FLYWHEEL FOR INNOVATION

TNO innovation for life

Nationale Waterstofdag, Waterstof als multitasker van de duurzame energie ACRRES, Donderdag 6 februari 2020,

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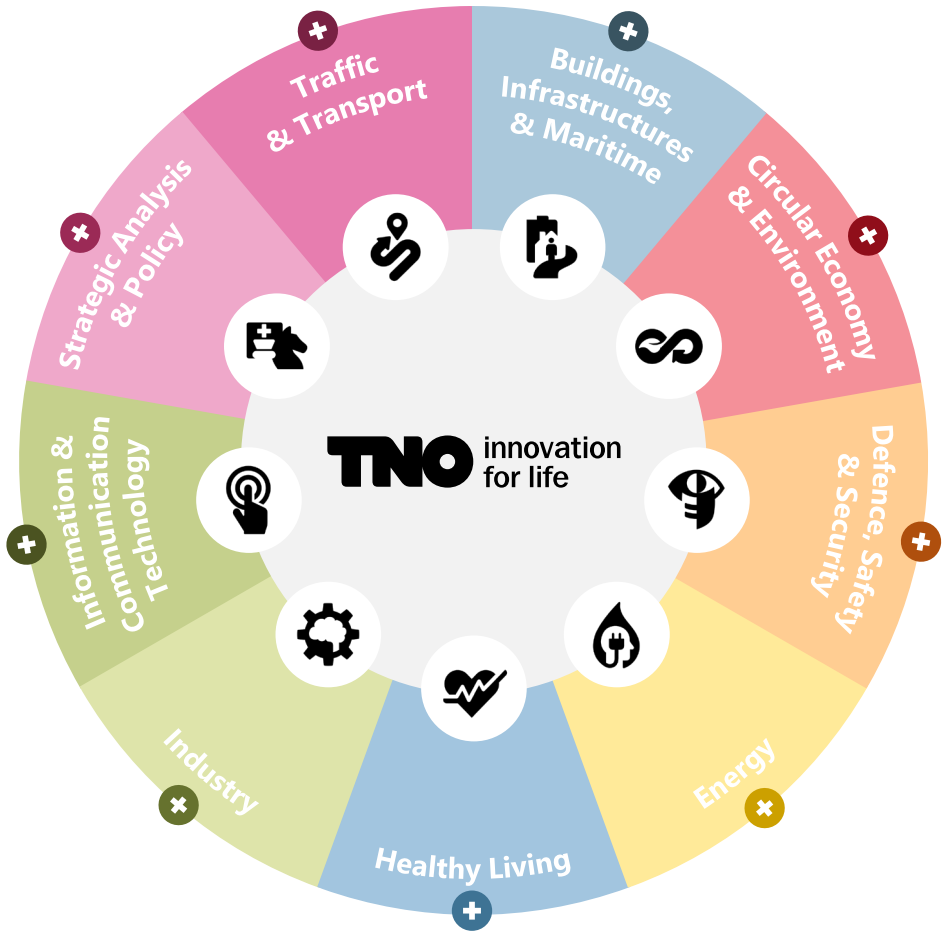
TNO.NL

intermediair FAVORIETE WERKGEVER AWARDS 18

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

Waterstof krijgt een systeem functie

OUR AMBITION

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

WHY HYDROGEN?

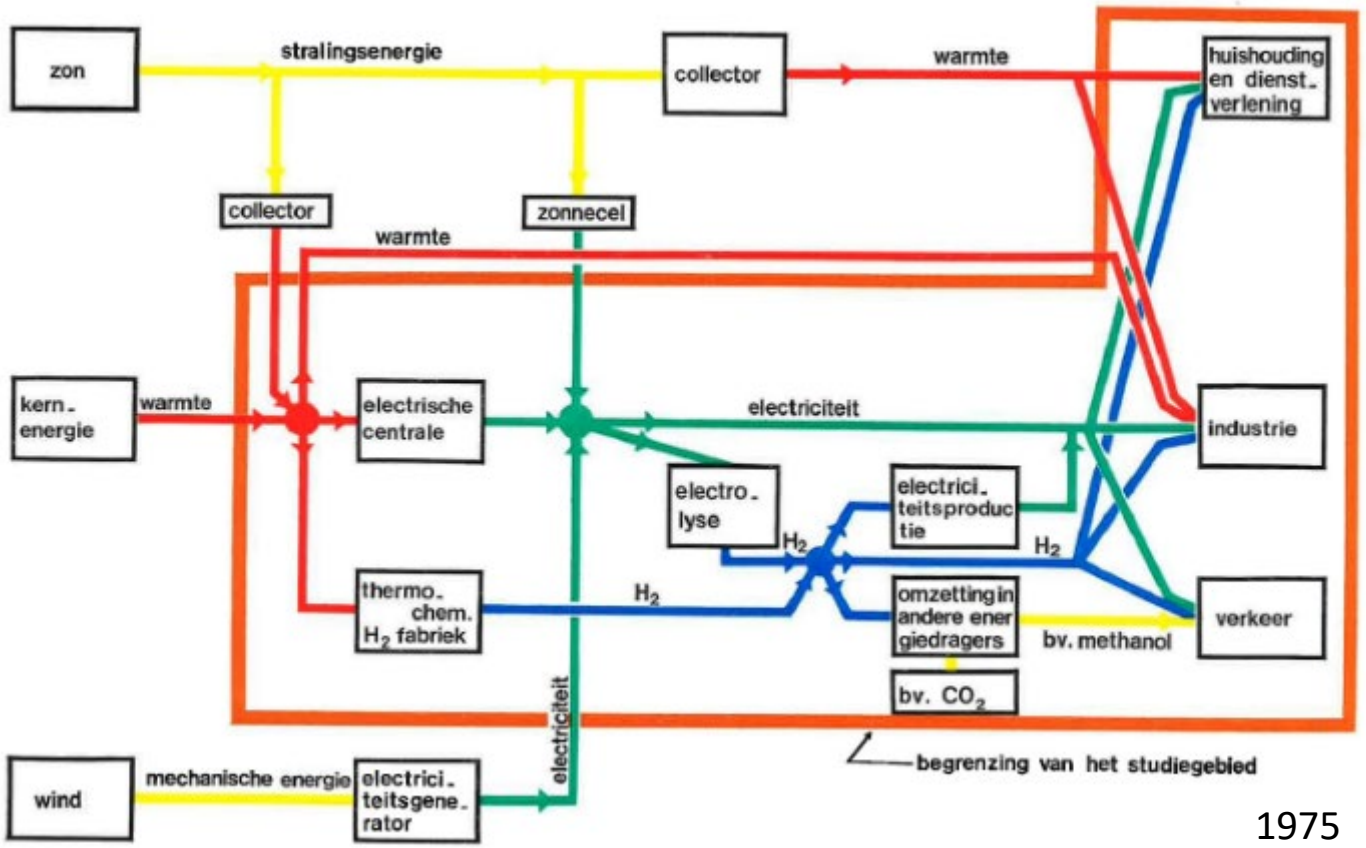
Hydrogen can be seen as an enabler for the transition towards renewable energy:

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

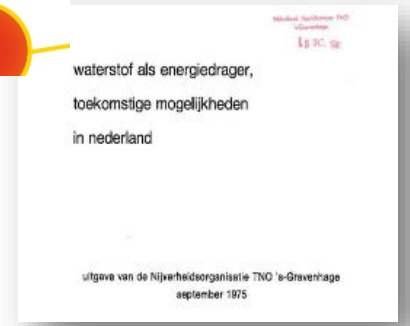
WHAT WE DO?

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

Toepassing van waterstof is al lang bekend

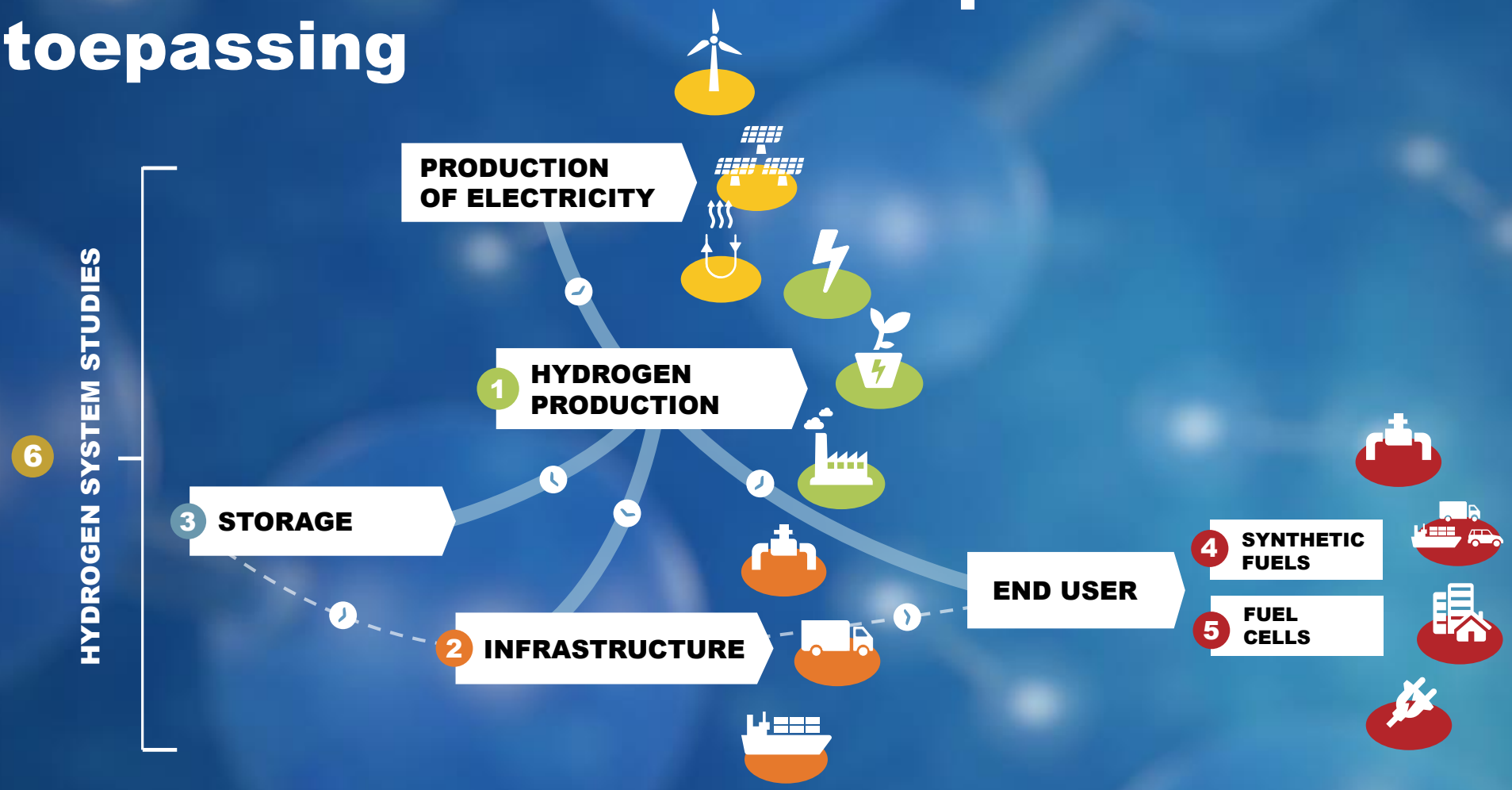


1975



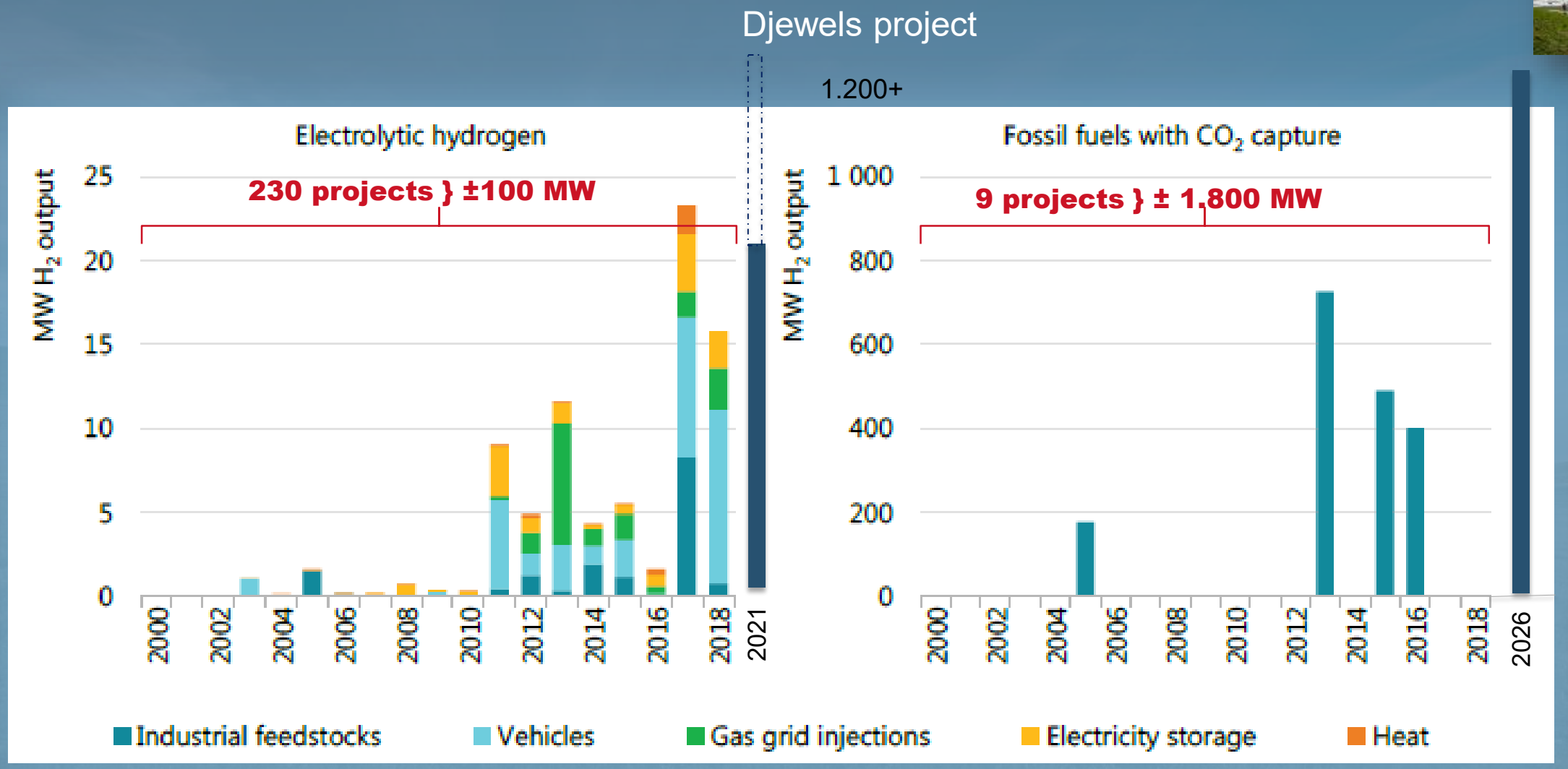
Sources: Waterstof als energiedrager, toekomstige mogelijkheden in Nederland, TNO (1975) en Een programmatische aanpak voor innovaties op het thema waterstof in Nederland voor de periode 2020 – 2030 (TKI NIEUW GAS – 2020) Gigler, Weeda, Hoogma, de Boer)

Onderzoek van waterstof productie tot aan toepassing



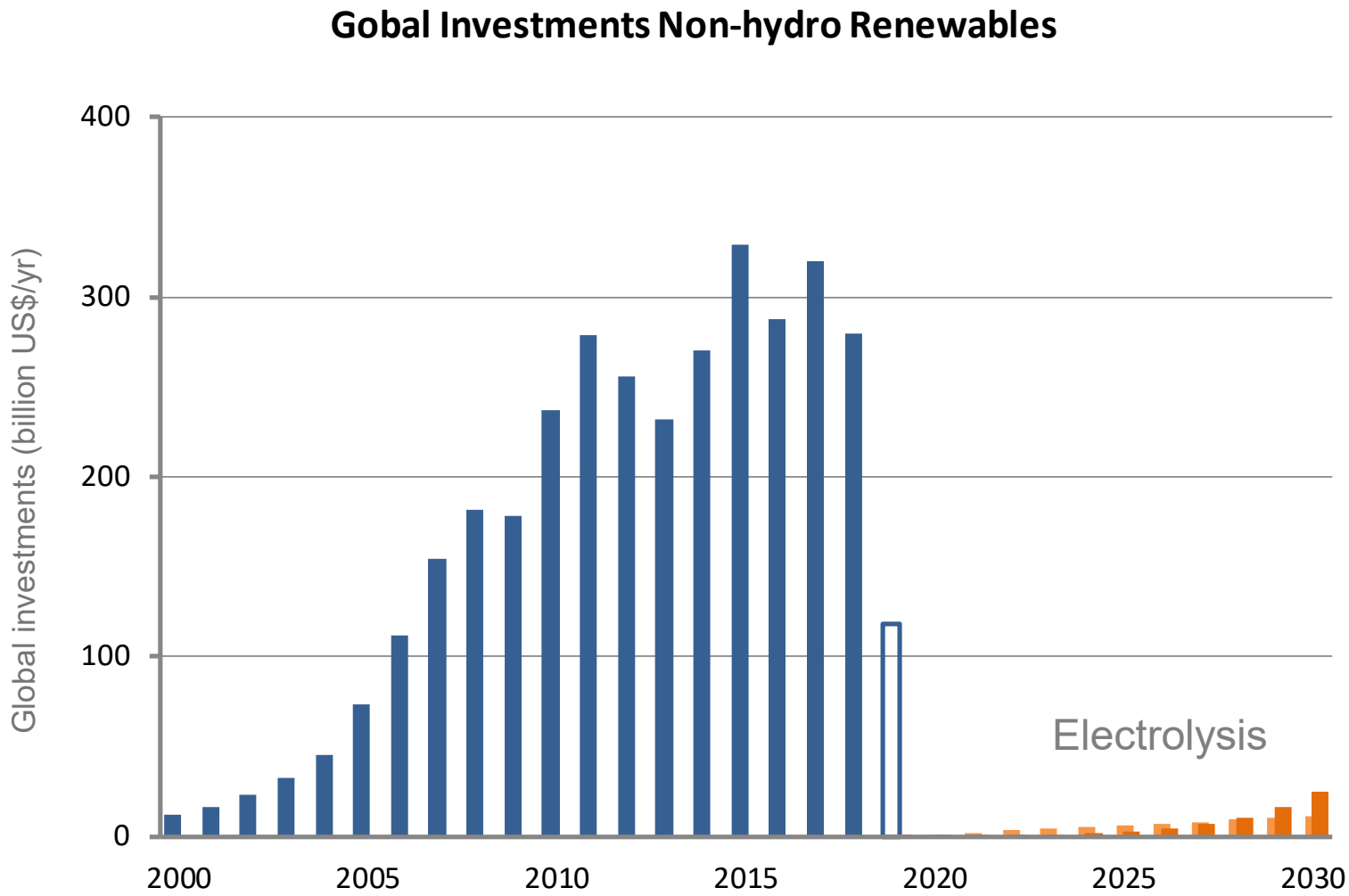
GROENE WATERSTOF IS DE TOEKOMST

H-vision project



Source: IEA 2019, TNO

GROENE WATERSTOF QUA SCHAAL GELIJK AAN WIND EN ZON IN 1990

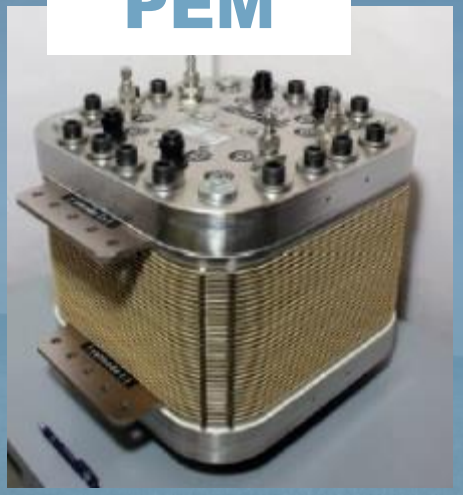


Sources: investment data: BNEF; and Kramer and Haigh, Nature, 462, 568-9 (2009)

ELECTROLYSE TECHNOLOGIE IS BESCHIKBAAR

Alkaline

PEM



SOE

AEM

DE 4 GROOTSTE UITDAGINGEN VAN GROENE WATERSTOF

Reducing costs

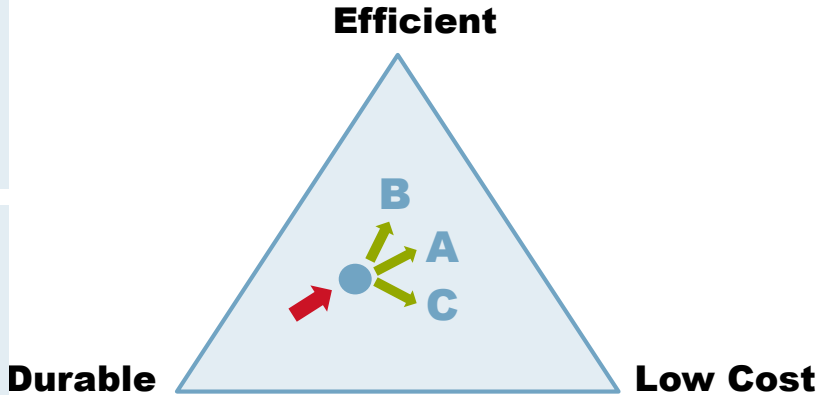
Industrialization

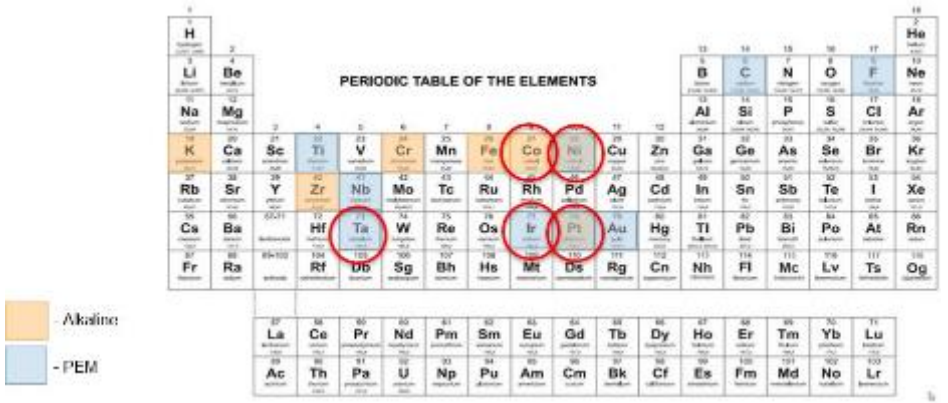
More Renewable electricity

Scarce materials

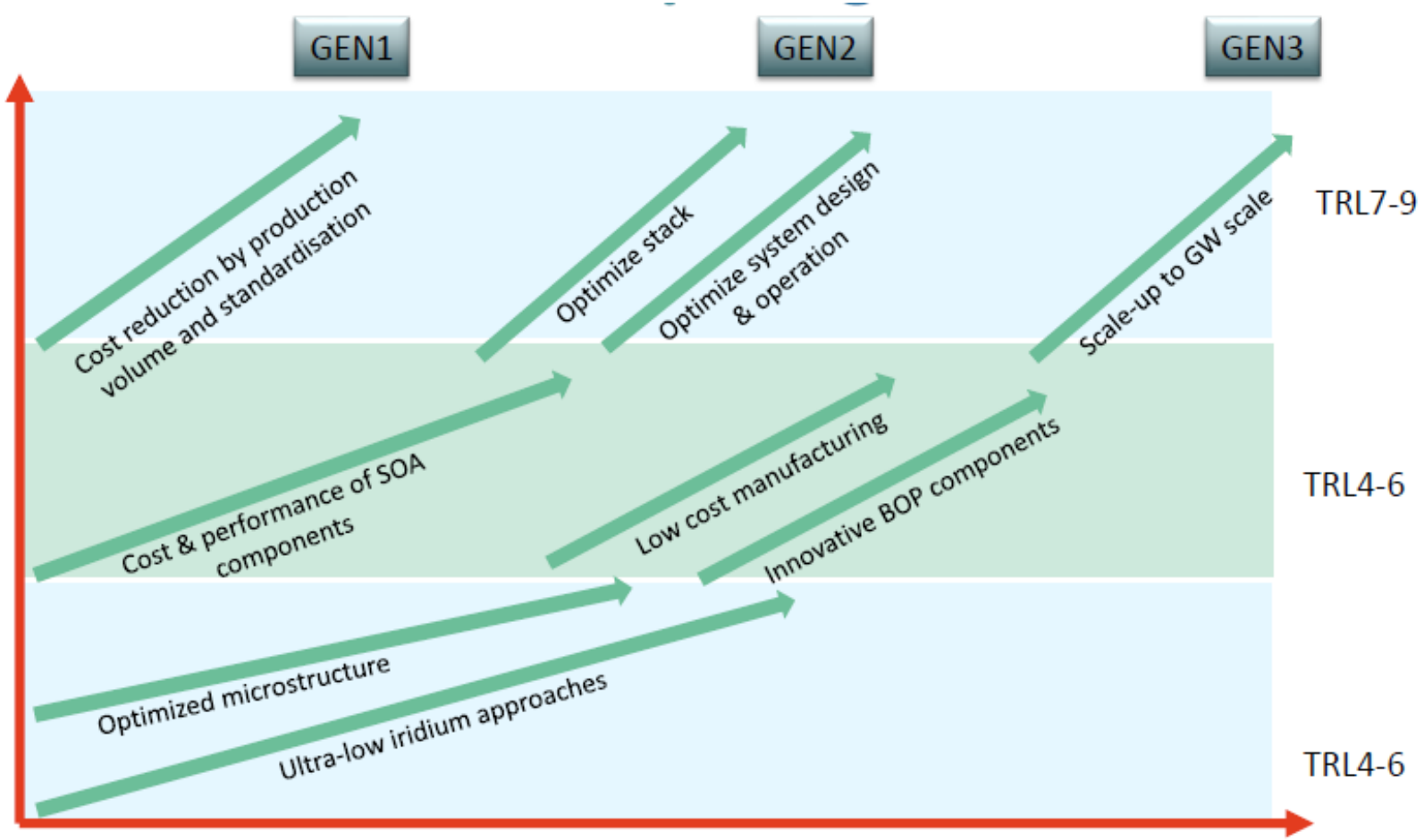
A. **Decrease membrane thickness**
B. **Operate at higher temperature**
C. **Use lower catalyst loadings**

Key objective of our R&D:
Reduce cost of components while maintaining durability

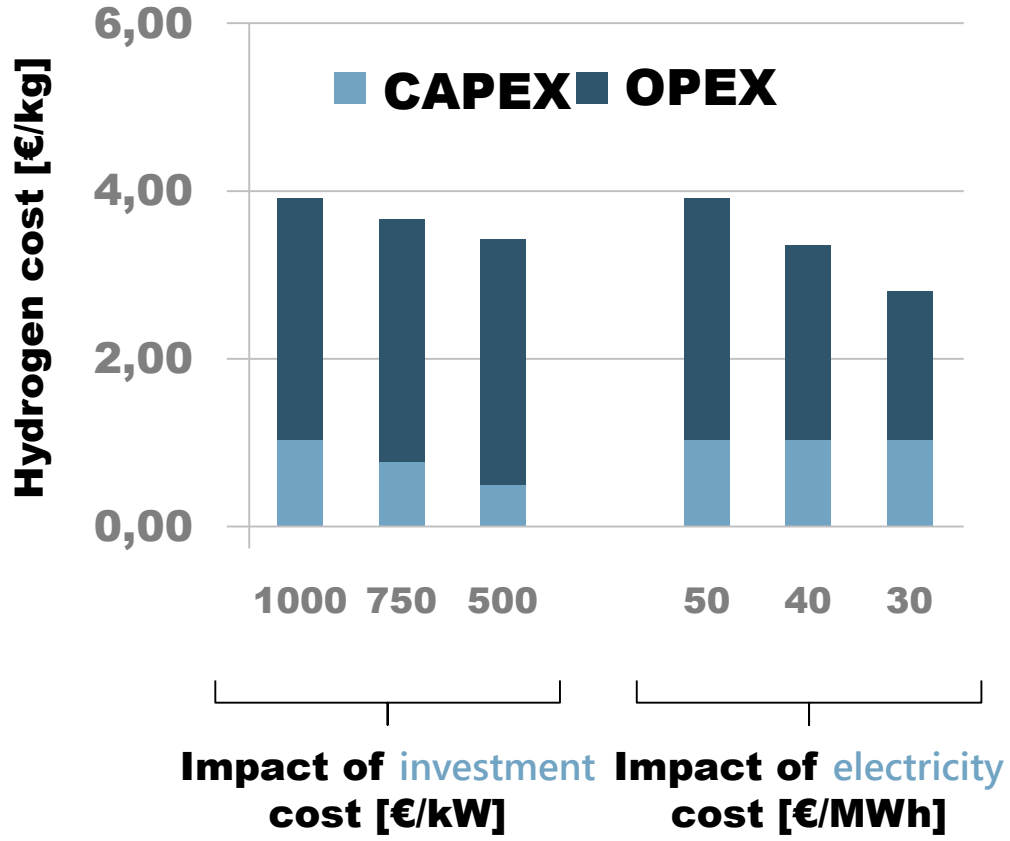




MET PARTNERS ONTWIKKELEN WE DE VOLGENDE GENERATIE ELECTROLYSERS



DE ELECTRICITEITSPRIJS IS BEPALEND VOOR DE KOSTPRIJS VAN WATERSTOF

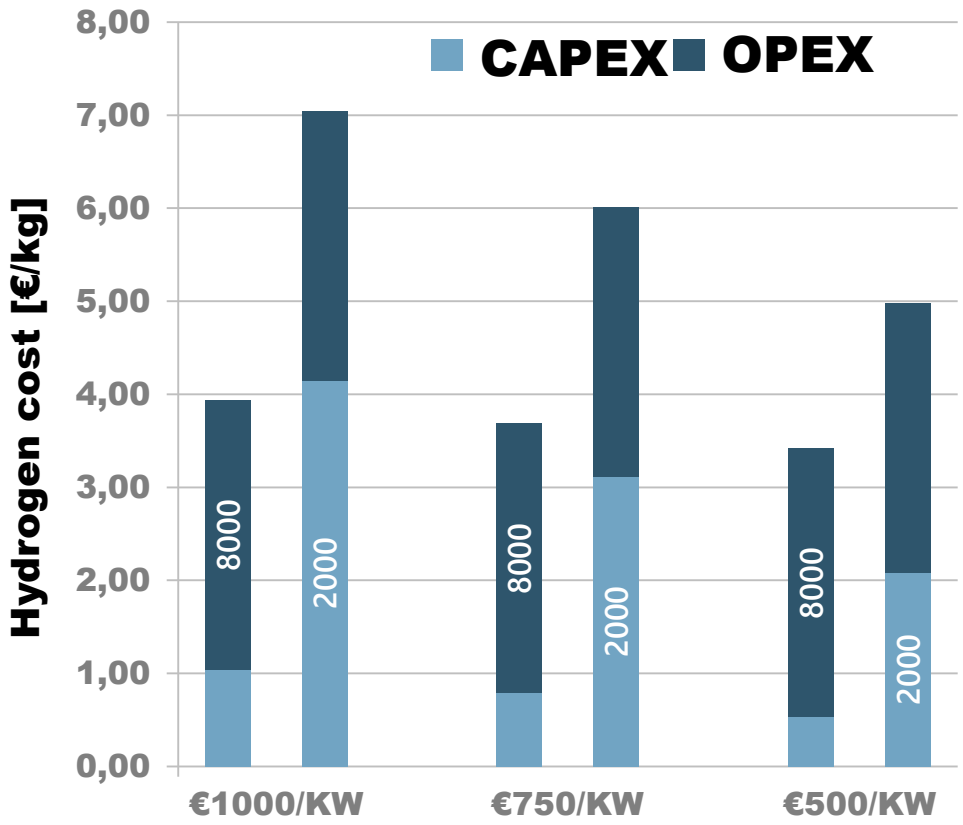


Two major costs:

- **Electrolyser costs (CAPEX)**
- **Electricity costs (OPEX)**

Base case (BC)	
Investment cost	1000 M€/kWh
Depreciation	15% /year
O&M	2% /year
Electricity price	50 Euro/MWh
Operating hours	8000 hours
Efficiency	60%

MAAR.... BIJ FLEXIBEL GEBRUIK WORDEN DE INVESTERINGSKOSTEN DOMINANT



Cost reduction

- Stack
- Balance of plant and system
- Smart contracts with offshore wind

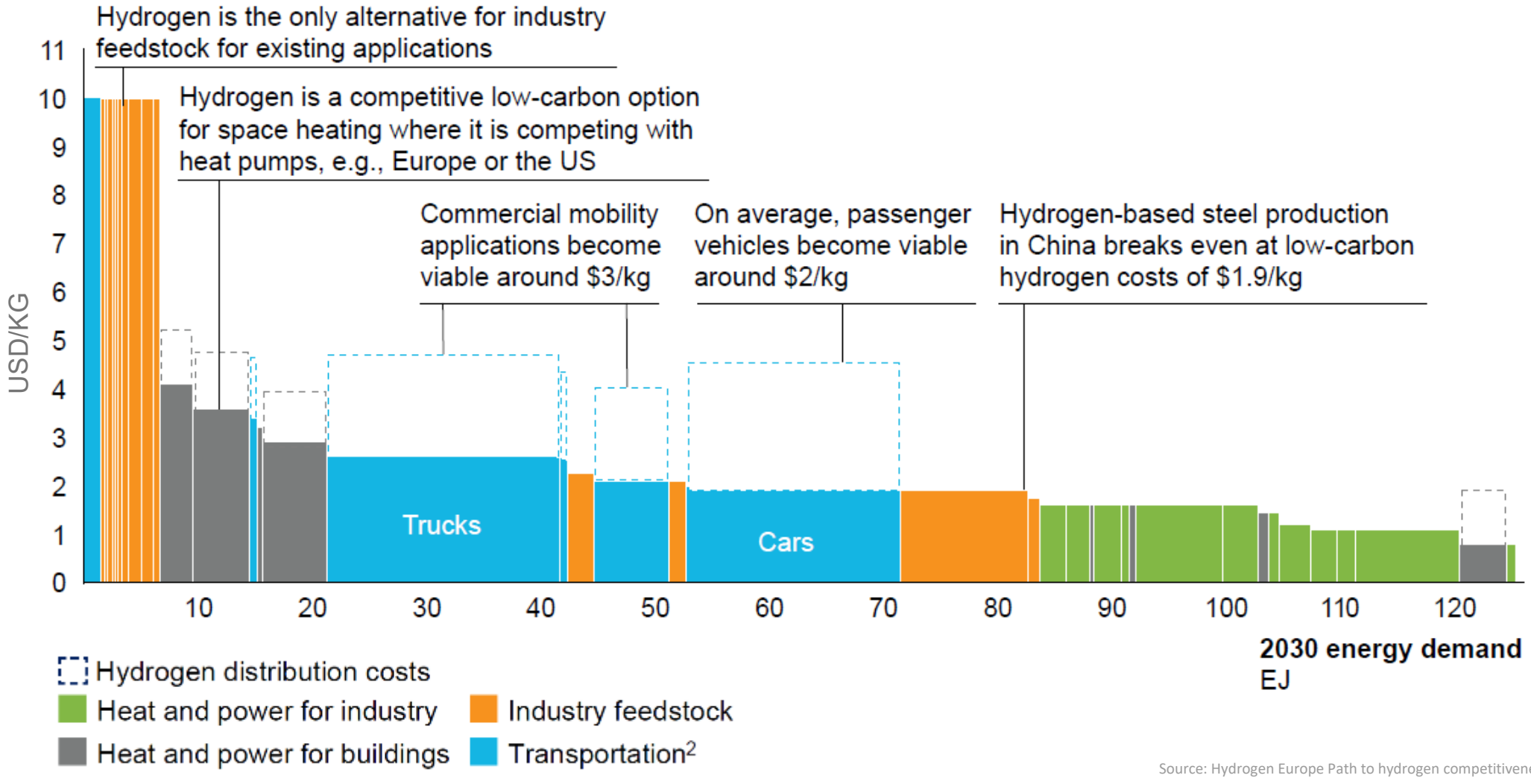
and

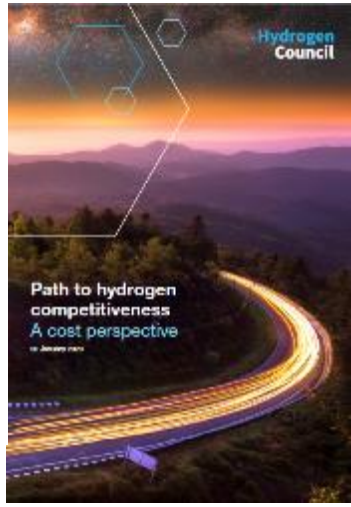
Increase profit

- Multiple H2 markets
- Reference cost grey hydrogen increases
- Value of flexibility
- Value of oxygen
- Value of heat

Operational hours per year

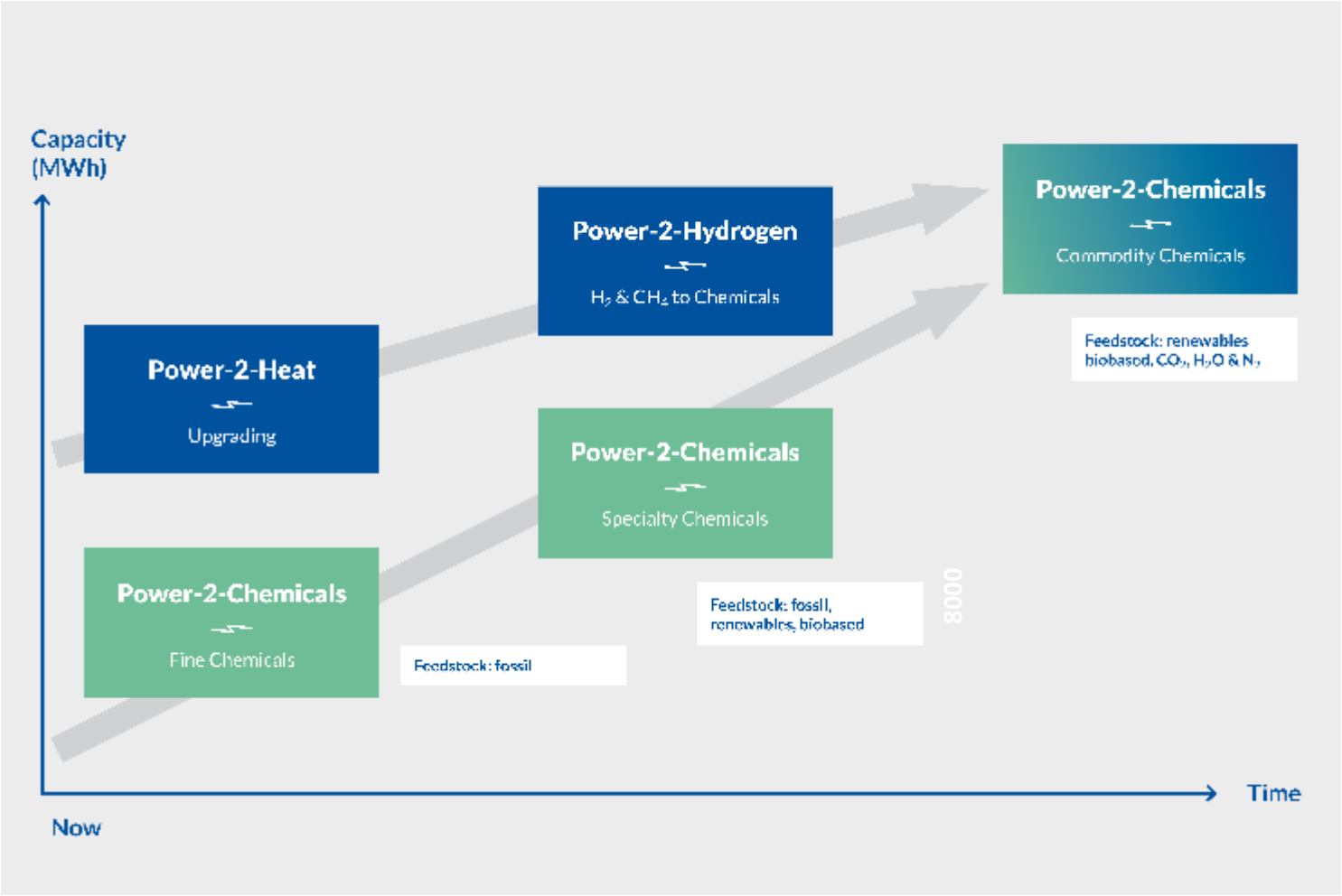
DE H2 MARKT PRIJS WORDT BEPAALD DOOR HET CO2 VRIJE ALTERNATIEF

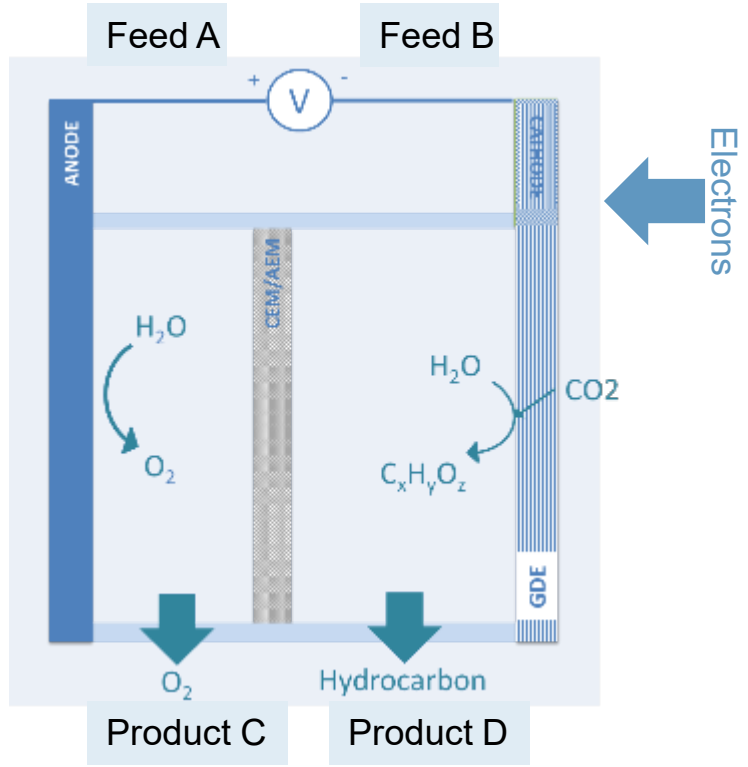




Source: Hydrogen Europe Path to hydrogen competitiveness A cost perspective – (20 January 2020)

WATER ELECTROLYSE IS DE EERSTE STAP





VOLTA CHEM

KANSEN VOOR CLEAN TECH INDUSTRIE

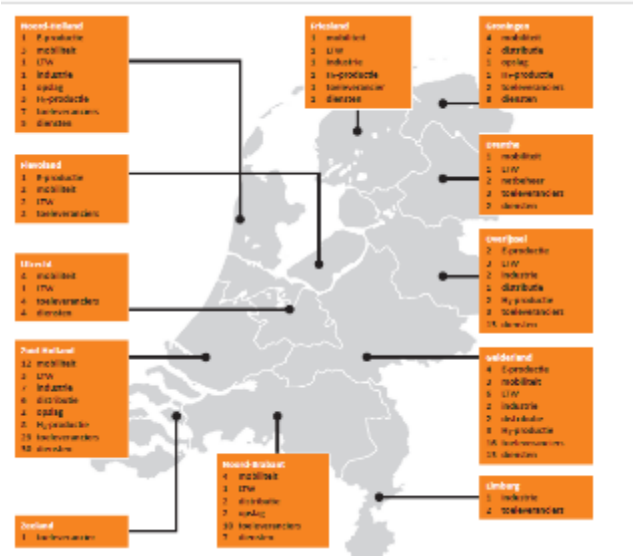
Energeia Archief Trilemma Columns Meer

Katrijn de Ronde • Energeia 10 dec 19

NIEUWS

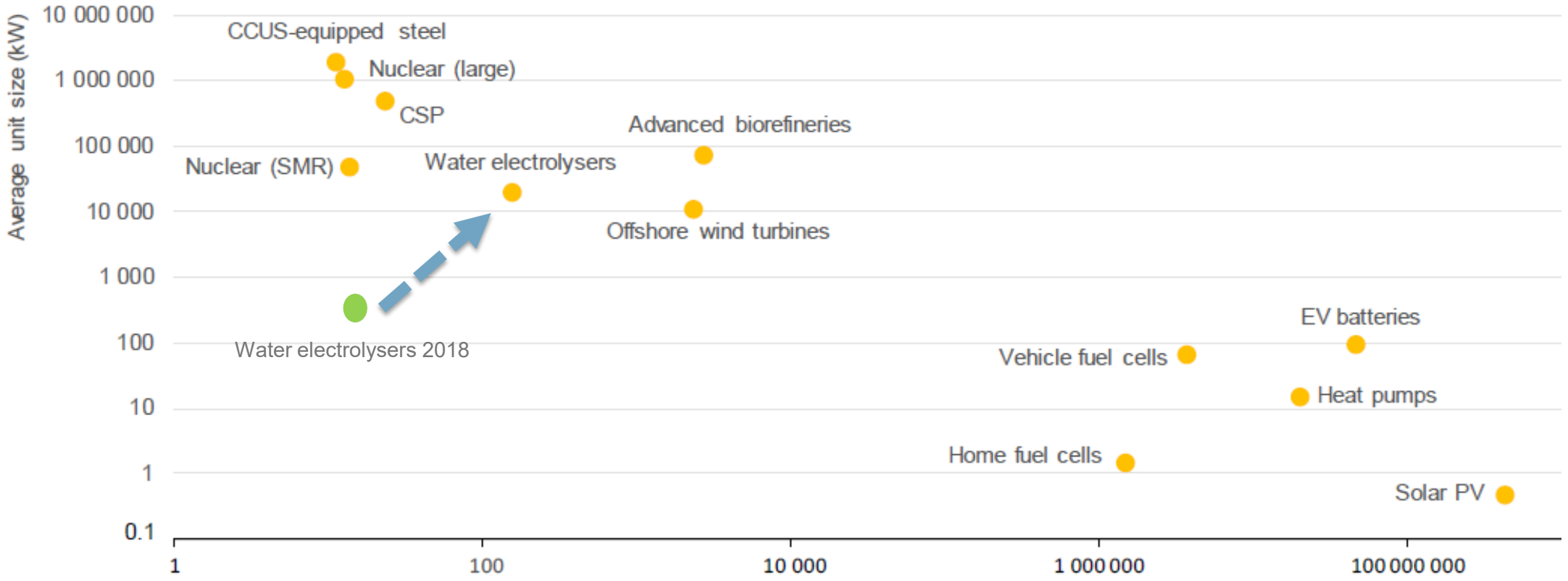
Nederlandse industrie moet elektrolysers gaan maken ?

Nederland moet een maakindustrie voor elektrolysers krijgen. Kennisinstituut TNO, technologiebrancheorganisatie FME en negen provincies hebben de handen ineen geslagen om bedrijven bij elkaar te brengen en te ondersteunen. Dat maken de organisaties deze dinsdag bekend op de European Industry and Energy Summit.



provincie Drenthe
Provincie Noord-Holland
FME POWERED BY DUTCH TECHNOLOGY
provincie Zuid Holland
provinsje fryslân provincie fryslân
provincie Overijssel
Provincie Zeeland
provincie Gelderland
PROVINCIE UTRECHT
provincie groningen
provincie limburg

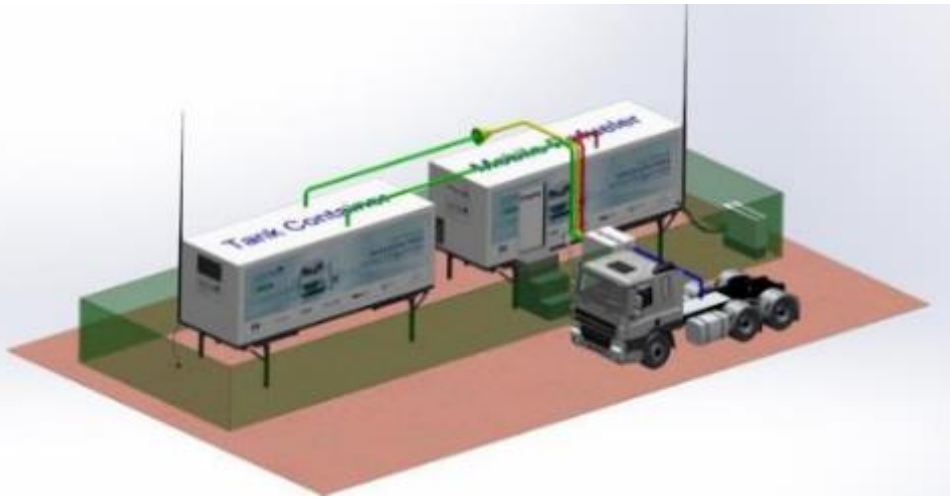
GROEI IN VERMOGEN EN AANTAL IS NODIG



Average number of units installed per year in the IEA Sustainable Development Scenario 2018 -2040

Source: 2020 -IEA -The Oil and Gas Industry in Energy Transitions; TNO

H2 SHARE - DEMONSTRATIE H2 VRACHTWAGEN EN MOBIEL TANKSTATION



Rigid with H2 Range extender

GVW	27 ton
Power	210 kW
Torque	2.000 Nm
Battery capacity	82 kWh
Battery charging	3C

Range extender	
Charging power	88 kW
Volume	30kg H2
Range	400 km

WANNEER IS LOKALE WATERSTOF PRODUCTIE NU HAALBAAR EN ZINVOL?

PV-panelen agrarisch gebied
Negatieve businesscase
NPV -0.25 mln euro, IRR 6%

Case 1

- Lokale gebruikersvraag: klein
- Transportkosten: hoog (niet lokaal)
- Willingness-to-Pay: hoog

Grootschalig zonnepark
Negatieve business case
NPV -12.1 mln euro, IRR 5%

Case 2

- Lokale gebruikersvraag: groot
- Transportkosten: hoog (niet lokaal)
- Willingness-to-Pay: laag

Energiehub bedrijventerrein
Positieve businesscase
NPV +1.4 mln euro, IRR 20%

Case 3

- Lokale gebruikersvraag: klein
- Transportkosten: laag (lokaal)
- Willingness-to-Pay: hoog

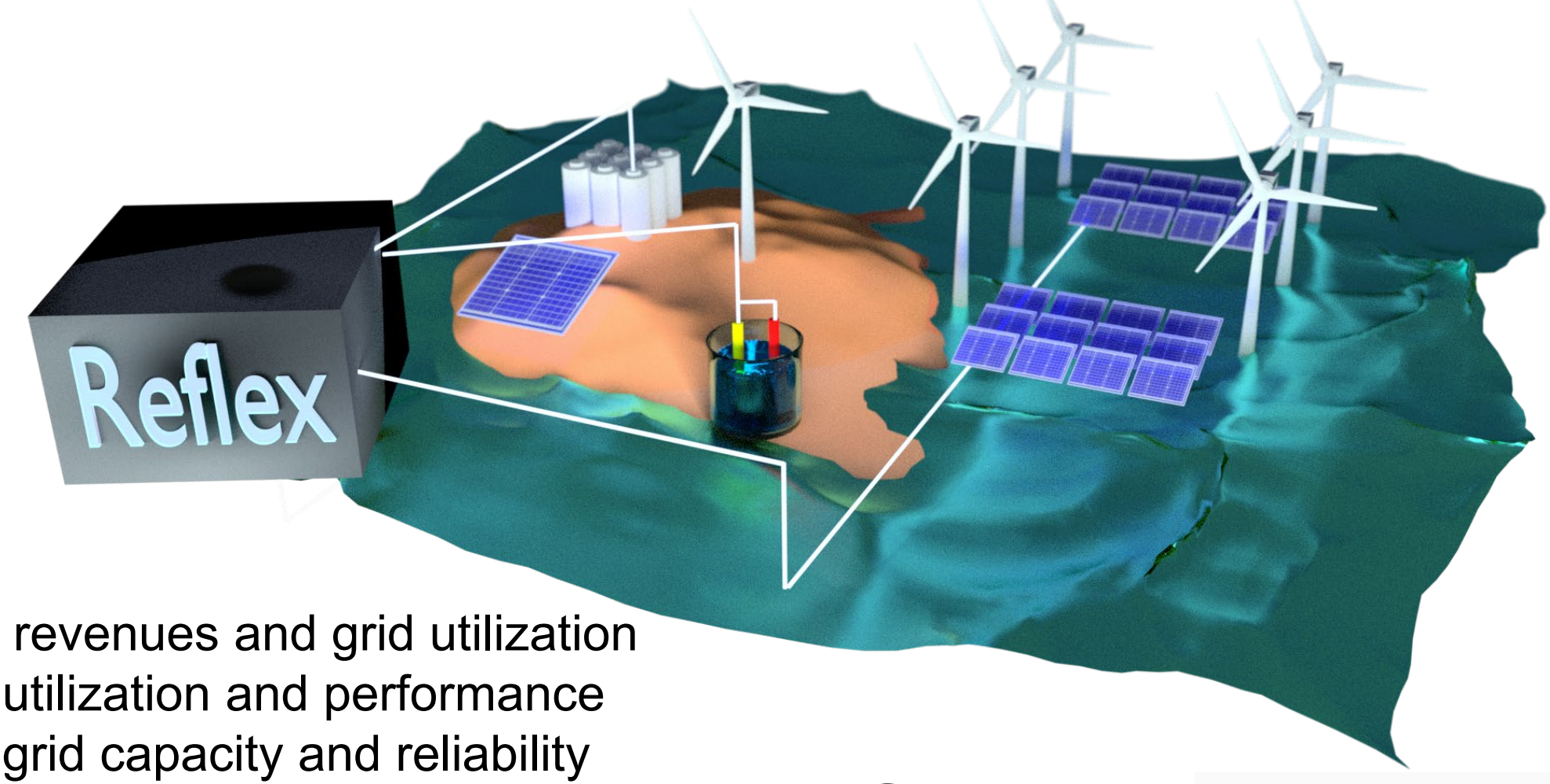
Industriële waterstof
Positieve businesscase
NPV +2.3 mln euro, IRR 9%

Case 4

- Lokale gebruikersvraag: groot
- Transportkosten: laag (lokaal)
- Willingness-to-Pay: laag

Source: TNO 2018 R11197 | Eindrapport Waterstof uit elektrolyse voor maatschappelijk verantwoord netbeheer – Businessmodel en businesscase

ONDERZOEK NAAR INZET LOKALE WATERSTOF PRODUCTIE GEKOPPELD AAN WIND EN ZON



Goals

- Increased revenues and grid utilization
- Improved utilization and performance
- Improved grid capacity and reliability
- Resilience to threats and failures

TNO innovation for life

Application Centre for Renewable Resources ACRRES Initiative of Wageningen University & Research

OPENING FARADAY LAB – APRIL 2020

Hydrogen

TNO innovation for life

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