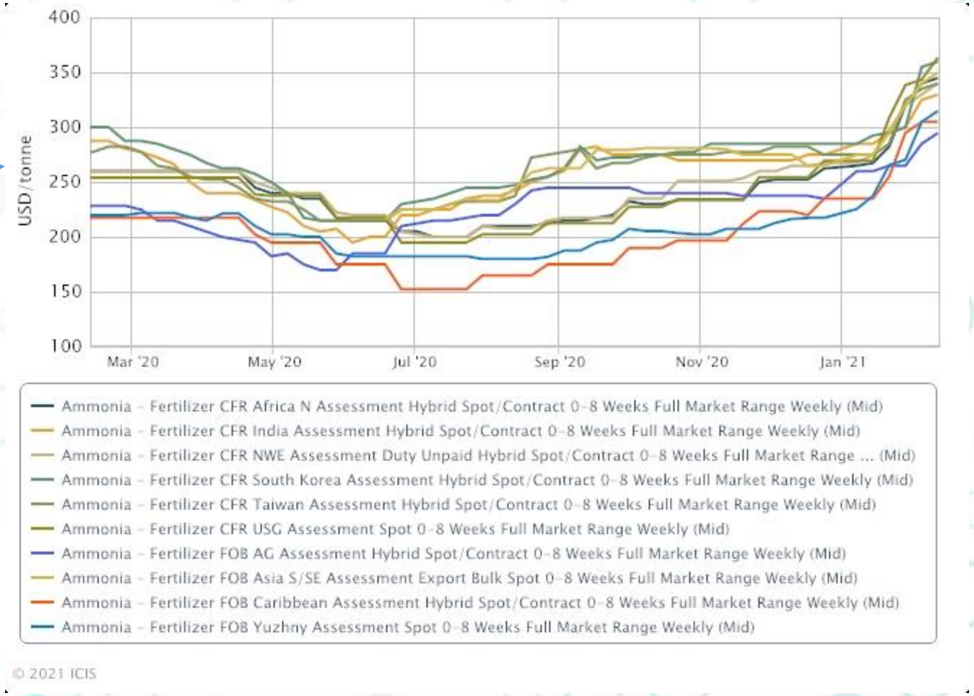
- Significant volumes of hydrogen as resource: currently Natural Gas as source

- Main clusters Chemelot and Zeeland, some smaller across the country as well.

Fertilizer Feedstock

NH3 market price (grey):
180-310 eu/ton

NG price dependent



Centralized, large, constant demand profile

Max. 294.000.000 kg H2/y
Min. 180.000.000 kg H2/y

Progress of the work in the period

- NH_3 – Which value chains?

Fertilizer Feedstock

NH3 market price (grey): 180-310 EU/ton

Centralized, large, constant demand profile

Max. 294.000.000 kg H2/y
Min. 180.000.000 kg H2/y

Import – No Backbone

Green H_2 – No Backbone

Blue H_2 ATR: +- 0,95 GW

Blue H_2 –backbone

Offshore wind: +- 2,8 GW
Electrolyzer: +- 2,4 GW

Green H_2 –backbone

Progress of the work in the period

- NH_3 – Which value chains?

Fertilizer Feedstock

NH3 market price (grey):
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Centralized, large, constant demand profile

Max. 294.000.000 kg H2/y
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Import – No Backbone

Green H_2 – No Backbone

Blue H_2 –backbone

Green H_2 –backbone

Progress of the work in the period

• NH_3 – Results

Fertilizer Feedstock

NH3 market price (grey):
180-310 EU/ton

Centralized, large,
constant demand profile

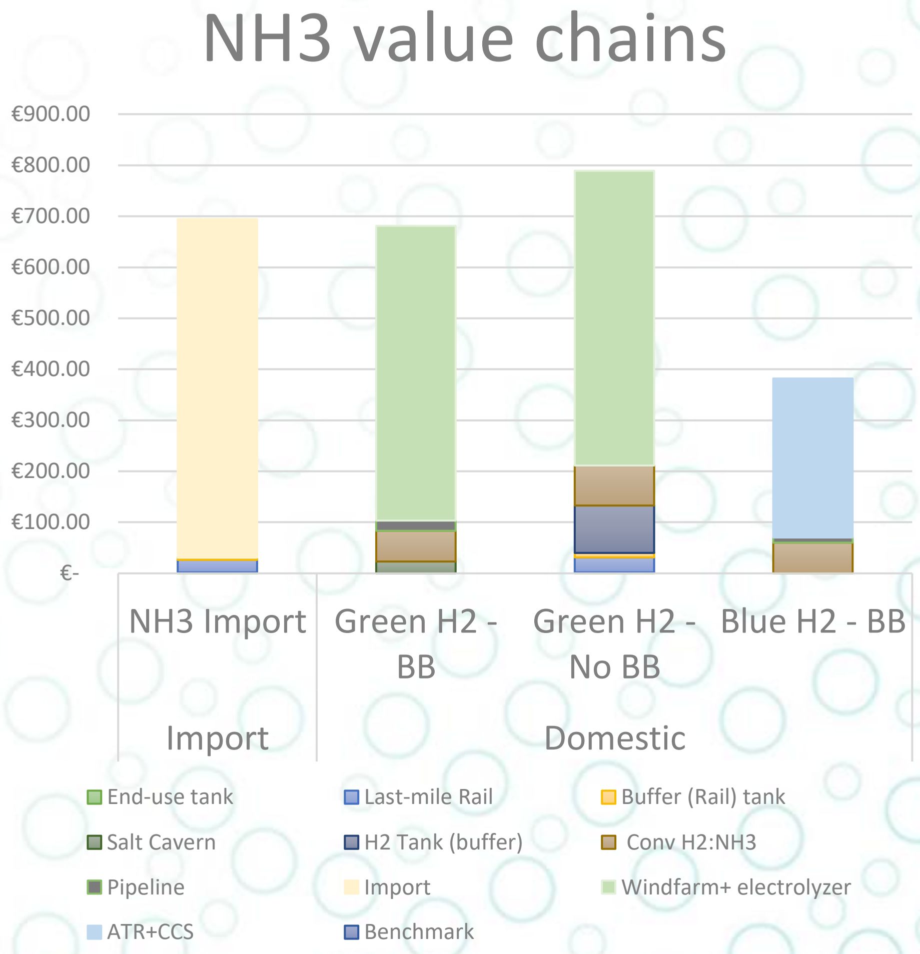
Max. 294.000.000 kg H2/y
Min. 180.000.000 kg H2/y

General:

- Cost of **H_2** are significant.
- Cost of **wind energy,** or **NG** for blue H_2 determine the cost of H_2.

Comparison:

- **Import** and **domestic green** NH_3 are quite competitive
- Storage of H_2 is required before NH_3 conversion when there is no backbone available -> this dramatically increases costs (ca. 1520 eu/ton)



Progress of the work in the period

Green H_2 –backbone

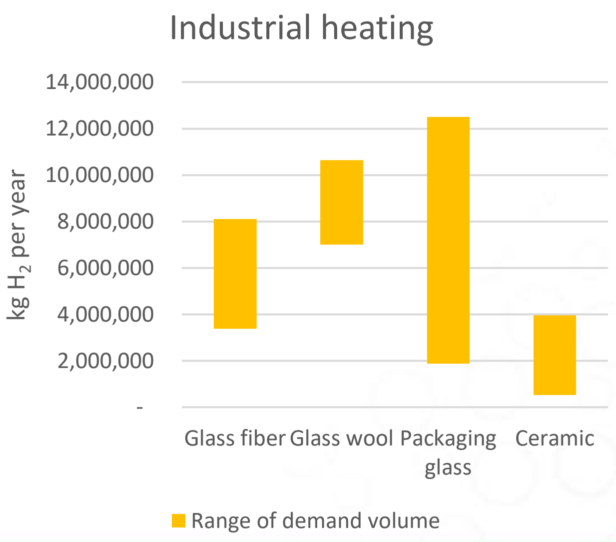
- Industrial heating – Which value chains?

Ceramic factory, glass industry, etc. (cluster 6)

Gas price: 25 - 75 eu/MWh

Decentralized, medium demand profile,
Week-weekly pattern

Max: 12.000.000 kg H2/y
Min: 2.000.000 kg H2/y



Progress of the work in the period

- Industrial Heating - Results

Ceramic factory, glass industry, etc. (cluster 6)

Gas price: 25 - 75 eu/MWh

Decentralized, medium demand profile, Week-weekly pattern

Max: 12.000.000 kg H2/y
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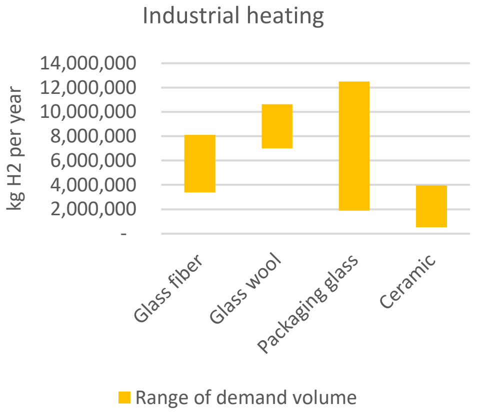
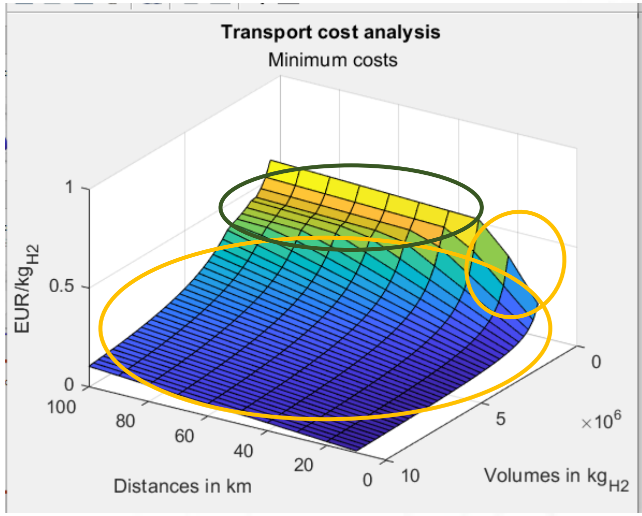
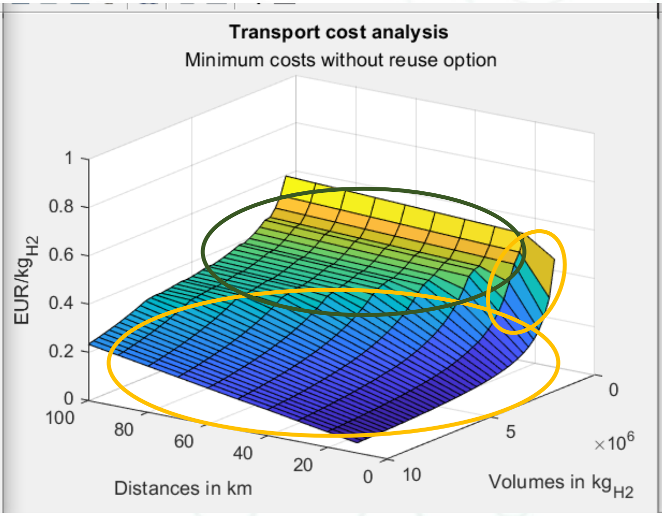
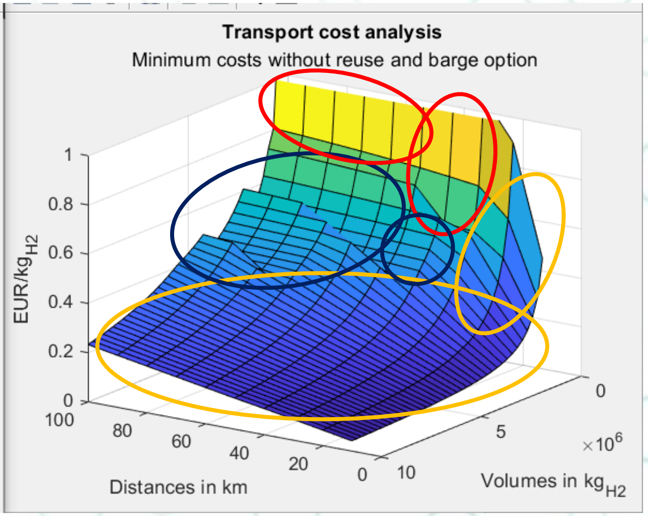




Reused pipeline
LOHC Barge



New pipeline
LOHC Barge



New pipeline
LOHC trucks
gH2 trucks

Progress of the work in the period

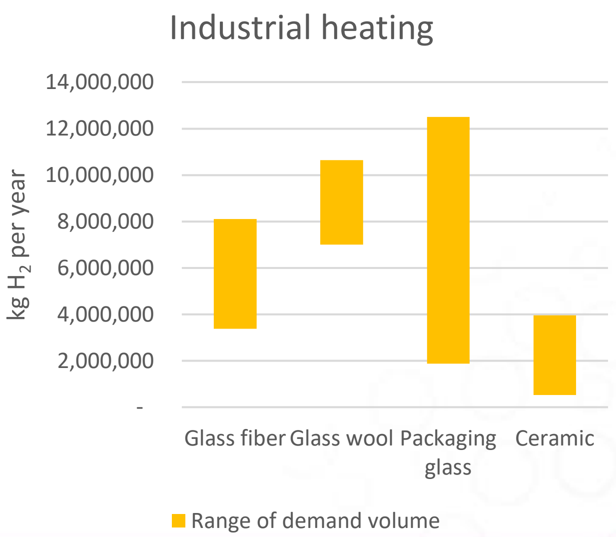
- Industrial Heating – Sustainable alternative

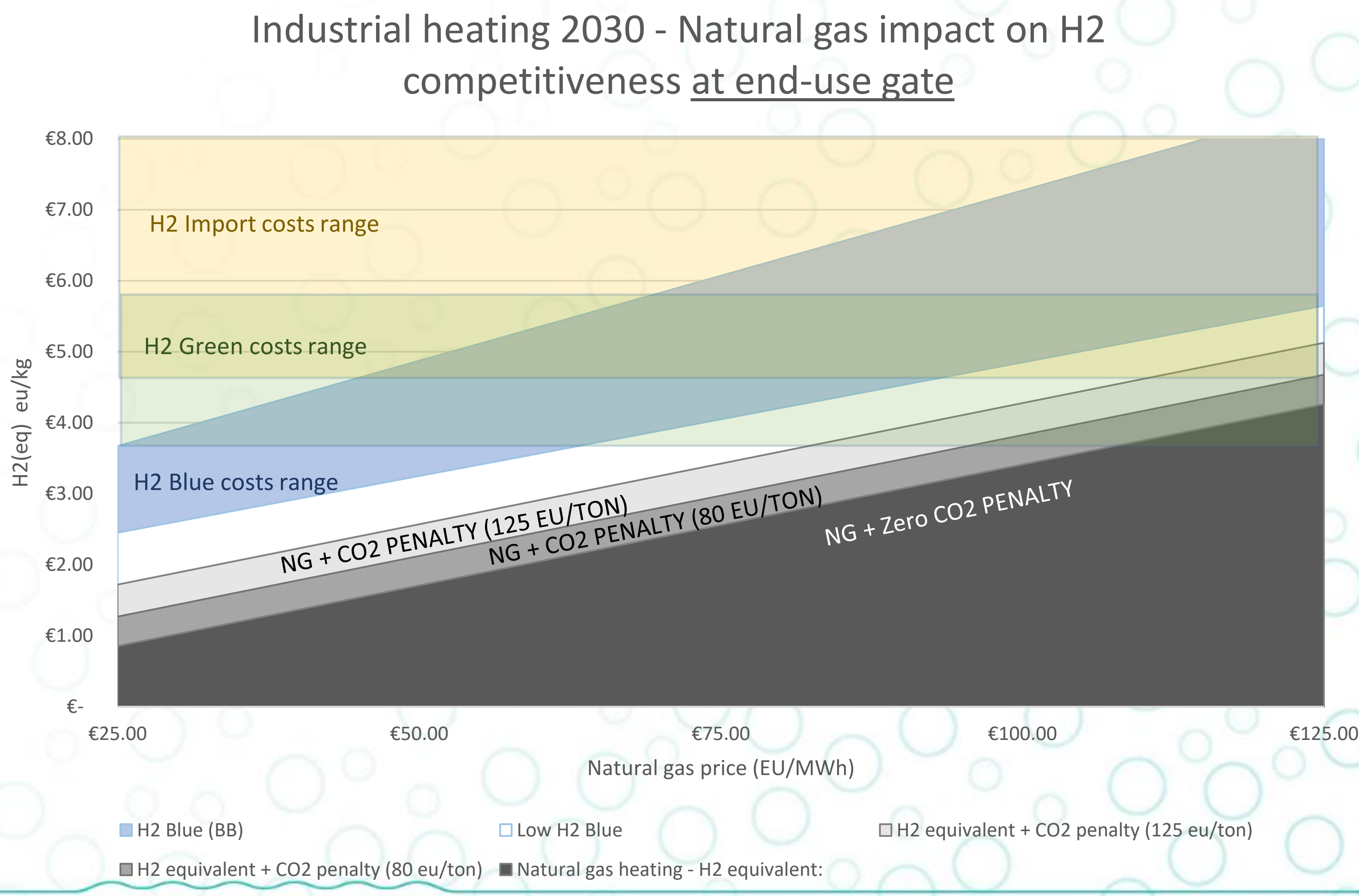
Ceramic factory, glass industry, etc. (cluster 6)

Gas price: 25 - 75 eu/MWh

Decentralized, medium demand profile,
Week-weekly pattern

Max: 12.000.000 kg H2/y
Min: 2.000.000 kg H2/y





Work to be done in the next period

Finish

Reporting

(end of December 2021)

Review

(January 2022)

Online

Early 2022

[Home – HyDelta](https://www.hydelta.nl) - *www.hydelta.nl*

HyDelta

Thank you for your attention!

Joris Kee

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WP7B

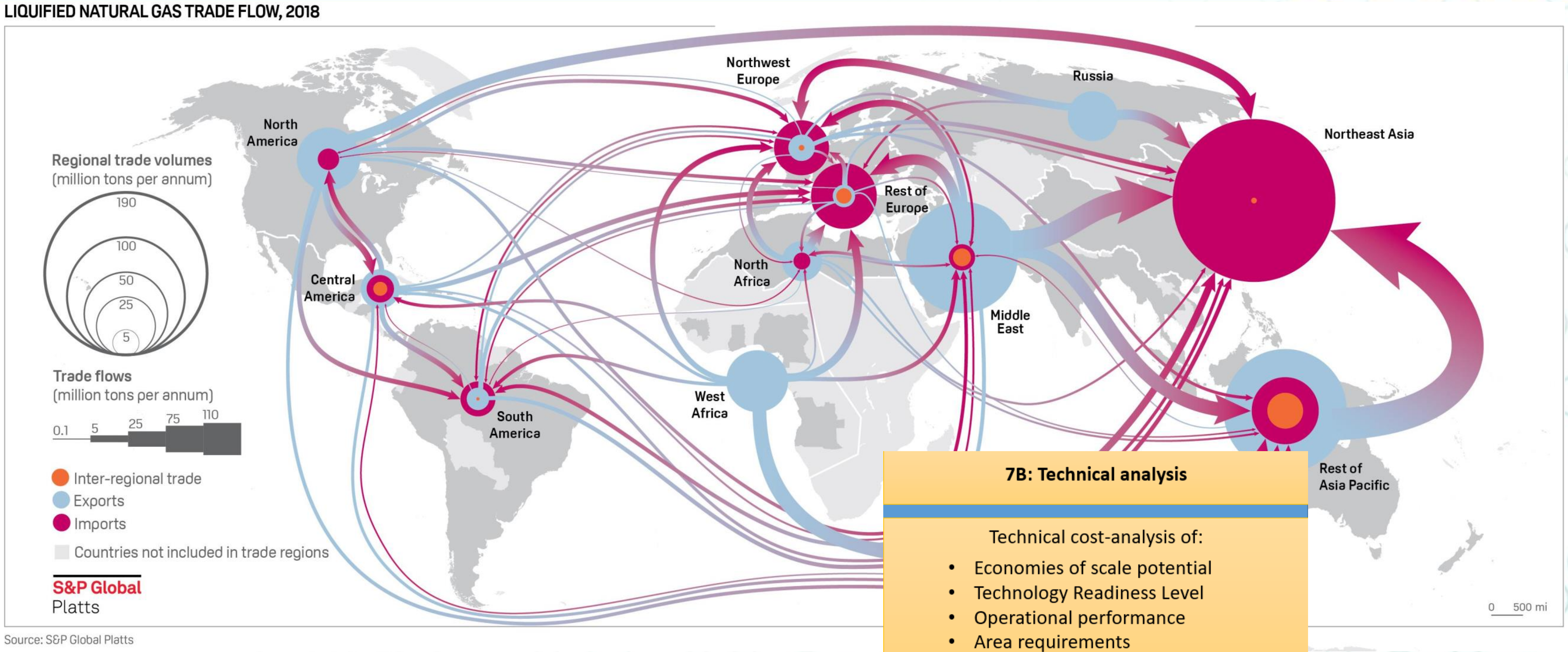
Technical analysis of H2 supply chains

TNO

Sara Wieclawska

07-12-2021

Main objectives of the WP



7B: Technical analysis

Technical cost-analysis of:

- Economies of scale potential
- Technology Readiness Level
- Operational performance
- Area requirements
- Learning curves

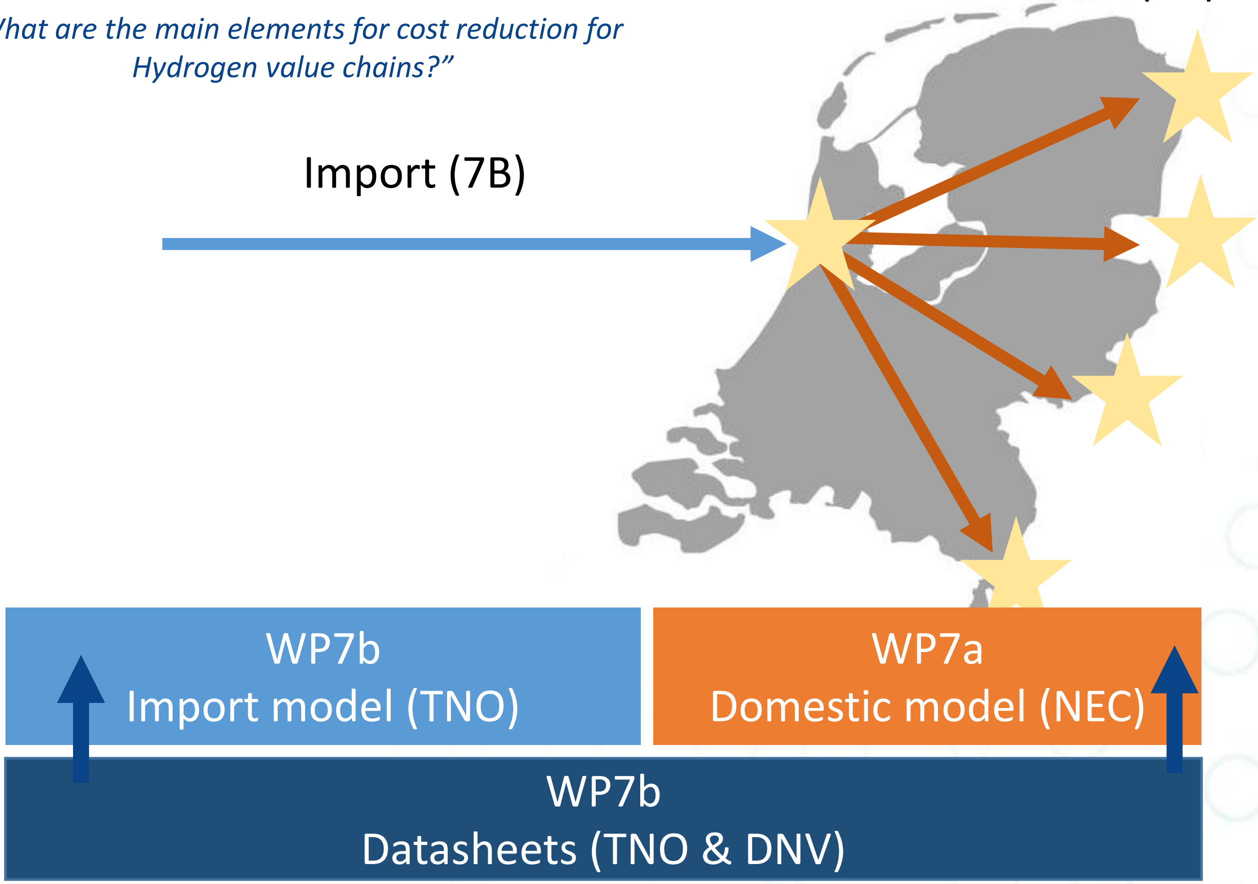
Main objectives of the WP

Output: analysis of H2 value chains

Answers to questions like:

“Which hydrogen users will get hydrogen via what means of carrier, transport and storage?’

“What are the main elements for cost reduction for Hydrogen value chains?”



Task 1 – value chain elements

- Identify and characterize the most important supply chain elements for the available options

Task 2 – technology development / innovation

- TRL & Scale-up potential
- Cost estimates + learning curves

Task 3 – innovation roadmap

- Draws on work from previous tasks
- Workshops with industrial partners
- Public report for conclusions & recommendations

Task 4 – cost models / factsheets

- Selection of relevant supply chains + scenarios
- Cost analysis per supply chain (input for WP7A)
- Report (documentation + analysis)

Progress of the work in Q3

Renewable energy source

Solar
Wind

Energy carrier conversion

LH2
Ammonia
LOHC
MeOH

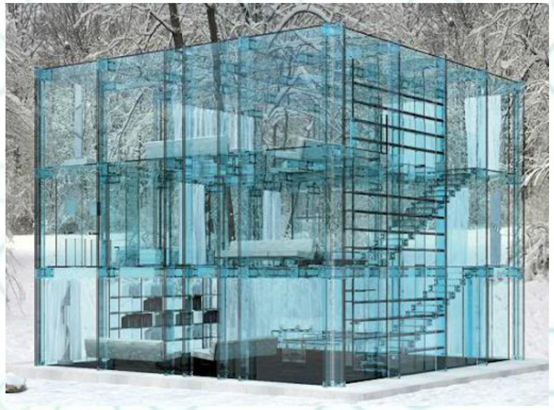
Transportation

Ship
Pipeline

Reconversion & consumption

GH2
Ammonia
MeOH

Transparant
Easy to use
Expendable



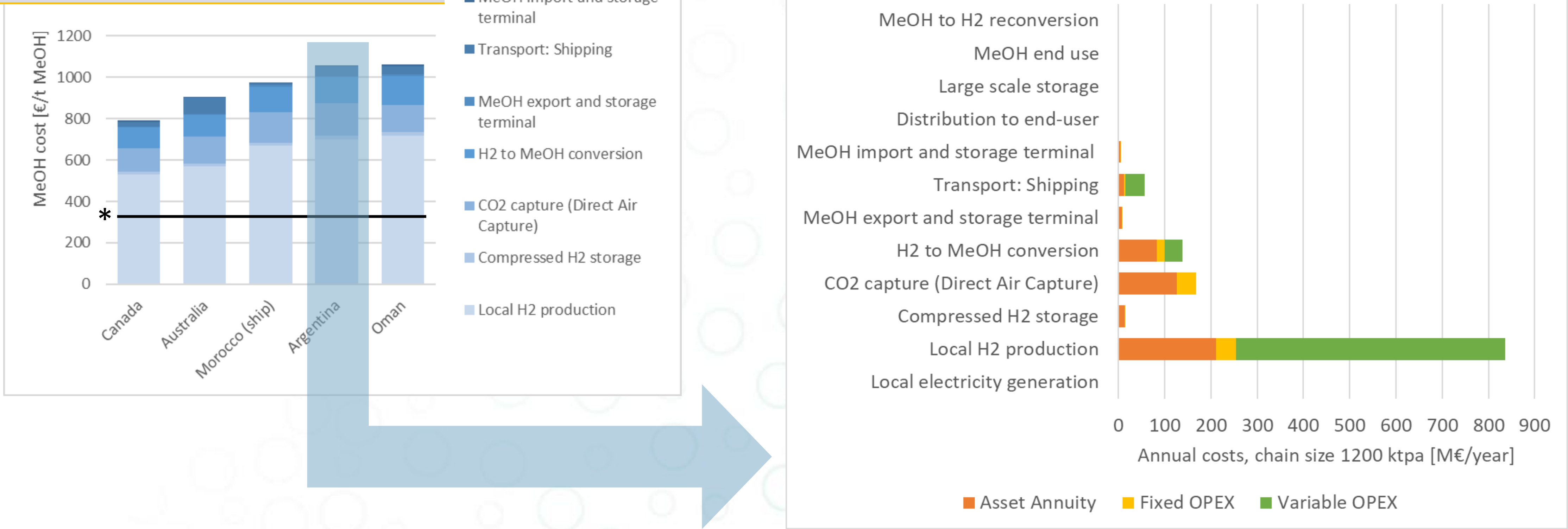
TNO H2 import SCM

Progress of the work in Q3

Example: Methanol import

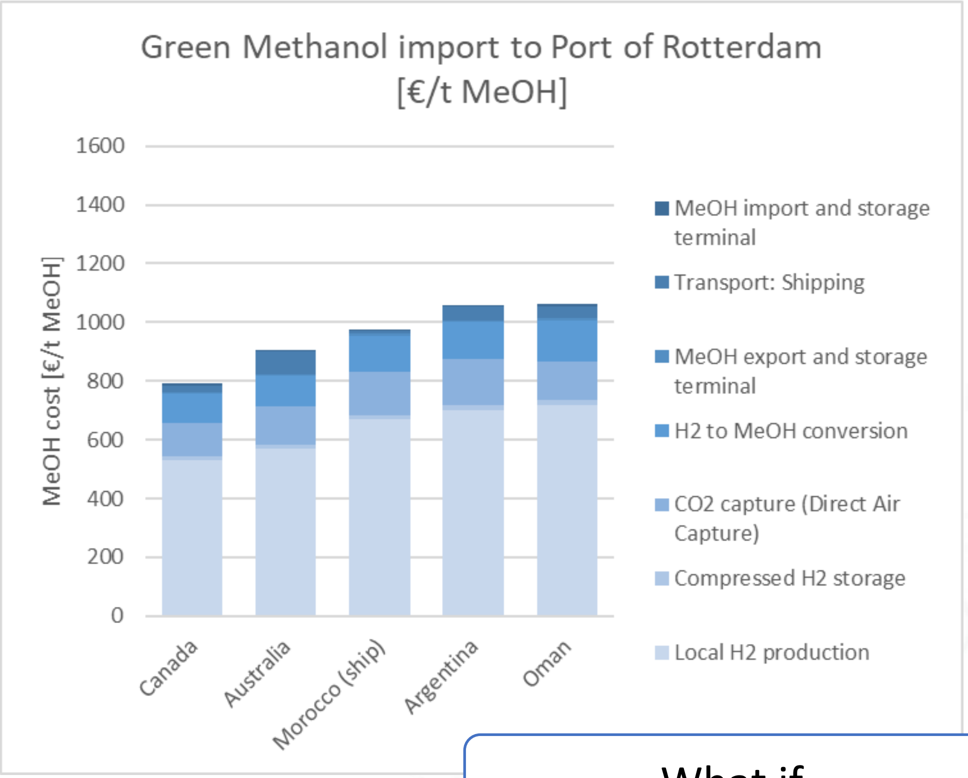
Green Methanol import to Port of Rotterdam [€/t MeOH]

Volume (ktpa)	1138	1245	1224	1267	966

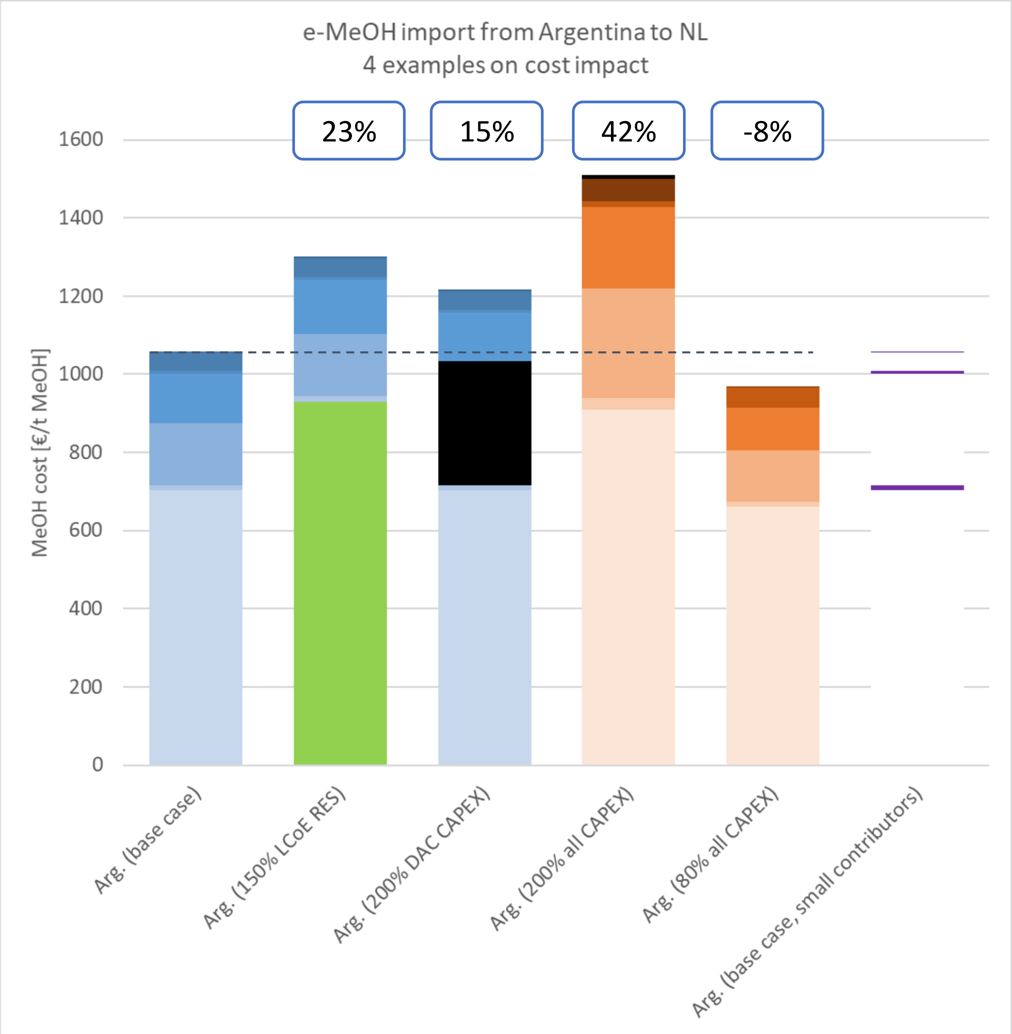


Progress of the work in Q3

Example: Methanol import



What if…



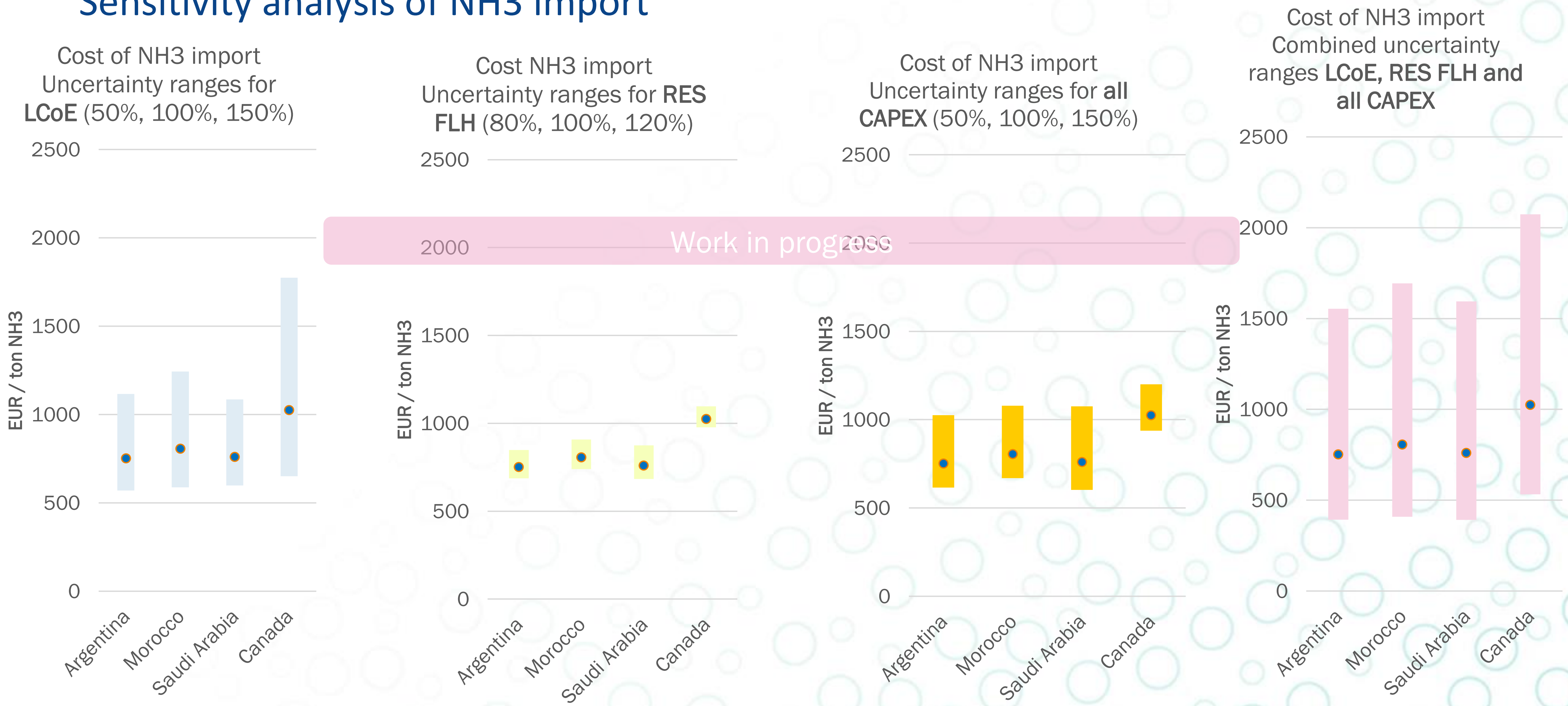
- What are the innovations with the largest cost **reduction** potential?
- Which processes/technologies are **critical**, despite their minor contribution to total costs?

Work to be done in the next period

- Sensitivity analysis
- Cost reduction potential
- Innovation roadmap

Work to be done in the next period

Sensitivity analysis of NH3 import



Work to be done in the next period

Cost reduction potential over time (NH3)

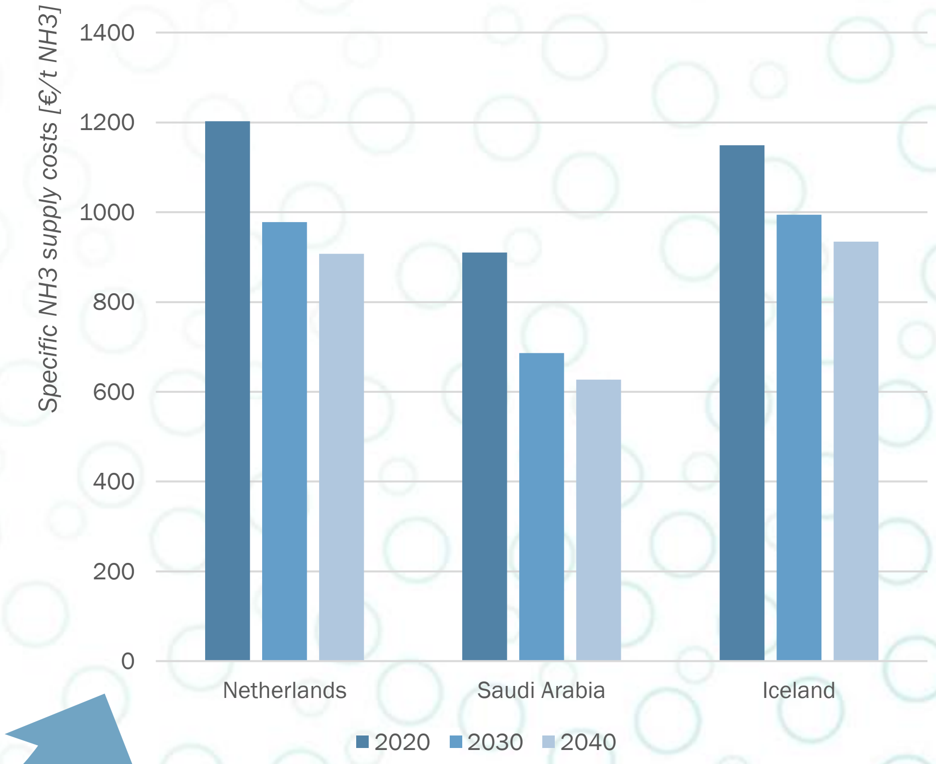
Alkaline AEL					
Description	Unit	Source ID	2020	2030	2040
Scale of the electrolyzer plant	[MW]		100	100	100
System energy efficiency	[%]	(1-3)	64	70	72
Specific power consumption	[kWh/kg H2]	(1-3)	52.1	47.6	46.3
Heat released	[%]		26	20	18
Total direct cost, specific	[€/kW]	(1-4)	780	407	332
System cost decline (annual)	[%]			2	2
Total direct cost	[M€]	(1-4)	78.0	40.7	33.2
Scaling factor	N/A		0.9	0.9	0.9
Fixed OPEX	[M€/y]		2.0	1.0	0.8

Dashboard of primary results

	Count	Country B vs.	Country C
Import supply chains (drop down):	Netherl	Saudi Arabia	Iceland
Year	2020		

2020
2030
2040

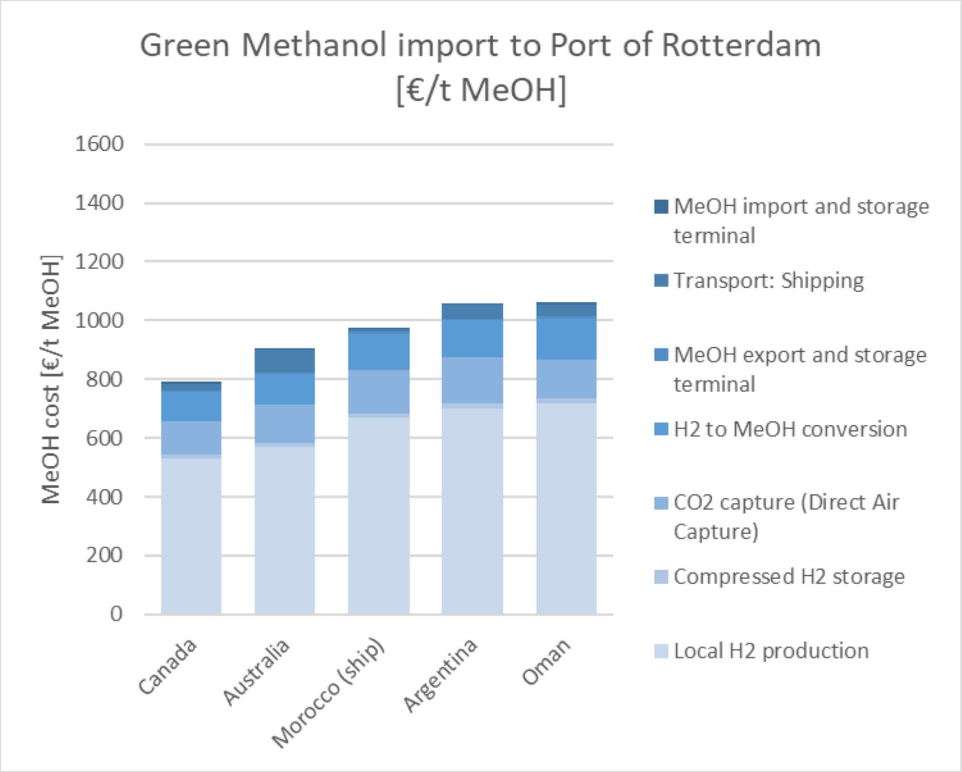
AEL cost reduction & efficiency improvement leads to decline in specific import cost NH3 (2020-2030-2040)



Work to be done in the next period

HyDelta

Benchmarking with other models/studies

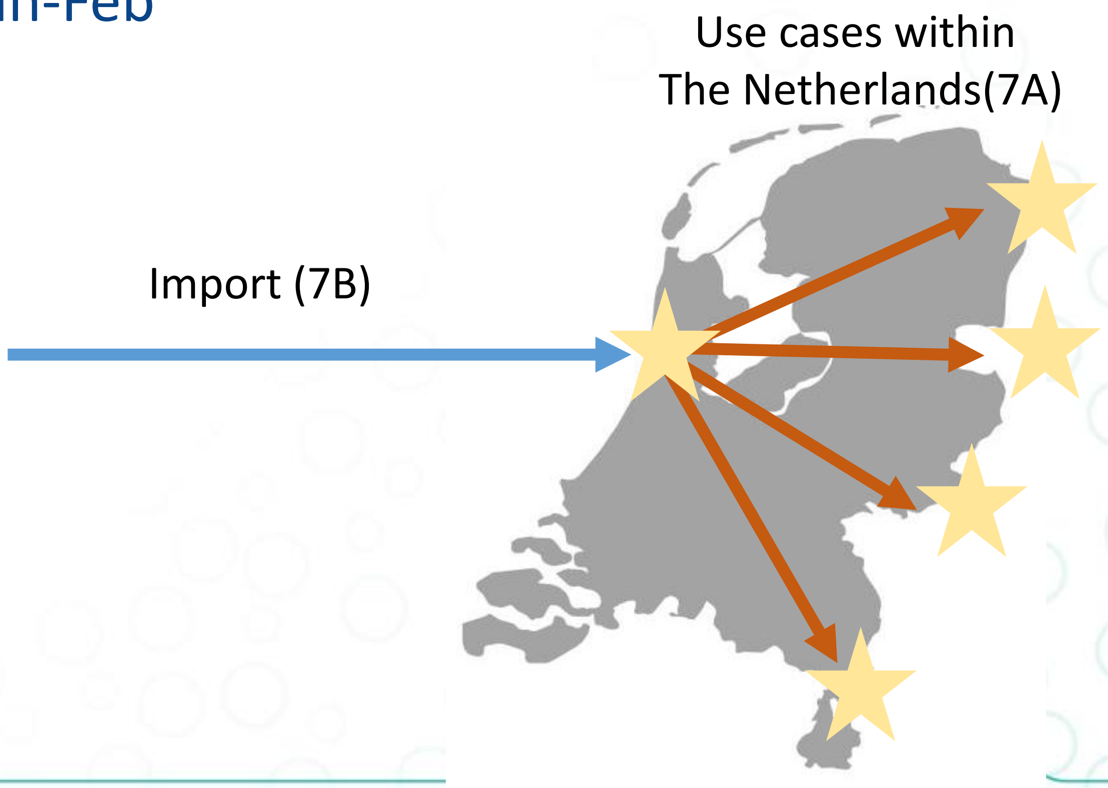


Country	TNO SCM 1.2 Import cost (€/t)	HyChain II Import cost (€/t)	TNO SCM 1.3 (HyDelta: in progress) Import cost (€/t)
Canada	906	785	837
Australia	1034	919	757
Morocco	1123	802	796
Argentina	1217	977	667
Oman	1194	702	966

Work to be done in the next period

HyDelta

- Innovation Roadmap
  - Answer to question “what are the drivers & barriers for different hydrogen users the coming years?”
  - Workshops with the end-users incl. dissemination (contact)
  - Planned Jan-Feb



HyDelta Wishlist…

1.How do imports by ship (e.g. NH3, LH2) compare with direct pipeline imports from nearby countries? (add pipeline transport)
2. Which input parameters are the main drivers of uncertainty? (add monte-carlo module?)
3, How do imports by HVDC + national H2-conversion compare with direct pipeline imports from nearby countries?
4. What is the value of storage? How do you guarantee security of supply via import?
5. How much does it cost to produce/import other carriers (e.g. e-methane, e-diesel, e-kero, syngas, ...)
6. Should company x produce chemical y in NL directly or in another country and import it?
7. How do different Dutch / EU / foreign policies (carrots/sticks) shift the balance between imports & locally produced H2? (economic/policy/market potential perspectief). E.g. REDII eliminating non-sustainable ship fuels
8. What are the End-user prices for the carriers? (cost -> price)
9. Is there a tipping point in transport distance between countries? When does distance not matter anymore?(add more logistics details)
10. What is the Carbon footprint/environmental impact reduction potential when importing to the NL? (LCA, discuss with Toon van Harmelen)
11. Biogene koolstof ipv ‘technische’ DAC route
12. Which supply chain activity is most cost-efficient in which country? Broader cost comparison between importing an intermediate product (e.g. syngas, MeOH) or directly importing e-fuels (e.g. synthetic kero). Last conversion step in NL. RG suggestie: opstellen workflow voor specifieke producten doorrekenen.
13. How would importing H2 from a given country interfere with their own decarbonization ambitions? – how (in)dependent from local developments could the supply chain be ‘installed’? -> how FAIR is green molecule import? What is the globally most EFFECTIVE supply chain to achieve the climate goals?
14. What is the relevance of the produced co-products (like O2) in the bigger picture?
15. What are the costs of 'the last mile' from import harbour to end-user? Which transport modalities?
16. How can asset repurposing / prevention of stranded assets influence the cost distribution and preference of value chains (e.g. MeOH>NH3)
17. What is the spatial claim/footprint of the H2 value chains?
18. Trends. E-demand vs. E-supply projections per country. Where do we expect an oversupply, = price reduction = logical place to produce H2
19. How does import compare to decentralized H2-product production? (for cluster6 H2 demand)
20. (4+15+19): what is the tipping point of decentral production vs. import/centralized production? --> what is the market potential of decentralized GREEN H2 production?/wat is de waarde (MVO reputatie, prijs, leveringszekerheid) van decentraal/centraal nationaal/import?
21. Why do you expect a mismatch in NW-EU?
22. Add non-electrolyzer technologies to produce green H2

HyDelta

Thank you for your attention!

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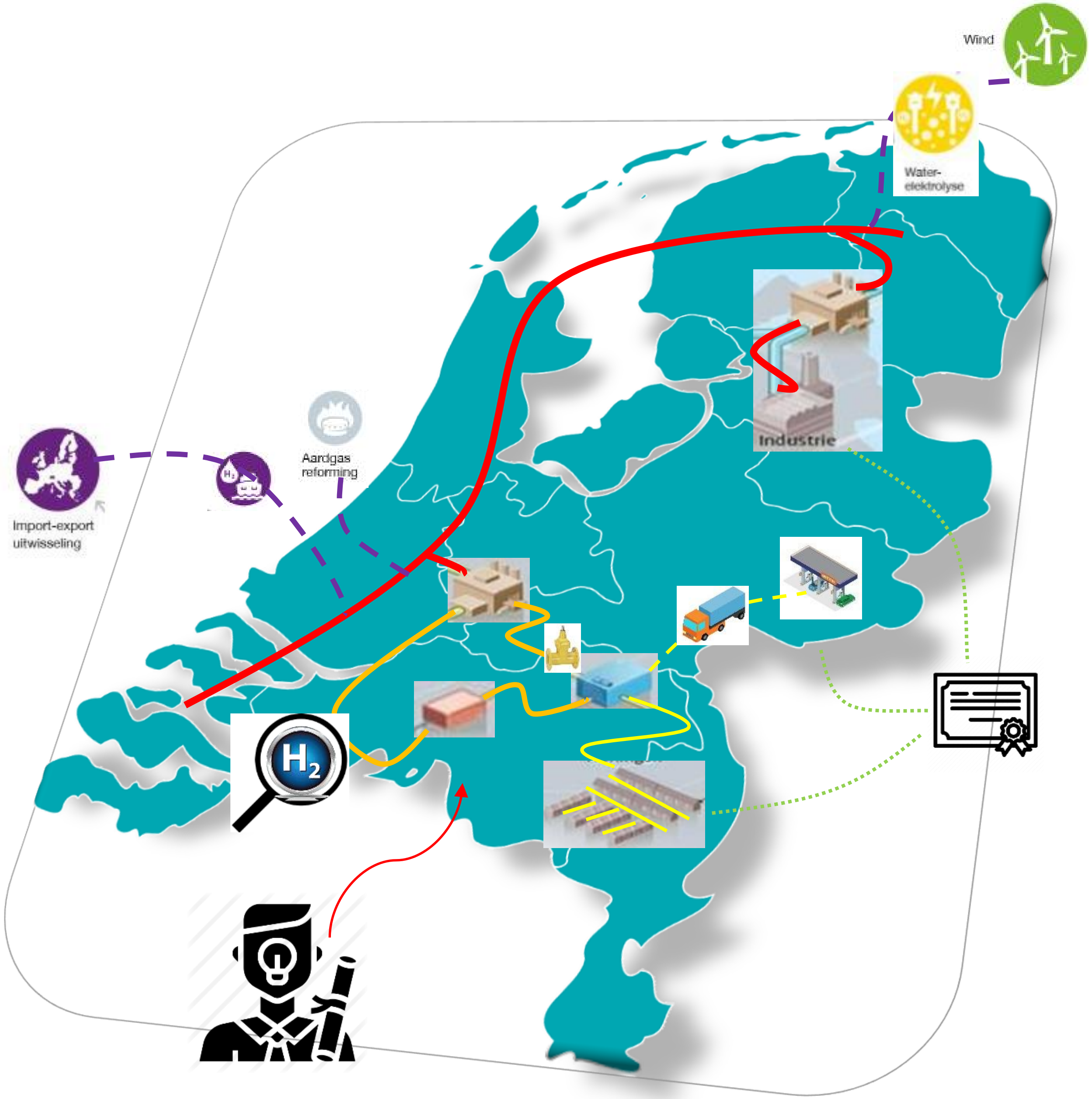
WP7C

System value of green hydrogen



DNV

Ekaterina Florez

07-12-2021

Main objectives of the WP

The study is aiming to develop a consensus position on the quantitative and qualitative benefits of using hydrogen, compared with decarbonization approaches that do not use hydrogen

Key steps

The first key step is to identify where hydrogen should best be used (end-user), based on its competitiveness versus alternative decarbonization options in different sectors.

Perspective → End user

Sectors → Industry

→ Built Environment

→ Mobility

Key steps (cont.)

But it is not just about the monetary benefits.

Society will benefit from hydrogen in different ways, and many of these benefits are ***qualitative*** – although some numerical data would be provided

These benefits include air quality, jobs, and energy security.

Infrastructure also plays a role

There are also societal benefits to using existing infrastructure where possible

The report will include a description of these, and it will exclude a detailed quantitative analysis. In any case, the degree of gas and electricity network changes will depend on the extent to which hydrogen is adopted in end-use sectors.

Progress of the work in the period

- Aligment on the aim of the project
- Model to quatify where hydrogen should best be used → end- user perspective.
  - Type of inputs needed
  - Type of subsectors to be analysed
  - Reach of the model
  - Started building the model
- Report template shared

Work to be done in the next period

Workstreams	Work to be done
Economic value & Decarrbonization value	Finish building the model Reviewing data Analysis outputs
Societal value	Review public available reports and findings from DNV interviews already carried out Analysis of information
Final recommendation	Conclusions and policy recommendations

Deliverables

- Draft report → Week 1, 2022
- Final report → Week 3-4, 2022

HyDelta

Thank you for your attention!

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Plenary Progress Meeting

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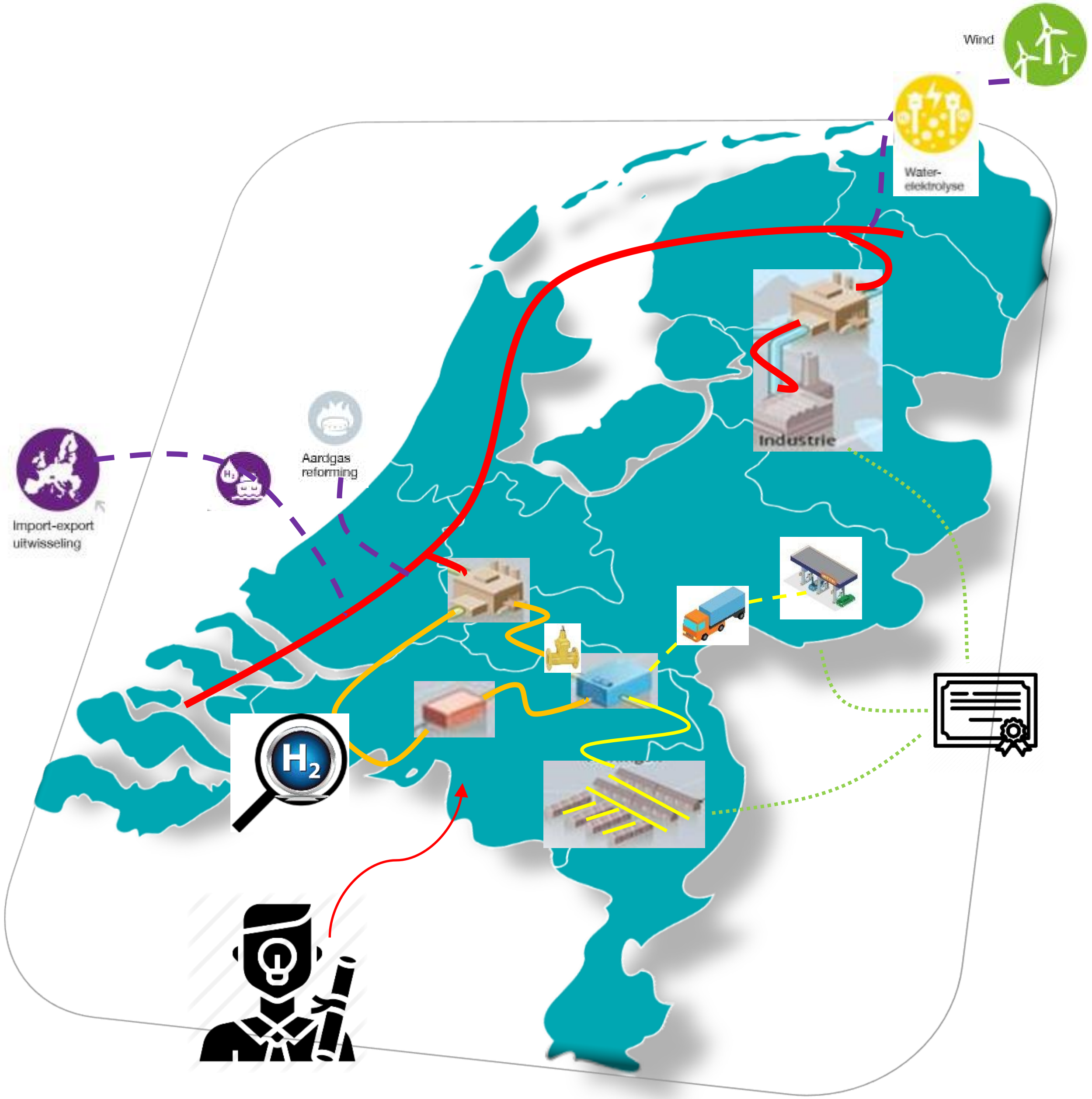
WP8

Admixing & mandatory blending

New Energy Coalition

Rob van Zoelen

07-12-2021



WP8 – Admixing & mandatory blending

- Main aim: to assess if and to what extent mandatory admixing policy regimes involving green hydrogen can effectively be introduced

	Activities	Method	Deadline
1	Literature review of physical and administrative admixing	Literature study	May
2	Assessment of comparable admixing regimes	Qualitative assessment	Jun
3	Introducing dedicated experiments to roll out admixing regimes in practice	Qualitative, interviews	Sept
4	Economic analysis of potential market developments in hydrogen certificate markets	Qualitative, small calculations	Dec
5	Listing the possible implications of the research for policies		Dec

Focus:
Administrative blending/
quota obligation

Partner(s):

New Energy Coalition

Catrinus Jepma
Jorge Bonetto
Rob van Zoelen

D8.2 Assessment admixing schemes

- Assessment based on four schemes, two voluntary and mandatory schemes
- Four criteria used

	Voluntary schemes		Mandatory (quota) schemes	
Scheme	RES-E GO's by CertiQ	Green gas GO's by Vertogas	Dutch fuel blending obligation	Norwegian-Swedish electricity quota
Sector	Electricity	Gas	Transport fuels	Electricity
Country	Netherlands	Netherlands	Netherlands	Norway and Sweden
Assessment criteria	• General and design characteristics • Legislative characteristics • Economic characteristics • Environmental characteristics			

- Three take-aways highlighted:

Trustworthiness	Tradability of certificates	Effects on investment
• Difference physical reality and administrative claims	• 'Leakage' of national support	• SDE++ & voluntary (price-based) • Mandatory (volume-based)

D8.3 Pilots for introducing hydrogen blending quota

HyDelta

- Three potential quota schemes are described, which could be implemented individually or next to each other:

Proposal:	1: Industrial	2: Gases	3: Fuels
Market sectors	(Specific) industrial applications (e.g. ammonia, methanol, refineries)	Gas suppliers	Fuel suppliers for transport applications
Obligated Target parties	End-user: Industries consuming hydrogen	Suppliers: Gas suppliers	Suppliers: Fuel suppliers that deliver more than 500.000 litres, kg or Nm^3 of fuel annually
Base of quota	% of total H_2 used in processes	% of total gas delivered	% of their total taxed fuels (GJ) supplied
Accepted quota energy carriers	• Renewable H_2 • (Low-carbon H_2)	• Renewable H_2 • (Biomethane) • (Synthetic methane)	• Current accepted renewable fuels • Renewable H_2

D8.3 Pilots for introducing hydrogen blending quota

- Three pilots towards implementation of a full quota scheme:

Proposal:	1: Industrial	2: Gases	3: Fuels
Type of pilot	• Virtual pilot	• Pilot in specific region	• Pilot or adapt existing regulations
Main challenges / points of attention	• What processes included incl. definitions • How/if to include import • Pace of the quota	• Safety and grid integrity • Test local grid conversion strategy in practice • Social aspects	• Whether to include refinaries in fuel or industrial quota • Development of HRS and hydrogen vehicles
Earliest starting date full scheme	2026	2028	2022*/2025

Notes:

- The impact of already a political announcement of starting (a) pilot(s) should not be underestimated
- The earliest starting dates implying that actions are taken today, and in the case of the industrial quota suggestions have been made that initial capacities should be in place to start the full scheme

WP8 – Next steps

	Activities	Method	Deadline
1	Literature review of physical and administrative admixing	Literature study	May
2	Assessment of comparable admixing regimes	Qualitative assessment	Jun
3	Introducing dedicated experiments to roll out admixing regimes in practice	Qualitative, interviews	Sept
4	Economic analysis of potential market developments in hydrogen certificate markets	Qualitative, small calculations	Dec
5	Listing the possible implications of the research for policies		Dec

Partner(s):

New Energy Coalition

Catrinus Jepma
Jorge Bonetto
Rob van Zoelen

HyDelta

Thank you for your attention!

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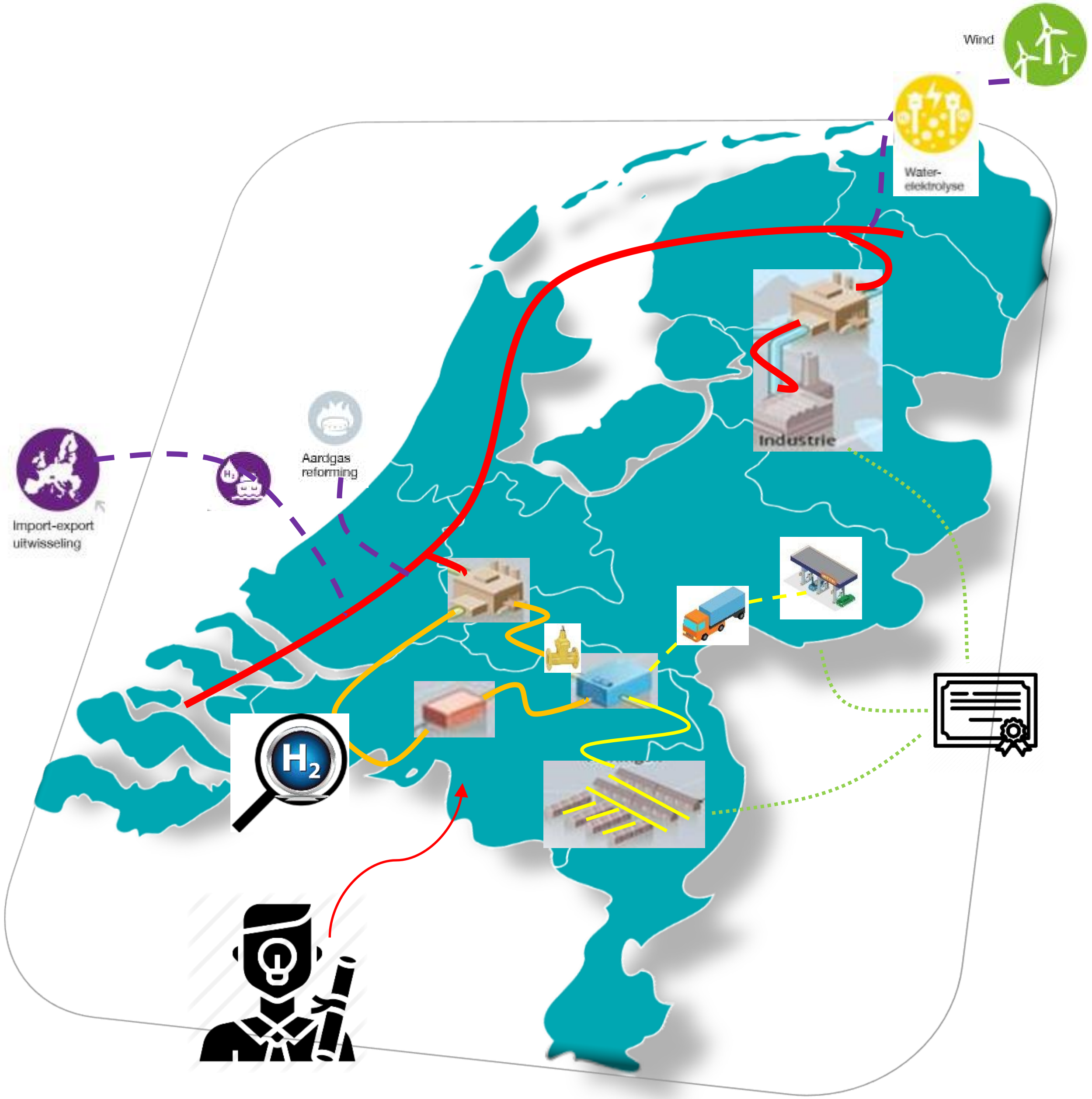
Part 2 – hydrogen safety



Plenary Progress Meeting

HyDelta

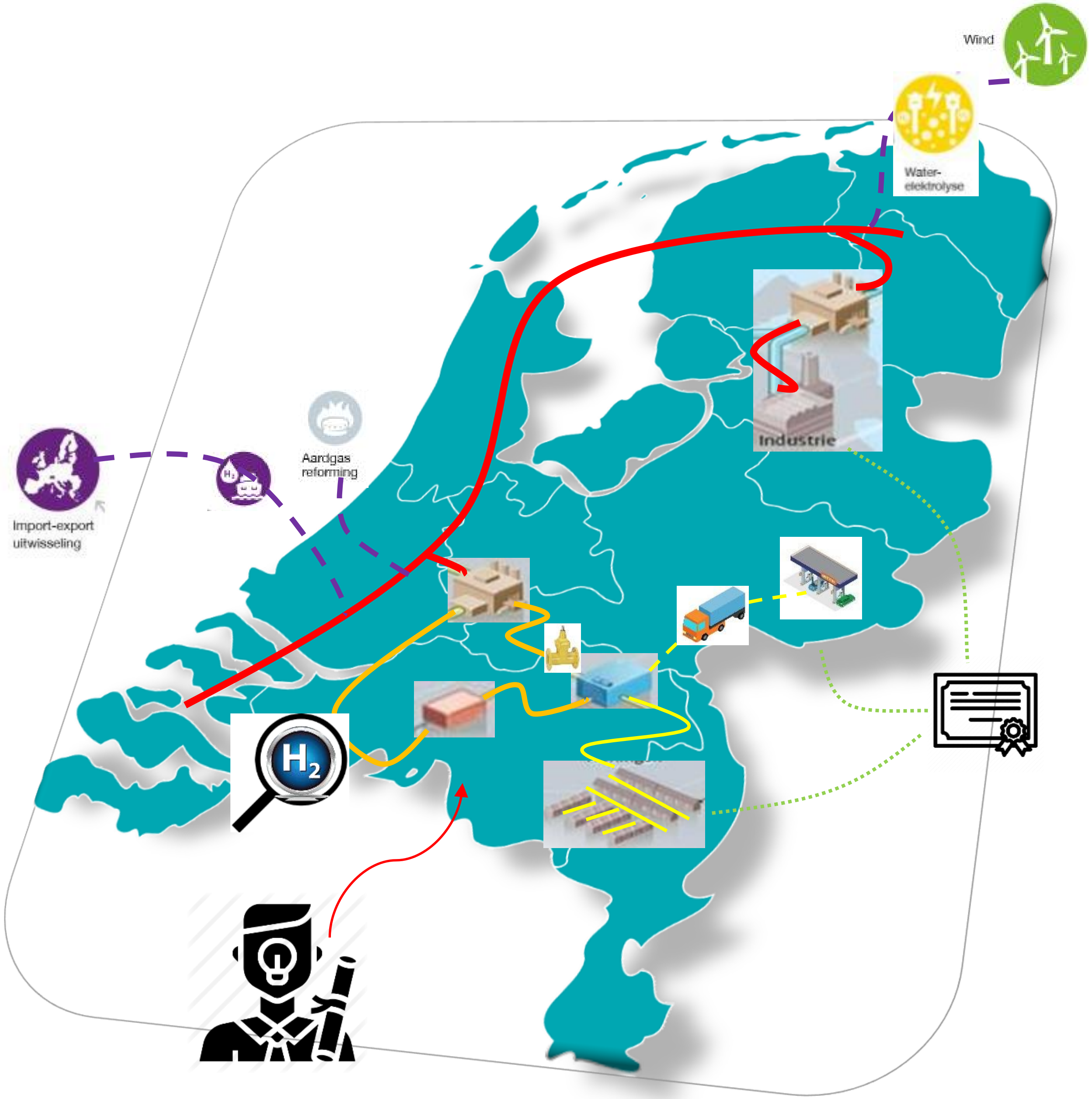
WP1a

Hydrogen Distribution and Safety

DNV / KIWA

Albert van den Noort (DNV)

7-12-2021

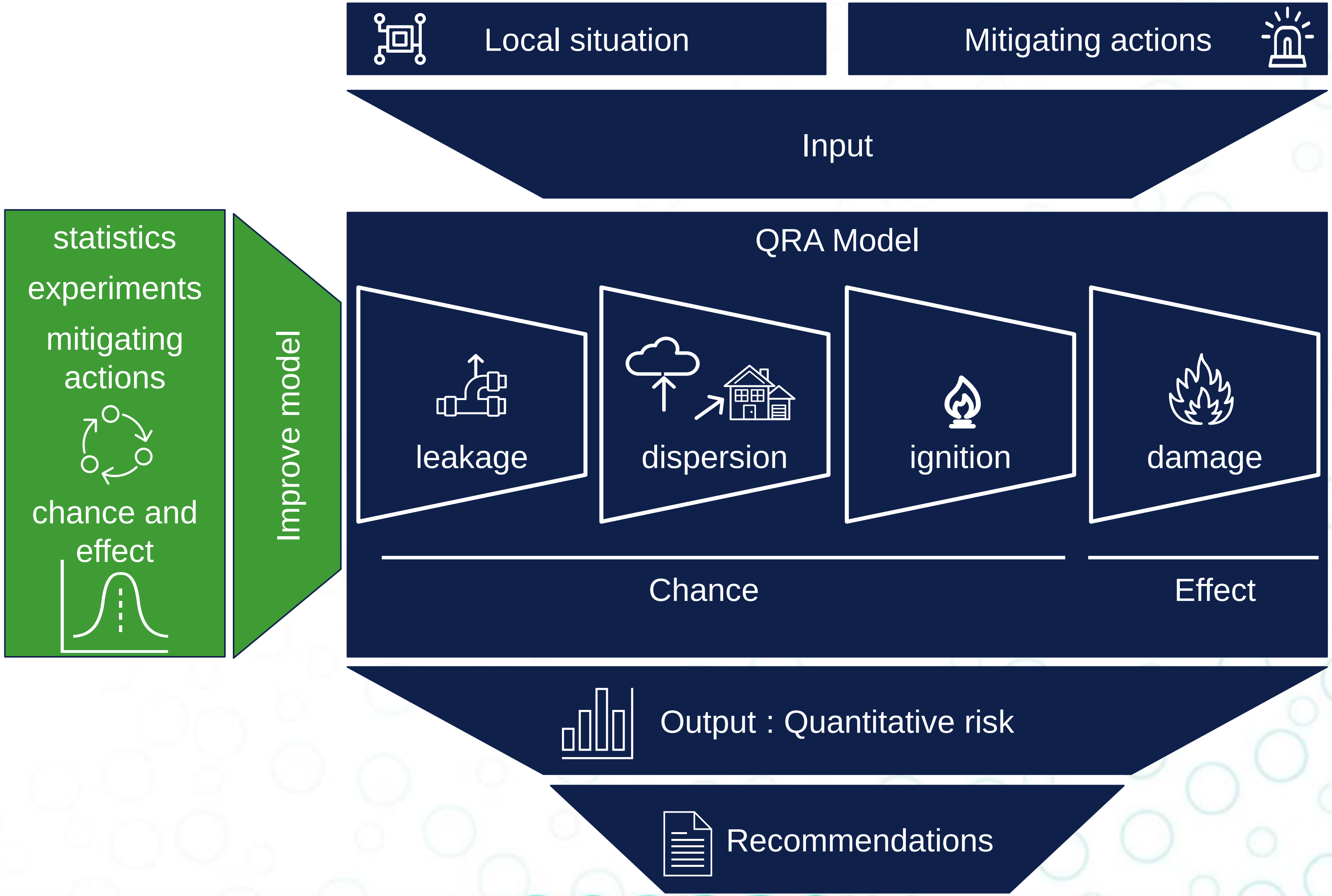


Main objectives of the WP

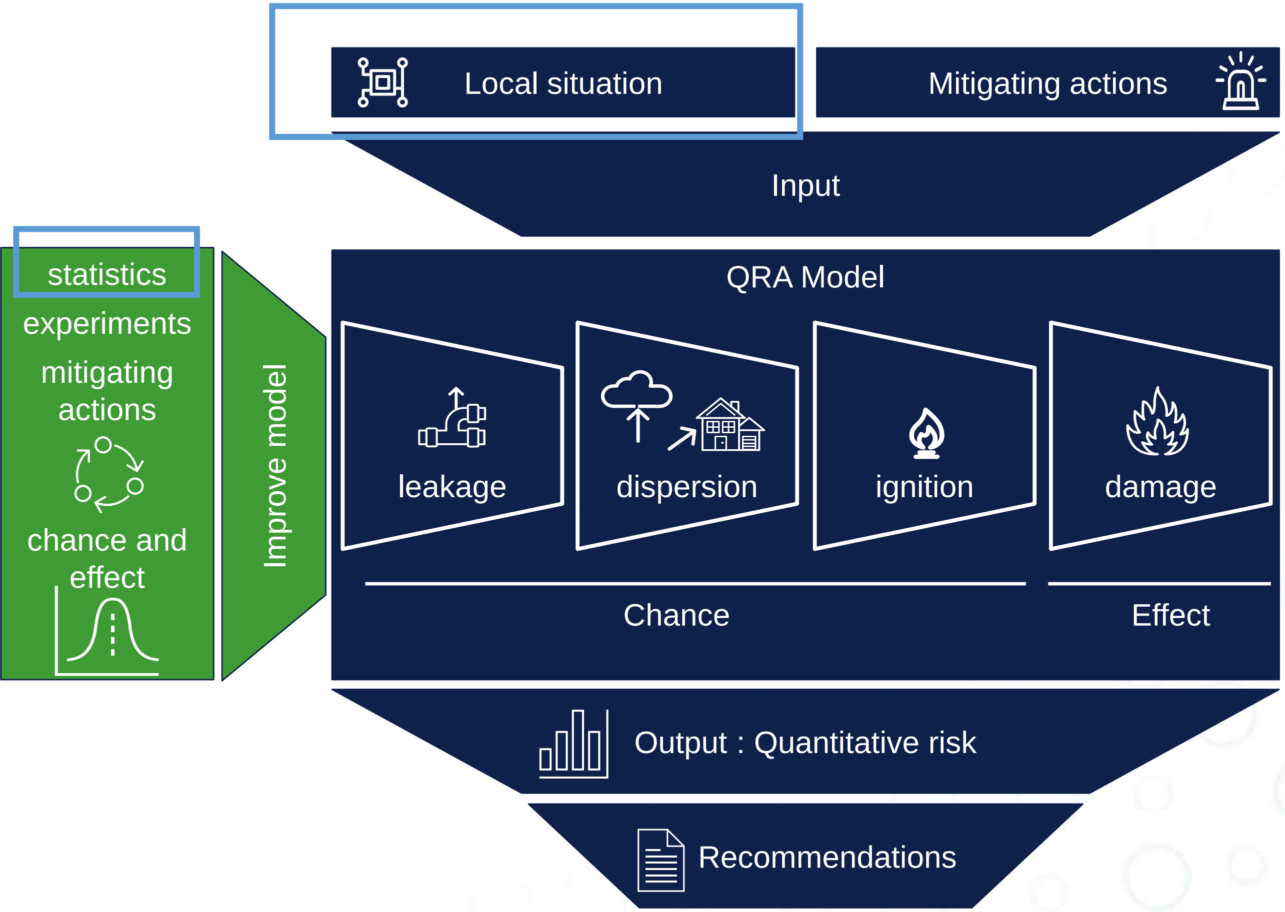
- Prove the safety case for hydrogen in the built environment is essential for pilots and future large-scale role-out.

- Goal: Understand **the safety risks** of hydrogen in the **built environment** and distribution grid and define appropriate **mitigating** actions for **acceptable** risks.
  - Build on existing / validated knowledge
  - Fill gaps in knowledge

Progress in this period: QRA Model

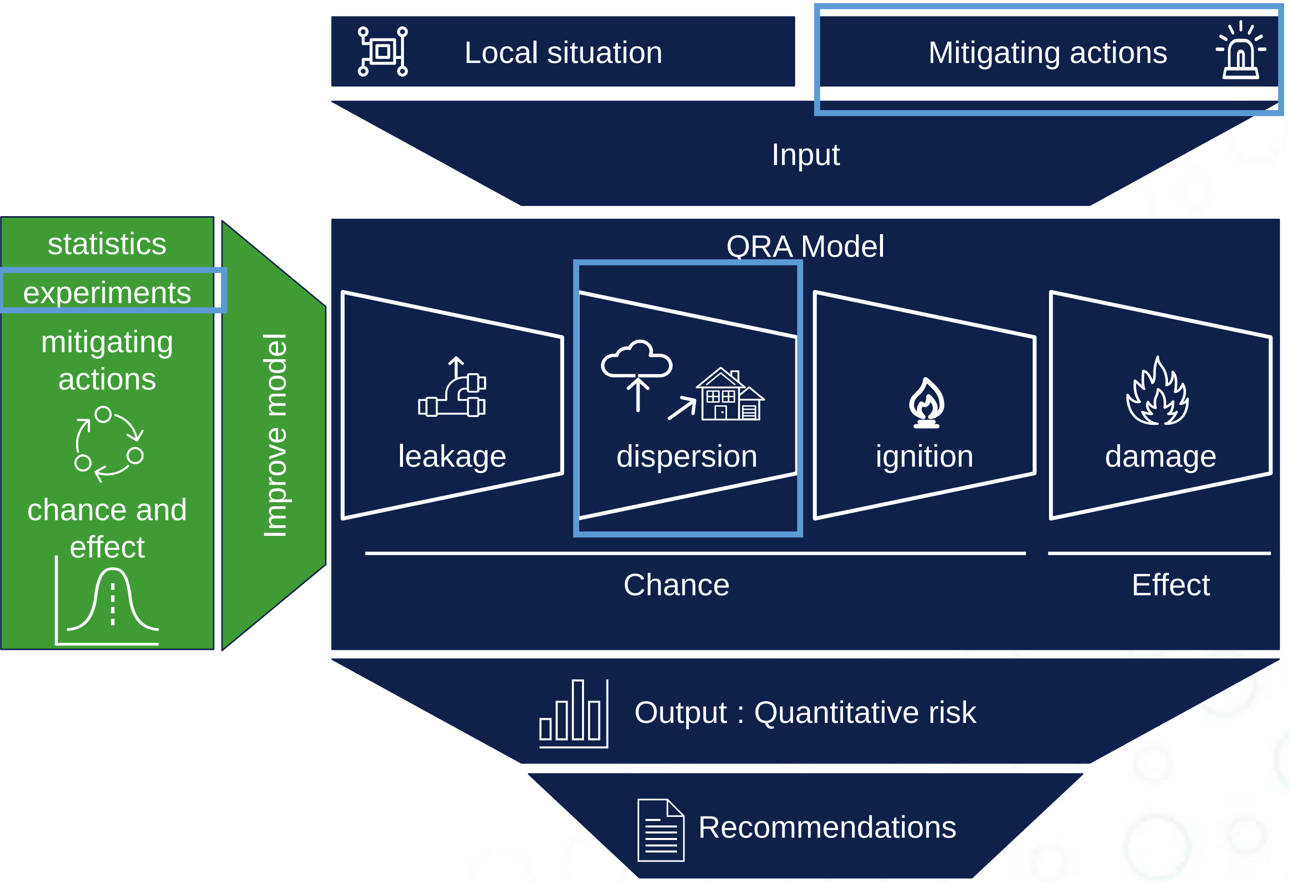


Progress in this period: compare UK vs NL



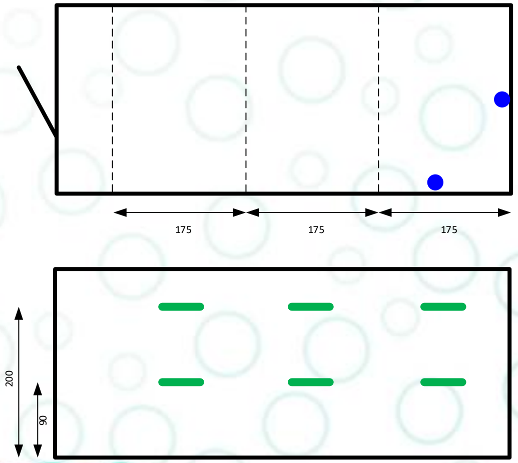
- Reviewing outcomes of the UK projects
  - Different materials for the distribution network
  - Location of equipment
  - Use of ECV
- Analysing leak rates and accidents in the Netherlands

Progress in this period: Experiments

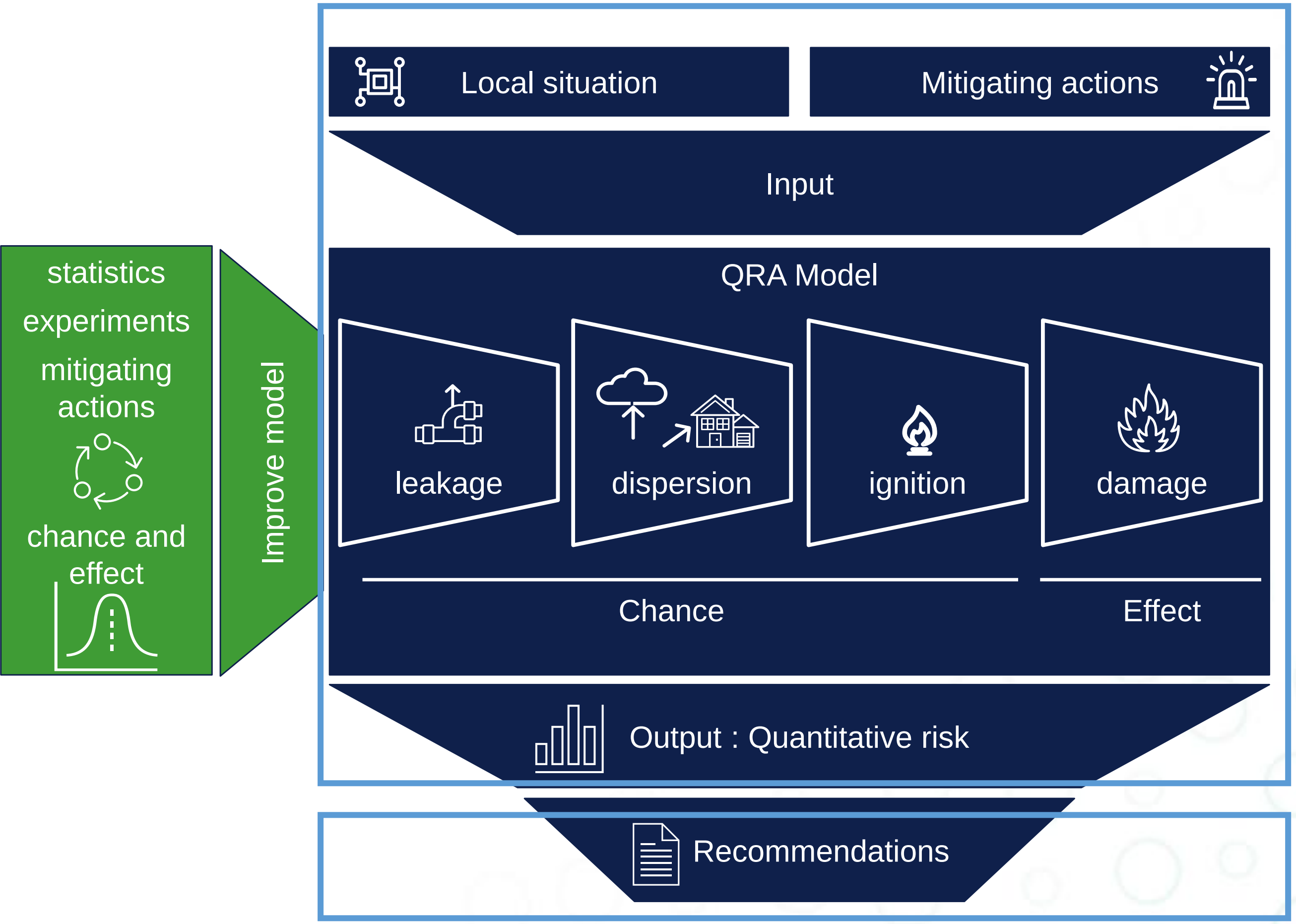


Setup experiments

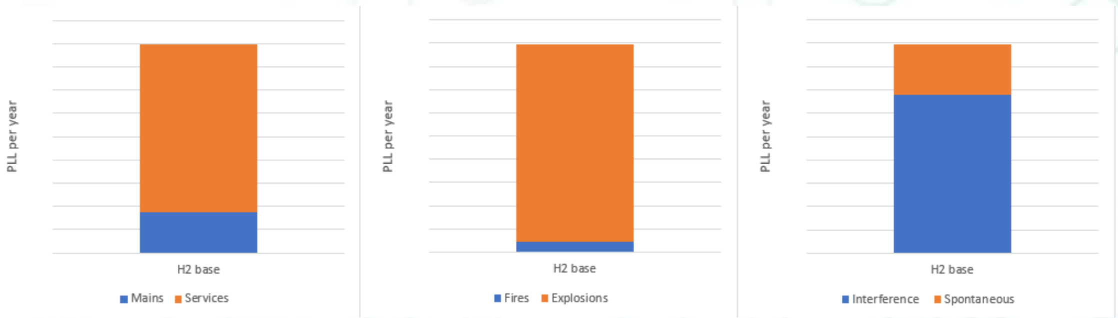
- To demonstrate the effectiveness of mitigating actions such as sensors and ventilation
- Accumulation of H2 in rooms for small leakages



Progress in this period: initial QRA modelling



- First calculations with the QRA model



- Draft first advice on mitigating actions in the Dutch hydrogen pilot projects

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Thank you for your attention!

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HyDelta

WP1E

Impact of high velocity of hydrogen flows

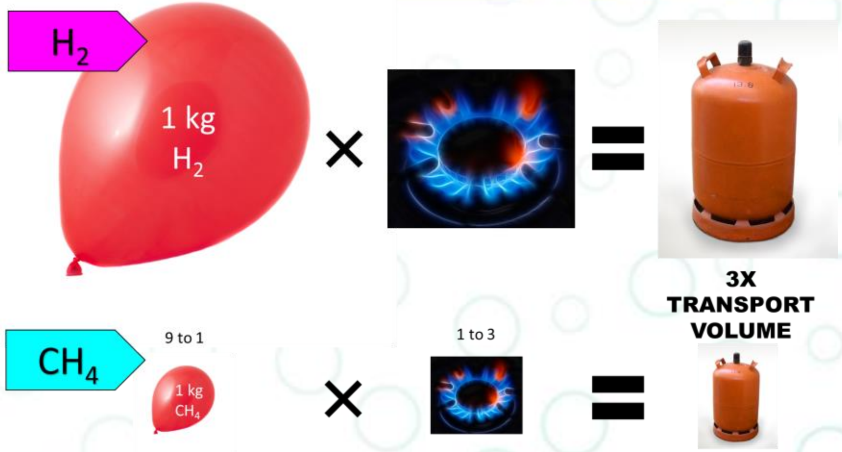
TNO

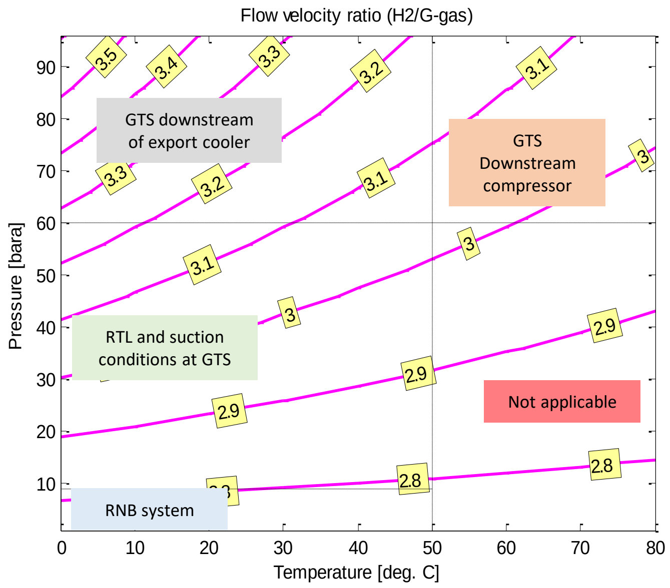
Néstor González Díez, Deputy RM HTFD

07-12-2021

Introduction

- When the same amount of energy as transported with natural gas is to be delivered in the form of hydrogen, the flow velocity has to increase significantly.
- In the schematic shown on the right, which compares hydrogen to methane, a flow rate ratio of ~3 is necessary to achieve this. For natural gas compositions, with different mol weight and calorific value, this value can be higher (in HyDelta we scope only G-gas)
- It is essential to understand whether the *existing* hardware will experience a larger integrity risk when flowing with hydrogen than when natural gas is transported





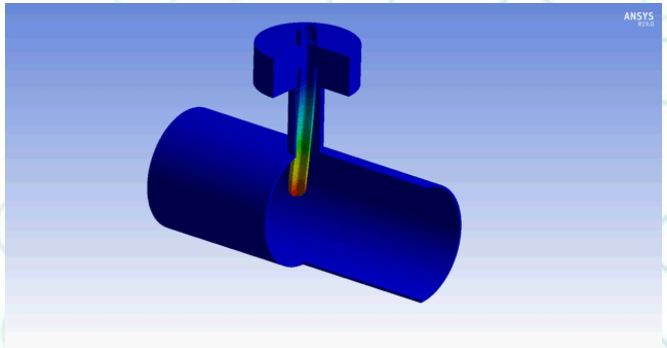
Main objectives of the WP

- Research objective
  - To understand the impact of an increased flow velocity of H2 on the different components of the existing gas transport and distribution infrastructure. In particular where it can create integrity threats or malfunctioning of instruments such as flow meters, filters, flow straighteners, dampers, mixers, control valves or other components.

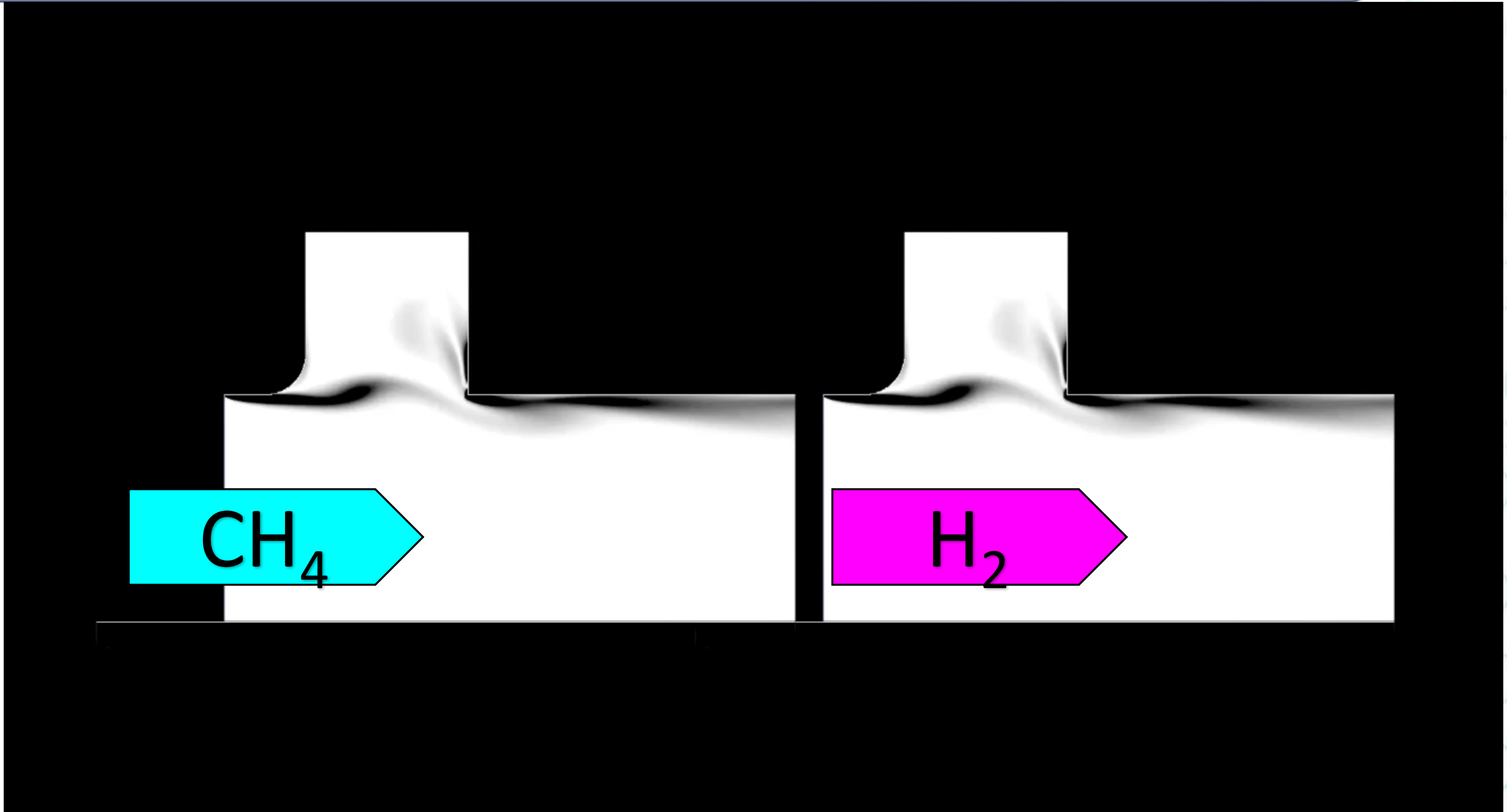
- Research questions

  What is the impact of elevated H2 flow velocities on:

  - Noise generation in piping and pressure reduction stations
  - Flow induced pulsations and vibrations
  - Intrusive equipment such as a thermowells
  - Erosion



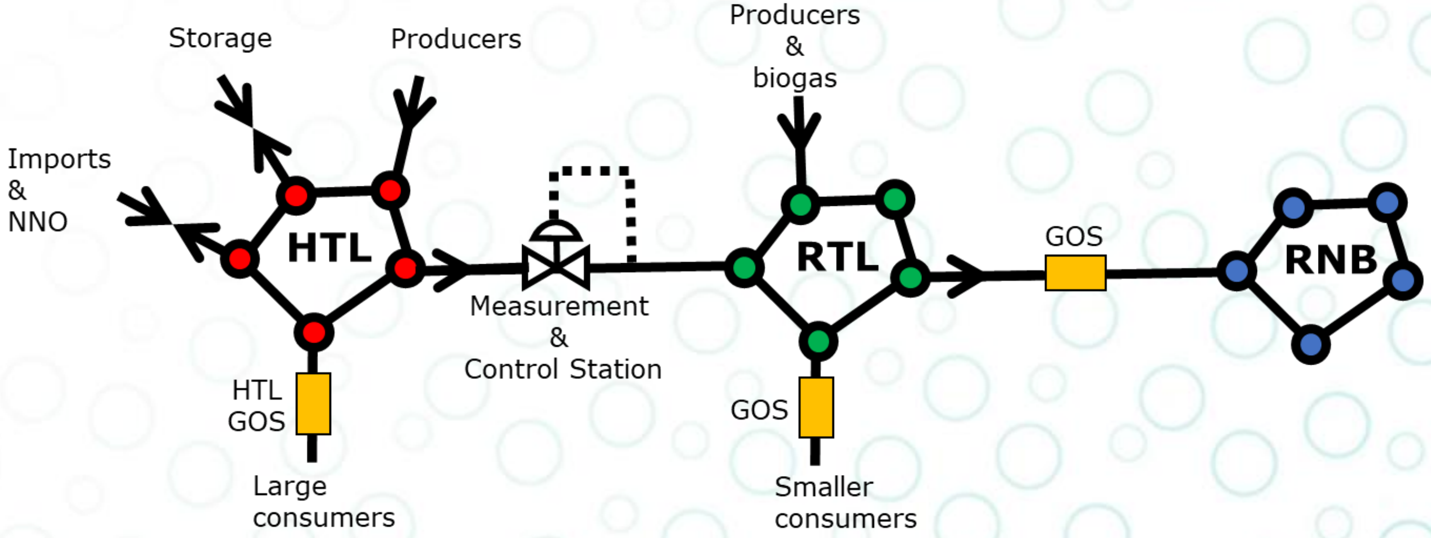
Main objectives of the WP



These animations are not made within HyDelta and cannot be shared without permissions from TNO.

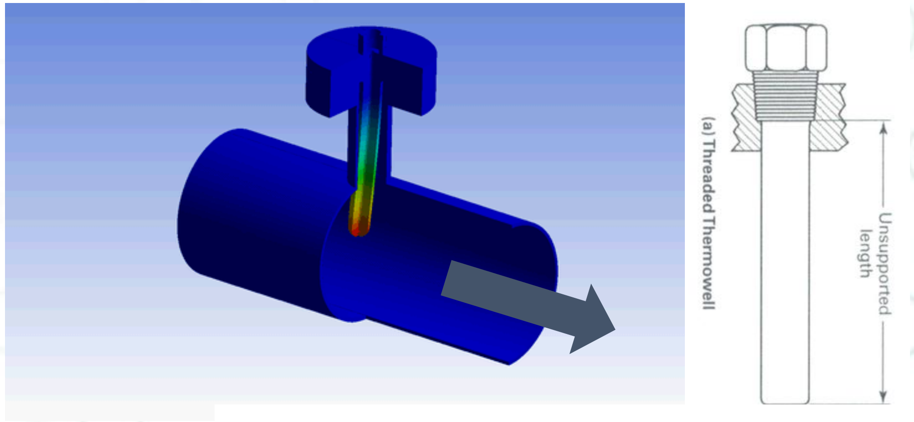
Mapping of typical "high speed flow" issues

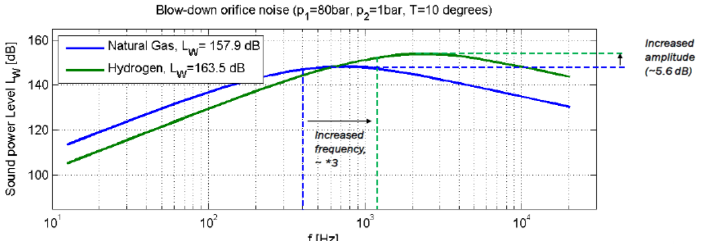
Segment of Gas System	FIV Intrusive Equipment	Flow Induced Turbulence	Flow Induced Pulsations	Acoustics Induced Vibration	Flow Induced Noise	Erosion
HTL pipeline						×
HTL compressor station	×	×	×	×	×	×
HTL storage station	×	×	×	×	×	×
HTL M&R station	×	×	×	×	×	×
HTL GOS	×	×	×	×	×	×
RTL pipelines						×
RTL GOS	×	×	×	×	×	×
RNB pipelines HP	×				×	×
RNB pipelines LP	×				×	×
RNB gas transfer stations	×	×		×	×	×
RNB gas district stations	×	×		×	×	×

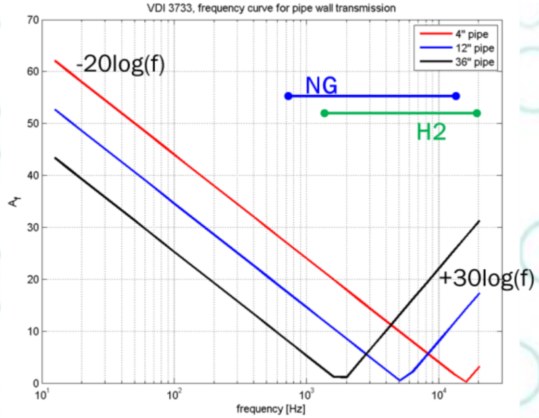


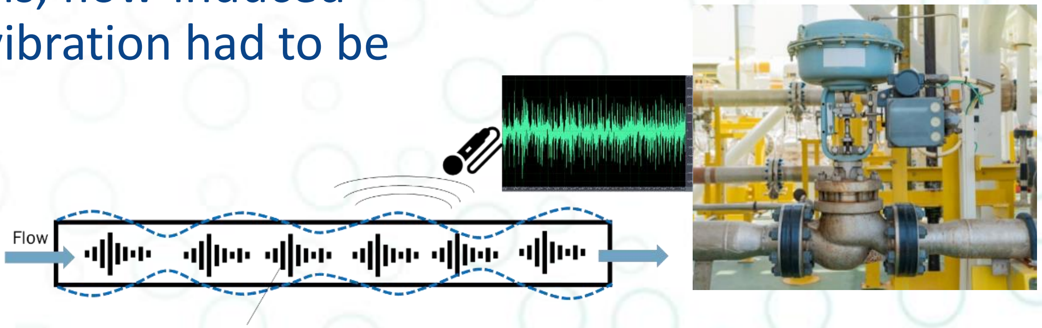
Summary of the work in the period January-June

- In the previous webinar (June 2021) we already described a number of effects of high speed hydrogen flows
- Thermowells with short-tapered designs are still compliant to the standard. Long, straight design would not, so they are recommended for replacement. This holds for GTS and RNB.
- Noise generation will shift frequency by roughly a factor of 3 in case of blow-down events. In most cases, lee flow noise will be radiated from H2 systems compared to NG. There may be some cases though where this does not happen.
- Erosion was identified as a possible barrier to increasing flow velocity, so additional work is performed in this area
- Additionally, flow-induced pulsations, flow-induced turbulence and acoustics-induced vibration had to be analysed.



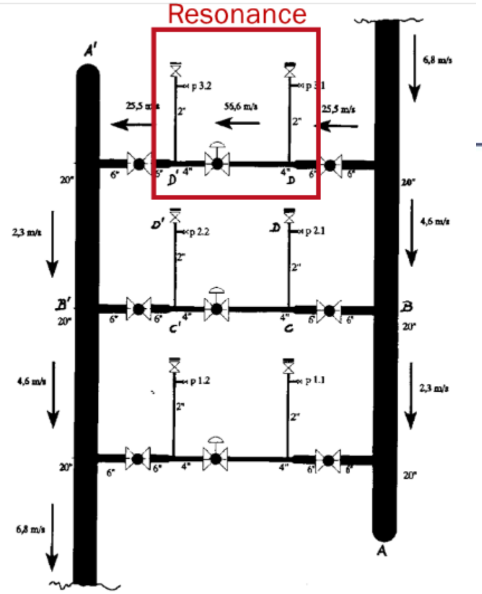


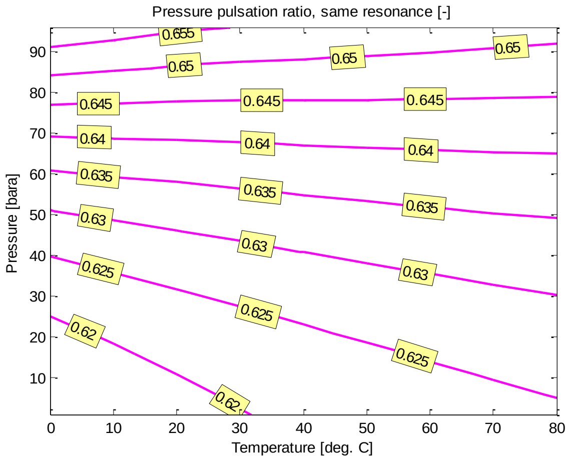


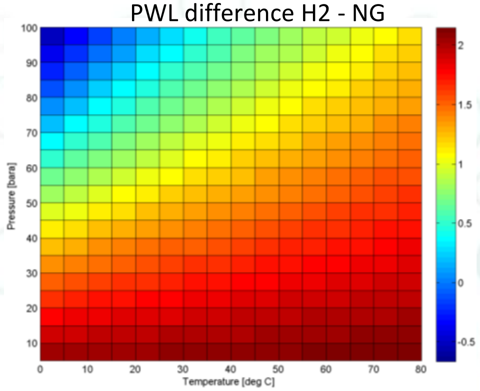


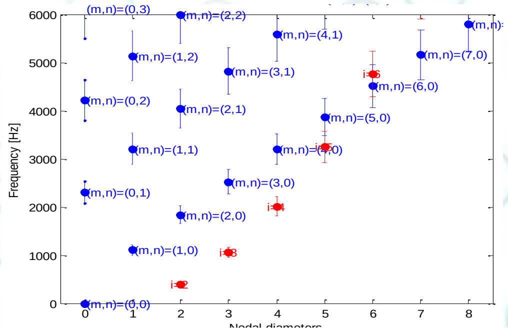
New Progress: FIT, FIP and AIV

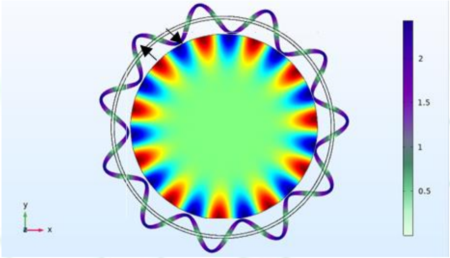
- Vibrational excitation due to flow-induced turbulence is expected to be more benign with hydrogen even at high flow velocities. Typical supporting layouts should remain sufficient to arrest excitations arising from flow turbulence generated at fittings.
- Flow-induced pulsations are expected to remain a risk similar to current operation with natural gas. While pulsation levels are expected to decrease, their frequency will increase, making them more likely to coincide with mechanical natural frequencies. Existing risk quantification and mitigation measures remain valid and should be applied.
- Acoustics-induced vibration as the result of depressurization events or pressure reduction in control streets or recycle valves will be more energetic with hydrogen. However, this energetic source is unlikely to translate effectively into a higher risk of failure. Installations featuring sudden pressure reduction intended for hydrogen re-use should be surveyed for AIV risk. Existing risk quantification and mitigation measures remain valid and should be applied. For the RNB systems, AIV has never been identified as a failure mechanism.

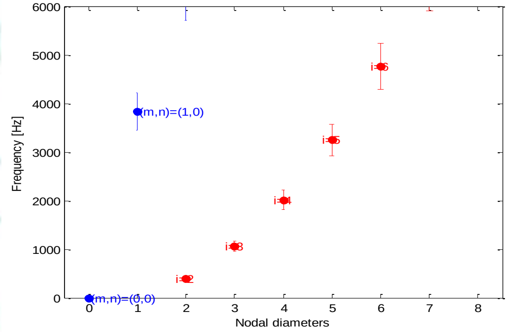






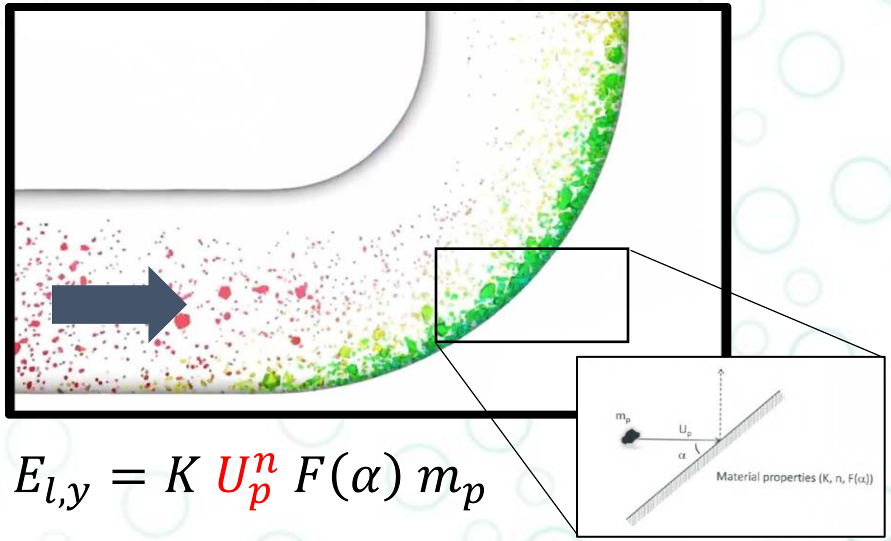




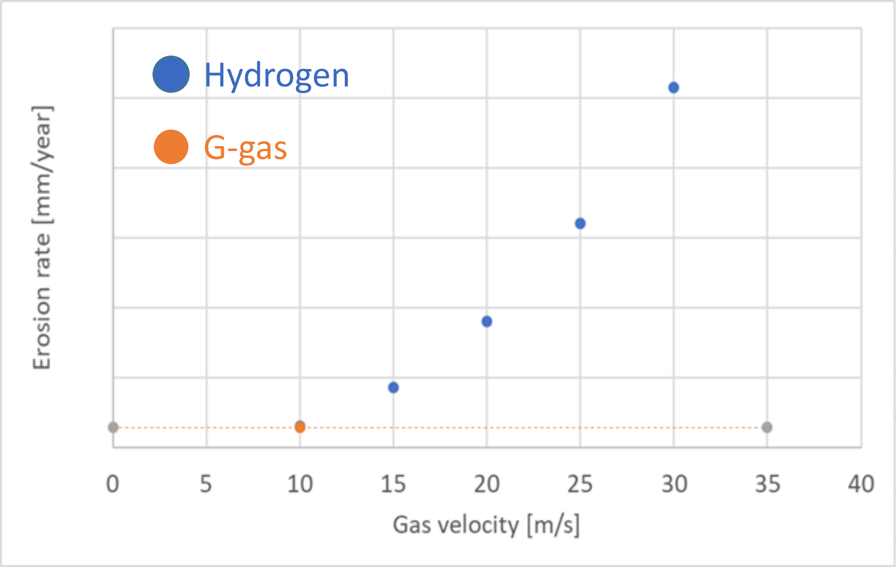


New Progress: Erosion

- Currently not an issue in GTS, RTL or RNB systems: measures to keep pipes clean, limited batches of solid particles flowing only in abnormal circumstances.
- Erosion rates calculated according to *DNVGL-RP-O501 Managing sand production and erosion*
- The effect of increased velocity and lower densities at H2 leads to higher erosion rates when the same solid rate is assumed
- Incidental batches of sand would pose acceptable erosion rates even with high speed H2 (order of magnitude: sub-microns of wall thickness loss per hour)
- We can't firmly state whether erosion is a barrier to increase flow velocity:
  - Quantification of realistic worst-case solid rates is lacking (legal limits too conservative)
  - Model used does not apply to low pressure H2 systems
  - Alternative guidelines (ASME, API) all lead to different results
  - Lack of data for PVC material constants consistent with the framework of the model
  - "Sibling" references in the UK and DE point to careful consideration of this aspect
- We recommend follow-up research with focus on determining realistic worst-case solid particle loading, how different that may be from current NG operations (if at all), and potentially CFD and tests

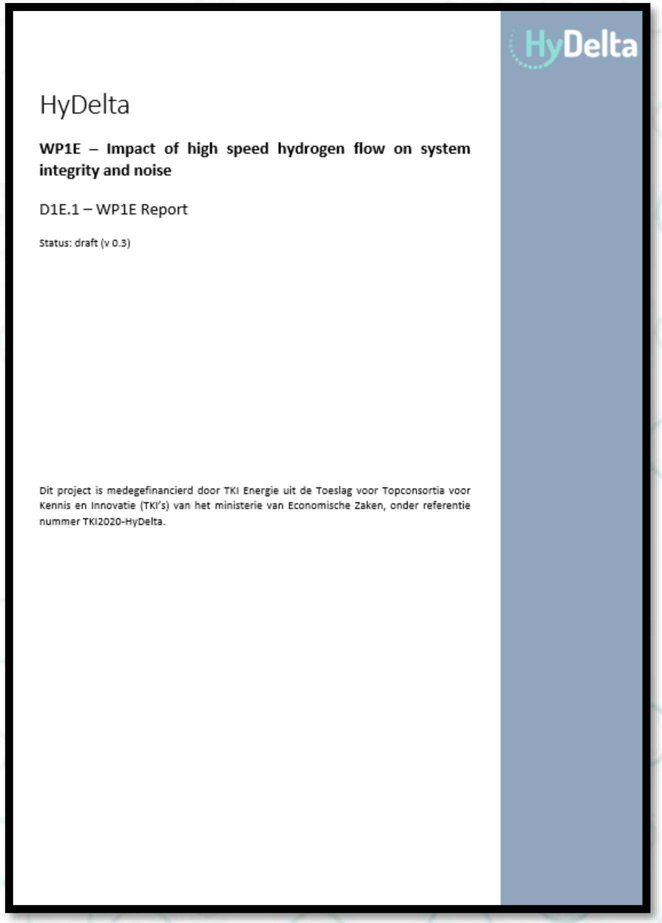


$$E_{l,y} = K\, U_p^n\, F(\alpha)\, m_p$$



Conclusions

- All mechanisms connected to limiting the flow velocity in the gas transport and distribution system have been analysed
- No showstoppers have been found that prevent increasing the flow velocity to levels equivalent to transport the same amount of energy as with G-gas
  - (H_2 transport by pipeline at elevated speeds is *already* done)
- Some uncertainties do remain:
  - Erosion: what levels of contamination to expect in future H_2 systems, especially in the RNB systems?
  - High frequency dynamics: more energy shifted to high frequencies in FIP and AIV, may be more difficult to control
  - Accuracy issues on metering equipment were not analysed
- Report almost ready for publication, stay tuned!



HyDelta

HyDelta

WP1E – Impact of high speed hydrogen flow on system integrity and noise

D1E.1 – WP1E Report

Status: draft (v 0.3)

Dit project is medegefinancierd door TKI Energie uit de Toeslag voor Topconsortia voor Kennis en Innovatie (TKI's) van het ministerie van Economische Zaken, onder referentie nummer TKI2020-HyDelta.

HyDelta

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Plenary Progress Meeting

HyDelta

WP2

Odorization of hydrogen

Kiwa Technology

Erik Polman

07-12-2021

Main objectives of the WP (Project partner DNV)

- 2.1: Selection of third odorant
  - Goal:

  find a good candidate odorant that is free of sulphur and is likely to meet the base requirements for an odorant

  - Approach:

  Set up selection criteria

  Make a list of candidate odorants (literature search)

  Make preselection

  Test smell (large scale field test and laboratory test)

  Select candidate odorant

  Write report

Main objectives of the WP (2) (DNV)

- 2.2: The influence of odorant on appliances
  - Goal:

  Find out the detrimental effects of trace components on fuel cells as well as combustion applications

  - Approach:

  Literature search

  Give advice

  Write report

Main objectives of the WP (2) (DNV)

- 2.3: What is the chemical stability of odorants in hydrogen related to the stability in natural gas
  - Goal:

  Find out the chemical stability:

  a: Long term chemical stability at high pressures

  b: The behavior in soil (gas leakage)

  c: The behavior of a hydrogen/odorant gas cloud (dissipating effects)

  - Approach:

  a: Laboratory experiments (GC analysis) of pressurized mixtures

  B: Report on laboratory experiments (done for NBNL) and literature search

  C: Literature search and analysis of experiments and CFD calculations

Main objectives of the WP (2) (DNV)

- 2.4: What is the risk of not odorizing?
  - Goal:

    Find out the risks for distributing non odorized hydrogen

    Approach:

    a: Analysis on gas incidents and the role of odorization for natural gas of the Nestor database

    b: Literature search

    c: Prepare report

Main objectives of the WP (2) (DNV)

- 2.5: Advice on an odorant for hydrogen
  - Goal:

    Advice on odorizing yes/no, candidate odorants and dosing

  - Approach:

    a: Laboratory test: identify smell for 3 candidate odorants, compare odor character and smell and compare to natural gas

    b: Literature search on foreign experiences

    c: Prepare report with advice on:

    odorize hydrogen yes/no

    type of odorant

    dosage

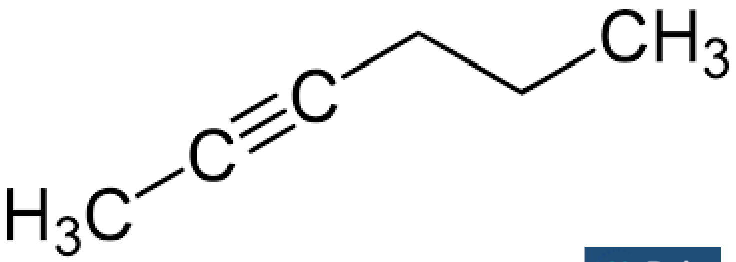
Progress of the work in the period

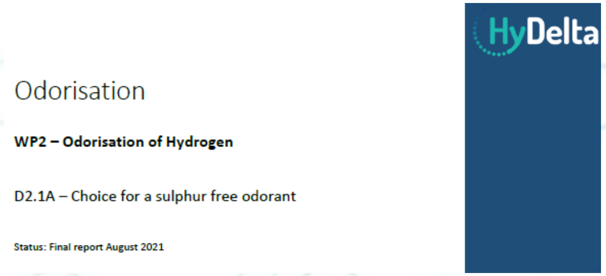
- 2.1: Selection of third odorant

  Selection of three candidate odorants

  Large scale test as well as panel test → selection of 2 hexyne

  Report is made and approved

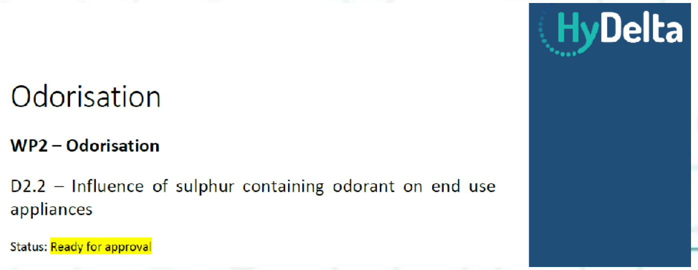




- 2.2: The influence of odorant on appliances

  Report is made and approved: soon made available

  - no insurmountable problems are for combustion equipment, when using hydrogen that is odorized with a sulphur-containing odorant, such as THT
  - all fuel cells degrade at sulphur contents of 1 ppm or more
  - feed stock processes are vulnerable for sulphur impurities (H_2-back bone will probably not be odorized)

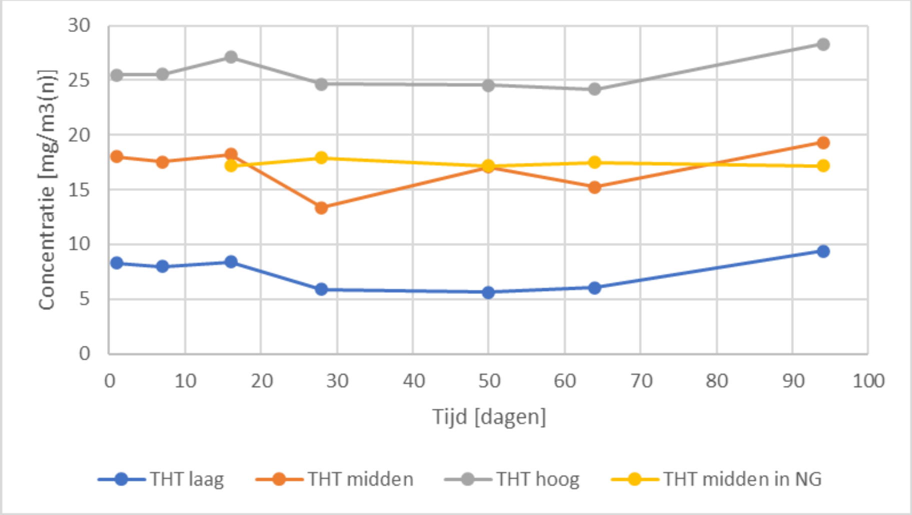


Progress of the work in the period (2)

- 2.3: What is the chemical stability of odorants in hydrogen related to the stability in natural gas

  Tests with three odorants (THT, GASODOR® S-free and 2-hexyne) at 100 bar pressure

  → no degradation observed



  Behavior in air: odorant stays in the hydrogen cloud (like natural gas). Convection is dominant, laminar diffusion is neglectable

  Soil behavior: results of NBNL will be available by the end of December 2021

  Report will be available (draft) after completion soil tests

Progress of the work in the period (3)

- 2.4: What is the risk of not odorizing?

  First analysis: > 25.000 cases in 2020 for natural gas distribution where odor detection was the indication of a disturbance

  Literature search in progress

  Report is in progress

- 2.5: Advice on an odorant for hydrogen
  - Tests with panel show:
    - Smell character and odour detection limit are similar for 3 odorants in hydrogen, compared to natural gas, only subtle differences
    - Literature search on foreign experiences in progress

  Report is in progress

Work to be done in the next period

- 2.3: wait on results soil test, analyze and summarize these and complete draft report
- 2.4 complete literature search and complete draft report
- 2.5 complete literature search and complete draft report

HyDelta

Thank you for your attention!

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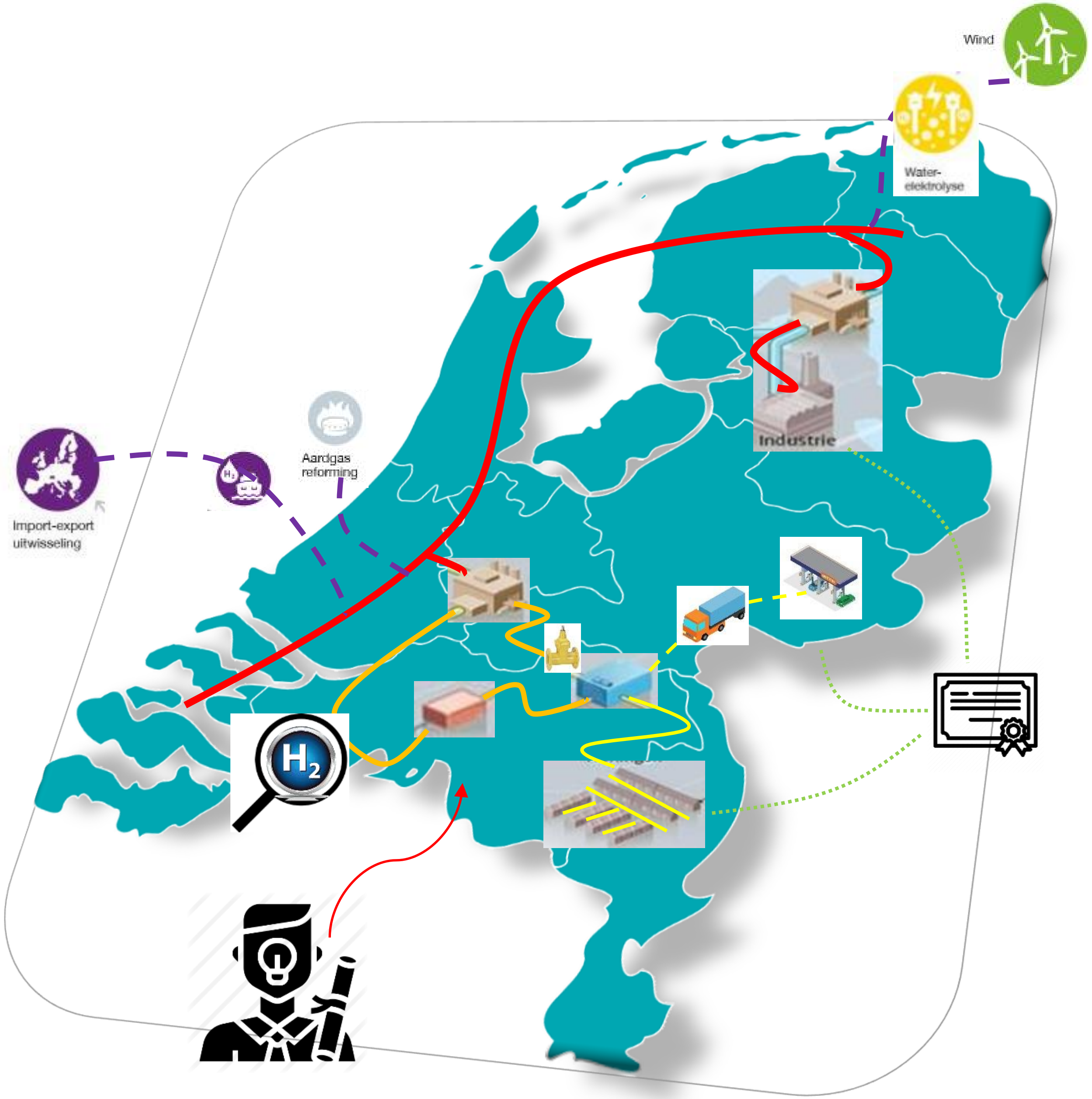
Work Package 3

Standards for hydrogen

Kiwa Technology

Hans de Laat

7-12-2021



Main objectives of the WP

- Insight in (European) standardization developments and status overview
- Gap analysis to missing knowledge
- How to develop the missing knowledge
- Reinforce the knowledge structure within Dutch standardization committees to contribute to the development of hydrogen networks in The Netherlands

- Outside the scope: mobility
  - natural gas vehicles and refueling stations
  - Hydrogen vehicles and refueling stations

Methodology

Discussions with standardization experts

- Project group (Kiwa Technology)
- Counseling group (Enduris, Liander, Enexis, Gas Transport Services)

Experts take actively part in standardization committees or have a wide overview of standards for gas networks

Sources

National and international bodies already have done work on categorization of subjects for hydrogen standardization

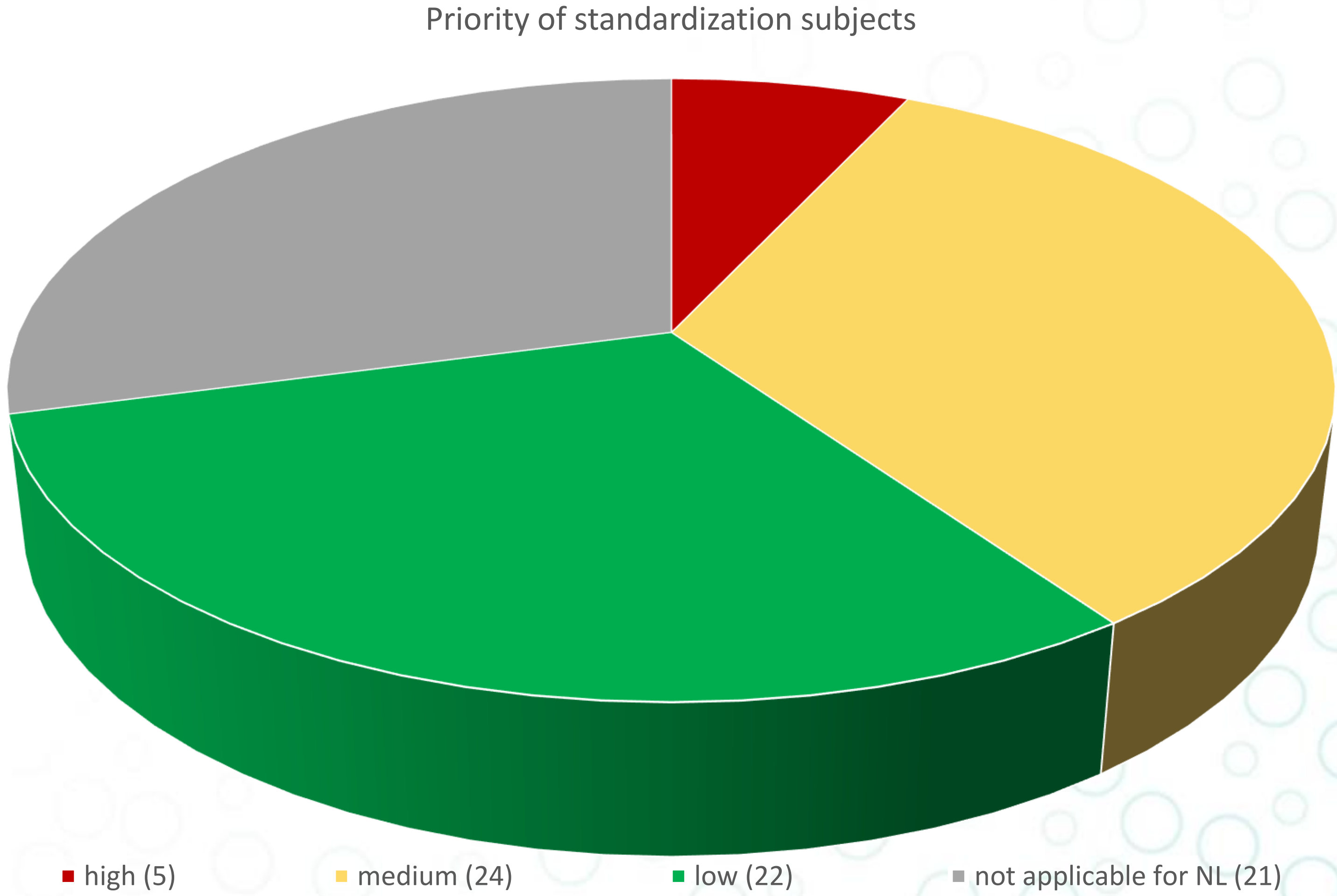
- Dutch platform H2IGO
- CEN/TC 234 Gas infrastructure
- SFEM Hydrogen
- Netbeheer Nederland
- Marcogaz

How to prioritize subjects?

Five criteria

- Specific Dutch interest
- Urgency (Relevant to the development of hydrogen networks)
- Responsibility (Network operator or component supplier?)
- Contribution of network operators (necessary or not?)
- Progress of the standardization acitivities

72 standardisation subjects indentified



Progress of the work in the period

Tables with standardization subjects. Per subject:

- Priority (Red/Yellow/Green)
- Source
- Standard number
- Status and/or action to be taken
- Technical content
- Standardization committee (CEN/ISO/NEN)
- Remarks

Hy ID	Ref ID	Prio	Onderwerp	Norm	Status/ Actie	Inhoudelijk	CEN/NL normcom.	Opmerkingen
31	H2IGO 2.2.1.1., SFEM	3	gashoeveelheidsmeting grootverbruik	EN 12480; 12405; 12261;	Toepasbaarheid voorlopige resultaten nagaan.	effecten nieuwe gassen in onderzoek in EURAMET verband	CEN: TC 237 (gasmeters) NL: 310066	effecten nog niet bekend. Resultaten onderzoek medio 2022
32	H2IGO 2.2.1.2., SFEM	3	gashoeveelheidsmeting; meetverantwoordelijken	Reglementen meetverantwoordelijken	Toepasbaarheid voorlopige resultaten nagaan.	Acties zijn afhankelijk van onderzoeksresultaten, o.a. van NEWGASMET	CEN: n.v.t. NL: VMNED en net-beheerders	nog niet bekend wat de geschikheid van de meters is
33	H2IGO 2.2.1.1, SFEM	3	gashoeveelheidsmeting; thermische hoeveelheidsmeting	EN 17526	Dialoog met meterleveranciers is gestart (Hydelta WP 1D). Extra aandacht geven aan kalibratieproces met lucht.	normen beschrijven nog geen waterstof, uitbreiding gestart.	CEN: TC 237 NL: 310066	MID-toegelaten meter verwacht vóór de start van de waterstofdemo's kleinverbruik
34	H2IGO 2.2.1.2., SFEM	3	gashoeveelheidsmeting; ultrasone hoeveelheidsmeting	EN 14236	Dialoog met meterleveranciers is gestart (Hydelta WP 1D). Extra aandacht geven aan kalibratieproces met lucht.	normen beschrijven nog geen waterstof, uitbreiding gestart.	CEN: TC 237 NL: 310066	MID-toegelaten meter verwacht vóór de start van de waterstofdemo's kleinverbruik
35	H2IGO 2.2.1.3, SFEM	3	gashoeveelheidsmeting turbinemeters	EN 12261	Bestaande meetinrichtingen	effect nieuwe gassen in onderzoek. NEWGASMET	CEN: TC 237 NL: 310066	effecten nog niet bekend. Resultaten onderzoek medio 2022
36	H2IGO 2.2.1, SFEM	1	gashoeveelheidsmeting; EVHI	EN 12405	EVHI's geschikt maken (H2 IGO 2.3.1.2). Goedkope gassensoren ontwikkelen. Aantal meetpunten vergroten?	bij variabele gassamenstelling H2 concentratie individueel meten	CEN: TC 237 NL: 310066	Meetinrichtingen kunnen H2 als dragergas toepassen, waardoor ze H2 niet detecteren
37	H2IGO 2.2.2.	1	wisselende gassamenstelling; met hoge frequentie de gassamenstelling bepalen	nieuw	Geografische aspecten en tijdsafhankelijke verschillen H2-aardgasmengsels (H2IGO 2.3.1.4)	H2 sensoren die in staat zijn om in een aardgasmatrix te meten zijn commercieel beschikbaar	CEN: n.v.t. NL: NBNL / H2IGO platform bijeenkomst 2021.	Nog geen start van dit onderwerp. Meterleveranciers en Meetverantwoordelijken hebben een voorkeur voor constant H2 gehalte.
38	H2IGO 2.2.3	1	Veiligheid en ATEX classificatie	ATEX richtlijnen	Waterstof is beschreven in ATEX regelgeving	Voor > 75% H2 in aardgas geldt MESG IIc	ATEX	Voor EVHI's is dit kritisch mits deze in de gasruimte ondergebracht zijn.
39	H2IGO 2.2.4	3	Wet- en regelgeving Verrekening	nieuw	Nagaan wat wettelijk mogelijk is. Huidige opvatting: je moet opgeven wat je levert, in dit geval kubieke meters.	Nog niet gestart. Is een belangrijk aspect van de waterstofdemo's.	CEN: n.v.t. NL: o.a. NBNL	verrekening van waterstof (nog) niet in de gascodes opgenomen.
40	H2IGO 2.2.4	3	Wet- en regelgeving Herleid controleren van de miswijzing van waterstofmeters	nieuw	Overleg met VSL over technische aspecten gestart (H2IGO 2.3.1.1 en 2.3.2.1)	Eerste specificatie van een meetsysteem geformuleerd	CEN: n.v.t. NL: NBNL	haalbaarheid nog onbekend. Het lijkt erop dat controle met lucht zal blijven. Wat is de relatie tussen waterstof en lucht?
41	H2 IGO 2.3.2.2	3	Meetcode gas	nationaal document	Nagaan wat er niet wordt afgedekt door de Meetcode gas	Toepasbaarheid voor H2/aardgasmengsels onbekend	CEN: n.v.t. NL: NBNL	
42	H2IGO 3.2	5	Keuze odorant voor H2	nationale richtlijnen	Totdat het odorant wordt toegepast, THT gebruiken in de waterstofdemo's.	Er is nog geen odorant gekozen. Alternatieven worden nu onderzocht.	CEN: n.v.t. NL: NBNL Hydelta WP 2	Het odorant moet voldoen aan de Nederlandse eisen. Er zijn enkele kandidaten.
43	H2IGO 3.2	5	Odorant voor H2 in aardgas	nationale richtlijnen	Ruikbaarheidstesten voor mengsels definiëren.	THT kan gebruikt worden.	CEN: n.v.t. NL: NBNL	De ruikbaarheid van een mengsel is nog niet voldoende aangetoond.

Priority standardization subjects

Five high priority subjects

- Pressure testing for pipelines
- Gas metering and flow computing
- Rapidly changing gas compositions
- ATEX classification
- Leak requirements and leak testing

Conclusions

European Standardization planning for hydrogen in networks is expected from 2021 until 2024 (Progress varies per Technical committee)

Dutch network operators are sufficiently represented in EN/ISO Technical committees by experts

Focus on subjects needs constant attention and adjusting, but is secured by co-operation between the experts

Conclusions

Standards are the best language for network operators to communicate with Safety and Metrology regulators (SodM and Agentschap Telecom)

Standardization requires practical experience. Demonstration projects are a source for practical knowledge

Recommendations

Priority international technical commmittees are:

- CEN/TC 234 Gas infrastructure
- CEN/TC 237 Gas meters
- ISO/TC 193 Natural gas
- ISO/TC 158 Gas analysis
- Liaison with CEN/TC 238 Appliances : for gas compositions

Recommendations

Focus on the five urgent subjects

Watch medium subjects

Update the priority tables in the report periodically, twice per year (frequency of TC plenary meetings)

Work to be done in the next period

- Finalize report

Thank you for your attention!

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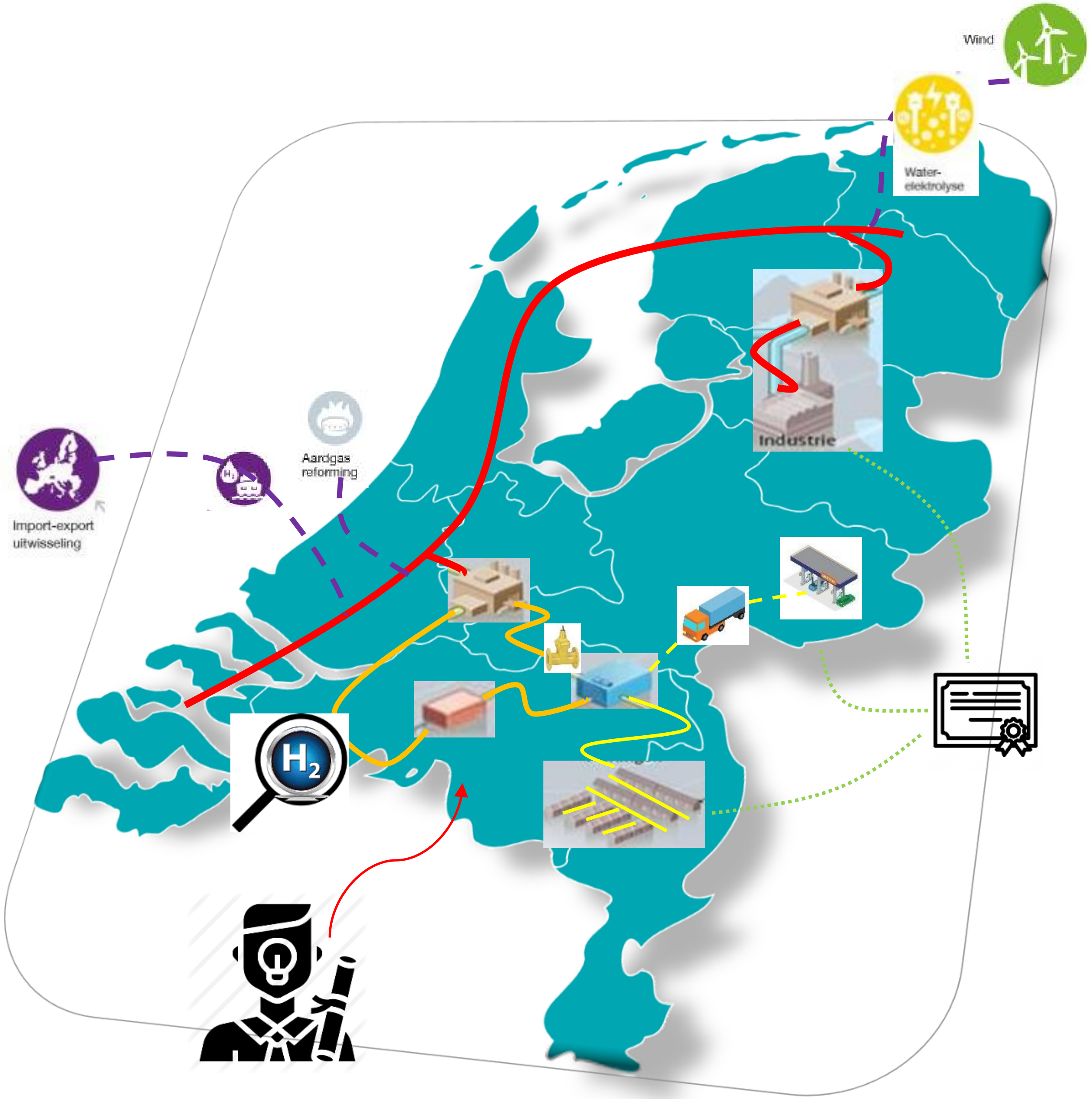
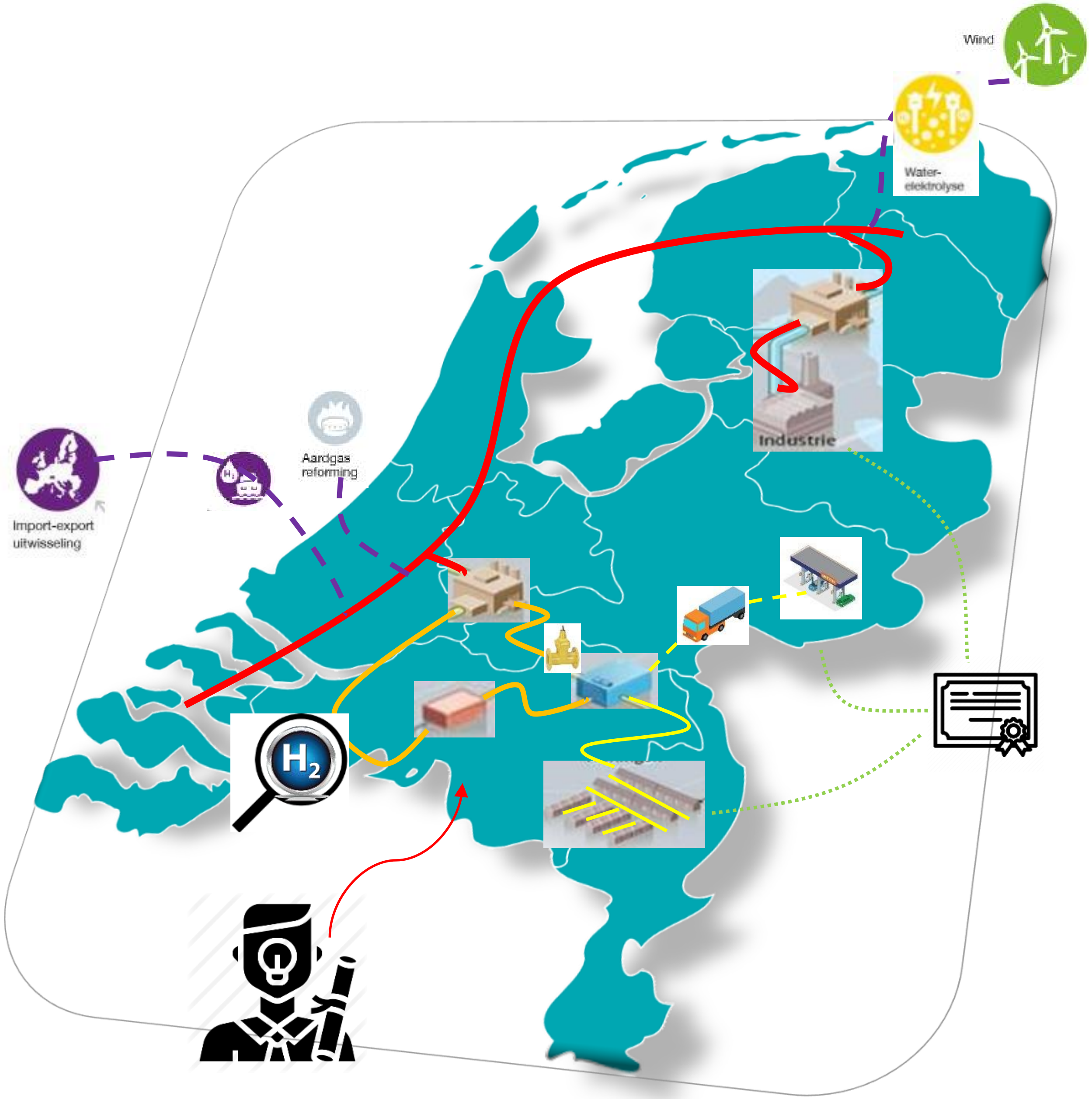
Intermediate break



Part 3 – hydrogen in the gas grid



Plenary Progress Meeting

HyDelta

WP1B

Gas stations

Kiwa Technology

Sander van Woudenberg

07-12-2021

Main objectives of the WP

- Filling the gaps of knowledge if and how gas stations for natural gas can be used for hydrogen
  - Are the materials in stations suitable for hydrogen?
  - Do existing stations work properly with hydrogen?
  - How can work safely be done on stations with hydrogen?

Progress of the work in the period

- Are the materials in stations suitable for hydrogen?
  - Research started before Hydelta began
  - “This literature study shows that the soft materials used in the DSO’s gas pressure control installations and found in this study, are also suitable for the distribution of hydrogen.”
  - “The next step is to identify the risks of increased permeation compared to the application with natural gas and stimulate the development of a certification scheme for hydrogen, both for new and currently used materials and components.”

Q207/ D1B.1 – suitability of current natural gas stations for distribution of hydrogen

Progress of the work in the period

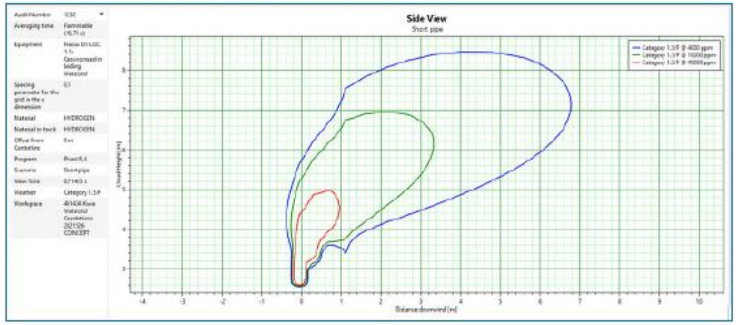
- Do existing stations work properly with hydrogen?
  - Method: testing. Testing with 65/100 Nm3/h capacity station and 30 Nm3/h capacity HAS (at 3 bar)
    - Exchange PSV in gas station to test both natural gas- and hydrogen behavior.
    - Three PSV’s tested in large capacity gas station and one PSV tested in HAS.
    - Test plan performed with range of settings to map differences (6-8 monitoring tests per PSV).
  - First results – testing:
    - The test program shows similar trends for natural gas and hydrogen
    - The capacity checks for the PSV’s have been performed for a ratio 3 between natural gas and hydrogen
    - The response pressures for the PSV’s are the same order of magnitude for natural gas and hydrogen



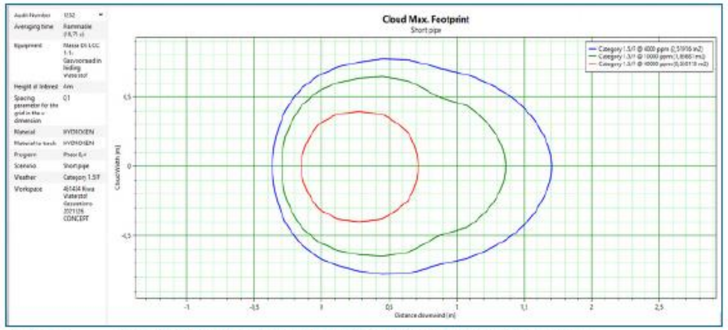
Q206/213/ D1B.1 – suitability of current natural gas stations for distribution of hydrogen

Progress of the work in the period

- How can work safely be done on stations with hydrogen?
  - Interviews held with DSO’s. Goal to determine LOC (loss of containment) scenario’s during construction and maintenance work, current practices with natural gas.
    - LOC 1: venting station and upstream gas line during installation
    - LOC 2: venting during functional test (B-inspection)
  - LOC scenario’s have been modelled with natural gas and hydrogen.
  - Results show that current working methods are applicable to work safely with hydrogen.



Figuur 5-8: Zijaanzicht brandbare wolk DS Scenario 1 Waterstof – horizontale uitstroming (rood = LEL, groen = 25% LEL, blauw = 10% LEL)

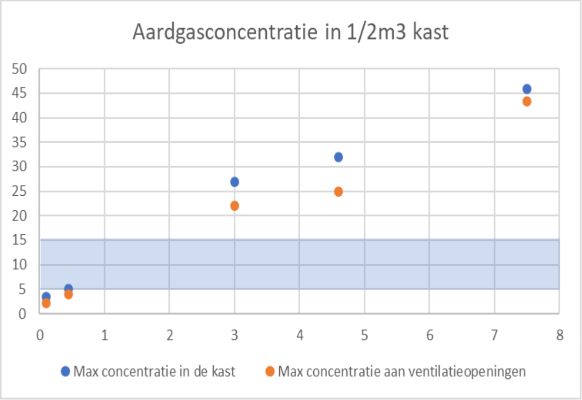


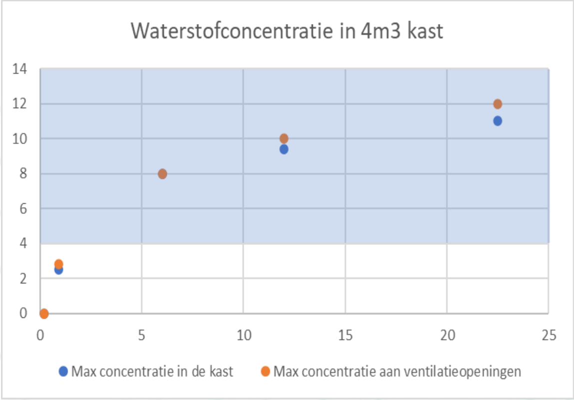
Figuur 5-9: Horizontale dwarsdoorsnede op 3 m. hoogte DS Scenario 1 Waterstof – verticale uitstroming (rood = LEL, groen = 25% LEL, blauw = 10% LEL)

Q208/ 209/ D1B.2 – availability of a substantiated working method to convert the ga stations to hydrogen

Progress of the work in the period

- Related to both safety and design of the stations: is the ventilation in stations also suitable for hydrogen?
  - Method: testing. Release defined flow of methane and hydrogen. Measure concentration.
  - Final results – small (1/2m^3) and large (4m^3) cabinet:
    - A similar leak size releases more flow with hydrogen compared to natural gas.
    - Directly at the vent opening, gas concentrations can be as high as within the cabinet.
    - At 0,5 meter away from the cabinet, measured gas concentrations are always well below 10% LEL. Even if gas leak is so large it can be heard.
    - Natural gas behavior has been recorded with a camera for small and large gas leaks.

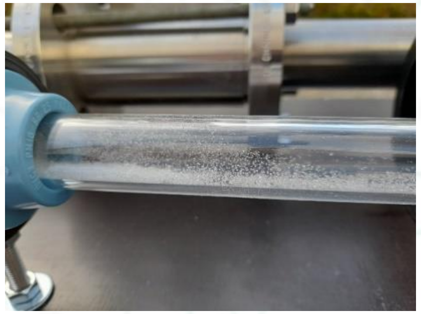


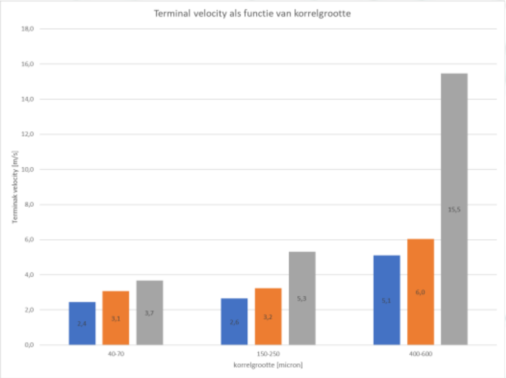


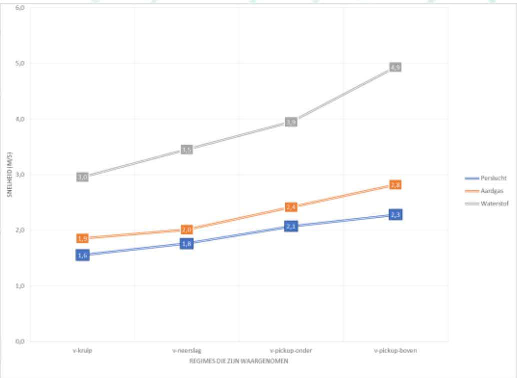
Q212/ D1B.3 – report if it is safe to adjust the zoning around hydrogen installations

Progress of the work in the period

- Related to both safety and design of the stations: examine the effect of increased gas velocity in hydrogen networks on the risk of accelerated contamination of filters (and subsequent mitigating strategies).
  - Method: literature study, mathematical modeling & testing. Prepare mathematical model to understand differences in test parameters necessary to build a suitable test setup.
  - First results – testing:
    - Test setup designed to visualize transport of dust and to quantify the amounts of dust for different gas velocities
    - Gas velocity ratio between natural gas and hydrogen lower than 3 to transport "typical" dust
    - Terminal velocities determined for different dust types to understand thresholds for dust transport







Q173/ D1B.4 – report on insights about the effect of the increased gas velocity in hydrogen networks on the risk of an accelerated contamination of filters

Recommendation for future work

- Optimization of gas cabinets
  - Inventory of applied cabinets in the public domain and assess optimization steps for mechanical redesign (if required).
- Is the ventilation in stations also suitable for hydrogen?
  - Modelling and (if possible) testing the effects of detonation if a flame is present near a gas station. Early workplan to be defined.
- Dust transport in natural gas and hydrogen gas?
  - Early plan defined for tests in an 8-bar environment
  - Understand how dust dosing in an 8-bar environment works
  - Assess impact of high gas velocities on filter endurance (30 m/s natural gas and 90 m/s hydrogen)

HyDelta

Thank you for your attention!

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Plenary Progress Meeting

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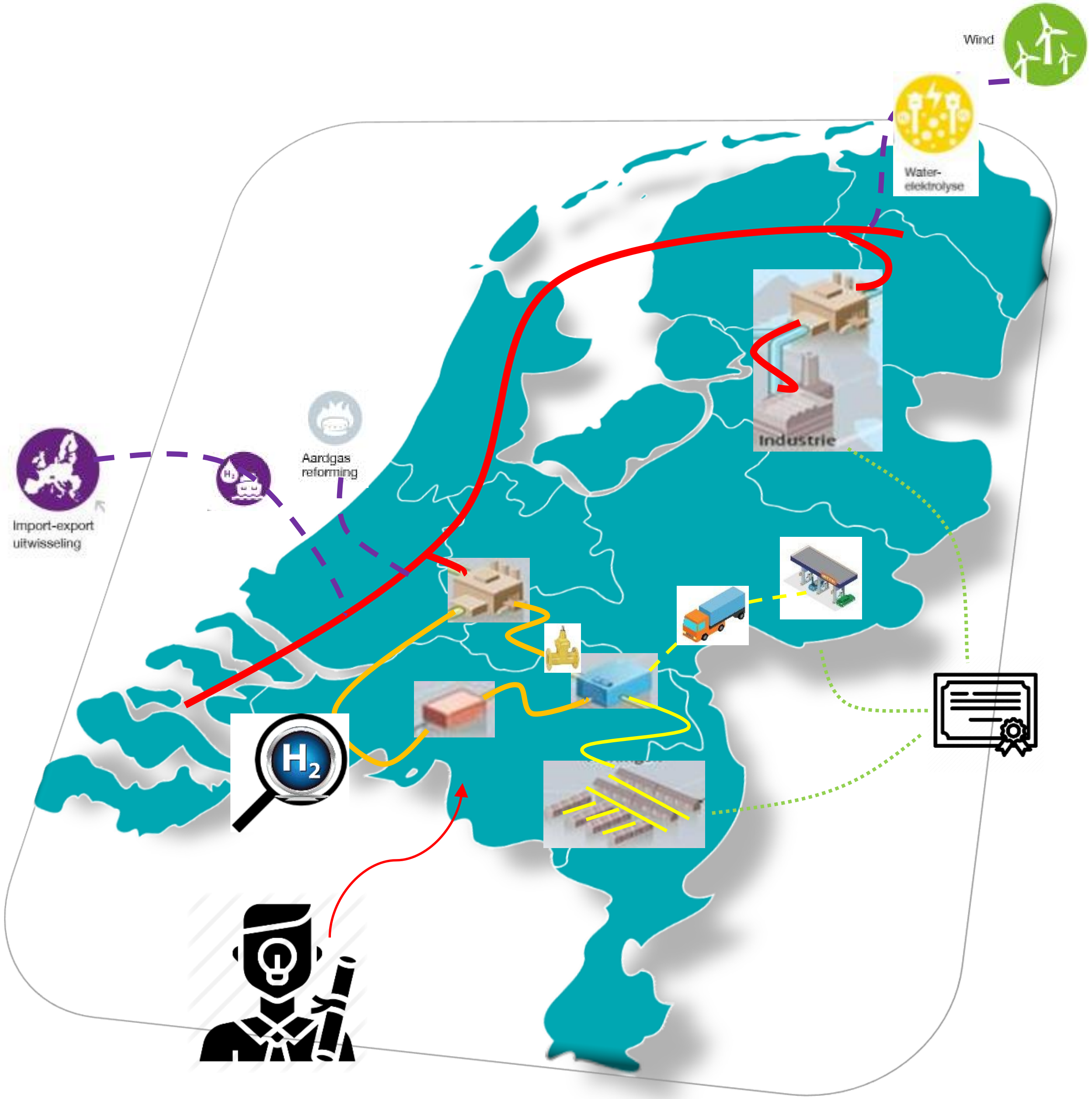
WP1C

Pipes and indoor installations

Kiwa Technology

Sander Lueb

7 december 2021



Main objectives of the WP (1)

- Determine whether **purging** of natural gas (distribution) pipelines can be done safely with hydrogen

- Determine if **leakage requirements** applied for natural gas are also applicable for hydrogen (focusing on connecting pipelines between distribution pipeline and meter cupboard)

- Determine the risk of not replacing **pressure regulators** (in house) during conversion to hydrogen

Main objectives of the WP (2)

- Determine the **effect of the existing gas grid** on the quality of hydrogen
    - Desorption of THT
    - Permeation of oxygen, nitrogen and water
- Determine the risks of the conversion to hydrogen at **consumer gas installations**
- Determine the developments concerning the suitability of **components and appliances** of gas consumers for hydrogen

Progress of the work in the past period

- Purging of natural gas with hydrogen

  - Report is finalized
  - Part of Plenary progress meeting of June 2021

Conclusions

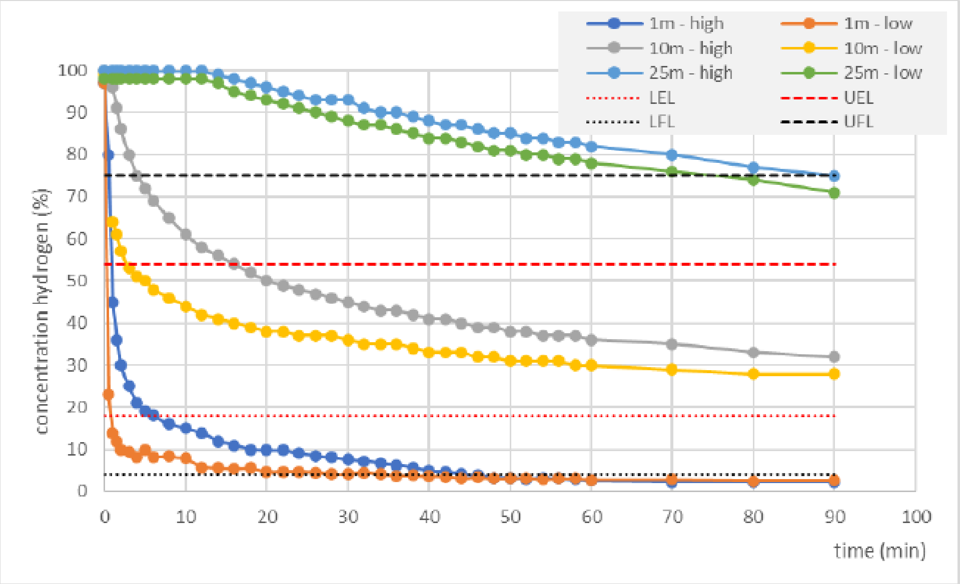
- purging of natural gas directly with hydrogen including flaring is safe en technically feasible
- a minimum purging speed of 0,4 m/s is necessary to replace the natural gas by hydrogen
- a purging speed of 1,0 m/s is recommended in order to speed up the total purge time

Progress of the work in the past period

- Purging of natural gas with hydrogen – additional activity, entry of air

  - Report is finalized

Graph 1. DN 100 – without shielding from air entry point



Conclusions

- Immediately after creating a leak (opening valve), hydrogen flows out and air enters into the tested DN 100 and DN 200 pipe
- In both the DN 100 and DN 200 pipe, an explosive mixture occurs almost immediately after entry of air.
- An explosive mixture remains in the pipes at each measuring point (1, 10 and 25 m) with both diameters throughout the measuring time (90 min)

Progress of the work in the past period

- Leakage requirements (pipelines distribution network)

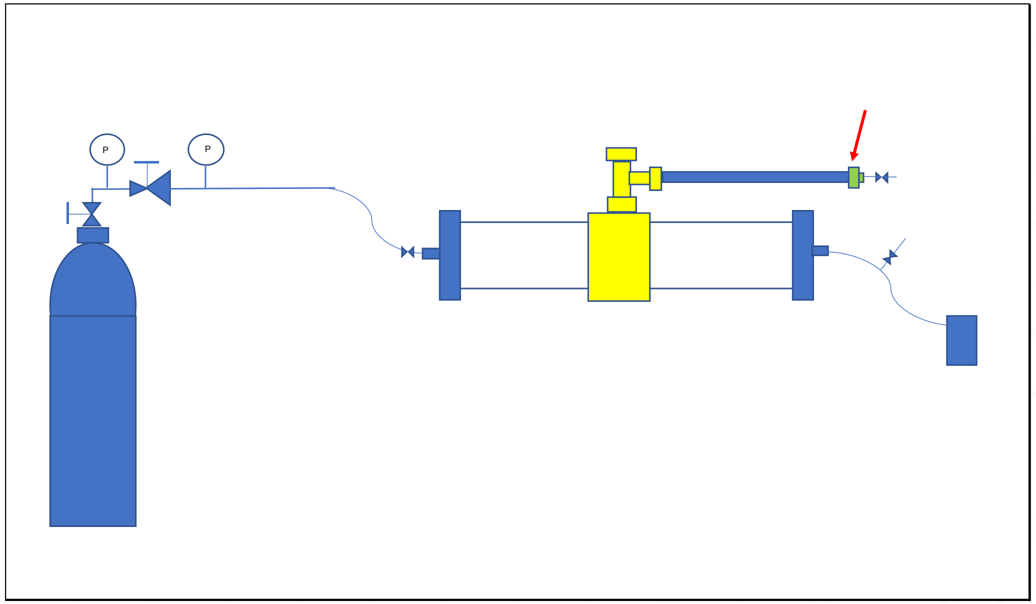
Scope

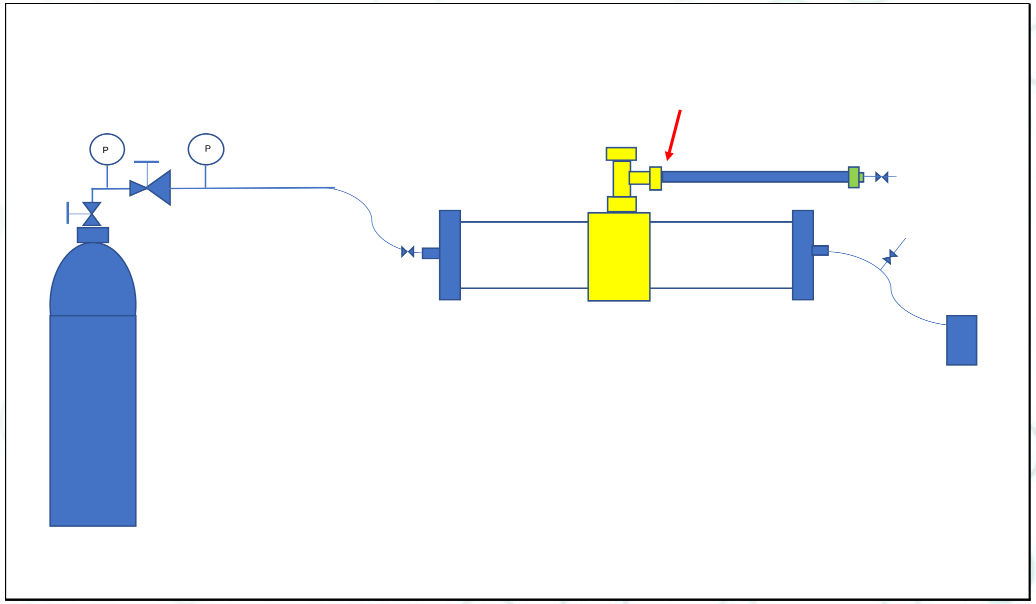
- Only focus on service lines
- Leakage of main pipe lines (requirement natural gas per leakage is < 5 l/h) will not lead to a higher risk level (even if assuming the leakage is 3 times higher with hydrogen).
- Testing of 4 types of leaks in service lines at 30, 100 and 200 mbar.
- Determination of leakrates based on practical measurements (pressure drop).
- Taking into account the report of DNV GL "behaviour of hydrogen leakages in the gasgrid"

  mixtures of hydrogen/air with concentrations hydrogen < 8%, will ignite not as easy as a natural gas/air mixture of 5,9%

Progress of the work in the past period

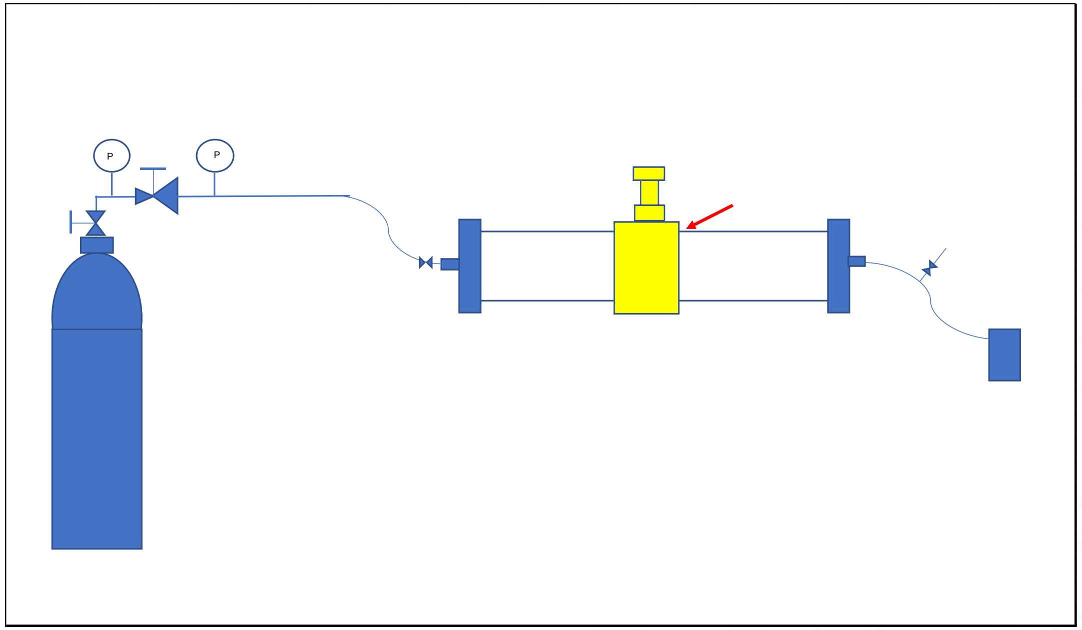
- Leakage requirements (pipelines distribution network)

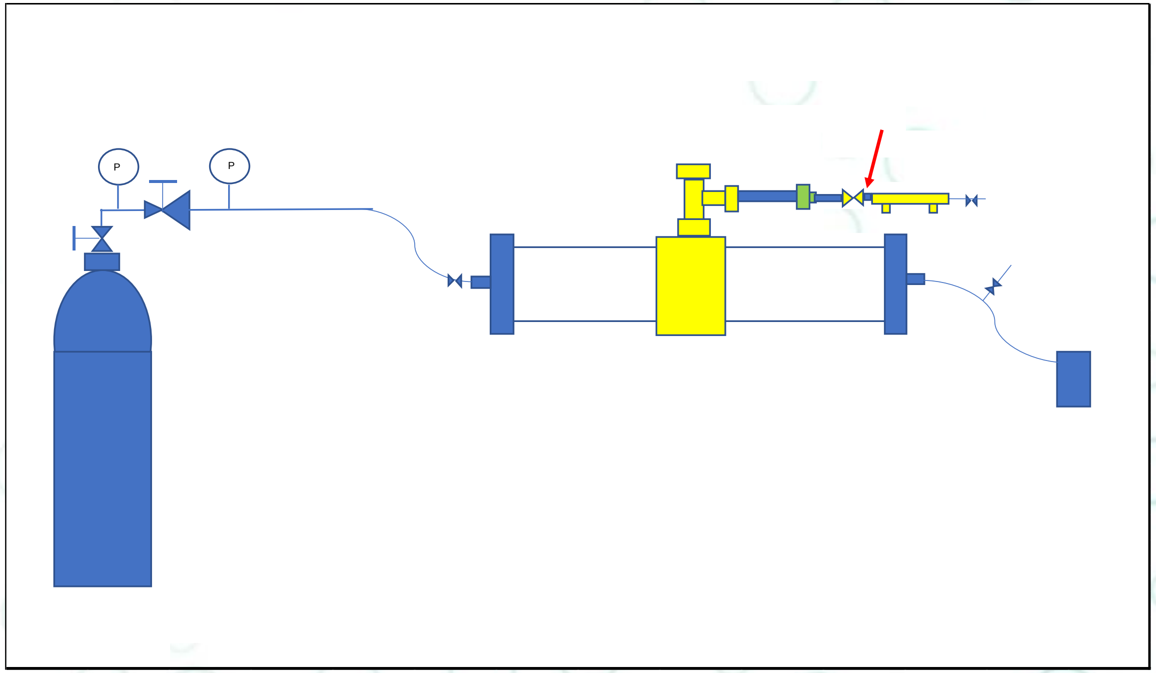




Progress of the work in the past period

- Leakage requirements (pipelines distribution network)





Progress of the work in the past period

- Leakage requirements (pipelines distribution network)

  - Report is finalized

  Conclusions
  - Average leakage of hydrogen is 1,83 higher compared to natural gas (4 types of leakages are measured)
  - For existing service lines maximum leakage requirement for hydrogen should be more stringent: 74% of the maximum leakage requirement for natural gas
  - For other leakage requirements (grid of the RNB's) as mentioned in NEN 7244-7, no change is needed

Progress of the work in the past period

- Leakage requirements (pipelines distribution network)

  - Values suggested for extension of NEN 7244-7 (table 4)

Maximum leakrate at testpressure equal to maximum operating pressure		
Type of pipeline	Natural gas Max. leakage (dm^3/h)	Hydrogen Max. leakage (dm^3/h)
Main pipe lines	5,0	5,0
Connection pipe - new	0,2	0,2
Connection pipe - existing	1,0	0,7
Meter-connections	0,1	0,1

Progress of the work in the past period

- Leakage requirements (pipelines distribution network)

  - Recommendations when switching from natural gas to hydrogen
    - Testing of each connection pipeline via a pressure-drop measurement
    - Main pipelines (30 and 100 mbar grid) testing via above ground leak-searching with carpet probe

Progress of the work in the past period

- Pressure regulators (in house)

  - Report is finalized

  Conclusions

  - No safety issues when using existing pressure regulators with hydrogen
  - When switching to hydrogen, existing pressure regulators might cause supply problems (faster activation of gas failure safety device, known as “B-klep or gas-gebrek-beveiliging”)
  - Regulation function of 40 tested regulators for hydrogen is similar like natural gas
  - Noise or vibrations with hydrogen is not observed
  - Closing pressure when using hydrogen a few mbars higher compared to natural gas

Progress of the work in the past period

- Effect of the existing gas grid on hydrogen
  - Desorption of THT and permeation of nitrogen, oxygen and water
  - Literature research is done
  - Testmaterial is collected (pipes)
  - Long-term-testing is started (permeation water in october, others in november)

Progress of the work in the past period

- Consumer gas installations

  - Report is finalized

  Conclusions

  - Main part of the incidents with natural gas are caused by carbon-monoxide, when switching to hydrogen this risk is lowered to zero.
  - At small gas leakages (< 1 dm^3 / h based on natural gas) risks when using hydrogen are similar to natural gas.
  - At larger gas leakages (> 10 dm^3 / h based on natural gas) risks when using hydrogen are getting higher
  - Mitigating measures should be focusing on preventing larger gasleakages

Progress of the work in the past period

- Consumer gas installations

Examples of additional mitigating measures to be investigated (see report for full description)

- Application of excess flow valves
- Inspection / testing of existing gas pipelines in house
- Installation and maintenance on complete gas installation only by certified installers
- Check on ventilation and correct use of cupboard
- Only use of hydrogen certified appliances
- When disconnecting appliances (for instances cooking appliances) shortening and blinding piping in a correct way.

Progress of the work in the past period

- Components and appliances (in house)

  - Draft report is finalized (status 18-11-21)
  - Interviews with manufacturers and test-institutes

  Conclusions

  - At this stage components and appliances are not completely ready for the use of 100% hydrogen.
  - Central heating – domestic hot water boilers developed for hydrogen will not be suitable to function shortly on natural gas
  - At this stage CH-DHW-boilers are developed which are able to function on natural gas **and** easily to modify to function on hydrogen.
  - It is expected that after 2023 components and appliances suitable and certified for hydrogen are deliverable to consumers

Work to be done in the next period

- Translation of reports from Dutch to English
- Observing long-term testing desorption THT
- Observing long-term testing permeation nitrogen, oxygen and water
- Reporting results of long-term testing (finalized end of March 2022)

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Plenary Progress Meeting

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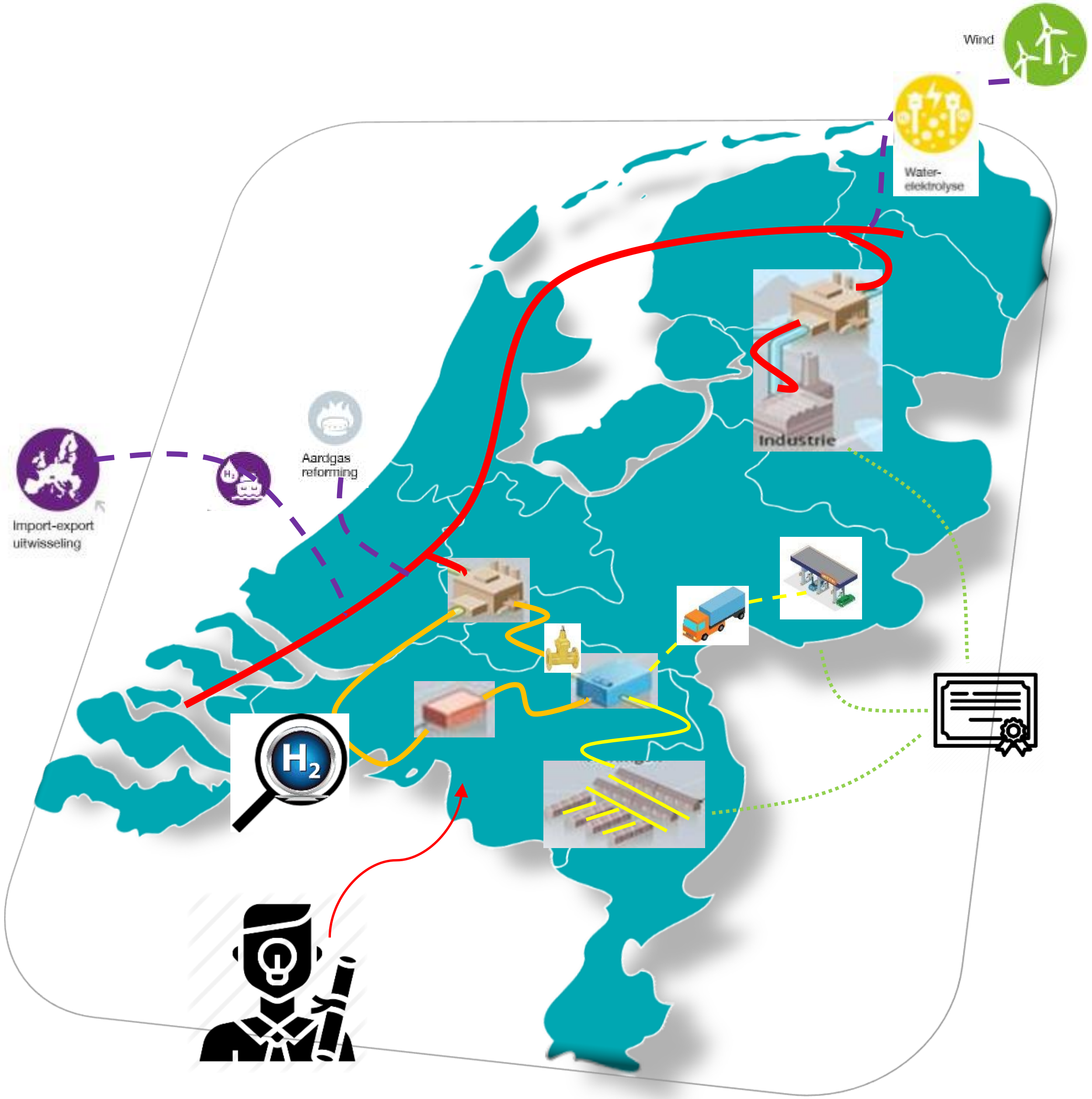
WP 1D

Metering of Hydrogen

Kiwa Technology

Hans de Laat

7-12-2021



Main objectives of the WP

Suitability of Ultrasonic and Thermal mass flow meters for hydrogen

Availability of the meters

Describe the integration of these meters in existing cabinets at the end-user

Effect of practical gas composition of hydrogen on meters

Implementation strategy for hydrogen meters in the *Meterpool Kleinverbruik*

Work in the past period

Integration in the metering cabinet

Description of the 12 steps for integration of hydrogen meters in the *Meterpool Kleinverbruik*

Integration in the metering cabinet

Gas Meters delivered to Dutch DSO's shall comply with *NPR 7028*

This is a Dutch regulation, divergent from EU Standards

- Screw thread according to "*Gasmeterschroefdraad*" for G4/G6 equivalent meters
- Distance between the connections for G4/G6 equivalent meters is *220* mm

Hydrogen meters are not (yet) available with NPR 7028 specification

- 2 out of 3 shortlisted manufacturers are new to the Dutch market
- Use adaptors for the time being, e.g. in demonstration projects
  - inform safety regulator (SodM)

Pressure absorption by the meter expected to be within limits at Q_{max}

12 steps for integration in the *Meterpool KV*

The steps are defined and text proposals are included in the report

1 Extension of the *Meterpool Kleinverbruik Regulation* with hydrogen meters

- The regulation is an official document and publicly available

2 Agree with the Dutch Metrology Regulator (Agentschap Telecom) on the text.

- Every update is agreed upon with the regulator. Usually, this requires one or two iterations

12 steps for integration in the *Meterpool KV*

3 Extend the text of corresponding documents for hydrogen meters

- Internal action for members of Netbeheer NL

Implementing provisions:

- Technical and statistical requirements
- for hydrogen meters the statistics do not change
- The test procedures for hydrogen meters change (purge, flows, test duration)

Work instructions:

- Application for a Dutch meter code
- Execution of meter checks
- Application and management of a meter test installation (required capacity is bigger)

12 steps for integration in the *Meterpool KV*

4 Application procedure for a Dutch meter code

- Metercode for kWh starts with E, for m^3 starts with G, for hydrogen starts with W

- A meter that is able to measure **both** natural gas **or** hydrogen receives two meter codes, one for natural gas and one for hydrogen

- When the grid switches from natural gas to hydrogen, the meter code is switched accordingly

- Both codes shall be mentioned on the type plate of the meter
  - Hydrogen composition shall be mentioned on the meter (ISO 14687, grade 2)

12 steps for integration in the *Meterpool KV*

HyDelta

5 Implementation of the periodical meter check procedures

- (At Liander IJklaboratorium, CIJ Borculo and Enexis)

Upgrade of test installations

- Capacity (when the hydrogen meter exceeds 40 m^3/h)
- Software (parameters of the measuring points and information in the test report)

12 steps for integration in the *Meterpool KV*

7 Auditing subjects

Technical audits with the operator

- Implementation of hydrogen meters in the test installations
- Ability of the operator for hydrogen meters

Administrative audits of the network operator

- Purchase process of hydrogen meters
- Metrological performance of the test installations

12 steps for integration in the *Meterpool KV*

8 To admit test installations to the Meterpool

- Sign up procedure and admittance protocol

9 To admit meter controllers and licensed meter controllers to the Meterpool

- Add hydrogen abilities to the audit subjects and
- field checks of the test installation

12 steps for integration in the *Meterpool KV*

10 Implement a traceable calibration procedure for hydrogen meters in The Netherlands

- There is no traceable calibration chain for hydrogen meters in The Netherlands yet

12 steps for integration in the *Meterpool KV*

Extension of the data analysis software

11 Extension of the files monthly uploaded by the Network operator

- Needs minor adaptation

12 Extension of the front-office at the Co-ordinator (MPS++); Extension of the back-office (GMS)

- Needs minor adaptation

Conclusions

Checking a hydrogen meter with air has not yet been confirmed by a meter manufacturer

MID approved hydrogen meters are available in time for demonstration projects. Installation with adapters to be discussed with the safety regulator

Extension of the *Meterpool* regulations, provisions and work instructions for hydrogen meters is fully described.

A traceable calibration facility for hydrogen meters in The Netherlands will consolidate the trust of Dutch consumers in hydrogen as a heating fuel

Conclusions

Gas network operators require a distinct separation for meters between small and large consumers for hydrogen, as currently exists for natural gas.

Recommendations

Analyse the behaviour of hydrogen meters before they are installed at a client

Implement the testing parameters for domestic hydrogen meters in the software of meter check installations

Extend the scope of the *Regulation Meterpool Kleinverbruik* and the corresponding documents with hydrogen meters

Develop a traceable test facility for hydrogen meters

Recommendations

Define a separation between meters in the regulated domain (small consumers) and those in the free domain (industrial consumers) for hydrogen

Work to be done in the next period

Finalize report

HyDelta

Thank you for your attention!

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Plenary Progress Meeting

HyDelta

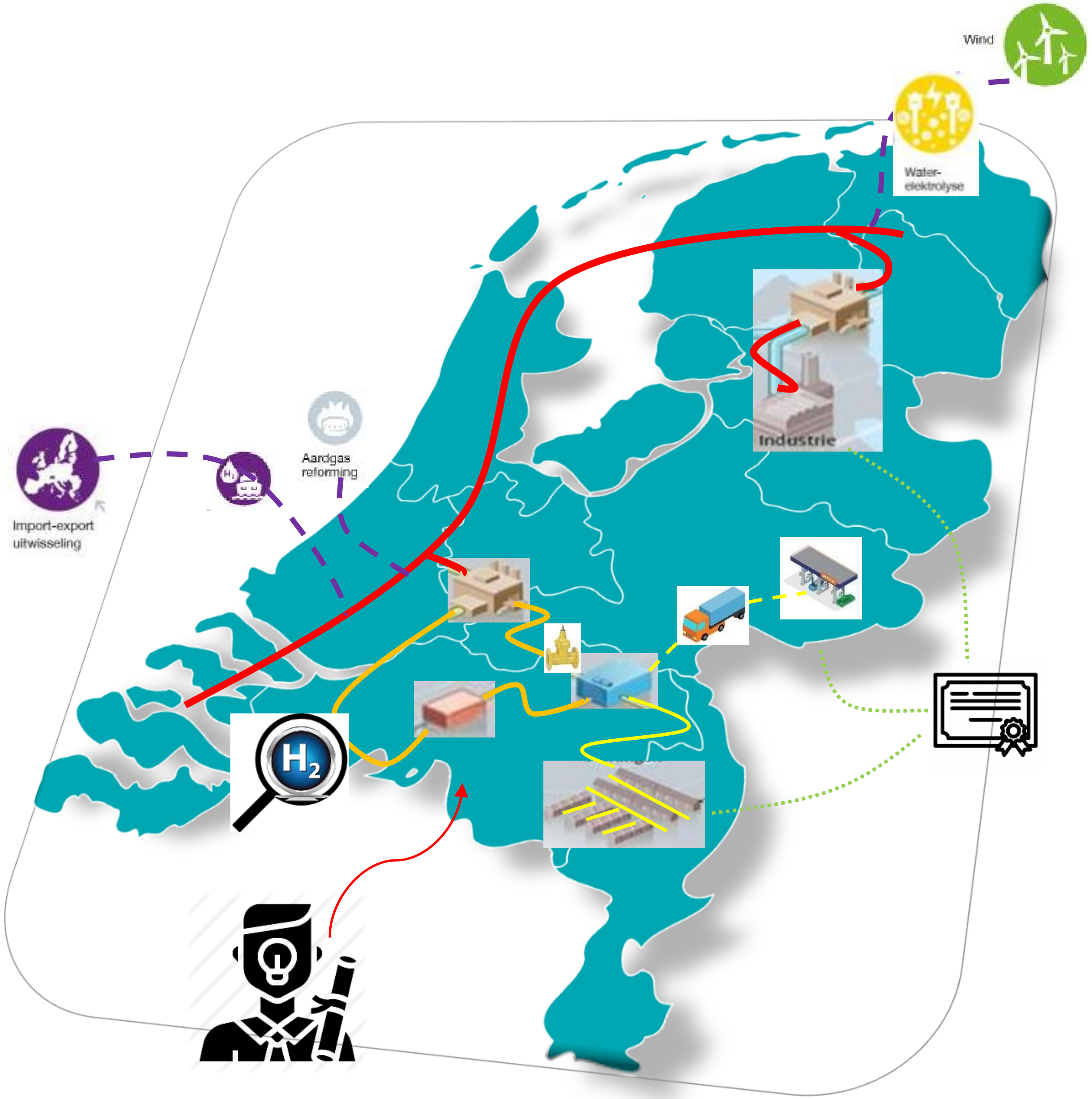
WP1F

Testing of shut-off valves in the national distribution grid

Kiwa Technology

Nard Vermeltfoort

7-12-2021



Main objectives of the WP

The main objective is to increase the knowledge about shut-off valves in the gas transportation grid, and their suitability for hydrogen transport networks.

- Main question: When an existing natural gas transport grid is converted to hydrogen, can the shut-off valves that are currently in use, remain operational?
  - What is the internal and external leak tightness of currently used shut-off valves? *(Leak testing of shut-off valves with natural gas and hydrogen)*
  - Are the materials used in shut-off valves suitable for hydrogen? *(Literature study)*
- Can the answers of this investigation be used for a statement on the suitability of the in-situ valves for the transport of hydrogen?

Progress of the work in the period

- Between June and mid-November there was good progress.
- 16 valves are identified for testing.
- In July there was an incident with a ruptured hose causing delays.
- New safety protocols and better materials are used.
- In October, the measurements were successfully recommenced.
- As of mid-November, 12 valves have been tested.

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Progress of the work in the period

Omschrijving	Producent	Bouwjaar	DN	Opmerking
Kogelafsluiter ANSI 600	CAMERON	1974	1050	
Kogelafsluiter ANSI 600	CAMERON	1990	900	
Kogelafsluiter ANSI 600	CAMERON	1997	900	
Kogelafsluiter ANSI 600	CAMERON	2000	1200	
Kogelafsluiter ANSI 600	GROVE	1963	900	Scrapertrap
Kogelafsluiter ANSI 600	GROVE	1965	1050	Scrapertrap
Kogelafsluiter ANSI 600	GROVE	1991	1200	
Kogelafsluiter ANSI 600	GROVE	1993	1050	
Kogelafsluiter ANSI 600	RMA	2006	900	Scrapertrap
Kogelafsluiter ANSI 600	RMA	2008	1200	
Kogelafsluiter ANSI 600	RMA	2009	1050	Scrapertrap
Kogelafsluiter ANSI 600	RMA	2011	1200	Scrapertrap
Plugafsluiter ANSI 600	CHRISTENSEN	1975	400	
Plugafsluiter ANSI 600	CHRISTENSEN	1992	400	
Plugafsluiter ANSI 600	CHRISTENSEN	2009	400	
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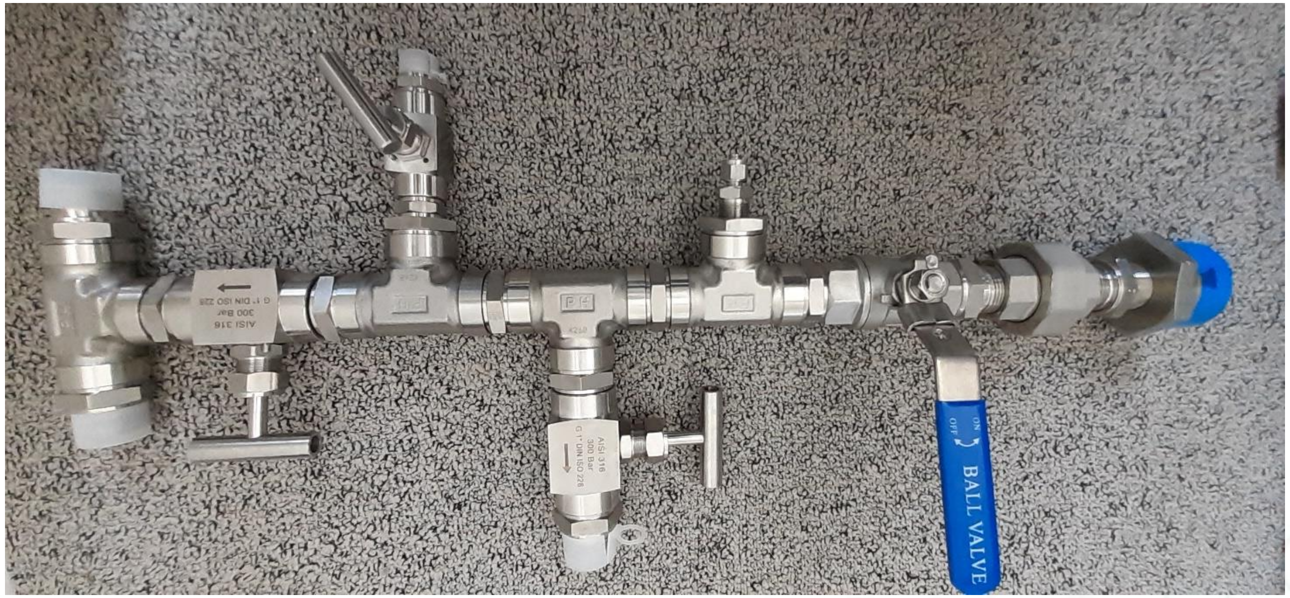

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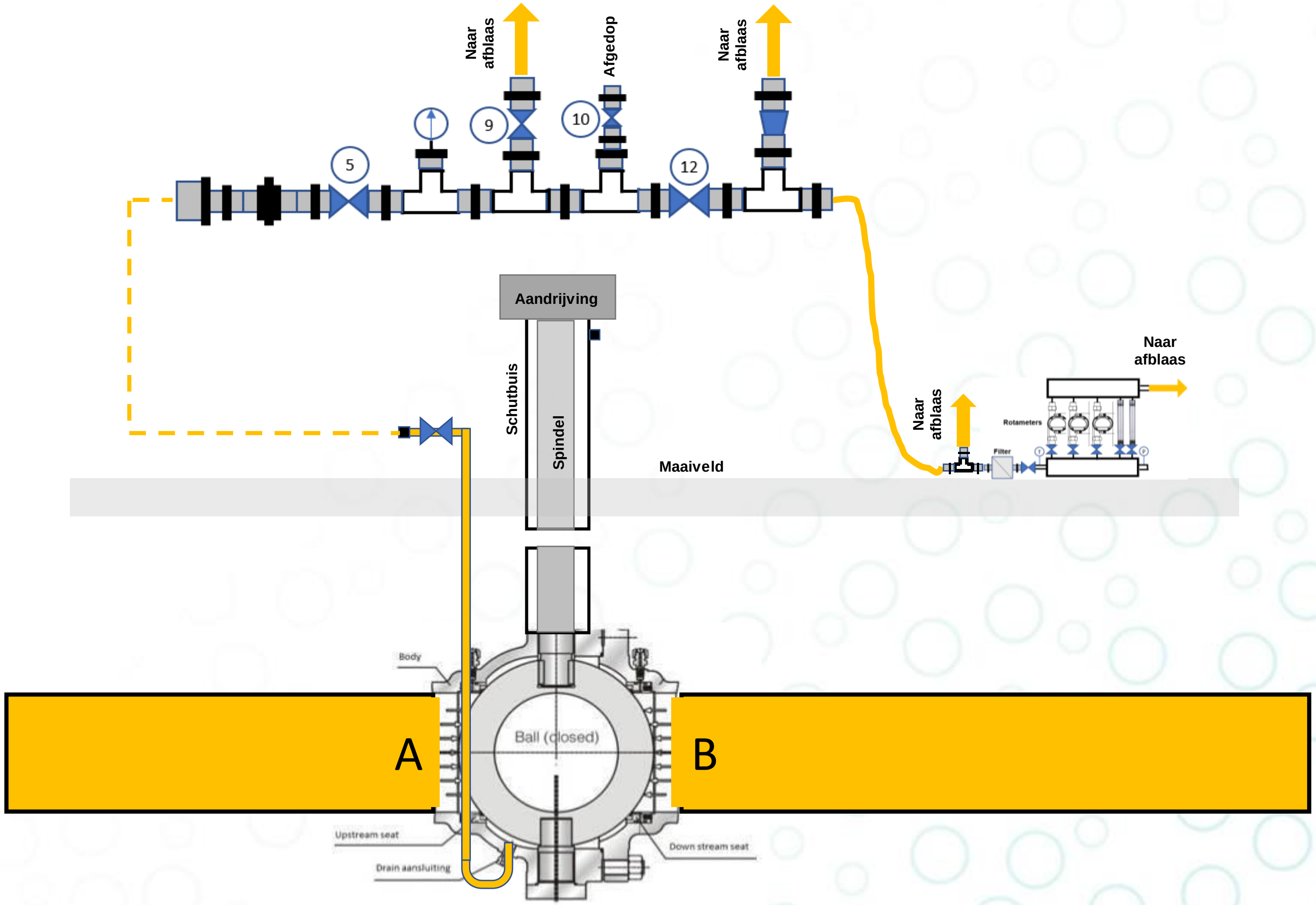
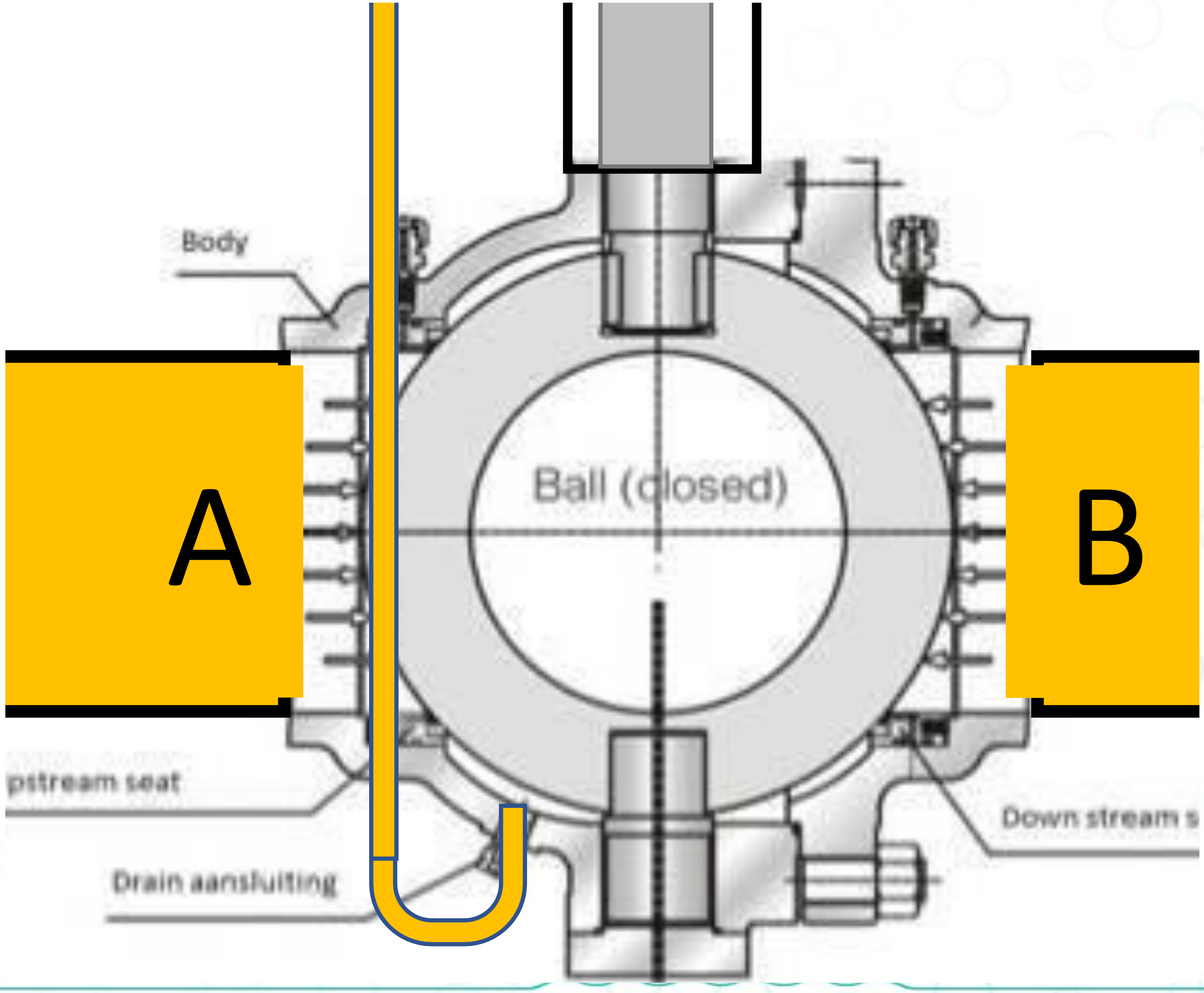


Progress of the work in the period



Progress of the work in the period

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Results and future work

- It is planned that in the period mid-November to mid-December the remaining 4 valves are tested.
- Processing of the measurements results.
- Preliminary results indicate that there is little external leakage both with natural gas as with hydrogen. Another observation is that there is more variation in the measured leak rates on the internal leakage.
- Finally, we need to analyze the results and write the final report.

HyDelta

Thank you for your attention!

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Plenary Progress Meeting

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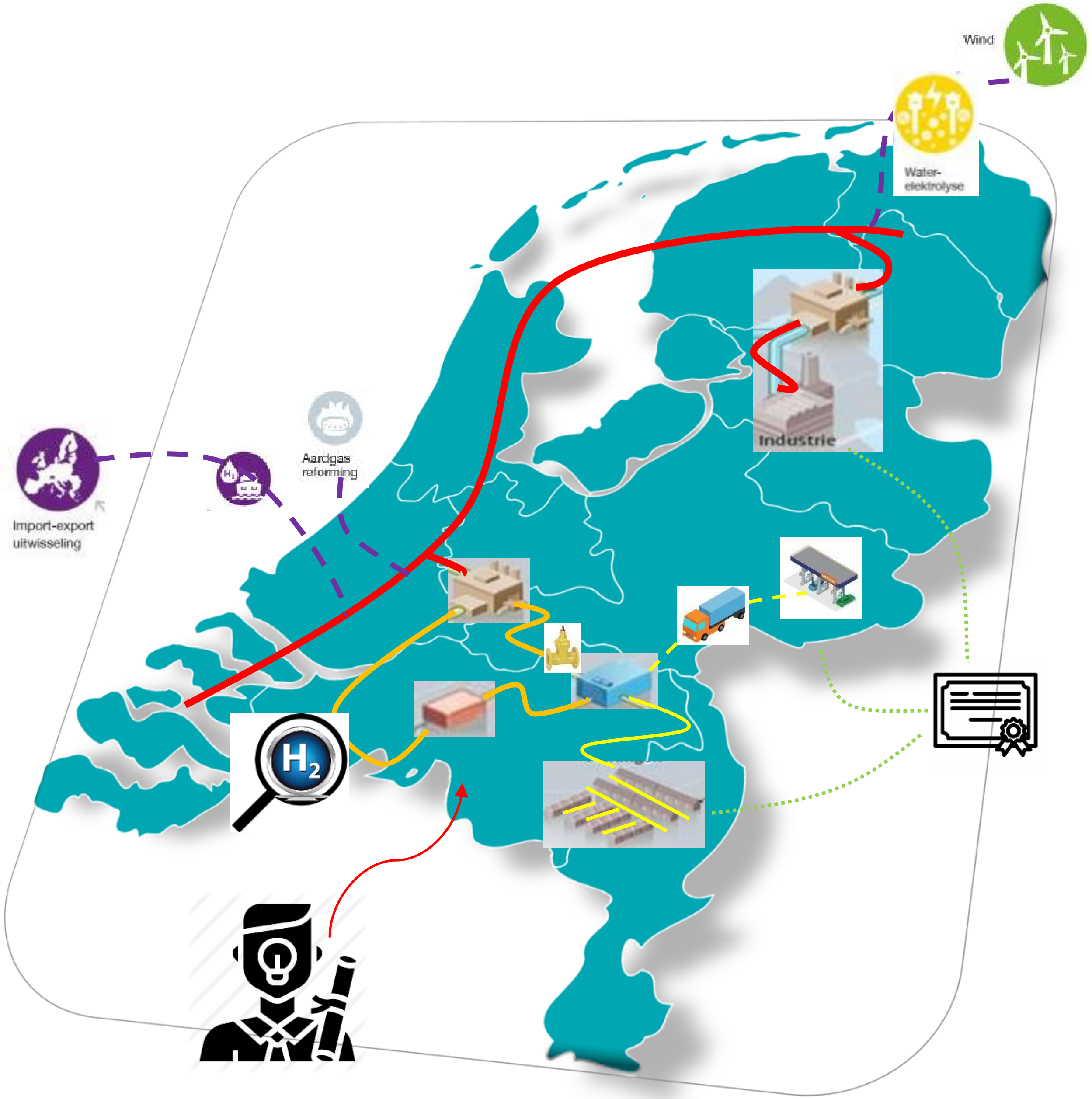
WP 4

Educational track



Kiwa

Suzanne van Greuningen

7-12-2021

Main objectives of the WP

The objectives of WP4 for this period were to finish all sub-deliverables and a draft report.

- Sub-deliverable **1** (vraagscenario's)

  Approach: literature research and interviews with network operators (input from the Expert Assessment Group)

- Sub-deliverable **2** (current state of available education)

  Approach: web-research and interviews with network operators and institutions for secondary vocational education (Dutch: MBO)

- Sub-deliverable **3** (gap-analysis)

  Approach: gap analysis of sub-deliverable 1 & 2

- Sub-deliverable **4** (eindtermen)

  Approach: available knowledge and interviews with network operators (input from the Expert Assessment group)

Progress of the work in the period

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- Sub-deliverable **1** (vraagscenario's)

Progress and details

- research and interviews completed

- input from network operators (EAG) received

- sub-deliverable finalized and sent for review

Recurring work

- *2040-2050*

Gasunie and regional network operators combined: 0-3.500 fte's per year for operation and maintenance

- *>2050*

Gasunie and regional network operators combined: 0-7.000 fte's per year for operation and maintenance

Significant results

- *<2030*

Several teams of engineers with H2 knowhow necessary for pilot projects of regional network operators as well as Gasunie.

One-off labour

- *2030-2040*

Gasunie: 573 fte's per year for construction of hydrogen backbone.

- *2040-2050*

Regional network operators: 0-161 fte's per year for modification of gas distribution network.

- *>2050*

Regional network operators: 0-161 fte's per year for modification of gas distribution network.

Progress of the work in the period

HyDelta

- Sub-deliverable **2** (current state of available education)

Progress and details

- *data collection from third parties completed*
- *input from network operators (EAG) received*
- *sub-deliverable finalized and sent for review*

Points of attention

- *In all parts of the sector are concerns about the limited available personnel. This regards both technical engineers as well as teachers to educate them.*
- *Complexification of the energy system will require more knowledge of different energies, carriers, grids, and buffers.*

Significant results

Current state of MBO education gas engineers (H2)

- *There are no MBO courses or programs in the field of gas infrastructure and distribution for hydrogen. Not in regular or private education or with operators.*
- *Some network operators do offer trainings to educate personnel on H2.*

Relevant available courses and being developed (H2)

- *Training waterstof* (Noorderpoort)
- *Praktijkcursus waterstof* (Kiwa)
- *Training for gas engineers focussing on transitioning the gas network to a hydrogen network is being developed (Kiwa-Alliander collaboration).*

Progress of the work in the period

- Sub-deliverable **3** (gap-analysis)

Progress and details

- *sub-deliverable finalized and sent for review*

Significant results

- *To educate the gas engineers that will have to facilitate the energy transition an MBO educational track needs to be developed.*
- *Efforts should be made to resolve the scarcity of executive personnel and teachers.*

- Sub-deliverable **4** (eindtermen)

Progress and details

- *input from network operators (EAG) received*
- *sub-deliverable finalized and sent for review*

Significant results

- *The first start of an educational track was made by formulating the 'eindtermen'.*
- *Nationally accepted 'VWI's' are necessary to convert these end terms into more specific learning goals.*

Progress of the work in the period

HyDelta

- Deliverable D.1

Progress and details

- *draft report sent to EAG for review on November 18th*

Significant results

- *See previous slides*

WP 4 The development of educational tracks
D4.1 De behoefte naar technisch personeel en advies voor versterken van educatie op het gebied van waterstof

2.1.1 Benoemen van de aanleiding en toepassingsmogelijkheden van waterstof.

2.1.2 De fysische en chemische eigenschappen van waterstof benoemen en vertalen naar de werksituatie.

2.1.3 De consequenties van verschil in fysische en chemische eigenschappen van aardgas en waterstof vertalen naar de werksituatie.

2.1.4 Uitleggen welke (veiligheids)risico's verbonden zijn aan het werken met waterstof

2.1.5 Toelichten wat de impact van incidenten met waterstof kan zijn op de beeldvorming van de maatschappij over waterstof.

2.1.6 Fysische en chemische eigenschappen van stikstof benoemen.

2.1.7 Op een veilige manier gebruik maken van stikstof bij het omzetten van een aardgasnet naar een waterstofnet.

2.1.8 Toelichten welke processtappen bij werkzaamheden aan het waterstofnet anders verricht moeten worden ten opzichte van het werken aan het aardgasnet.

2.1.9 Toelichten welke andere PBM's, gereedschappen en meetapparatuur gebruikt moeten worden bij werkzaamheden aan het waterstofnet ten opzichte van het werken aan het aardgasnet.

2.1.10 Toelichten welke storingen en schades kunnen optreden aan het waterstofnet en welke maatregelen er genomen moeten worden.

2.1.11 Uitleggen hoe er gehandeld moet worden bij calamiteiten aan het waterstofnet anders dan bij calamiteiten aan het aardgasnet.

2.1.12 Processtappen doorlopen bij het omzetten van het aardgasnet naar een waterstofnet (afhankelijk van de landelijke VWI's).

2.1.13 Processtappen doorlopen bij het zoeken naar en verhelpen van lekkages aan de distributieleiding, aansluitleiding, meteropstelling en binnenleiding in het waterstofnet (afhankelijk van de landelijke VWI's).

2.1.14 Op een veilige manier handelingen verrichten aan de distributieleiding, aansluitleiding, meteropstelling en binnenleiding in het waterstofnet bij onderhoud en storingen (afhankelijk van de landelijke VWI's).

5.2.2 Eindtermen specifiek voor werkzaamheden aan het waterstof hoge druk netwerk.

2.2.1 Toelichten welke processtappen bij werkzaamheden aan het waterstof hoge druk netwerk anders verricht moeten worden ten opzichte van werken aan het aardgas hoge druknetwerk.

2.2.2 Uitleggen welke specifieke veiligheidsrisico´s er zijn rondom het gebruik van waterstof in een hoge druknetwerk en hoe hierna te handelen.

Eindtermen as formulated in the draft report

Work to be done in the next period

- First draft of report (D4.1) reviewed by Expert Assessment Group
- Meeting with EAG to discuss comments (Dec 9th)

- Complementing deliverable 4.1 by processing recommendations and comments of EAG

- Second draft of report (D4.1) reviewed by Expert Assessment Group
- Review by the Supervisory Group

- Delivering final report (D4.1).

Thank you for your attention!

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Thank you for your attention!

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