FLYWHEEL FOR INNOVATION

TNO innovation for life

Towards GW-scale electrolysis

TNO.NL

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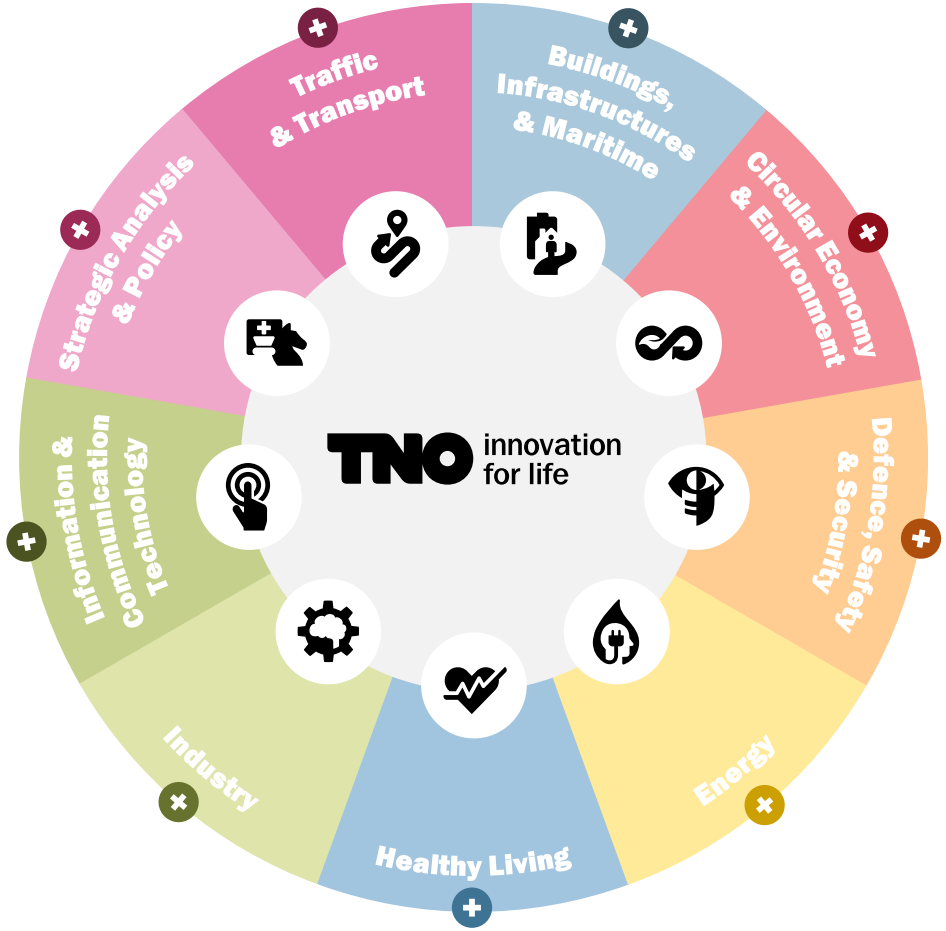
HOW DO WE MAKE OUR LIVES

MORE SUSTAINABLE?

WE DO THIS BY TAKING A MULTIDISCIPLINARY APPROACH



HYDROGEN

THE KEY TO THE ENERGY TRANSITION

ECN › TNO innovation for life

TNO Hydrogen Research Program

OUR AMBITION

The ambition of TNO is to accelerate the energy transition together with knowledge institutions, companies and governments

WHY HYDROGEN?

Hydrogen can be seen as an enabler for the transition towards renewable energy:

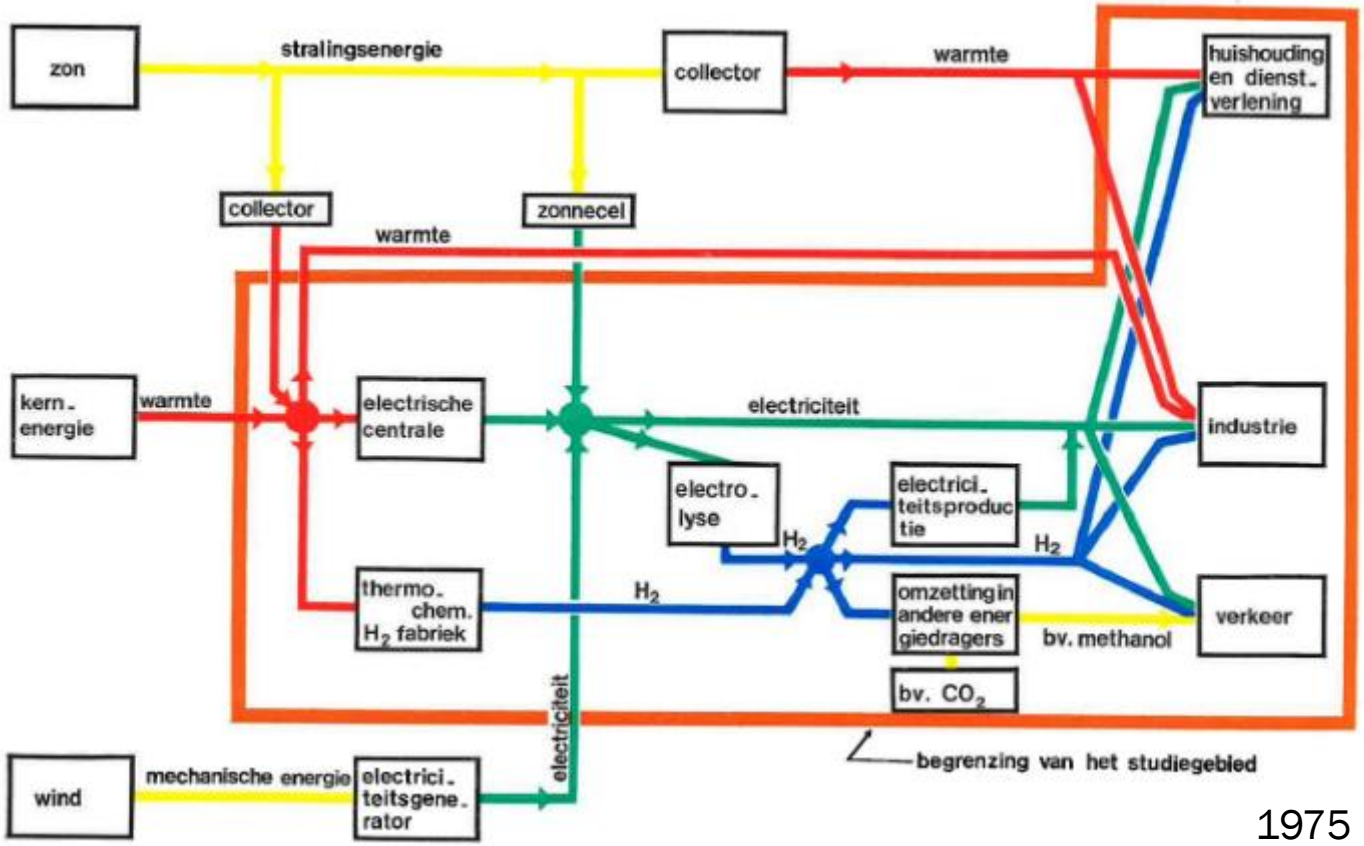
- ‘Unlock’ renewable energy
- Providing long term (seasonal) storage capability complementing intrinsically intermittent solar and wind
- Providing carbon neutral energy for heavy duty transport
- Providing a carbon free source of (high temperature) heat

WHAT WE DO?

- 6 programs
- 50+ projects
- Various research groups & key experts
- Multiple facilities
- Over 40 years of Hydrogen research

Research in hydrogen supply chain

Over 40 years experience in hydrogen



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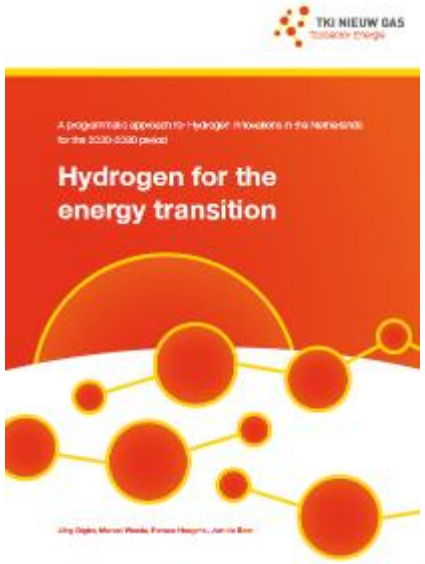

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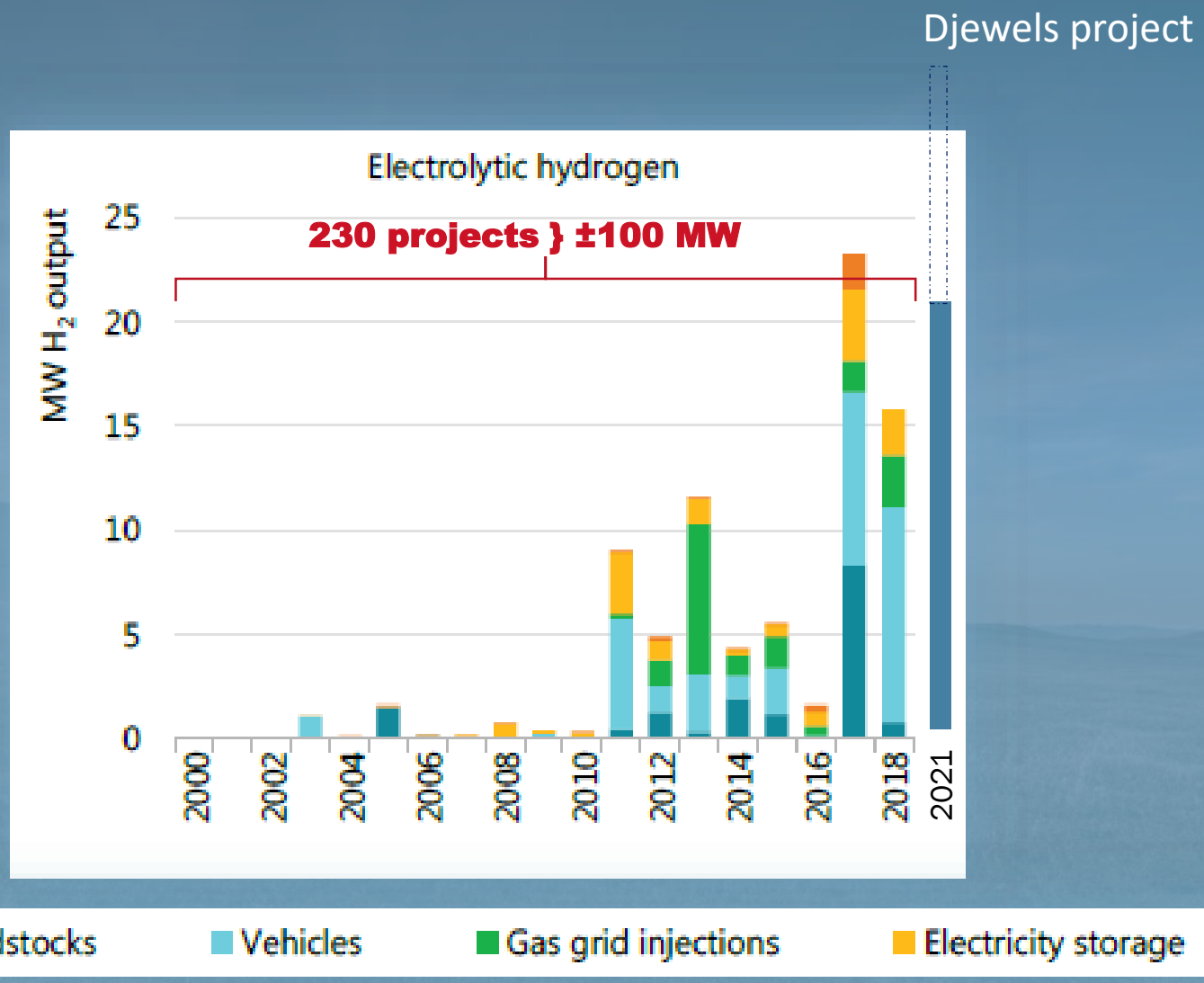
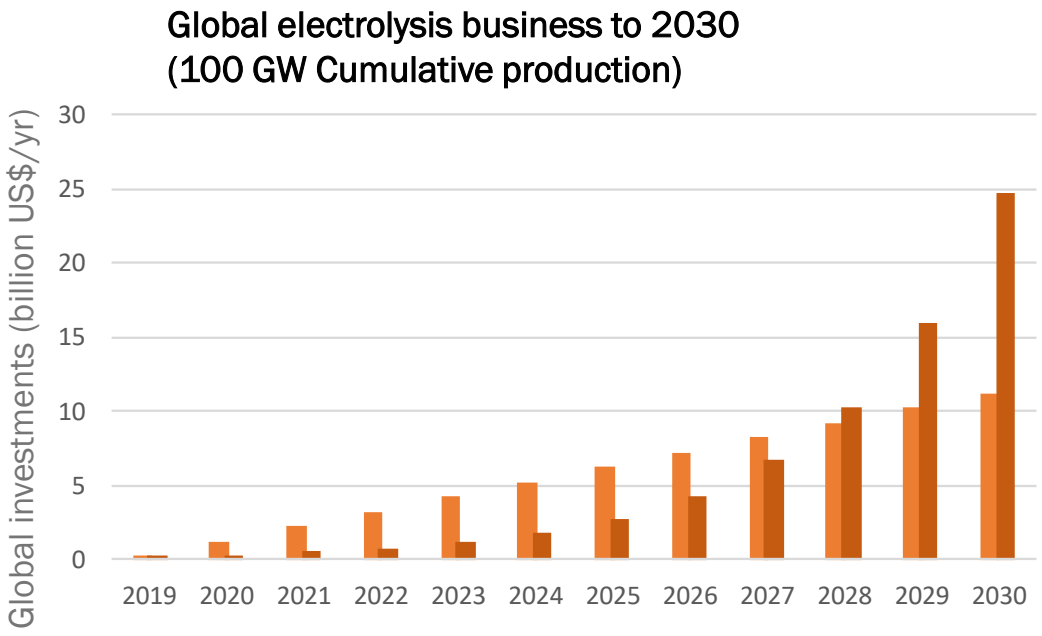
Sources: Waterstof als energiedrager, toekomstige mogelijkheden in Nederland, TNO (1975) en Een programmatische aanpak voor innovaties op het thema waterstof in Nederland voor de periode 2020 – 2030 (TKI NIEUW GAS – 2020) Gigler, Weeda, Hoogma, de Boer)

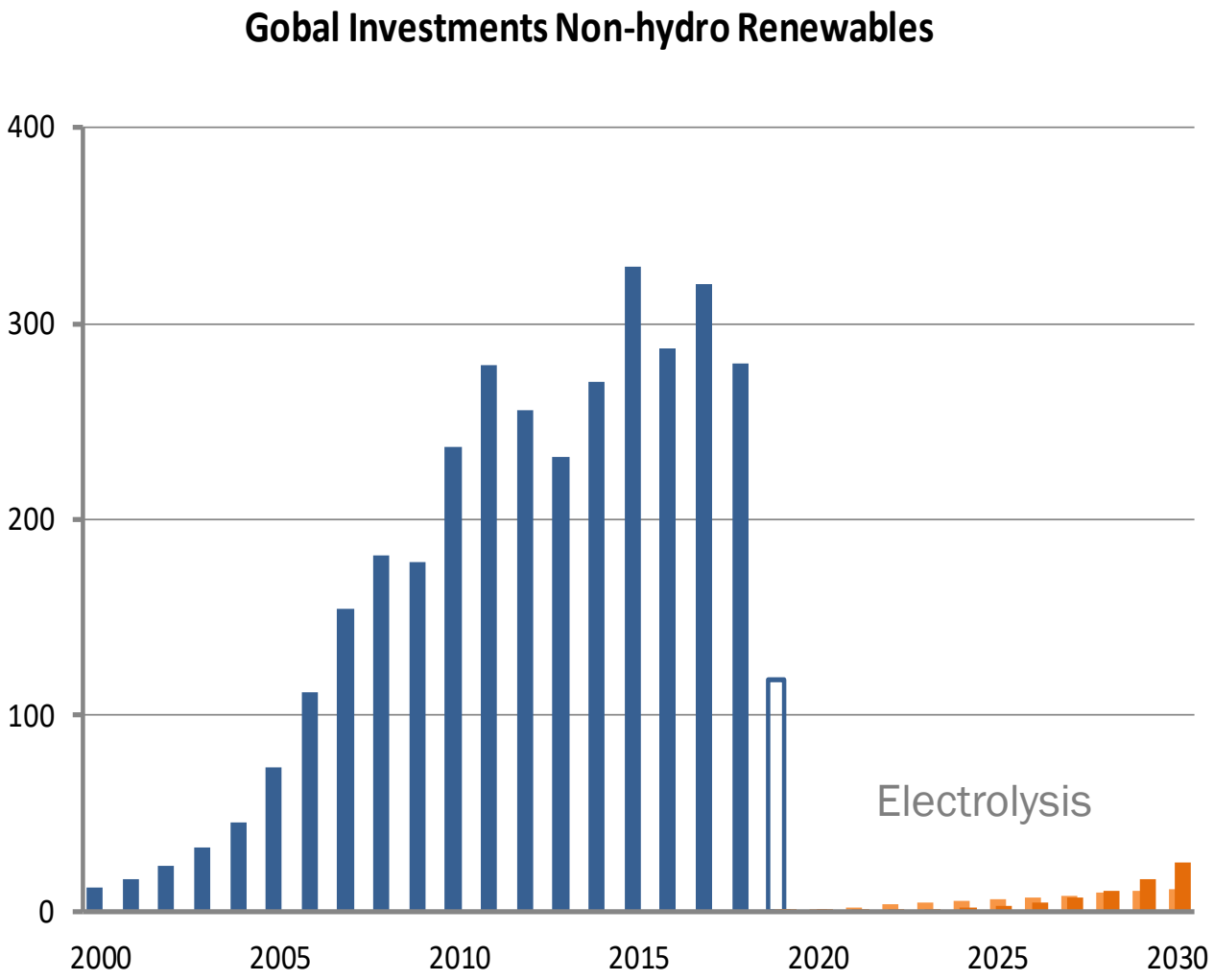
GREEN HYDROGEN IS THE FUTURE



Source: IEA 2019, TNO

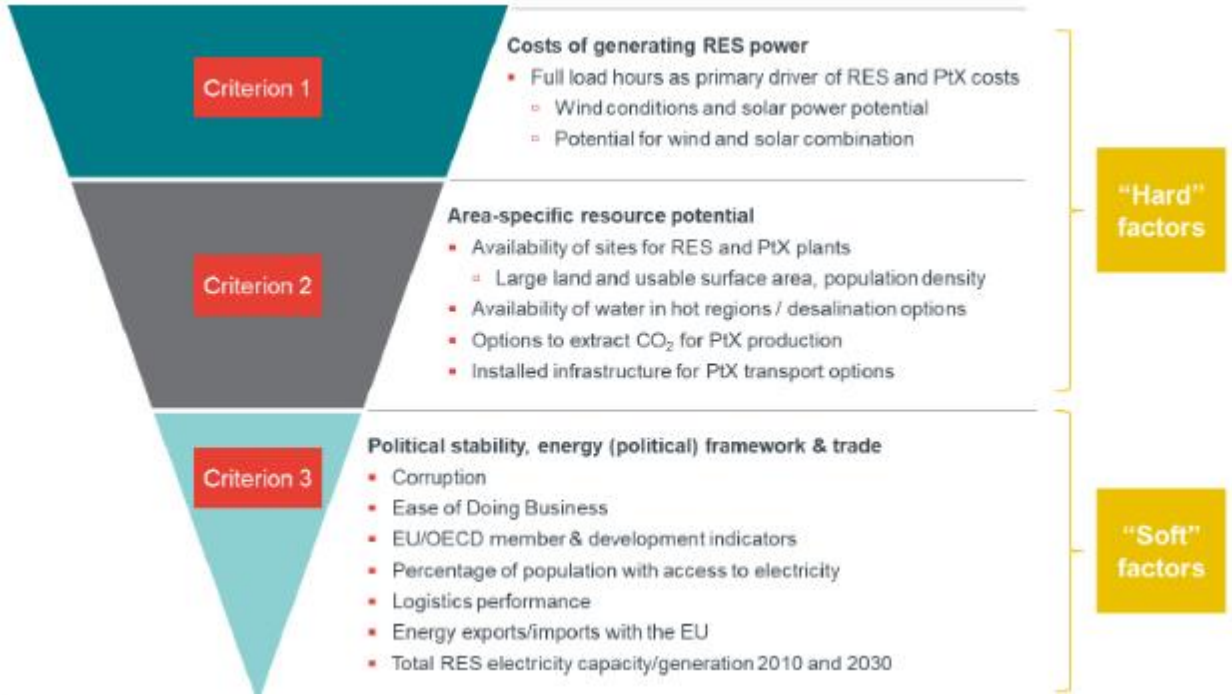
ELECTROLYSIS IS 10 TO 20 YEARS 'BEHIND' SOLAR





Sources: investment data: BNEF; and Kramer and Haigh, Nature, 462, 568-9 (2009)

DRIVERS FOR GREEN HYDROGEN PRODUCTION



For illustration only, not an extensive list of strong potential P2X producers

Low Case	Reference	High Case
10,000 TWh	20,000 TWh	41,000 TWh

Source: Frontier Economics

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EUROPE SETS CLEAN HYDROGEN AS A KEY STRATEGY

Clean Hydrogen Alliance key priority in Europe's new Industrial Strategy

Europe, industrial consortium proposing a green deal of 2 x 40 GW

THE EUROPEAN COMMISSION ANNOUNCES THE CLEAN HYDROGEN ALLIANCE

The Commission presented today, 10 March 2020, a new **European Industrial Strategy** to help Europe's industry lead the transition towards climate neutrality and digital leadership.

The Strategy sets out the key drivers of Europe's industrial transformation and proposes a comprehensive set of future actions, including a **Clean Hydrogen Alliance** to accelerate the decarbonisation of industry and maintain industrial leadership.

Smart sector integration is a key part of the new strategy, as it aims to use all carriers of energy more effectively, by linking different sectors. Clean Hydrogen is a prime example of where this can have a real benefit. It is disruptive in nature and requires stronger coordination across the value chain.

The Alliance will bring investors together with governmental, institutional and industrial partners, building on the successful template of existing industrial alliances, and on the work done within the framework of the FCH JU.

"We welcome the proposal of a Clean Hydrogen Alliance, which can explore all benefits that hydrogen can bring to the EU economy and jobs. This initiative is a clear evidence of the success of our public private partnership and we will actively support it" said Bart Biebuyck, FCH JU Executive Director.

More information can be found here .

Image:

- Expected summer 2020
- Netherlands and Germany leading
- identify technology needs, investment opportunities,barriers and enablers

CROSS BORDER COOPERATION'S ARE BEING FORMED TO DEVELOP NEW HYDROGEN SUPPLY CHAINS

Cooperation between Netherlands and Germany on infrastructure and storage

PROJECT GOALS HY3

The Dutch, German and Nordrhein Westfalen governments have asked TNO and FZ Jülich to study the prefeasibility of a transnational hydrogen economy at the border of the Netherlands and Nordrhein Westfalen.

Project goals are:

- Analyze the feasibility of a **transnational green hydrogen** infrastructure in the border area of the Netherlands and North Rhine-Westphalia
- Examine the **potential of GHG-reduction** and increase of the renewable energy deployment in the industry sector by a transnational green hydrogen infrastructure
- Examine **possible business cases** for future green hydrogen infrastructure by using transnational (Dutch-German) hydrogen production and existing transportation and storage facilities
- Examining **industrial interest** in green hydrogen infrastructure and potential **field of applications** as well as potential synergies with hydrogen applications in other sectors
- Describing the existing **regulatory framework** in the context of green hydrogen production, transport, storage, trading and usage and examining the framework that would be needed to establish transnational green hydrogen infrastructure as well as respective business cases

Die Landesregierung Nordrhein-Westfalen

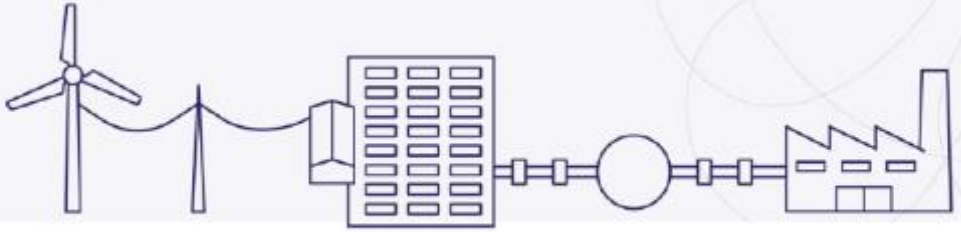
Bundesministerium für Wirtschaft und Energie

Joined development study with industry for potential hydrogen supply chains

HyChain – up to TW in 2050 – global supply chains?

Conditions and impact of emerging hydrogen supply chains

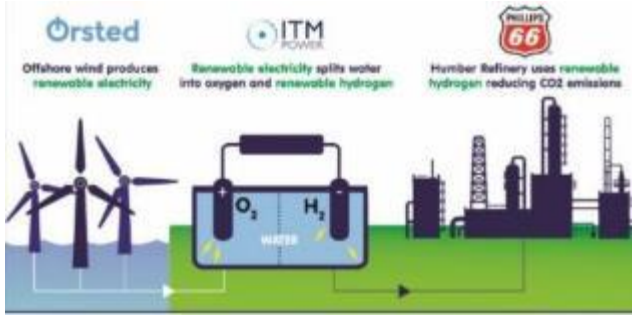
HyChain 1 – Understanding Hydrogen use in industry under transition
HyChain 2 – What is the role of import ?
HyChain 3 – Technology overview for transport, conversion and storage
HyChain 4 – Integral model and scenario analysis
HyChain 5 – Societal and geopolitical implications



Institute for Sustainable Process Technology

CURRENT MARKET: PRE-FEASABILITY STUDIES, ENGINEERING AND FIRST LARGE SCALE PILOTS

Feasability and engineering studies (examples)



UK front-end engineering design, 100 MW

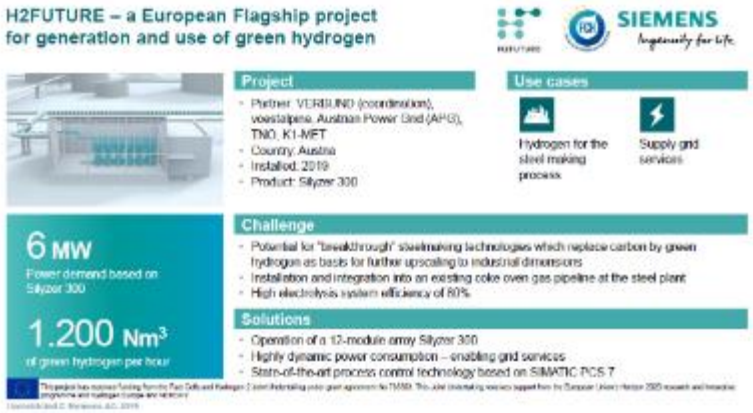
NL Feasability, 2-3 GW in 2028, Shell, Gasunie, TNO & DNVGL

NL Feasability and pre- engineering and modelling study 1 GW
Gasunie, Yara, Shell, Nouryon ISPT, TNO

DK Feasability study towards 1,3 GW for e-fuels for aviation and maritime
Orsted, Maersk, DSV, DFDS, SAS

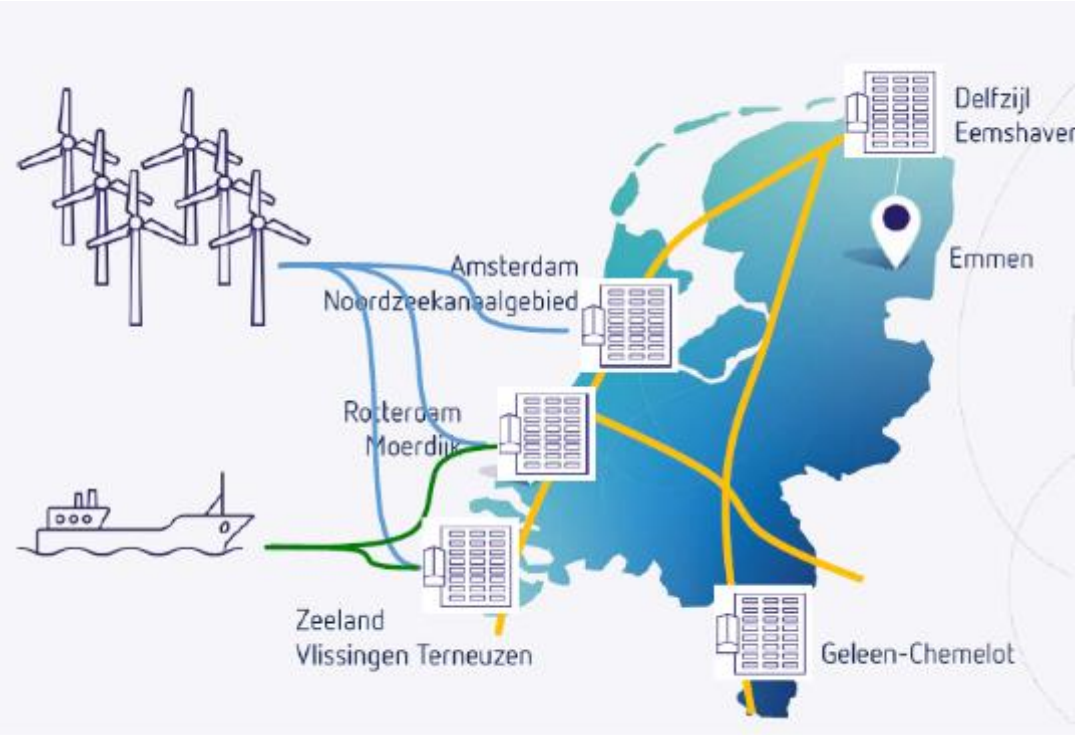
First large scale (pilot) projects

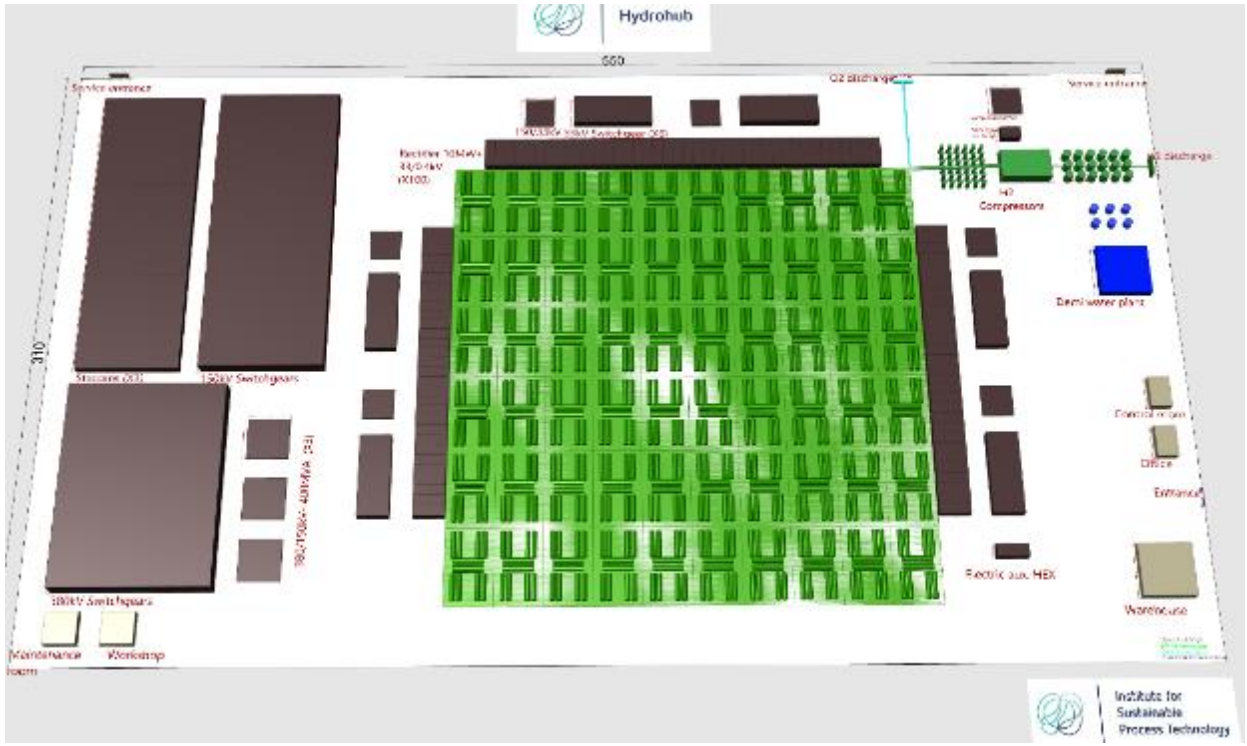
NL, Djewels project 20 MW, FID 2020



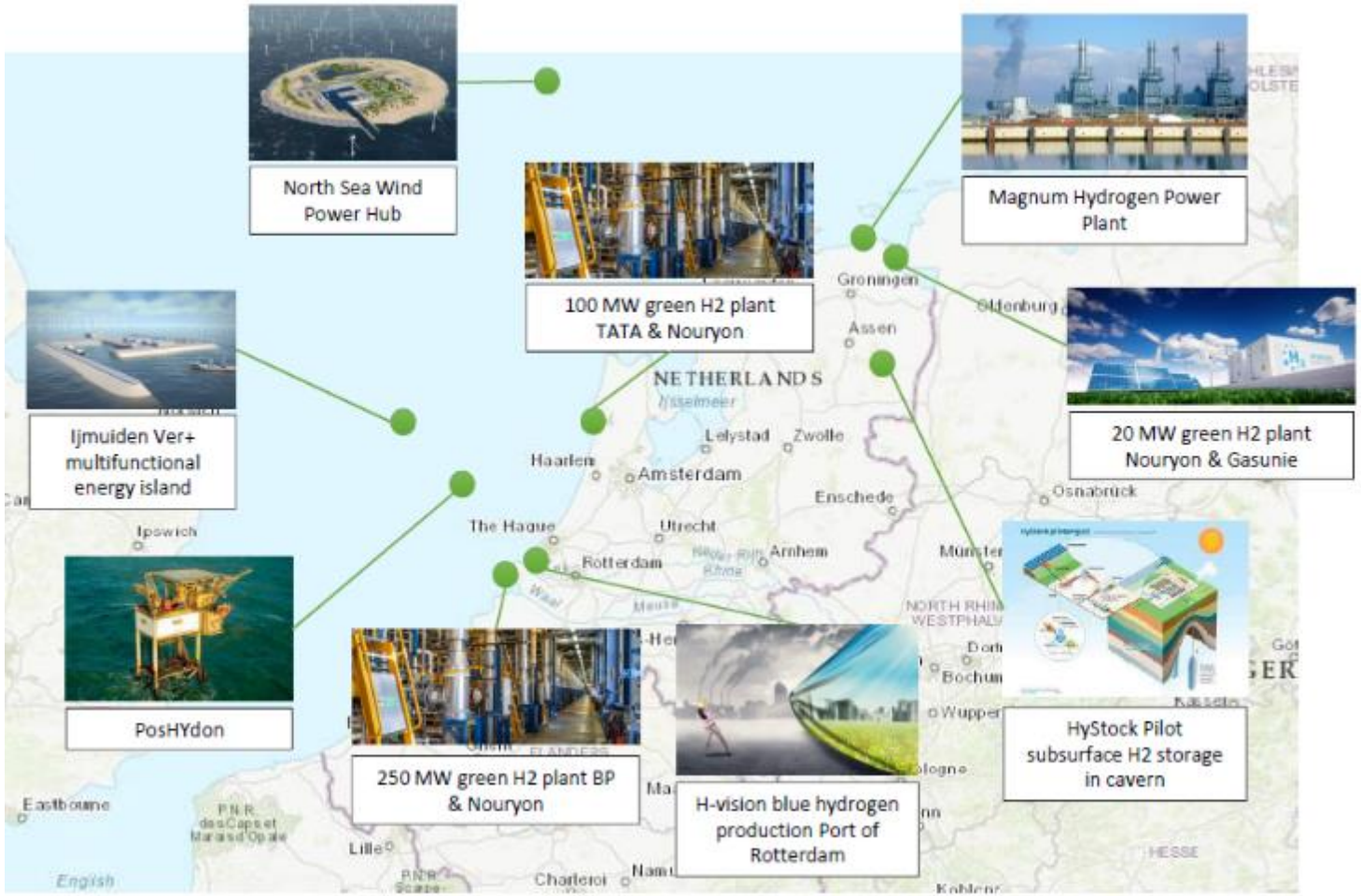
Austria, H2Future project 6 MW, 2019

DESIGNING THE FIRST 1 GW ELEKTROLYSIS PLANT





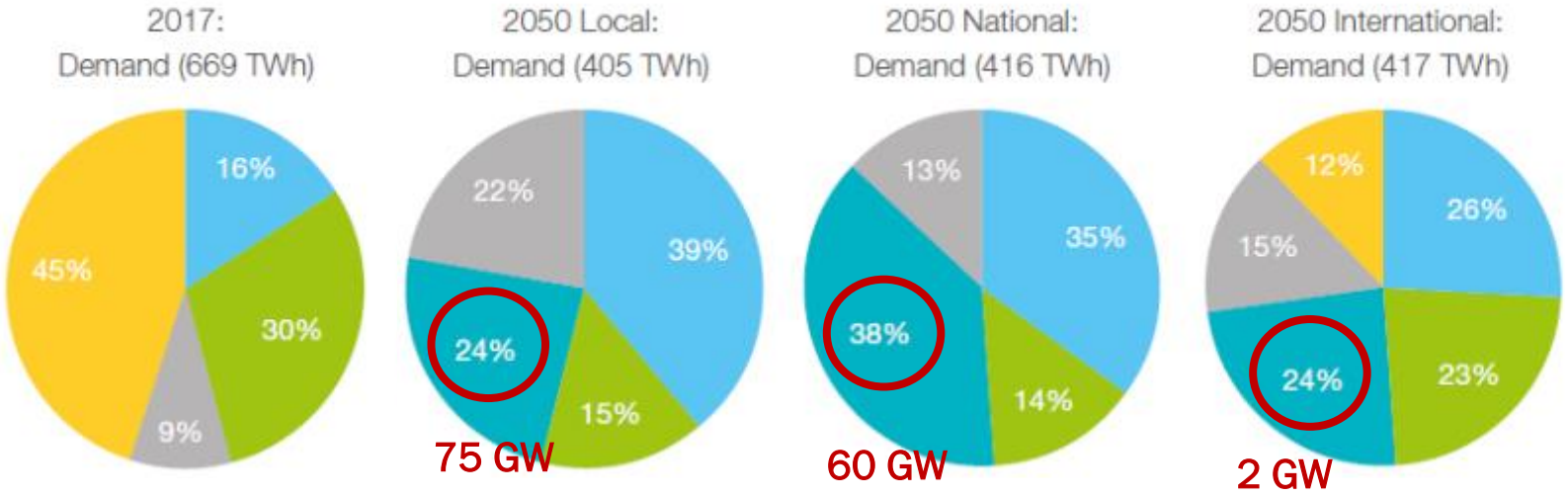
OVER 25 LARGE GREEN HYDROGEN PROJECTS BEING DEVELOPED IN THE NETHERLANDS



Name	Size
PosHydon (offshore elektrolyser)	1 MW
H2Molen (windturbine i.c.m. elektrolyser)	2 MW
W2C (vergassing en waterstofproductie voor methanol)	nnb
Djewels 1 (elektrolyse voor methanol)	20 MW
H2Maritiem (waterstofproductie voor scheepvaart)	1 MW
Holthausen (waterstofproductie voor tankstation)	1 MW
Zenid1 (waterstofproductie en dac voor synthetische kerosine)	nnb
e-THOR (waterstofproductie en warmtebenutting)	5 MW
Curthyl (waterstofproductie uit wind)	1-10 MW
NAM cs. (waterstofproductie voor diverse toepassingen)	10 MW
BEN (biomassavergassing en waterstofproductie)	nnb
SCW cs. (waterstofproductie uit biomassa)	nnb
Djewels 3 (waterstofproductie voor waterstofperoxide)	30 MW
Djewels 2 (waterstofproductie voor synthetische kerosine)	50 MW
FastTrack (waterstofproductie voor industrie)	40-100 MW
H2ermes (waterstofproductie voor staal, syn. kerosine)	100 MW
MULTIPLHY (waterstofproductie voor biofuels)	2,6 MW
HyNetherlands (waterstofproductie)	100 MW
Power2fuel (waterstofproductie voor syn. brandstoffen)	100 MW
SCW cs. (waterstofproductie uit biomassa)	100 MW
Hydrogen Delta Sluiskil (waterstofproductie)	100-150 MW
Hydrogen Delta Sloe (waterstofproductie)	100-200 MW
Shell250MW (waterstofproductie voor synthetische kerosine)	250 MW
H2fifty (waterstofproductie voor olieraffinage)	250 MW

SCENARIO'S HYDROGEN DEMAND NL & GE

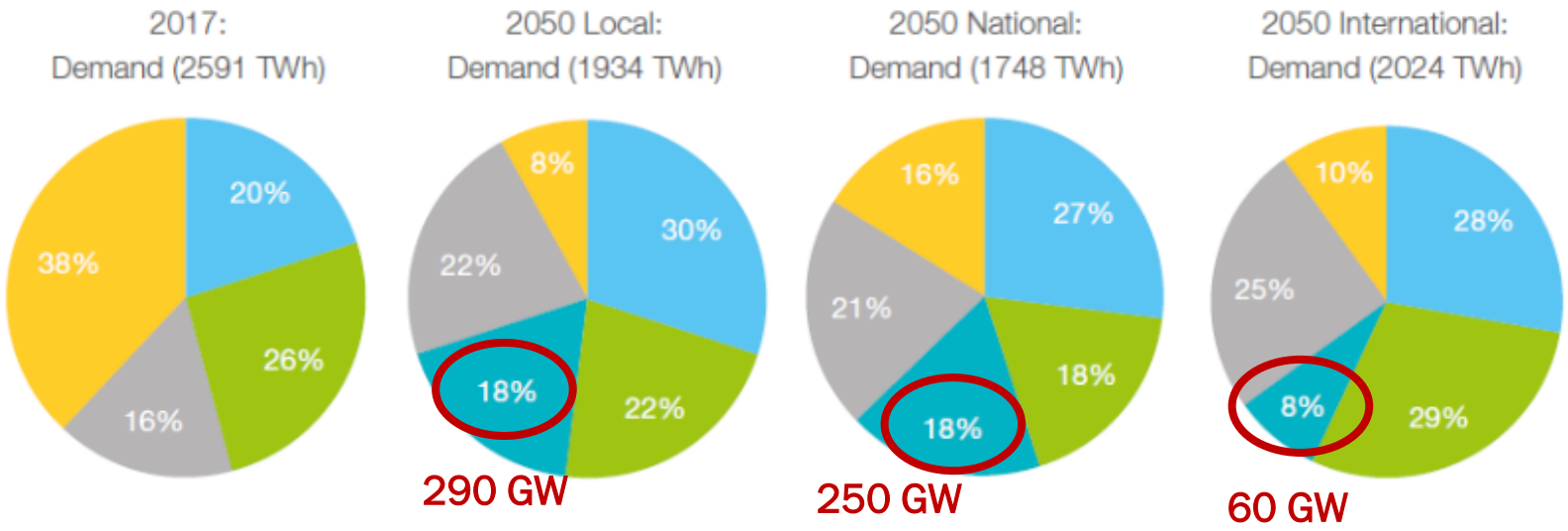
Final energy demand for the Netherlands (2017 and three 2050 scenarios)



Electricity
Methane
Hydrogen
Others
Liquid fuels

Installed electrolyser capacity

Final energy demand for Germany (2017 and three 2050 scenarios)



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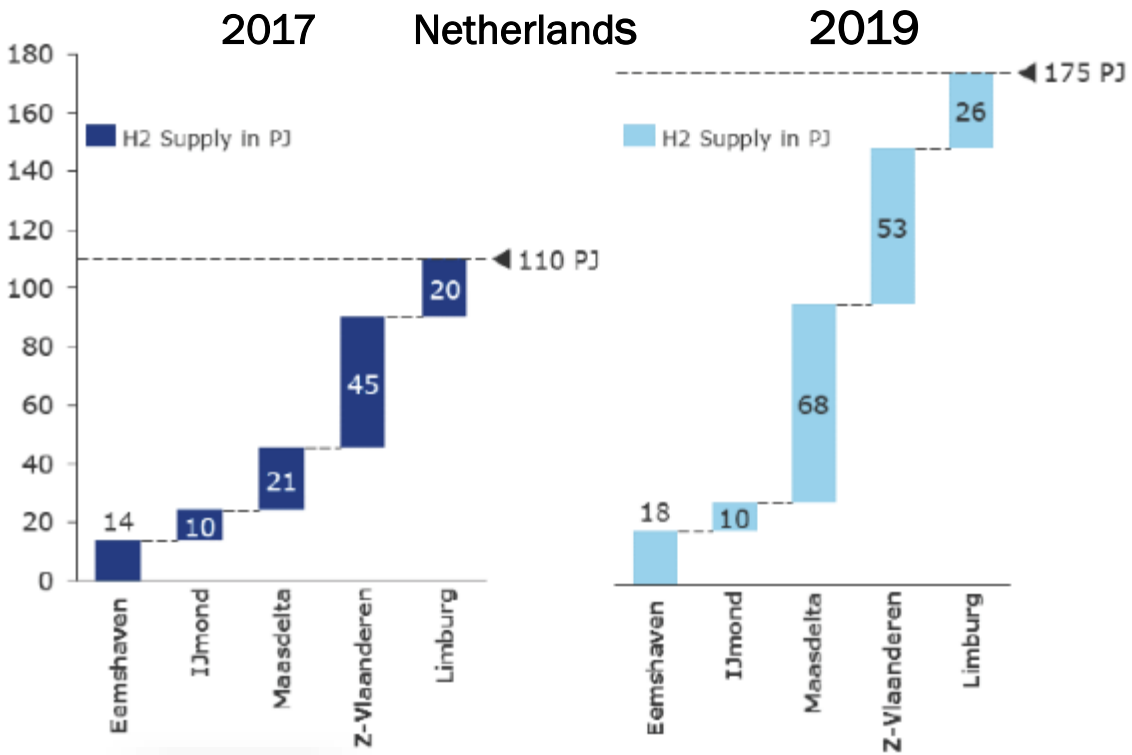
CURRENT AND FUTURE HYDROGEN PRODUCTION & DEMAND

Netherlands and Germany are together the 2 largest grey hydrogen producers in Europe

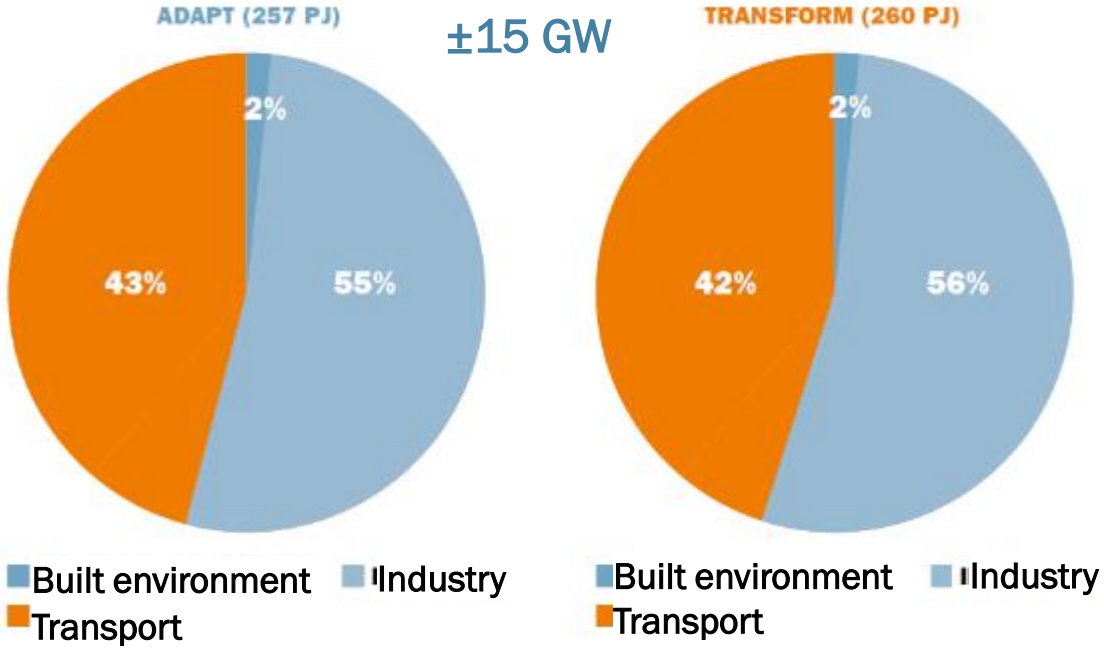


2 TNO scenario's for hydrogen demand in the Netherlands by 2050

Mainly low carbon (blue) hydrogen

Mainly renewable (green) hydrogen

±15 GW



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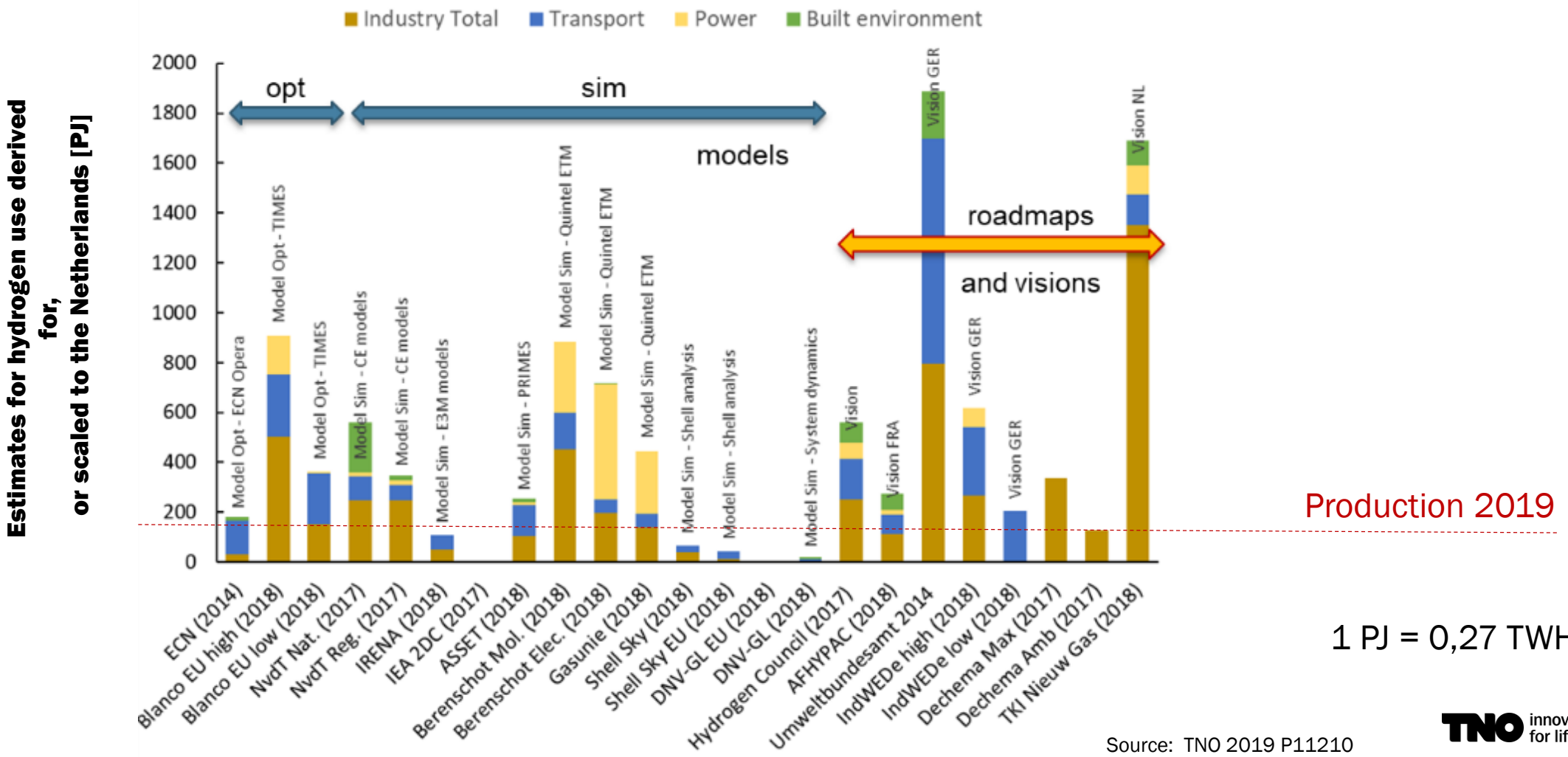
2050 ESTIMATES VARY WIDELY, HYDROGEN WILL PLAY A CRUCIAL ROLE IN A RENEWABLE ENERGY SYSTEMS



Production 2019

1 PJ = 0,27 TWH

Source: TNO 2019 P11210

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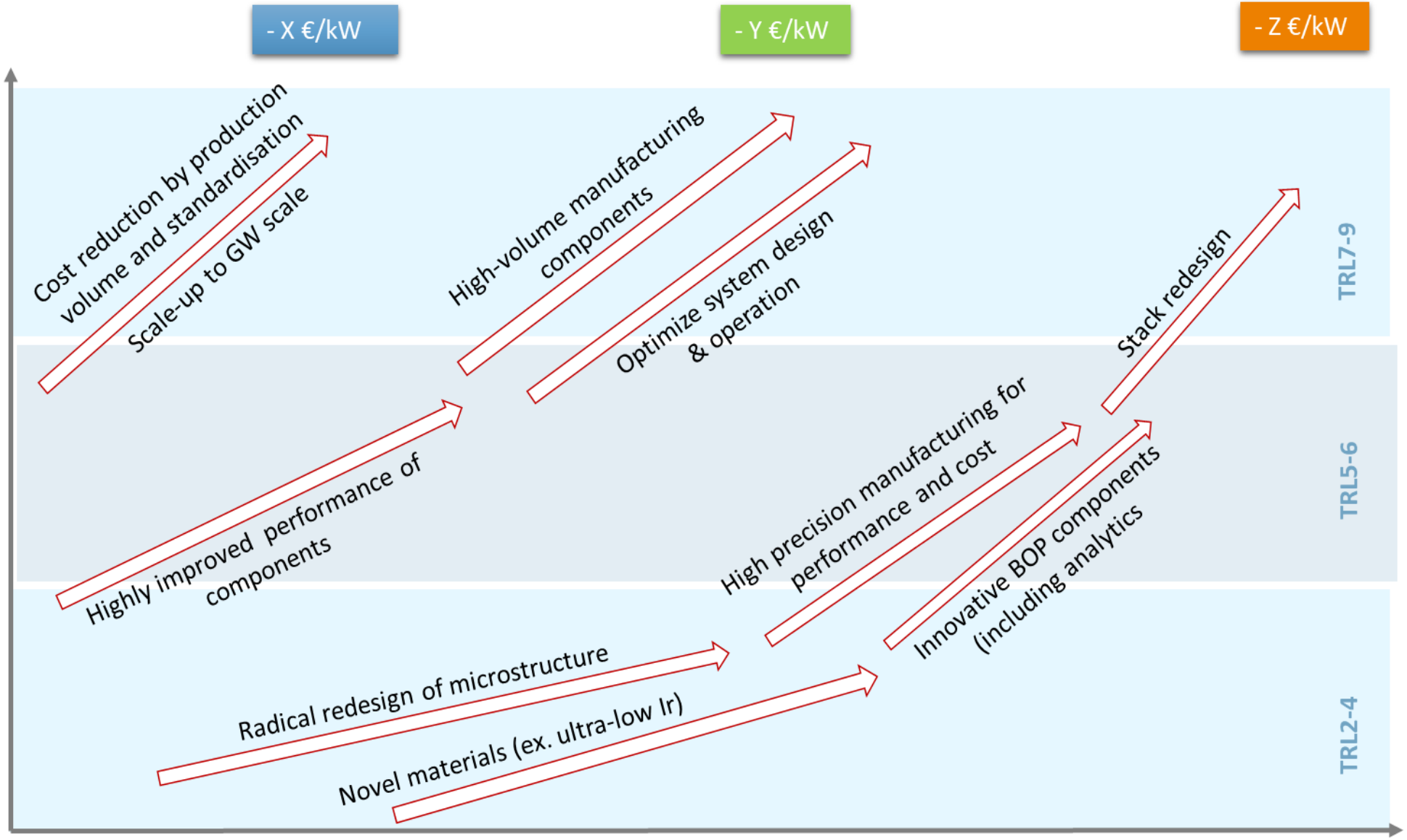
NEXT GENERATION ELECTROLYSERS

… IN NEXT WEBINAR



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Join the hydrogen innovation program and accelerate the energy transition

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