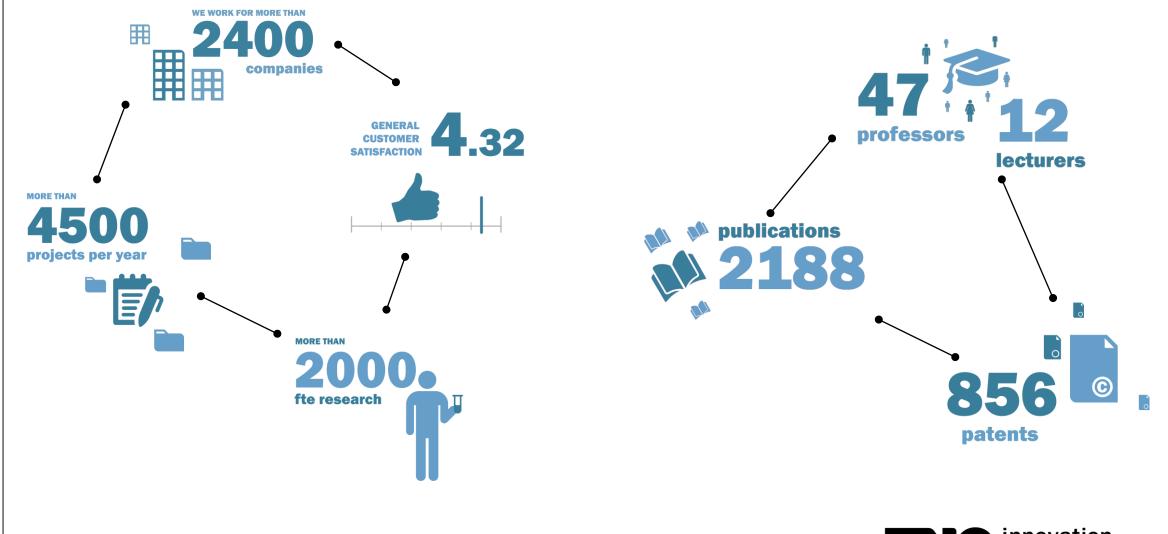


> HYDROGEN TRANSPORT IN THE NORTH SE RECENT TNO PROJECTS | NÉSTOR GONZÁLEZ

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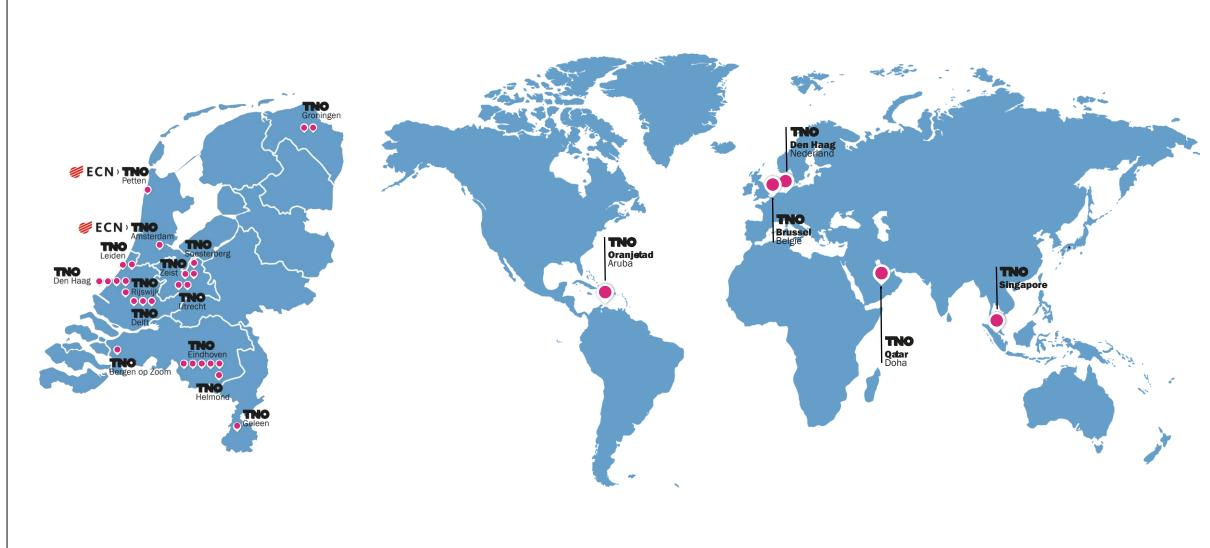
.01 INTRODUCTION TO TNO .02 NORTH SEA ENERGY & POSHYDON .03 TECHNOLOGY DEVELOPMENT @ TNO

TNO END 2017

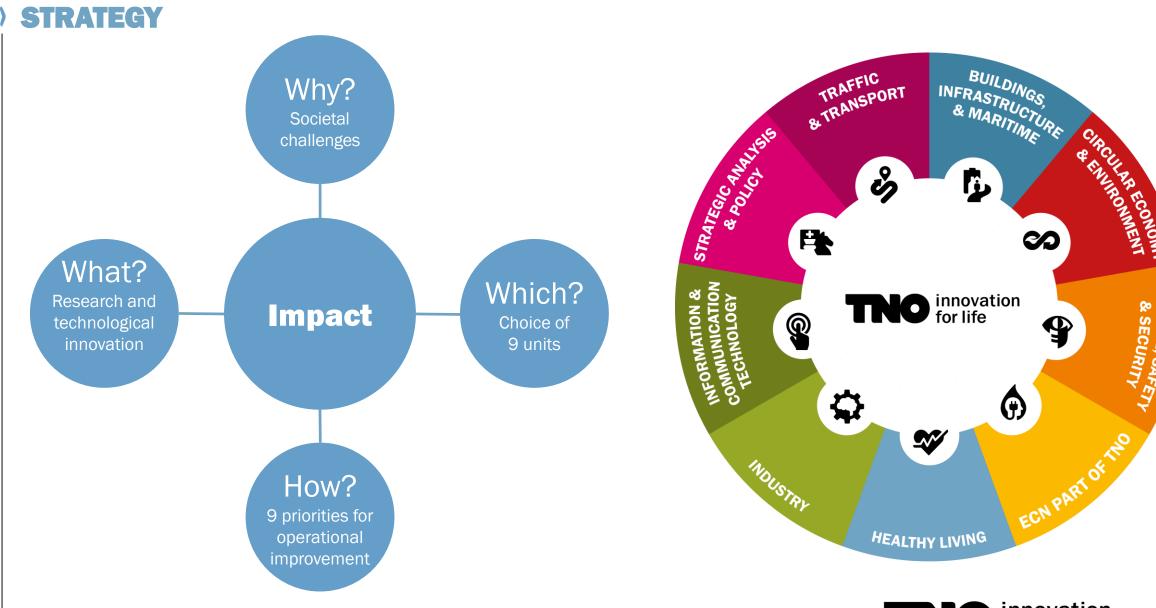




LOCATIONS









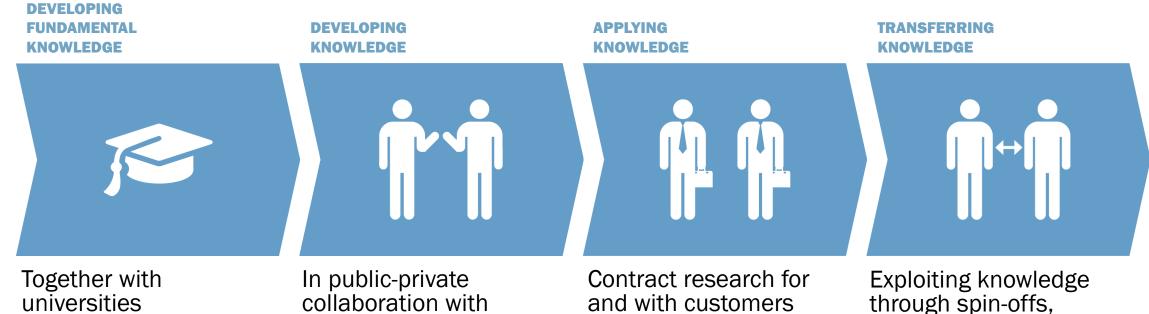
CIRCULAR ECONOMY CIRCULAR ECONOMY

DEFENCE, SAFETY & SECURITY

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9

INNOVATION PROCESS



collaboration with partners from the golden triangle

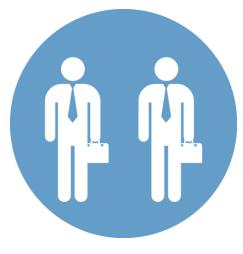
and with customers

Exploiting knowledge through spin-offs, licences, etc together with other companies



THREE ROLES OF TNO





TNO AS CATALYST IN PUBLIC-PRIVATE PARTNERSHIPS

- Open innovation, such as the Holst Centre, and driven by demand from Topsectors
- Funding: mix of private & public

TNO AS EXECUTOR OF CONTRACT RESEARCH FOR CUSTOMERS

 Funding: 100% paid by the customer

TNO AS EXECUTOR OF ASSIGNED TASKS

- Geological Survey of the Netherlands
- Research for Ministry of Defence
- Research for Ministry of Social Affairs and Employment



HYDROGEN SCOPE IN TNO



Program lines

- Hydrogen production
- Infrastructure
- Storage
- Output Synthetic fuels
- 6 Fuel Cells
- Hydrogen system studies

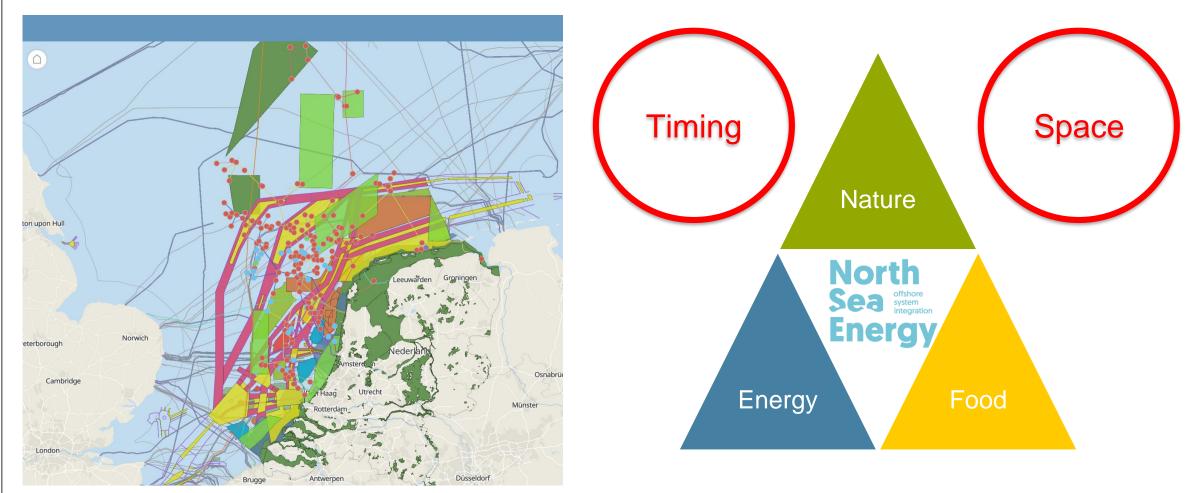


TNO ENERGY TRANSITION

SYSTEM INTEGRATION IN THE NORTH SEA



THE NORTH SEA CROWDED WITH MANY INTERESTS AND FUNCTIONS



https://north-sea-energy.eu/en/energy-atlas/



THE NORTH SEA ENERGY PROGRAM A PUBLIC-PRIVATE PARTNERSHIP

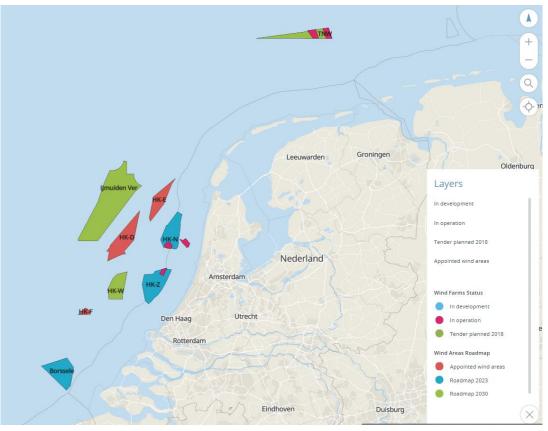


Research program aimed at research & development of opportunities for system integration by integrating offshore wind and gas

Phase IV: + 30 partners from industry, research and NGO www.north-sea-energy.eu



OFFSHORE WIND IN NETHERLANDS FROM 1 TO 60 GW



Eemshave Qudeschip Zwolle Lel vstav Amster dan Utrech Arahen Eindhover Esrl Nederland, Community Map Contributors

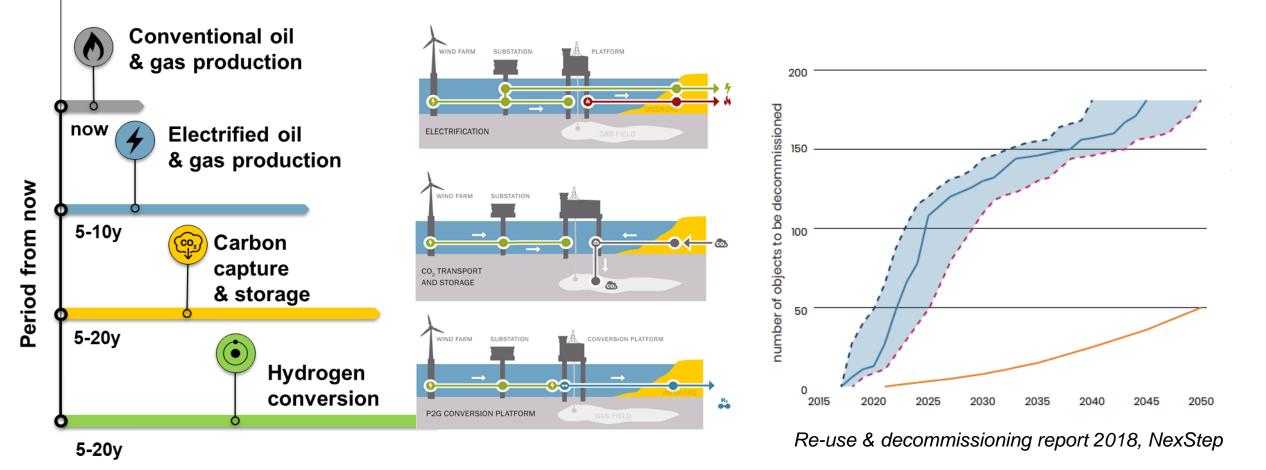
Source: North Sea Energy Atlas

Offshore wind build-up known quite well up to 2030 (11,5 GW). Towards 2050 up to 60 GW of wind

Source: Kamerbrief Wind 2019

 Until 2030 transport and landing of wind from offshore full electric
 TNO innovation for life

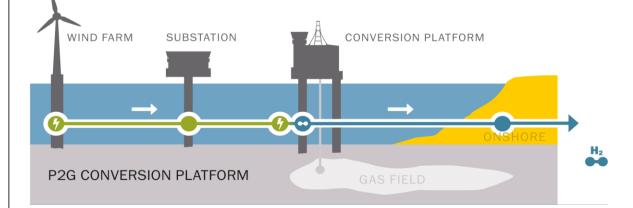
SYSTEM INTEGRATION OFFSHORE INFRASTRUCTURE BECOMING "AVAILABLE" FOR OTHER FUNCTION

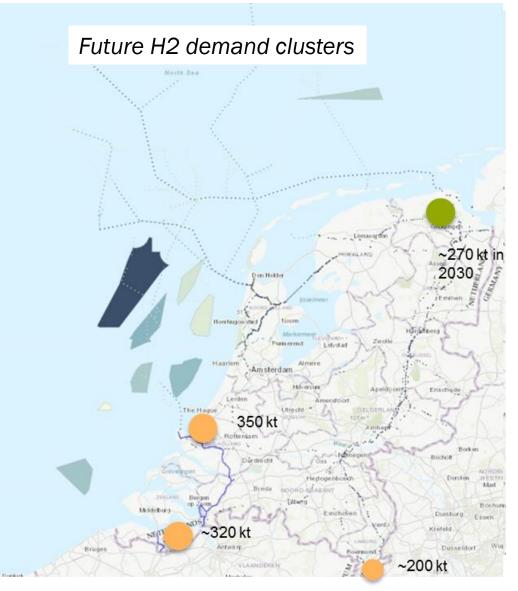


TNO innovation for life

OFFSHORE POWER-TO-GAS

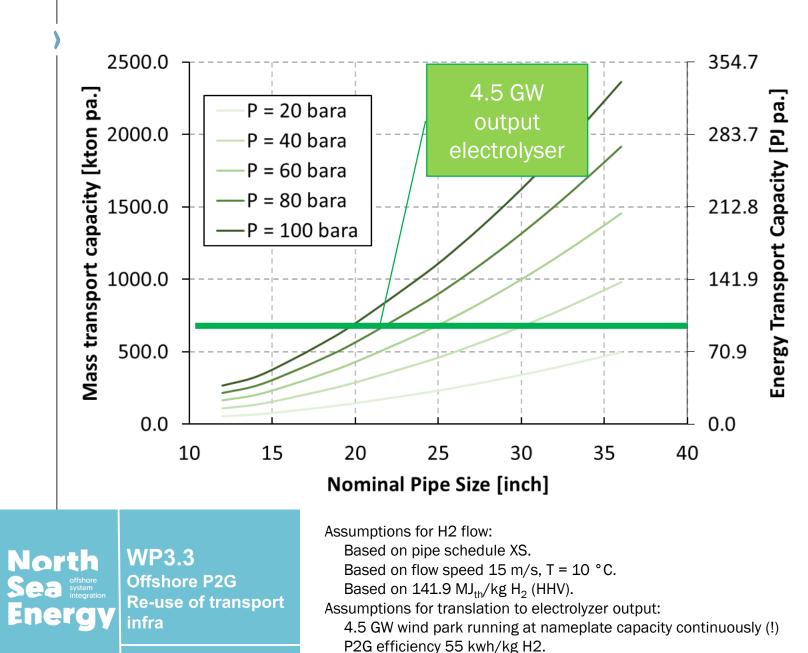
- > Convert offshore wind power into hydrogen
- > Hydrogen transport via existing pipelines
- Offshore wind can generate green electrons or molecules
- > P2G facilitates sector coupling with other industries

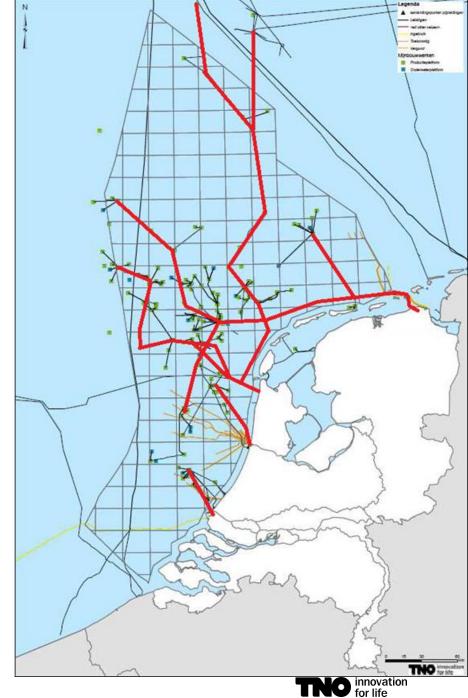




North Sea energy Atlas <u>http://www.north-sea-energy.eu</u> Contouren van een Routekaart Waterstof 2018 NIB De Groene Waterstofeconomie in Noord Nederland 2017







PIPELINE RE-USE CHALLENGES - OFFSHORE

- Offshore pipelines in Dutch continental shelf typically looking
 - X60s, longitudinally welded
 - > Trenched
- Questions very similar as those for on-shore:
- > Material degradation
- > Fatigue
- Impact for fittings
- > Tolerable concentration in natural gas? Associated equipment?
-) In addition:
 - > Injection in a live flowline producing hydrocarbons (two-phase flow)
 - Offshore safety
 - > Operational procedures (shut-ins, operator training, etc)

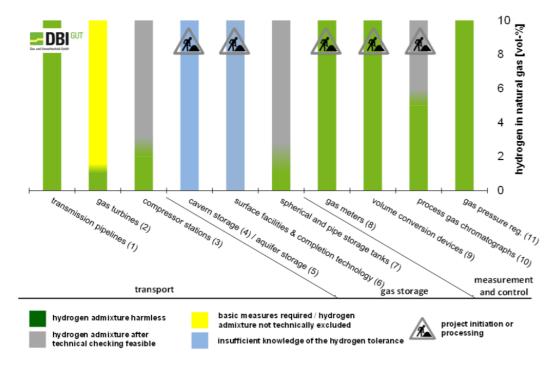
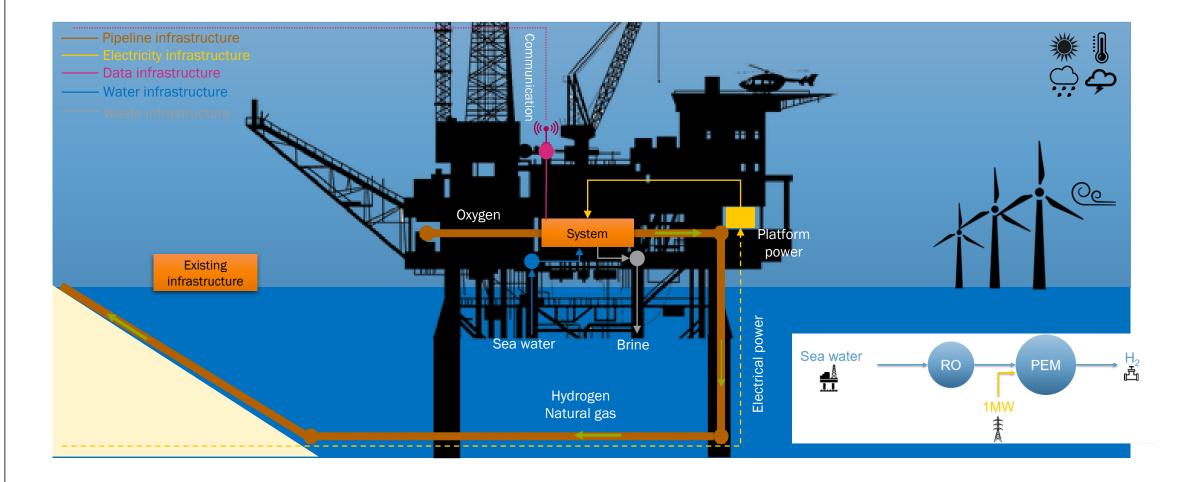


Figure 1: Hydrogen tolerance of gas transmission network, storage, measurement and control; March 2017



3P2GO - POSHYDON OVERALL SYSTEM ARRANGEMENT

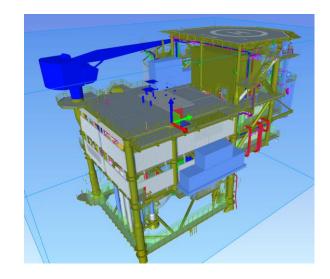




3P2GO - POSHYDON PILOT OBJECTIVE

Determine costs of offshore hydrogen production compared to onshore

- Installation
- Operation
- > Maintenance and inspection
- Determine performance of offshore hydrogen production
- > Under offshore conditions
- > Under dynamic loading conditions, mimicing offshore wind profiles
- > System performance (RO and electrolyser)
- > Learn about admixing of hydrogen with natural gas
 - > Up to 10% in gas stream from Q13a to P15
 - > Around 1% in gas stream from P15 to Maasvlakte
- Safety aspects
- Design criteria
- > Combined production of O&G and Hydrogen





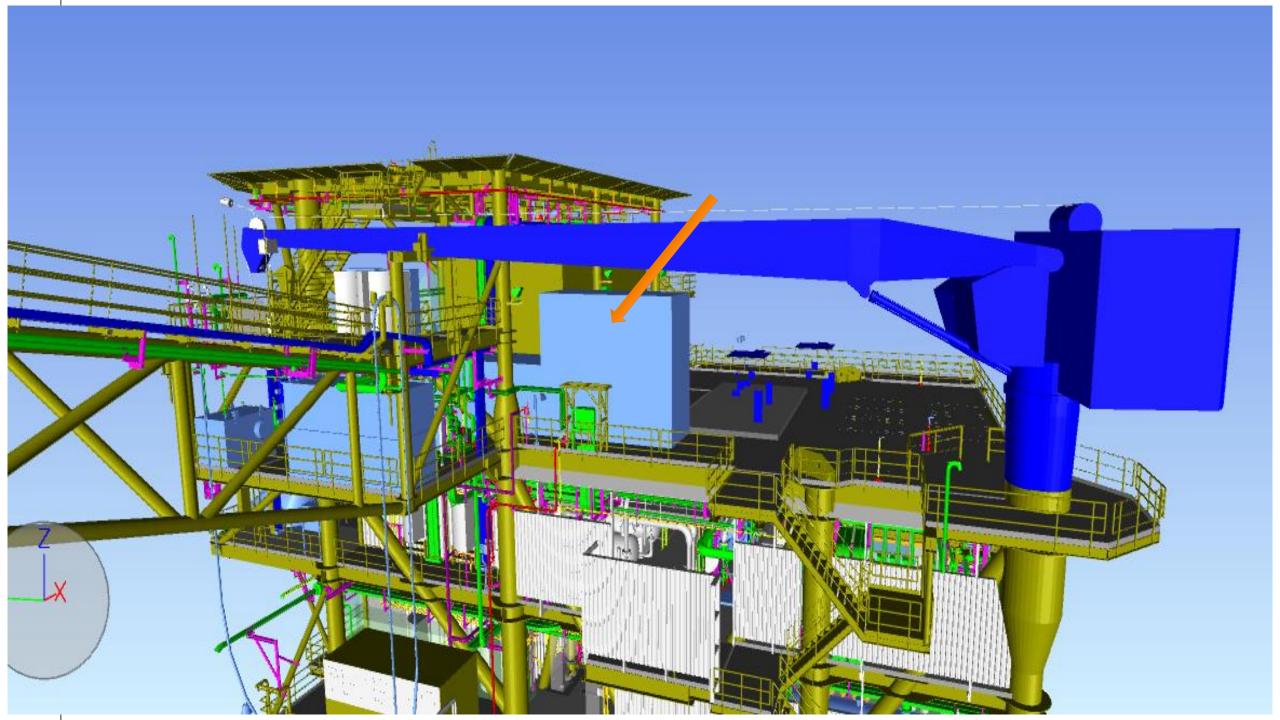


3P2GO - POSHYDON NEPTUNE ENERGY Q13A PLATFORM SPECS

-) Installation: 2013
- > Location coordinates: offshore The Hague
- > Distance from the Scheveningen shore: 13.4 km
- Normally unmanned
-) Main deck area: 400m²
-) Deck load: 1680 kg/m²
- Maximum POB: 14 fte
-) Water depth: 20 m
- > Fully electrified from shore (25 kV)
- > Power capacity 9 MW of which 25% used
- > Current production: 4000 b/d oil + 40,000 Nm³/d gas

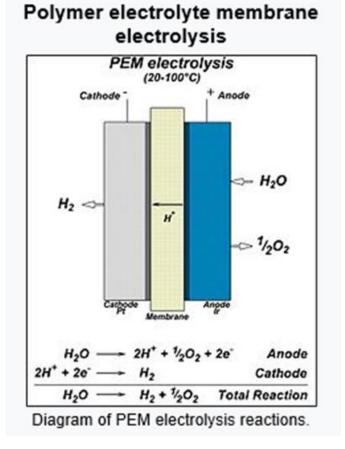






3P2GO - POSHYDON TECHNOLOGY SELECTION

>	Туре:	PEM electrolyser
>	Manufacturer	Hydrogenics
>	Nr. of Cell stacks:	1
>	Input power:	1 MW
>	Water consumption:	300 l/h
>	Hydrogen flow:	200Nm³/h
>	Hydrogen purity:	99.998%
)	Outlet pressure:	30 barg
)	Footprint:	40ft container
>	Weight:	lifting weight of < 20 tonnes
>	Seawater treatment	RO desalinisation

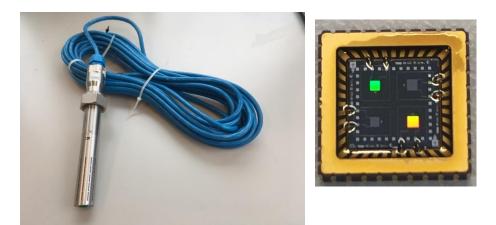


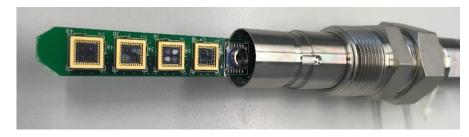


GAS COMPOSITION MONITORING LOW COST, IN-LINE

- Development initiated by the gas grid operators.
 Facing a future huge variation in gas composition (high calorific Russian gas, Biogas, LNG).
- In the Netherlands relatively strong reduction of fossil gas due to depletion of the Groningen gas field and recent earth quakes.
- Need for monitoring the gas quality at feed-in and further on in the network. High amount of measuring points, combined with models.
- No suitable sensors available. Goal **TNO sensor technology** development
 - Inline monitoring
 - Cost effective
 - Fast response

) ATEX



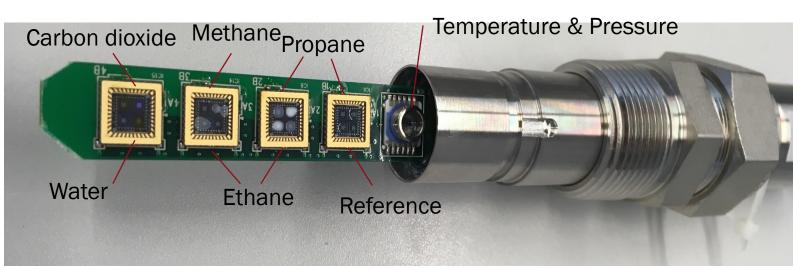


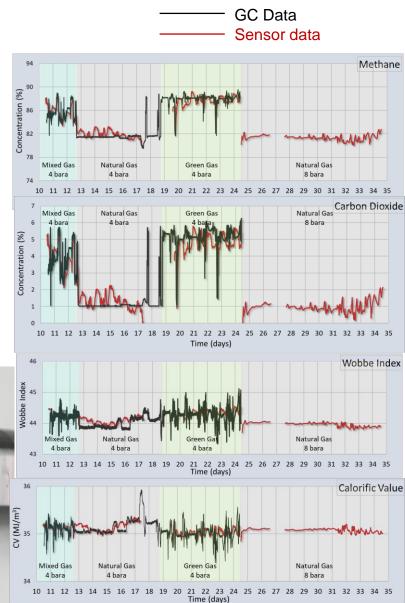
- Realized by combining capacitive electrodes and responsive coatings
- > Enables calculation of calorific value, Wobbe Index, Methane Number, density, ..



GAS COMPOSITION SENSOR TECHNOLOGY AND PERFORMANCE

- > Array of 8-10 chips that measure the change in capacitance
 - The coating will preferably absorb one of the gases and capacitance increases
 - > Upon a decrease in concentration the capacitance decreases and makes the sensor reversible
 - > Temperature and pressure sensors are integrated
 - Prototype used for natural gas / biogas field tests

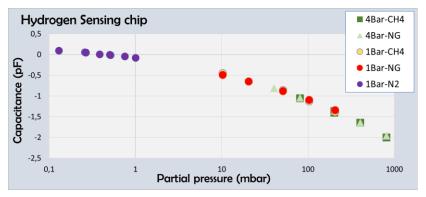




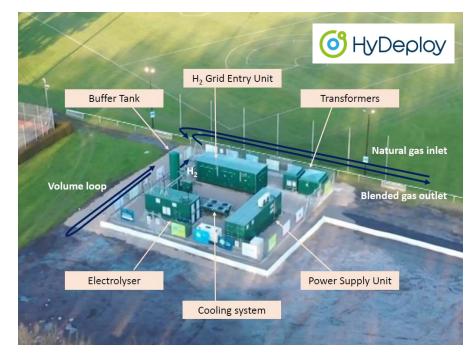


GAS COMPOSITION SENSOR APPLICATION TO HYDROGEN

- Prototype development for measuring full composition of hydrogen blended with natural gas, together with gas grid operators.
- > Aimed operation range 0.1 90 Vol% Hydrogen
- > First field trial in the HyDeploy project (Keele, UK) starting June 2020
- Three sensors are installed, measuring concentration of C1-C3, C4+, Nitrogen, CO2 and Hydrogen
- > 20% Hydrogen blended in the grid



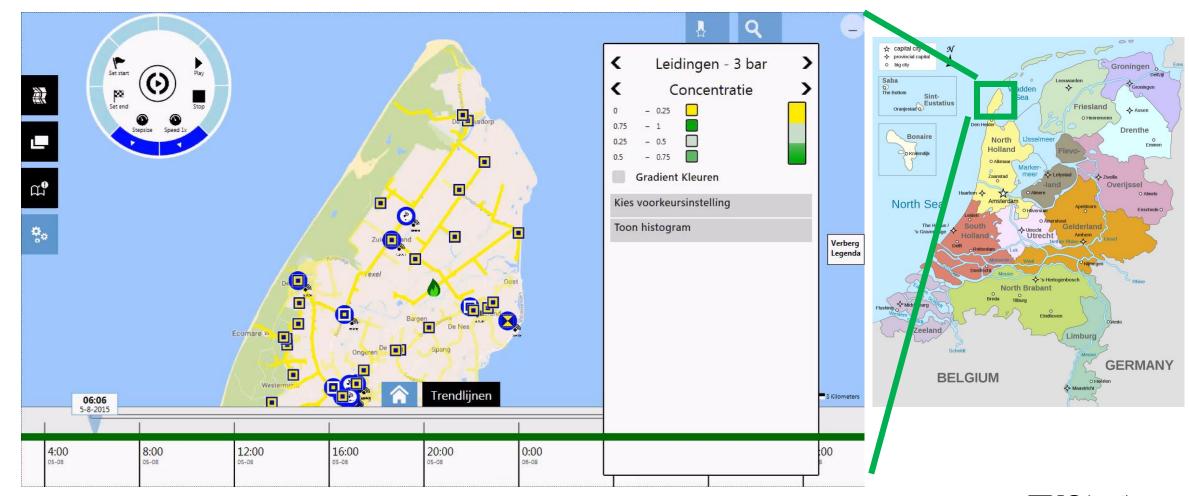




TNO Lab results, sensitivity to H2 additions



NETWORK MODELLING + GAS SENSOR = ONLINE NETWORK MANAGEMENT



NO innovation for life



TO CLOSE









Innovative H2 monitoring technology

In-line, cost-effective composition sensor
H2 purity sensor
H2 flow meter

Network real-time management

- Dynamic network behaviour
- Dynamic risk assessment
- Design optimization (risks security of supply)
- Spatial planning and optimization
- (new!) Combination for H2 and electricity network (within Leveringzekerheid)

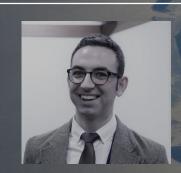
Safe and reliable H2 transport

Safeguarding the safety and integrity of H2 production and transport infra
Feasibility offshore hydrogen

Operational optimization of hybrid assets

• Model-based operational optimization of hybrid assets combining renewable power and conversion to green energy carriers

YOUR TIME



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