

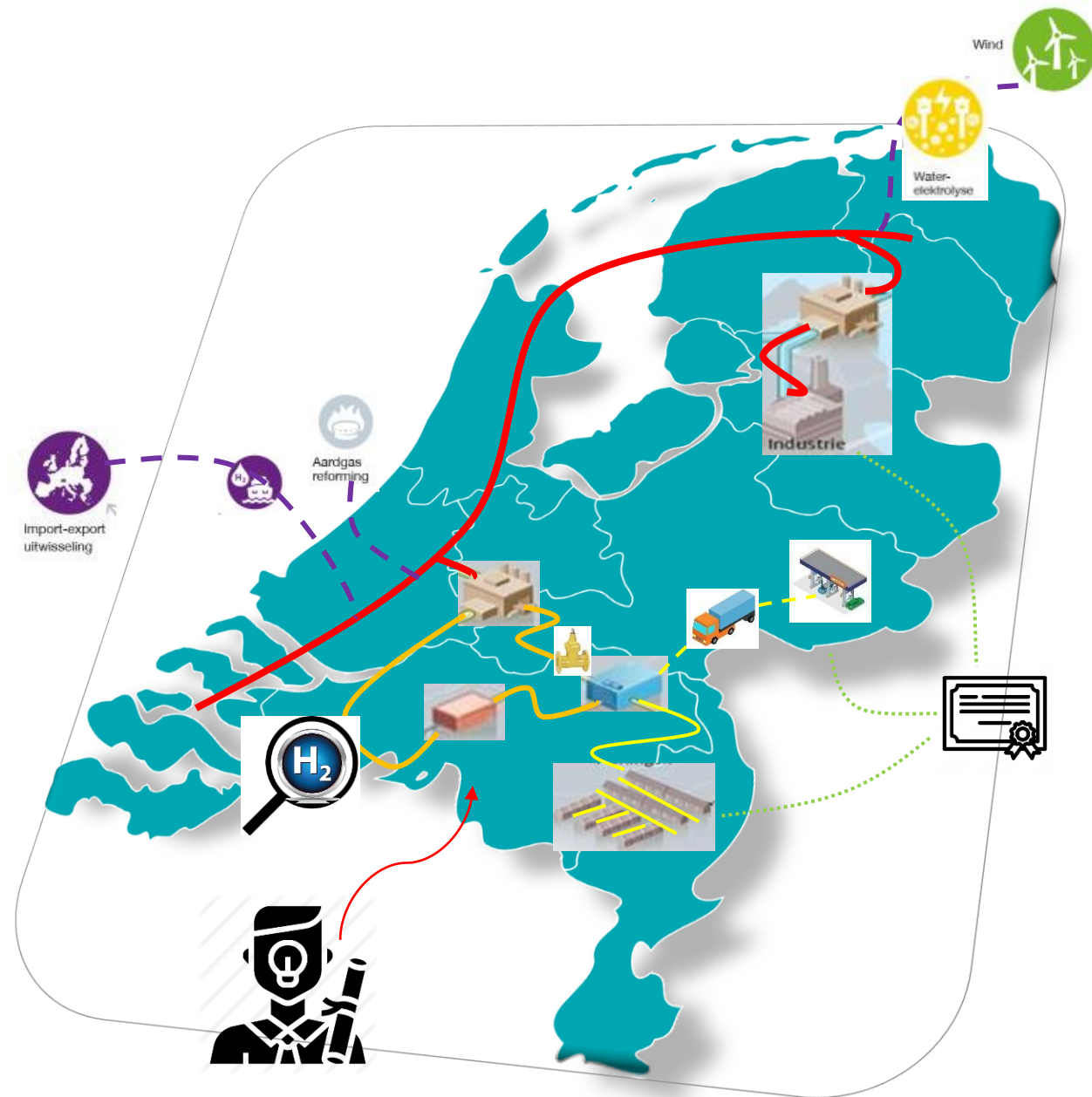


Plenary Progress Meeting 1 Introduction

NEC

Julio Garcia-Navarro – project coordinator

30-06-2021



1. Dutch Government Strategy

Released March 2020, strong support for hydrogen, recognising unique Dutch situation. Current political situation (awaiting new cabinet) hinders next steps



Ministerie van Economische Zaken
en Klimaat

2. Dutch Innovation Strategy

Strong plea for innovation along 5 lines: a. government policy, b. pilots and demos, c. creating good boundary conditions, d. long-term R&D, e. supportive measures



TKI NIEUW GAS
Topsector Energie

3. Dutch Projects

More than 130 projects are in preparation, but strong need to turn paper into real-life projects



Nationaal Groeifonds



4. National Hydrogen Programme

Under construction, to be delivered first week of July 2021. Summarises high ambitions, bottlenecks, activities to be undertaken by whom and when

NWP Nationaal
Waterstof
Programma

5. International Hydrogen Platform

Dutch stakeholders establishing a platform with a joint approach towards other countries

NL Netherlands

6. Electrolyser Manufacturing Platform

Currently 30+ parties organising themselves around (supply chains of) electrolyzers

TNO innovation
for life

FME  POWERED
BY DUTCH
TECHNOLOGY


















Dutch H2 projects (industry & mobility)



Dutch H2 projects (built environment)

Overview ongoing hydrogen pilots in NL

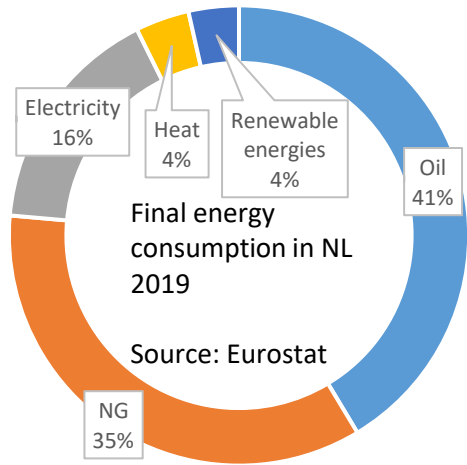
Currently there are **seven** ongoing **hydrogen pilots** in different parts of NL **focused** on the application of hydrogen in the **built environment**.

- 1 North Sea Wind Power Hub**
North Sea Hub 2030 - 2050
Electrolysis for the transport of hydrogen to the mainland.
 
- 2 Entrance terrain Hanzehogeschool**
Groningen 2019 - 2020
Tests with a hydrogen network including hydrogen boilers.
 
- 3 Hydrogen district Wagenborgen**
Wagenborgen 2020 - 2030
30-40 existing residences with hybrid hydrogen heatpumps.

- 4 Hydrogen pilot H2 Oosterwolde**
Oosterwolde 2021 - 2026
Hydrogen for the integration of large scale solar-PV energy generation.

- 5 Hydrogen pilot Hoogeveen**
Hoogeveen 2020 - ∞
H₂ application in existing infrastructure and built environment.
 
- 6 Temporary conversion Uithoorn**
Uithoorn 2020
Converting 14 residences from natural gas to hydrogen.

- 7 Demo- en training residence**
Apeldoorn 2020 - 2026
Demo en training residence for hydrogen on the KIWA terrain.

- 8 Hydrogen pilot H2 Lochem**
Lochem 2022 - 2025
Hydrogen as an alternative to natural gas in monumental premises.

- 9 Hydrogen pilot The Green Village**
Delft 2019 - 2025
Managing a 100%-hydrogen network.
  
- 10 Hydrogen pilot P2G**
Rotterdam Rozenburg 2013 - 2023
Closed hydrogen system in the built environment.

- 11 Pilot Stad aan 't Haringvliet**
Stad aan 't Haringvliet 2025 - ∞
Preparing for the distribution and application of hydrogen in the built environment.
 



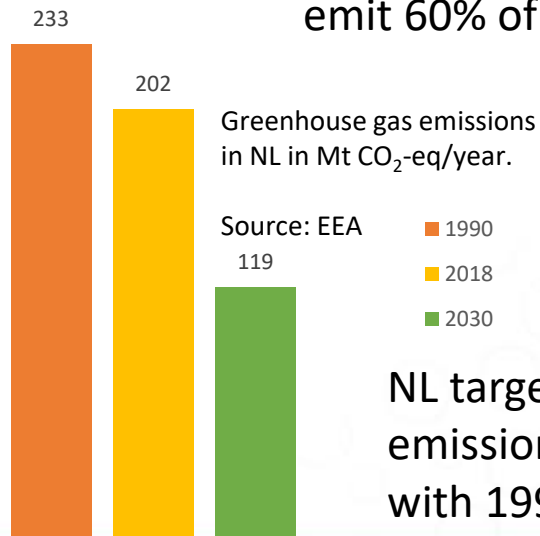
Introduction HyDelta

Current energy landscape in NL

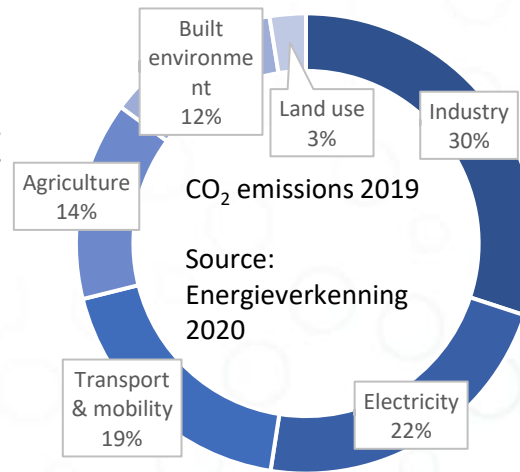


Current NL energy mix: >76% fossil fuels

Industry, T&M, BE emit 60% of CO₂



NL target: -49% CO₂ emissions (compared with 1990) by 2030

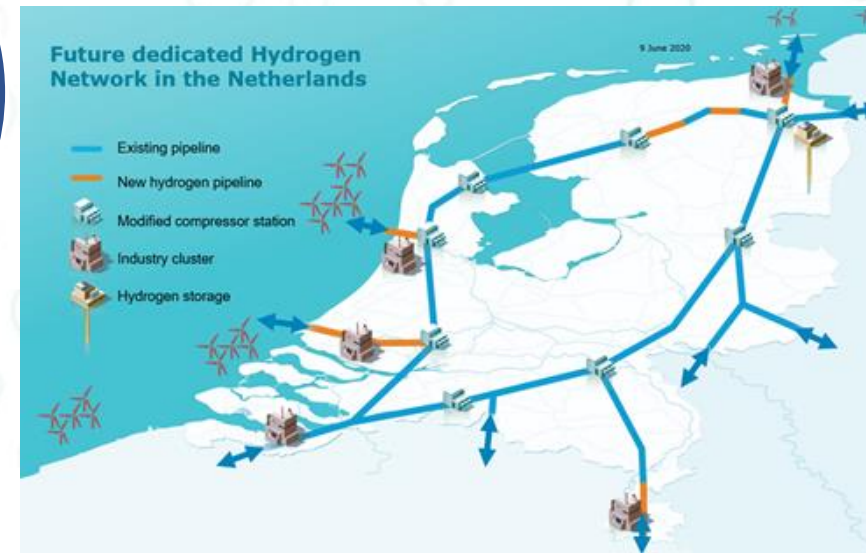


What is HyDelta?

Started as an **idea** to form a **public-private** partnership between **research** institutions and the Dutch gas **TSO & DSOs**

Objective: to **study** the short-term **feasibility** to **transport** **H₂** in the **existing NG network** (either blended in NG or 100% pure)

The **existing NG network** is a **Key-Enabling System** for the Dutch future **hydrogen economy**:



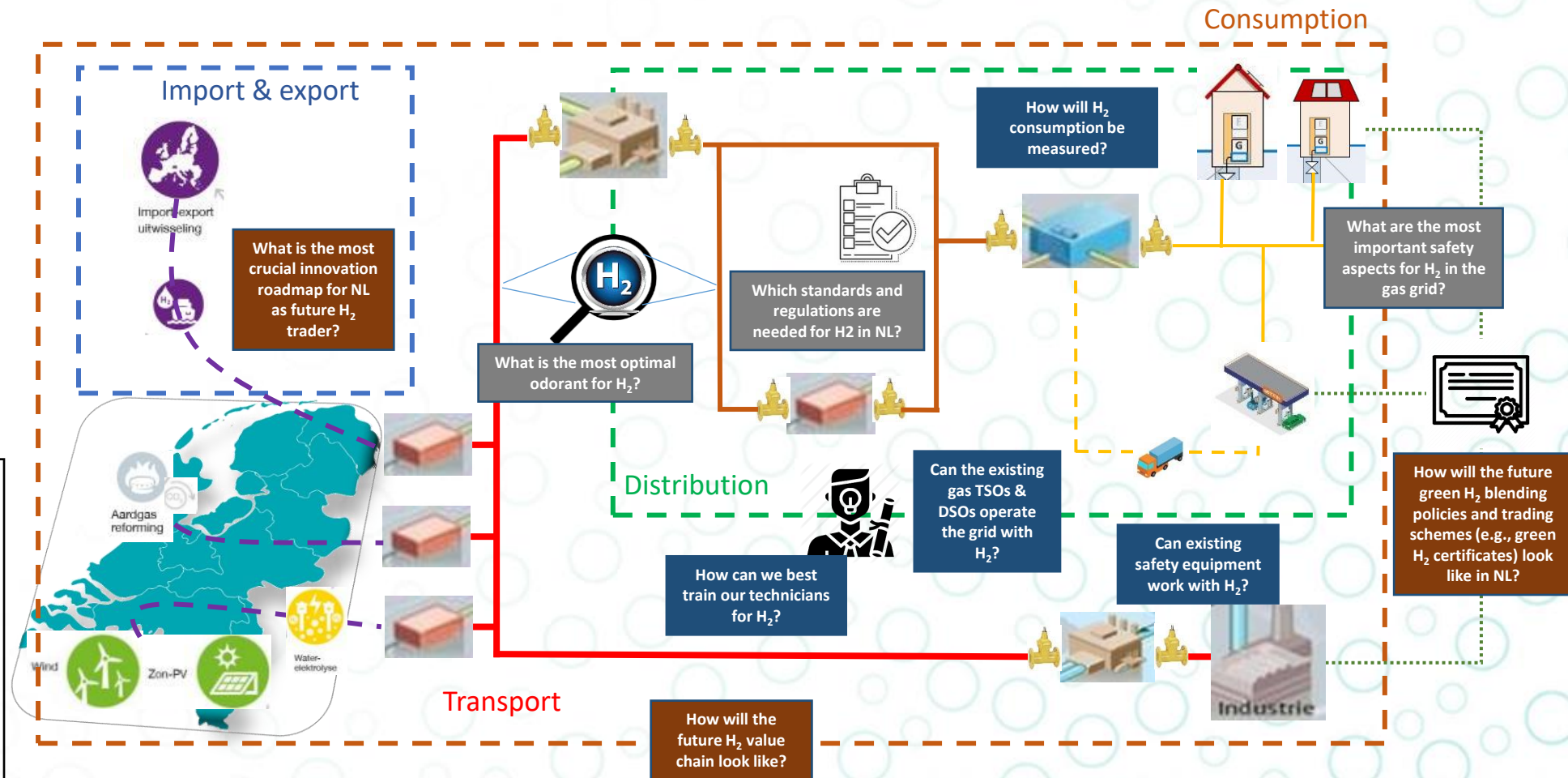
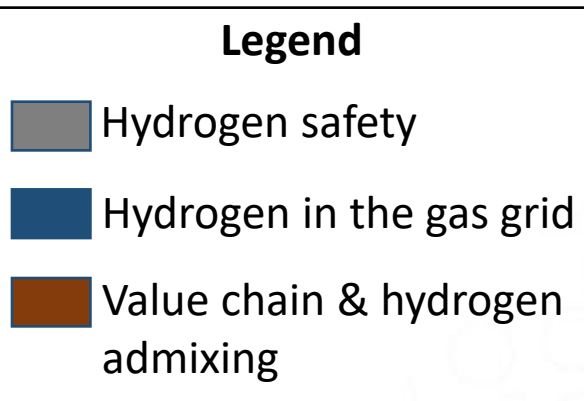
Installed NG transportation capacity in NL:
350 GW

Planned capacity for H₂ transport in the network (2030):
15 GW

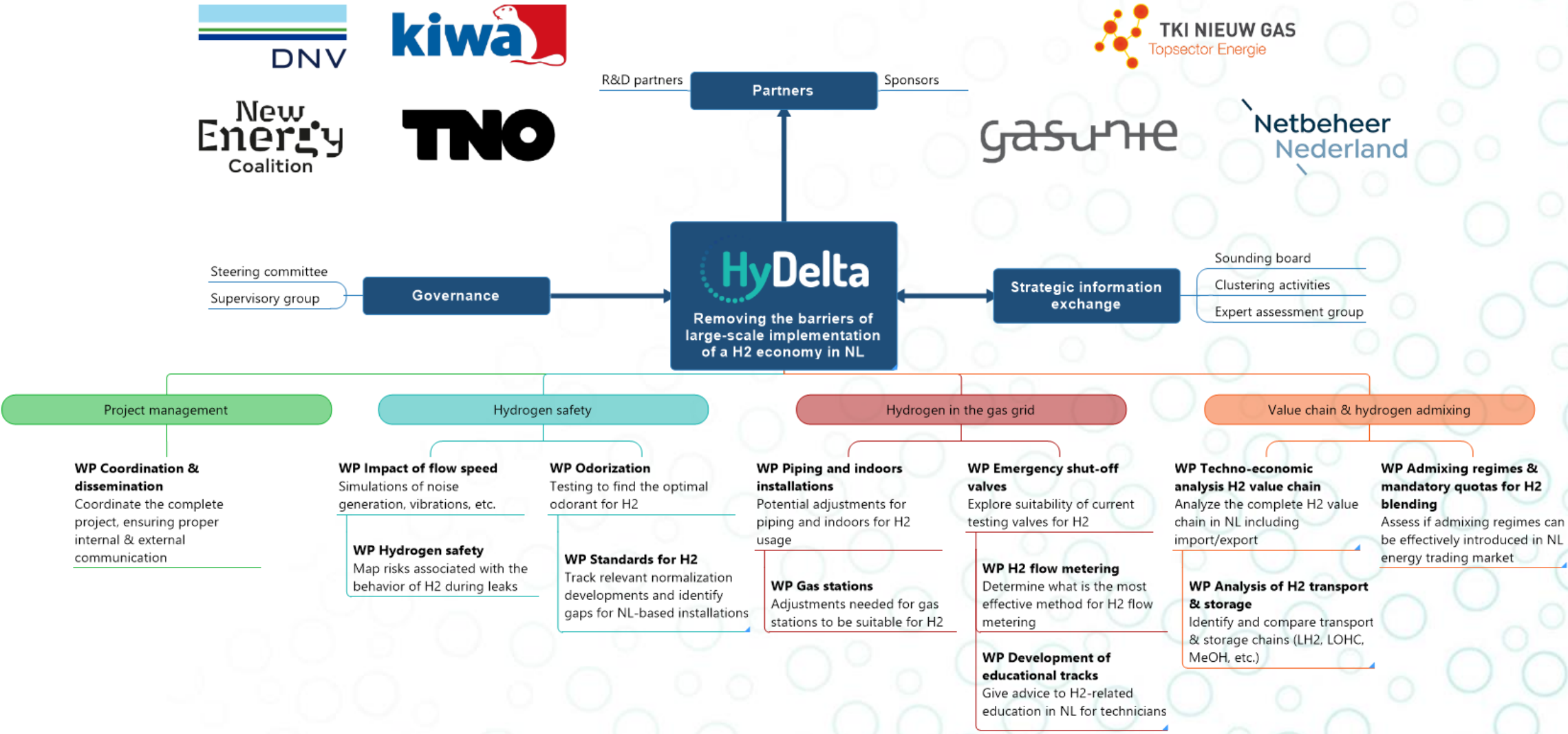
Research questions

Overview of the research questions in HyDelta

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**



Project consortium



Agenda for today

- **10-min presentations** with an intermediate break
- **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	Timeslot	Event
10:00 – 10:10	Welcome & intro presentation HyDelta	11:20 – 11:50	Topic 2: Hydrogen in the gas grid (part 2)
10:10 – 10:50	<u>Topic 1: Hydrogen safety</u> 10:10 – 10:20 WP1A Hydrogen & safety Albert van den Noort, DNV 10:20 – 10:30 WP1E Impact of hydrogen flow speed on safety Néstor Gonzalez Diez, TNO 10:30 – 10:40 WP2 Odorization of hydrogen Harm Vlap, DNV 10:40 – 10:50 WP3 Standards for hydrogen Hans de Laat, Kiwa		11:20 – 11:30 WP1D Hydrogen flow metering Hans de Laat, Kiwa 11:30 – 11:40 WP1F Testing of shut-off valves in the gas transportation grid Cees Lock, Kiwa 11:40 – 11:50 WP4 Development of educational tracks Sjoerd Delnooz, Kiwa
10:50 – 11:10	<u>Topic 2: Hydrogen in the gas grid (part 1)</u> 10:50 – 11:00 WP1B Gas stations Sander van Woudenberg, Kiwa 11:00 – 11:10 WP1C Piping & indoor installations Sander Lueb, Kiwa	11:50 – 12:20	<u>Topic 3: Value chain & hydrogen admixing</u> 11:50 – 12:00 WP7A Techno-economic value chain analysis Joris Kee, New Energy Coalition 12:00 – 12:10 WP7B Technical analysis of hydrogen supply chains Sara Wieclawska, TNO 12:10 – 12:20 WP8 Admixing & mandatory blending Rob van Zoelen, New Energy Coalition
11:10 – 11:20	<u>Intermediate break</u>	12:20 – 12:30	<u>Final remarks and closing</u>



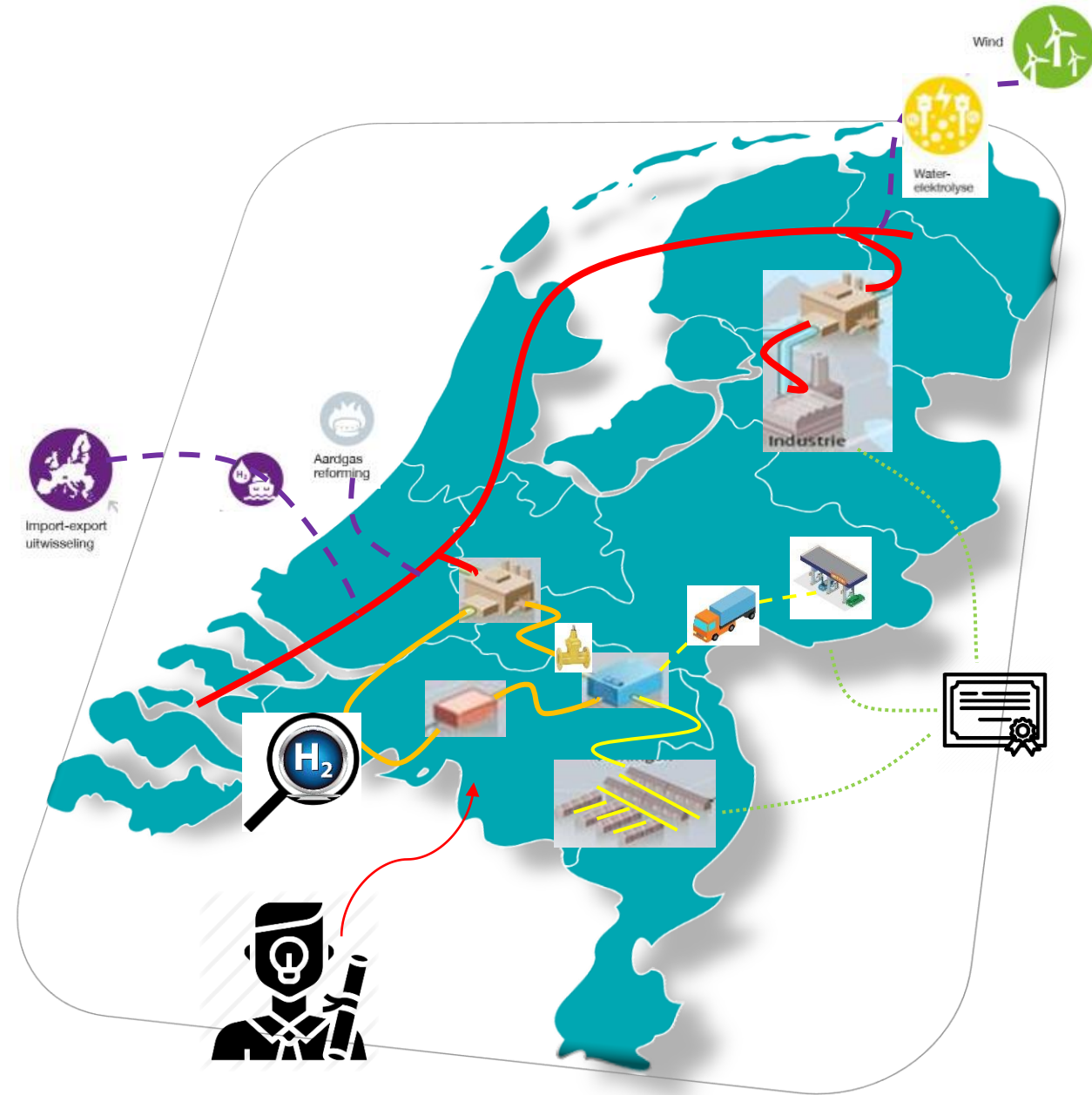
WP1A

Hydrogen Distribution and Safety

DNV / KIWA

Albert van den Noort (DNV)

30-06-2021



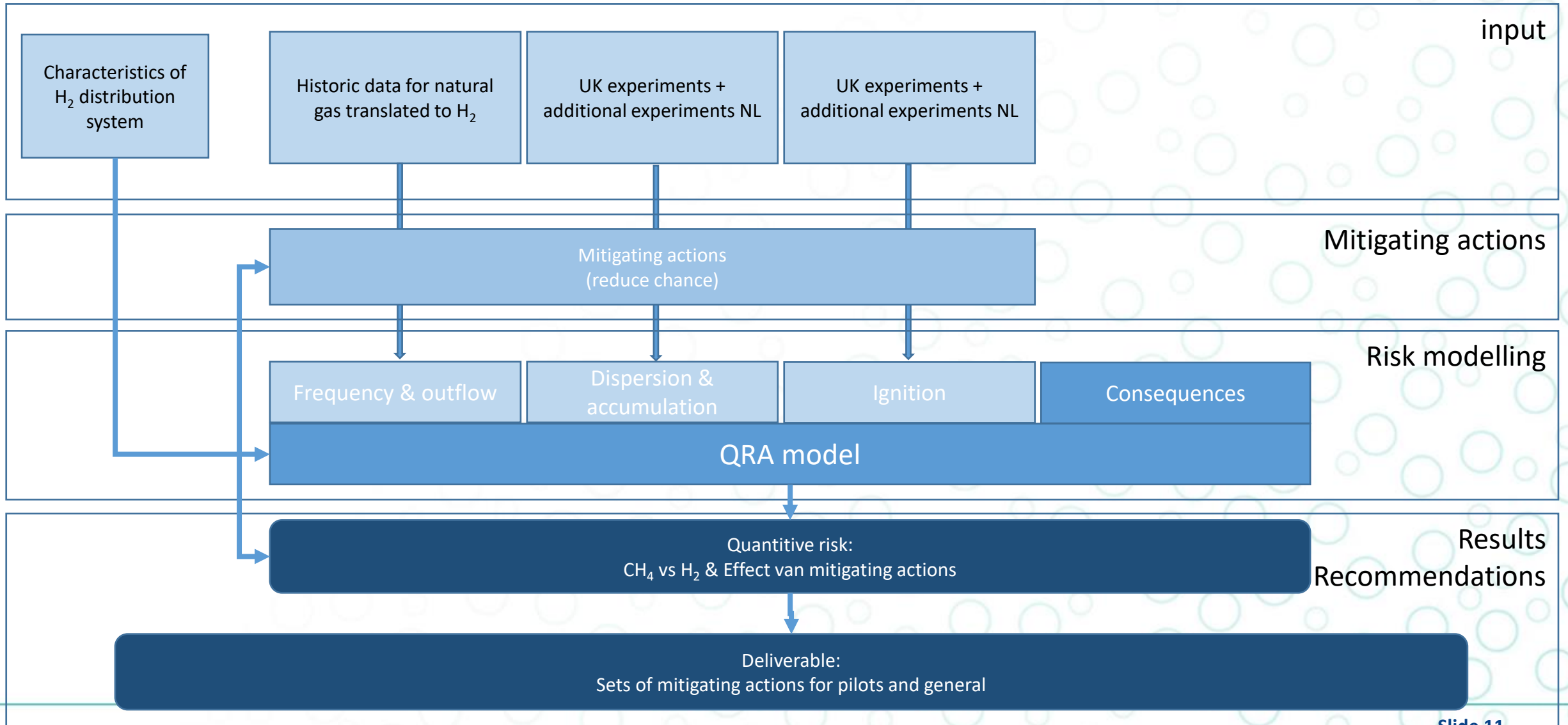
Main objectives of the WP

- 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: Approach

- Phase 1: Build on existing / validated knowledge
 - Overview in 'behavior of hydrogen at leakages' (DNV 2020)
 - Experience from UK (H21 / Hy4heat) translated to Dutch Situation

-> Inventarisation and prioritisation of gaps in knowledge

- Phase 2: Fill gaps in knowledge
 - Additional experiments to fill gaps in knowledge
 - Recommendations for set of mitigating actions



Work to be done in the next period

- Translation of the UK QRA model for The Netherlands and quantify risks
- Define and execute additional experiments
 - To fill gaps in knowledge
 - To show effectiveness of mitigating actions
- Make recommendations for sets of mitigating actions for pilots and general



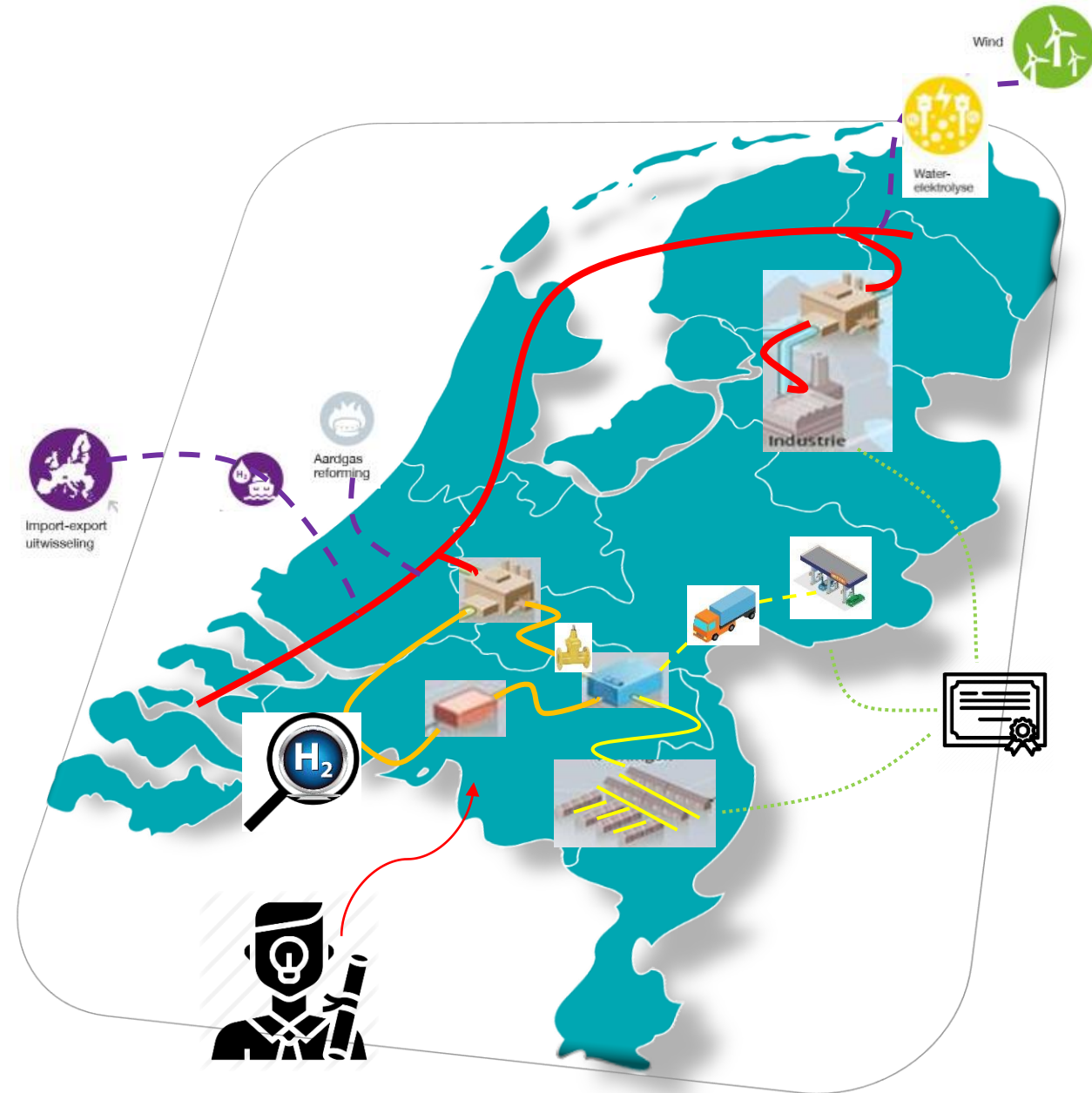
WP1E

Impact of high velocity of hydrogen flows

TNO

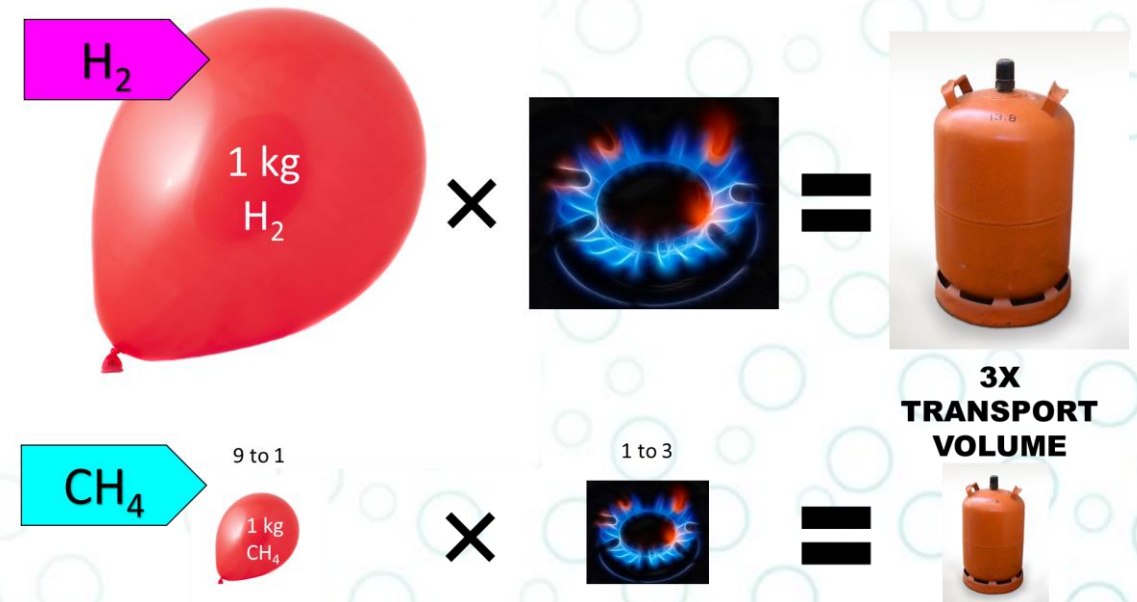
Néstor González Díez, Deputy RM HTFD

30-06-2021



Introduction

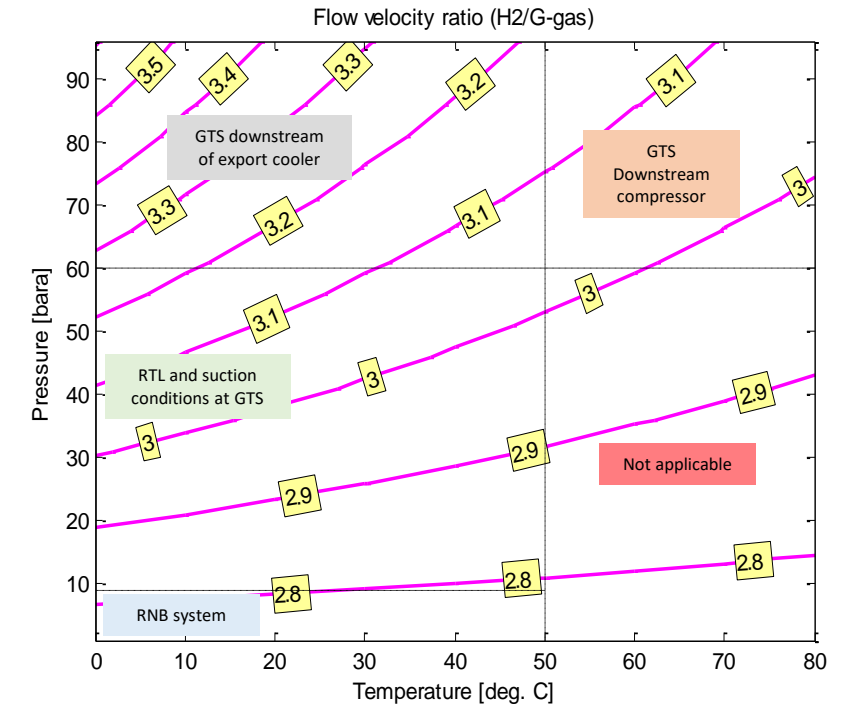
- When the same amount of energy as transported with natural gas is to be delivered in the form of hydrogen, the flow velocity has to increase significantly.
- In the schematic shown on the right, which compares hydrogen to methane, a flow rate ratio of ~3 is necessary to achieve this. For natural gas compositions, with different mol weight and calorific value, this value can be higher
- 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



- 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
 - Metering accuracy (in cooperation with 1D)
 - Erosion (in cooperation with 1B)

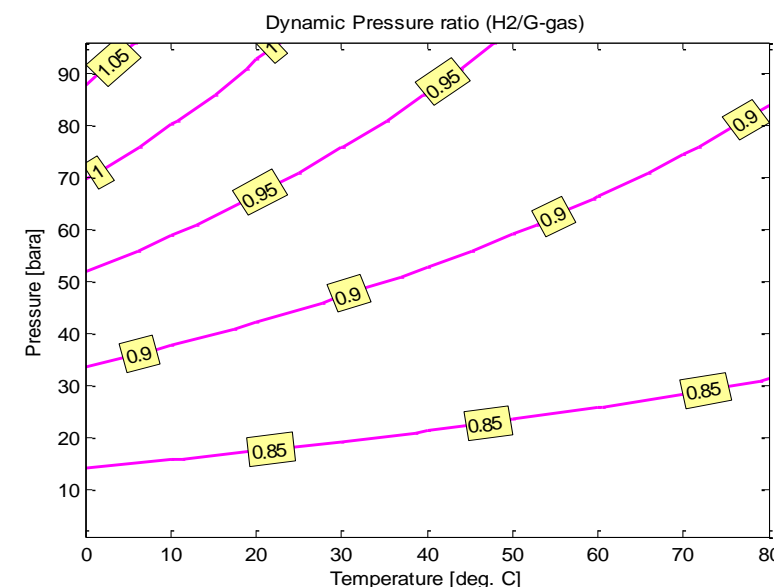
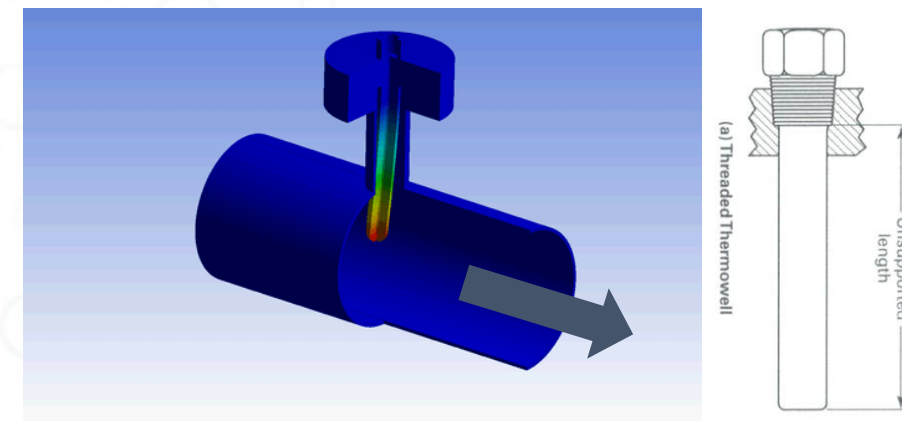
Progress of the work in the period

- Velocity ratio
 - When compared to G-gas and transporting the same amount of energy, H2 will need to flow about 3 times faster in the system
 - This is the central assumption of this WP as worst-case condition. Whether such H2 volumes will occur at similar pressures and temperatures can still be debated



Progress of the work in the period

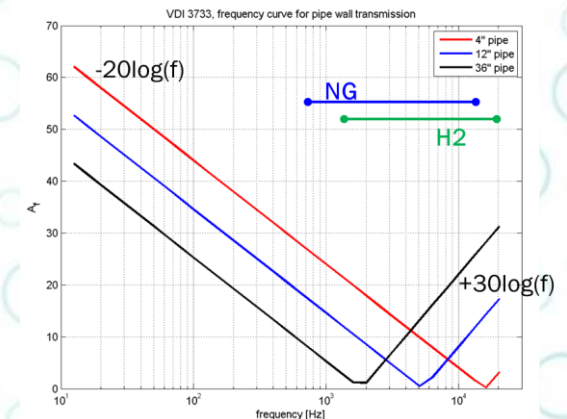
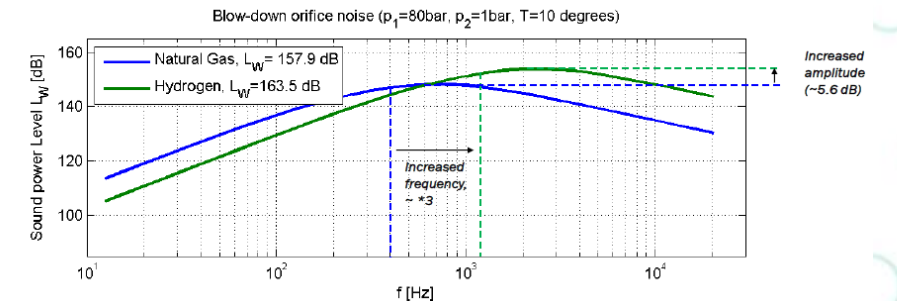
- Intrusive Equipment – Thermowells
 - Assessment based on ASME PTC 19.3 TW-2016
 - Whether TW can fail depends on the coincidence between their natural frequency and vortex-shedding frequency
 - A number of typical cases in the Dutch system have been analysed
 - Short-tapered designs are still compliant to the standar, but not long, straight designs
 - Aerodynamic forces are similar between H₂ and G-gas, as dynamic pressure at equal energy transport capacities is similar (and Reynolds number remains high enough)



Progress of the work in the period

- Noise Generation

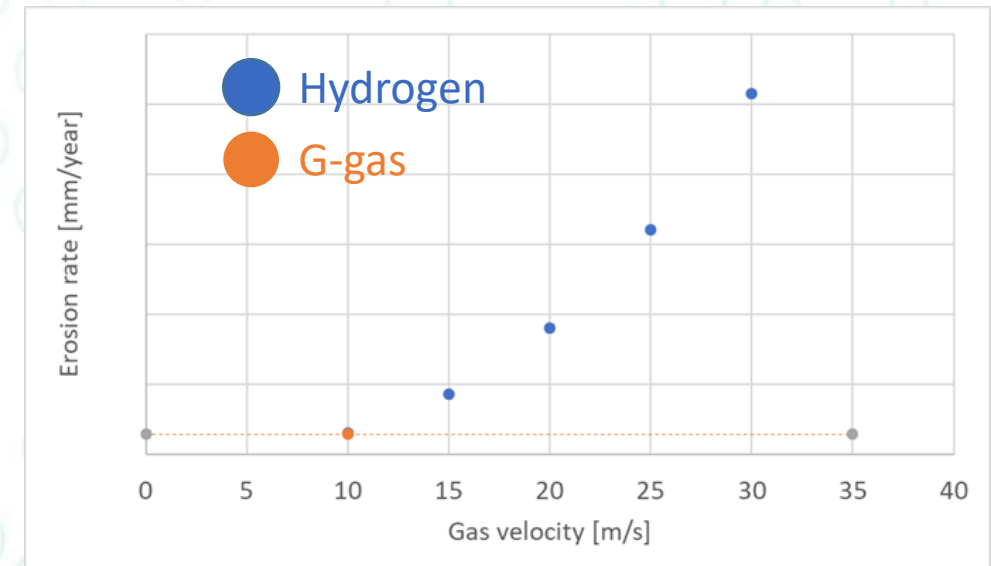
- For conversion of gas transport infrastructure, flow-induced noise by pressure let-down devices may be a relevant aspect
- Negative consequences of flow-induced noise are the risk on fatigue failure, environmental noise radiation and disturbance of flow metering equipment
- H2 can make more noise compared to NG at similar pressure let-down locations, which means a higher risk to the integrity of the system
- Noise will happen at a higher frequency. The frequency has to be put also in the perspective of what humans are sensitive to (A-weighting) and how much of this spectrum can radiate from the pipe to the outside environment
- Pipe will normally block more noise with H2 than with G-gas (impedance term)
- Tests are extremely valuable to double-check these conclusions. Tests executed so far (outside HyDelta) at low pressure conditions favour H2 over G-gas when it comes to spectra recorded in the surroundings of pressure let-down equipment.



Progress of the work in the period

- Erosion

- Currently not an issue in GTS, RTL or RNB systems (partly thanks to filters, see 1B)
- Particles can only be present due to extraordinary circumstances.
- The effect of increased velocity and lower densities at H₂ leads to higher erosion rates at the same solid rate
- H₂ as a gas has little effect on the outcome. The effect of fluid properties is limited in the current model, and therefore the effect of flow velocity is dominant.
- As similar (high enough) flow velocities, similar erosion rates are expected between natural gas and hydrogen.



Work to be done in the next period

- The following is still in the to-do list:
 - Finalize/complete some of the questions that have arisen during the execution of the tasks just described, such as additional sensitivity analyses
 - Incorporate investigations related to flow-induced pulsations and vibrations in the context of HyDelta
 - Support 1D concerning the accuracy issues in metering equipment that may be expected in the presence of highly unsteady flows
 - Compile the final report

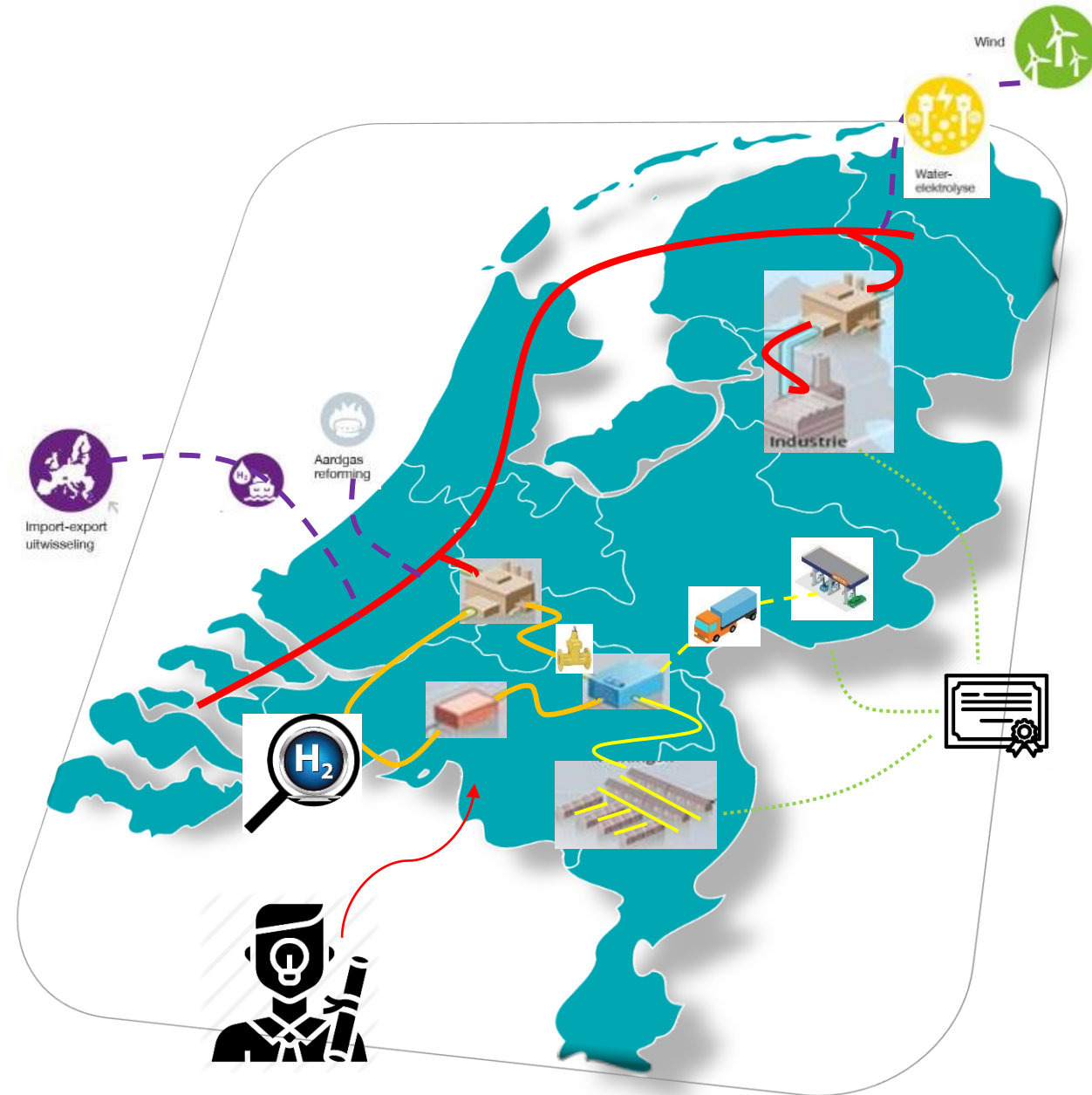


WP2 Odorisation

Kiwa & DNV

Harm Vlap/ Erik Polman

30-06-2021



Background

Hydrogen distribution should take place in a safe way. Odourisation of hydrogen seems a necessity. This work package is meant to fill some of the knowledge gaps in order to pave the way for the introduction of a hydrogen odorant.

Two candidate odorants already have been chosen:

- Tetrahydrothiophene (THT): sulphur containing odorant, used in Dutch natural gas
- Gasodor® S-Free: sulphur free alternative. Have been used in the past in natural gas

Research goals

1. Select a suitable (third) sulphur free candidate odorant
2. Determine the stability of the odorant in hydrogen
3. Inventorize the behaviour of the odorant/hydrogen mixture in air and in the soil (status existing knowledge)
4. Inventorize the impact of odorant on fuel cells and appliances (status existing knowledge)
5. Inventorize safety aspects (Bow Tie analysis)
6. Determine the functionality of the odorant with a panel

Research goal 1: Selection of a suitable third candidate odorant

About 20 candidates have been inventorized, based on physical properties (unique, not soluble in water, boiling point, reported odour character) three were selected for a panel test:

- 5-Ethylidene-2-norbornene
- Tert-butyl methyl ether
- 2-hexyne

2-Hexyne has been selected and taken up in the remaining programme besides THT and Gasodor® S-Free

The choice was made based on a panel test and this odorant showed:

- Unique flavour
- Low odour threshold. good smellability at low concentration
- an unpleasant distinct odour
- and is **sulphur free**
- The nominal concentration in hydrogen is determined at **15 mg/m³n**

Research goal 2: Determine the stability of the odorant

- Aim of the test: find out whether a mixture of odorant in hydrogen remains chemically stable by measuring the concentration range over a period of three months by sampling
- Status: in progress: for three odorants at three concentration ranges (low, medium, high) pressurised mixtures (100 bar) in hydrogen were made.
- Tests up to now (two weeks)) show stable behaviour

Research goal 4: Impact on appliances:

- In progress

Other R&D packages:

- Not started yet

Work to be done in the next period

Stability of odorant

- Complete existing long term stability tests up to beginning of August '21 and report

Impact appliances

- Finish overview and report

Behaviour of odorant/hydrogen mixtures in soils and air

- Make inventory (October '21)

Safety aspects

- Make Bowtie analysis (September '21)

The Bowtie method is a risk evaluation method that can be used to analyse and demonstrate causal relationships in high risk scenarios. ... First of all, a Bowtie gives a visual summary of all plausible accident scenarios that could exist around a certain Hazard.

Functionality of the odorant

- Do laboratory tests with panel (October '21)

HyDelta

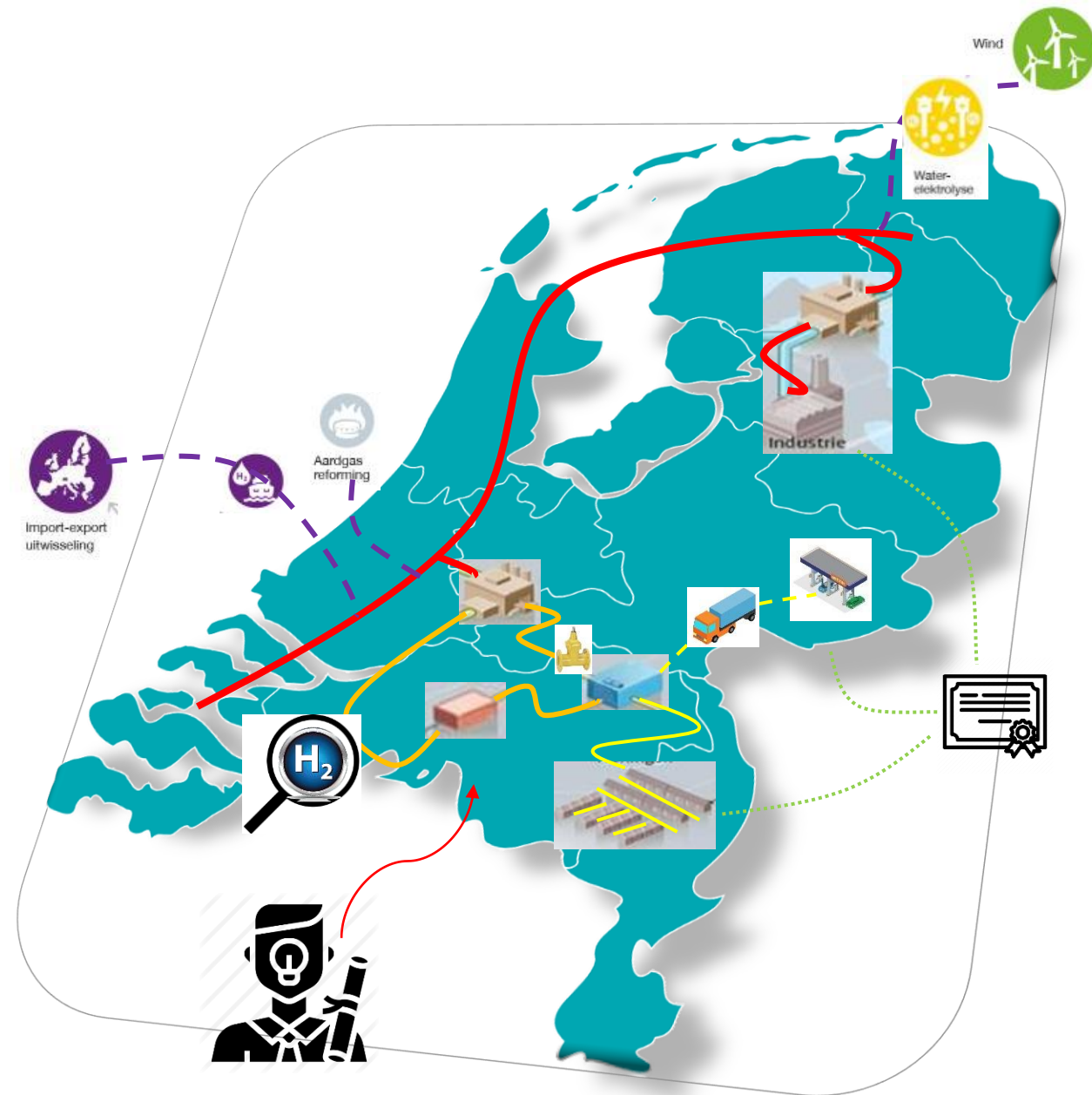
WP3

Standards for Hydrogen

Kiwa

Hans de Laat

30-06-2021



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

Progress of the work in the past period

Gathering information on existing research and on priorities of standardization

Both National and International

National:

- Work of H2IGO (Hydrogen in the built environment)
- Comments of national standardization committees

International

- from CEN TC's: Gas Infrastructure, Test gases, Gas Meters, Natural gas, Analysis of gases, Hydrogen in Energy systems
- Sector Forum Energy Management Hydrogen
- Marcogaz hydrogen market analysis
- CEN- GERG hydrogen research

- Inventory of relevant existing standards and standardization needs
- A priority from an national and international perspective
- Timeplan for standardization topic (a timeplan is sometimes not specified)

Gaps identified

- Gas meters - All measuring principles
- Odorization
- Gas quality - H2NG, H2 in former NG grids, H2 in dedicated grids
- Determination of gas quality parameters
- Equipment for H2 concentration monitoring in the gas flow
- Sensors for leak detection (maybe partly relevant; these exist already For H2)
- Sealings and connections (Rubber materials, screw connections, steel samples)
planning to be verified
- Industrial valves *planning to be verified*
- Leakage related safety risks *planning to be verified*

Gaps identified

- Allowable H₂ concentration in natural gas grids is very low,
 - <2% when tanks in CNG vehicles are considered
 - <3% According to Netbeheer Nederland

- Report on the findings regarding standards of hydrogen

Work to be done in the next period

- Compare the standardization planning to national needs
- Extend to “medium” priorities when relevant
- Finalize the Gap Analysis
- Formulate recommendations to develop missing knowledge
- Point out experts to take part in standardization committees
- Write report

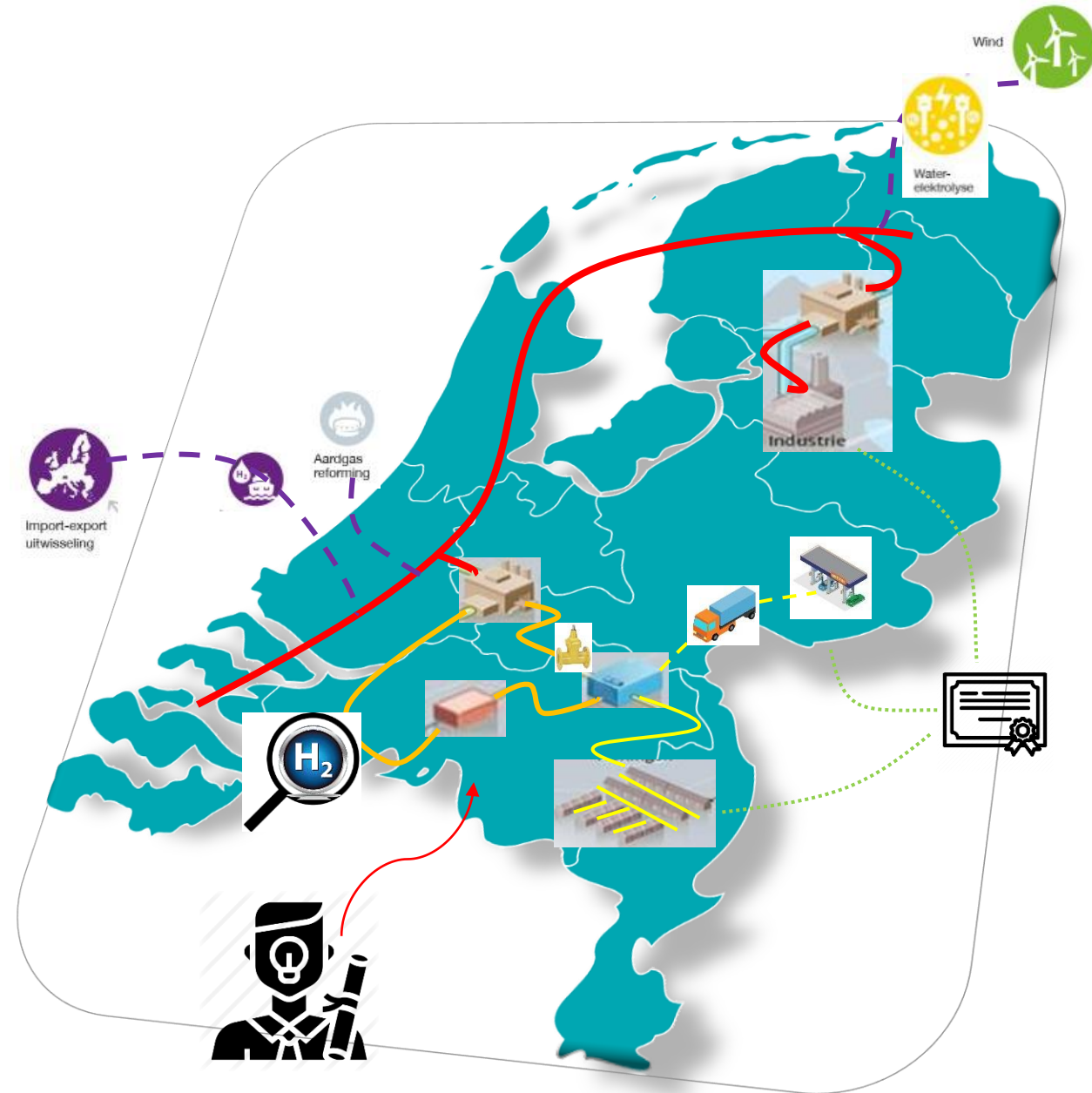


WP1B Gas stations

Kiwa

Sander van Woudenberg

30-06-2021



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.”



- 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.
 - Preliminary results show that current working methods appear to be safe with hydrogen.

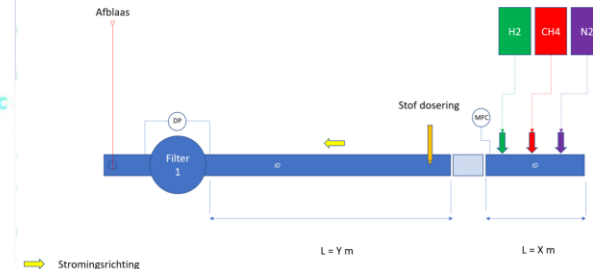
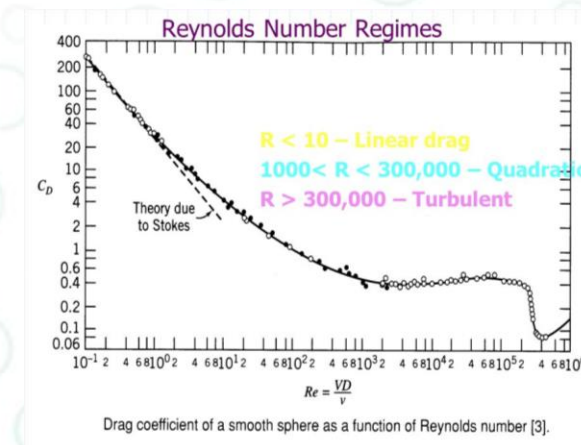
Progress of the work in the period

- 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.
 - First results – small cabinet:
 - A similar leak size releases more flow with hydrogen compared to methane.
 - Directly at the vent opening, concentration can be as high as within the cabinet.
 - At 0,5 m, concentration is always well below 10% LEL. Even if gas leak is so large it can be heard.



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: mathematical modeling & testing. Prepare mathematical model to understand differences in test parameters necessary to build a suitable test setup. Quantify differences in contamination of gas filters.
 - First results – mathematical modeling:
 - Input small scale test setup prepared to assess all parameters in transporting dust using model
 - Ratio 3 in gas velocity between methane and hydrogen shows same order of magnitude dust transport rates
 - Assessment of scale up under evaluation in view of required gas flow rates



Work to be done in the next period

- Is the ventilation in stations also suitable for hydrogen?
 - Modelling and (if possible) testing the effects of detonation if a flame is present near the station.
 - Setting safety distances for stations.
- Do existing stations work properly with hydrogen?
 - First test with one station (before start of HyDelta) shows encouraging results
 - Define test protocol (accuracy of pressure reduction, effectiveness of safety devices, maximum flow, sound levels)
 - 2nd half of 2021 tests are being planned (full capacity)

Work to be done in the next 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).
 - Start preparation to build small scale test setup and define test matrix
 - Define how full scale test can be defined to test with methane/ hydrogen by using mathematical model
 - Assess types of dust/ gas filters available to use in tests
 - Define test protocol (how do we test, what do we record, how to test accurately)



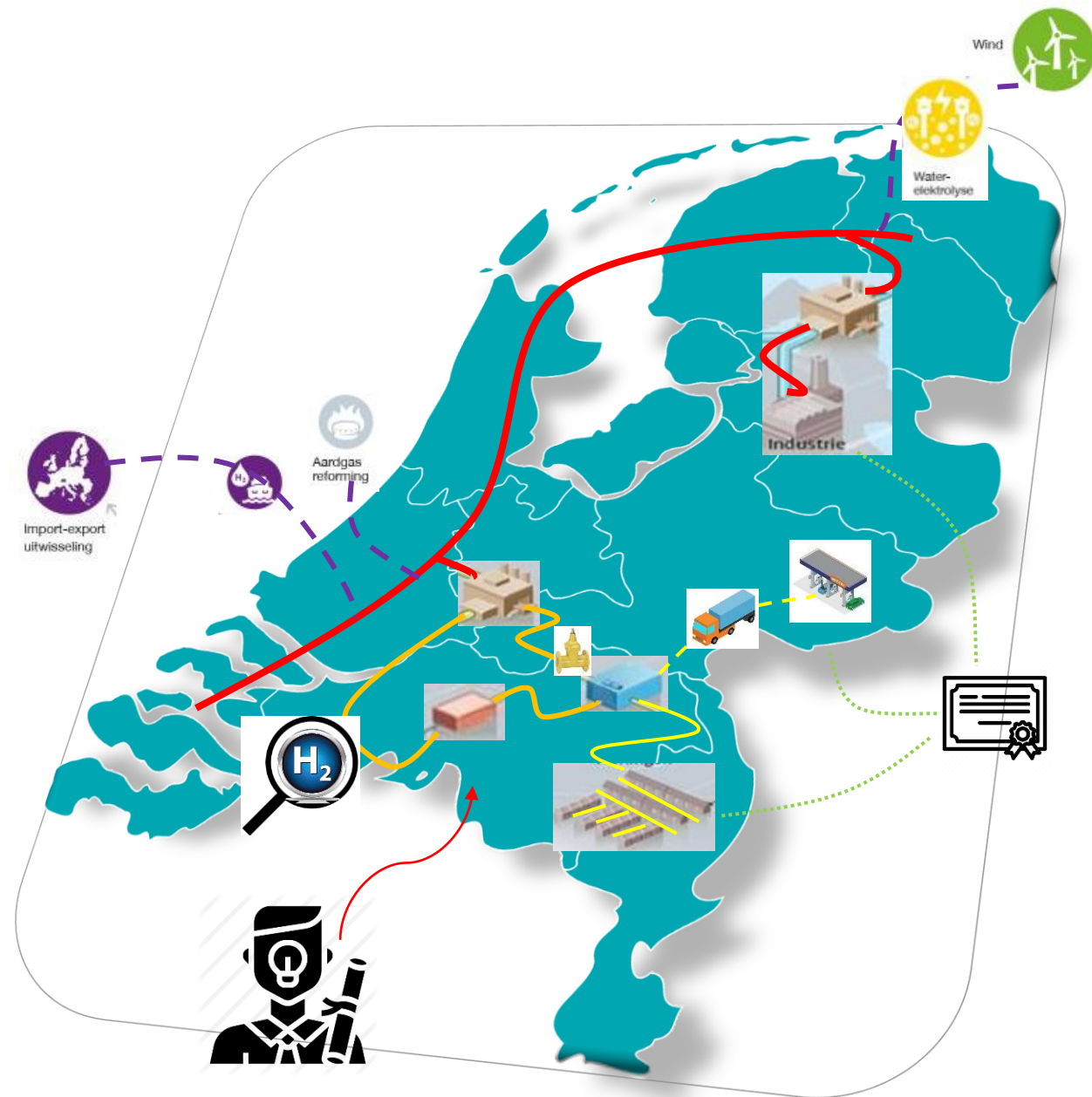
WP1C

Pipes and indoor installations

Kiwa

Sander Lueb

30-06-2021

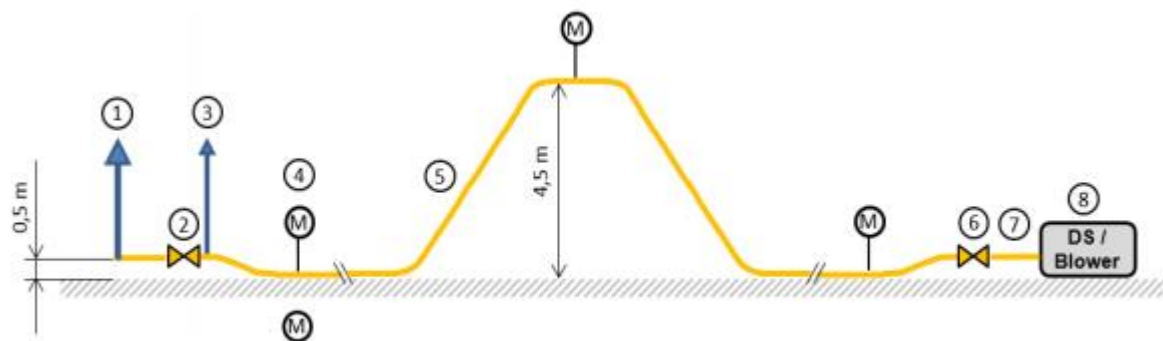


Main objectives of the WP (1)

- Determine whether **purging** of natural gas (distribution) pipelines can be done safely with hydrogen
- Determine the risk of not replacing **pressure regulators** (in house) during conversion to 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 **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

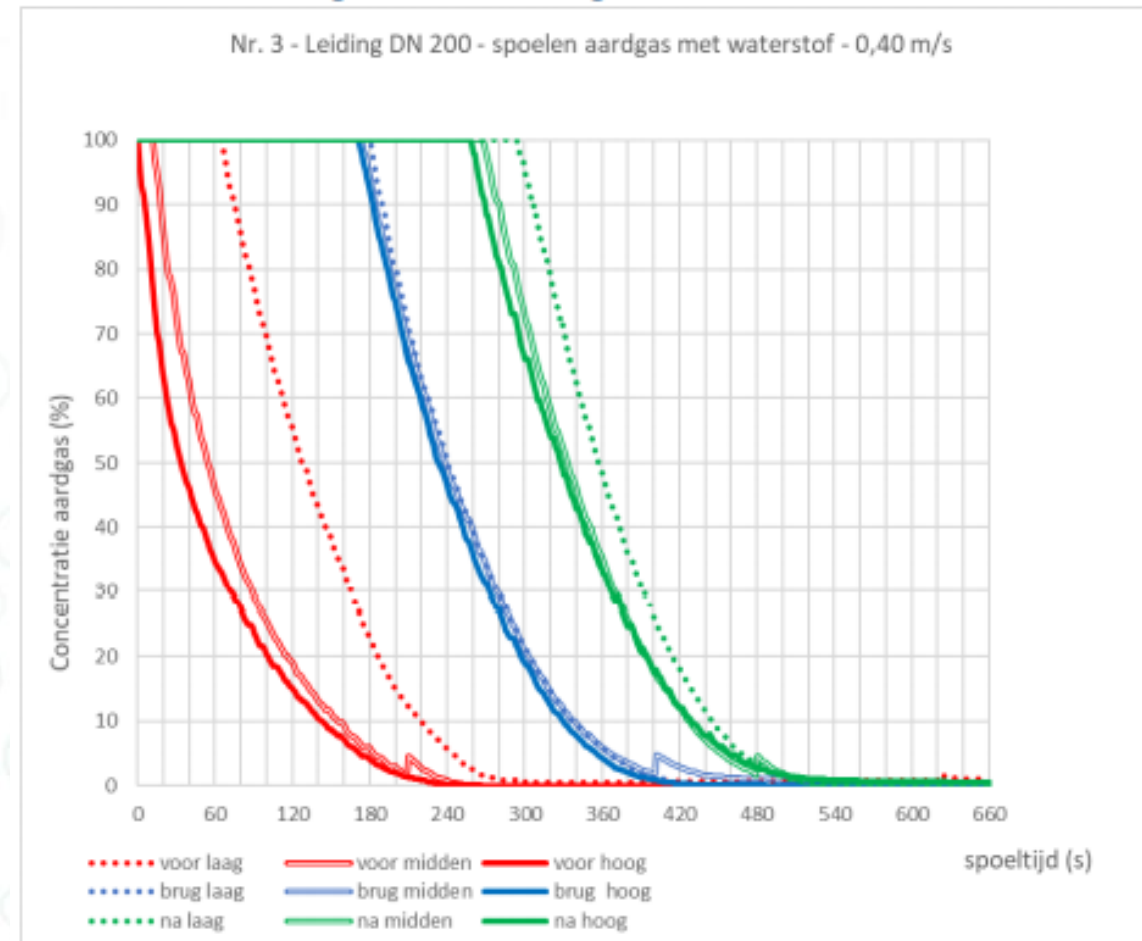
Progress of the work in the past period



Figuur 1. Testleiding met een totale lengte van circa 200 meter.

Video with some of the results

<https://youtu.be/S2woOm4YrqY>



Progress of the work in the past period

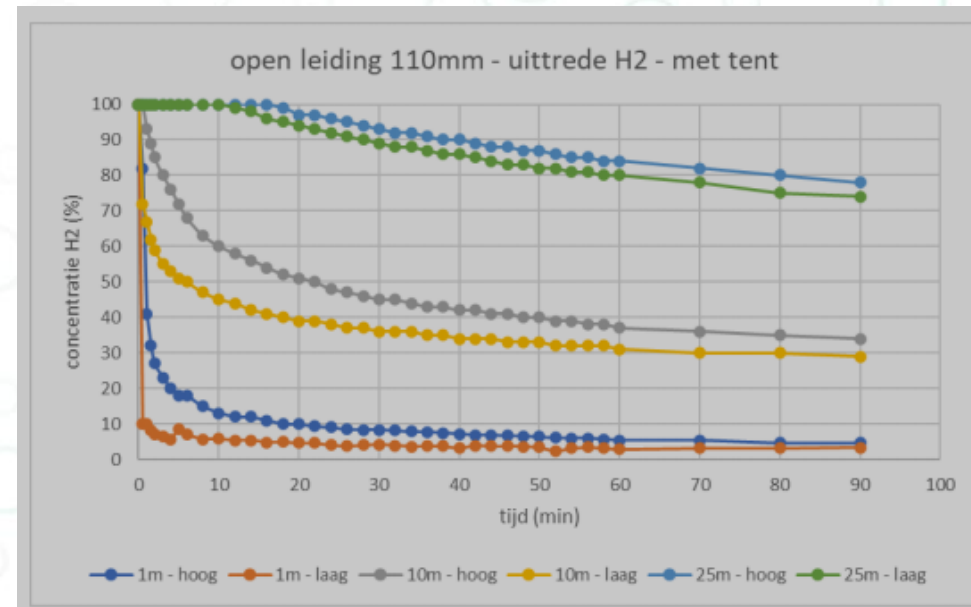
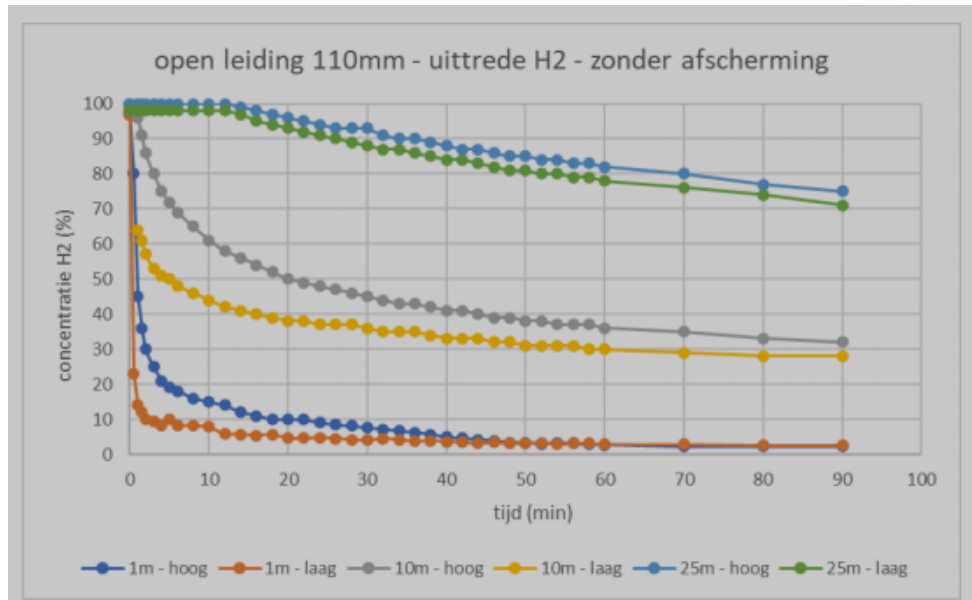
- Purging of natural gas with hydrogen
 - Report is finalized

Conclusions

- purging of natural gas 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

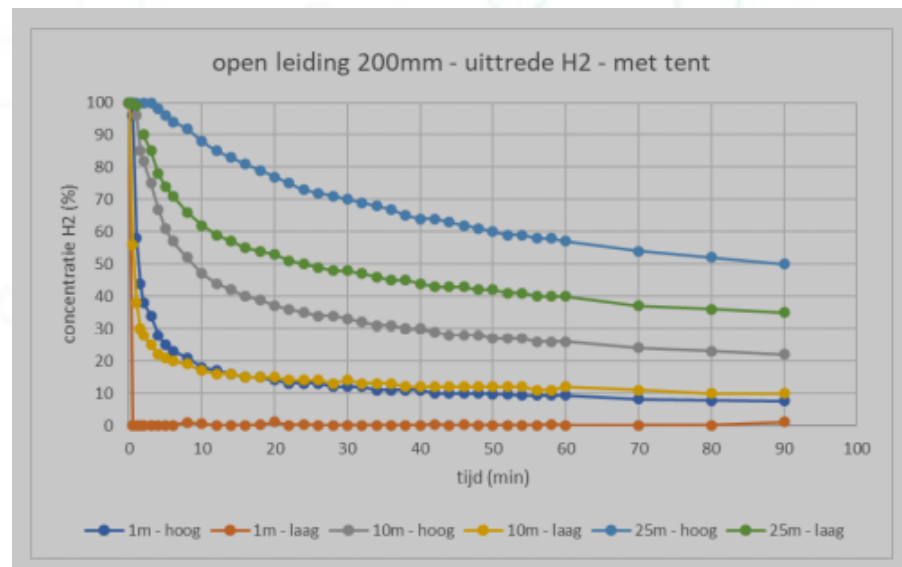
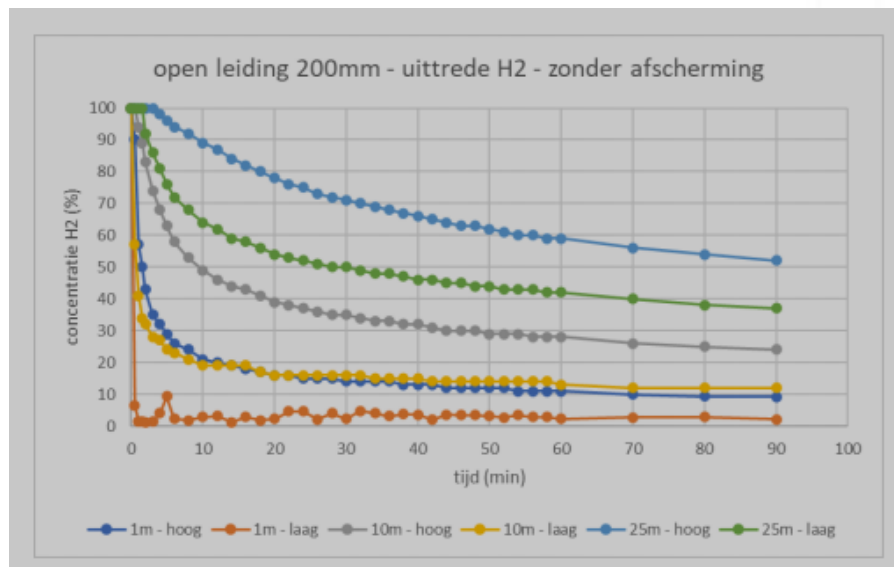
Progress of the work in the past period

- Purging of natural gas with hydrogen
 - Extra measurements are done on hydrogen-filled pipes (DN 100 and DN 200)
 - 100% H₂ filled pipe is opened in the atmosphere to determine the speed of inlet of air
 - Occurs for instance in case of repair of leakages
 - Measurements in open air and in a tent
 - Distances 1, 10 and 25 meter of opening



Progress of the work in the past period

- Purging of natural gas with hydrogen
 - Extra measurements are done on hydrogen-filled pipes (DN 100 and DN 200)



- Risk of not replacing pressure regulators
 - Started with risk analysis and check on available literature and test results
 - Preparing test programme and discussed with Expert Assessment Group (EAG)
 - Discussion of first results with EAG (4 regulators)
 - Testing of 40 (used) pressure regulators with hydrogen
 - Tested with H₂ flow of 15 m³/h
 - 10 of these regulators are selected for verification test with natural gas (testing in July)

- Risk of not replacing pressure regulators
 - Tested according NEN 7239
 - Tested on functionality of regulating with varying flow (0 to 15 m³/h) and inlet pressure of 37,5 and 100 mbar
 - Closing pressure during normal operation
 - Closing function in case of no supply pressure
 - Internal and external leakage
 - Noise and vibrations

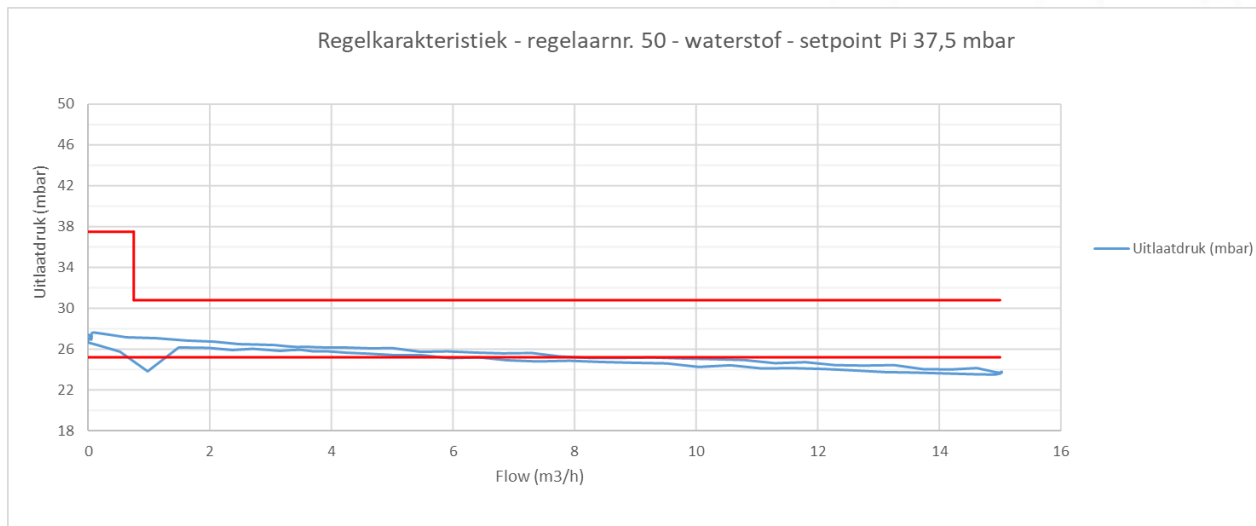
Progress of the work in the past period

- Risk of not replacing pressure regulators

Description regulator	Behavior with H ₂	Amount
No complaints	OK	9
No complaints	Not OK	5
With complaints	OK	3
With complaint	Not OK	21
Unknown if complaints	OK	1
Unknown if complaints	Not Ok	1

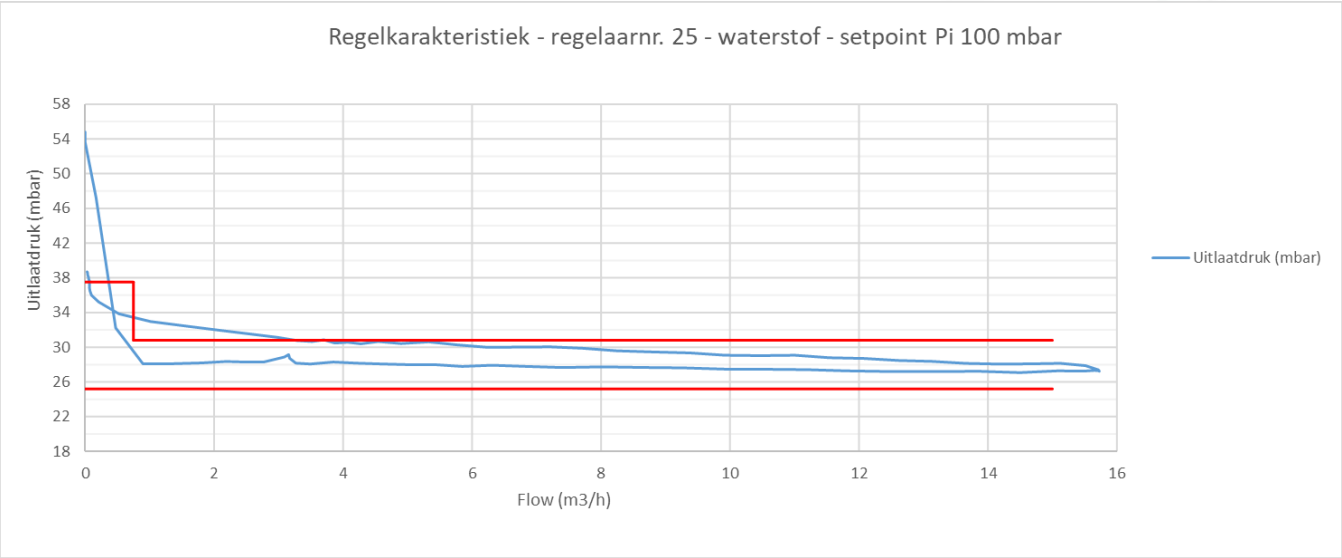
Progress of the work in the past period

- Risk of not replacing pressure regulators



Monster#	wel/geen klacht	Regelgedrag 37,5 ok?	Regelgedrag 100mbar ok?	sluitdruk ok?	gasgebrek ok?
1	geen	bijna	ja	ja	ja
2	geen	bijna	ja	ja	nvt
16	geen	nee	ja	ja	nee
18	geen	bijna	ja	nee	nee
40	geen	ja	ja	nee	nvt
41	geen	ja	ja	ja	nvt
42	geen	ja	ja	ja	nvt
43	geen	ja	ja	ja	nvt
48	geen	nee	ja	ja	nvt
49	geen	ja	ja	ja	nvt
50	geen	nee	ja	nee	nvt
51	geen	ja	ja	ja	nvt
52	geen	bijna	ja	ja	nvt
53	geen	ja	ja	ja	nvt

- Risk of not replacing pressure regulators



Monster#	wel/geen klacht	Regelgedrag 37,5 ok?	Regelgedrag 100mbar ok?	sluitdruk ok?	gasgebrek ok?
6	wel	nee	nee	ja	nee
7	wel	ja	ja	nee	ja
8	wel	ja	ja	ja	nee
9	wel	bijna	nee	nee	nee
10	wel	nee	nee	ja	nvt
11	wel	ja	ja	ja	nee
12	wel	ja	ja	ja	nee
13	wel	ja	ja	ja	ja
14	wel	ja	bijna	ja	nee
19	wel	ja	ja	ja	nee
21	wel	ja	nee	ja	nvt
22	wel	ja	bijna	nee	nvt
23	wel	ja	bijna	ja	nvt
24	wel	ja	ja	nee	nvt
25	wel	nee	nee	nee	nvt
26	wel	bijna	ja	nee	nvt
28	wel	ja	nee	nee	nee
35	wel	ja	nee	nee	nvt
36	wel	nee	bijna	ja	nee
37	wel	ja	ja	nee	nvt
38	wel	ja	nee	nee	nvt
44	wel	ja	bijna	nee	nee
45	wel	ja	ja	ja	nee
47	wel	ja	ja	ja	ja

- Risk of not replacing pressure regulators
 - Closing pressure (when not fulfilling requirements) varies between 40 to 70 mbar
 - Closing function with no supply pressure (B-klep) when not fulfilling the requirements; closing at inlet pressures above 17,5 mbar
 - Noise of vibrations are not observed

- Test program desorption THT prepared and discussed with EAG – literature study executed – test program adjusted
- Test program permeation of oxygen, nitrogen and water prepared and discussed with EAG – literature study executed – test program adjusted
- Plan of action concerning risk at consumers installations at conversion to hydrogen discussed with EAG
 - Based on existing literature en experiences with hydrogen (collection of data started in april)
 - Based on experiences with natural gas (registered data of accidents)
- Plan of action concerning developments suitability components and appliances to hydrogen discussed with EAG
 - Preparations of questionnaires manufacturers, notified bodies (Kiwa NL, Kiwa UK), DNVGL UK

Work to be done in the next period

Description	Question nr.	Collecting samples	Testing	Desk study	Report delivered to Steering Committee
Pressure regulators	185	<i>done</i>	July	<i>done</i>	30 September
Leak tightness	124	June	July-August	<i>done</i>	8 October
Desorption THT	135	July - Aug	Sept – December	<i>done</i>	31 March 2022
Permeation oxygen, nitrogen, water	135	July	Aug – December	<i>done</i>	31 March 2022
Risk at consumers	101	n.a.	n.a.	June – August	30 September
Development's consumers installation	61	n.a.	n.a.	July – September (interviews)	15 December



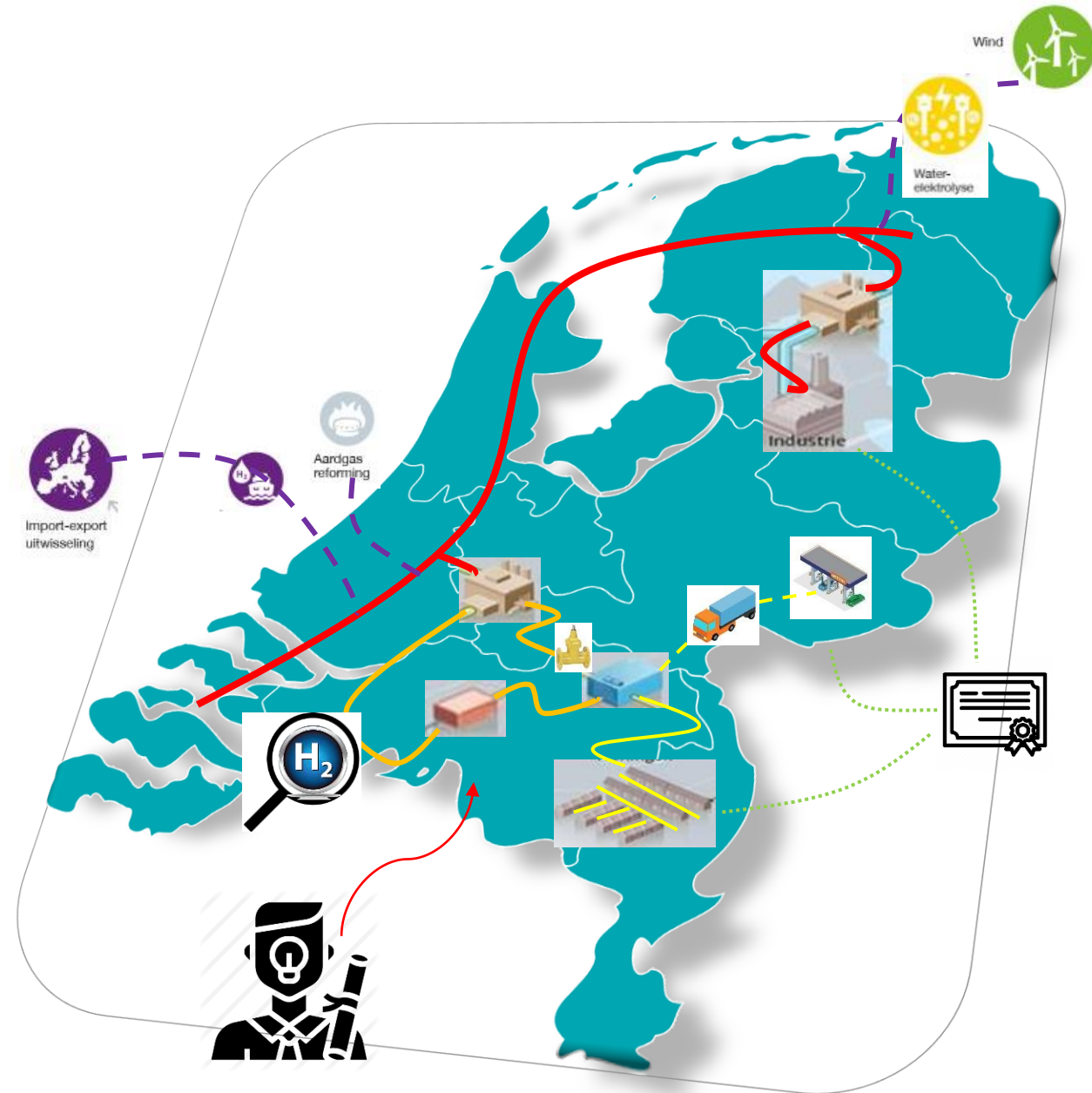
WP1D

Metering of Hydrogen

Kiwa

Hans de Laat

30-06-2021



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 KV*
- Requirements and wishes regarding the hydrogen purity from stakeholders

- Steps and processes to arrive at a calibration process of thermal and ultrasonic gas meters for hydrogen
- Stimulation of the availability of gas flow meters that are suitable for renewable gases (including 100% hydrogen).
- Requirements and wishes regarding the hydrogen purity for stakeholders
- Recommendations for installing a hydrogen meter in an existing metering cabinet at an end-user

flow meters for hydrogen

- A survey among meter manufacturers was made by the DSO's and Kiwa
- Three meter manufacturers are developing a domestic hydrogen meter
- The measuring principles are ultrasonic and thermal mass flow
- The meters are intended for connections used in general, these are more compact than in Dutch metering cabinets
- The capacity of the meters is targeted for end users that now have a G4 natural gas meter



Availability of the meters

- The Dutch NMI (NoBo) is a partner for approval of the meters
- The MID approval of the meters is likely on time before residential demonstration projects start
- The gas mentioned on the meter is likely according to ISO 14687
- The meter manufacturers are willing to supply meters to the demonstration projects

Describe the integration of these meters

in existing cabinets at the end-user

- The network operators adhere to the “Dutch” distance between connection center lines of 200 mm
- The hydrogen meters have a distance of 120 mm



on meters

- The acoustic and thermal properties of hydrogen are different from those of the gases we are used to
- Both ultrasonic meters and thermal mass flow meters use these properties to measure the gas flow
- Recently, Netbeheer Nederland published an outlook on practical hydrogen compositions in gas networks, that is similar to ISO 14687 ($\geq 98\%$ purity)

Effect of practical gas composition of hydrogen

on meters

- Influence on speed of sound
- The speed of sound in H₂ is much higher than in other gases
- 2% allowable impurity decreases the speed of sound
- The meter accuracy class is +/- 1,5%

		ISO 14687	average	
molecule	speed of sound	share	speed of sound	difference
	m/s		m/s	
H ₂	1270	98%		
N ₂	349	2%	1252	-1,45%
CO ₂	267	2%	1250	-1,58%

Effect of practical gas composition of hydrogen

on meters

- Influence on the thermal conductivity
- The thermal conductivity of H₂ is much higher than of other gases
- 2% allowable impurity decreases the thermal conductivity
- The meter accuracy class is +/- 1,5%

		ISO 14687	average	
molecule	thermal conductivity	share in gas	thermal conductivity	difference from H ₂
	W/mK		W/mK	
H ₂	0,174	98%		
N ₂	0,024	2%	0,1710	-1,72%
CO ₂	0,015	2%	0,1708	-1,83%

in the *Meterpool KV*

- 12 steps are identified
- The three most important steps are of a technical nature
 - Application of a Dutch meter code for a hydrogen meter
 - Measuring procedure of hydrogen meters from the field
 - Calibration of measuring installations
- Other steps involve statistics, regulation, auditing of experts and data exchange
- These need fine-tuning for hydrogen meters

purity from stakeholders

- The publication of the outlook on hydrogen composition by NBNL has changed the nature of this research objective
- The execution will be discussed in the coming months

- Approach of the Metrology Regulator (Telecommunications Agency)
 - Hydrogen meters shall be MID approved and subjected to a quality system equivalent to the *Meterpool KV*
- Traceable calibration of hydrogen meters
 - A set of requirements for a calibration installation for hydrogen meters was discussed with VSL
 - VSL proposed three technical solutions for such an installation
 - Sonic nozzle ejectors, Bell prover and rotary meters

Work to be done in the next period

- Integration in the metering cabinet
- How does a meter react on practical H₂ compositions?
 - What test gas does the NoBo use?
 - Are these compositions considered in the design?
- Describe the 12 steps for integration in the *Meterpool KV*



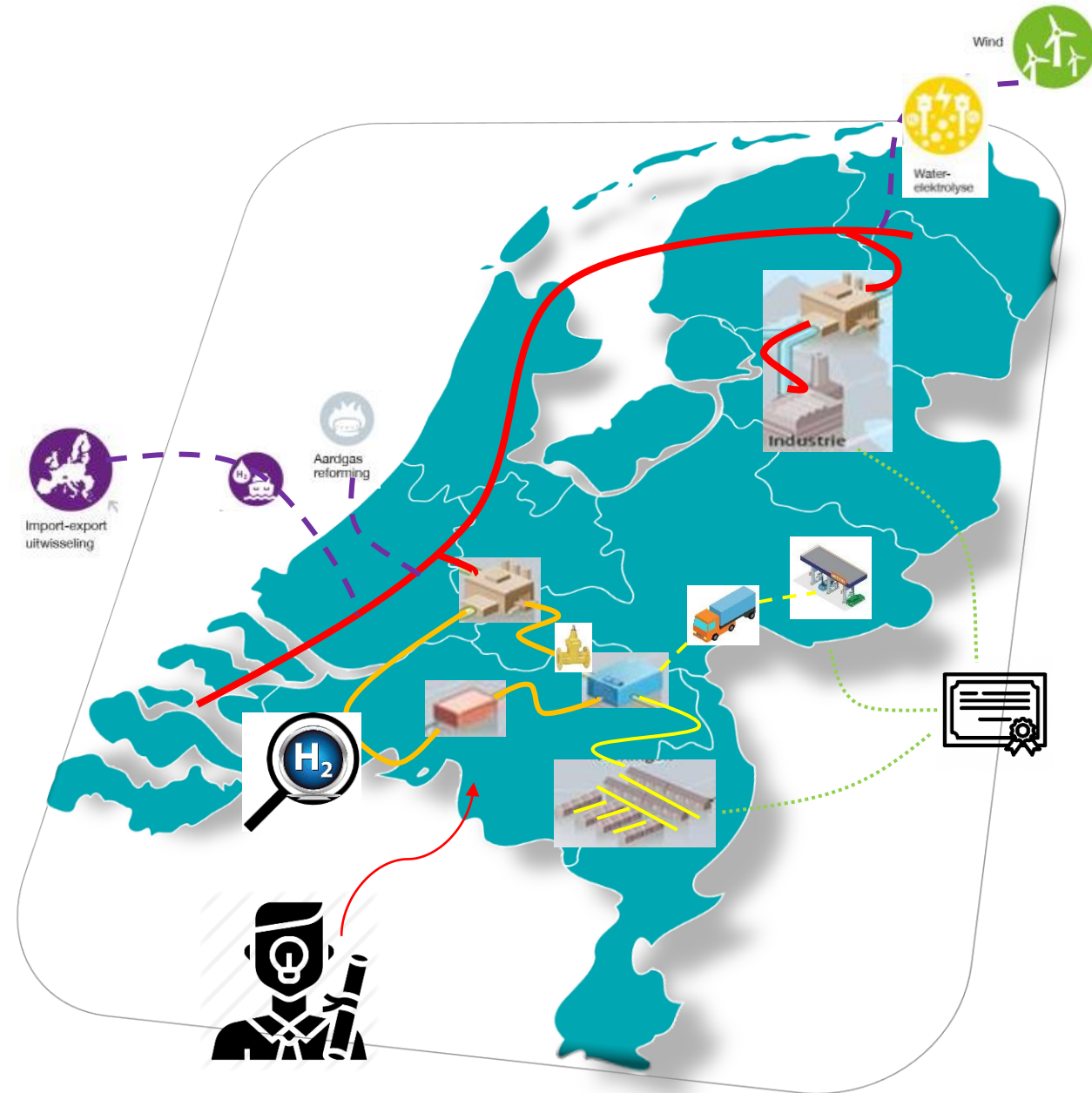
WP1F

Testing of shut-off valves in gas transport pipelines

Kiwa

Cees Lock

30-06-2021



Increasing the knowledge about the suitability for hydrogen of shut-off valves used in the gas transportation grid.

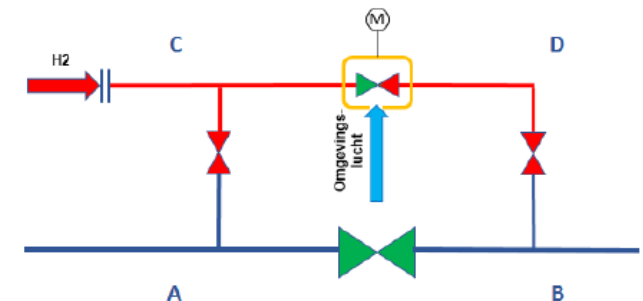
- Can the shut-off valves used in the natural gas transport grid be used for the transport of hydrogen?
- What is the internal and external leak tightness of a selection of currently used shut-off valves?
- Are the sealing materials used suitable for hydrogen?
- Can the results be used for a statement on the suitability of the in-situ valves for the transport of hydrogen?

Progress of the work in the period

- Inventory of shut-off valves used for gas transport above 16 bar.
- Selection of valves to be tested

Producent	Type	DN-reeks	Bouwjaar	Aantal	Lekdichtheid
Grove	Kogelafsluiter	900 – 1200	1963-1993	4	In- en uitwendig
Cameron	Kogelafsluiter	900 – 1200	1974-2000	4	In- en uitwendig
RMA	Kogelafsluiter	900 – 1200	2006-2011	4	In- en uitwendig
Christensen	Plugafsluiter	400	1975-2009	4	Uitwendig

- Preparation of test procedures
- Leakage testing (External) of 3 valves with natural gas (no leakage)



Test procedure (in general)

- Tests will be performed at 67 (or current pressure)/ 40/ 25 bar
- First test is with natural gas followed by a second test with 100% Hydrogen
- External leakage will be determined according to ISO 15848; A.2
- Internal leakage will be determined according to EN 12266-1; A. 4.2
- Leak rate will be determined by using a Hi Flow Sampler

Work to be done in the next period

- Week 26/ 30 (July) testing of first set of 7 valves with hydrogen
- September 2021 testing of remaining valves
- Analysis of results
- Reporting



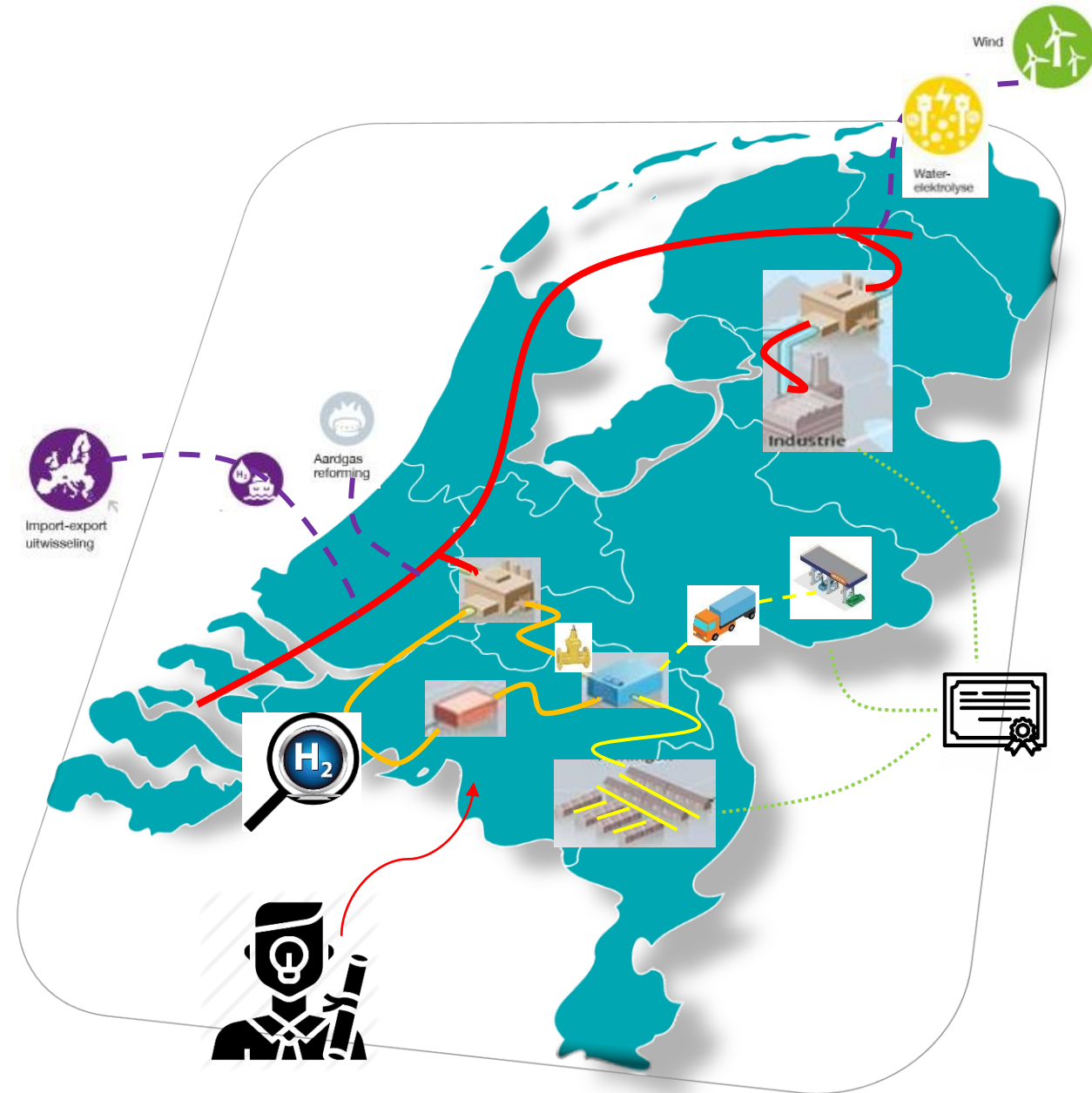
WP4

Educational Tracks

Kiwa & NEC

Sjoerd Delnooz

30-06-2021



Main objectives of the WP

The main objective is to give an overview on necessary educational curricula for technical personell with regard to Hydrogen:

Question 1

How will the need for technical personell (mechanics, engineers) develop over time in relation with upscaling of hydrogen economies?

Question 2

What current education is available and what educational terms should be added to accommodate the upscaling of hydrogen transport & distribution?

Question 3

What current facilities (e.g. training locations) are available and what extra facilities should be added?

Progress of the work in the period

- Execution of workpackage started in may 2021,
- Progress of work:
 - Question 1 : Collating of reports on upscaling of hydrogen economies in relevant sectors is work in progress.
Deliverable: overview of needed growth in availability of both education and technical personnel over time. July 2021
 - Question 2: Inventory of educational institutions and training offered is done: Education on hydrogen in relation to automotive is available, education on all other aspects seems to be missing or minimal. Private institutions and technical business schools added now, interviews to follow up.
Deliverable: GAP analysis (automotive, industry, transport & distribution, built environment) between current and needed education for technical personnel. September 2021
 - Questions 3: To be started.
Deliverable: list of needed educational terms per category and type of technical personnel. October 2021



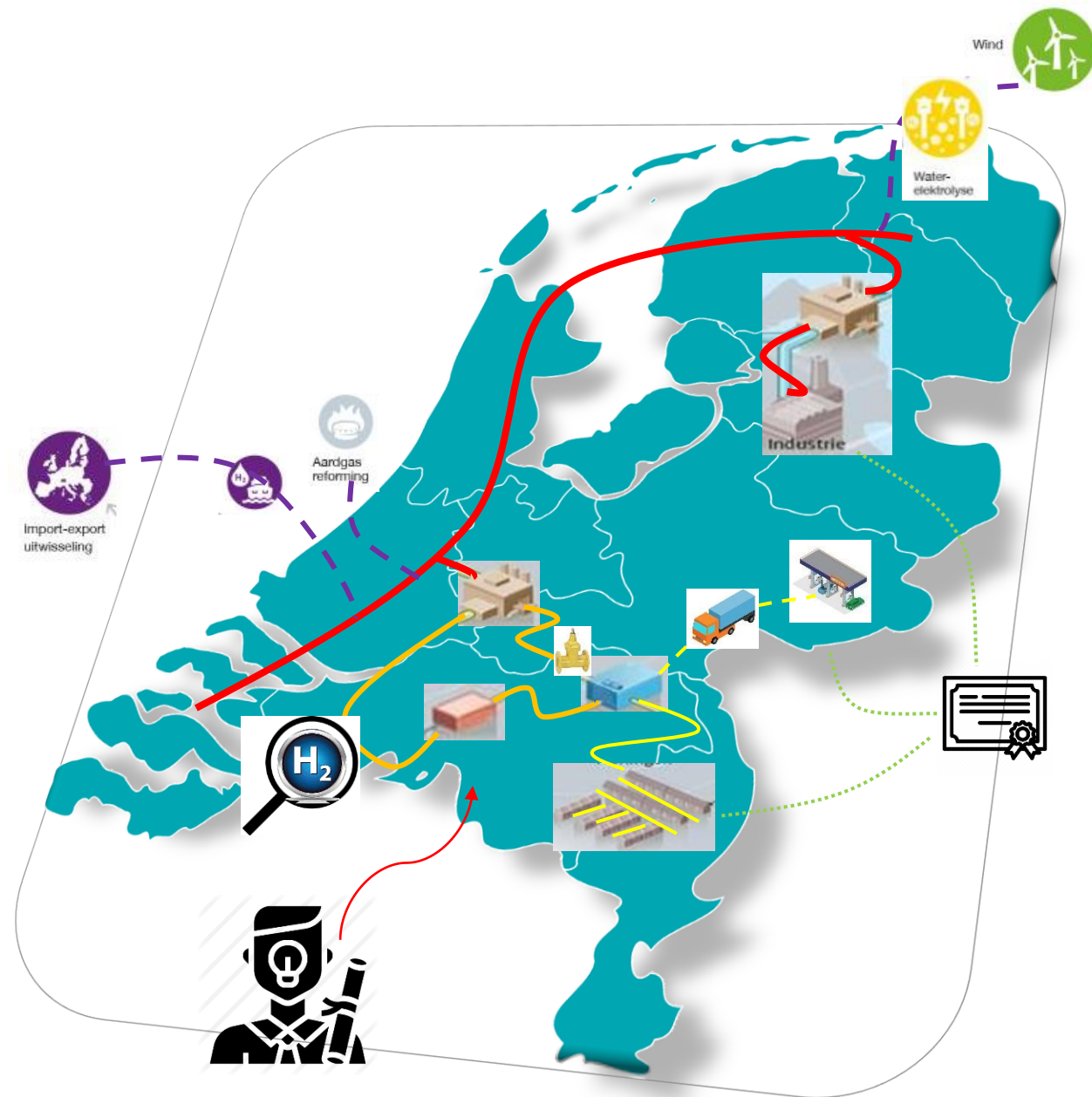
WP7A

Techno-economic value chain analysis

NEC (TNO, DNV)

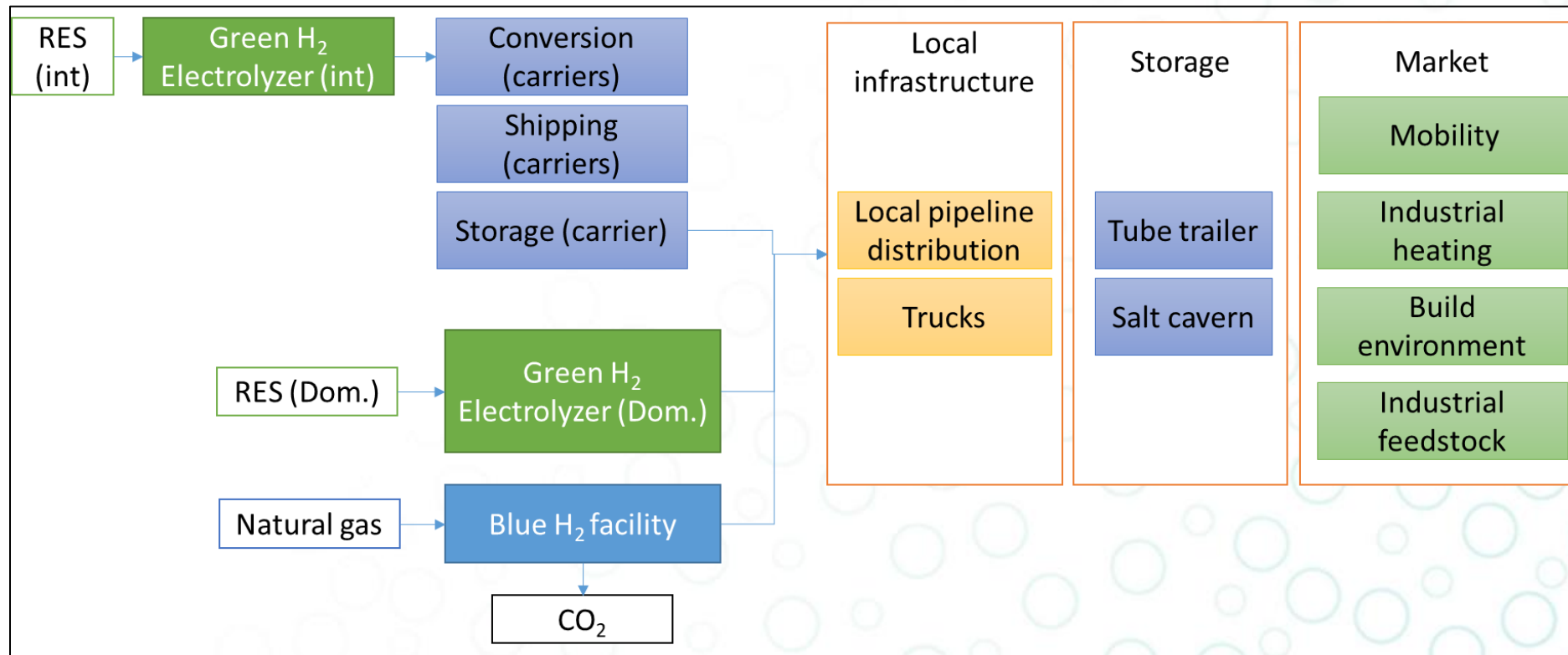
Joris Kee (Thomas Hajonides, Albert van den Noort)

30-06-2021



Main objectives of the WP

Value chain element collection – Dutch context



Main objectives of the WP

Task 1: Literature overview

Analyze existing knowledge on H₂ Value Chains

Task 2: Market analysis for end-uses

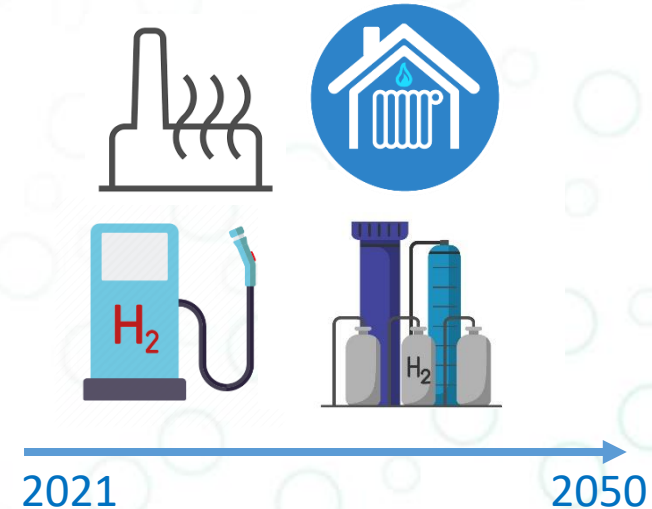
Identify market boundaries and new market dynamics between the carriers

Task 3: Logistic analysis for storage and transport volumes taking into account purity and demand/supply profiles.

Task 4: Economic analysis and sensitivities of value chains

- Calculate Levelized costs, NPV's to identify business cases.
- Results: Willingness to pay, innovation requirements and economic incentives.

Task 2: Market



Task 3: Logistics



Task 4: Business cases and sensitivities



- Literature overview – current state of value chain research (WIP)
 - Energy system modelling and approaches
 - Dutch and international hydrogen strategies
 - Hydrogen value chain modelling and research
- Brief conclusions
 - Type of modelling (optimization, calculation, etc.) impacts type of results
 - National hydrogen strategy characteristics: Domestic or international supply, blue or green hydrogen, decarbonization of end-uses.
 - Hydrogen value chain modelling focuses a lot on mobility sector, less on other sectors or sector integration
 - Hydrogen purity underexposed in the discussion, also for sector integration.

Progress of the work in the period

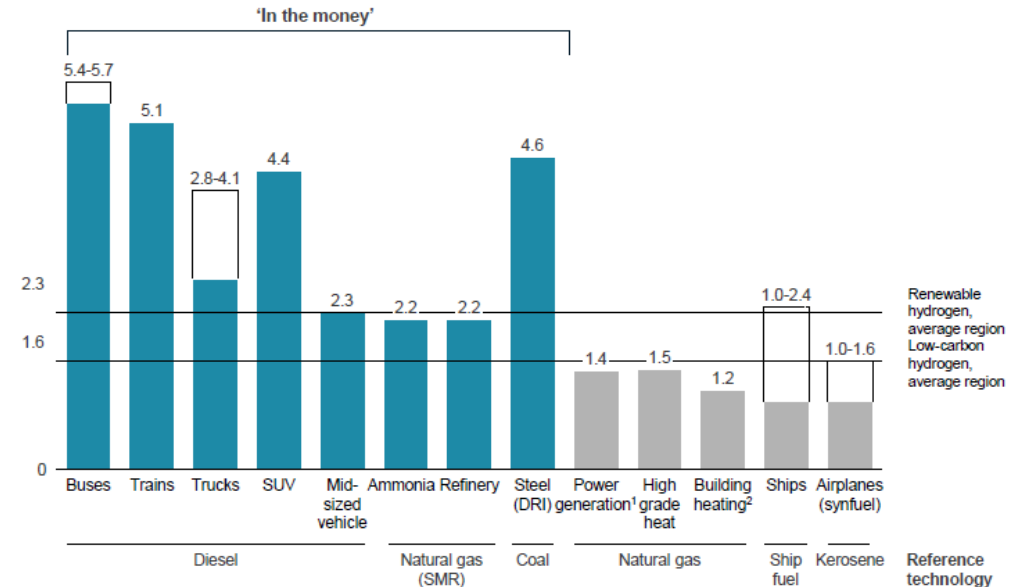
- Market analysis
 - Definition of energy carrier markets and potential developments (bottom-up)
 - Identify potential market integration of energy carriers (H₂, NH₃, etc.)

Market integration



Exhibit 19: Required hydrogen production cost for breakeven with conventional solutions, with 100 USD/t CO₂e

USD/kg in 2030

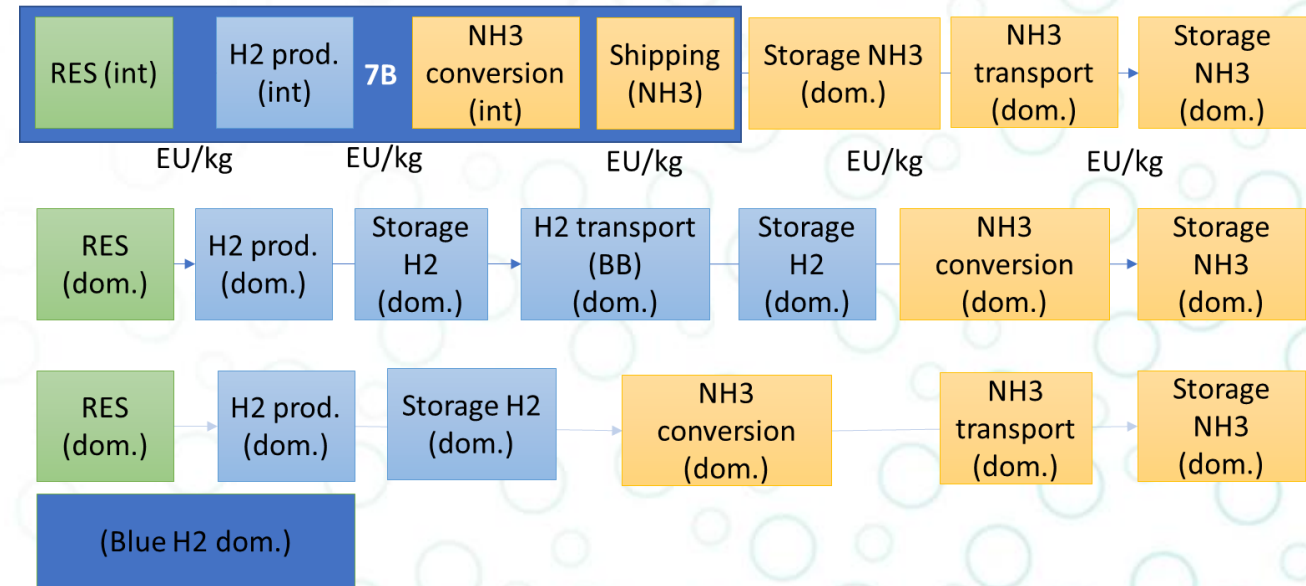


1. Average of combined cycle and single cycle turbine applications
2. Boiler with existing network

Progress of the work in the period

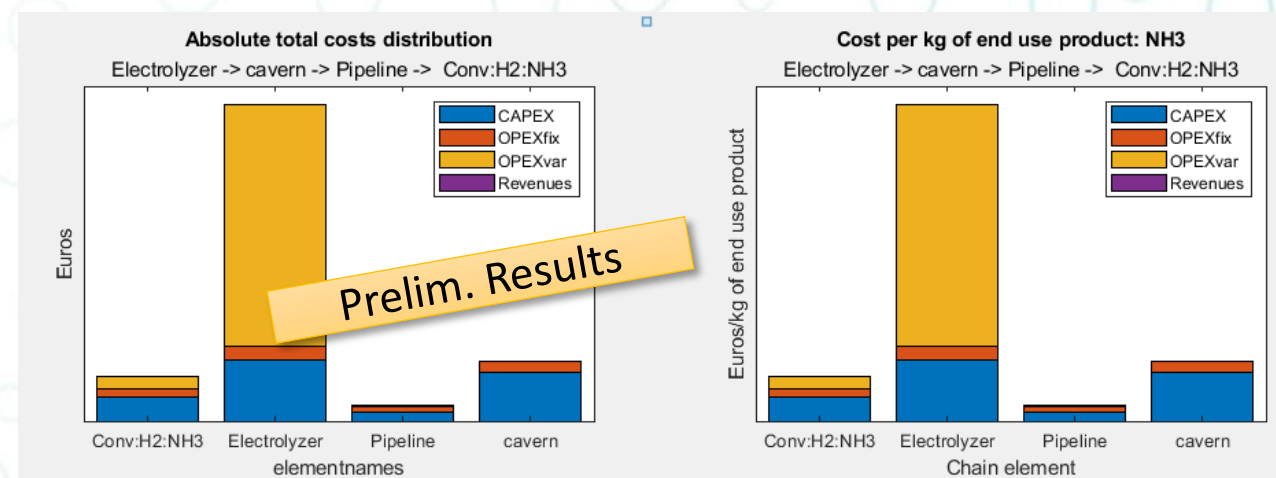
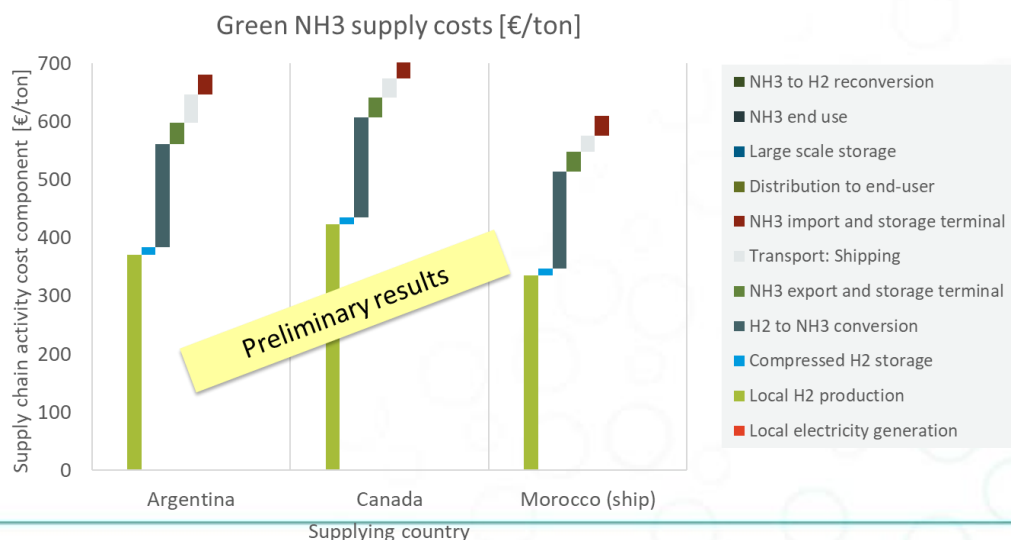
- Design of Value chain model: first NH3

- Import vs domestic value chains
- Onshore vs inland
- Green vs blue



Work to be done in the next period: Modelling

- Modelling of value chains for the 4 considered end-uses
- Compare value chains on levelized costs and net present value (calculation)
- Are the value chains competitive? (willingness-to-pay)
- What incentives in technical and financial regimes are necessary to evolve hydrogen economy?



Work to be done in the next period: Market analysis

- Market dynamics analysis of energy carriers
 - Design of qualitative narrative of potential interaction and development (top-down)
 - Integrate with defined markets and end-uses to a qualitative report



What do these developments mean for TSOs en DSOs?

- How to transport energy?
- Other infrastructure? What role for TSO and DSO?



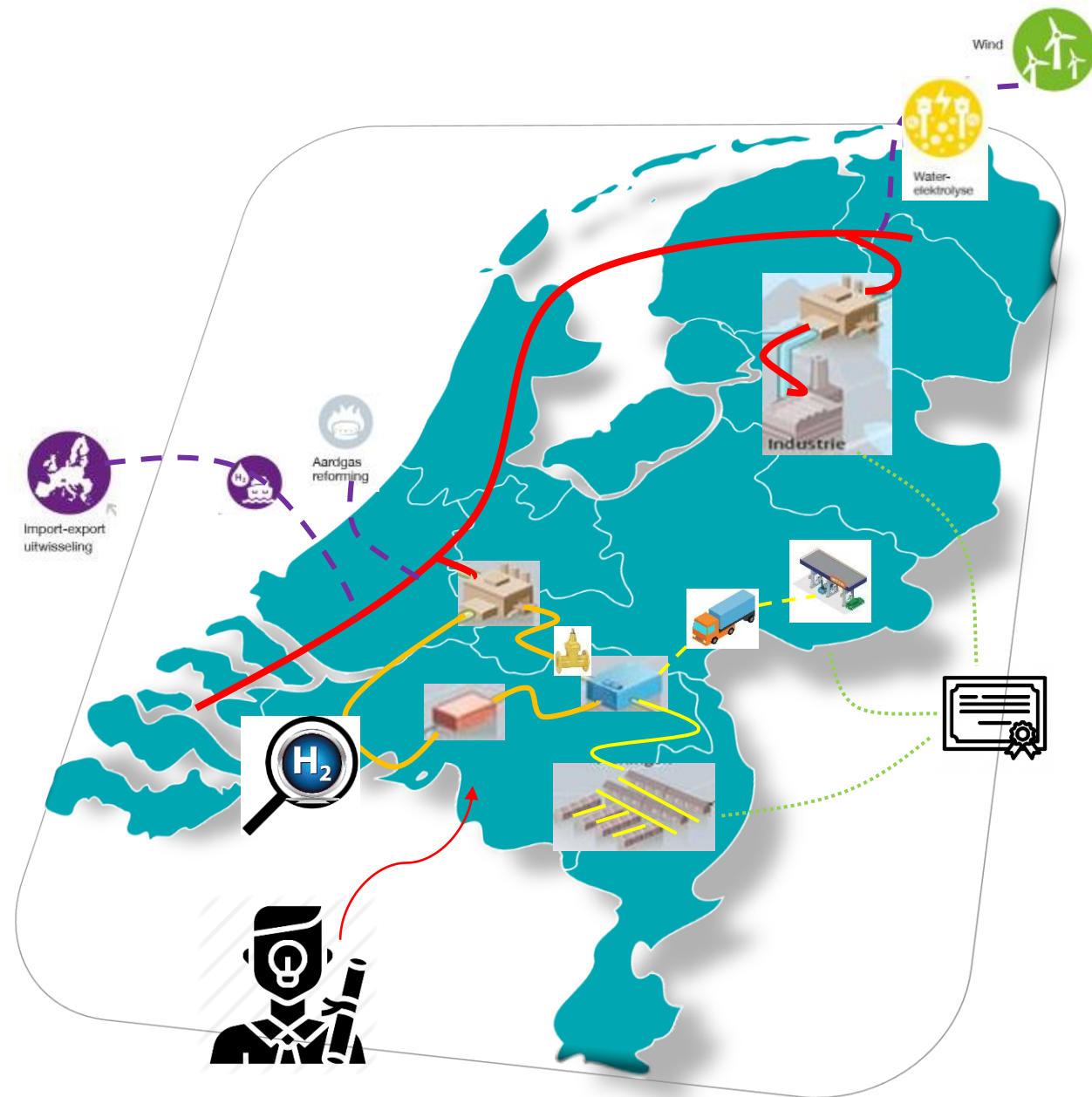
WP7B

Innovation roadmap & hydrogen import

TNO

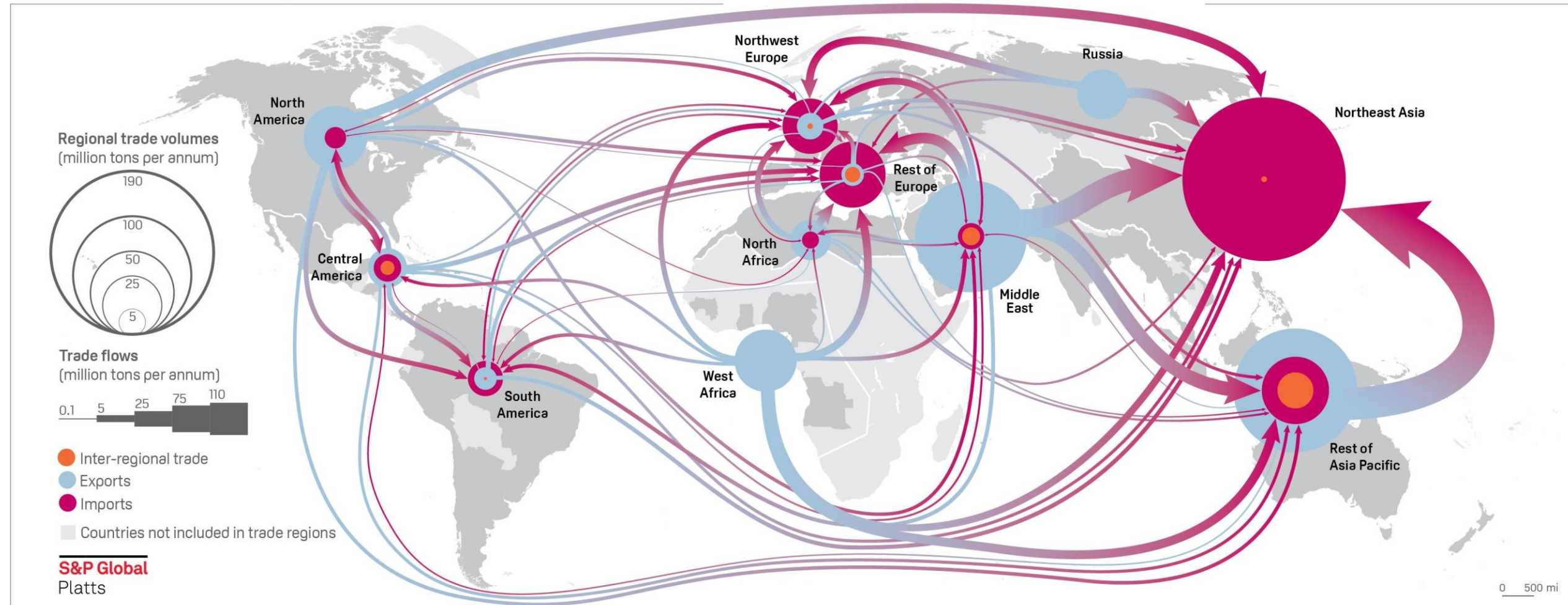
Sara Wieclawska

30-06-2021



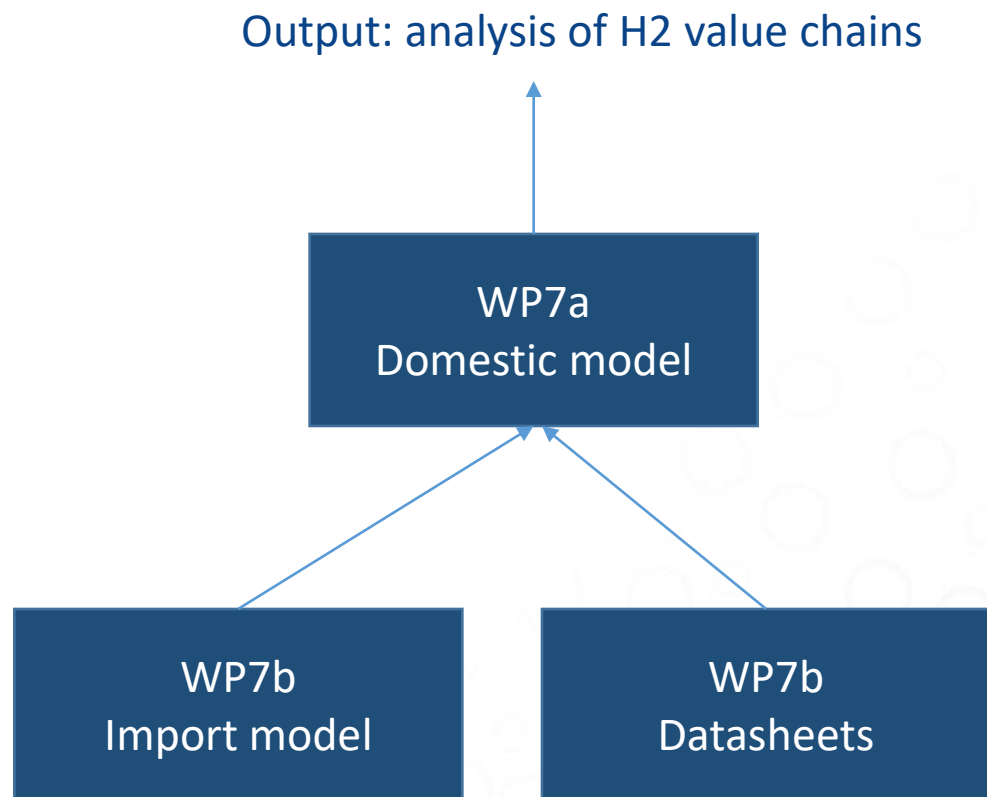
Main objectives of the WP

LIQUIFIED NATURAL GAS TRADE FLOW, 2018



Source: S&P Global Platts

Main objectives of the WP



Task 1 – value chain elements

- Identify and characterize the most important supply chain elements for the available options (LH₂, NH₃, LOHCs, MeOH, HCOOH, KBH₄)

Task 2 – technology development / innovation

- TRL & Scale-up potential
- Operational performance envelope ?
- Plot space requirements ?
- 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

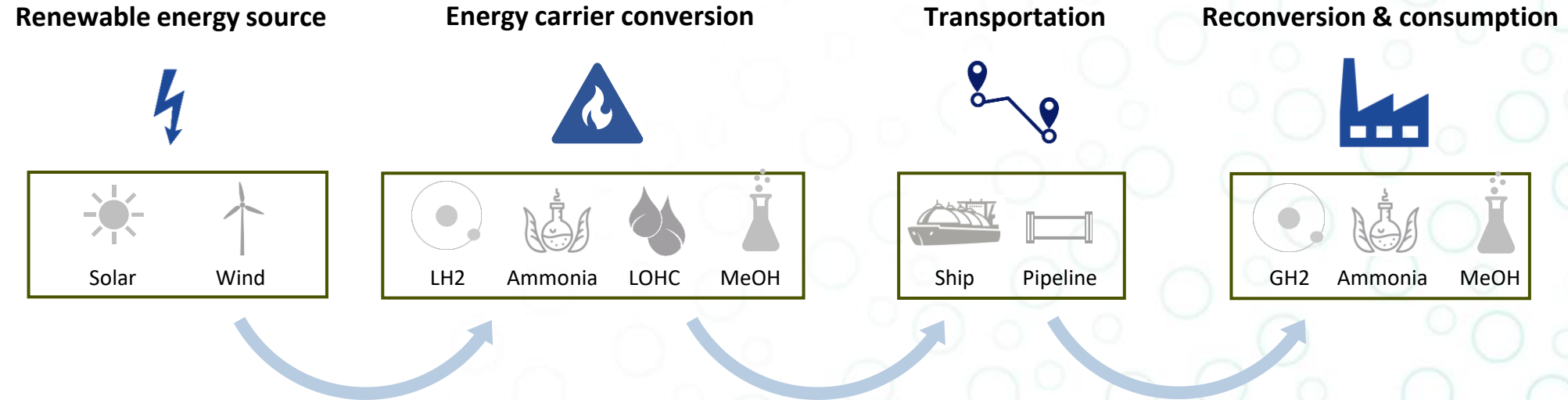
- Selection of relevant supply chains + scenarios
- Cost analysis per supply chain (input for WP7A)
- Report (documentation + analysis)

Progress of the work in the period

WP7b
Import model



• Scope of the model



Import to NL:

- 10 countries

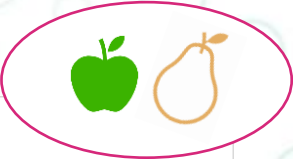
Assumptions:

- 2030
- 3GW RES locally, 2.7GW PtH2
- Design capacity 1000 ktpa (MeOH)
- Scaling factors included
- Electr. Back-up: grid, LCoS

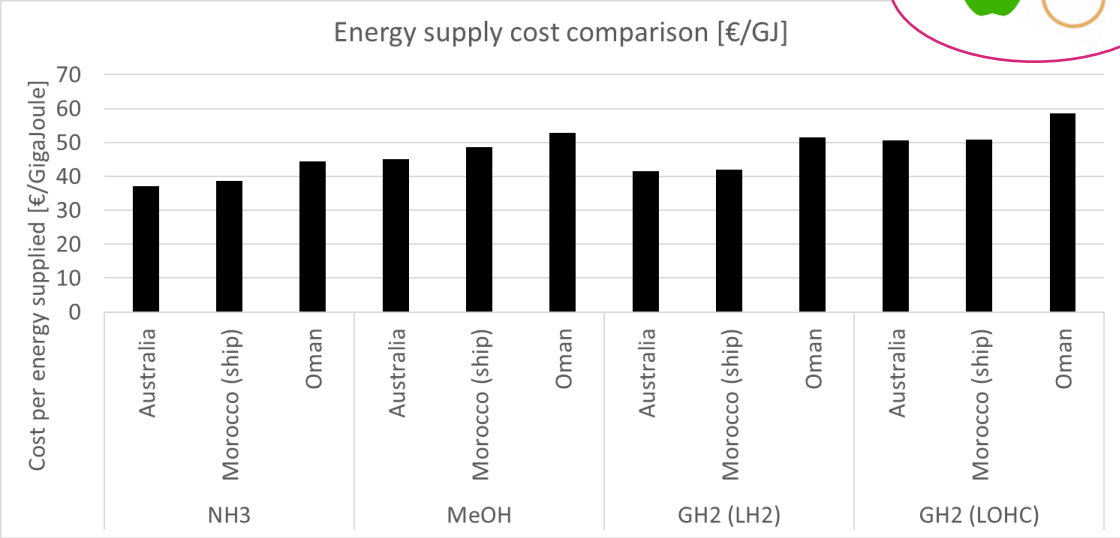
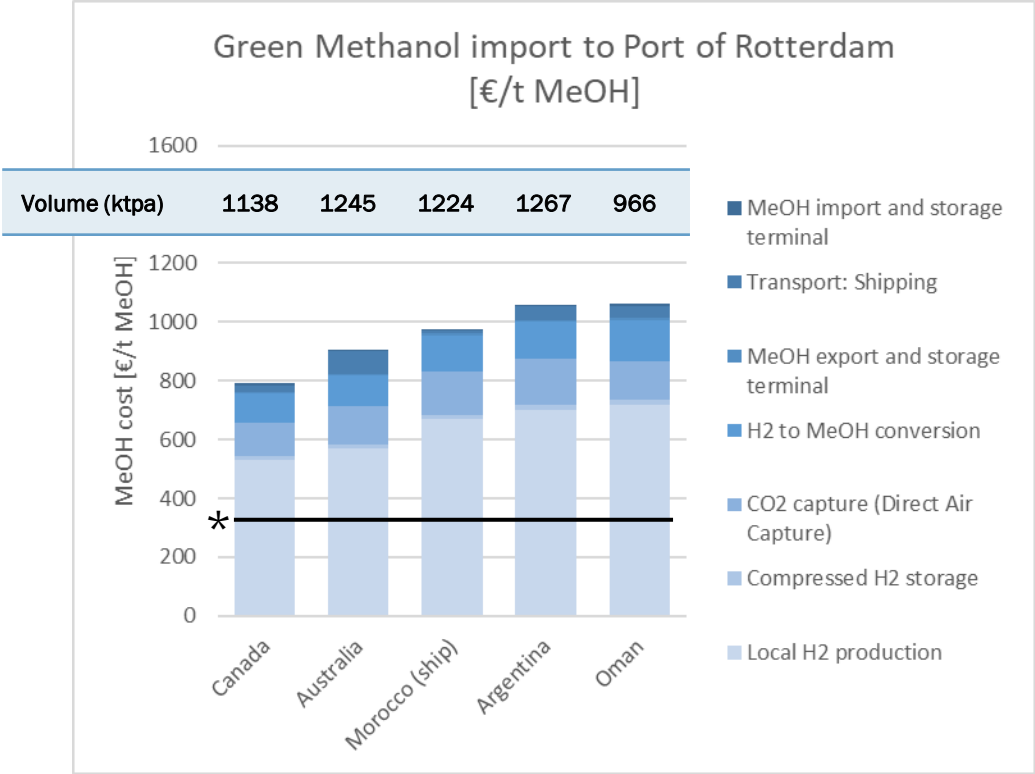
Results:

- Country comparison per carrier
- €/ton
- Illustrate impact of changes

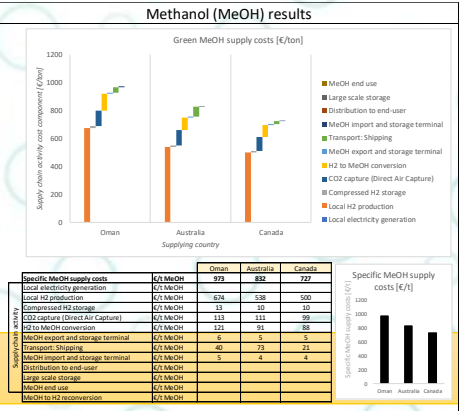
Progress of the work in the period



- Results

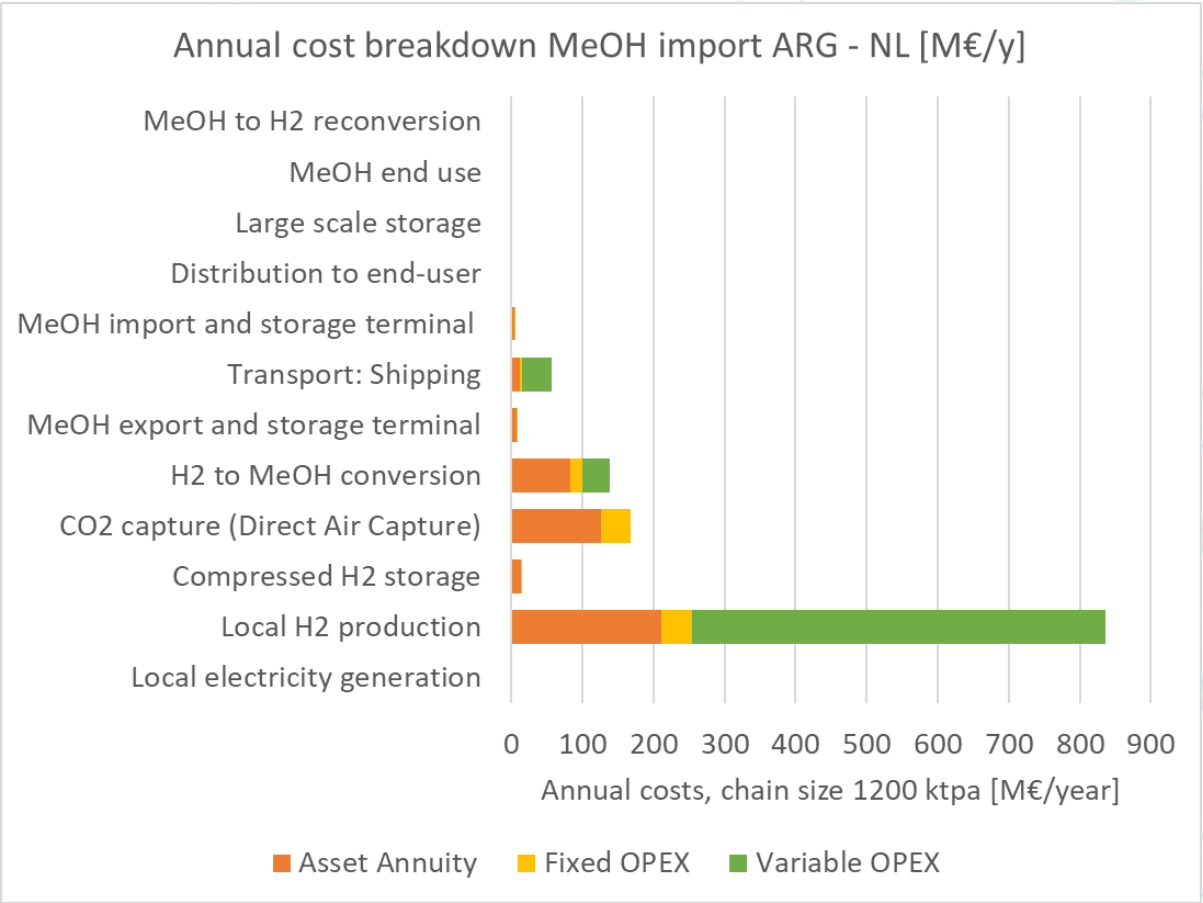
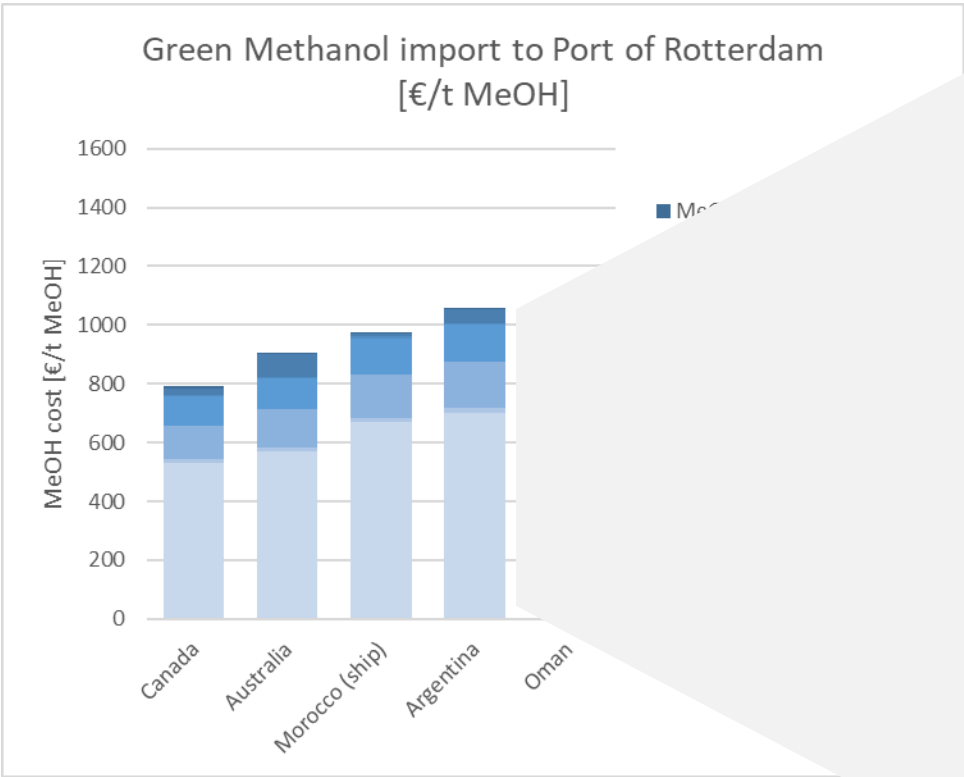


Each hydrogen carrier chain has specific ‘characteristics’



Progress of the work in the period

- Results



WP7b Datasheets

[illegible]

Work to be done in the next period

Next steps:

Q2/3 2021

- ☐ **Improve input** data with tech. database 7B
- ☐ **Add** remaining supply **chain elements**

Q3/4 2021

- ☐ How do imports by ship (e.g. NH₃, LH₂) compare with **direct pipeline imports** from nearby countries? (add pipeline transport)
- ☐ Which input parameters are the main drivers of **uncertainty**?
- ☐ What impact have technology **learning curves** on import costs between 2020 and 2040?

Task 1 – value chain elements

- Identify and characterize the most important supply chain elements for the available options (LH₂, NH₃, LOHCs, MeOH, HCOOH, KBH₄)

Task 2 – technology development / innovation

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- Report (documentation + analysis)



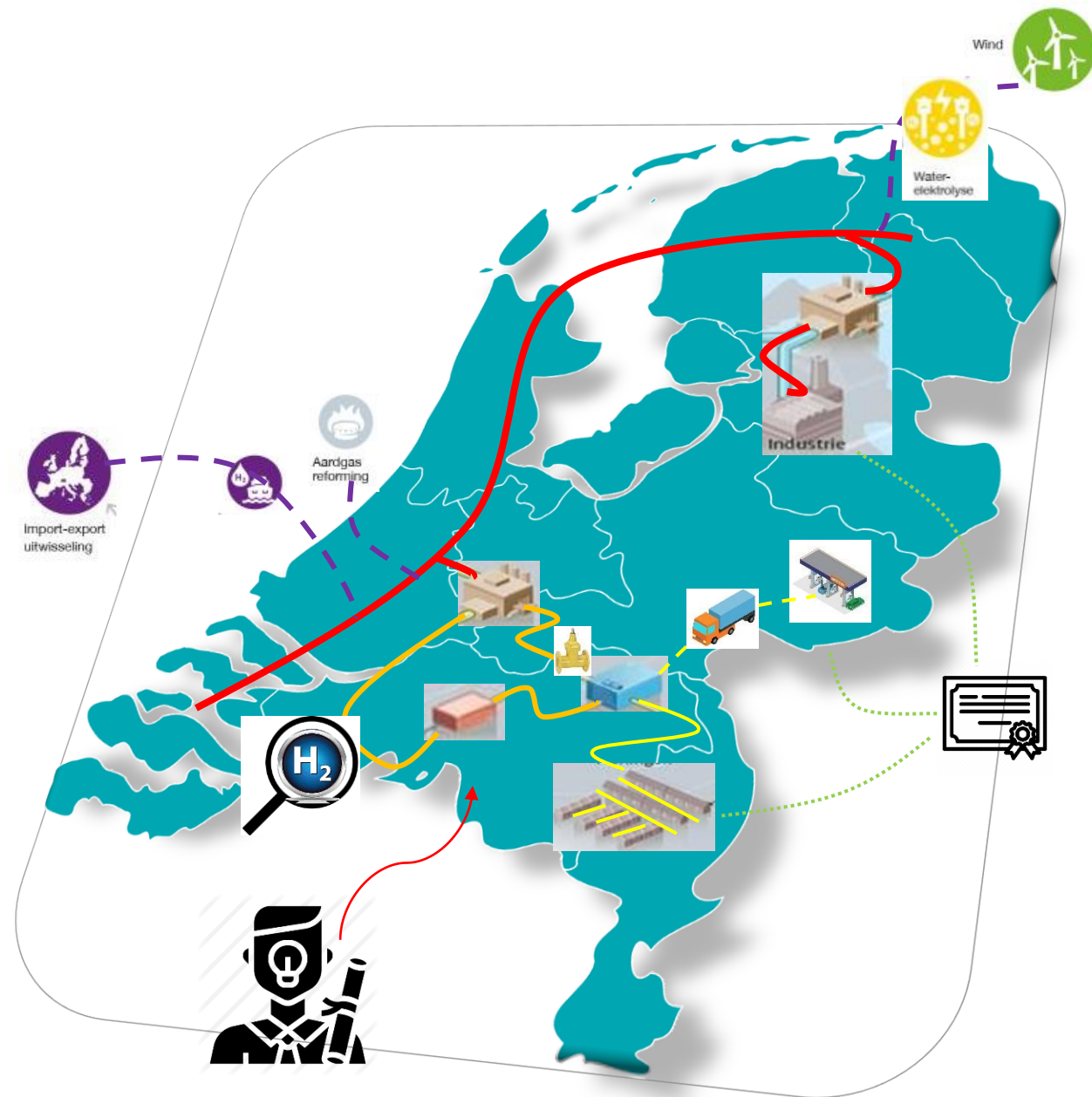
WP8

Admixing & mandatory blending

NEC

Rob van Zoelen

30-06-2021



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	Input	Deadline
1	Literature review of physical and administrative admixing	Literature study	KIWA/WP1, RVO, Hydrogen Europe, and others	May
2	Assessment of comparable admixing regimes	Qualitative assessment	Vertogas	Jun
3	Introducing dedicated experiments to roll out admixing regimes in practice	Qualitative, interviews	TBD	Sept
4	Economic analysis of potential market developments in hydrogen certificate markets	Qualitative, small calculations	Input WP7A	Dec
5	Listing the possible implications of the research for policies			Dec

Partner(s):

**New
Energy
Coalition**

Catrinus Jepma
Jorge Bonetto
Rob van Zoelen

Deliverable 8.1: Summary physical admixing



- Differing gas conditions
 - Effects on materials
- Tolerance of various applications and components

- Need for odorization
 - Risks of leakage
 - Permeation risks
 - Excavation risks



- No Significant blending levels currently legally allowed in the Netherlands
- Blending limits differ strongly among European countries

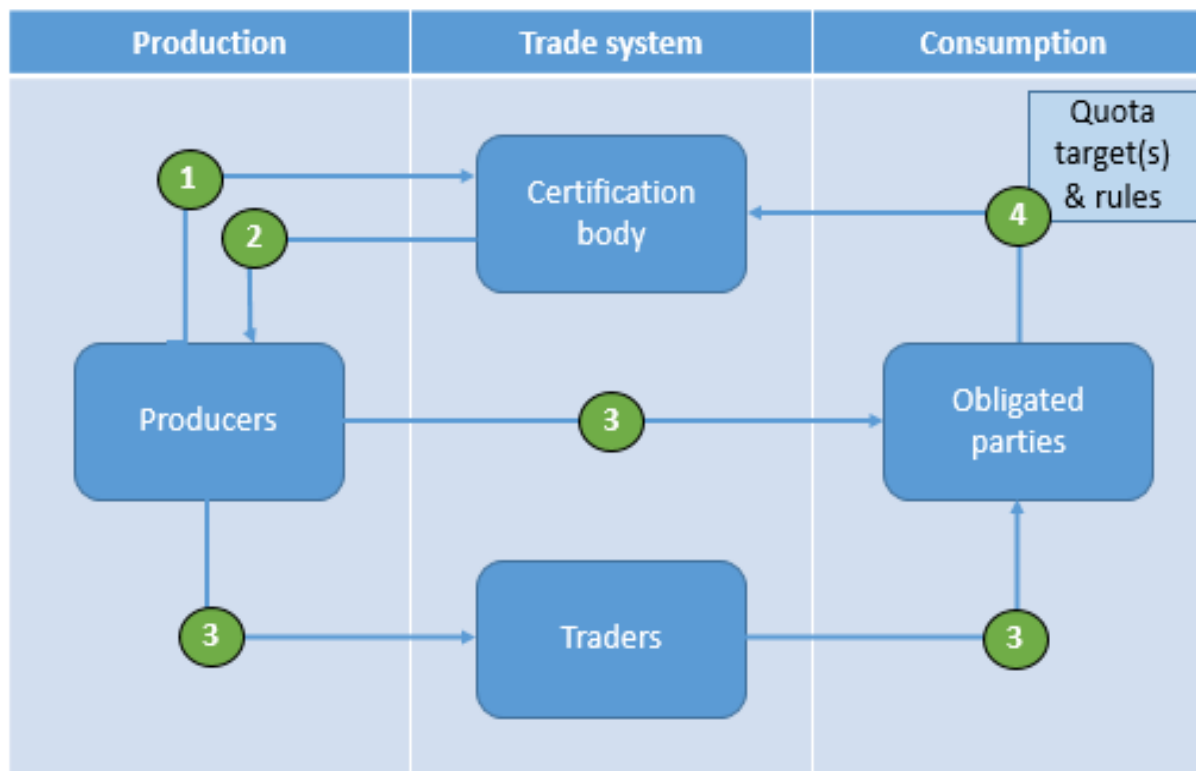
- 1/3 of energy content per m3 supplied gas
- The (perceived) value of pure hydrogen differs from the value of natural gas



Major discussion points:

- What 'blending pathway'? (0%→100% / <20%→100% / <20%→...%→100%)
- How the strategy distinguishes between the transport and distribution grids?

The concept of administrative admixing



1. Producer shares required production data with certification body
2. Certification body issues the fitting amount of certificates on the account of the producer
3. Certificates can be traded between producers, traders and obligated market parties, separate from the physical energy trade
4. Based on the quota, a specific amount of certificates should be cancelled every period by the obligated market parties

Deliverable 8.1: Summary administrative admixing

- Only quota schemes have been implemented with regards to electricity or transport fuels
- A quota may kickstart demand
- The actual design of the quota may depend on a mix of political choices

Production	Trading system	Consumption
<ul style="list-style-type: none"> • What criteria are set and if different types of certificates be distinguished • If imported certificates allowed to be used to comply to the quota • If and what additionality criteria are set by the scheme 	<ul style="list-style-type: none"> • If certificate prices are maximized, facing minimum levels, or both • If certificates can be traded freely, and are tracable • If certificates expires or banked forever • If explicit measures are taken to avoid fraud and abuse 	<ul style="list-style-type: none"> • If the scheme applies generically or to specific sectors only, or different quotas are set in different sectors • If the overall quota level varies with economical conditions and/or environmental targets
<ul style="list-style-type: none"> • If the acceptance of the certificates is contingent upon existence of satisfactory level of physical blending 		

Work to be done in the next period



Voluntary:

- CertiQ electricity
- Vertogas green gas

Mandatory:

- Dutch Fuel blending
- Norwegian-Swedish electricity quota



Thank you for your attention!

Questions? Send them to:

j.garcia@newenergycoalition.org



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