Waterstof:
wat, status en perspectieven

Adwin Martens
WaterstofNet

> 70.000 km **2 tankstations** **12 projecten**

Antwerpen, 20 juni 2018

Waterstof ??

- Waterstofeconomie lost energieprobleem op
- Waterstof wordt onmogelijk gemaakt door olielobby
- Waterstof is de eeuwigdurende belofte
- Waterstof is toppunt van duurzaamheid …. of… waterstof is helemaal niet duurzaam
- Waterstof is gevaarlijk (knalgas, Hindenburg, waterstofbom, Fukushima,….)
- Batterijen maken waterstof overbodig…

WaterstofNet

- Start 2009
- projectorganisatie gevestigd in Turnhout en Helmond
- focus op projecten en roadmaps:
  - 0-emissie mobiliteit
  - energie opslag
- Ontwikkelen, management, realisatie, communicatie
- Samenwerking met bedrijven, overheden en kennisinstellingen
- Vertegenwoordigt België in IEA → Hydrogen Europe
- Lid van Hydrogen Europe
- Hands-on ervaring (5y exploitatie & onderhoud H2 tankstation Helmond & diverse demonstratie projecten

WaterstofNet

2012 2013 2014 2015 2016 2017 2020

Hydrogen Refueling Station Halle

Hydrogen Refueling Station Helmond

Scenario refueling stations Belgium

Hydrogen Mobility Europe

29 refueling stations and 325 cars

2 Buses Eindhoven

Interreg North-West Europe H2-Share

Demonstration of a hydrogen truck in 4 European Countries

Interreg Vlaanderen Nederland

Europa investeert in uw regio

1MW Fuel Cell plant

H2 garbage truck

Hyundai ix35 at WaterstofNet

Life 'N Grab Hy

clean cities, clean air with hydrogen

Demonstration of 2 garbage trucks in 10 cities

Bedrijvencluster Power-to-gas

HYLAW

Analyse regelgeving/barrières

Approved July 2017

H2 boats

H2 forklift truck

H2 passenger bus

POWERTOGAS Roadmap for Flanders

Feasibility study Power-to-gas

BEMOTION

29 buses in 7 cities

Interreg Vlaanderen-Nederland

Demonstrations on infrastructure and zero-emission applications in Flanders and the Netherlands

H2Benelux

Approved July 2017

DONQUICHOTE

Hydrogen in smart grid environment

HIGHVLOCITY

14 buses in 4 cities

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Revive

Status August 2017

International driving forces for hydrogen

- **Waterstof is al gekend in industrie (500 mld Nm³/jaar)**

- **Zero-emissie transport**

  - infrastructure
  - vehicles > 10.000 > 1.000 > 100 > 10

- **Green electricity**

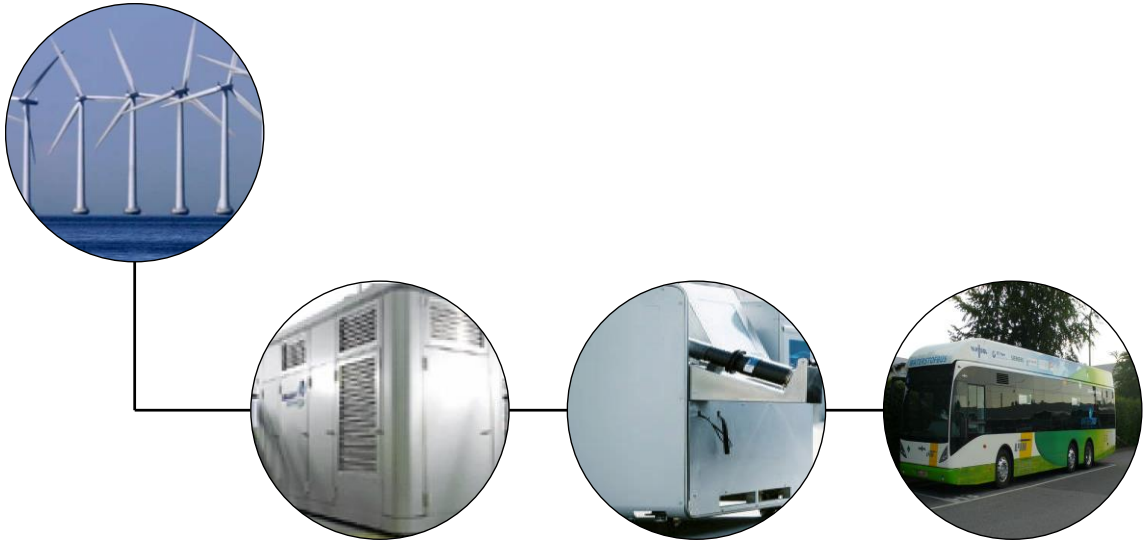
  - value of renewables 150 50 30 19
  - need for storage

- **Europe supports hydrogen and fuel cells (> 100 M€/year, 1,4 Bln €/7 year)**

Wat is waterstof ?

- Symbool: H in de praktijk H_2
- Meer dan 90% van alle atomen in het heelal
- Zit bijna altijd aan iets vast
  - aan zuurstof : water
  - aan koolstof : aardgas, olie, butaan, propaan,…

Waarom waterstof ?



Karakteristieken waterstof

- 14 maal lichter dan lucht
  - Veiligheid
  - Opslag
- Opslag (vloeibaar, gasvormig)
  - Gewicht (1 kg = 100 km)
  - Volume
- Veiligheid
  - Breed explosievenster
  - Lage ontstekingsenergie
  - Vakmanschap

WaterstofNet
Interreg Vlaanderen Nederland
Europese Unie
Europees Fonds voor Regionale Ontwikkeling
Ministerie van Economische Zaken
Met steun van de Vlaamse overheid

rijden op waterstof

- Waterstofbus Van Hool
  - 40 kg waterstof tanken in 10 minuten
  - 400 km rijden zero-emissie

- Batterij - elektrische bus die 400 km rijdt
  5000 kg batterijen en 8 uur laden

  Auto:
  5 kg waterstof, 5 minuten tanken, 500 km rijden

  Batterij-elektrisch : korte afstanden, kleine voertuigen

  Waterstof-elektrisch : lange afstanden, grote voertuigen

Veiligheid waterstof



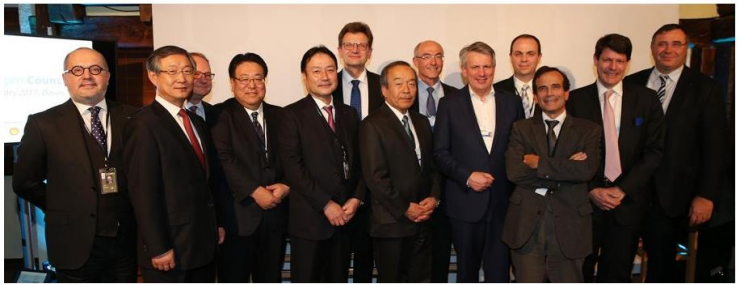
WaterstofNet

Hydrogen Council:

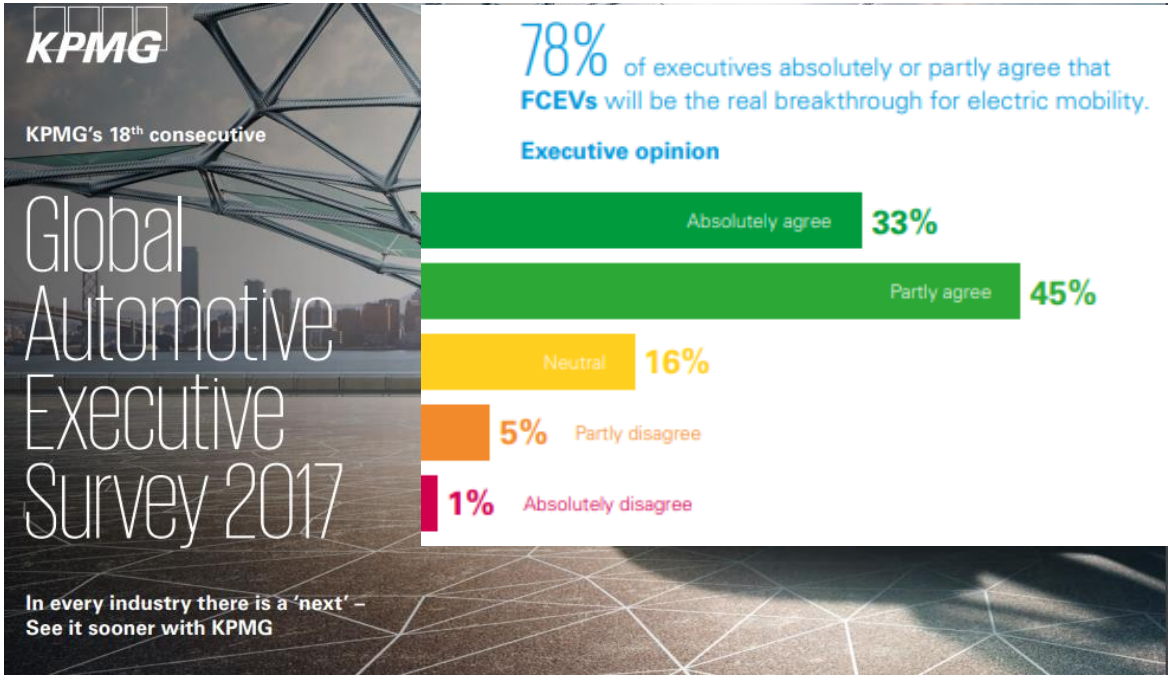
13 multinationals invest 10 billion in hydrogen

AIR LIQUIDE Creative Oxygen · ALSTOM · AngloAmerican · BMW GROUP · DAIMLER · ENGIE by people for people

HONDA · HYUNDAI · Kawasaki · THE LINDE GROUP · TOTAL · TOYOTA



Annual analyses KPMG (> 900 executives)



Business potential for hydrogen in mobility

WaterstofNet

Crucial **price vehicles**

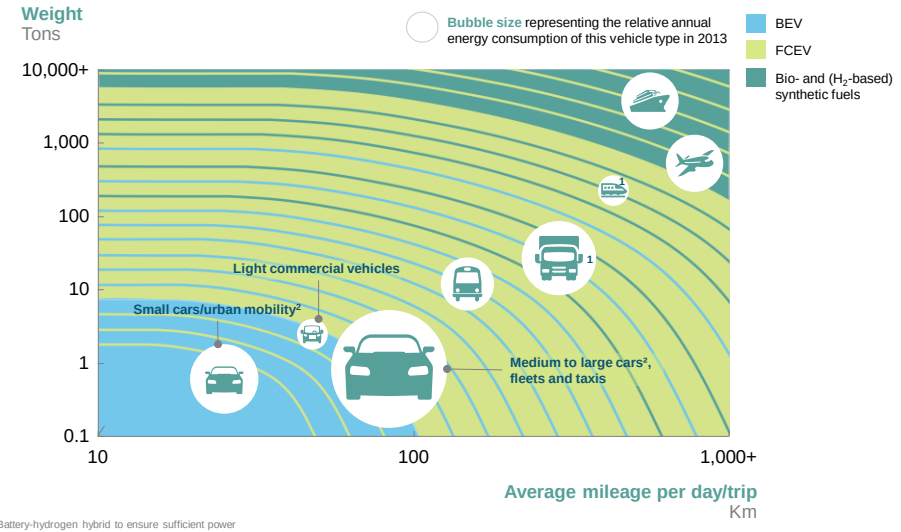
price hydrogen

advantages

FCEVs will play an essential role in decarbonizing transport

Projected economic attractiveness

Reference: HYDROGEN-COUNCIL-Vision-document



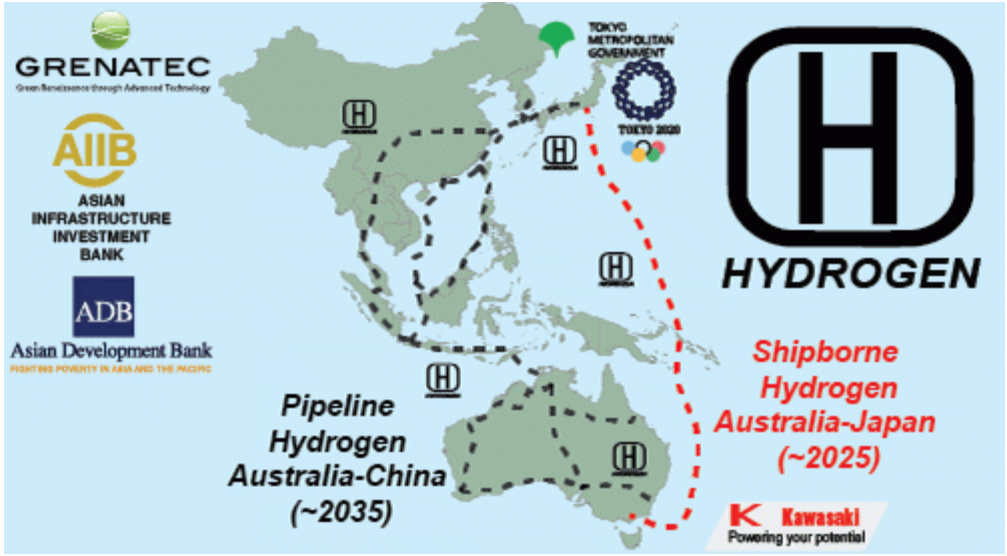
1 Battery-hydrogen hybrid to ensure sufficient power
2 Split in A- and B-segment LDVs (small cars) and C+-segment LDVs (medium to large cars) based on a 30% market share of A/B-segment cars and a 50% less energy demand

Source: Toyota, Hyundai, Daimler

Leeds: aardgas/CCS naar waterstof (H21)

WaterstofNet

Japan


GRENATEC
Green Renaissance through Advanced Technology
AIIB
ASIAN INFRASTRUCTURE INVESTMENT BANK
ADB
Asian Development Bank
FIGHTING POVERTY IN ASIA AND THE PACIFIC
TOKYO METROPOLITAN GOVERNMENT
TOKYO 2020
HYDROGEN
Pipeline Hydrogen Australia-China (~2035)
Shipborne Hydrogen Australia-Japan (~2025)
Kawasaki
Powering your potential

Groningen


Green Hydrogen Economy Northern Netherlands 2030
Noordelijke InnovationBoard
4.000MW wind
Gemini Wind
NorNed
Cobra
Legend
Hydrogen pipeline
Syngas pipeline
CO pipeline
CO_2 pipeline
O_2 pipeline
Electricity grid
Non-electrified railway
Ferry
Bus transportation
Hydrogen innovation center
Windfarm
1000 MW biomass gasification
1000 MW electrolysis hydrogen
Solar Hydrogen smart city areas
x indicates number in province
Green ammonia
Green methanol
Hydrogen fueling station
x indicates number in province
Hydrogen harbor facilities
Hydrogen distribution centers
Hydrogen ferry
Hydrogen drones
Hydrogen sailboat
Hydrogen bus
Hydrogen train
Eemshaven
Delfzijl
Leeuwarden
Groningen
Harlingen
33
Bremen
Hamburg
36
10
Heerenveen
Assen
27
12
8
Emmen
Hoogeveen
Rotterdam
Ruhr region

Cable versus pipeline cost

	Cable (BritNed)	Pipeline (BBL)
Capacity	1 GW	15 GW
Construction Cost	€ 500 mln	€ 500 mln
Volume (year)	8 TWh	120 TWh

Uniek waterstofleidingnet

2012: 1 MW fuel cell plant byproduct hydrogen

WaterstofNet

- 1MW (1,6MW Piek) elektriciteit gekoppeld aan 6kV Net
- 168 stacks
- 12 600 cellen (75 per stack)
- 70 kilo waterstof per uur

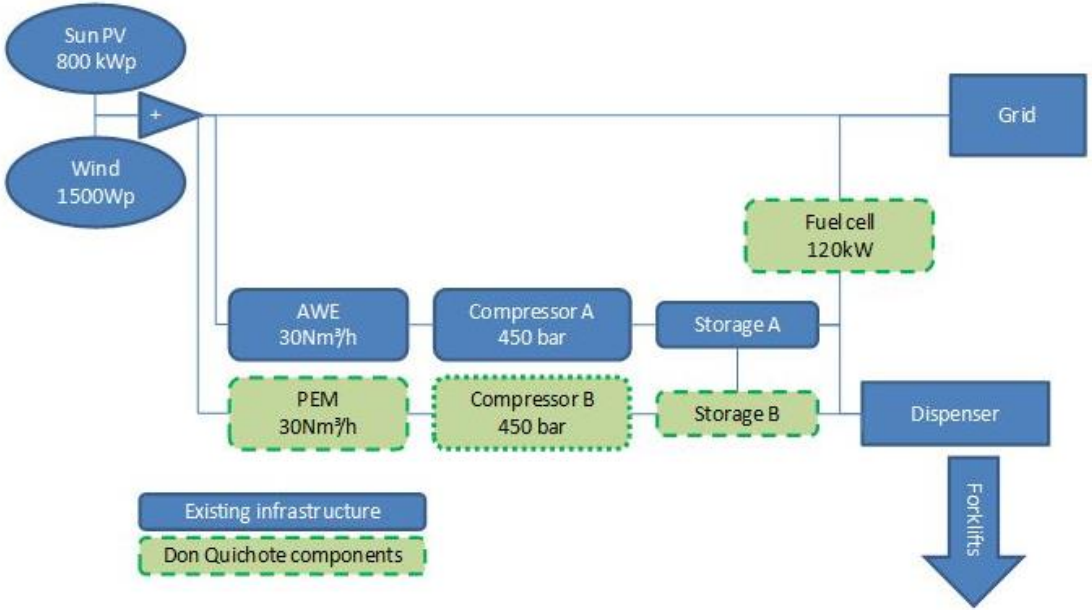
2012 : Tankinfrastructuur : tankstation bij Colruyt in Halle

- Operationeel: sinds 2012
- Locatie: Halle, België
- Groene waterstof uit zon/wind
- Vlaamse leverancier, Hydrogenics
- Drukniveau: 350 bar
- Toepassing: heftrucks, 1 – 2 -12 - 75
- 5000 tankingen
- Grootste vloot in Europa
- Start activiteiten waterstof Colruyt Group

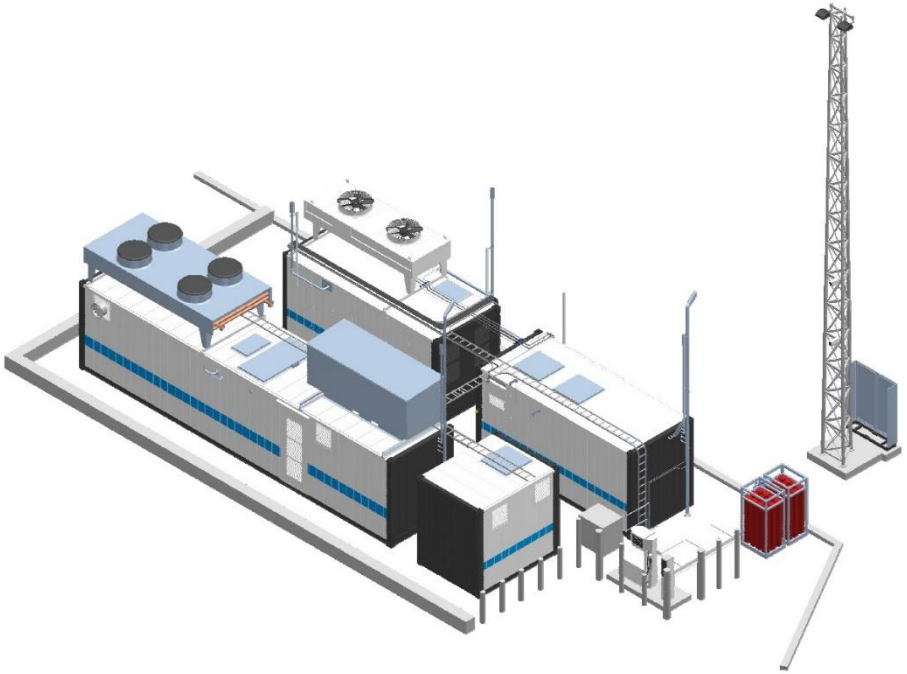
Heftrucks op waterstof

- 2013 : 2 heftrucks
- 2016 : 20 heftrucks
- 2018 : indoor + 75 heftrucks (WR 2.0)

Don Quichote: uitbreiding tankstation bij Colruyt in Halle (Don Quichote)



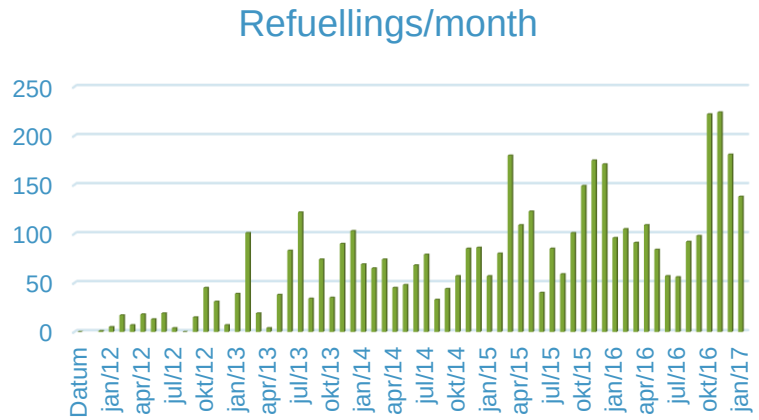
Don Quichote: uitbreiding tankstation bij Colruyt in Halle (Don Quichote)

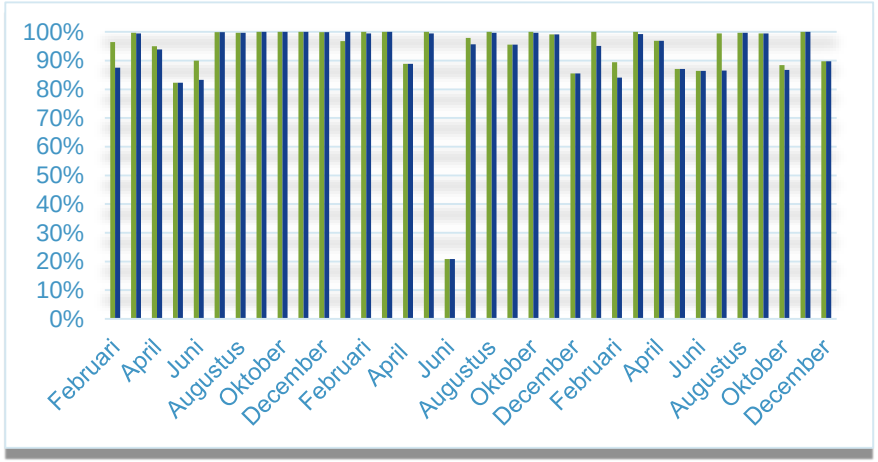


Tankinfrastructuur : uitbreiding tankstation bij Colruyt in Halle (Don Quichote)

- Benchmark van alkalische elektrolyse en PEM-elektrolyse
- Demonstratie van gebruik van waterstof in logistieke toepassingen (o.a. heftrucks) en/of in een brandstofcel (120 kW) teruglevering aan het elektriciteitsnet
- Cost: € 4,946,134
- Europese funding FCH JU: € 2,954,846
- Partners: WaterstofNet vzw, Etablissement Franz Colruyt, HyET, TUV Rheinland, JRC,Thinkstep, Icelandic New Energy Ltd, FAST
- Opening op 9 maart 2016
- Veel bezoekers: EU, MIT, ….

Fuellings and availability (> 5000)





WaterstofNet

2013: Tankstation Automotive Campus Helmond

- **Operational:** since 2013, > 1000 refuellings
- **Location:** Helmond, The Netherlands
- **Production:** renewable hydrogen, electrolyses 30 Nm3/h or 2,7 kg/hr
- **Pressure level:** 350 & 700 bar
- **Storage:** 150 kg
- **Application:** passenger vehicles, buses, garbage truck
- **Extensively used for test programme by Toyota Motor Europe**

2013: vuilniswagen (E-Trucks) en bus (VDL)

WaterstofNet

2 bussen (VDL) in Helmond

Sloepen op waterstof

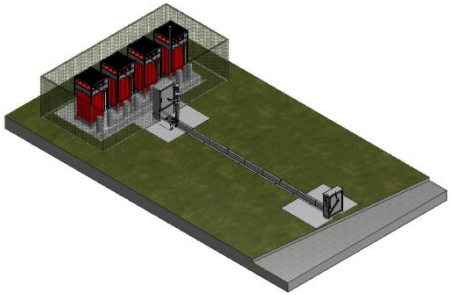
2 sloepen met fuel cell

HYDROGEN XPERIANCE

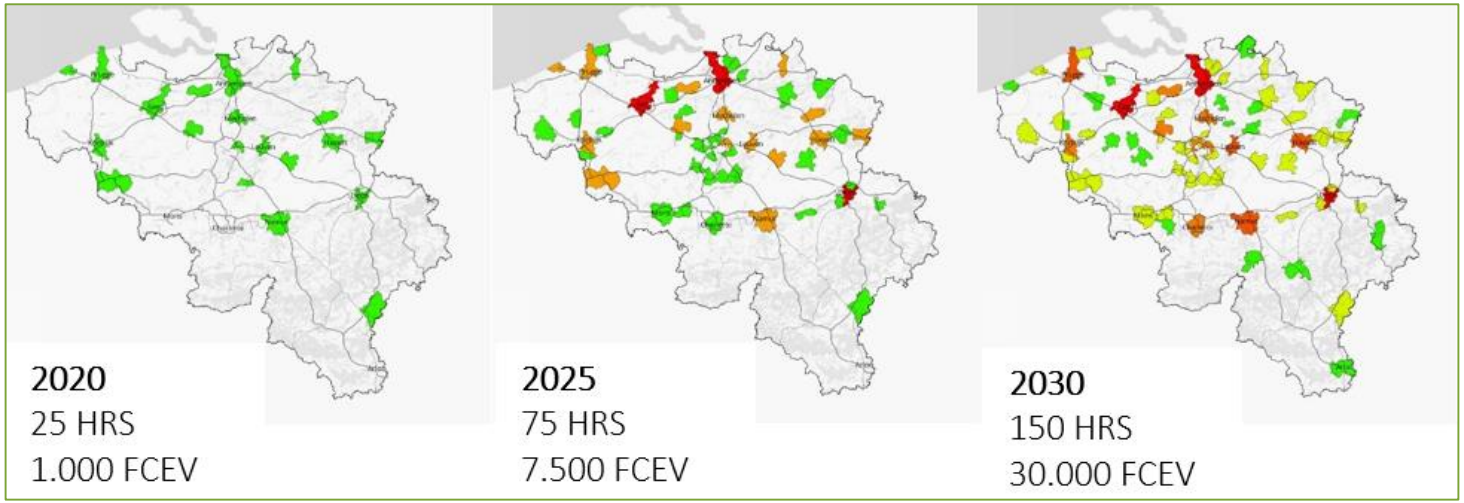
- Vaartuig: Vlet 700, 7,26 m x 2,30 m x 0,60 m (L x B x D)
- Ontwikkelde drijflijn: PEM-brandstofcel (1,2 – 2 kW), accu’s (48 V, 230 Ah)
- Opslag waterstof: 200 bar, 4 flessen van 30 liter (watervolume)

WECO 635

- Vaartuig: spitgat sloep, 6,35 m x 2,30 m x 0,55 m (L x B x D)
- Klassieke drijflijn: 11 kW diesel met 2,2 elektromotor met batterij (48 V, 55 Ah)
- Ontwikkelde drijflijn: PEM-brandstofcel (2 – 5 kW)
- Opslag waterstof: 350 bar



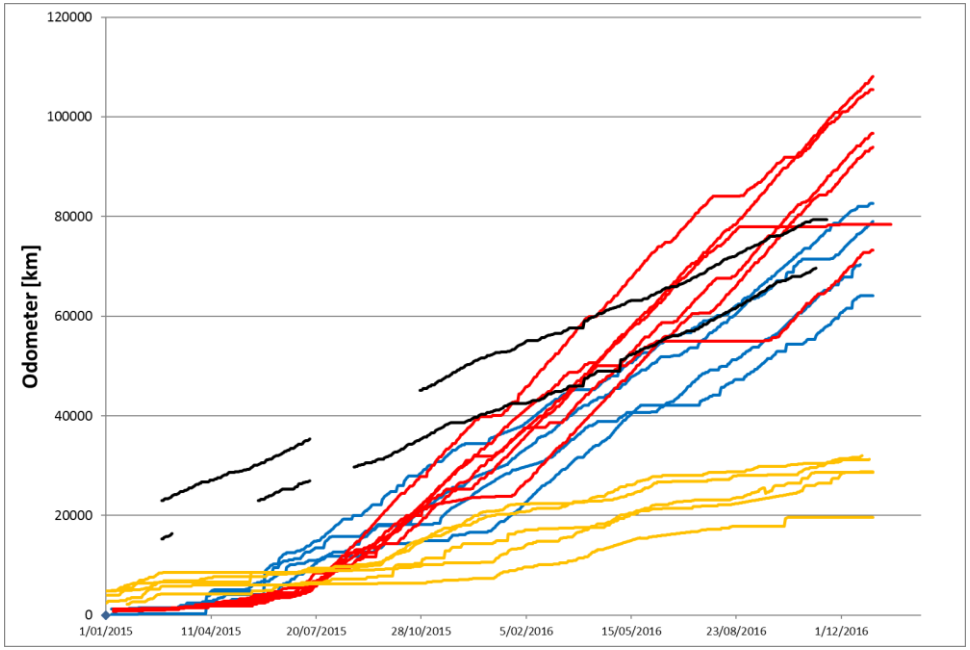
Tankinfrastructuur : H2Mobility Belgium



Projectaanvraag: H2Benelux (TEN-T/CEF)

- 8 tankstations + 80 auto's
  - 4 Nederland
  - 3 België
  - 1 Luxemburg

Bussen op waterstof



www.fuelcellbuses.eu

WaterstofNet

6,6 million km

driven up to 30 September 2016

Fuel Cell Electric Buses knowledge base

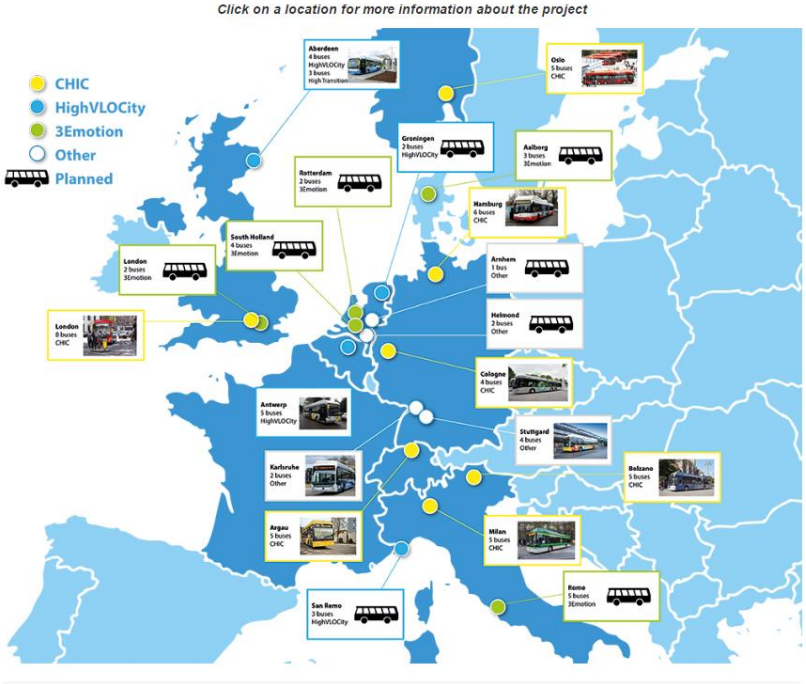
Fuel Cell Electric Buses

FCEB's are producing NO harmful emissions and CO2. They are quiet and have a long driving range.

Framework

Policy, safety, regulations, codes and standards & grants.

www.fuelcellbuses.eu



www.fuelcellbuses.eu

WaterstofNet

City, Country	Number of buses in service	Bus manufacturer	Operator	Bus type	H2-Storage	Project	In operation since
Aberdeen, UK	6	Van Hool	StageCoach	13m, 3 axles	50kg	HyTransit	2014
	4		First Group			HighVLOCity	
Aalborg	3	Van Hool	North-Jutland region/City Aalborg	13 meter, 3 axles	40 kg	3Emotion	2017
Antwerp, Belgium	5	Van Hool	De Lijn	13m, 3 axles	40 kg	HighVLOCity	2014
Argau, Switzerland	5	Mercedes/ Evobus	Postbus	12m, 2 axles	40kg	CHIC	2011
Arnhem, the Netherlands	1	Hymove	Syntus	12m, 2 axles, Wheelhub electric motors	30 kg	H2bus for PTO Syntus	2017
Bolzano, Italy	5	Mercedes/ Evobus	STA Südtiroler Transportstrukturen AG	12m, 2 axles	35 kg	CHIC	2013
Cologne	2	Van Hool	RVK	13m, 3 axles	40 kg	CHIC	2015
	2	APTS		18m, 3 axles			2013
Groningen	2	Van Hool	Qbuzz	13m, 3 axles	40 kg	HighVLOCity	2017
Hamburg, Germany	4	Mercedes/ Evobus	Hamburger Hochbahn AG	12m, 2 axles	35 kg	CHIC	2011
	2	Solaris		Articulated, 18m, 3 axles,	45 kg		2015
Helmond, The Netherlands	2	VDL	Hermes/ Connexxion	Articulated, 18m, 3 axles,	40 kg	H2busses Eindhoven	2017
Karlsruhe, Germany	2	Mercedes/ Evobus	KIT, Karlsruhe Institute for Technology	12m, 2 axles	35 kg	KIT project	2013
London, UK	8	Wrightbus	Transport for London, TfL	12m, 2 axles	30 kg	CHIC	2010
London, UK	2	Van Hool	Transport for London, TfL	10m, 2 axles	30 kg	3Emotion	2017
Milan, Italy	5	Mercedes/ Evobus	SASA spA-AG	12m, 2 axles	35 kg	CHIC	2013
Oslo, Norway	5	Van Hool	Ruter	13m, 3 axles	35 kg	CHIC	2013
Rome, Italy	5	tbd	ATAC	12m, 2 axles		3Emotion	2018
Rotterdam	2	Van Hool	RET	13m, 2 axles	40 kg	3Emotion	2017
San Remo, Italy	3	Van Hool	Rivièra Transporti	13m, 3 axles	40 kg	HighVLOCity	2013
South Holland, The Netherlands	4	tbd	Connexxion	13m, 3 axles	40 kg	3Emotion	2017
Stuttgart, Germany	4	Mercedes/ Evobus	SSB, Stuttgarter Strassen Bahnen AG	12m, 2 axles	35 kg	NIP/NOW/CEP	2014

in operation	planned

www.fuelcellbuses.eu

Home / Performance data (0)

erstofNet

STATUS Sept 30, 2016						
Location	**Project**	**# buses**	**# km driven**	**# kg H2**	**# tons of CO2 emission avoided**	**# litres of Diesel saved**
Aargau	CHIC	5	1 308 601	103 769	1398	523 440
Bolzano	CHIC	5	554 027	48 027	592	221 611
Cologne	CHIC	4	254 386	38 017	272	101 754
Hamburg	CHIC	6	477 197	41 528	510	190 879
London	CHIC	8	1 368 831	133 949	1462	547 532
Milan	CHIC	5	199 875	20 709	213	79 950
Oslo	CHIC	5	559 721	73 715	598	223 888
Berlin*	CHIC	4	898 477	205 188	960	359 391
Aberdeen (First)	HighVLOCity	4	246 092	27 053	263	98 437
Antwerp	HighVLOCity	5	124 056	10 929	132	49 622
Aberdeen (Stagecoach)	HyTransit	6	460 991	45 203	492	184 396
Karlsruhe	KIT	2	172 281	13 148	184	68 912

* Buses have been taken out of circulation since 2014

6 624 535	7 075	2 649 814
total km driven	**total avoided tons CO2 emission**	**total saved litres of Diesel**

Vuilniswagens op waterstof

2013: Waterstofregio 1.0 (Interreg)

2016: Life & GrabHy (Life)

(2 in 10 EU-steden)

In uitvoering ReViVe 15 vuilniswagens (JU-FCH)

WaterstofNet

Demo Sites

- Breda
- Helmond
- Groningen
- Amsterdam
- Antwerp
- Fribourg
- South Tyrol
- Roosendaal

REVIVE across Europe

Core objectives

- Develop a high performance fuel cell refuse truck that can provide the flexibility of incumbent solutions
- Trial the trucks in their operating environment
- Compile the evidence base for continued rollout of the technology
- Raise the profile of the technology as a viable option for waste collection
- Demonstrate that hydrogen fuelled refuse vehicles can have a significant impact on the utilisation of urban refuelling stations

Vrachtvervoer op waterstof

WaterstofNet

2016: Waterstofregio 2.0

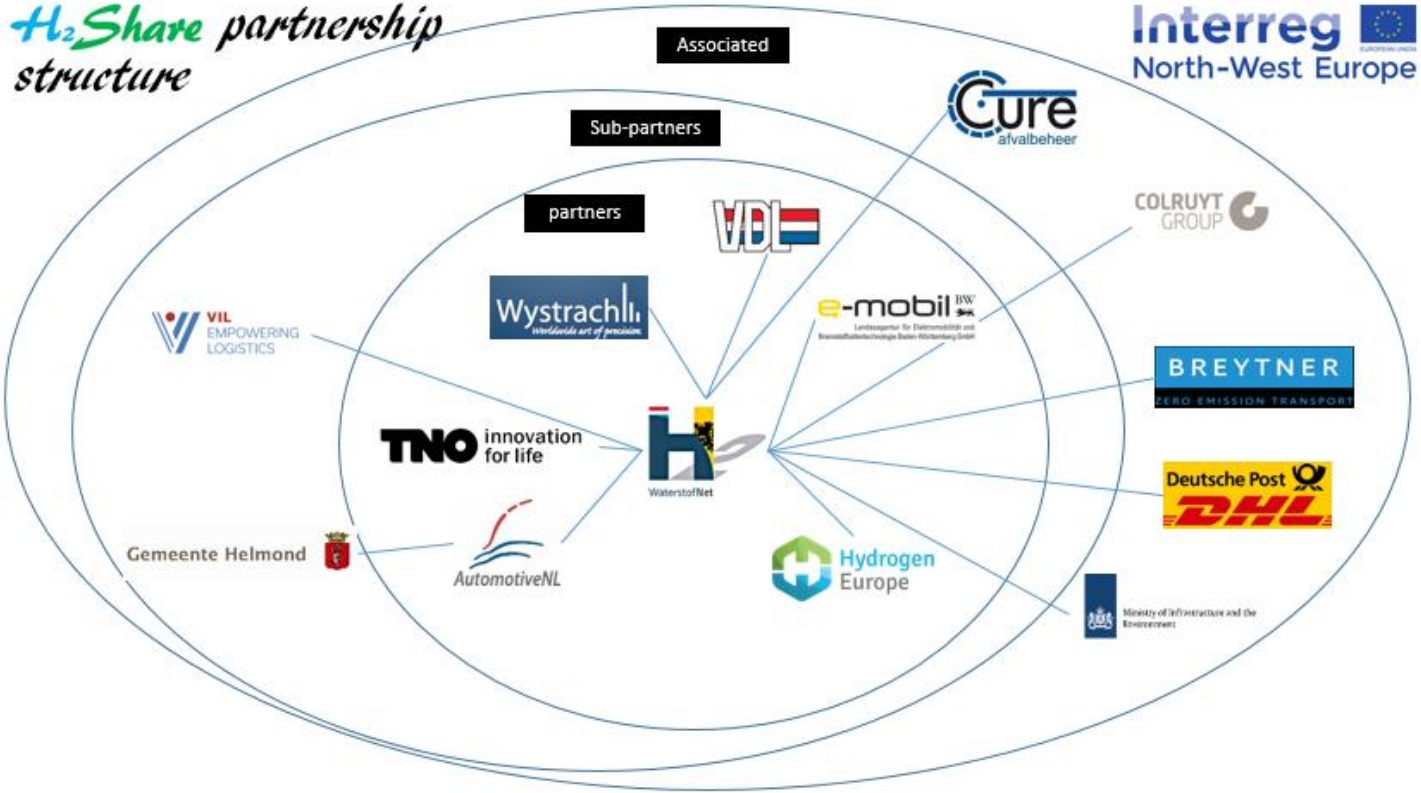
Vrachtwagen 40 ton op waterstof (Interreg)

2016: H2SHare (Interreg)

Vrachtwagen 26 ton

Mobiel vulstation

H_2Share partnership structure



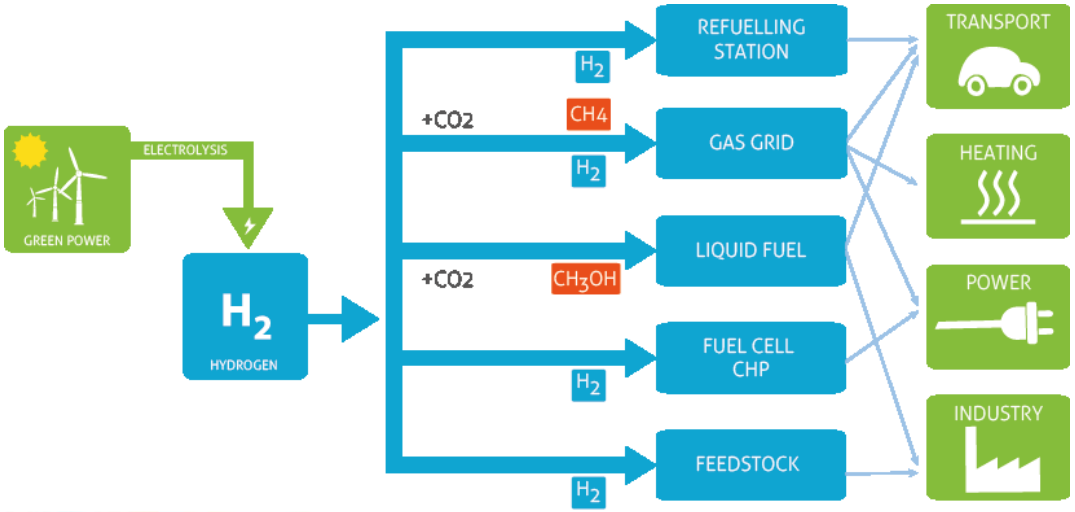
Interreg North-West Europe

WaterstofNet

Power to Gas

WaterstofNet

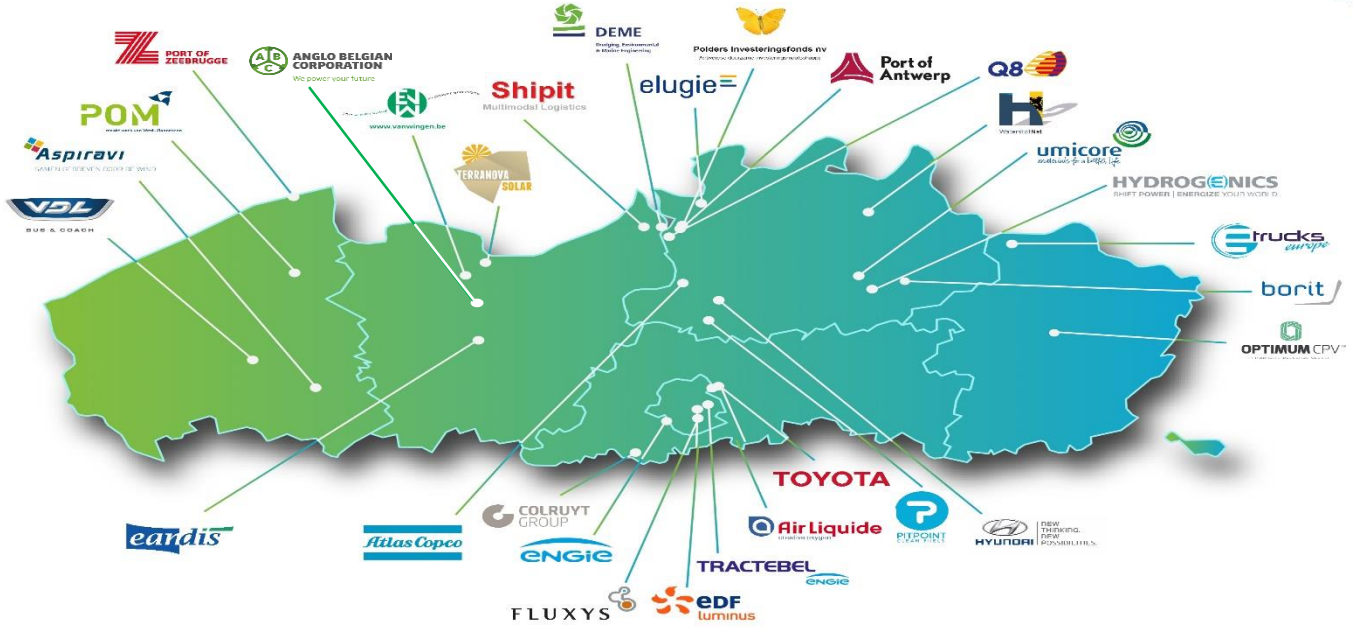
Productie Hernieuwbare energie → Electrolyse → Compressie, opslag transport → Net-operators → Systeem integrators → Waterstof gebruikers



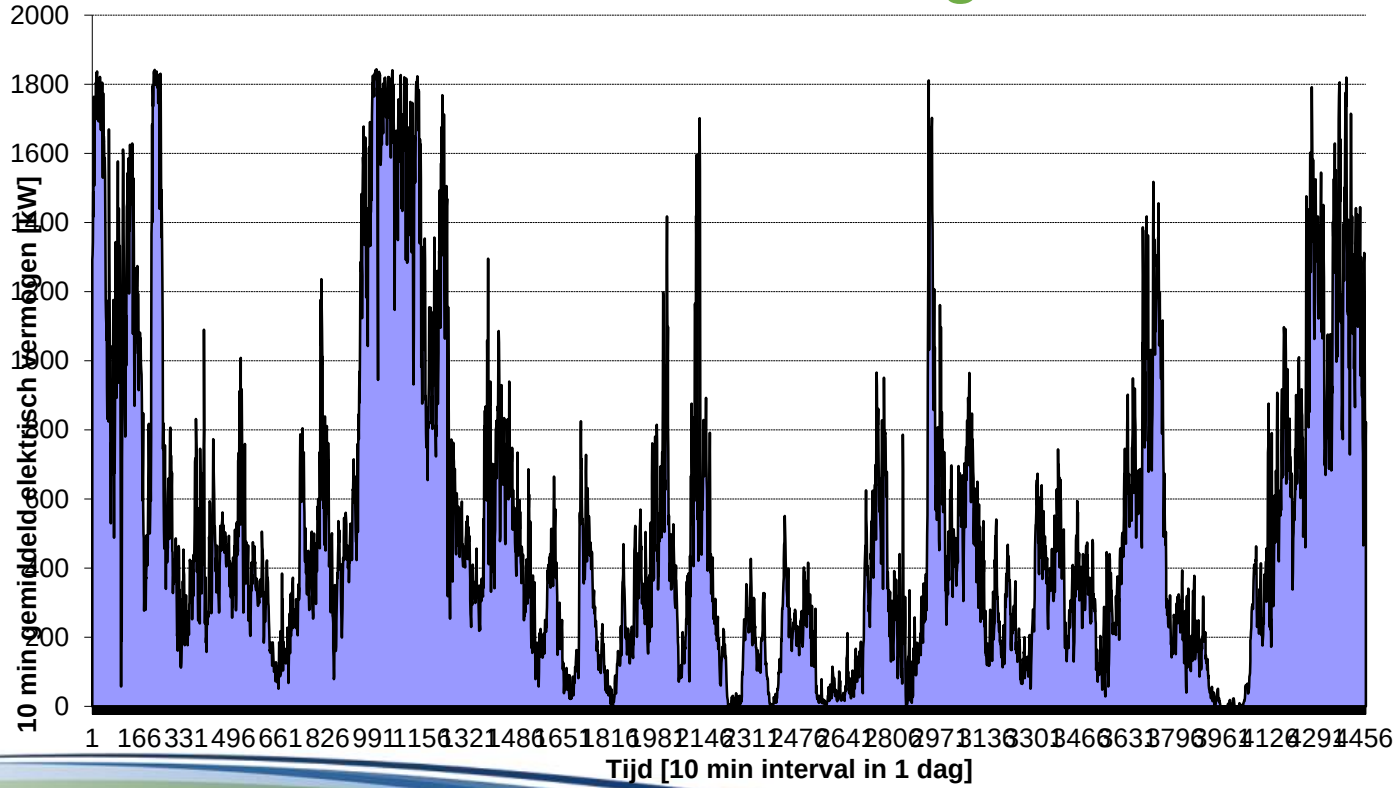
POWERTOGAS Industry Cluster Flanders

Cluster Power-to-gas

WaterstofNet

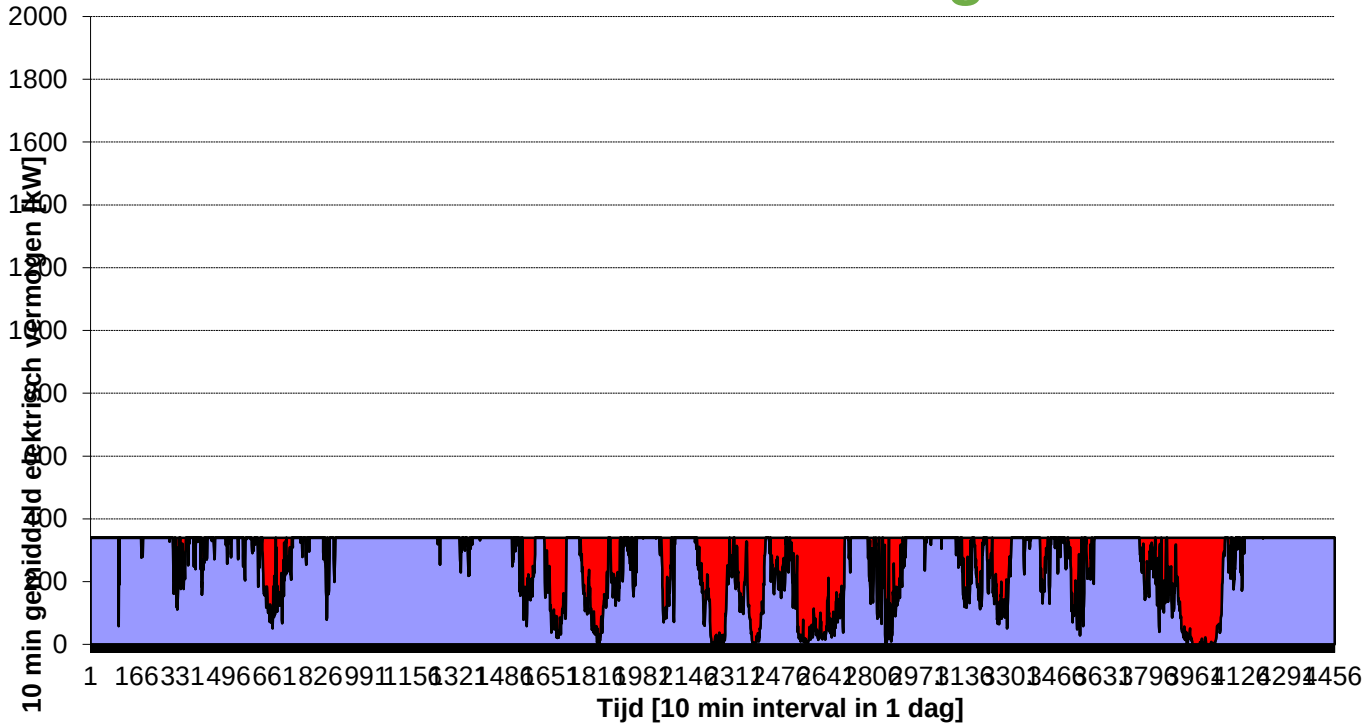


Cluster Power-to-gas



WaterstofNet

Cluster Power-to-gas



Green H_2 production

Running

Colruyt distribution centre
From wind-solar

Planned

Wilrijk ISVAG
From waste-electricity

Remo-stort Houthalen
From waste via plasma gasification

Study phase

Terranova Solar Zelzate
From Solar-wind

Port of Zeebrugge
From (offshore) wind

“Lessons learned” voor waterstofprojecten

- samenwerken met ‘key-spelers’ die willen EN kunnen: technologie en eindgebruiker
- resultaat gericht werken
- communiceren op basis van resultaten
- dynamiek in netwerk spelers brengen en aanhouden
- opbouwen geloofwaardigheid: projecten blijven leven na de opening en na de subsidie

Via onze nieuwsbrief blijft u op de hoogte www.waterstofnet.eu