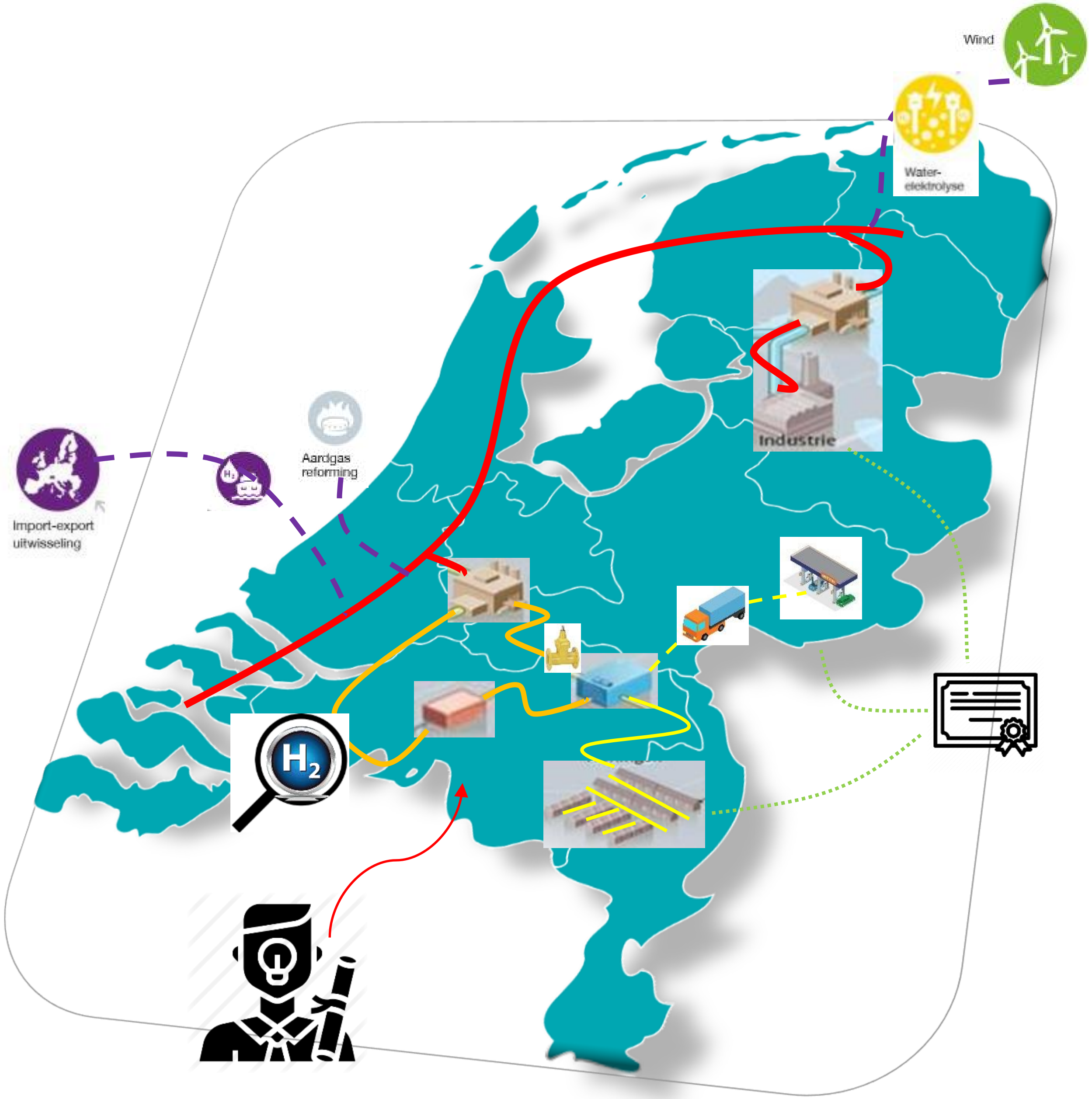
HyDelta

Plenary Progress Meeting 1
Introduction

NEC

Julio Garcia-Navarro – project coordinator

30-06-2021



Dutch Hydrogen Landscape

HyDelta

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) electrolysers

TNO innovation for life

FME POWERED BY DUTCH TECHNOLOGY

Dutch H2 projects (industry & mobility)

HyDelta

Dutch H2 projects (built environment)

HyDelta

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.
TenneT, Gasunie

2. **Entrance terrain Hanzehogeschool**
Groningen 2019 - 2020
Tests with a hydrogen network including hydrogen boilers.
Rendo Netwerken, Coteq

3. **Hydrogen district Wagenborgen**
Wagenborgen 2020 - 2030
30-40 existing residences with hybrid hydrogen heatpumps.
Enexis Netbeheer

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

5. **Hydrogen pilot Hoogeveen**
Hoogeveen 2020 - ∞
H_2 application in existing infrastructure and built environment.
Rendo Netwerken, Gasunie

6. **Temporary conversion Uithoorn**
Uithoorn 2020
Converting 14 residences from natural gas to hydrogen.
Stedin

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

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

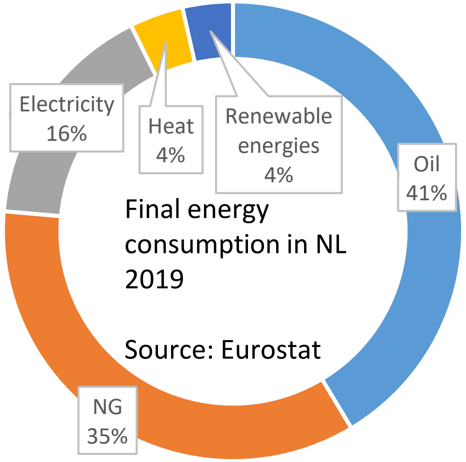
9. **Hydrogen pilot The Green Village**
Delft 2019 - 2025
Managing a 100%-hydrogen network.
Enexis Netbeheer, Stedin, Alliander

10. **Hydrogen pilot P2G**
Rotterdam Rozenburg 2013 - 2023
Closed hydrogen system in the built environment.
Stedin

11. **Pilot Stad aan 't Haringvliet**
Stad aan 't Haringvliet 2025 – ∞
Preparing for the distribution and application of hydrogen in the built enviroment.
Stedin, Gasunie

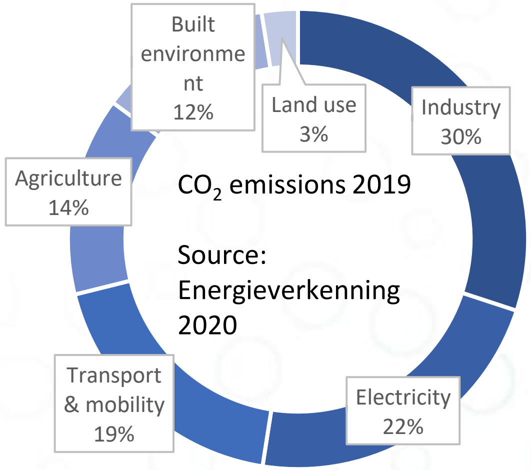
Introduction HyDelta

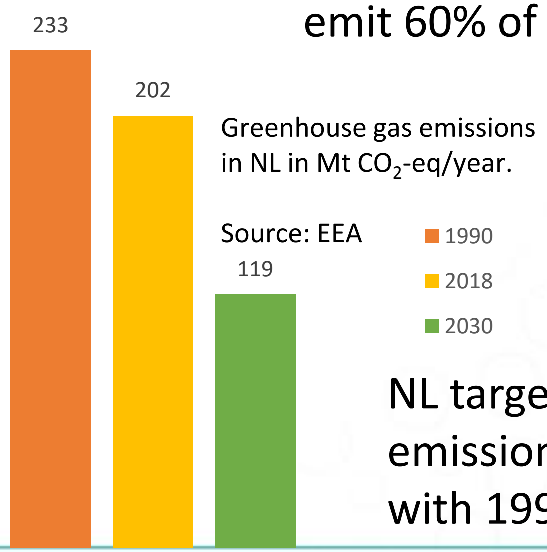
Current energy landscape in NL



Current NL energy mix: >76% fossil fuels

Industry, T&M, BE emit 60% of CO_2





NL target: -49% CO_2 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** $\mathbf{H_2}$ 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**:

Source: Gasunie, 2020

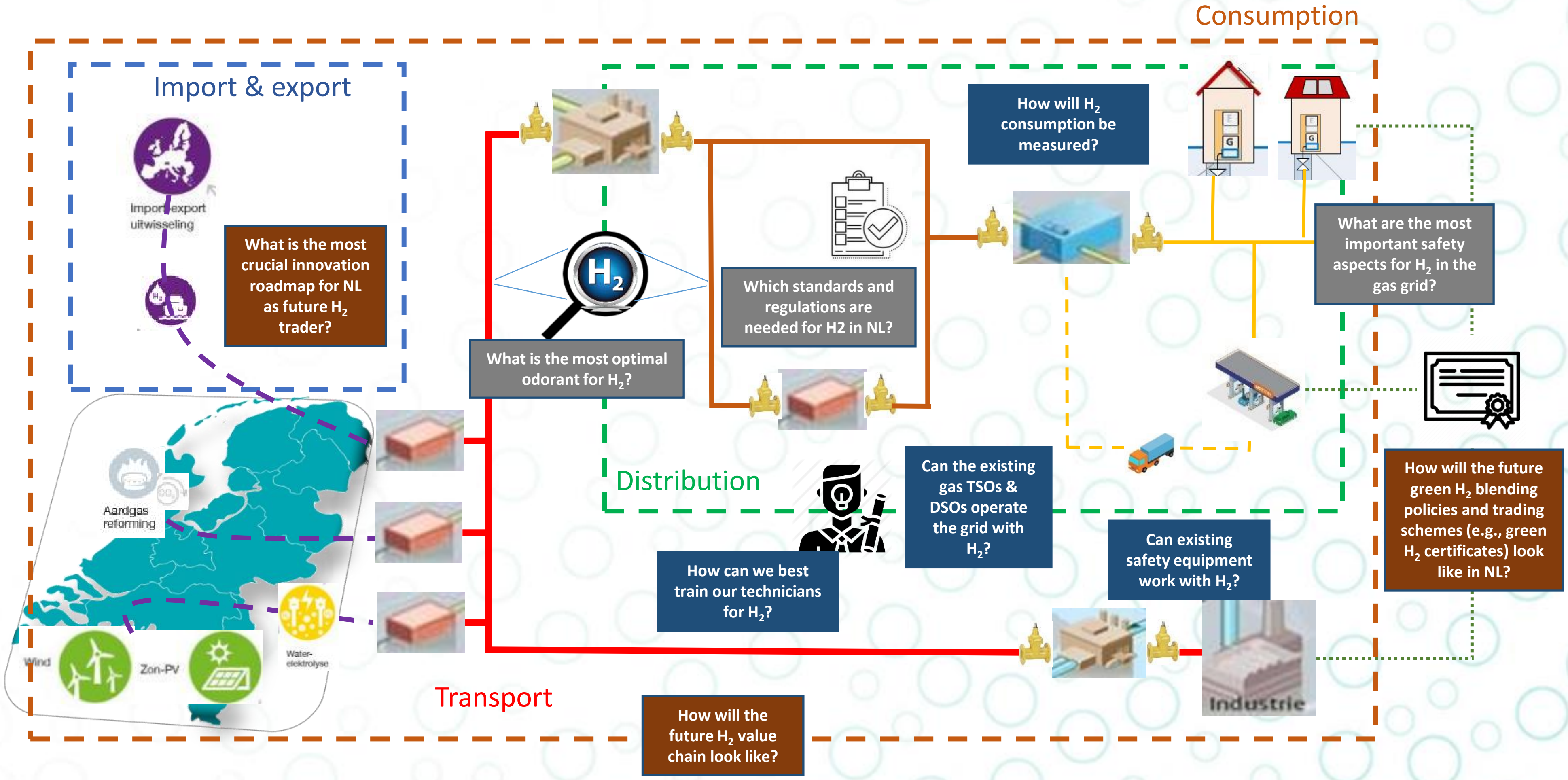
Installed NG transportation **capacity** in NL: 350 GW

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

Research questions

Overview of the research questions in HyDelta

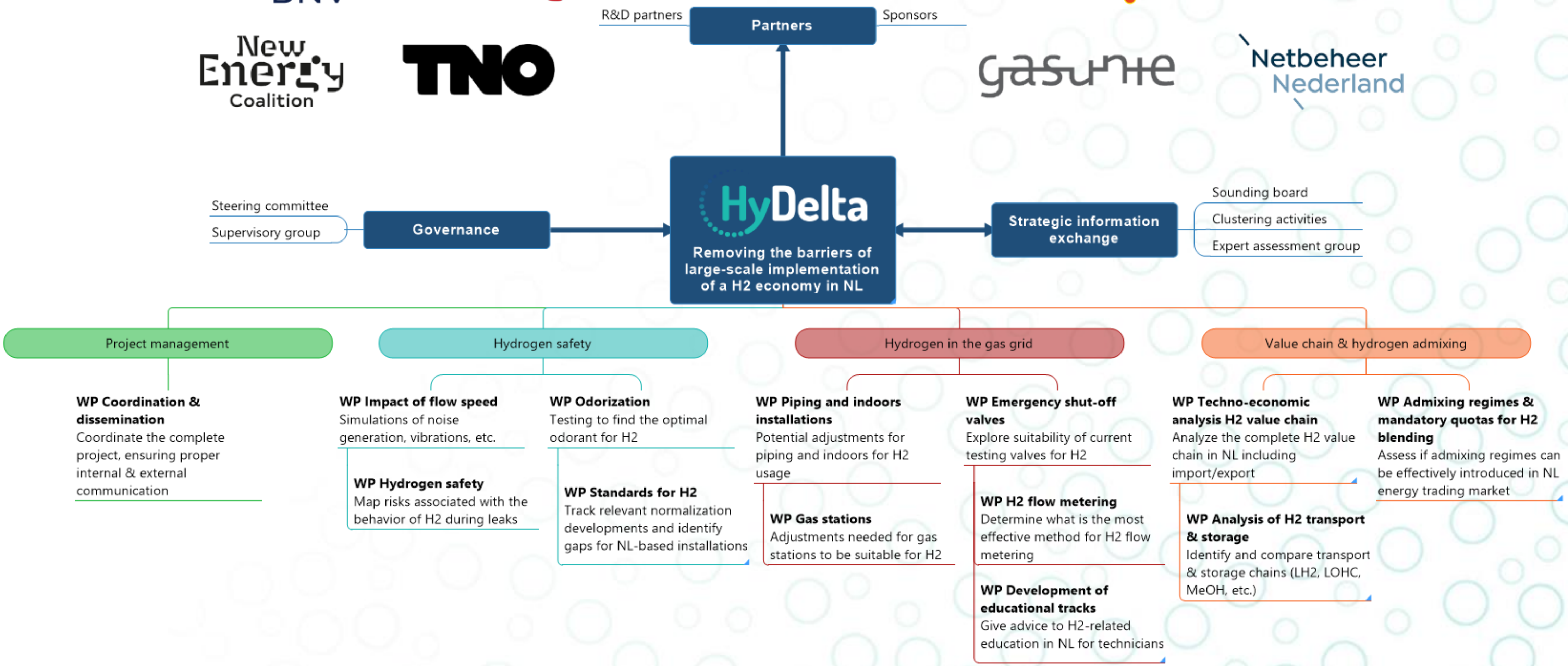
HyDelta 1.0 is a **consortium** project **aimed** at conducting **research** on the area of **transport** or **blending** of **hydrogen** in the existing **NG network** in **NL**



Legend

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

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**

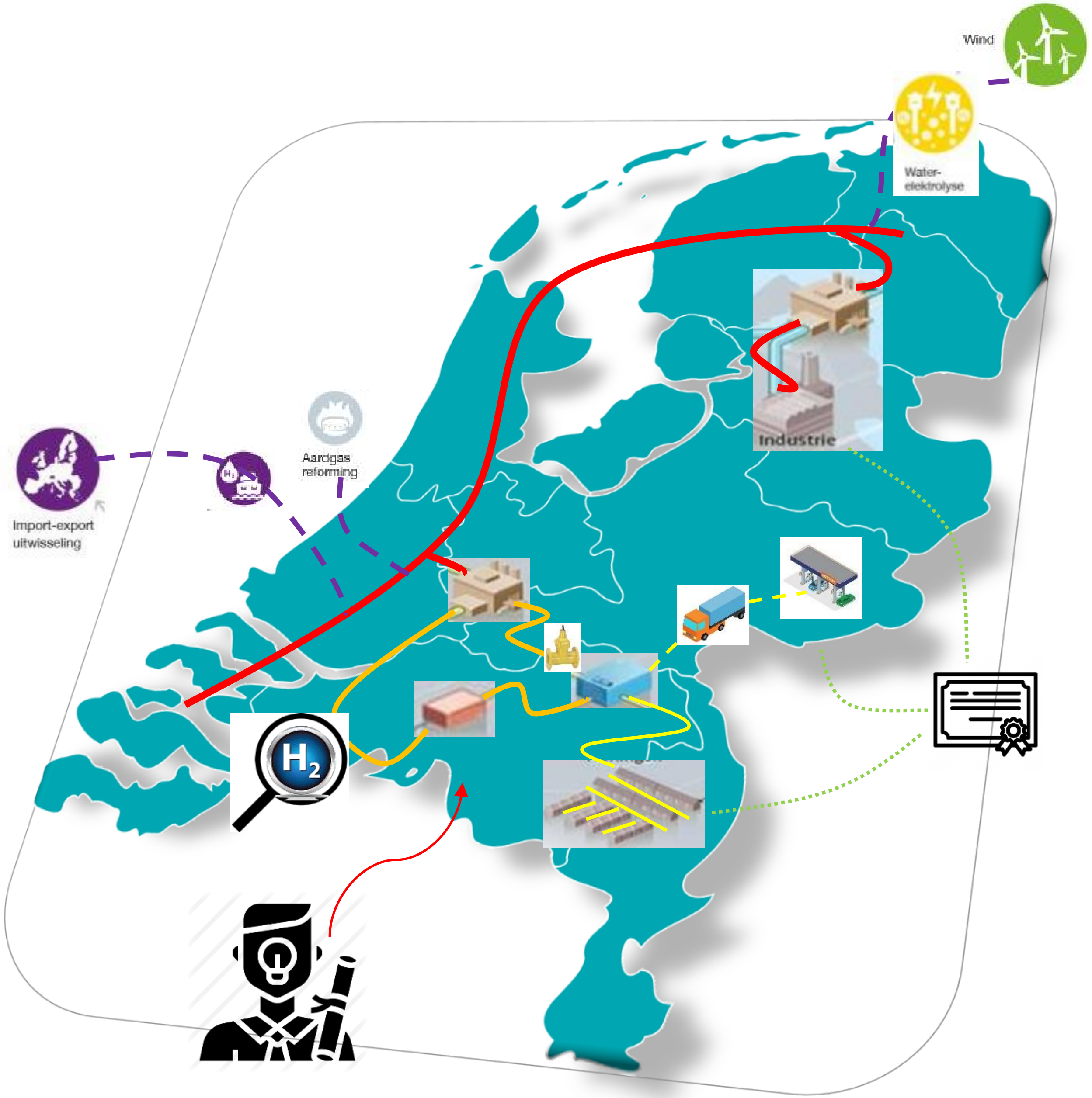
Timeslot	Event
10:00 – 10:10	Welcome & intro presentation HyDelta
10:10 – 10:50	Topic 1: Hydrogen safety 10:10 – 10:20 WP1A Hydrogen & safety Albert van den Noort, DNV 10:20 – 10:30 WP1E Impact of hydrogen flow speed on safety Néstor Gonzalez Diez, TNO 10:30 – 10:40 WP2 Odorization of hydrogen Harm Vlap, DNV 10:40 – 10:50 WP3 Standards for hydrogen Hans de Laat, Kiwa
10:50 – 11:10	Topic 2: Hydrogen in the gas grid (part 1) 10:50 – 11:00 WP1B Gas stations Sander van Woudenberg, Kiwa 11:00 – 11:10 WP1C Piping & indoor installations Sander Lueb, Kiwa
11:10 – 11:20	Intermediate break

Timeslot	Event
11:20 – 11:50	Topic 2: Hydrogen in the gas grid (part 2) 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
11:50 – 12:20	Topic 3: Value chain & hydrogen admixing 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
12:20 – 12:30	Final remarks and closing

HyDelta

WP1A

Hydrogen Distribution and Safety



DNV / KIWA

Albert van den Noort (DNV)

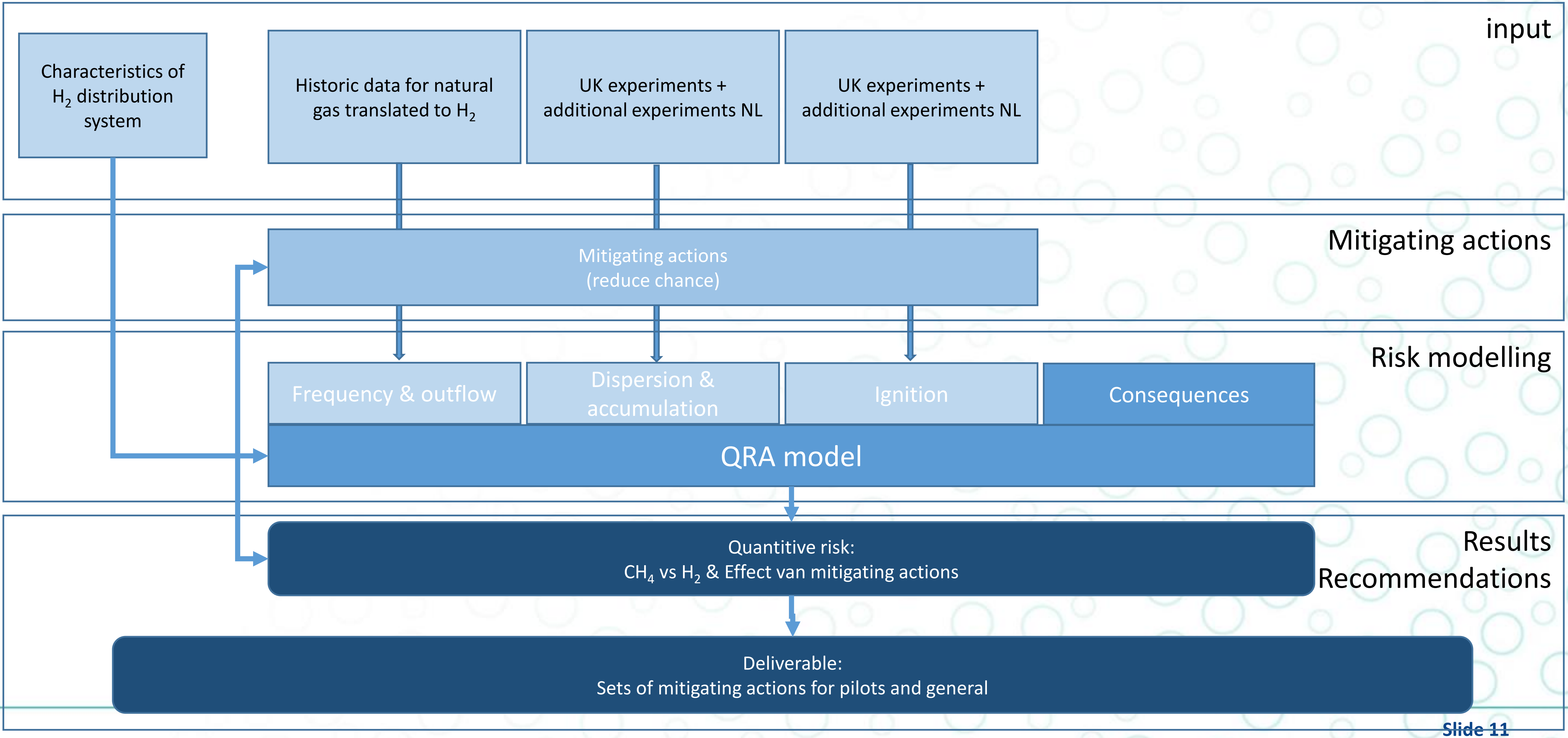
30-06-2021

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 priorisation 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

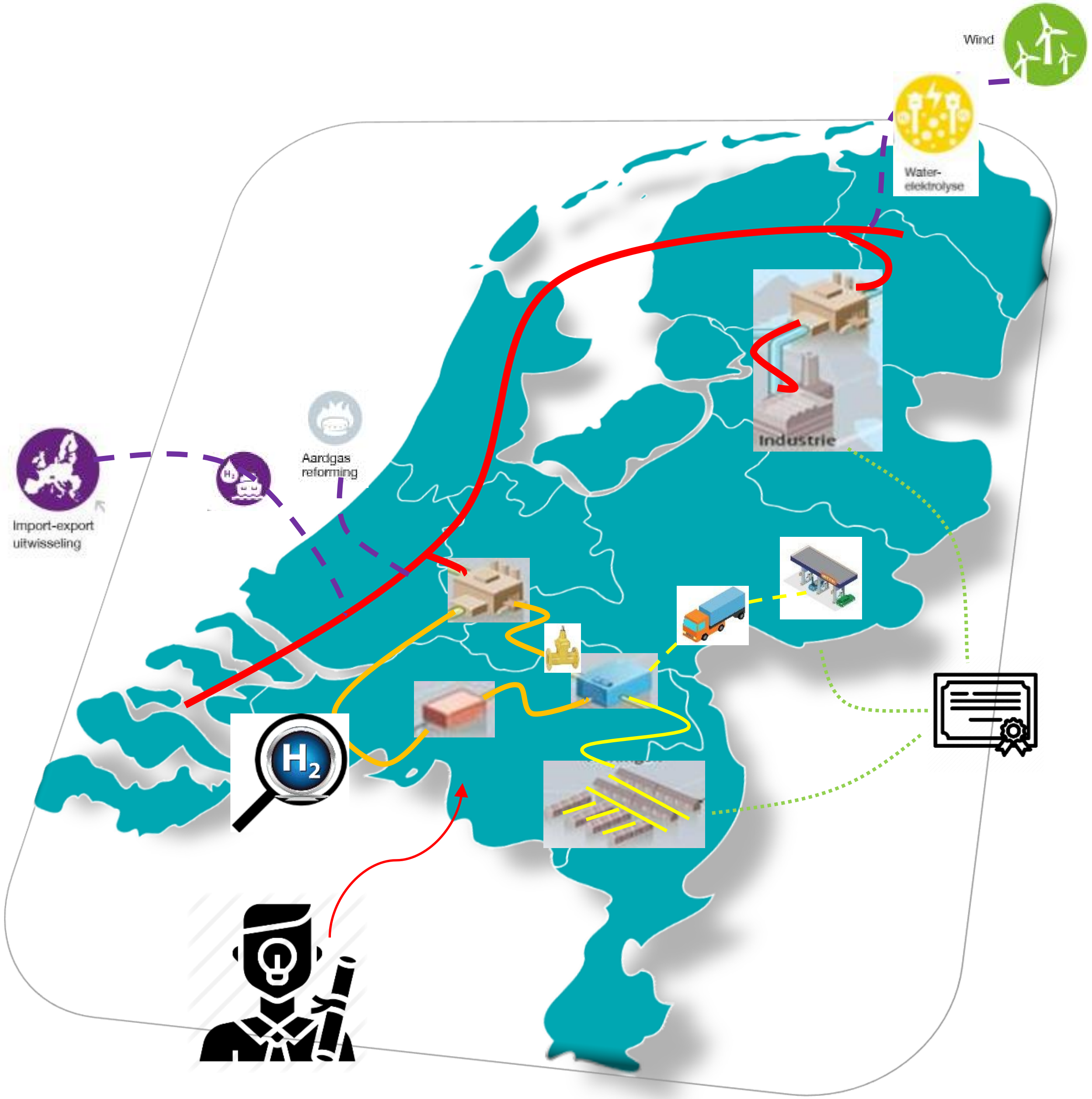
WP1E

Impact of high velocity of hydrogen flows

TNO

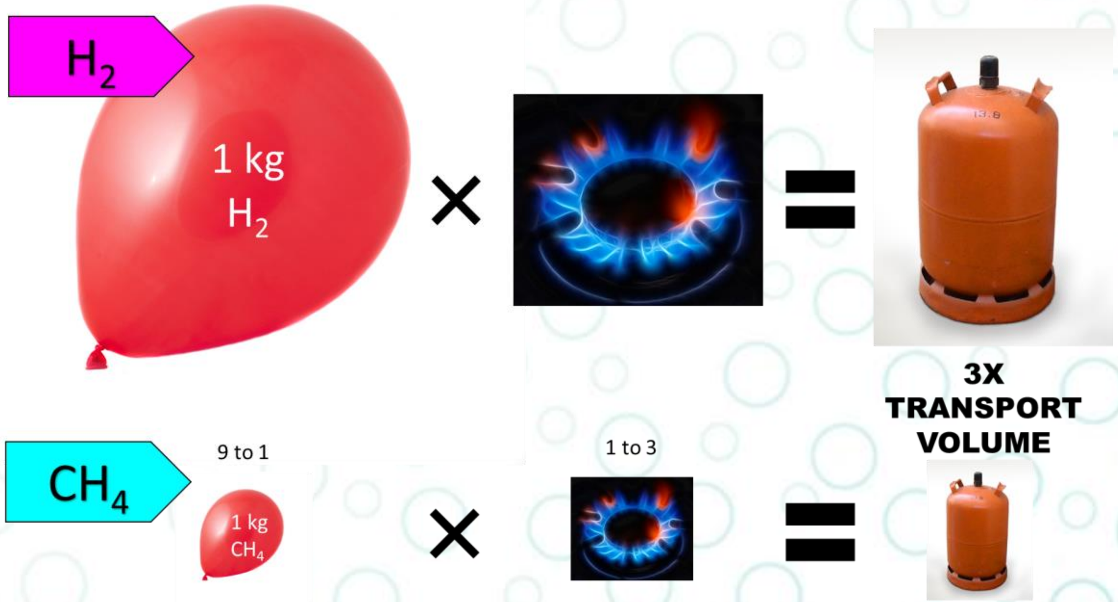
Néstor González Díez, Deputy RM HTFD

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

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.

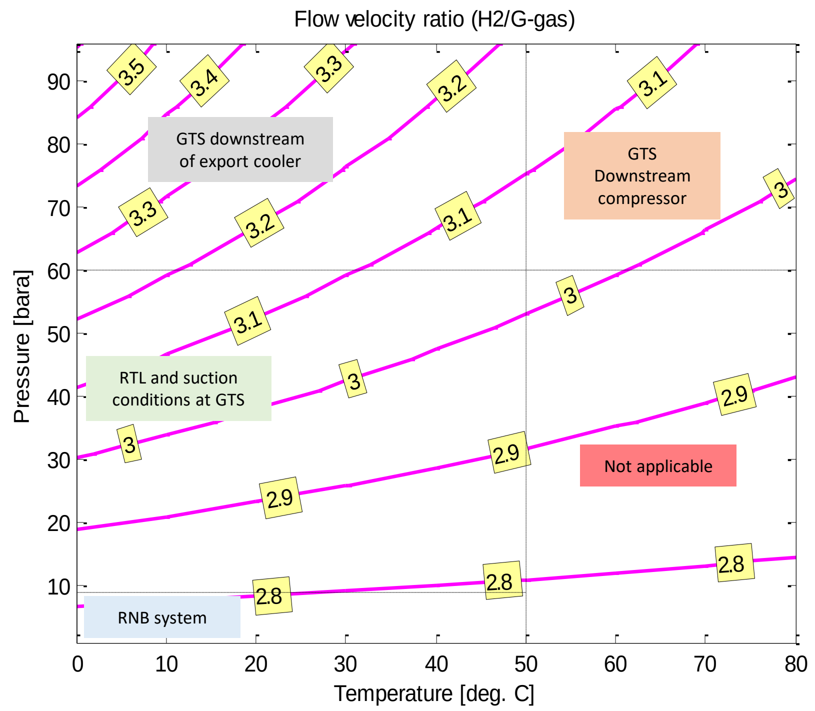
- Research questions

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

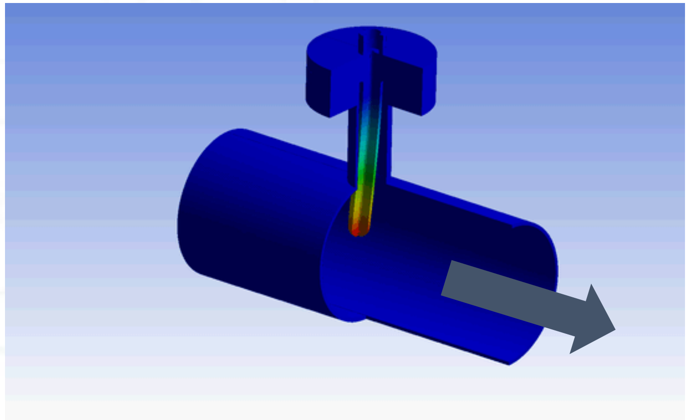
Progress of the work in the period

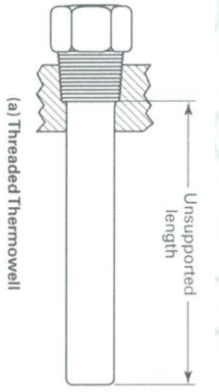
- Velocity ratio
  - When compared to G-gas and transporting the same amount of energy, H2 will need to flow about 3 times faster in the system
  - This is the central assumption of this WP as worst-case condition. Whether such H2 volumes will occur at similar pressures and temperatures can still be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

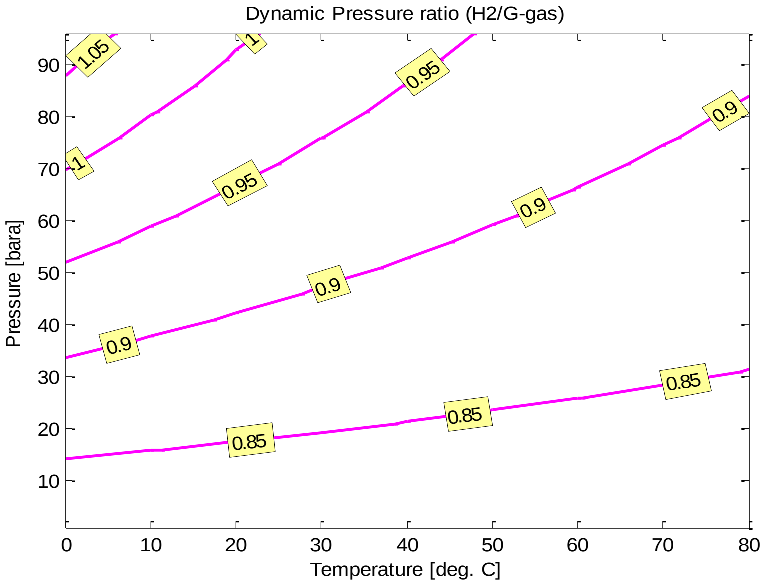


Progress of the work in the period

- 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)

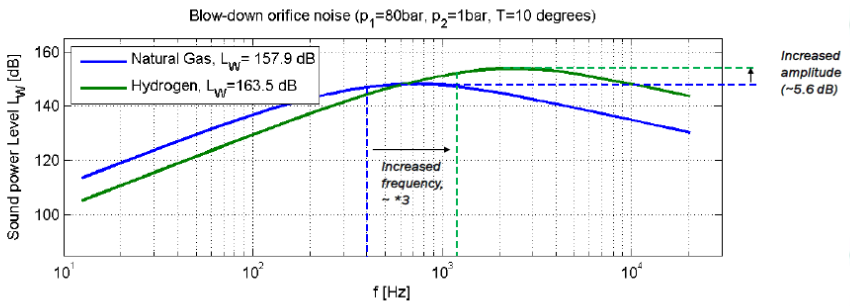


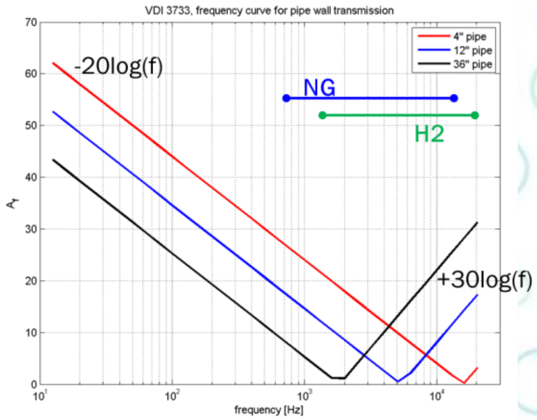




Progress of the work in the period

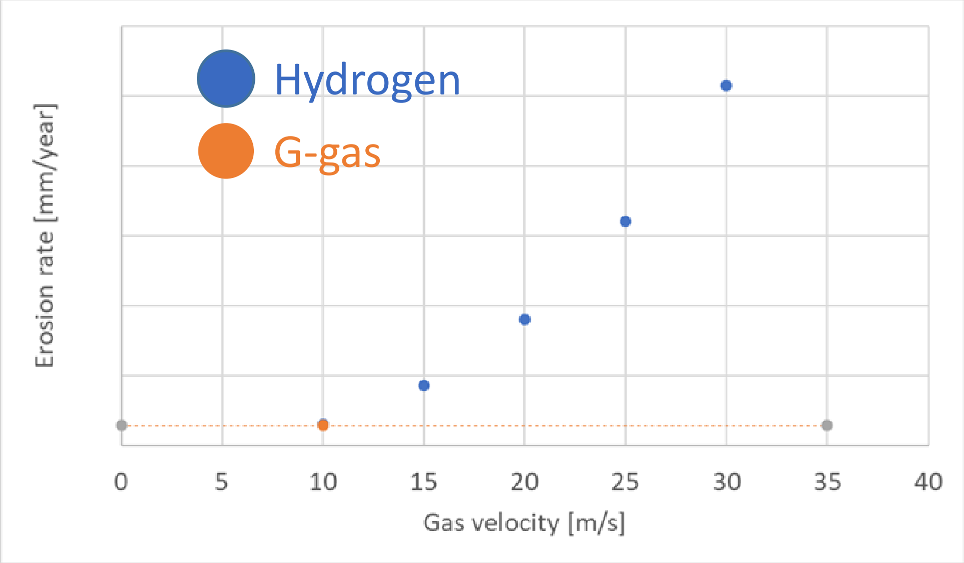
- Noise Generation
  - For conversion of gas transport infrastructure, flow-induced noise by pressure let-down devices may be a relevant aspect
  - Negative consequences of flow-induced noise are the risk on fatigue failure, environmental noise radiation and disturbance of flow metering equipment
  - 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

HyDelta

- The following is still in the to-do list:
  - Finalize/complete some of the questions that have arised during the execution of the tasks just described, such as additional sensitivitity 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

HyDelta

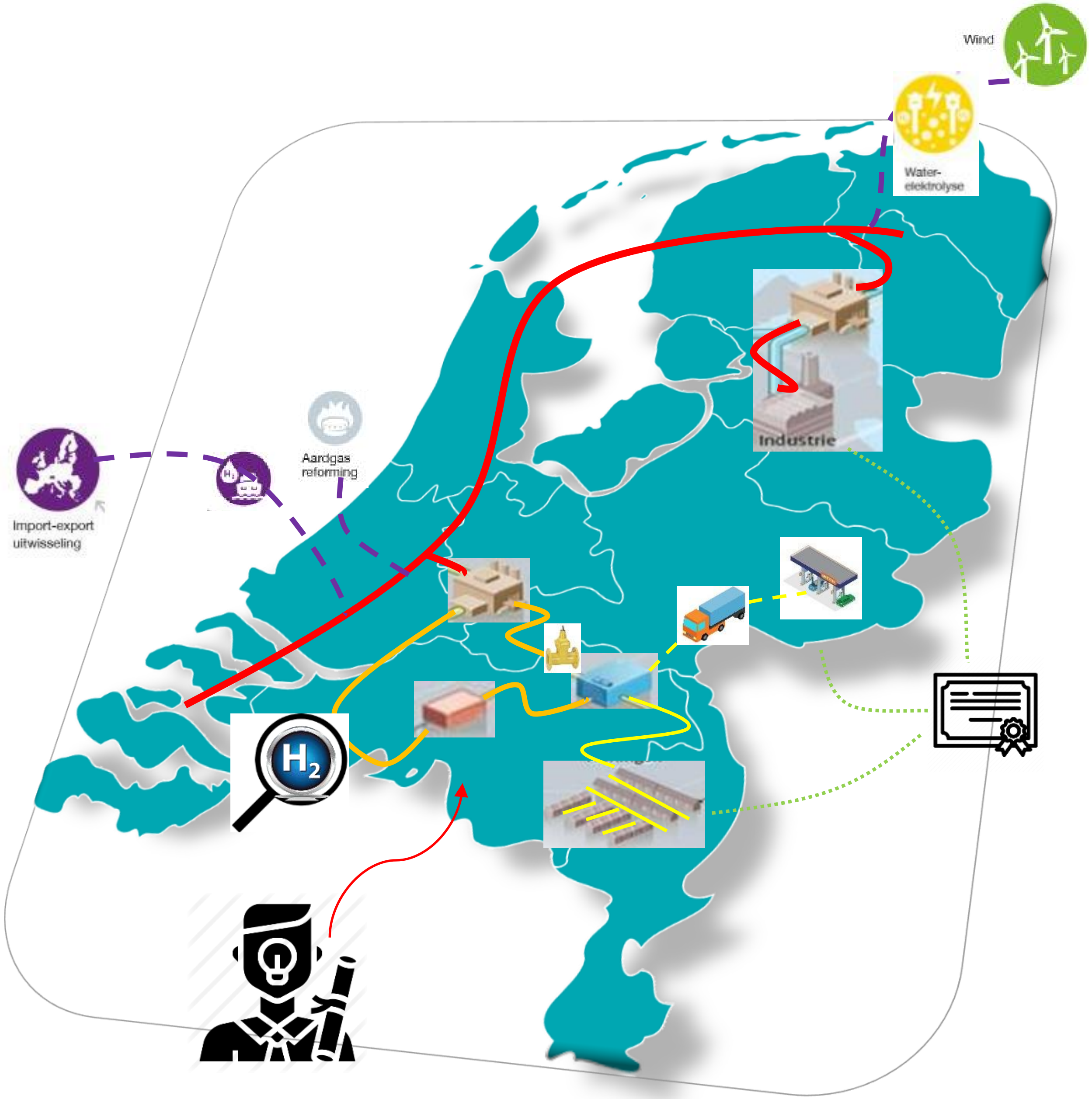
WP2

Odorisation

Kiwa & DNV

Harm Vlap/ Erik Polman

30-06-2021



Main objectives of the WP

Background

Hydrogen distribution should take place in a safe way. Odorisation 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

Progress of the work in the period (1)

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-Ethylideen-2-norbonene
- Tert-butyl methyl ether
- 2-hexyne

2-Hexyne has been selected and taken up in the remaining progamme 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**

Progress of the work in the period (2)

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

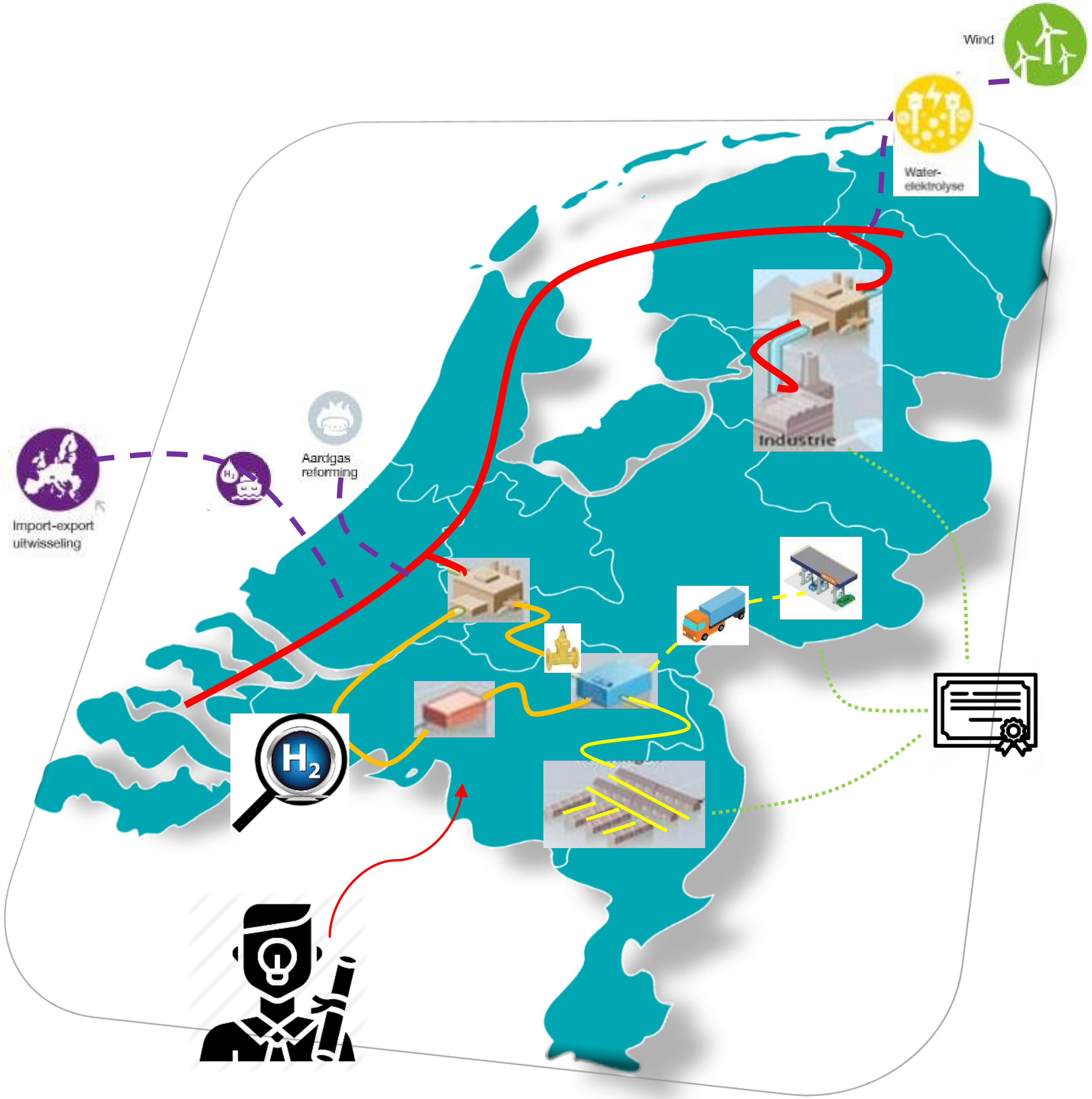
WP3

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

Intermediate results

- 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

Deliverable

- Report on the findings regarding standards of hydrogen

Work to be done in the next period

HyDelta

- 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

HyDelta

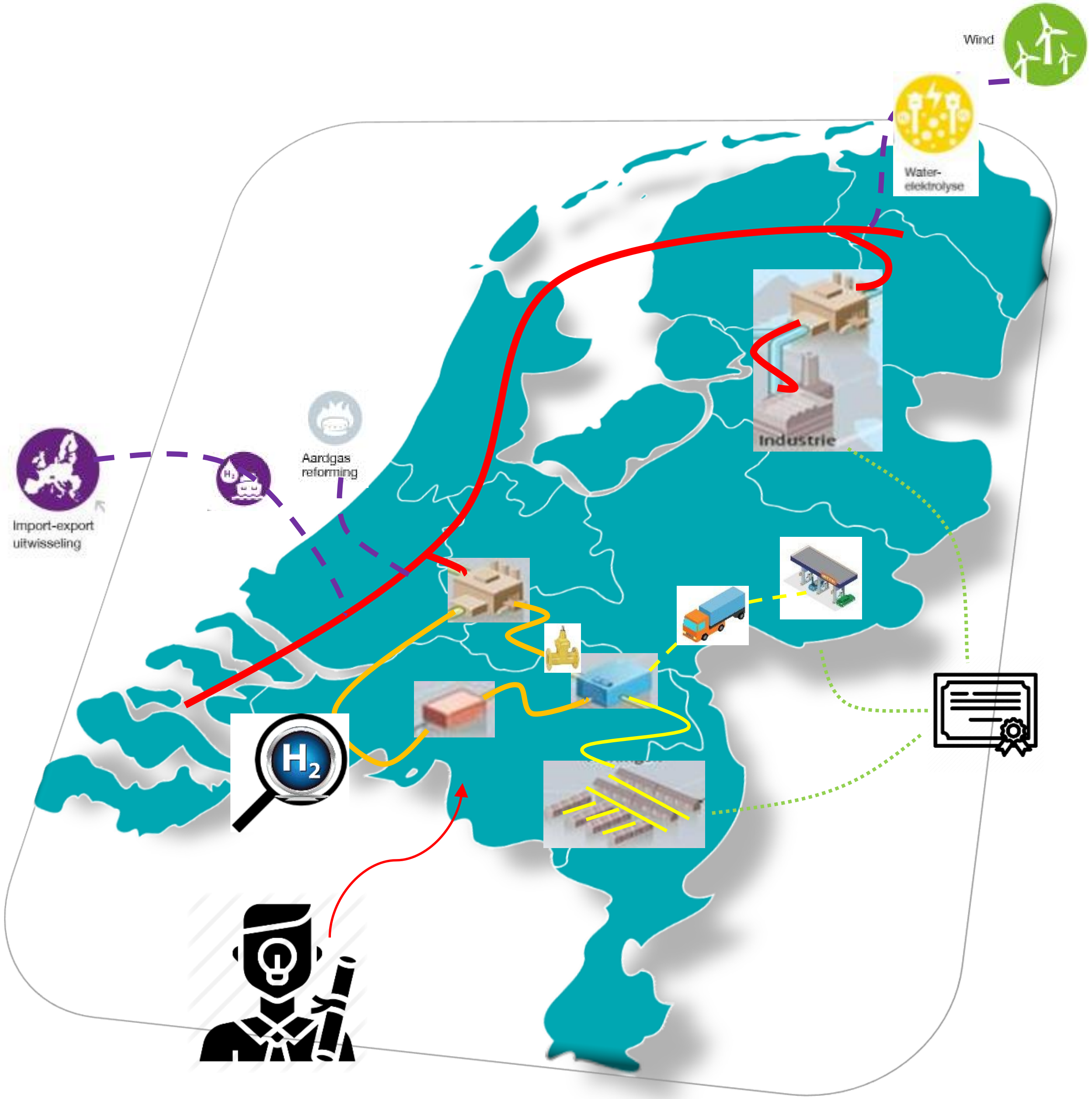
WP1B

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.”

Progress of the work in the period

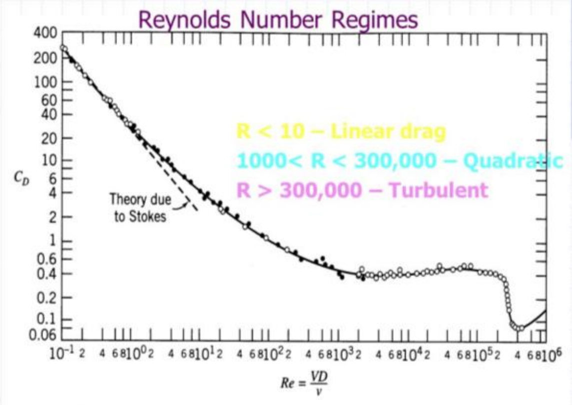
- How can work safely be done on stations with hydrogen?
  - Interviews held with DSO’s. Goal to determine LOC (loss of containment) scenario’s during construction and maintenance work, current practices with natural gas.
    - LOC 1: venting station and upstream gas line during installation
    - LOC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

Progress of the work in the period

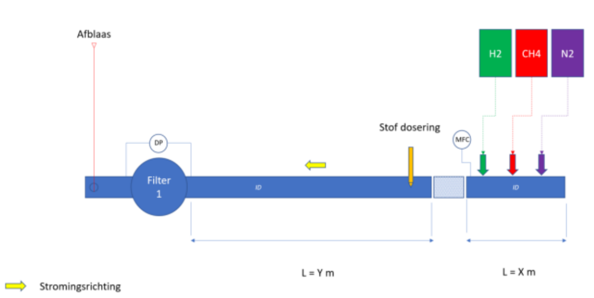
- Related to both safety and design of the stations: is the ventilation in stations also suitable for hydrogen?
  - Method: testing. Release defined flow of methane and hydrogen. Measure concentration.
  - First results – small cabinet:
    - A similar leak size releases more flow with hydrogen compared 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



Drag coefficient of a smooth sphere as a function of Reynolds number [3].



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)
  - 2^{nd} 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)

HyDelta

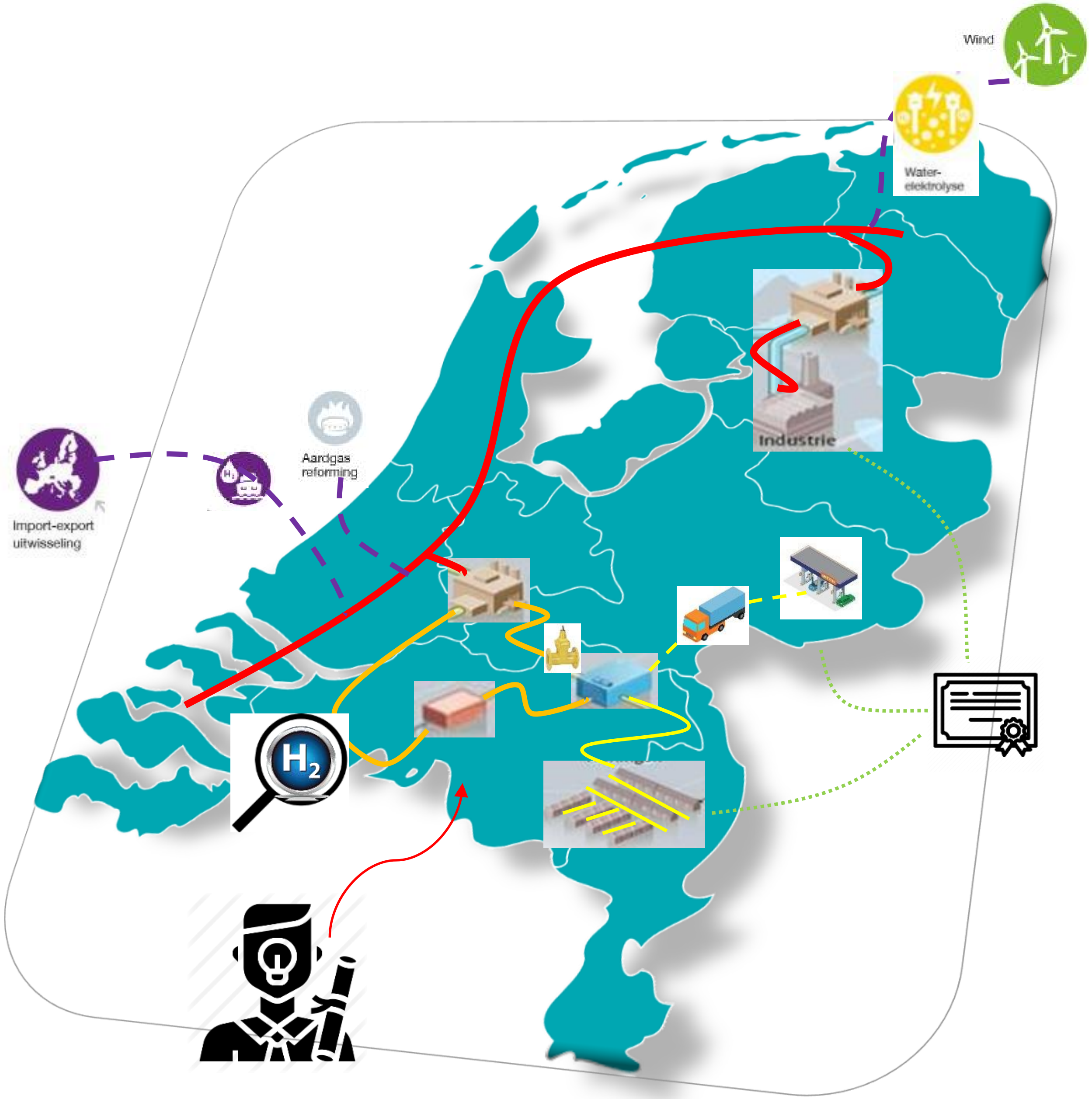
WP1C

Pipes and indoor installations

Kiwa

Sander Lueb

30-06-2021



Main objectives of the WP (1)

HyDelta

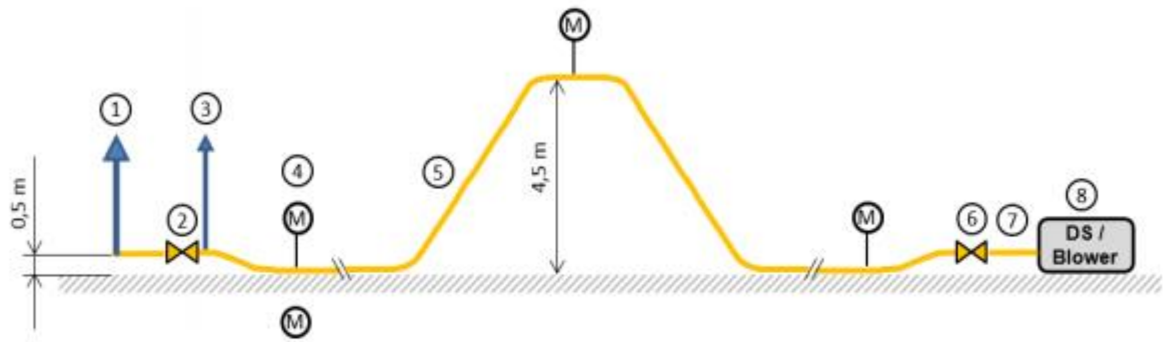
- Determine whether **purging** of natural gas (distribution) pipelines can be done safely with hydrogen

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

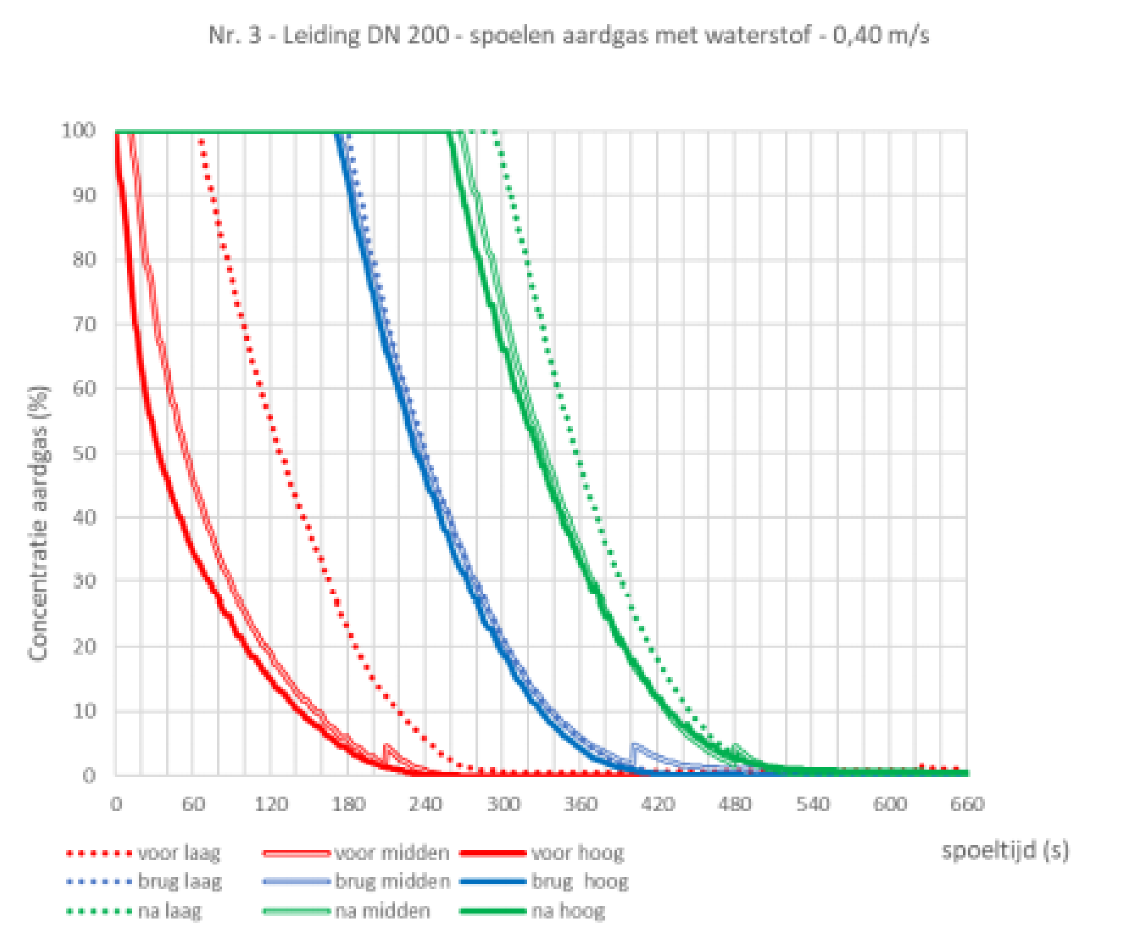
Main objectives of the WP (2)

- 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

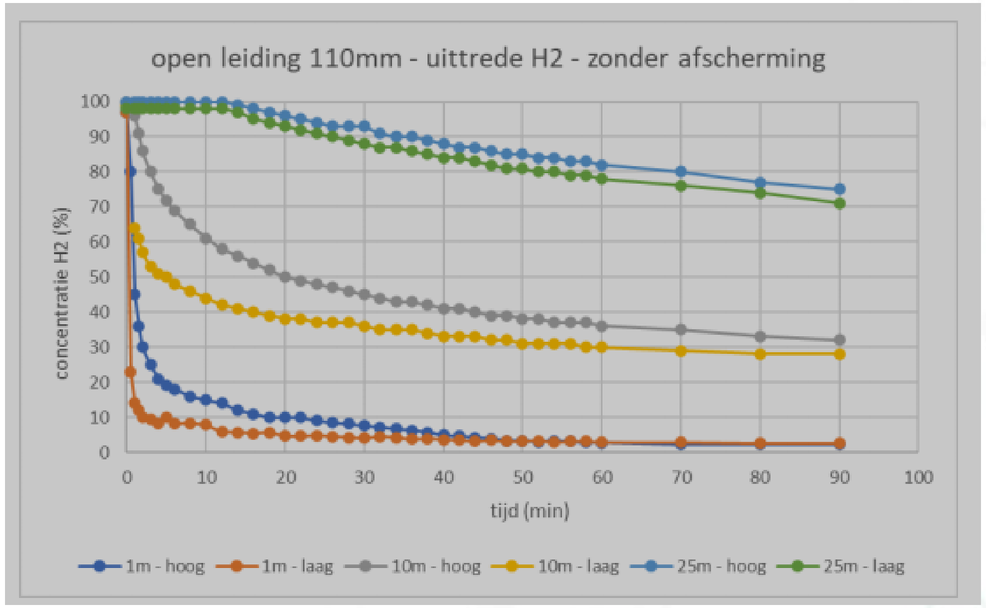
- Purging of natural gas with hydrogen

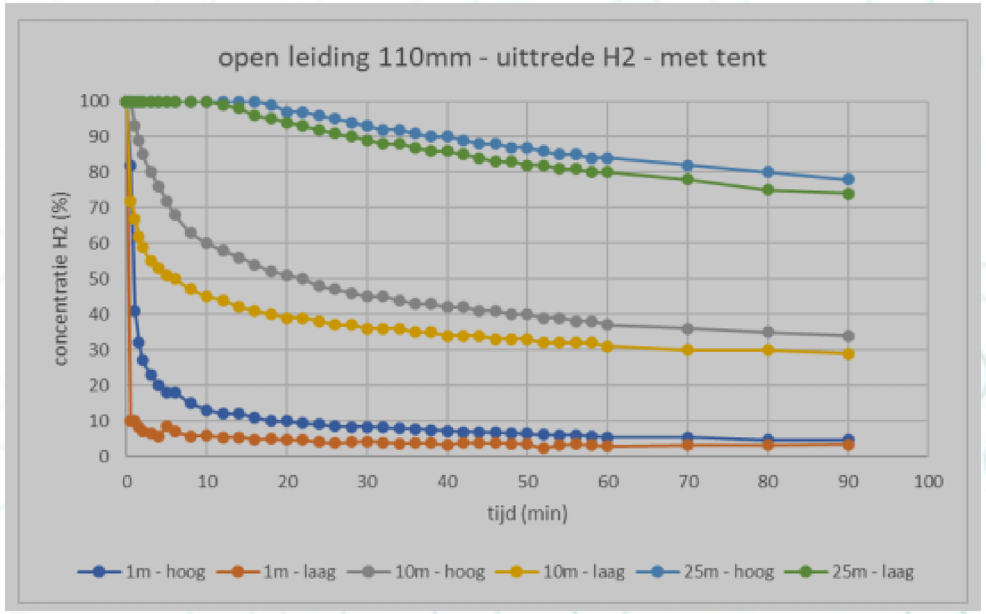
  - Report is finalized

  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

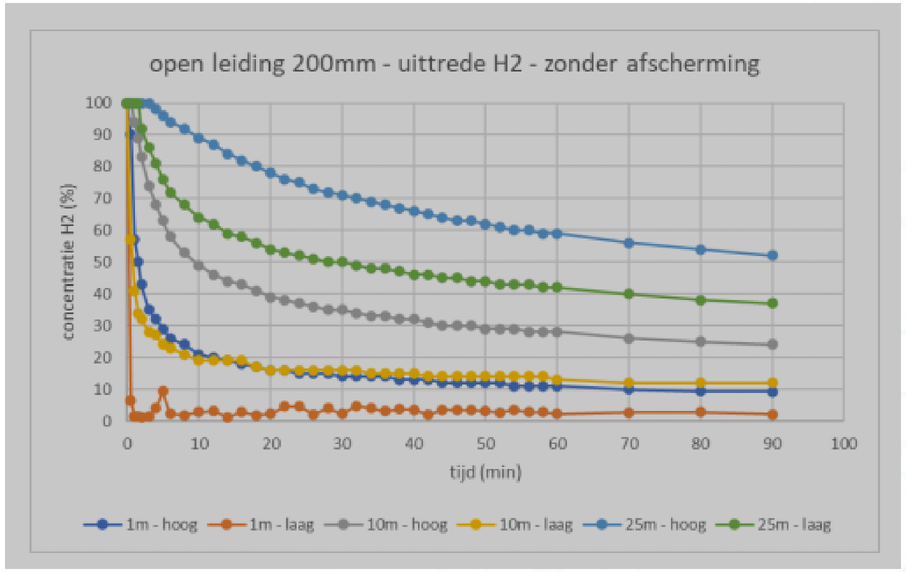
- Purging of natural gas with hydrogen
  - Extra measurements are done on hydrogen-filled pipes (DN 100 and DN 200)
    - 100% H_2 filled pipe is opened in the atmosphere to determine the speed of inlet of air
    - Occurs for instance in case of repair of leakages
    - Measurements in open air and in a tent
    - Distances 1, 10 and 25 meter of opening

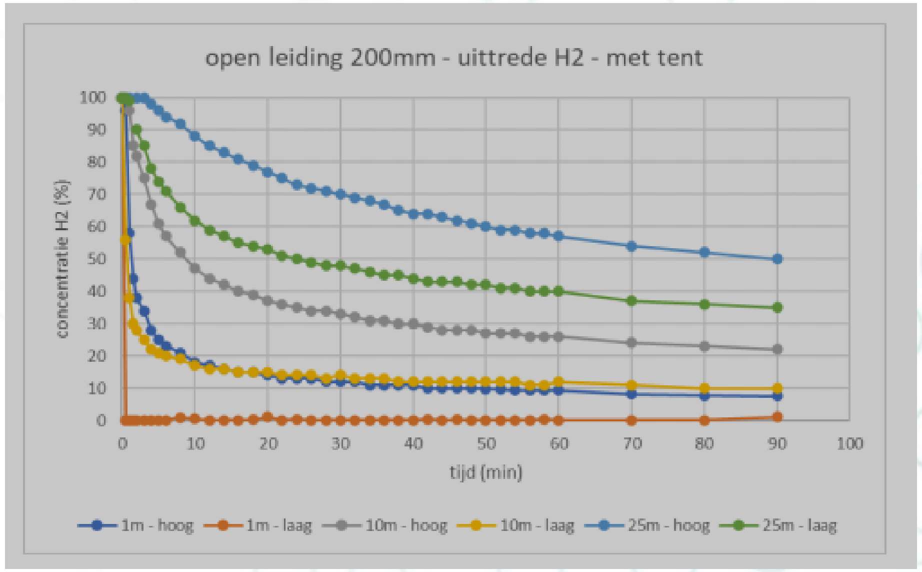




Progress of the work in the past period

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





Progress of the work in the past period

- 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 H_2 flow of 15 m^3/h
  - 10 of these regulators are selected for verification test with natural gas (testing in July)

Progress of the work in the past period

- Risk of not replacing pressure regulators
  - Tested according NEN 7239
  - Tested on functionality of regulating with varying flow (0 to 15 m^3/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

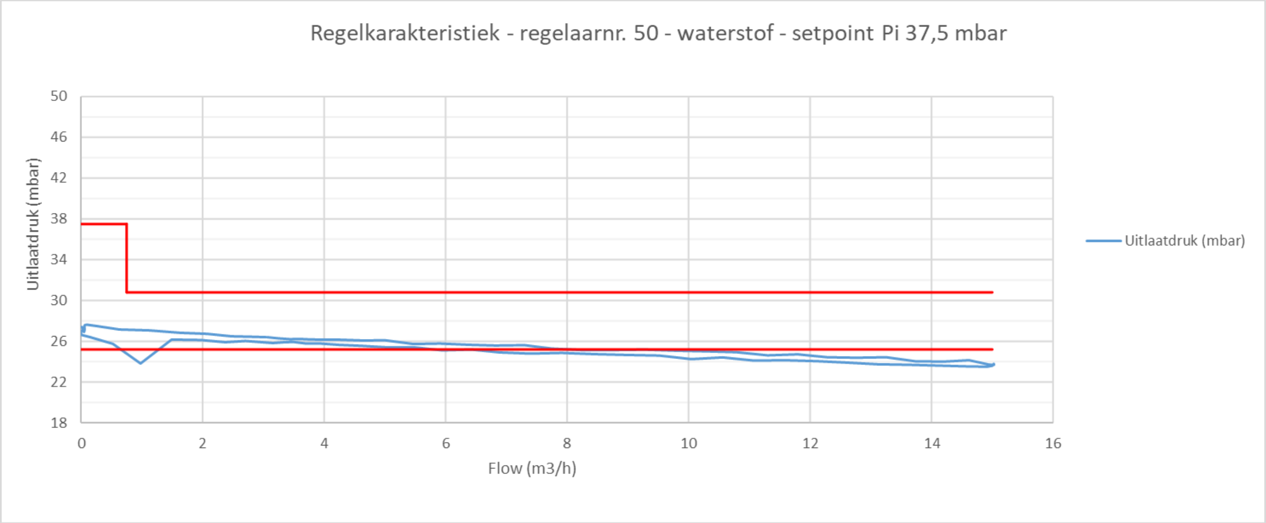
- Risk of not replacing pressure regulators

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

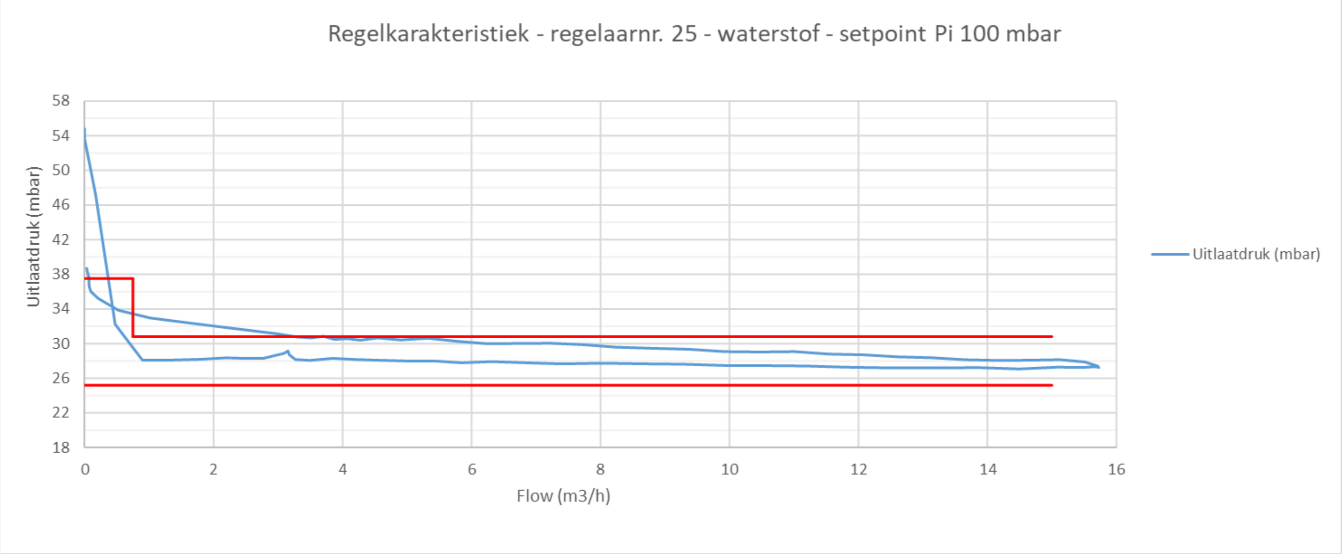
- Risk of not replacing pressure regulators

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



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?
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

Progress of the work in the past period

- 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 fulling the requirements; closing at inlet pressures above 17,5 mbar
  - Noise of vibrations are not observed

Progress of the work in the past period

- 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

HyDelta

Description	Question nr.	Collecting samples	Testing	Desk study	Report delivered to Steering Committee
Pressure regulators	185	*done*	July	*done*	30 September
Leak tightness	124	June	July-August	*done*	8 October
Desorption THT	135	July - Aug	Sept – December	*done*	31 March 2022
Permeation oxygen, nitrogen, water	135	July	Aug – December	*done*	31 March2022
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

HyDelta

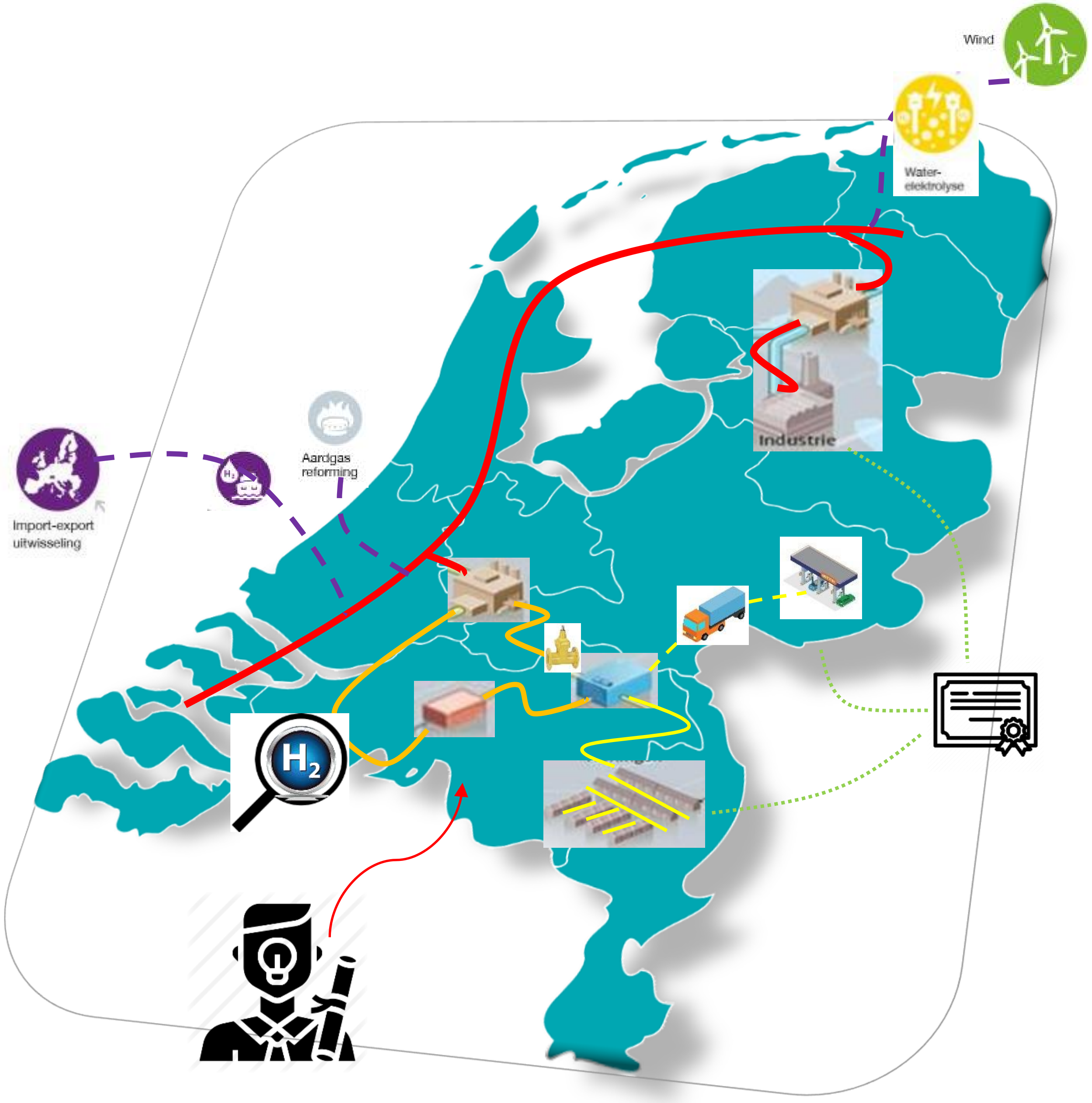
WP1D

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

Deliverables

- 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

Suitability of Ultrasonic and Thermal mass 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 demostration 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

Effect of practical gas composition of hydrogen 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 (>=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	
H2	1270	98%		
N2	349	2%	1252	-1,45%
CO2	267	2%	1250	-1,58%

Effect of practical gas composition of hydrogen on meters

- Influence on the thermal conductivity
- The thermal conductivity of H_2 is much higher than of other gases
- 2% allowable impurity decreases the thermal conductivity
- The meter accuracy class is +/- 1,5%

molecule	thermal conductivity	ISO 14687 share in gas	average thermal conductivity	difference from H2
	W/mK		W/mK	
H2	0,174	98%		
N2	0,024	2%	0,1710	-1,72%
CO2	0,015	2%	0,1708	-1,83%

Implementation strategy for hydrogen meters

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

Requirements and wishes regarding the hydrogen 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

Other information gathered

- 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*

HyDelta

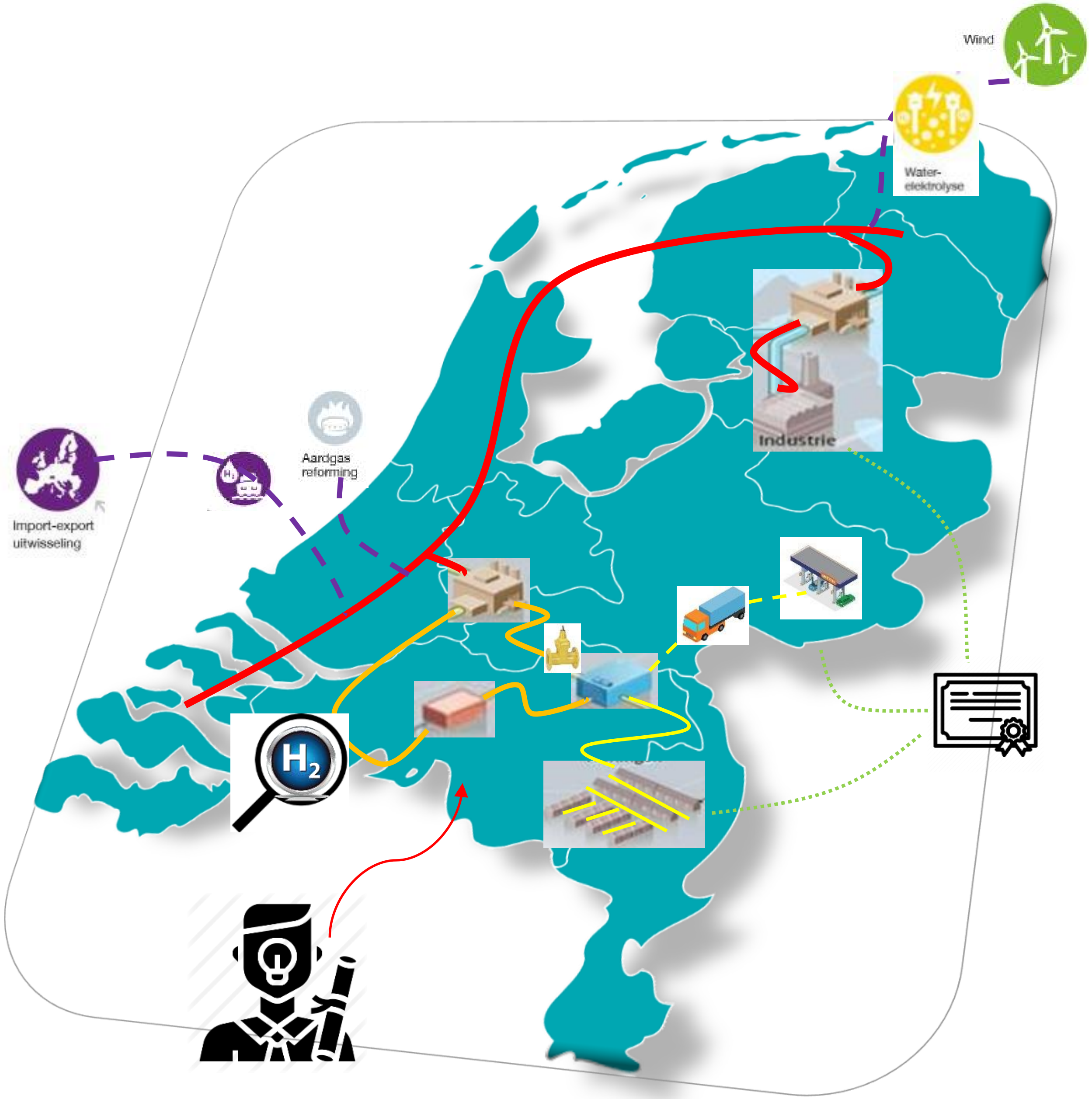
WP1F

Testing of shut-off valves in gas transport pipelines

Kiwa

Cees Lock

30-06-2021



Main objectives of the WP

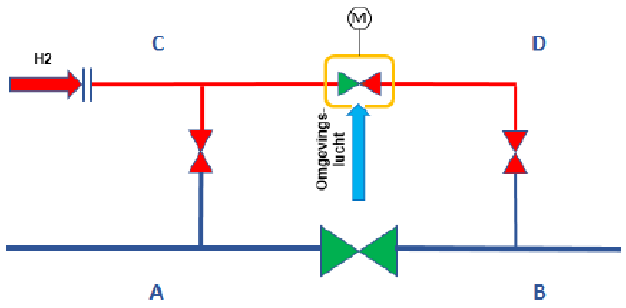
Increasing the knowledge about the suitability for hydrogen of shut-off valves used in the gas transportation grid.

- 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)

Progress of the work in the period

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

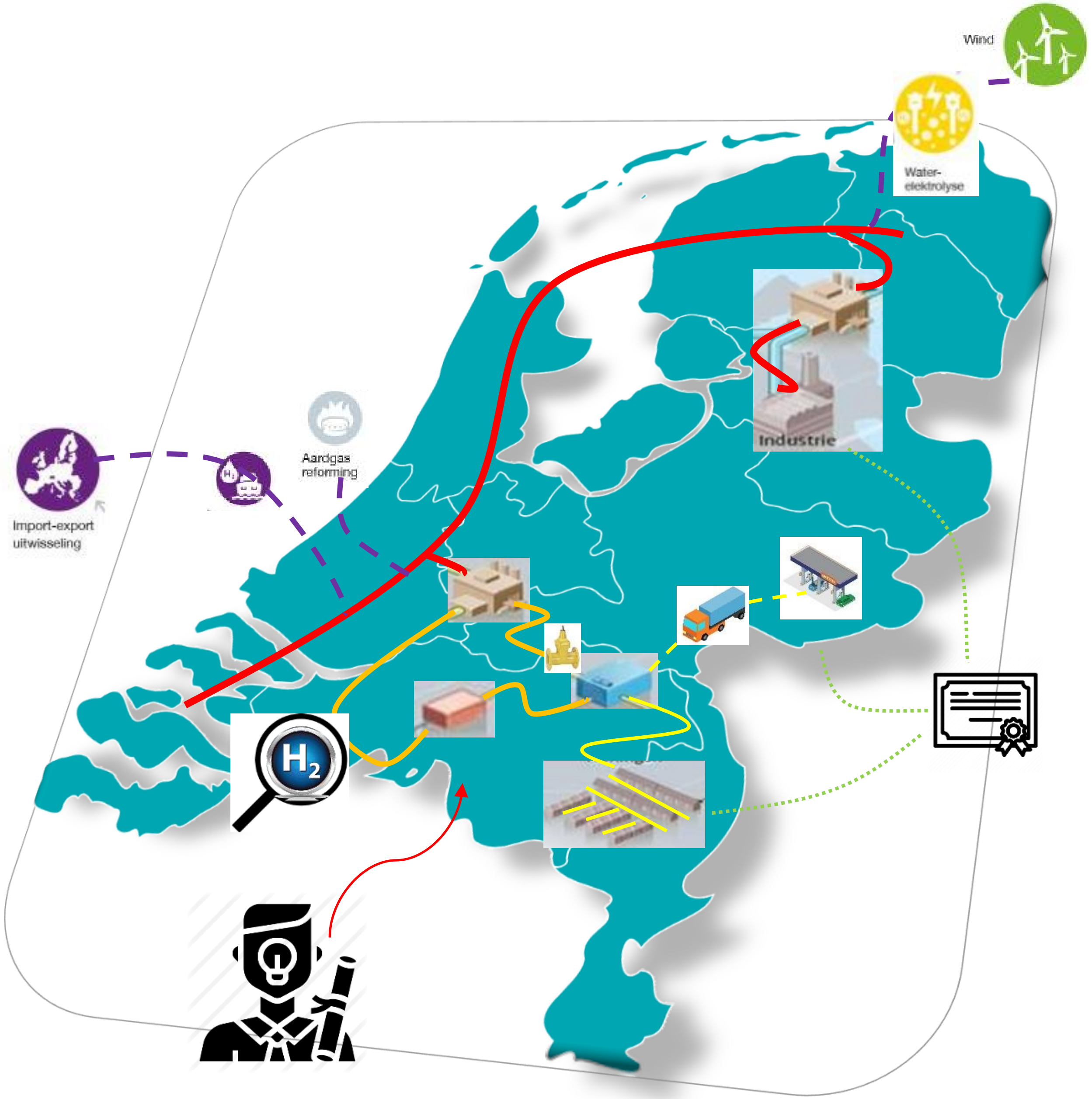
WP4

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

HyDelta

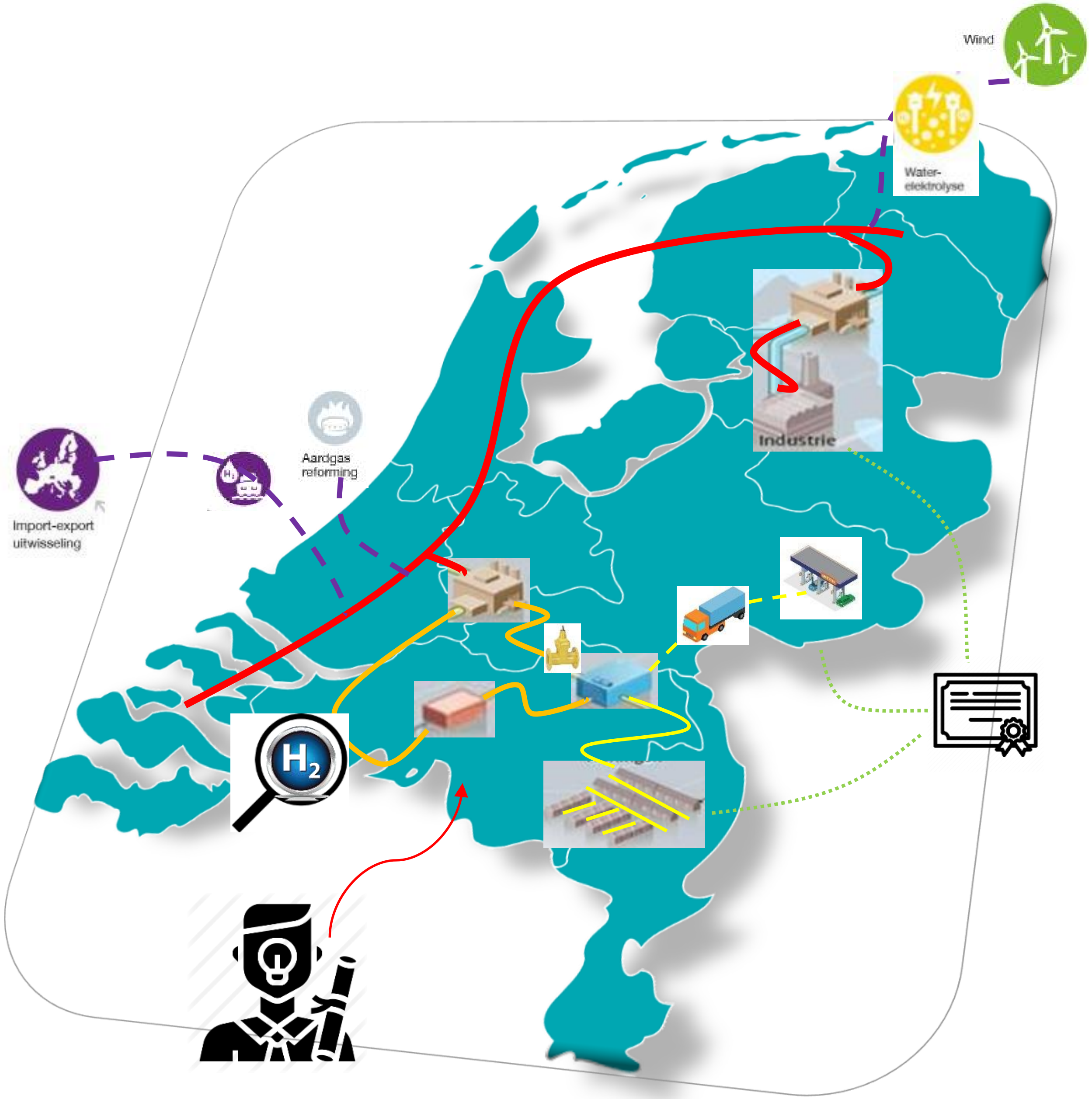
WP7A

Techno-economic value chain analysis

NEC (TNO, DNV)

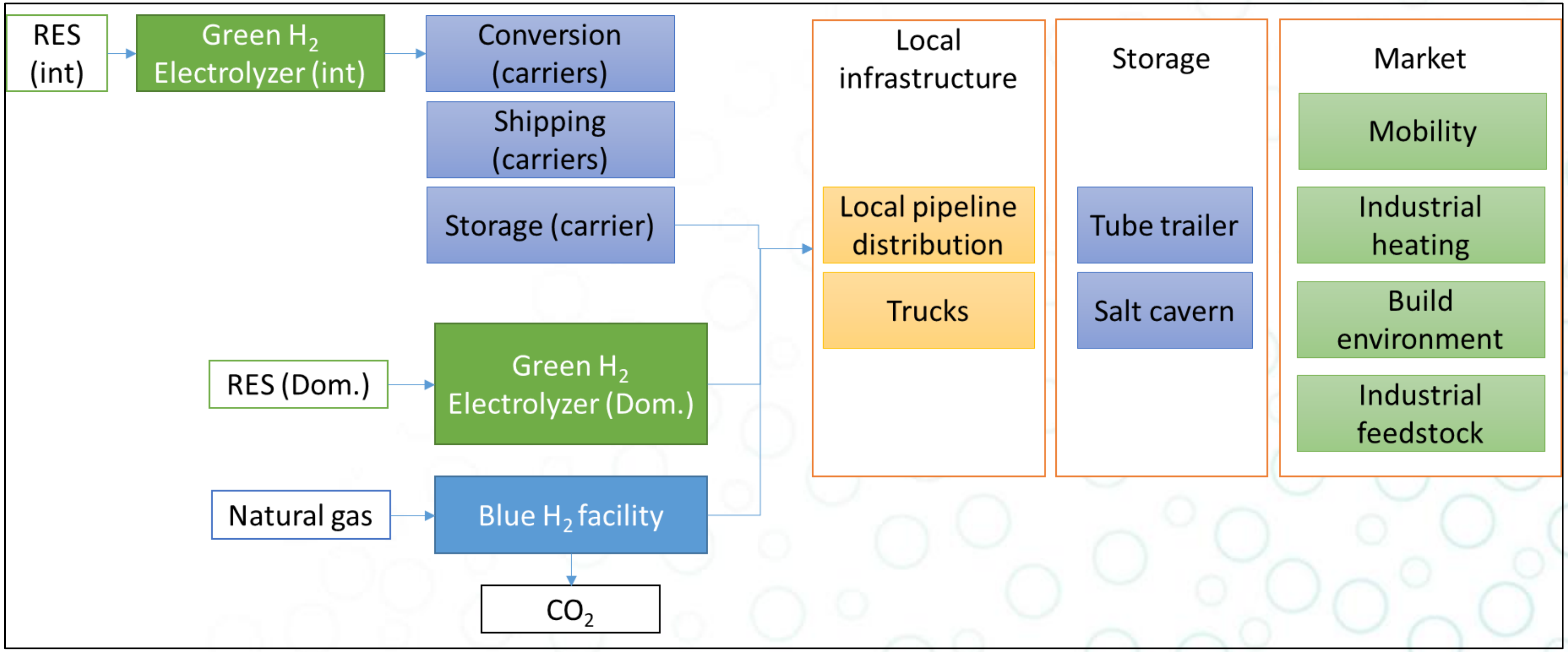
Joris Kee (Thomas Hajonides, Albert van den Noort)

30-06-2021



Main objectives of the WP

Value chain element collection – Dutch context



Main objectives of the WP

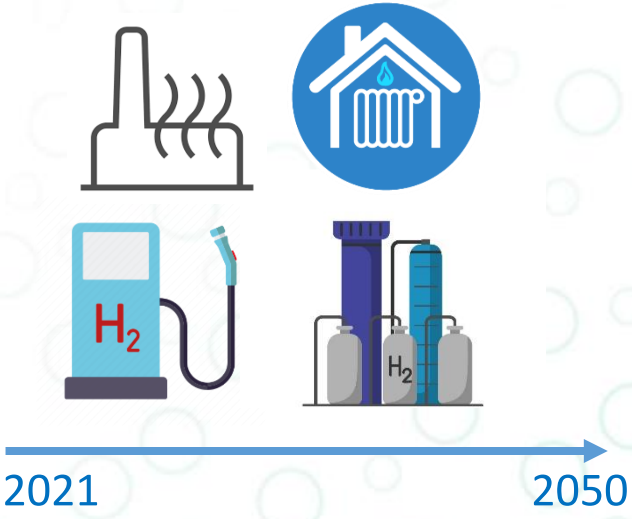
Task 1: Literature overview
Analyze existing knowledge on H_2 Value Chains

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

Progress of the work in the period

HyDelta

- 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

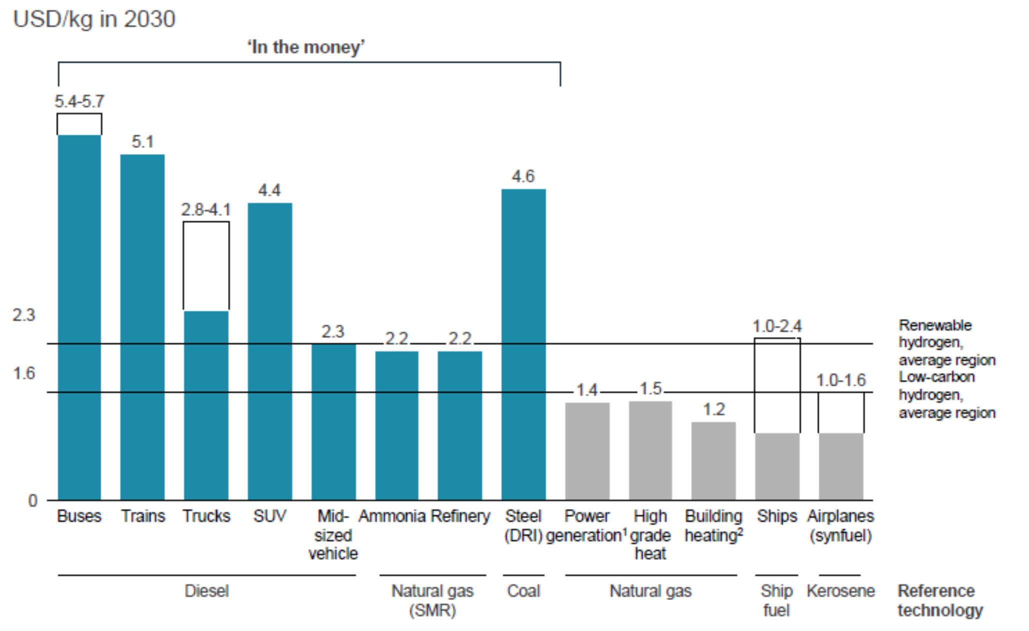
- Brief conclusions
  - Type of modelling (optimization, calculation, etc.) impacts type of results
  - National hydrogen strategy characteristics: Domestic or international supply, blue or green hydrogen, decarbonization of end-uses.
  - Hydrogen value chain modelling focuses a lot on mobility sector, 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

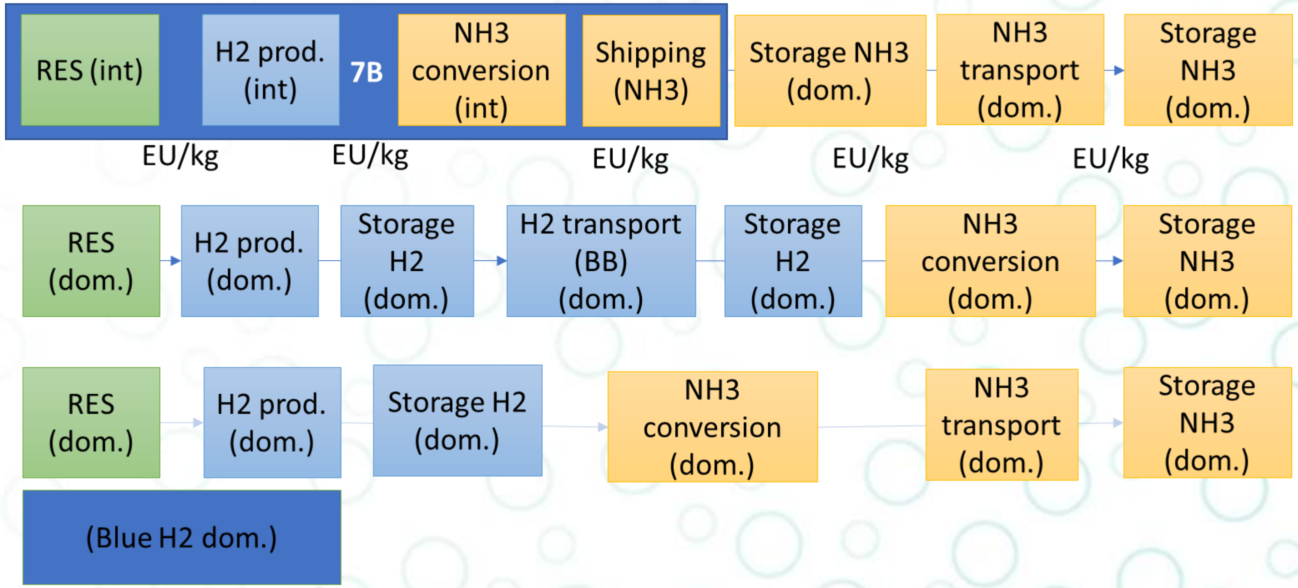
Exhibit 19: Required hydrogen production cost for breakeven with conventional solutions, with 100 USD/t CO_2e



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

Progress of the work in the period

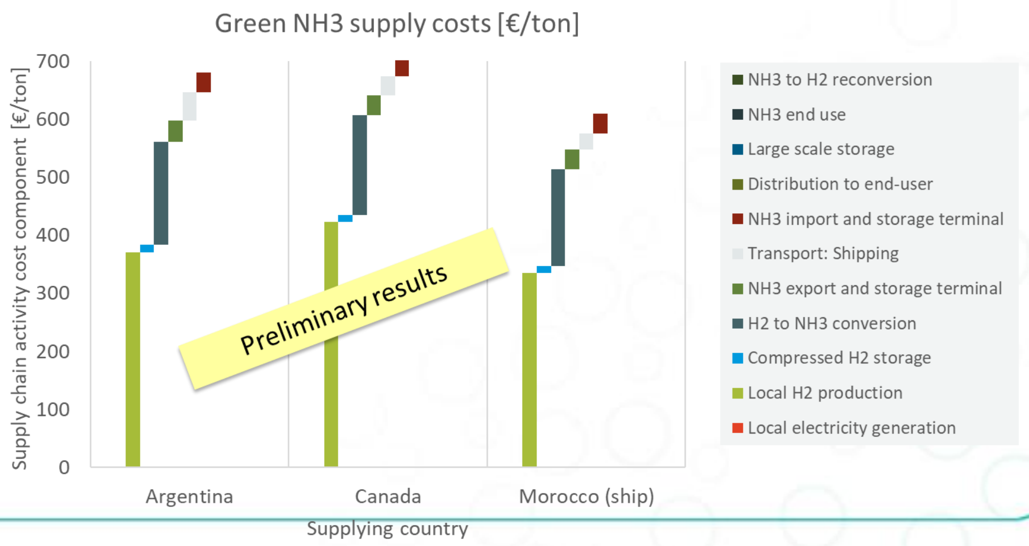
- Design of Value chain model: first NH3
  - Import vs domestic value chains
  - Onshore vs inland
  - Green vs blue

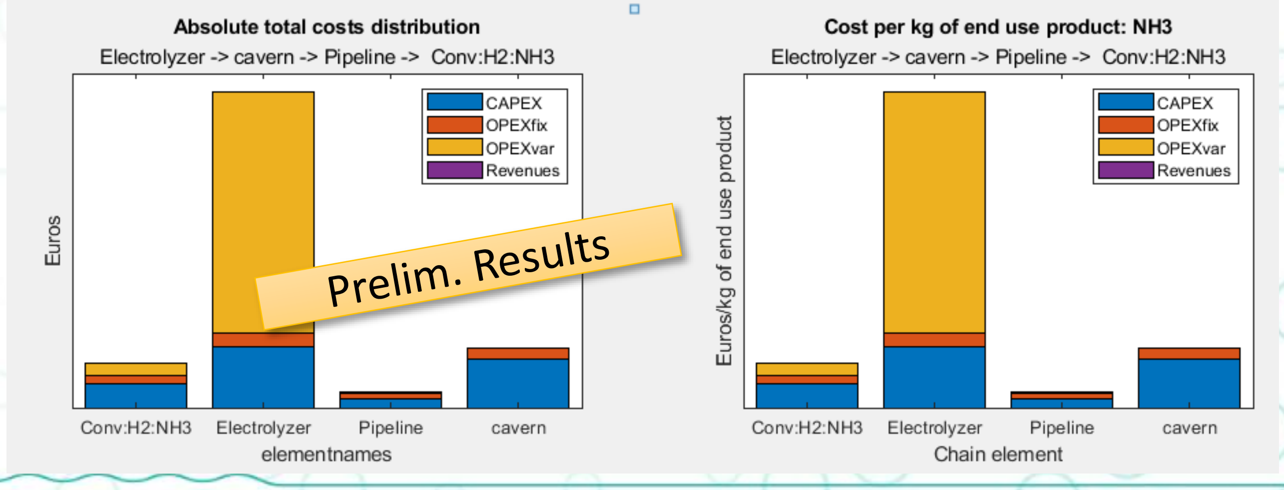


Work to be done in the next period: Modelling

- 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?

HyDelta

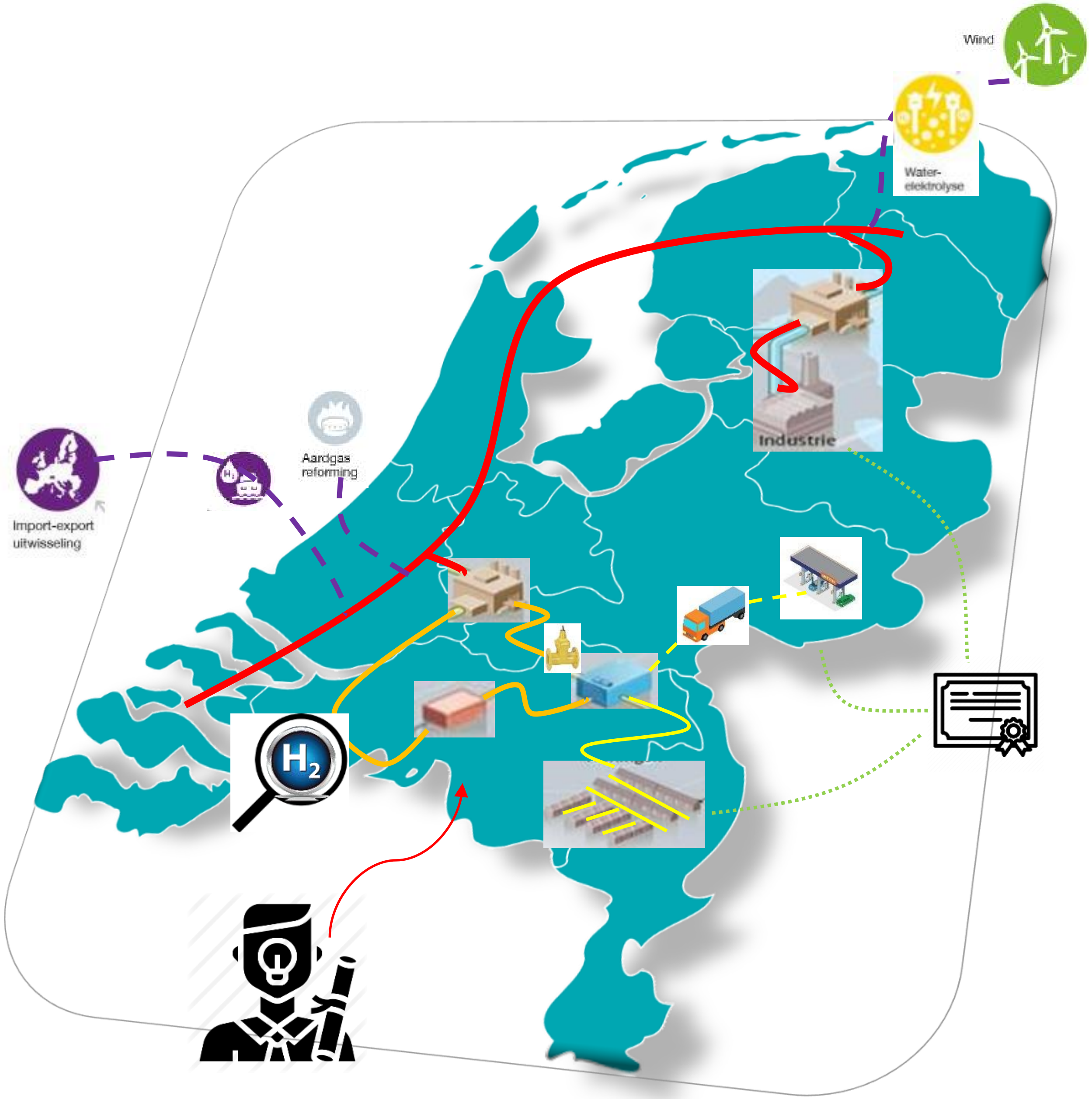
WP7B

Innovation roadmap & hydrogen import

TNO

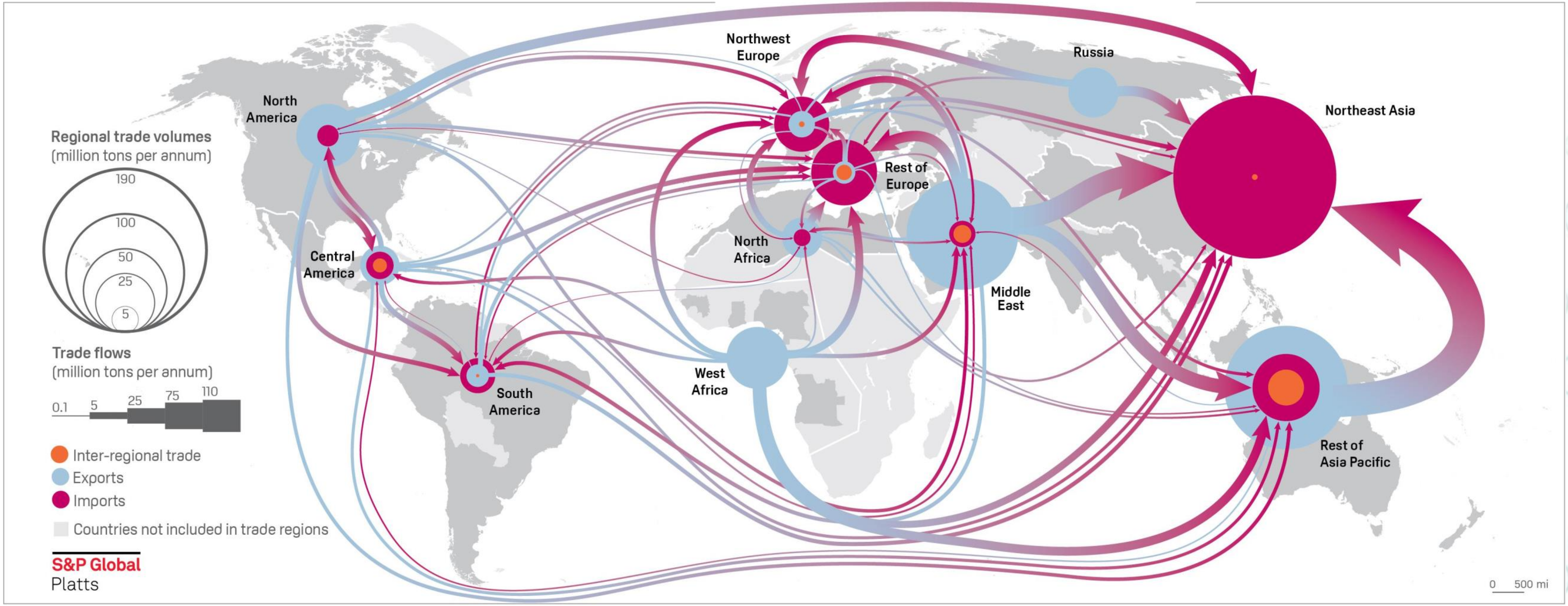
Sara Wieclawska

30-06-2021



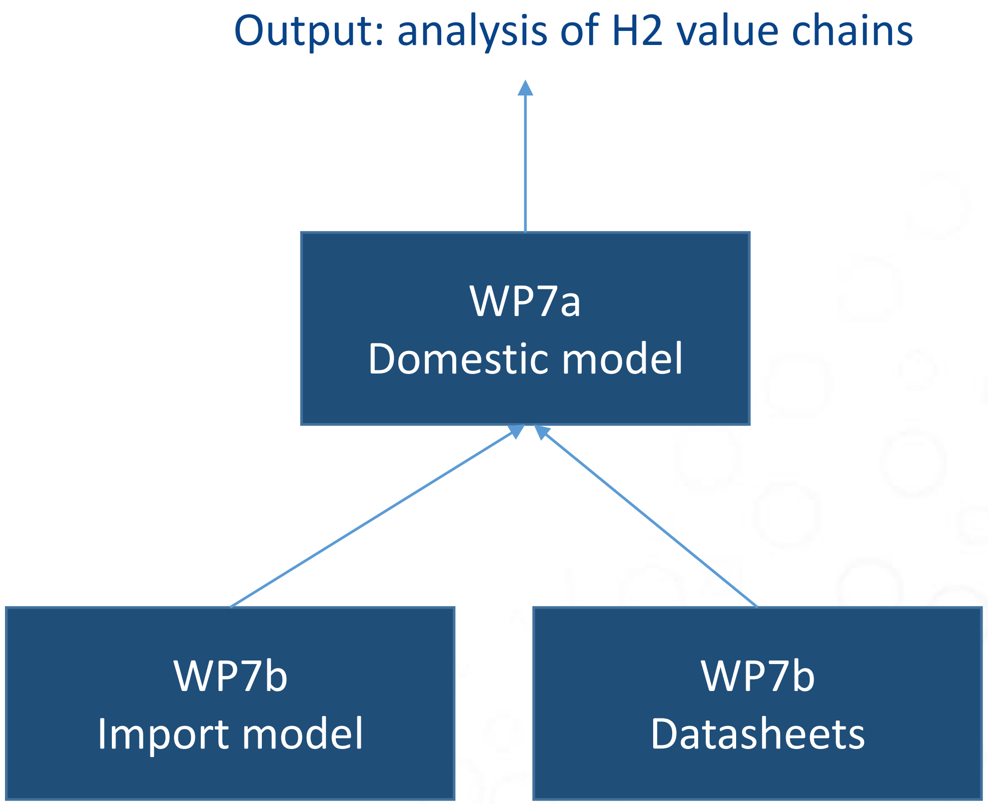
Main objectives of the WP

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 (LH_2, NH_3, LOHCs, MeOH, HCOOH, KBH_4)

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

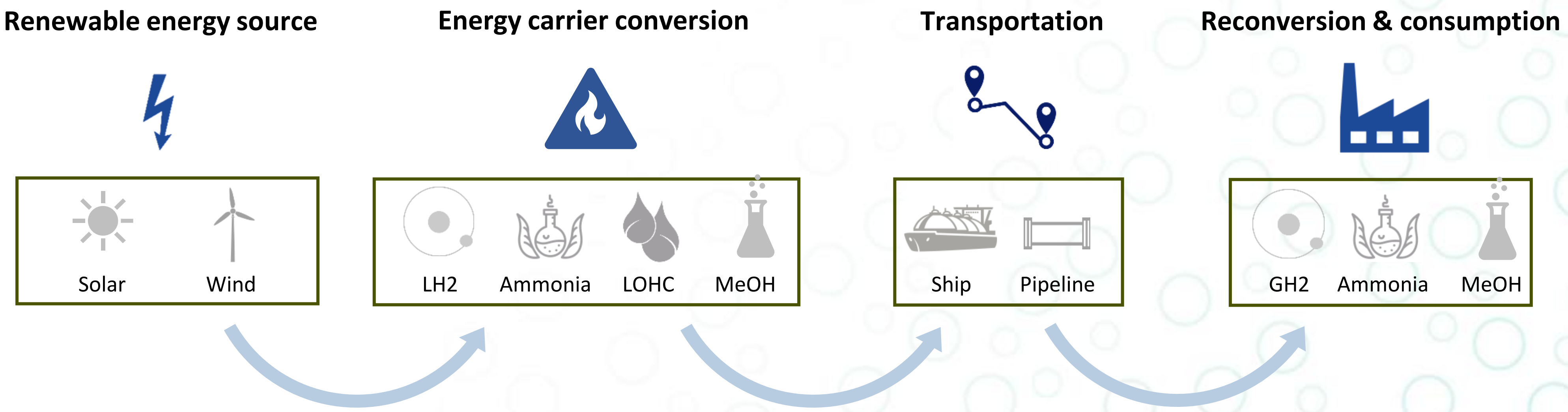
Task 4 – cost models / factsheets

- 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

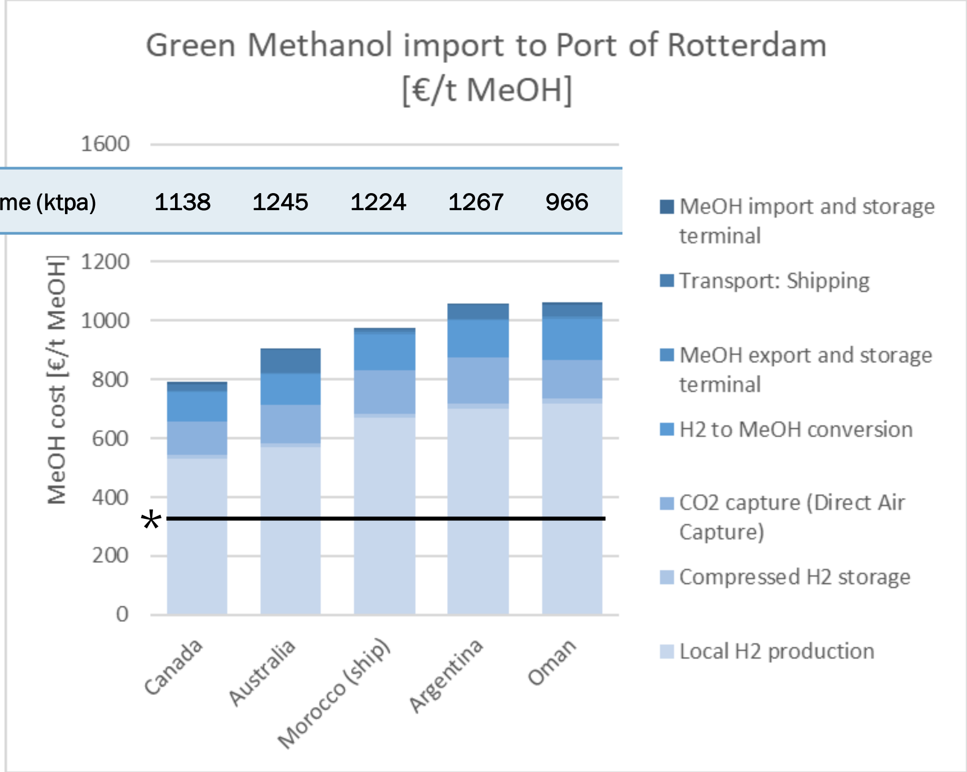
Assumptions:
- 2030
- 3GW RES locally, 2.7GW PtH2
- Design capacity 1000 ktpa (MeOH)
- Scaling factors included
- Electr. Back-up: grid, LCoS

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

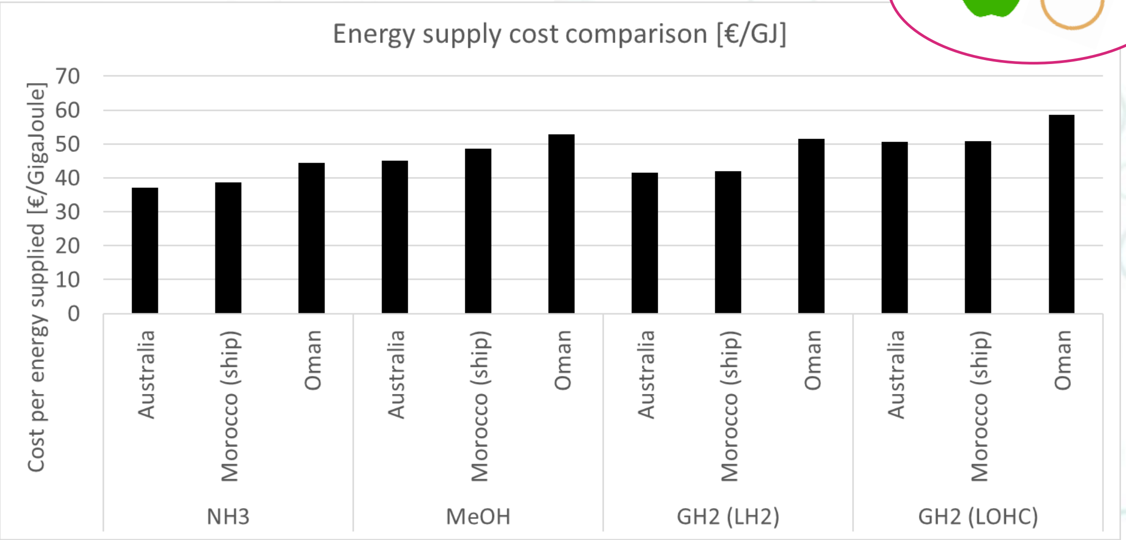
Progress of the work in the period

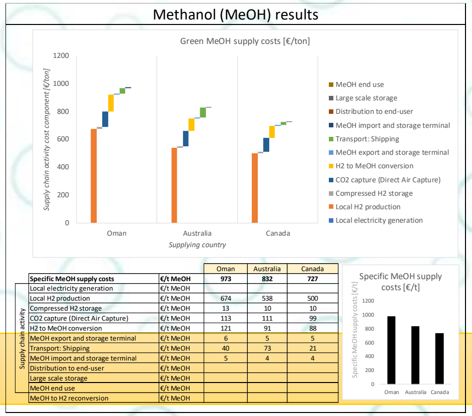
WP7b
Import model

- Results



Volume (ktpa)	1138	1245	1224	1267	966





			Oman	Australia	Canada
	Specific MeOH supply costs	**€/t MeOH**	**973**	**832**	**727**
Supply chain activity	Local electricity generation	€/t MeOH			
	Local H2 production	€/t MeOH	674	538	500
	Compressed H2 storage	€/t MeOH	13	10	10
	CO2 capture (Direct Air Capture)	€/t MeOH	113	111	99
	H2 to MeOH conversion	€/t MeOH	121	91	88
	MeOH export and storage terminal	€/t MeOH	6	5	5
	Transport: Shipping	€/t MeOH	40	73	21
	MeOH import and storage terminal	€/t MeOH	5	4	4
	Distribution to end-user	€/t MeOH			
	Large scale storage	€/t MeOH			
	MeOH end use	€/t MeOH			
	MeOH to H2 reconversion	€/t MeOH			

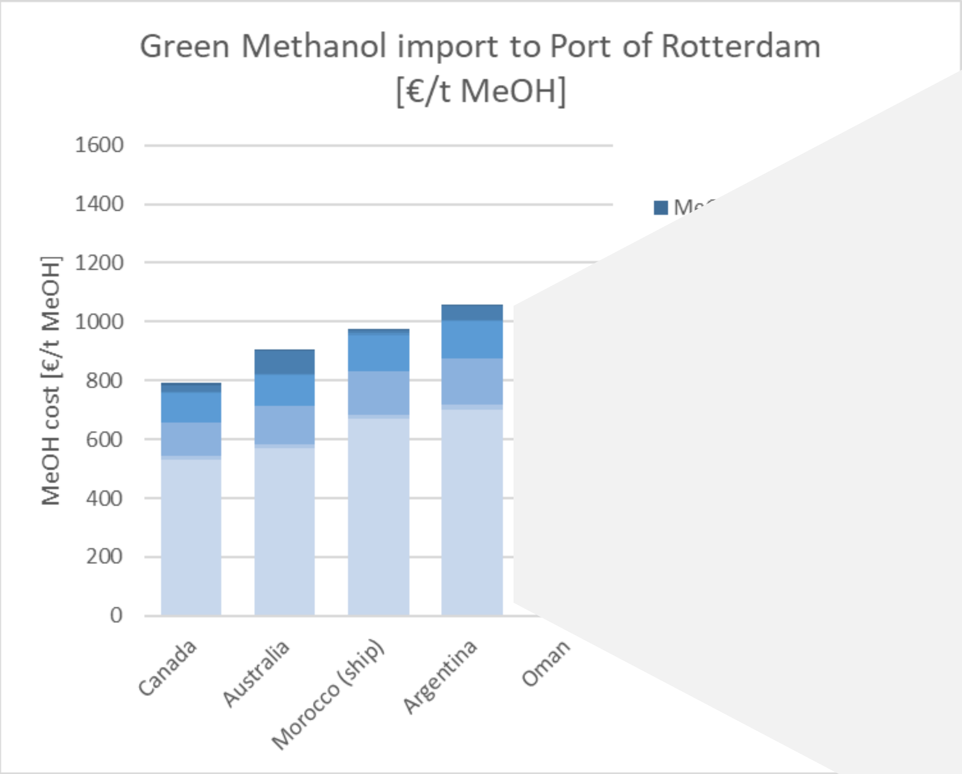
Each hydrogen carrier chain has specific ‘characteristics’

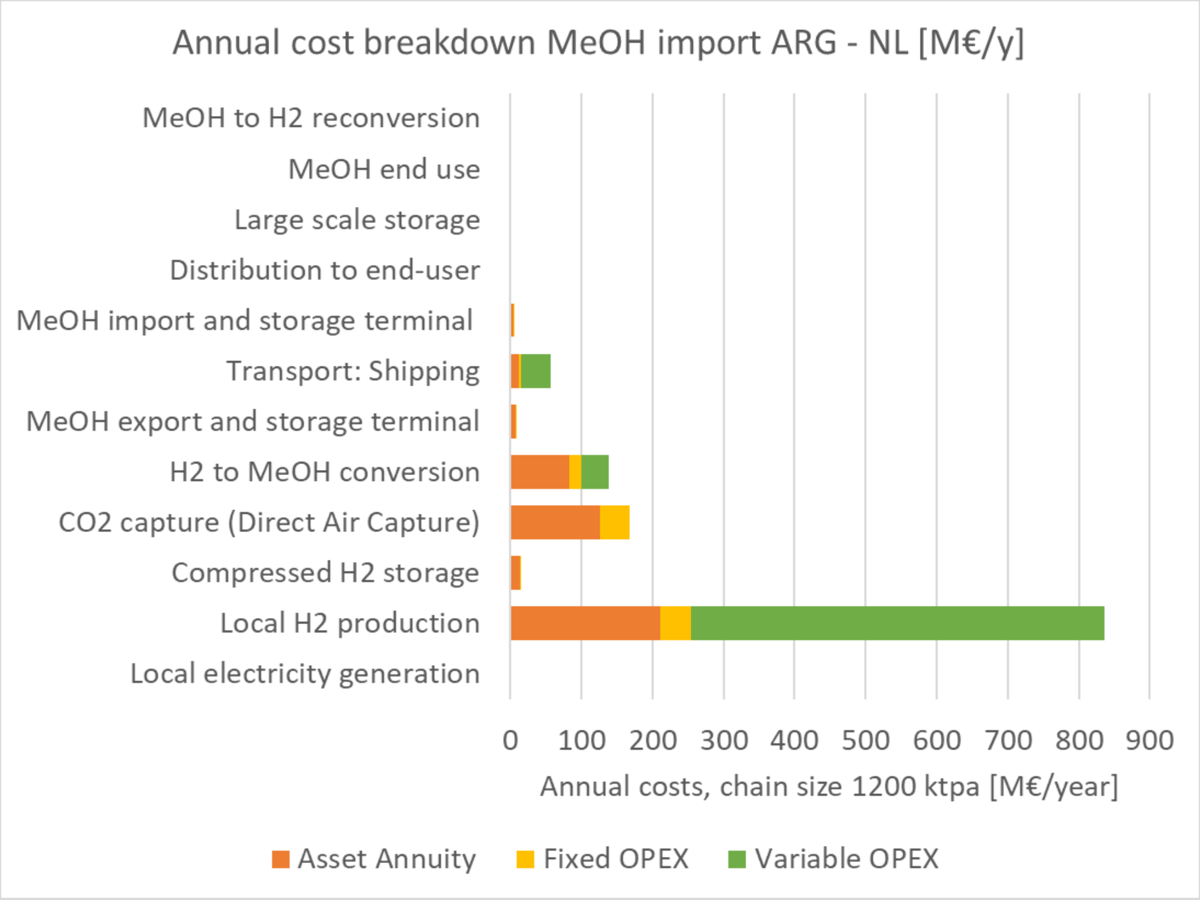
Progress of the work in the period

WP7b
Import model

HyDelta

- Results





Progress of the work in the period

WP7b Datasheets

HyDelta

- Results

Tag	Production	Tag	Conversion	Tag	Terminals (export/import)	Tag	Shipping	Tag	Storage	Tag	Reconversion	Tag	Infrastructure
P1	Electrolysis - Alkaline	C1	H2 compression	T1	Terminal - LH2	SH1	Shipping LH2	ST1	CH2 storage - HP vessels	R1	LH2 regasification	I1	GH2 pipeline
P2	Electrolysis - PEM	C2	H2 liquefaction	T2	Terminal - NH3	SH2	Shipping NH3	ST2	CH2 storage - salt caverns	R2	NH3 dissociation	I2	GH2 Compressor station
P3	SMR + CCS	C3	NH3 synthesis	T3	Terminal - MeOH	SH3	Shipping MeOH	ST3	Liquid storage (LH2)	R3	MeOH reforming	I3	?
P4	ATR + CCS	C4	MeOH synthesis	T4	Terminal - LOHC	SH4	Shipping LOHC	ST4	Liquid storage (NH3)	R4	LOHC dehydrogenation		
		C5	LOHC hydrogenation	T5	Terminal - FA	SH5	Shipping FA	ST5	Liquid storage (MeOH)	R5	FA decomposition		
		C6	HCOOH synthesis	T6	Terminal - KBH4	SH6	Shipping KBH4	ST6	Liquid storage (LOHC)	R6	KBH4 decomposition (?)		
		C7	KBH4 synthesis										

P1: Electrolysis - PEM

Parameter name	Description	Unit	Source ID	Values/estimates 2020 Low	2020 Mid	2020 High	2030 Low	2030 Mid	2030 High	2040 Low	2040 Mid	2040 High	Remarks
	Scale of the electrolyzer plant	[MW]			20			20			20		AC input power to the system (i.e. larger than the total DC capacity of the stacks). Anchor point for CAPEX scaling
	System energy efficiency	[%]	(1-3)		60			66			70		Power2H2 system efficiency, LHV basis. These values correspond to running at nominal capacity.
	Specific power consumption	[kWh/kg H2]	(1-3)		55.6			50.5			47.6		Total power input for the system
	Heat released	[%]			30			24			20		Low temp / rough estimate. This is inversely correlated with system efficiency and roughly estimated as 90% - system efficiency (assuming that 10% of the energy input can't be recovered as heat)
	H2 output, hourly	[t/h]			0.4			0.4			0.4		At nominal capacity / correlated with system efficiency
	Annual utilization	[%]			45			50			65		Assumed to run on green power. Utilization increases as more RES are integrated to the grid & power storage capacity expands
	Operating hours	[h/y]			3942			4380			5694		
	H2 output, annual	[kt/y]			1.4			1.7			2.3		Depends on the annual utilization of the plant. Values correspond to a 20MW (power input) plant capacity
	O2 output, annual	[kt/y]			11.4			13.9			18.0		Based on the mass balance (8 kg of O2 per kg of H2)
	Total direct cost, specific	[€/kW]	(1-4)		1000			652			481		Specific TDC, excluding indirect & EPC costs. The 2030 cost estimate is based on the expectation that costs would drop to 800 €/kW by 2025
	System cost decline (annual)	[%]						4			3		(Guesstimate for) CAPEX reduction beyond 2025
	Total direct cost	[M€]	(1-4)		20.0			13.0			9.6		(1-4) / TNO estimates for future TDC, per annual capacity Overall investment cost (not annualized)
	Scaling factor	N/A			0.9			0.9			0.9		Rough estimate of cost reduction potential when scaling up above 20MW. Electrolyzers don't scale well, because stacks and most of their auxiliary systems are multiplied.
	Fixed OPEX	[M€/y]			0.5			0.3			0.2		Assumed to be 2.5% of TDC, annual cost
	System footprint	[m2]											

Work to be done in the next period

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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 (LH_2, NH_3, LOHCs, MeOH, HCOOH, KBH_4)

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)

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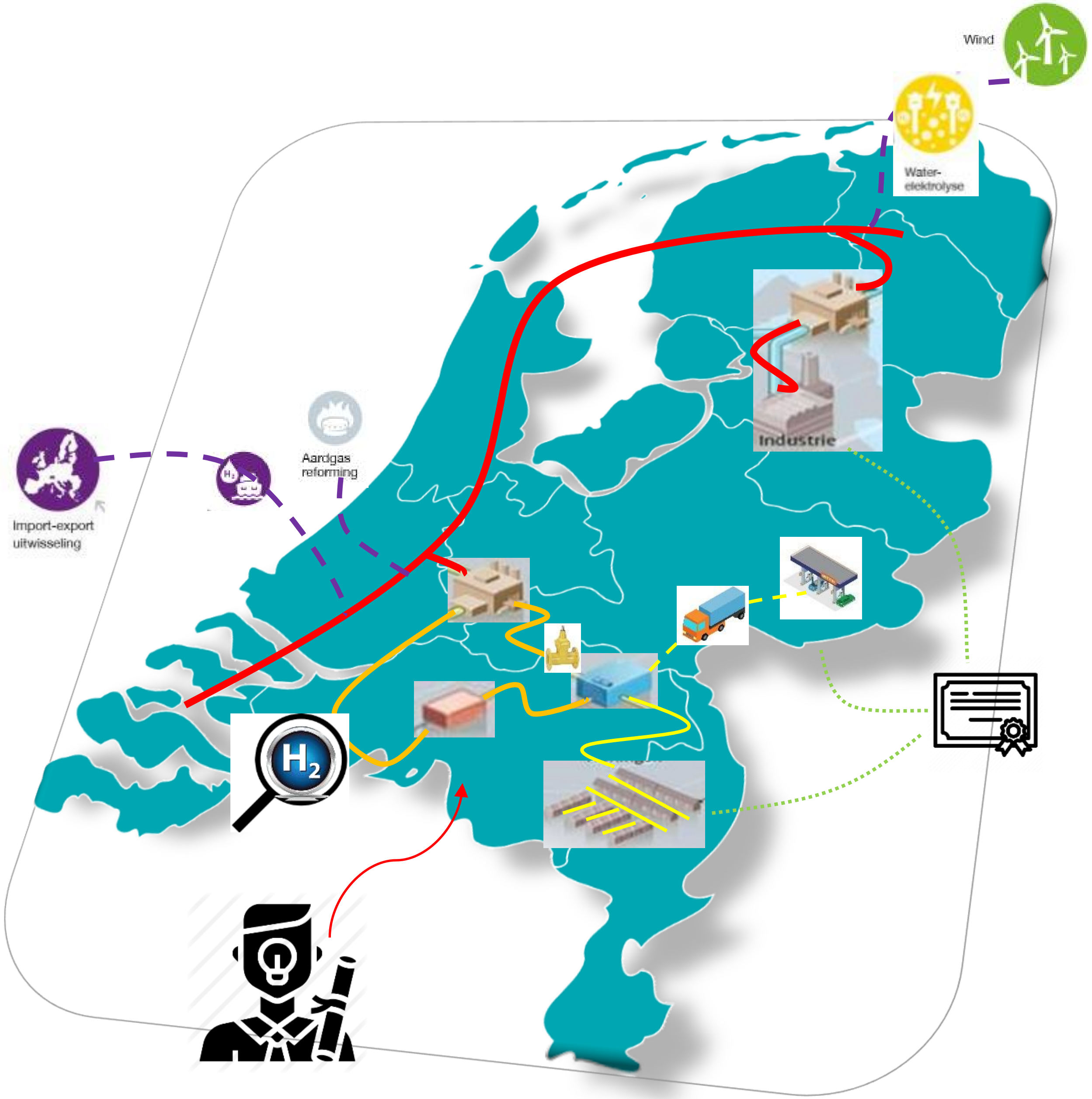
WP8

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

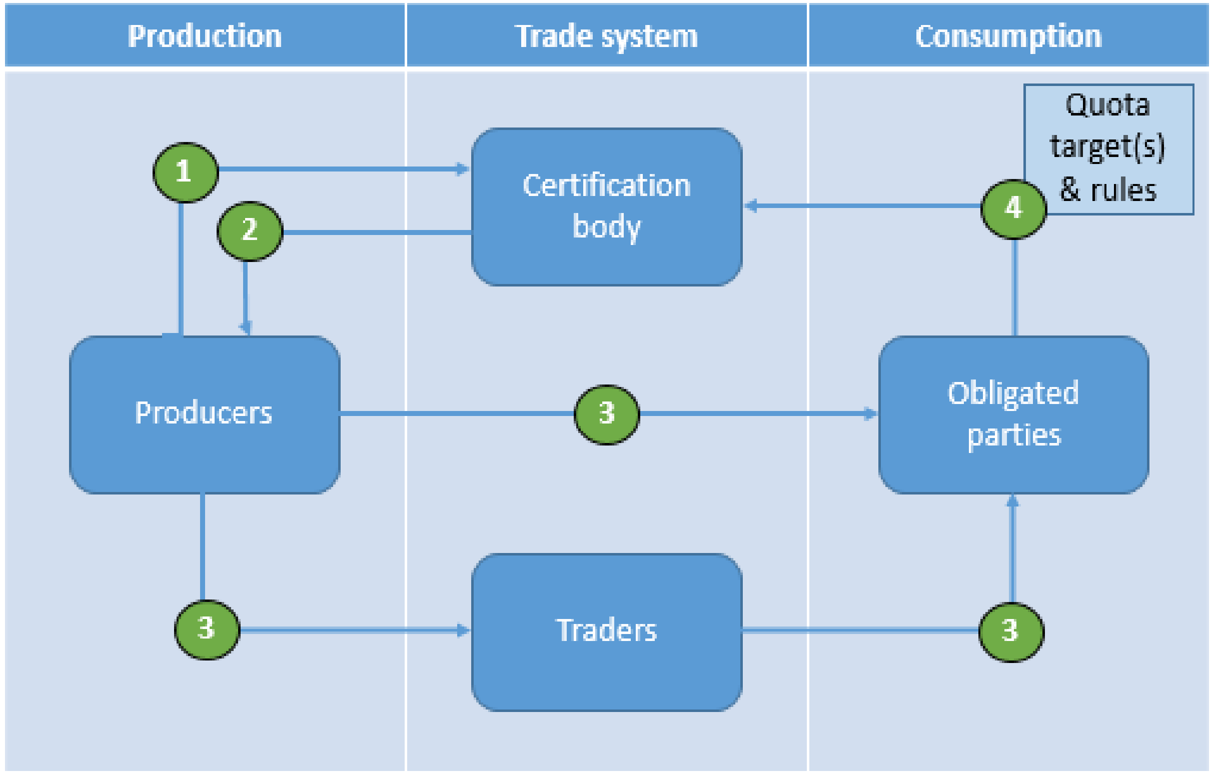
Deliverable 8.1: Summary physical admixing

• 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
• What criteria are set and if different types of certificates be distinquished • If imported certificates allowed to be used to comply to the quota • If and what additionality criteria are set by the scheme	• 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	• 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
• If the acceptance of the certificates is contingent upon existence of satisfactory level of physical blending		

Work to be done in the next period

Finished this month	Jul-Sep	Aug-Dec	Nov-Dec
Assessment of admixing schemes	Describing experiments to roll out blending schemes	Economic analysis	Policy recommendations

Voluntary:

- CertiQ electricity
- Vertogas green gas

Mandatory:

- Dutch Fuel blending
- Norwegian-Swedish electricity quota

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Thank you for your attention!

Questions? Send them to:

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