Kenniscentrum Gasnetbeheer

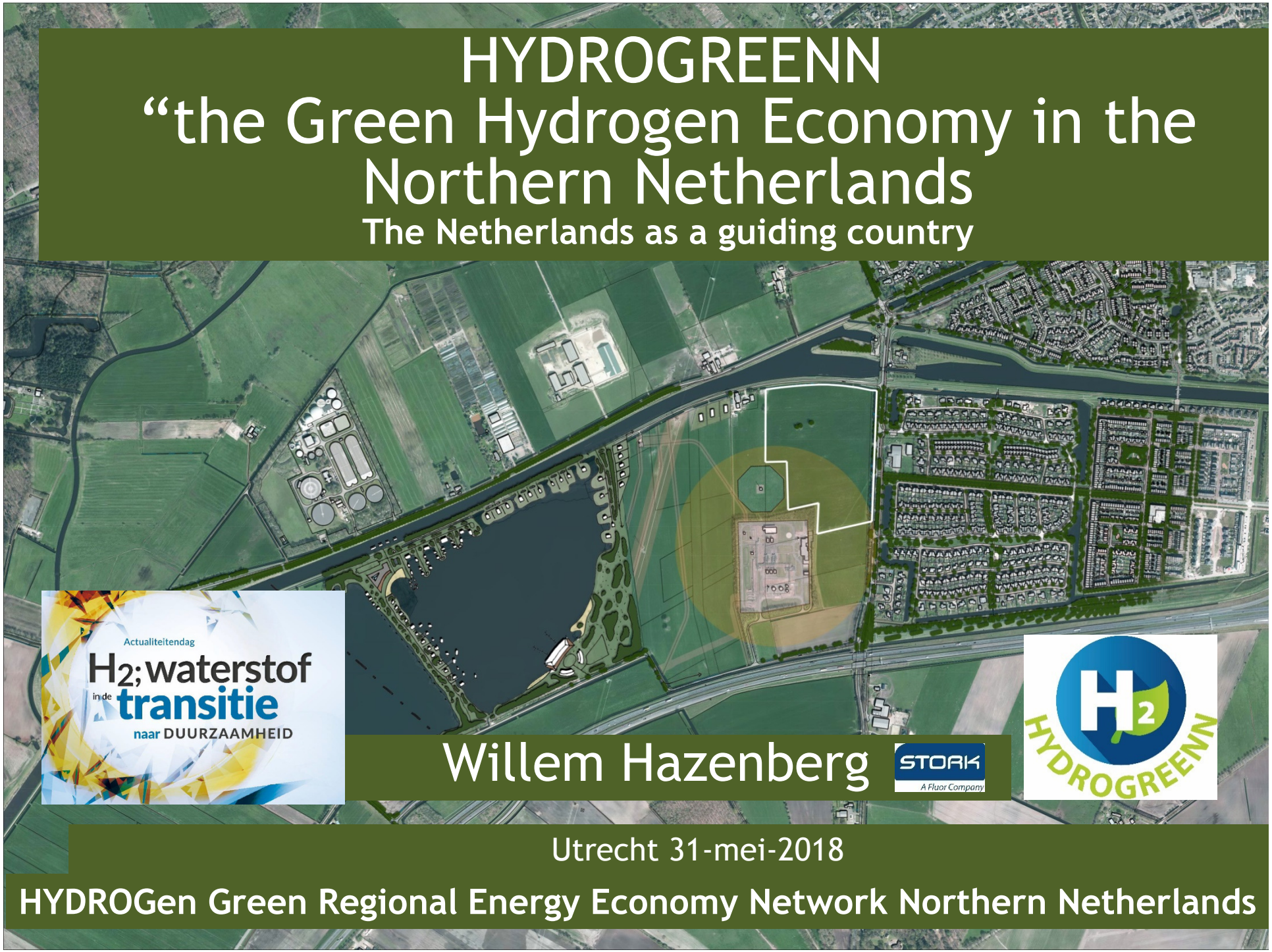
kiwa

STORK
A Fluor Company

Willem Hazenberg

H2 HYDROGREEN

HYDROGREENN
“the Green Hydrogen Economy in the Northern Netherlands
The Netherlands as a guiding country



Willem Hazenberg
STORK
A Fluor Company

H2 HYDROGREENN

Utrecht 31-mei-2018

HYDROGen Green Regional Energy Economy Network Northern Netherlands

Speaker

- Willem D. Hazenberg MBA EUR ING RI
- Project manager Stork P&T (Large projects)
- Business Development Hydrogen and Geothermal
- Chairman “HYDROGREENN”
- Project manager Hydrogen city Hoogeveen for consortium
- Member Expert team NAM renewable energy
- Kernteam member NEN Waterstof in de bebouwde ongeving.
- Supervisory board member MBO Hydrogen education Gas 2.0
- Supervisory board member TKI Human agenda – Learning communities.
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- www.stork.com

GLOBAL BUSINESS
WITH STRONG LOCAL PRESENCE

BP
Global third party inspection

Procter&Gamble
Maintenance

General Mills
Maintenance

IBM
Facility maintenance services

Huntsman
Mechanical services

BP
Mechanical & fabric maintenance

ECOPETROL
Maintenance & construction

Drummond
Maintenance services

Petroperu
Small cap construction & maintenance services

Repsol
Mechanical & fabric maintenance

NEXEN
Fabric maintenance

RWE
Maintenance, modifications & TA

TATA Steel
Maintenance, modifications & TA

Shell/BG
Assess - Inspect - Repair

ExxonMobil
Refinery maintenance & TA

QSGTL
Maintenance, rotating equipment

KNPC
Inspection services & leak sealing

BHP BILLITON
Rail maintenance & construction

LyondellBasell
TA services

Avebe
Small cap construction

AKZO NOBEL
Mechanical services

SABIC
Chemical plant maintenance & TA

DSM
Mechanical services & TA

SHELL NAM
Onshore/offshore maintenance

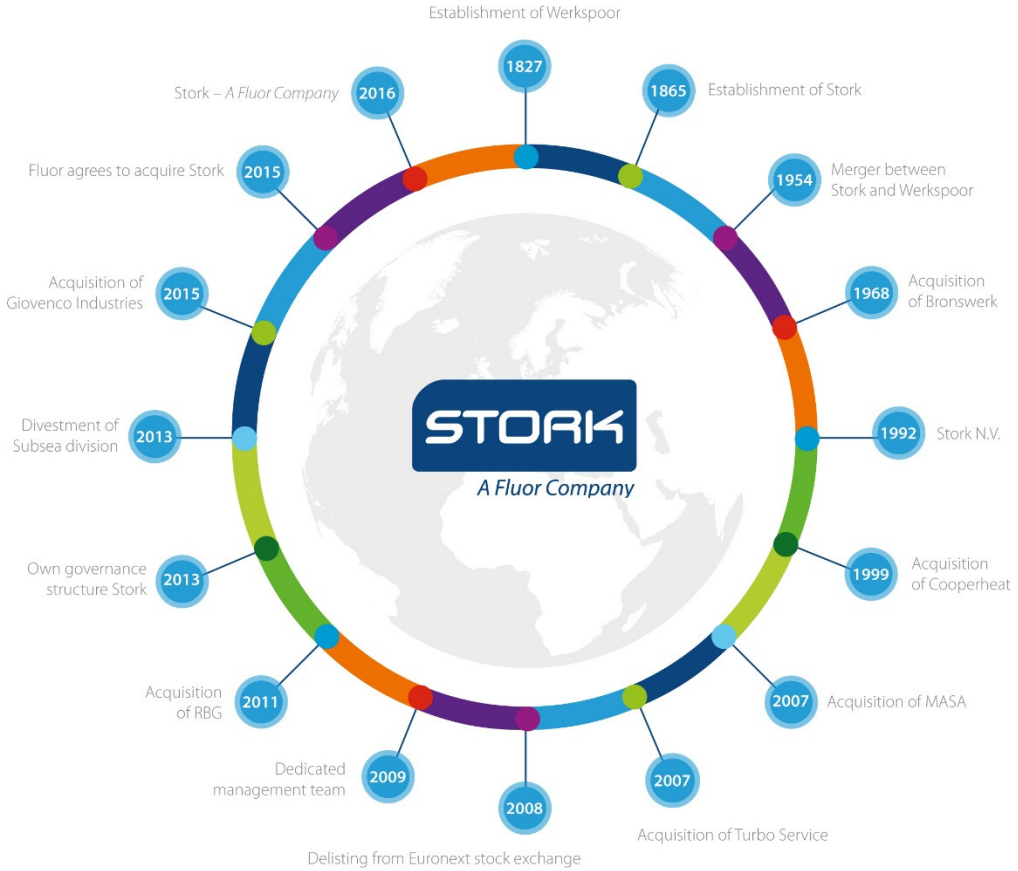
GE
Inspection services

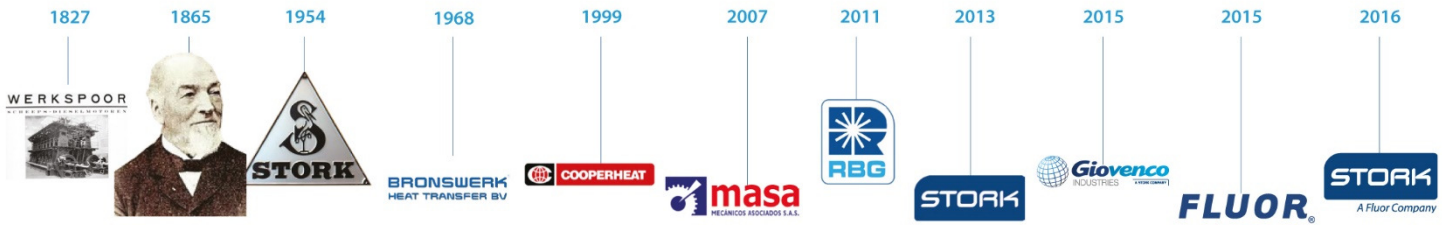
WOODSIDE
Life extension fabric maintenance

RIO TINTO
Rail maintenance & construction

- **SINCE 1827**

history of stork





Coalition of Hydrogen ambassadors Kick-off

12 September 2017

WWW.LOODSKOTTER.NL

STORK A Fluor Company

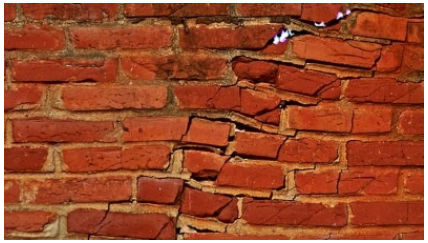
EnTranCe ENERGY TRANSITION CENTRE

HYDROGREENN Status

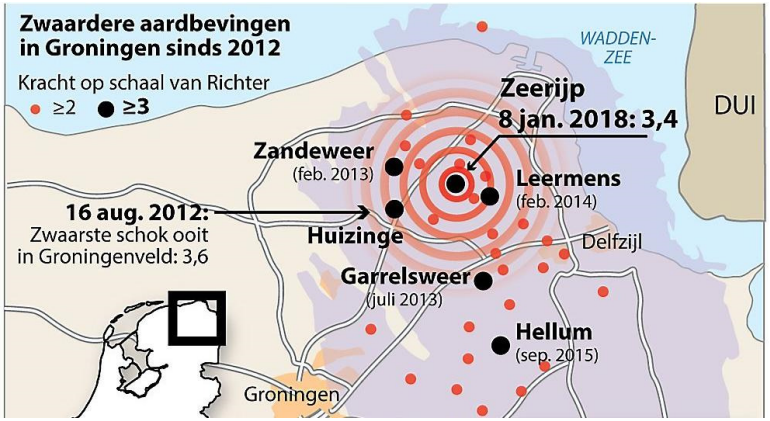
HYDROGen Green Regional Energy Economy Network Northern Netherlands

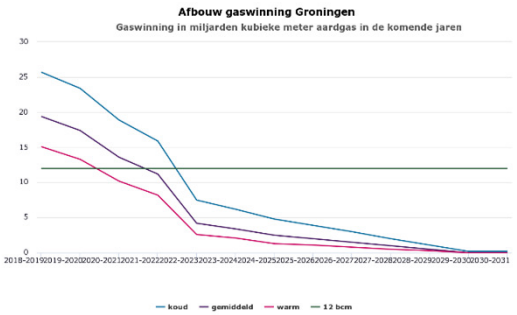
- 160 direct members
  - -15 informative members
- 88 Organizations
  - 78 Direct
  - 10 Informative
  - **KEY = OPEN INNOVATION PLATFORM**

Main Drivers



- Paris Agreement CO_2 reduction targets
- PM Rutte 3 -Target 30 to 50K a Year houses from Natural gas. Should be 200.000 a Year
- Earthquake problem Groningen gas field
  - Reduce Natural gas consumption from 21.4 BCM to 12 BCM in 4 years (2022)
  - Reduction to 0 BCM Natural gas consumption (2030)

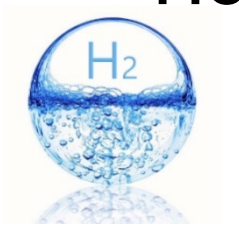




Main problem renewable energy

- You produce more energy then needed or
- You produce less energy then needed or
- You produce the same energy amount as needed.

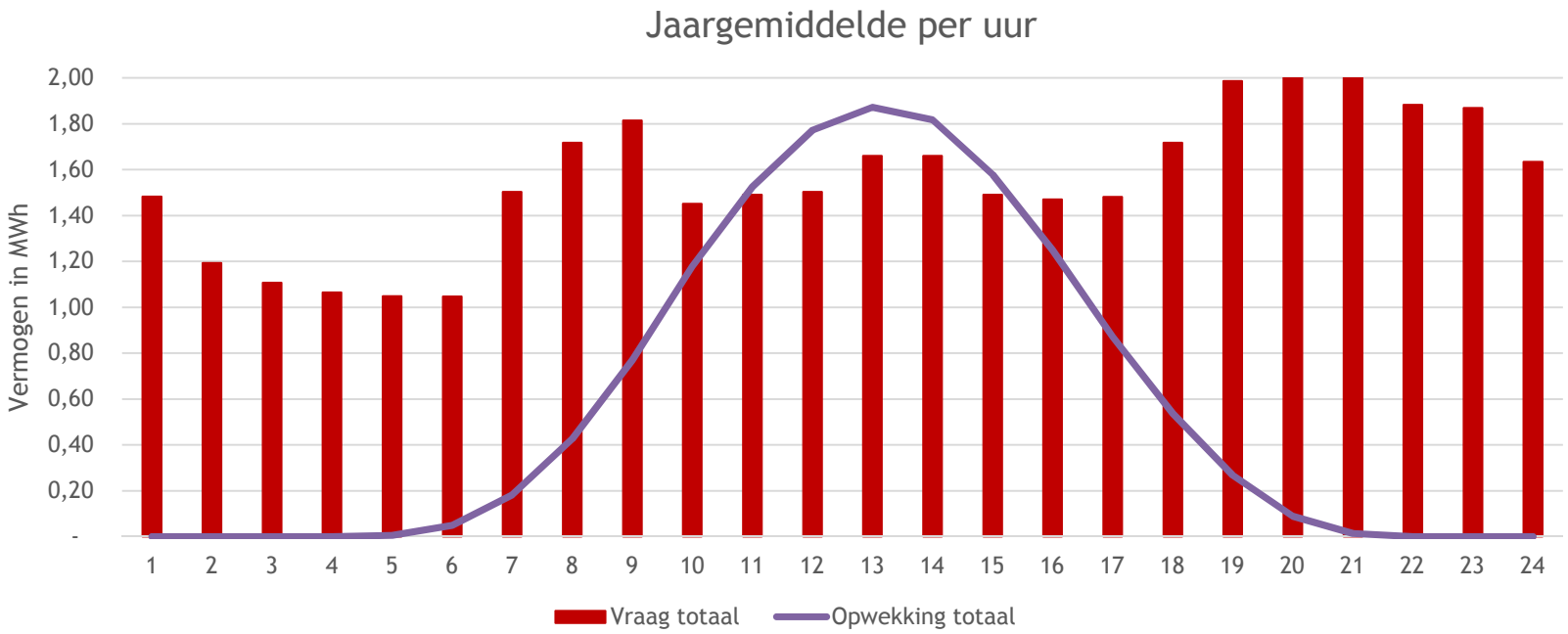
- In the past is energy production follow consumption.
- By renewable production depending of solar or wind production. (climate/day/season)
- How to solve that gap?



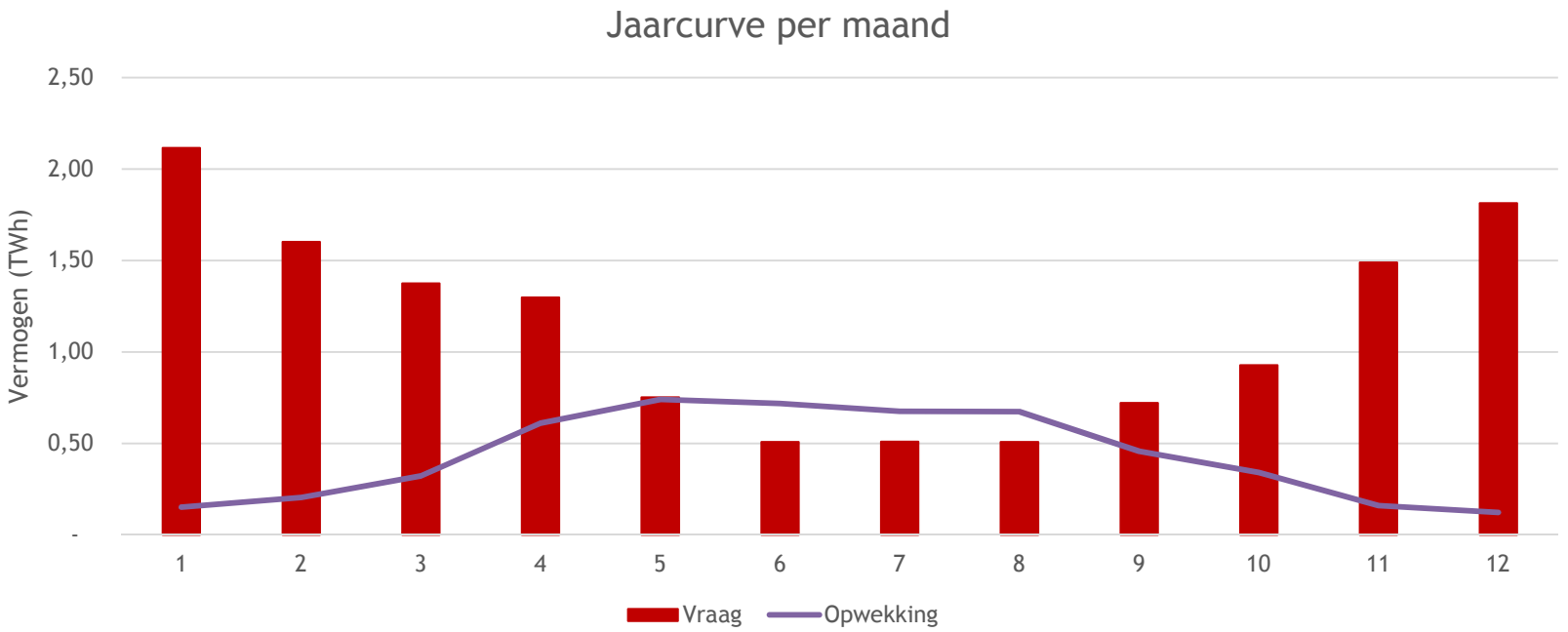
Key numbers

- Nijstad-Oost 80 houses, Erflanden 1030 houses
- 24 Ha Solarfields needed for these houses
- All houses have 12 solar panels
- Energy balance without the conversion losses
- Maximum storage capacity needed is 4 900 MWh, about 145 tons H_2

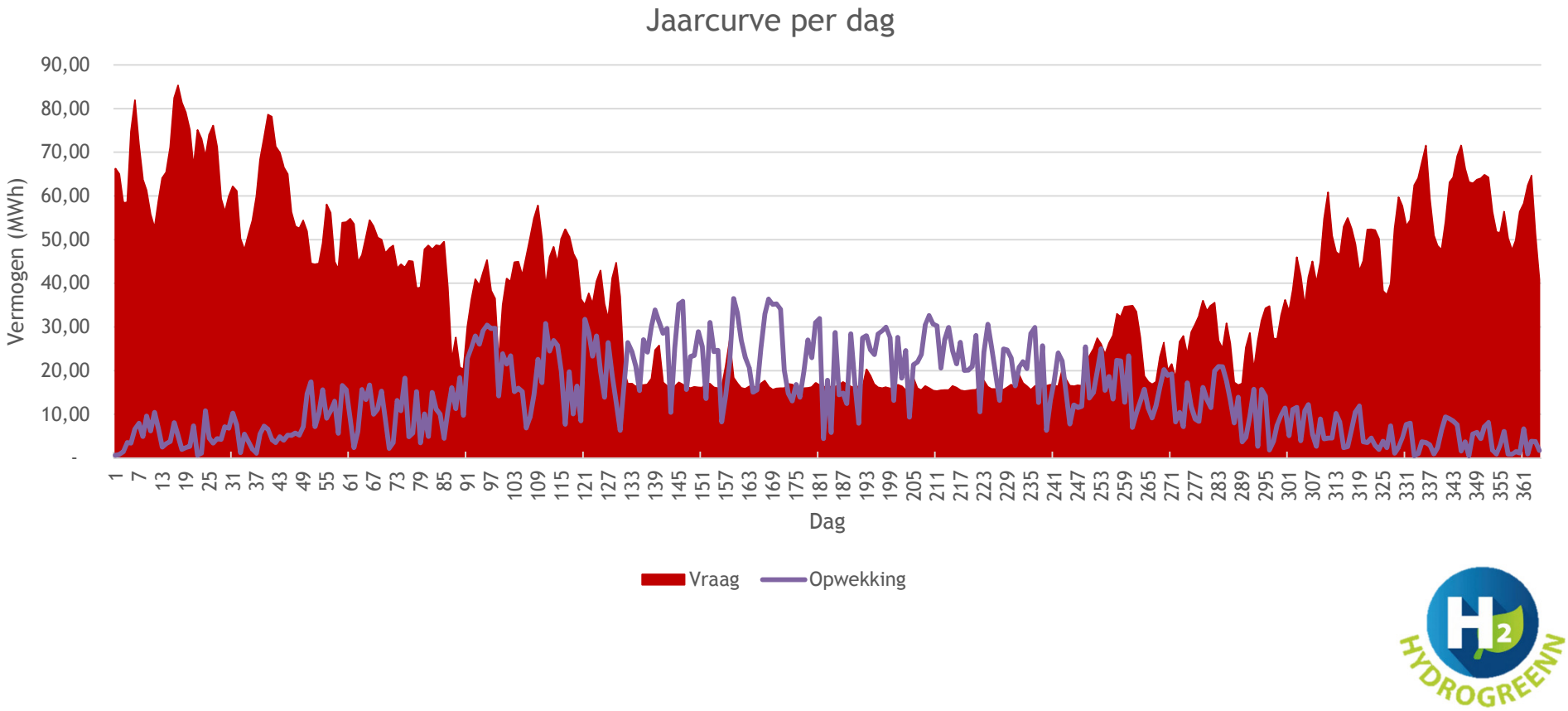
Day Curve consumption / solar production



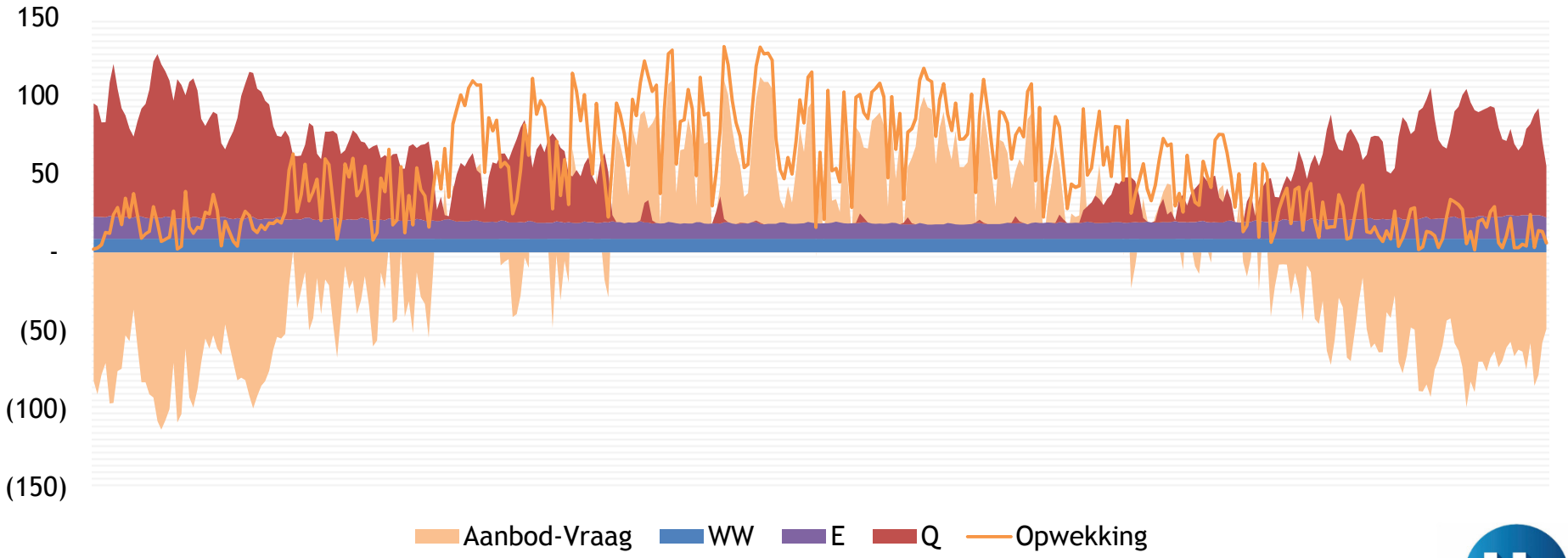
Year Curve consumption / solar production



Year curve demand vs production

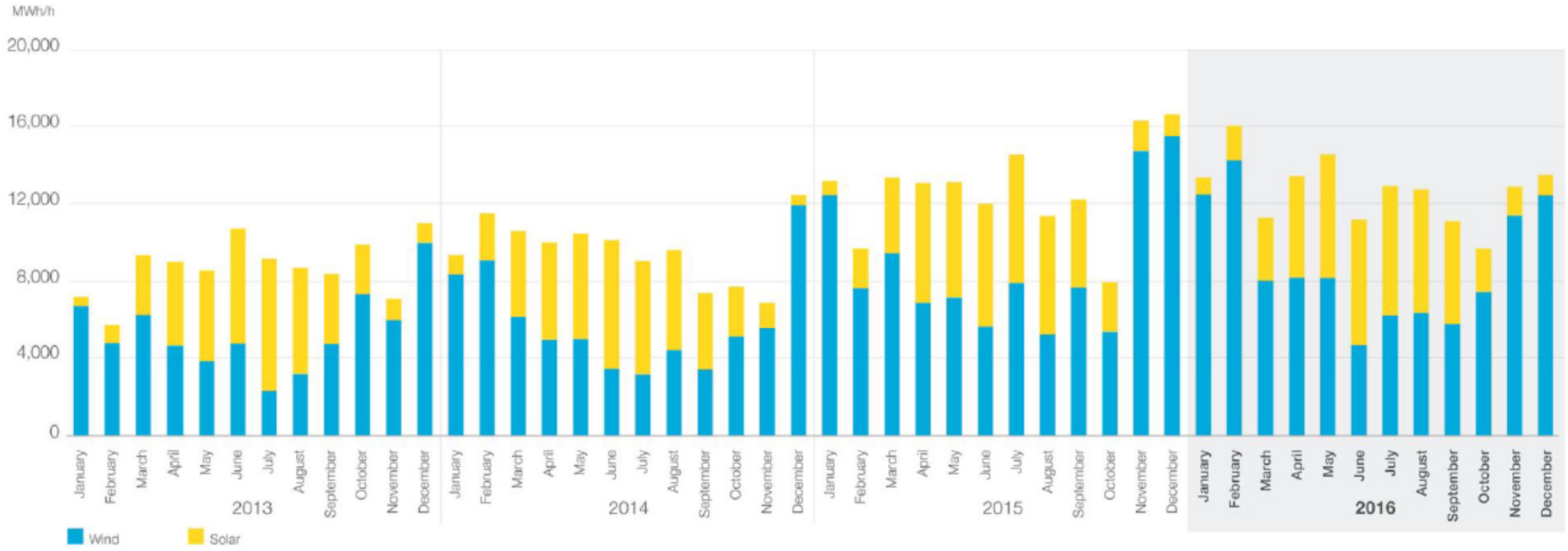


Year curve (MWh) in day totals



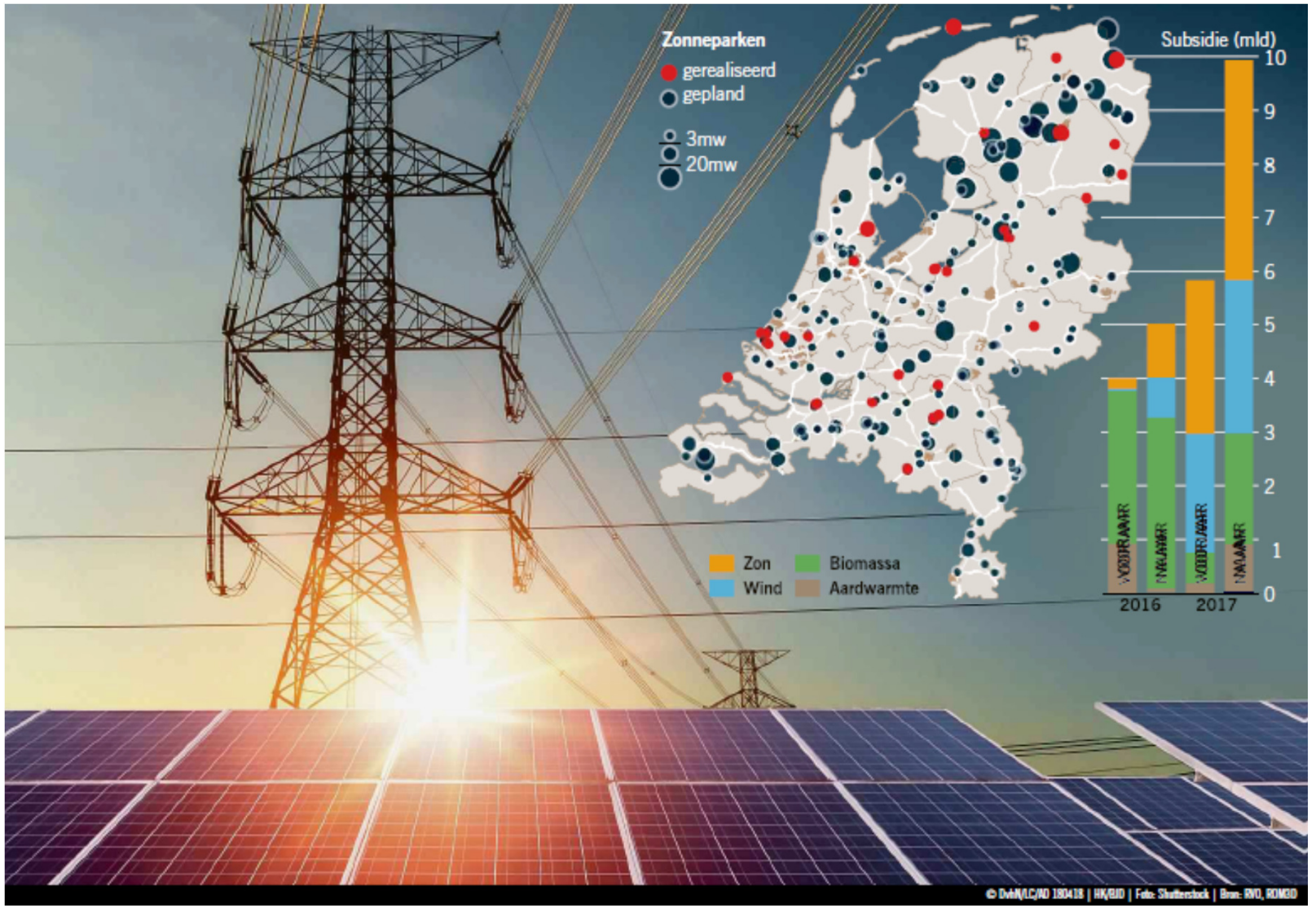
Sun needs Wind

Complementary sources during the year



Source: 2017 Mel Kroon CEO Tennet

Dutch Solar parks (incl plan)



How to transport all this electrical energy?

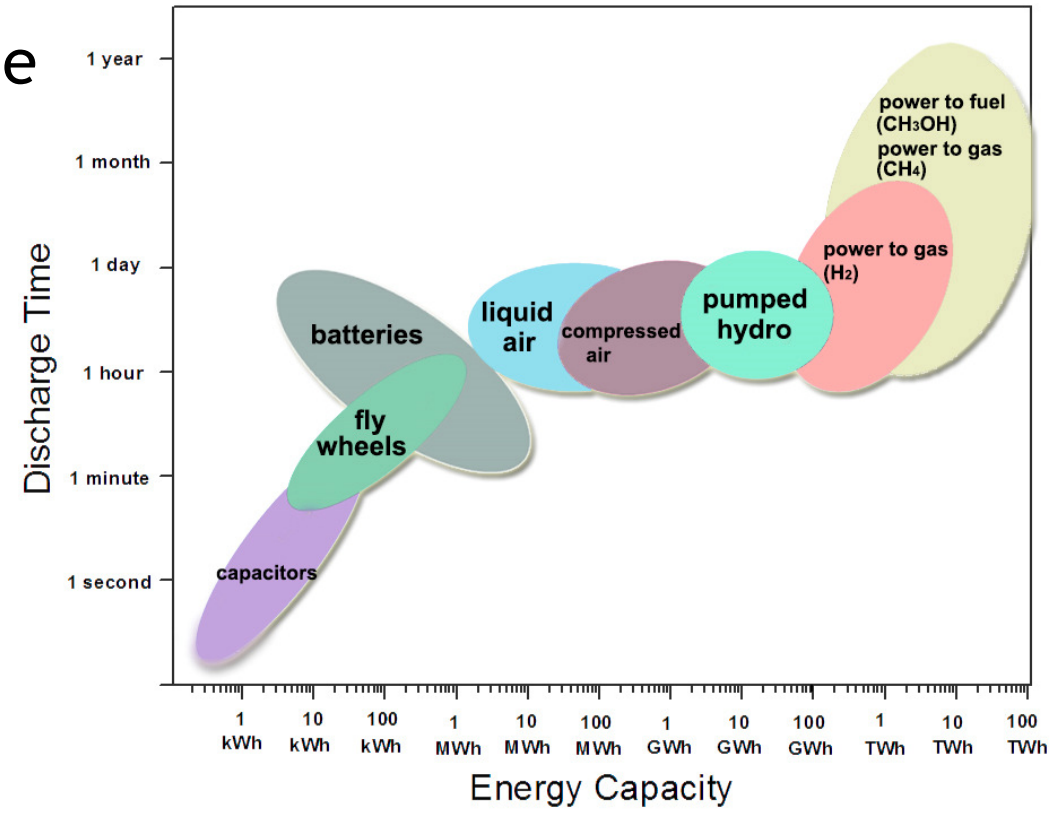
Expensive and low social acceptance

How to Storage of Surplus of Renewable Energy

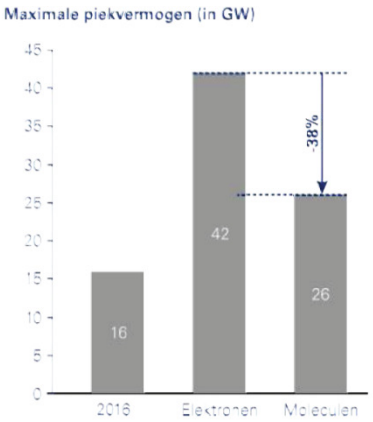
- Sharp growing of renewable Power generation
- Need for power storage
- Different -

  technologies available

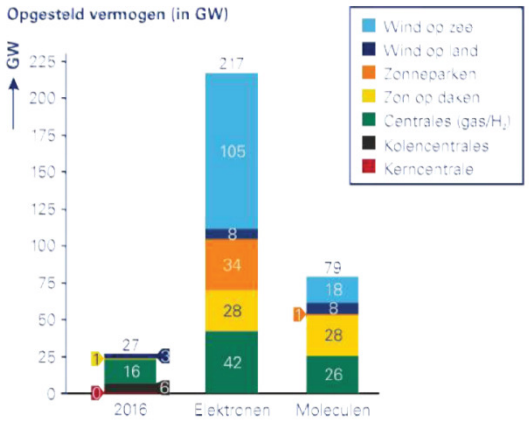
- Hydrogen is an option



Cost Scenario Hydrogen v.s. Fuel Electric



Figuur 4. Maximale piekvermogen in GW.



Figuur 5. Opgesteld vermogen in GW.

Source 2018: Berenschot
Electronen en/of Moleculen
(Netherlands case)

	Evolution of Gas	Prosumer	Diversified energy	Electric Future
Practical obstacles	Low/Medium	Very high	Medium/High	High
Incremental cost	£104-122bn	£251-289bn	£156-188bn	£274-318bn
Incremental cost per consumer up to 2050	£4,500-5,000	£11,000-12,500	£6,800-8,000	£12,000-14,000

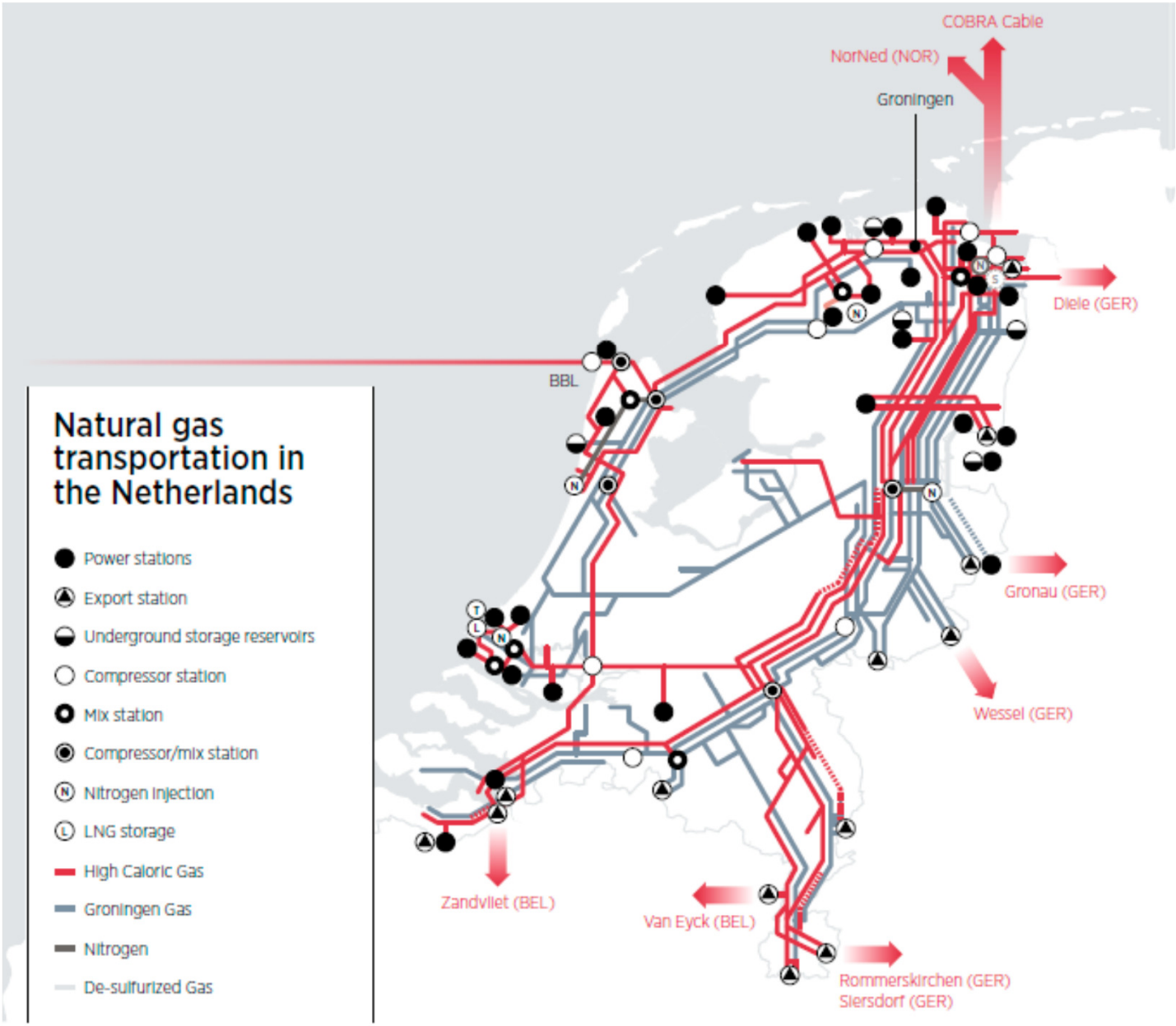
Source 2016: KPMG 2050 Energy Scenarios – The UK Gas Networks

Cost direct line

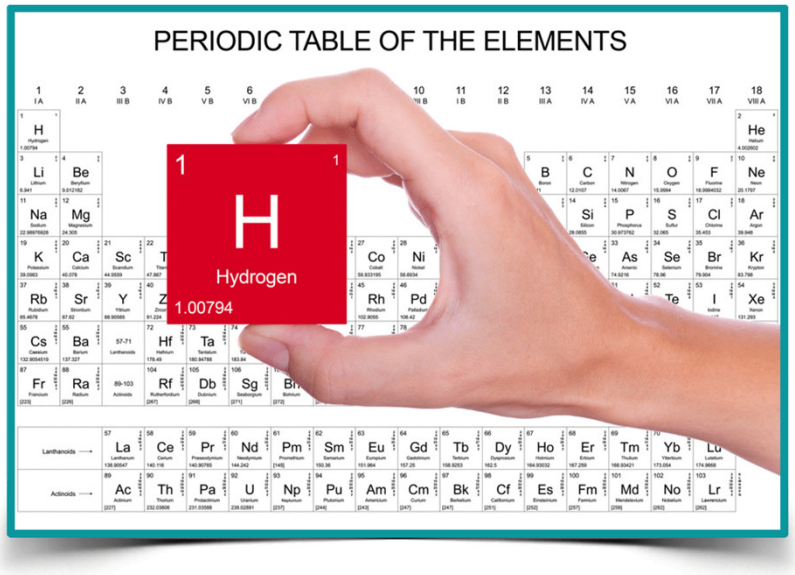
Gas is cost effective energy transport medium

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

National gas transportation in the Netherlands



What is Hydrogen



Hydrogen is a:

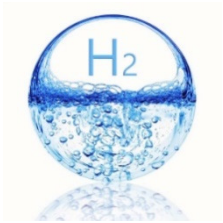
- colorless,
- odorless,
- tasteless,
- non-toxic,
- nonmetallic,
- highly combustible diatomic gas
- with the molecular formula H_2

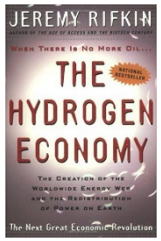
What is Hydrogen Economy

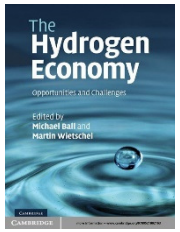
The **hydrogen economy** is a proposed system of delivering energy using hydrogen.

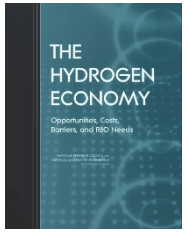
The term "hydrogen economy" refers to the vision of using hydrogen as a low-carbon energy source – replacing, for example, gasoline as a transport fuel or natural gas as a heating fuel

The term *hydrogen economy* was coined by John Bockris during a talk he gave in 1970 at General Motors (GM) Technical Center.[1] The concept was proposed earlier by geneticist J.B.S. Haldane.[2]

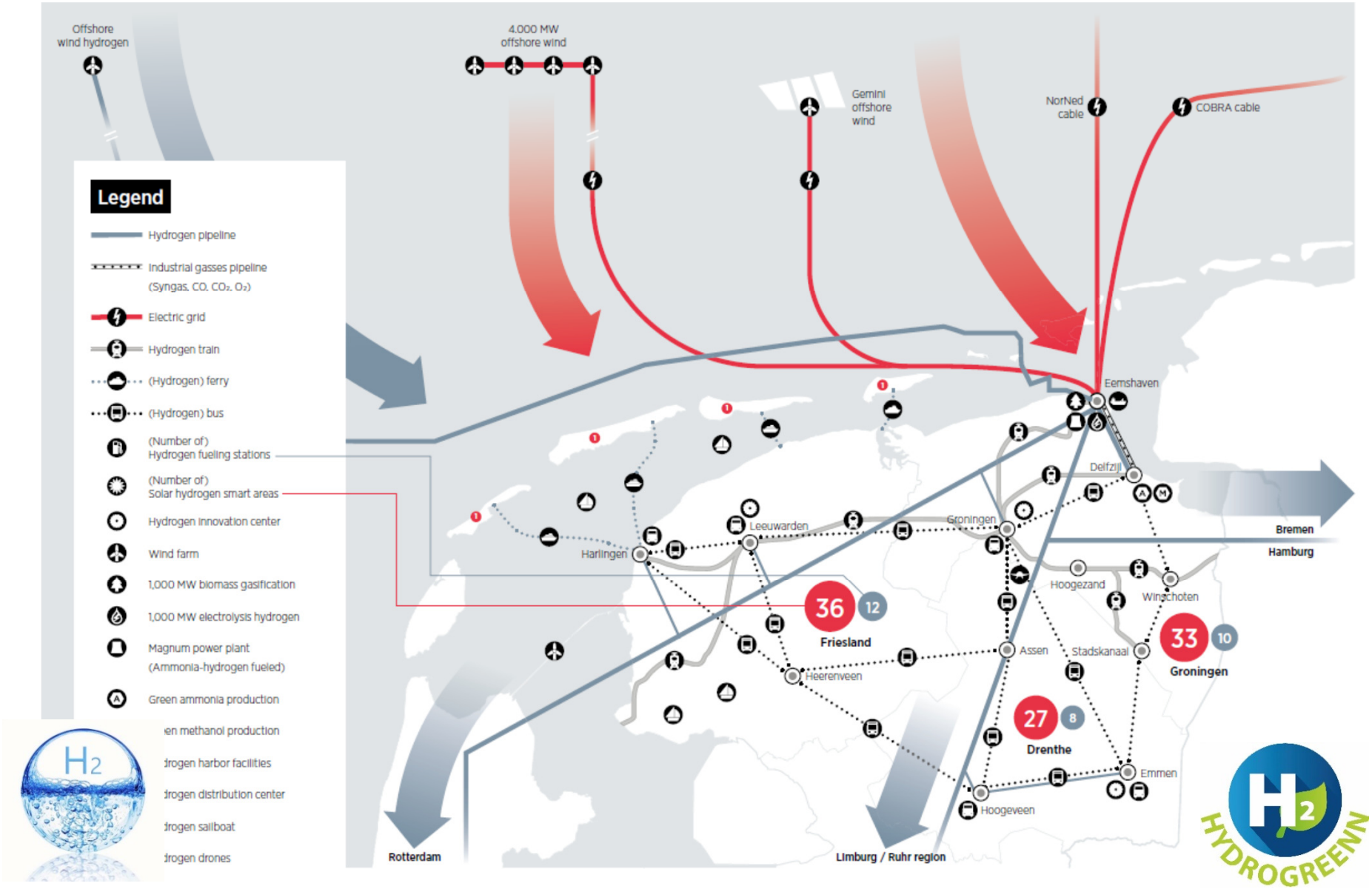








The overall Hydrogen plan up to 2030

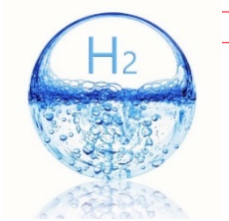


High Level roadmap 2017-2030

Under construction | A | Priority to realize
Included in investments | A A | (A) | Not included in investments

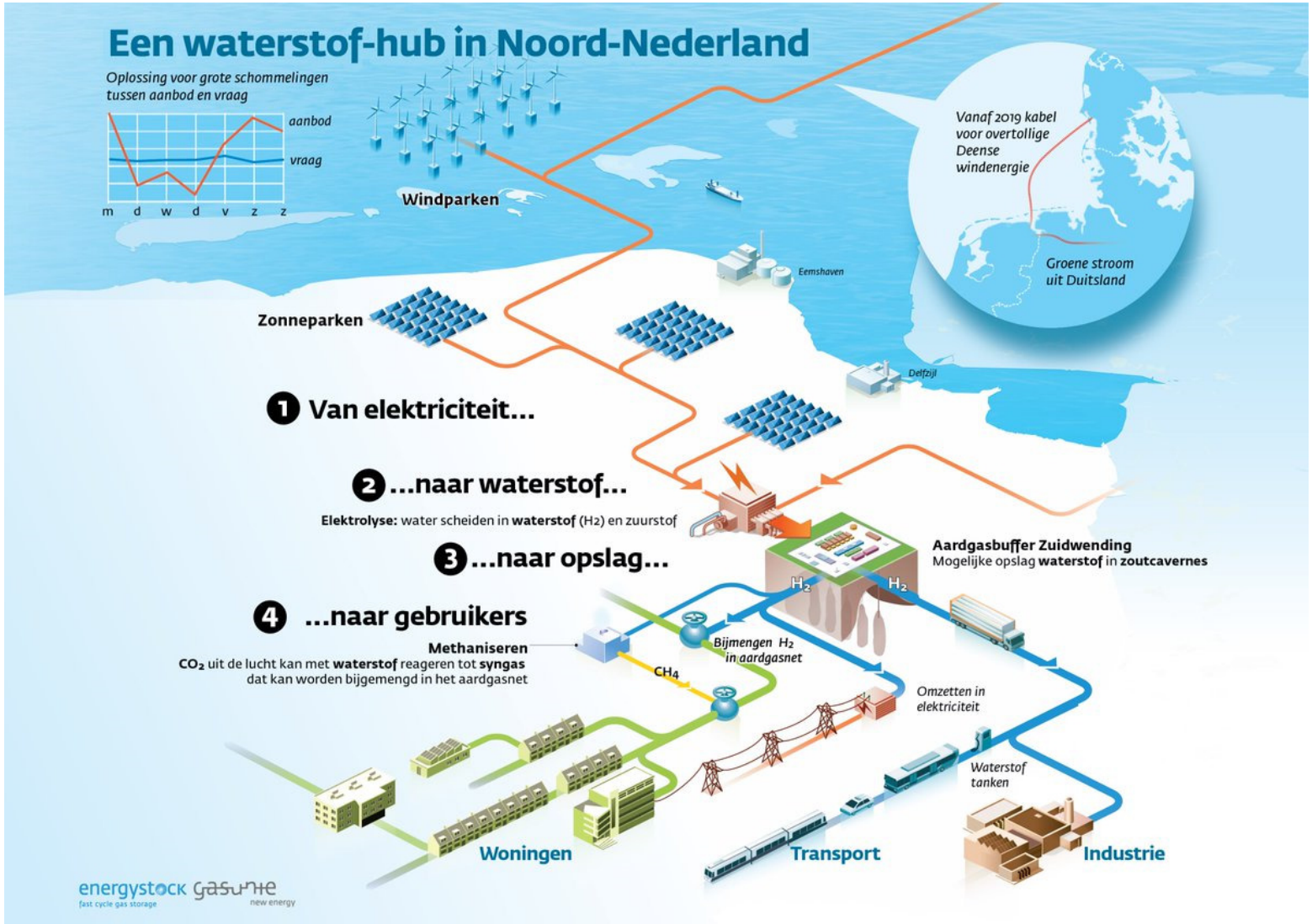
	2017	2018	2019	2020	2021	2022
Wind offshore	*600 MW Gemini*				1,000 MW	
Electrolysis			**20 MW**		**480 MW**	
Biomass gasification					**20 MW**	
Solar-hydro areas		**Ameland**	**1 icon area**	**1 icon area**		5 areas
Offshore cable	*600 MW Gemini*		*700 MW Cobra*		1,000 MW wind	
Ammonia					(Magnum Nuon First import)	**Delfzijl 150,000 tons production**
Methanol						
Pipeline					**Delfzijl, Rotterdam, Limburg**	
Fueling stations	**Delfzijl**	**2**	**4**	**6**	**8**	**10**
Distribution centers					**Harlingen i.e. trains**	Groningen i.e. trains
Fuel cell balancing						
Harbor facilities			**Truck loading**		Ammonia import	
Busses	**2**	**6**	**20**	**20**	**20**	**20**
Trains			**Groningen-Leeuwarden**		**10**	**20**
Trucks	**2**	**6**	**10**	**20**	**30**	**50**
Cars		20	100	500	1,000	3,000
Boats			**Ecolution**	Sail boats	Sail boats	First ferry
Others		Forklifts	Drones	Robots	Mobile	
Research, innovation centers	Energy Academy Europe, research universities, universities of applied sciences, EnTranCe (Groningen), Wetsus (Leeuwarden), Emmtec (Emmen)					
Trading platform						
Trade fair		Shows	Shows	First time	1	1
Green certificates					Established NL	Established Germany
Regulations		**Provisionally established**			Fully implemented	
Education	MBO, HBO, universities, high schools, primary schools, etc.					
	Automotive, fire department, police, installation technicians, builders, technicians, regulators, etc.					

2023	2024	2025	2026	2027	2028	2029
1,000 MW		1,000 MW		1,000 MW		(Far offshore wind)
500 MW			(1,000 MW)			(1,000 MW)
480 MW		500 MW				
5 areas	10 areas	10 areas	15 areas	15 areas	15 areas	20 areas
1,000 MW wind		1,000 MW wind		1,000 MW wind		(1,000 MW NorNed 2)
	Delfzijl 150,000 tons production		(Magnum Nuon 1.3 million tons import)			
	Delfzijl 150,000 tons		Delfzijl 150,000 tons			
Ruhr area, Harlingen, Emmen				Bremen-Hamburg		(Offshore gas/hydrogen pipeline)
10	10	10	10	10	10	10
Emmen	Leeuwarden		Hoogeveen		Harlingen electrolysis	Emmen electrolysis
		100 MW	100 MW	100 MW	100 MW	100 MW
Biomass import						(Hydrogen shipping)
50	50	50	50	50	50	50
20						
50	50	50	100	100	100	100
6,000	10,000	10,000	15,000	15,000	20,000	20,000
First yacht	First fishing boat	First freight ship				
Energy Academy Europe, research universities, universities of applied sciences, EnTranCe (Groningen), Wetsus (Leeuwarden), Emmtec (Emmen)						
						Established
1	1	1	1	1	1	1
		Established Europe				
MBO, HBO, universities, high schools, primary schools, etc.						
Automotive, fire department, police, installation technicians, builders, technicians, regulators, etc.						

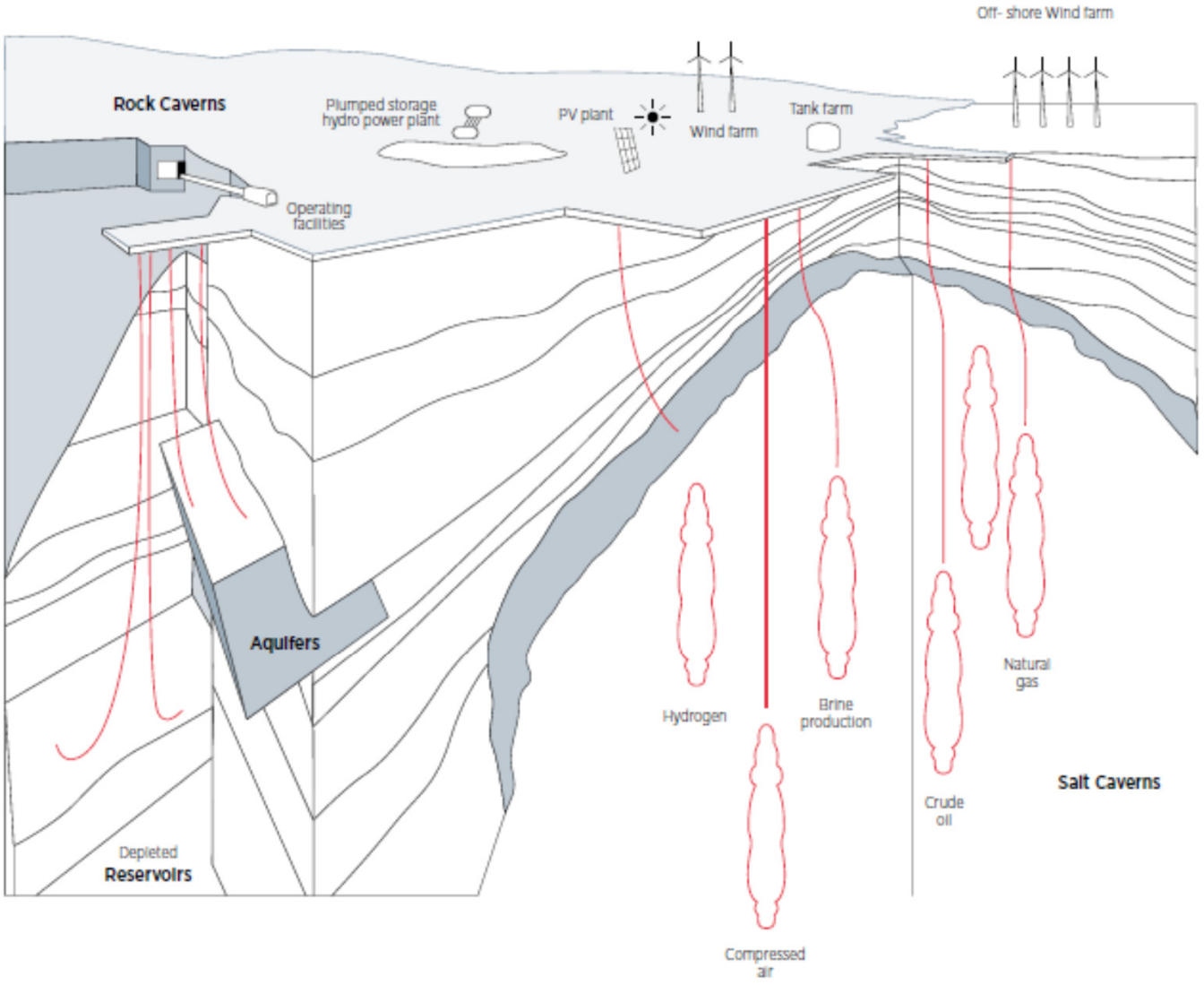


H2 HYDROGREENN

Hydrogen Hub North Netherlands



Hydrogen storage (in Salt Cavern)



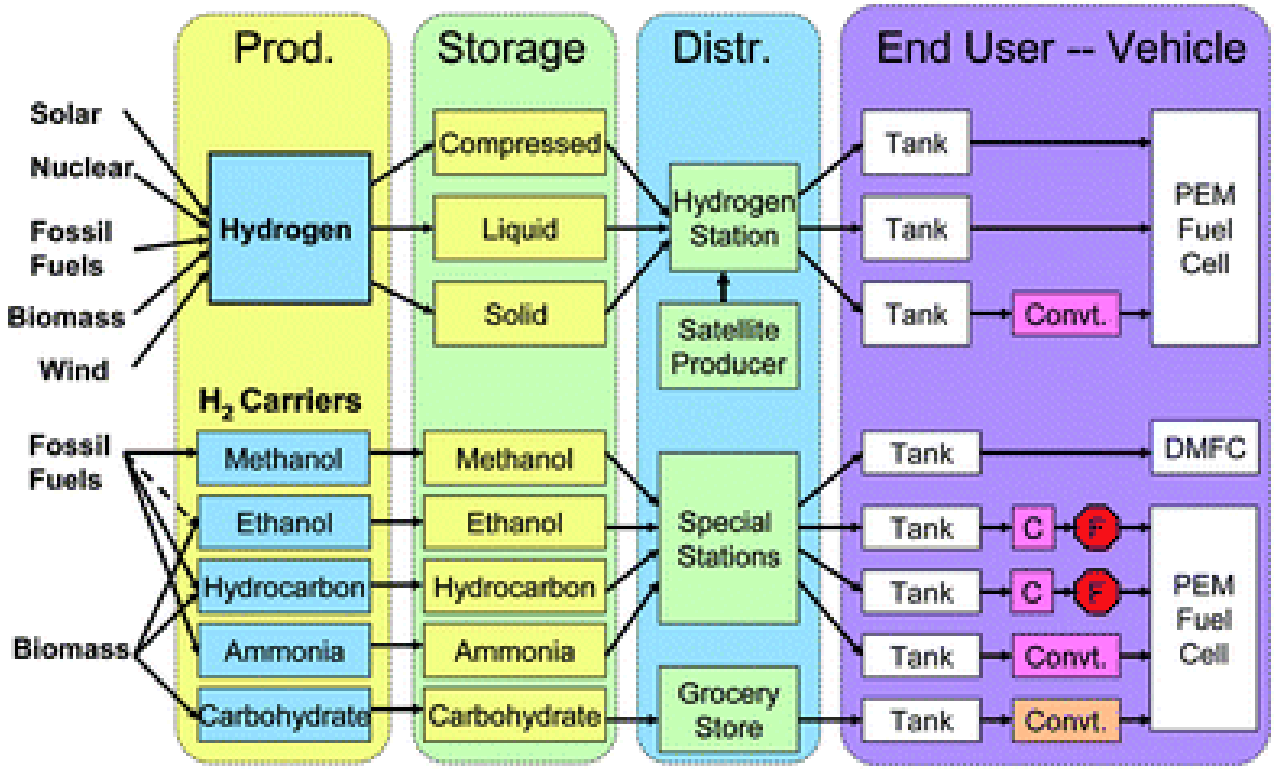
Tennet/Gasunie – Long term project 2050

North Sea Wind Power Hub

Key factors for success

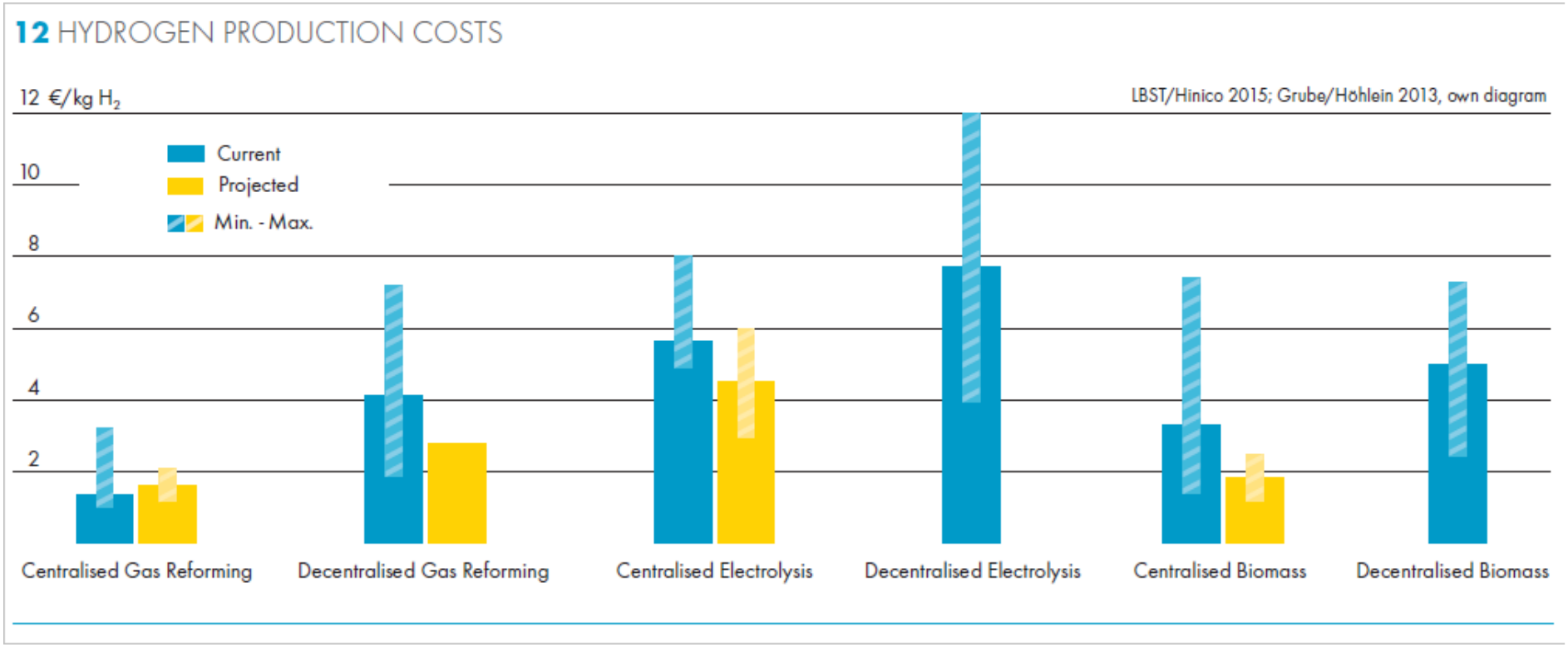
- Scale
- Location
- Island
- Hub and spoke

How do we create Hydrogen



Picture Y.-H. Percival Zhang 2009

Hydrogen production cost



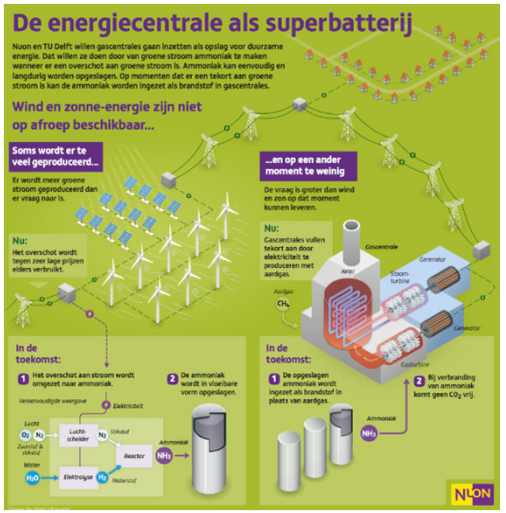
Source: [Shell_hydrogen_study]

Regional project Hydrogen North Netherlands

Gasunie begint met groene waterstof

Voor waterstof wordt toekomst voorzien bij aandrijving auto's

Zo'n 10.000 zonnepanelen



De energiecentrale als superbatterij

Wind en zonne-energie zijn niet op afroep beschikbaar...

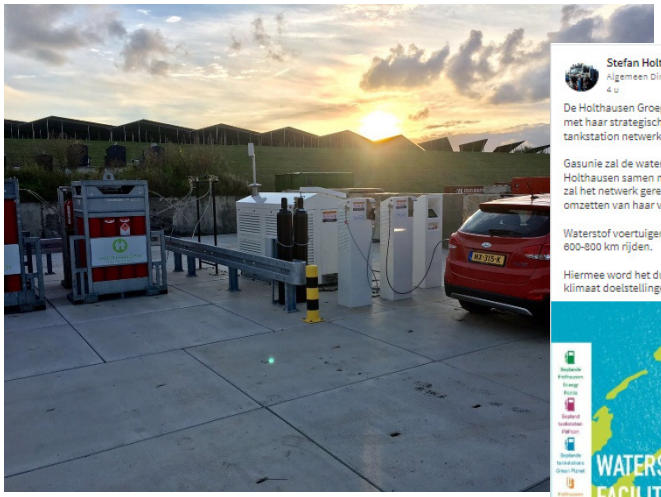
Soms wordt er te veel geproduceerd...

...en op een ander moment te weinig

Nu:

In de toekomst:

Regional project Hydrogen North Netherlands

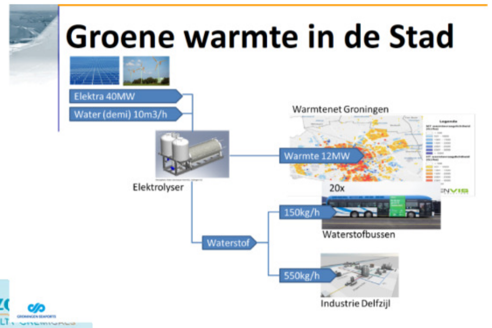


Electrolysis scale up

1000 MW
Eemshaven
> 2030

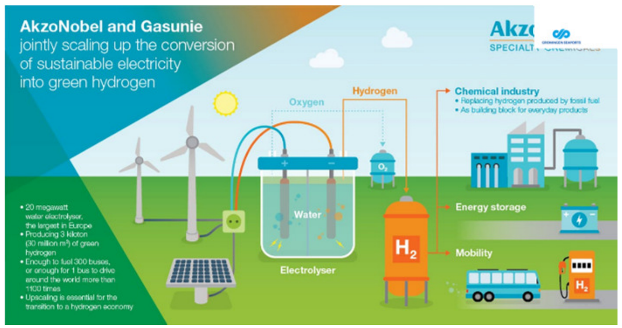
40 MW City Groningen
2020 INV -2023-24 project

Groningen Seaport project



300 MW
K14 NAM
Study 2025

20 MW Delfzijl
2019 INV (2021
operational



1 MW
Zuidwending
2018

Gasunie begint met groene waterstof

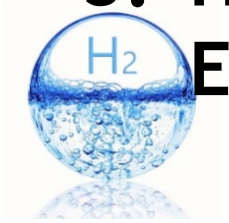
Zo'n 10.000 zonnepanelen

Actual HYDROGREENN cases

1. Hydrogen Train Groningen – Leeuwarden- Start May 2018 – Train on-track for Pilot Jan 2019.

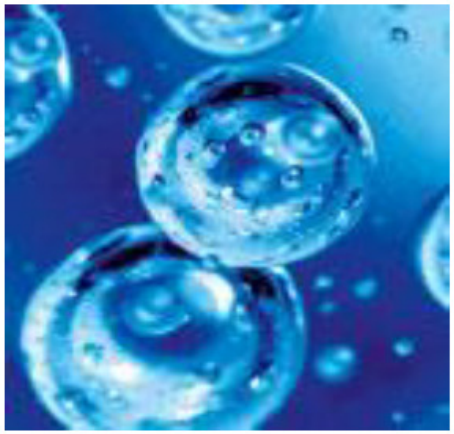
2. Map 74 Hydrogen project Key-parameters all production and plant project up to 2030 for back-bone design Nord Netherlands
   - **Nitin Maurya,** *EnTranCe*

3. **Hydrogen city heating Hoogeveen- Nijstad-East and Erflanden**

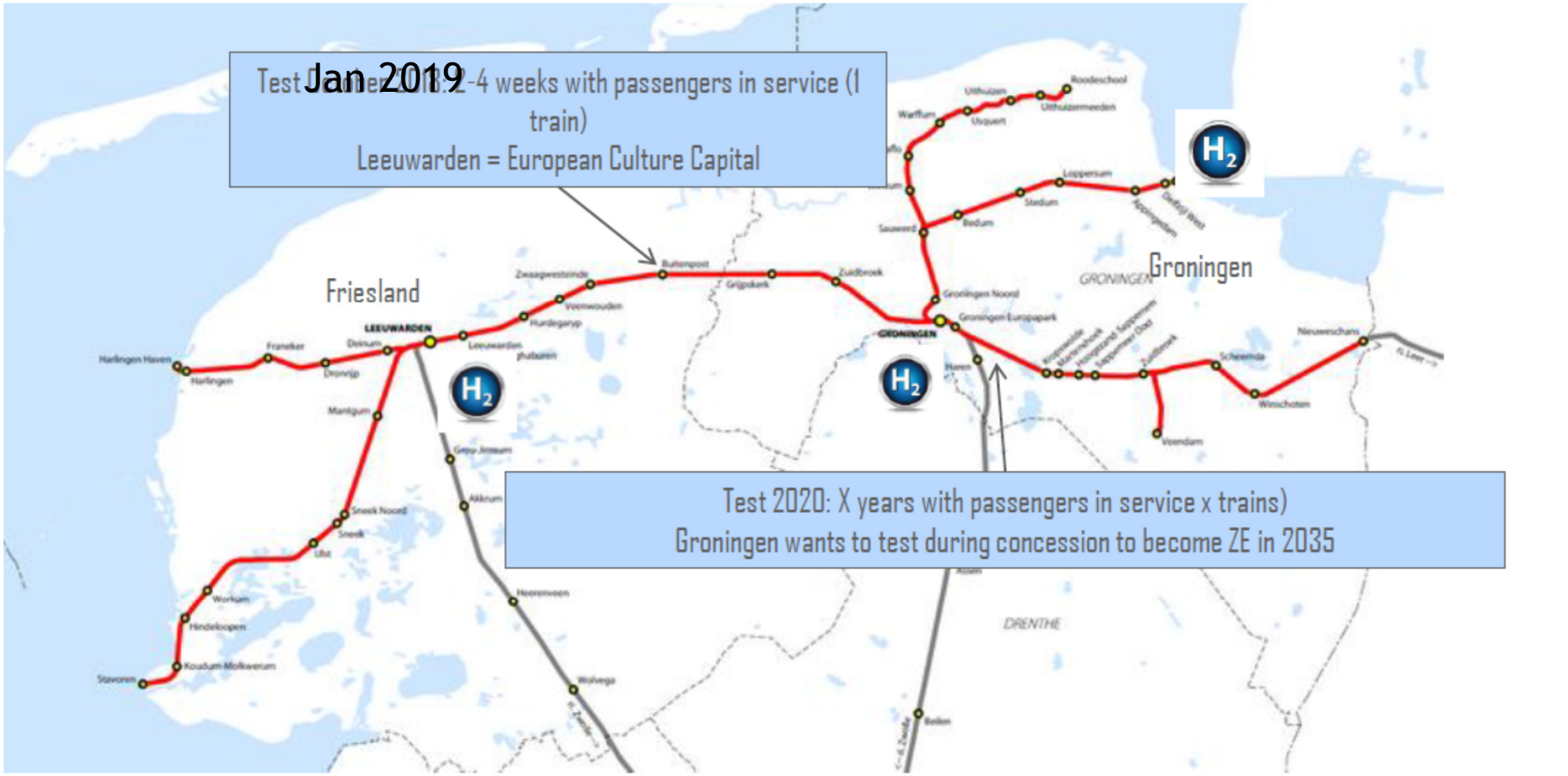


Value chain Hydrogen train

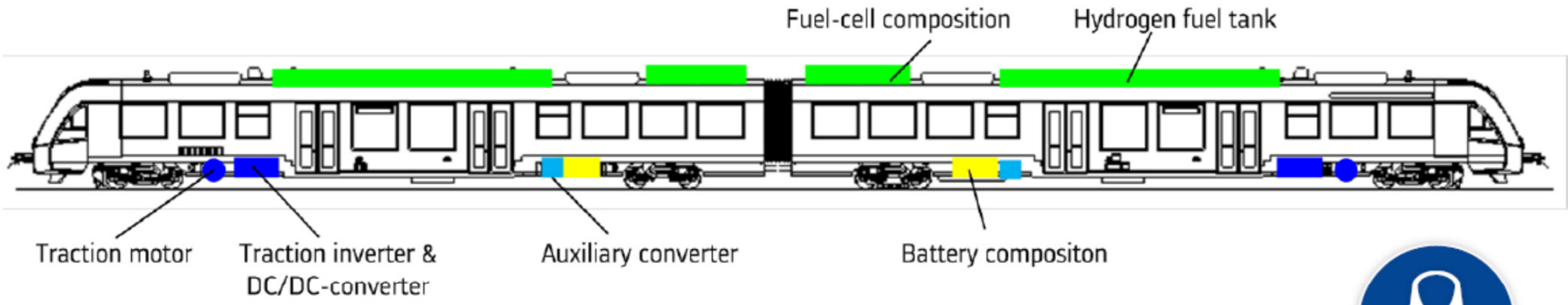
It’s all about Energy and weight

Coal	Diesel	Hydrogen
		
34 MJ/kg	43 MJ/kg	120 MJ/kg
		

Plan testing province Groningen and Friesland



Diesel technology was replaces with hydrogen and fuel cell technology



- No CO2 emission
- Noise reduced with 60% due to Electrical engine
- Performances remain (passenger capacity, acceleration, max 140 km/h, till 1000 km)
- Low Life Cycle Cost (balancing energy level / battery usage)
- Primary electric energy by fuel cells plus storage by li-ion batteries (additional acceleration and recovery of braking energy)
- Reduced energy consumption due to Intelligent energy management
- Tank time 10-15 minutes @ 350 Bar and maximum 180 kg per train

Train businesscase (OPEX)

Tabel 23: Totale kosten – alles in een jaarlijks bedrag

Totale kosten	Eenheid	H_2 inkopen	Groene energie	Wind	Zon
Jaarlijkse exploitatiekosten (15 jaar) Excl. subsidie	[M€/jaar]	33.2	37.0	35.5	47.8
Jaarlijkse exploitatiekosten (20 jaar) Excl. subsidie	[M€/jaar]	30.8	34.1	30.6	40.8
Jaarlijkse exploitatiekosten (15 jaar) Incl. subsidie	[M€/jaar]	33.2	37.0	26.4	31.9
Jaarlijkse exploitatiekosten (20 jaar) Incl. subsidie	[M€/jaar]	30.8	34.1	21.5	24.9

Source 2016: Arcadis Onderzoek batterij Waterstoftrein

HanzeResearch
University of Applied Sciences

Energy

Hydrogen

Hydrogen Map for North Netherlands

EnTranCe ENERGY TRANSITION CENTRE

Energy Academy Europe

Hydrogen map

Background

- The designing of this map will have an objective of serving as a building block for an optimal configuration of all the existing and planned hydrogen activities in North of Netherlands.
- Creation of an interface through google map where all the hydrogen projects will be visible.
- ***Example - http://www.avih.nl/biomassakaart/***

To identification of lowest cost delivery mode

Structure of mathematical optimization of Hydrogen supply chain

Inputs to the Map

- Fossil fuels feedstock
- Renewable energy resources
- Biomass potential
- Production technologies
- Scales of production
- Storage type and capacity
- Roads transport
- Pipelines

Scenarios

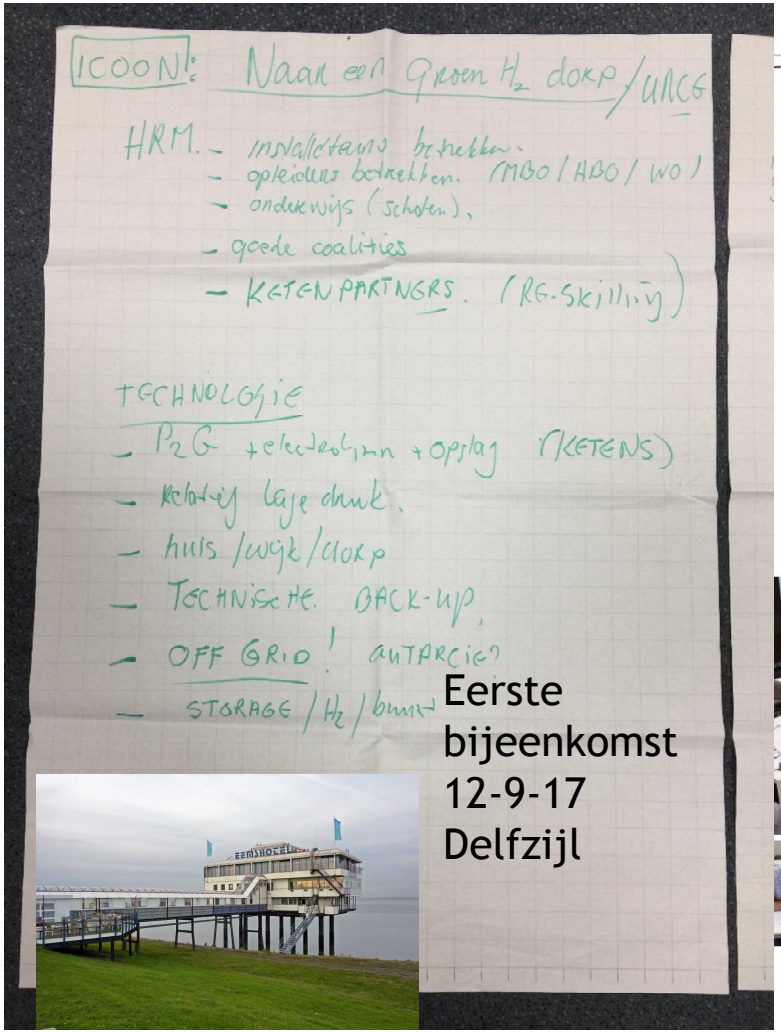
- Flexible Hydrogen Demand
- Hydrogen FCV market penetration
- Environmental policies

Hoogeveen next step project

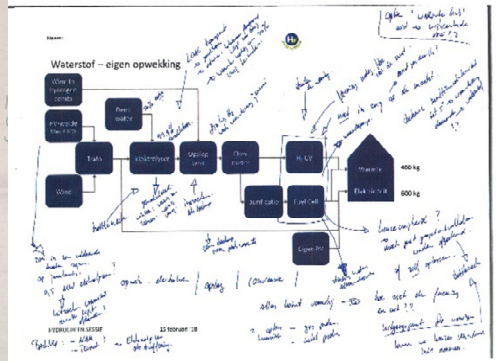
- Hoogeveen Nijstad-east will be the first 100% hydrogen neighborhood in The Nederland/ Europa / world.
  - Hoogeveen 3Q 2019
  - Tokio 2020 (Fuel Cell)
  - - Hy4Heat (London) - UK programm
  - Leeds 2026 (Blue Hydrogen)
- Unique opportunities for other cities and technology development.


8 Km
Pesse
Green Planet
Hoogeveen Nijstad Oost Waterstof wijk
Project Status
RWZI
Echten
Nijstad-
Oost 79
woningen
Erflanden 1130
woningen
Recreatie
woningen 105
stuk
NAM
Zonneweide optie 4 MW/ 5HA
H2
Gemeente
Hoogeveen
H2
HYDROGREENN

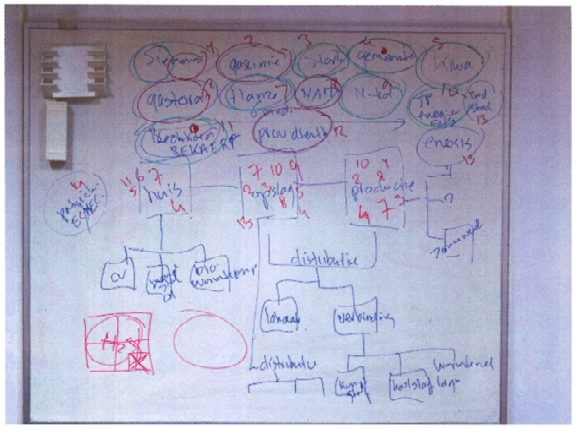
Wat is er in 1 jaar gebeurd in Waterstof land

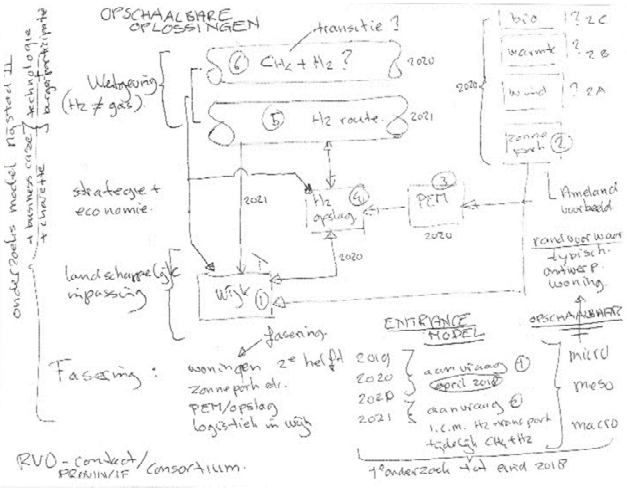


Design sessies Entrance



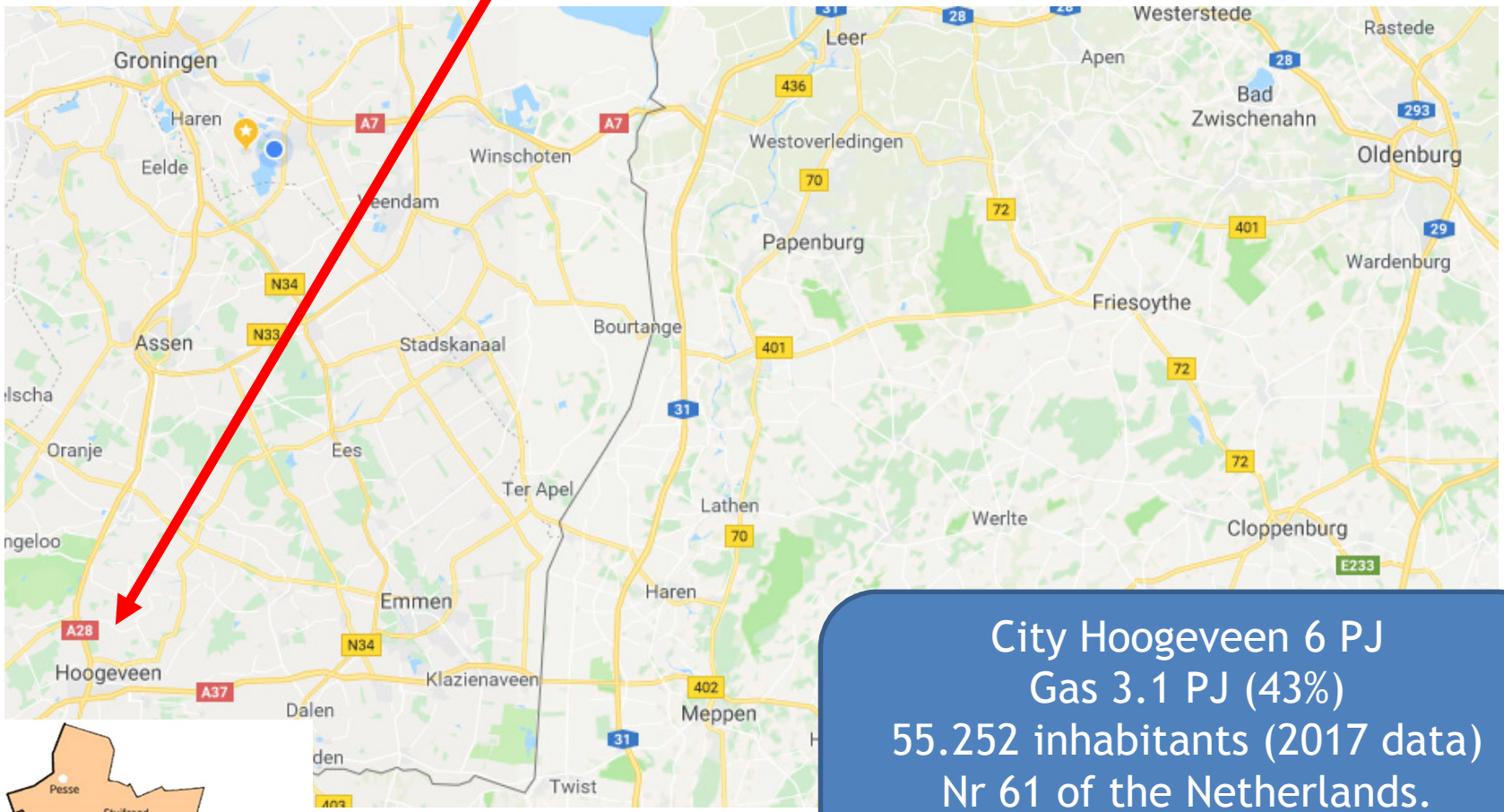
Project coalitie – RVO plan Hoogeveen





Wat is er in 1 jaar gebeurd in Waterstof land

Hoogeveen (Drenthe)



City Hoogeveen 6 PJ
Gas 3.1 PJ (43%)
55.252 inhabitants (2017 data)
Nr 61 of the Netherlands.
127,77 km²

Project doelstelling

- **De doelstelling van dit project is om een (techno-economische) blauwdruk en bijbeh technologie op te leveren om heel de warmtevoorziening, op basis van een watersto ketel, van deze woningen op 100% waterstof (H2) te laten functioneren.**

- **Deze blauwdruk en technologie moeten vertaalbaar zijn naar bestaande woonwijker rest van Nederland. Naast reductie van aardgasgebruik, zal hiermee ook een marktka betrokken partijen worden gecreëerd.**

- **De blauwdruk zal niet enkel technologisch zijn, ook de maatschappelijke businesscas sourcing strategie en het draagvlak onder bewoners zal worden meegenomen.**

- **Deze benadering zal worden afgezet tegen andere waterstof gebaseerde oplossingen (brandstofcel, lokaal warmtenet, etc.), zodat voor- en nadelen inzichtelijk worden.**

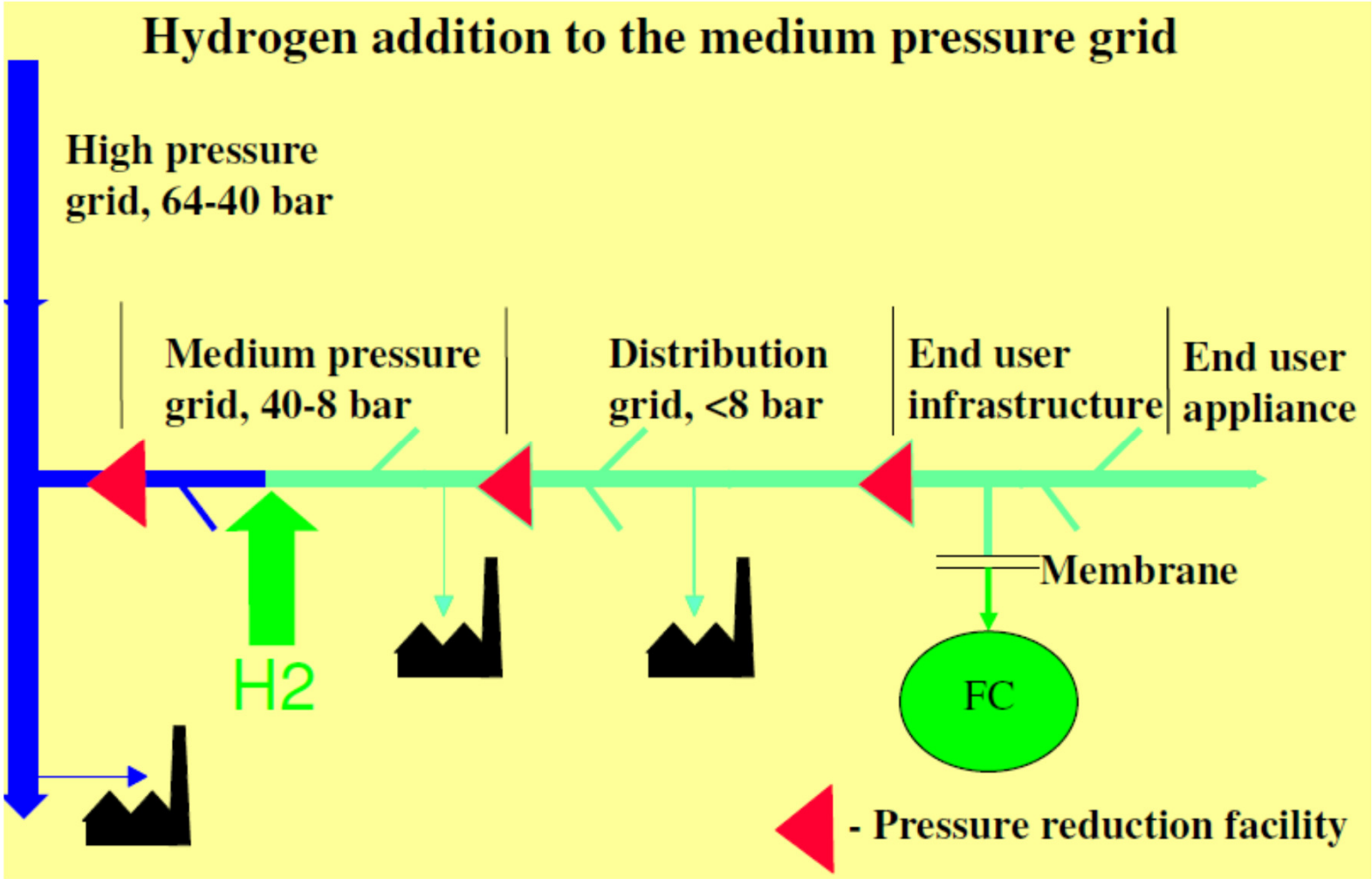
- **Dit project staat niet op zichzelf. Nijstad-Oost is een demonstratieproject dat als kata dient voor de bestaande gebouwde omgeving**

CASE HOOGEVEEN 27 Members

Ameland 14 houses test case 2007-2011

HYDROGEN
LAB 30%
Field test Average 11.5% MAX 18.6%

NATURALHY project



Source IGRC 2008 – G. Tiekstra . F.P. Koopman NV Nederlandse Gasunie

Safety HyHouse project

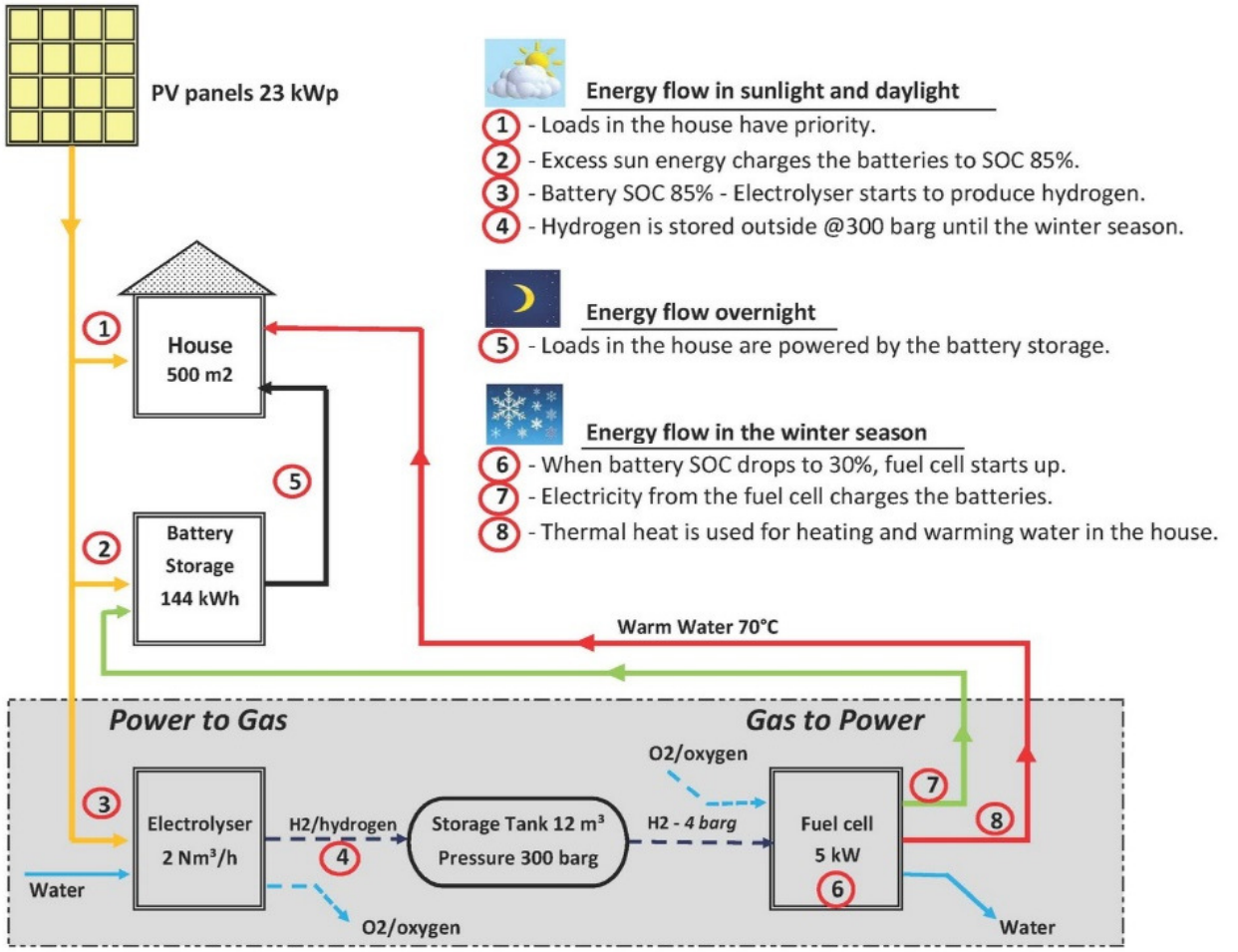
- **What is the HyHouse Project?**
- Kiwa Gastec was charged with evaluating the risks associated with using hydrogen in a domestic setting. This 'HyHouse' project took place in a two storey, three-bedroom farmhouse in Scotland provided by SSE.
- Gas leaks are rare but do occur from time to time from sources as diverse as a defective gas appliance to DIY accidents. The project was designed to prove whether accidental leaks from a pure hydrogen or hydrogen and natural gas mixture supply would have more or less risk attached than a leak from a natural gas supply.
- The outcome of the HyHouse project was reassuring. Hydrogen is much lighter than natural gas, which means that if there is a leak in a house it is less likely build up to dangerous amounts than natural gas is.
- The project concluded that the risk associated with using hydrogen in the home was no greater than the risk associated with using natural gas.
- http://www.kiwa.co.uk/uploadedFiles/About_Us/GaC/Hy%20House%20Report.pdf

Hydrogen in single houses

- **Hans-Olof Nilsson Gothenburg project**
- https://www.linkedin.com/pulse/true-pioneer-goes-off-grid-michael-jensen/

Hans-Olof Nilsson Gothenburg project configuration

Power to gas installation keeps a family home and their EV´s running around the year



Energy flow in sunlight and daylight

1. - Loads in the house have priority.
2. - Excess sun energy charges the batteries to SOC 85%.
3. - Battery SOC 85% - Electrolyser starts to produce hydrogen.
4. - Hydrogen is stored outside @300 barg until the winter season.

Energy flow overnight

5. - Loads in the house are powered by the battery storage.

Energy flow in the winter season

6. - When battery SOC drops to 30%, fuel cell starts up.
7. - Electricity from the fuel cell charges the batteries.
8. - Thermal heat is used for heating and warming water in the house.

STORK
A Fluor Company

Waterstof huis Borkum (DE)
Solenco Power en Giocomini

Video Solenco power box

https://binged.it/2JeAdQd

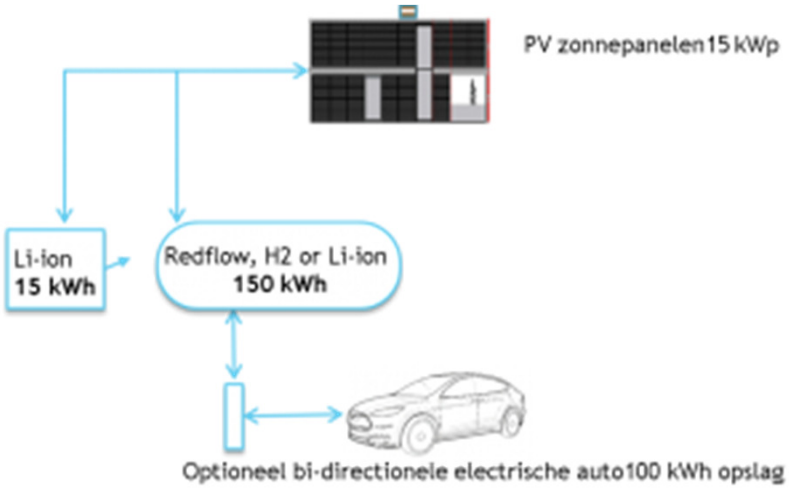
http://www.vdbenergy.com/

Mike Strizki USA Hydrogen house

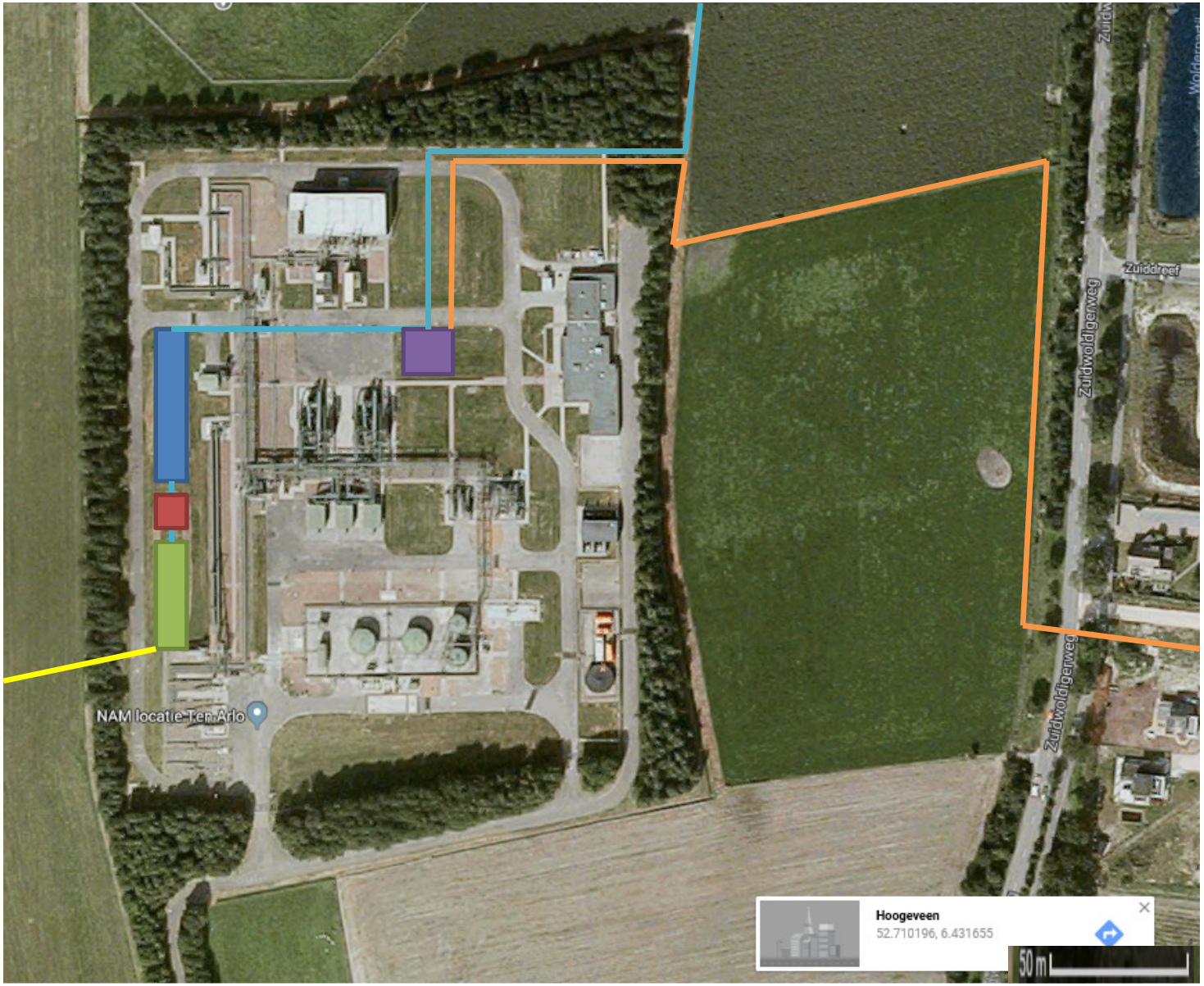
- Hydrogen House project USA
- http://www.hydrogenhouseproject.org/index.html

Livefree concept NL

- http://live-free.eu/language/nl/main/



NAM location Ter Anlo

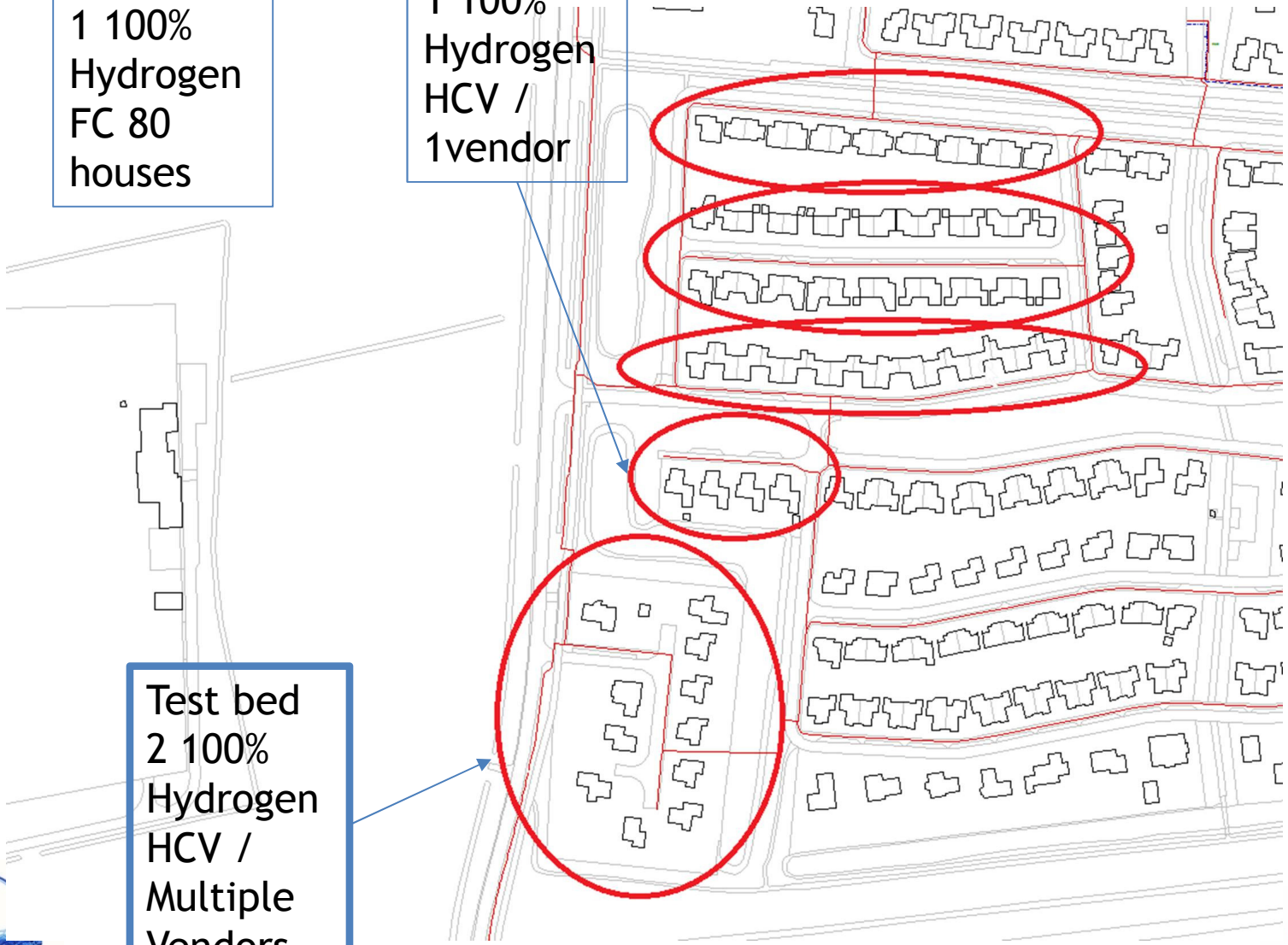


- E aansluiting
- H_2-leiding
- H_2/CH_4 leiding
- Electrolyser
- Compressor
- Opslag
- Mengstation/ drukregelaar

Erflanden on Hydrogen

Test bed
1 100%
Hydrogen
FC 80
houses

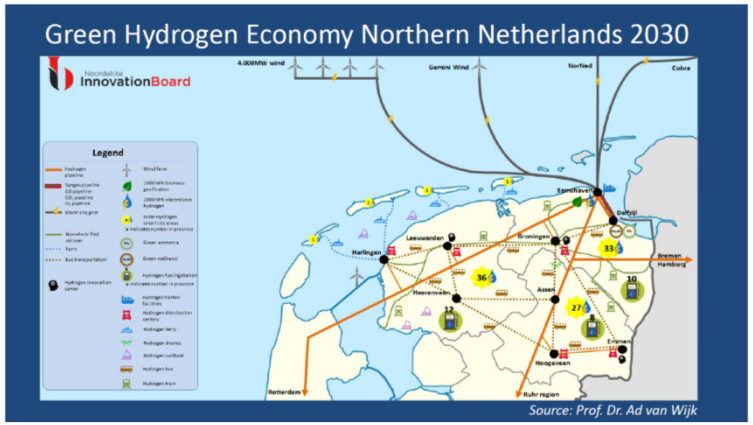
Test bed
1 100%
Hydrogen
HCV /
1vendor



Test bed
2 100%
Hydrogen
HCV /
Multiple
Vendors

Phases 2018-2030

- Phase 0 `- Concept design and basic engineering package
- Phase 1 (2019)- start construction new build Nijstad-east op 100% H2
- Phase 2 (2020)- Erflanden on H2/natural gas mixture 20%, 30%, 100%
- Phase 3 - Erflanden on 100% H2
- Phase 4 - Hydrogen back-bone from Emmen will be available (SHELL-NAM Gasontzwavelingsfabriek (GZI-NEXT)
  http://www.dvhn.nl/drenthe/NAM-wil-duurzame-energie-opwekken-op-plek-gasontzwavelingsfabriek-Emmen-22707099.html
- Phase 5 - The entire city Hoogeveen can use H2

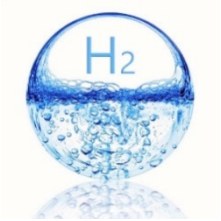


Hydrogen pipeline to Hoogeveen

Hydrogen pipeline to Hoogeveen

High Level plan

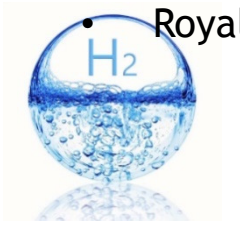
- 80 new houses on fuel cell technology
- 1.130 houses (Erflanden)
  - 1.126 houses long term test “current” CV heating systems
    - 3 years on 20% H2/Natural Gas
    - 7 years on 30% H2/Natural Gas
  - 4-15 houses on 100% CV with new Hydrogen CV heating system (new development)



HYDROGREENN

Consortium Partners Hydrogen Hoogeveen

- Gemeente Hoogeveen
- Stork Nederland B.V.
- Nederlandse Gasunie N.V.
- GasTerra B.V.
- Nederlandse Aardolie Maatschappij
- Bekaert Combustion Technology B.V.
- N-TRA B.V.
- Instituut Fysieke Veiligheid (IFV)
- Siemens Nederland BV.
- Nedstack B.V.
- JP-Energiesystemen B.V.
- Hanze University of Applied Sciences
- Provincie Drenthe
- Stichting New Energy Coalition
- Visser & Smit Hanab Distributie B.V.
- Green Planet Pesse B.V.
- DNV-GL Netherlands B.V.
- Enexis
- Royal haskoningdhv



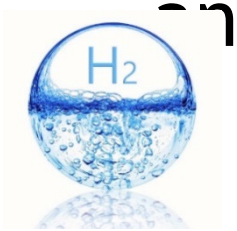
HYDROGREENN

Investment consortium members

- 11.300+ hours in-kind hours
- 180.000 Euro investment

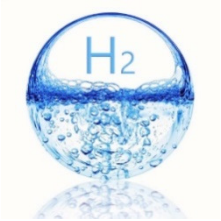
- Project Start next phase 1-6-2018
- Project end next phase 31-5-2019
- Construction Start 3Q 2019

- Request national Subsidy for development and research H_2 burner “home” set.



Main Goals Hoogeveen

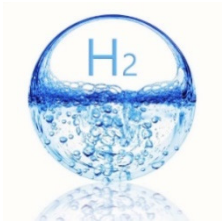
- Local generated Green energy (solar PV)
- Local stored Green Energy
- Use of Hydrogen
- No addition cost for end users
- Expanding know-how and field test Hydrogen in urban area
- Develop Hydrogen home heating CV.
- Field test large installation VINEX wijk.



HYDROGREENN

Research questions

1) Can we use hydrogen to generate heat and/or electricity in homes?
2) How do we deliver the energy content of hydrogen at the right time and quantity at homes?
3) How do we deliver or produce hydrogen in the residential area?
4) How do we use hydrogen to generate heat and/or electricity in the residential area?



HYDROGREENN

Additional questions

Smart hydrogen

- Is it possible to design a hydrogen central heating boiler?
- Is a fuel cell meaningful?
  Heat, electricity, residential and neighbourhood level
- What about the hydrogen flowmeter?
- How does the integration of hydrogen in or on the house look like?
- Which representative tests needs to be performed for houses and neighbourhoods?

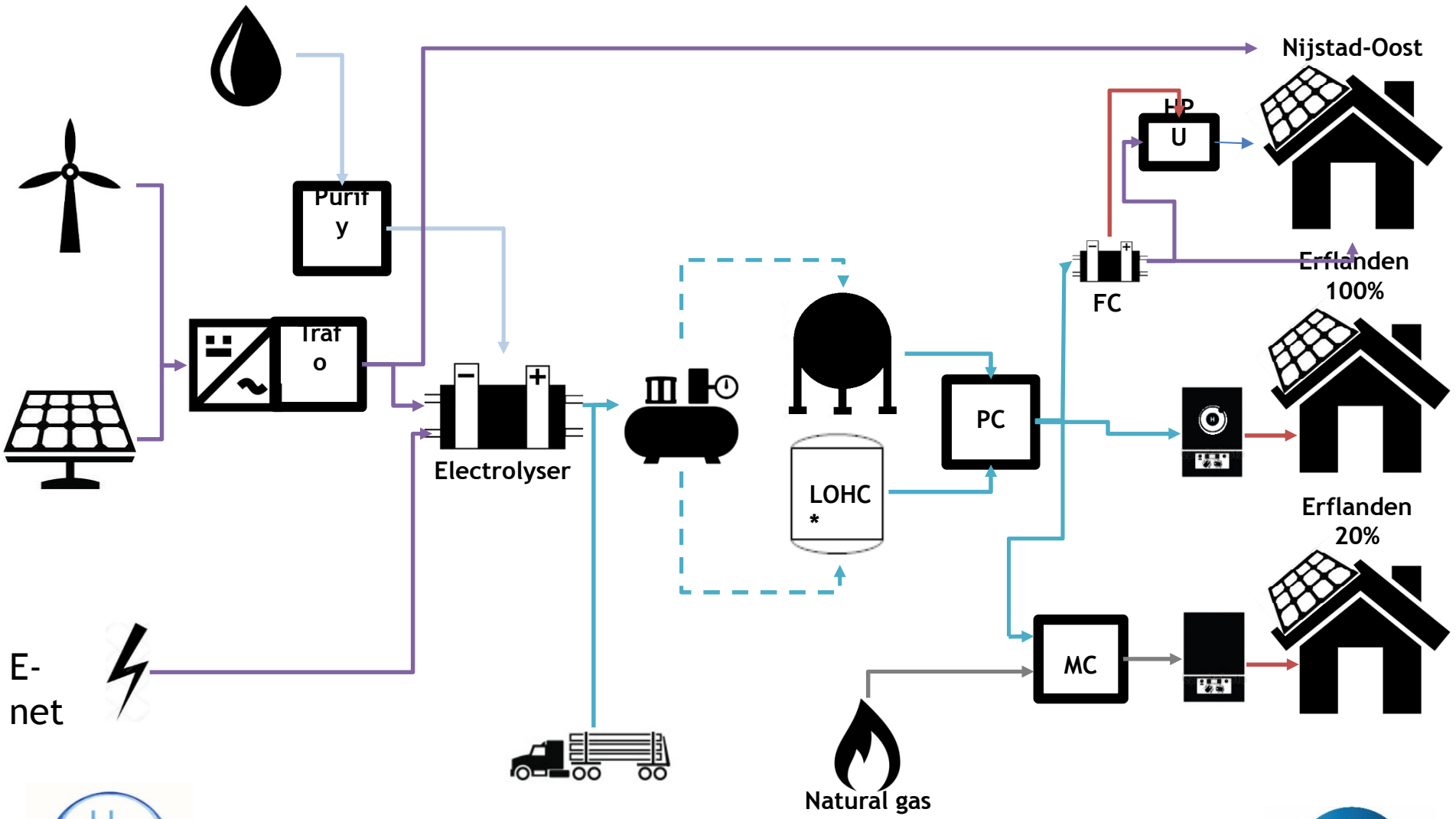
Smart buffering

- What are the design criteria's for an energy network?

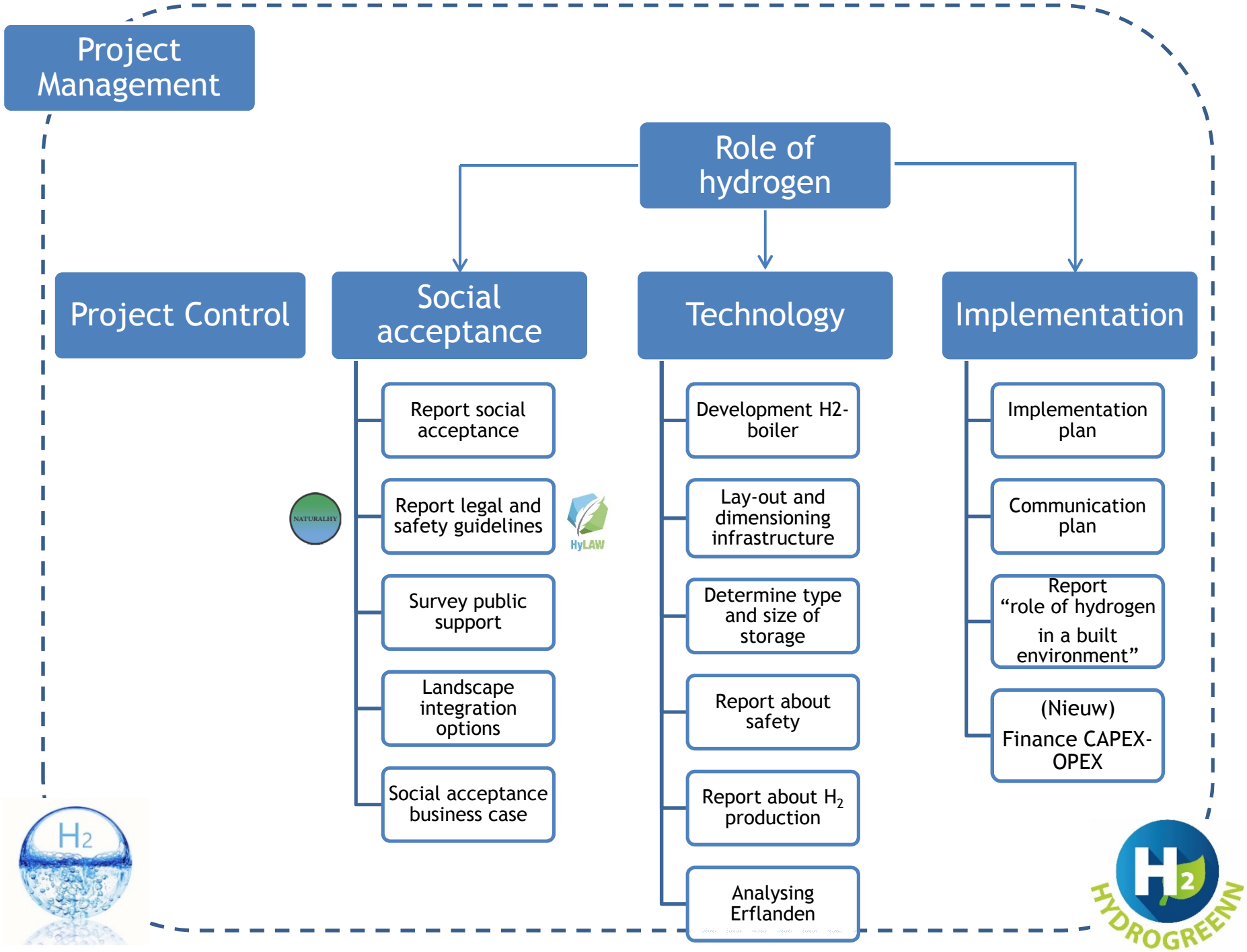
Smart Production

- What are the logistical requirements, local and external issues?
- What is the security of supply and/or delivery terms?

General Layout (concept)



*Liquid Organic Hydrogen Carrier


Project Management
Role of hydrogen
Project Control
Social acceptance
Technology
Implementation
Report social acceptance
Report legal and safety guidelines
Survey public support
Landscape integration options
Social acceptance business case
Development H2-boiler
Lay-out and dimensioning infrastructure
Determine type and size of storage
Report about safety
Report about H_2 production
Analysing Erflanden
Implementation plan
Communication plan
Report "role of hydrogen in a built environment"
(Nieuw) Finance CAPEX-OPEX
NATURALHY
HyLAW
H_2
HYDROGREENN

Werkpakketverdeling

Werkpakket	Werkpakket omschrijving	Werkgroepleider	Organisatie WP-leider
WP-1	Project Management	Willem Hazenberg	Stork
WP-2	Project Beheersing	Willem Hazenberg	Stork
WP-3	Rol van Waterstof	Jan Jaap Aué	Hanze University of Applied Sciences
WP-4	Maatschappelijke acceptatie	Kees Boer	Gemeente Hoogeveen
WP-5	Technologie	Bastiaan Meijer	N-TRA B.V
WP-5.1	Brander ontwikkeling	Joan Teerling	Bekaert Combustion Technology B.V.
WP-6	Implementatie	Kees Boer	Gemeente Hoogeveen

Business case

100 houses, 10 years:

	Savings of Natural Gas		
Hydrogen (%)	CO2 (ton)	Amount (m^3)	€ 0,75 per m^3 *
0	0	0	€ -
20	99	276.029	€ 207.021,84
30	224	414.044	€ 310.532,77
100	2.484	1.380.146	€ 1.035.109,22

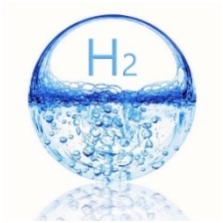
Hydrogen			
kg	€ 10,-- per kg	€ 7,-- per kg	€ 5,-- per kg
0	€ -	€ -	€ -
72.918	€ 729.176,94	€ 510.423,86	€ 364.588,47
109.377	€ 1.093.765,41	€ 765.635,79	€ 546.882,71
364.588	€ 3.645.884,71	€ 2.552.119,30	€ 1.822.942,35

* Incl. Energy taxes and VAT; Excl. Network costs

Break even price H_2: € 2,84

Cold week in January:
- 2 kg H_2 average per hour (30%)
- 10 kg H_2 peak per hour (30%)

1 MW electrolyser: 16 – 19 kg H2 per hour



HYDROGREENN

Business case

1100 houses, 10 years:

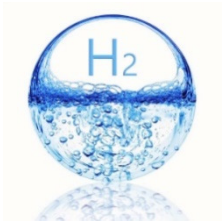
	Savings of Natural Gas			Hydrogen			
Hydrogen (%)	CO2 (ton)	Amount (m^3)	€ 0,75 per m^3 *	kg	€ 10,-- per kg	€ 7,-- per kg	€ 5,-- per kg
0	0	0	€ -	0	€ -	€ -	€ -
20	1.093	3.036.320	€ 2.277.240,29	802.095	€ 8.020.946,36	€ 5.614.662,45	€ 4.010.473,18
30	2.459	4.554.481	€ 3.415.860,44	1.203.142	€ 12.031.419,54	€ 8.421.993,68	€ 6.015.709,77
100	27.327	15.181.602	€ 11.386.201,46	4.010.473	€ 40.104.731,80	€ 28.073.312,26	€ 20.052.365,90

* Incl. Energy taxes and VAT; Excl. Network costs

Break even price H_2: € 2,84

Cold week in January:
- 22 kg H_2 average per hour (30%)
- 116 kg H_2 peak per hour (30%)

1 MW electrolyser: 16 – 19 kg H2 per hour



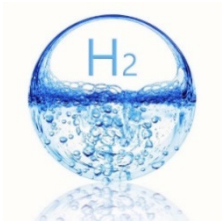
Business case

10 houses		Savings of Natural Gas			Hydrogen			
Year	Hydrogen (%)	CO2 (ton)	Amount (m^3)	€ 0,75 per m^3 *	kg	€ 10,-- per kg	€ 7,-- per kg	€ 5,-- per kg
1 - 10	**100**	248	138.015	€ 103.510,92	36.459	€ 364.588,47	€ 255.211,93	€ 182.294,24
1130 houses								
1 - 3	**20**	337	935.739	€ 701.804,05	247.191	€ 2.471.909,83	€ 1.730.336,88	€ 1.235.954,92
4 - 6	**30**	758	1.403.608	€ 1.052.706,08	370.786	€ 3.707.864,75	€ 2.595.505,32	€ 1.853.932,37
7 - 10	**100**	11.229	6.238.258	€ 4.678.693,69	1.647.940	€ 16.479.398,88	€ 11.535.579,22	€ 8.239.699,44
					Monitoring:	€ 23.000,00		
					Total:	€ 23.046.761,94	€ 16.139.633,35	€ 11.534.880,97

* Incl. Energy taxes and VAT; Excl. Network costs

Break even price H_2: € 2,84

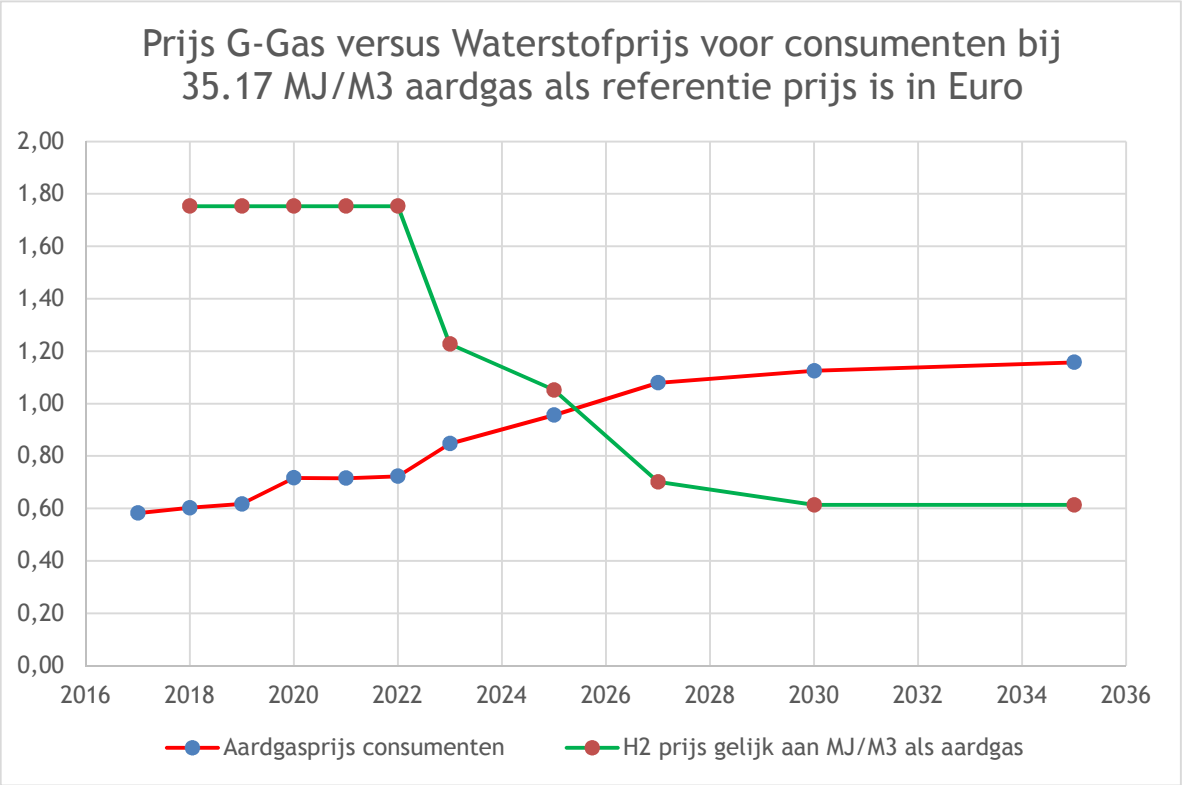
Cold week in January:
- 22 kg H_2 average per hour (30%)
- 116 kg H_2 peak per hour (30%)



1 MW electrolyser: 16 – 19 kg H_2 per hour
Dutch PBL expect natural gas industry price increase 0,21 (20215) > 0,28 (2030) = + 33%

HYDROGREENN

H2 In The Netherlands



With current market development:

Blue H2 at the moment 2-3 times cost of Grey H2. Green H2 is 2-3 times cost of Blue H2.

Green H2 expected to compete with Blue H2 in 10-15 years if on large scale

These assumptions are volatile as the market can change.

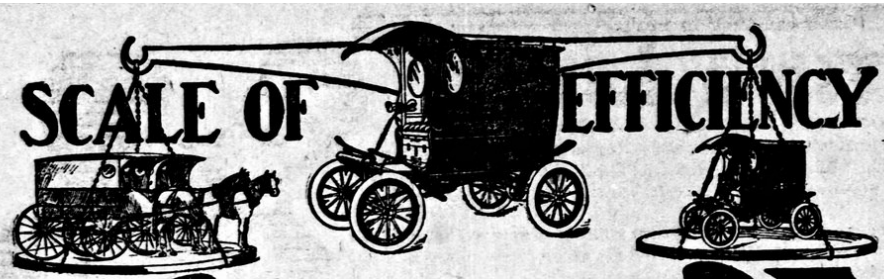
Business case – blijft lastig maar vroeger ook

Horse vs. Automobile

BEFORE you discard your horse and buy an auto it is well to think of the cost.
Figure how much you spend for harness and then think of what new tires amount to.
Figure up what it takes to feed Dobbin in a year and then think of gasoline, repairs and storage charges.
Dobbin is worth what you paid for him two years ago, where's the man with an auto that can say the same?
Come in and get a new harness instead of a new car and remember that Dobbin will take you through snow and mud as well as on good roads and that his carburetor is never out of order.

Ed. Klein

732 Massachusetts Street



SCALE OF EFFICIENCY

Oldsmobile Talks to Merchants.

One Oldsmobile Express Will do the Work of Two Ordinary Delivery Wagons

"IT DELIVERS THE GOODS."

We know this because *it is being done every day.*
We have the figures to prove it.
Its speed in covering long distances, its unlimited endurance and its cheapness to operate are the reasons why.
The yearly saving in operating cost over two horses is $675.00—the saving over three horses is $1,375.00.
An Oldsmobile Light Delivery Car will usually *pay for itself in one year*—often sooner.

A merchant's savings on an $850 investment in an Oldsmobile Express will equal the yearly earning capacity of $10,000 at 7 per cent. It will pay any merchant to look into this matter carefully. He can have an actual test made, if he wishes, without cost. Our agent will put his time and gasoline against the merchant's time and give a demonstration that will prove our claim.

Send for catalogue, *mailed free.* Oldsmobile Runabout, $650; Touring Runabout, $750; Light Tonneau, $950; Oldsmobile Light Delivery Car, $850.

OLDS MOTOR WORKS, Detroit, Mich.

AGENT

Wichita Automobile Co.

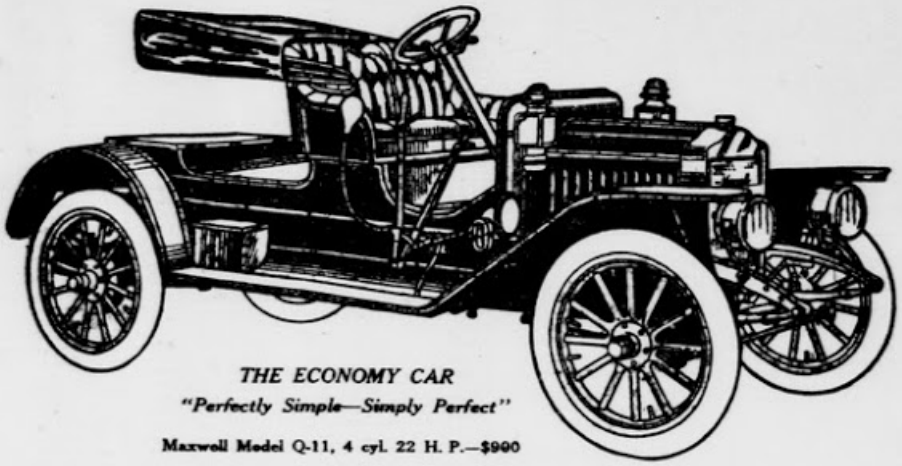
Business case

The First Real Cost-Test Ever Made

Automobile *vs.* Horse

"Maxwell" per passenger mile—$1\frac{8}{10}$ cents

Horse and Buggy per passenger mile—$2\frac{1}{2}$ cents



THE ECONOMY CAR

"Perfectly Simple—Simply Perfect"

Maxwell Model Q-11, 4 cyl. 22 H. P.—$990

"Maxwell" Prices Are Never Cut

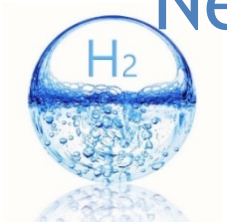
Maxwell prices have always been **right,** based on big output and honest profit.

Others cannot equal Maxwell performance even at higher prices.

Hence one after

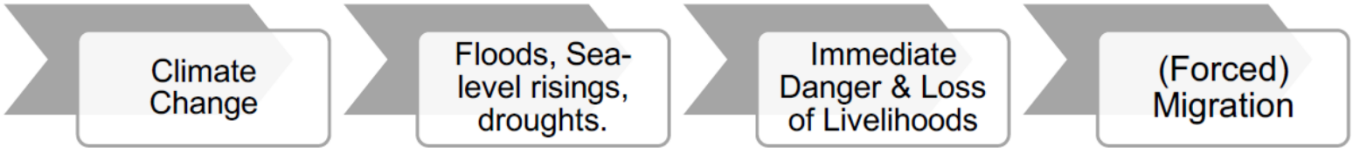
Business Netherlands outlook

- Yearly replaced HR-CV Heating systems (1.000-2.600 euro/set) = 350.000 sets.
- Expected life 15 years.
- 7.6 Million houses
  - 4.3 Million private houses
  - 3.3 Million rent houses
    - 2.2 million owner corporation
    - 1.1 million Owner other
- More then 1 million houses who could use the Hydrogen CV heating system in the Netherlands



Social acceptabele business case wat neem je mee

- Bespaarde kosten netverzwaring?
- CO2 prijs?
- Dijkverhogingen?
- Hogere verzekeringspremies (meer water en stormschades)
- Milieu verandering / klimaatverandering?
- Klimaat vluchtelingen?
- Hogere ziektekosten?
- Gezondheidszorg?

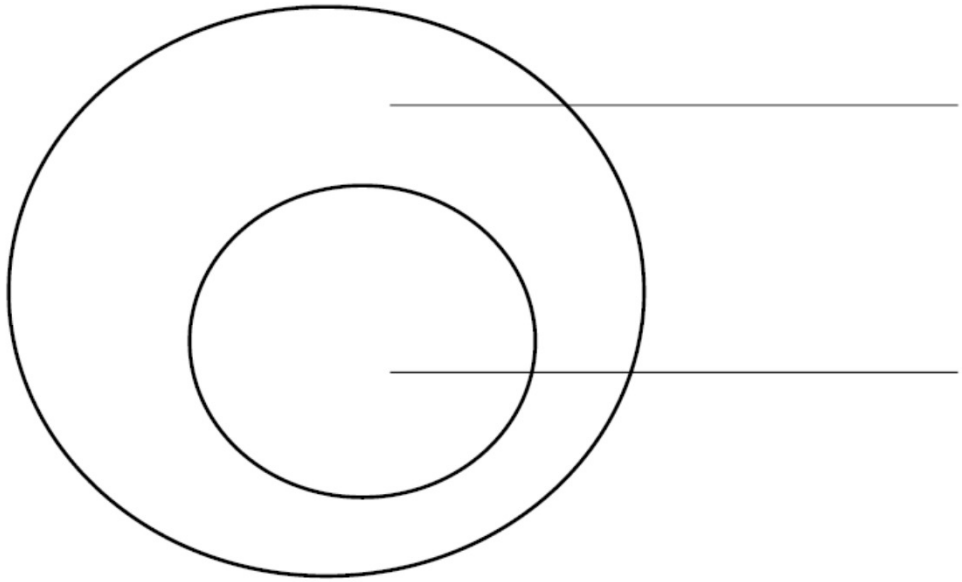


Common sense approach to Climate Change induced (Forced) Migration

Source: Danielle Spiering (Universiteit Tilburg)

http://arno.uvt.nl/show.cgi?fid=141881

Environmental change- climate change



Environmental change
Both man-made (e.g., corporate pollution, deforestation) and natural (e.g .Volcanic eruption, tsunami)

Climate change
Both Anthropogenic forcing & natural variability resulting into climate change (i.e. higher temperatures and in extent sea-level rises etc.)

The effects of climate change within the larger framework of environmental Change. Source Danielle Spiering (Universiteit Tilburg

Technical Feasibility

	Evolution of Gas	Electric Future
Technical Feasibility	Gas networks already meet peak heat demand Hydrogen well understood but conversion yet to be tested at scale No additional storage needed to cover peak	Major difficulty in meeting peak heat demand Large amount of inter-seasonal electricity storage a major barrier Large electricity back up capacity needed to cover renewable intermittency Overall technology proven and well understood

Customer acceptance

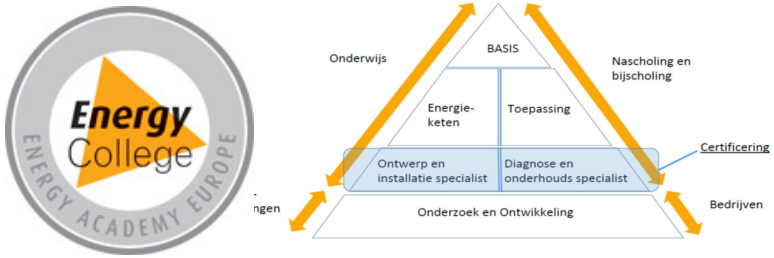
	Evolution of Gas	Electric Future
Customer acceptance	Functionality and space requirements the same as today Customers may be reluctant to change	Heat pumps efficient but challenging where space is limited Challenging to get consumers to accept different functionality well understood

Society acceptance

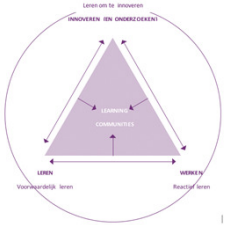
	Evolution of Gas	Electric Future
Society acceptance	Limited disruption from new gas infrastructure Acceptance of new CO2 disposal facilities required	Significant urban disruption as electricity infrastructure is reinforced Domestic retrofitting will be a considerable challenge

HYDROGREENN Opleidingen links

- MBO opleiding Waterstoftechnicus.
  - Start feb. 2019 plan



- SER Learning communities
  - *Begeleidingsgroep ontwikkeling Learning Communities*



- *EnTrance - SNN - HYDROGREENN combi*
  - **Waterstof Booster - HYDROGREENN**

- Hanze Hoogeschool WTB
  - Nick Numan Afstudeer opdracht Installatie concept Nijstad-Oost 29-8-2018 afgestudeerd.
-

- *PHD promotie onderzoek TU-Delft*
  - *Toekomstbeelden rondom de waterstofeconomie*

Conclusion

- The natural gas network is a strong backbone for transition towards a sustainable energy system
- – Everybody is already connected (no divestments)
- – It allows for input all sources
- – Highly efficient storage capacity

Hydrogen Promotion

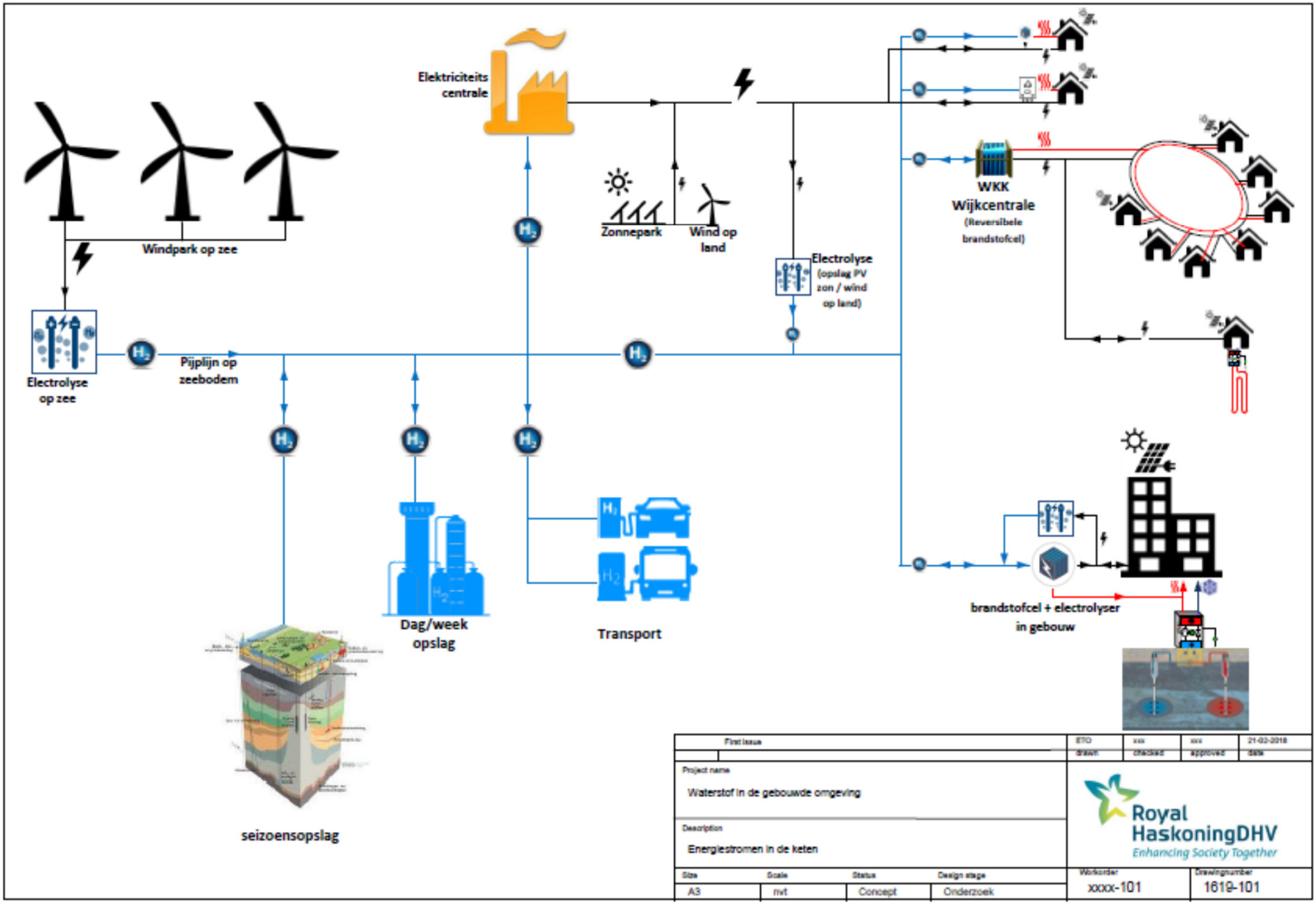
Roadmap voor waterstof economie
Samenwerken in een route naar de Olympische Spelen in Tokyo 2020

15 MAART 2018 Charles van Santvoord MMS BM

Questions







First issue	ETO	xxx	xxx	21-02-2018
	drawn	checked	approved	date

Project name: Waterstof in de gebouwde omgeving

Description: Energiestromen in de keten

Size	Scale	Status	Design stage
A3	nvt	Concept	Onderzoek

Royal HaskoningDHV
Enhancing Society Together

Workorder	Drawingnumber
xxxx-101	1619-101