

Groene waterstof- productie via elektrolyse

Kansen en uitdagingen in een mondiale markt

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NL

Holland High Tech
Global Challenges, Smart Solutions



Wat is 1 GW Electrolyser plant?

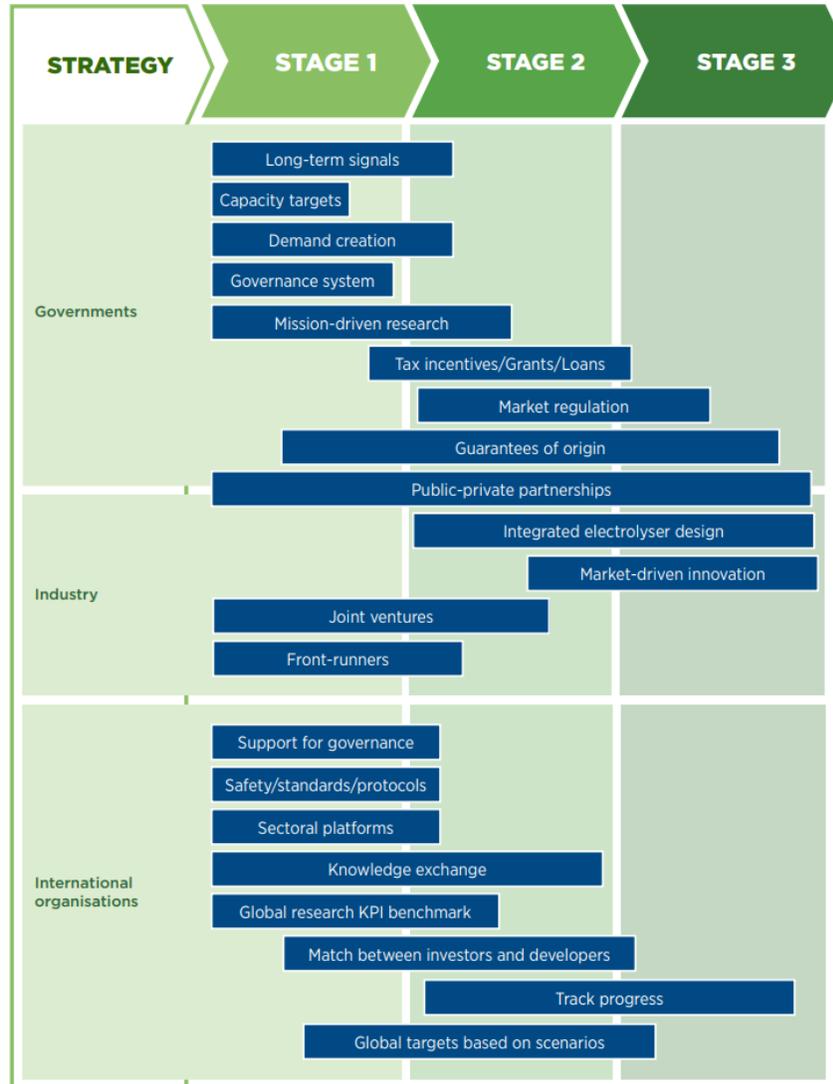


Institute for
Sustainable
Process Technology

- 1 GW electrolyser produceert ~150 kton waterstof
- De NL industriële vraag (~ 1500 kton (10 GW)
- 10 mil ton (~67 GW)
- 1 GW electrolyser plant kost 730 - 830 Million Euro, mits we werken aan innovatie



Figure 36. Main actions and functions for key stakeholders influencing the scale up of green hydrogen.



Based on IRENA analysis.

Wat moeten we doen om dit te halen?



Institute for
Sustainable
Process Technology



2022

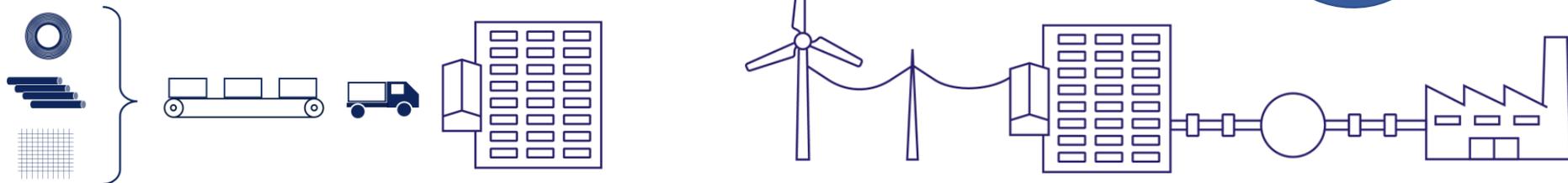
2030

2050

- ❑ Commercialisatie huidige technologie en supply chain voor Generatie 1
- ❑ Innovatie voor volgende generaties

Ambition:

- NL 4 GW
- EU 40 GW
- Worldwide 90 GW





Hoe helpt ISPT Hydrohub hierbij?

❑ Commercialisatie huidige technologie en supply chain voor Generatie 1

- Hydrohub MW Test Center (commercialisatie en industrialisatie),
- GW project (kosten reductie)
- Veiligheid programma (veiligheid, standardisatie)
- Hychain (strategie H₂)
- Green Ammonia Innovation Platform (logistiek).

❑ Innovatie voor volgende generaties

- Hyscaling (maakbaarheid en volgende generaties), partnerschap met TNO
- Next level SOE (nieuwe kansrijke technologies), partnerschap met TNO

Dit doen we samen met meer dan 100 partners uit de industrie, overheid, gas en electriciteit operators, kennisinstellingen en universiteiten. ISPT organiseert deze samenwerking en geeft sturing.

Elektrolyser stack ^(1/2)

Different sizes PEM and Alkaline



› ITM PEM stack @Hystock Groningen NL



› TNO – Hydron Short stack Petten NL



› NEL Alkaline stack manufacturing site



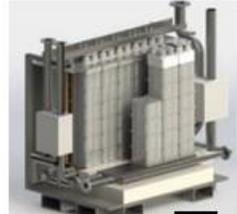
› Demag-elektrolyser @ Aswandam Egypt, 1959 largest electrolyser ever build 203 MW .(Photo Thijs de Groot)



› ThyssenKrupp Alkaline diaphragm

Elektrolyser stack (2/2)

Different players and there are more (to come)

Atmospheric alkaline	Pressurized alkaline	PEM (atmospheric and pressurized)	SOE (high temp)	AEM
 Thyssenkrupp 	 McPhy 	 Siemens 	 Haldor Topsoe 	 Enapter 
 AKC (Asahi Kasei Corp) 	 John Cockerill 	 Elogen 	 Cummins 	 Hydrolite 
 NEL 	 Hydrogen-Pro 	 ITM 	 Sunfire 	 Alchemr 
 Green Hydrogen systems 	 Sunfire 	 Plug power 	 Nel 	 Elcogen 

Not an extensive list, but it includes the current main players for each technology. Multiple technology developers and start-ups working on new generation technology especially in PEM and AEM

Source: HyCC, Thijs de Groot (2022); adapted by TNO; different electrolyser suppliers

success of Dutch industry

Strategies to position the Netherlands in the next decade

4 strategies

Product innovation

- › Support Dutch companies to become active in the electrolyser supply chain (Dutch technology inside)

Demonstration

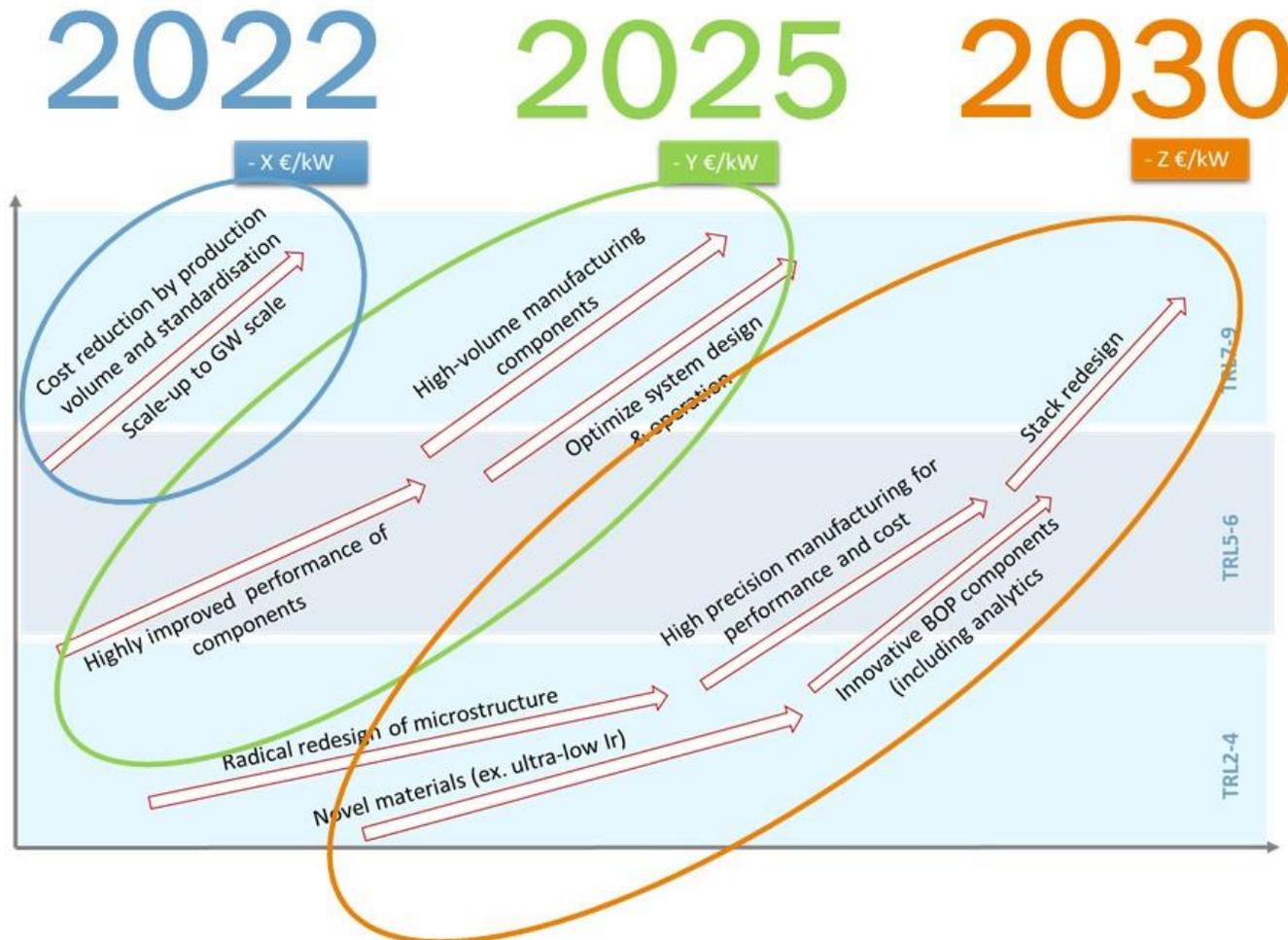
- › Support industry clusters with transition to CO₂ free production processes based on green hydrogen

Production equipment

- › Developing High-volume & high precision production equipment (and assembly in the NL)

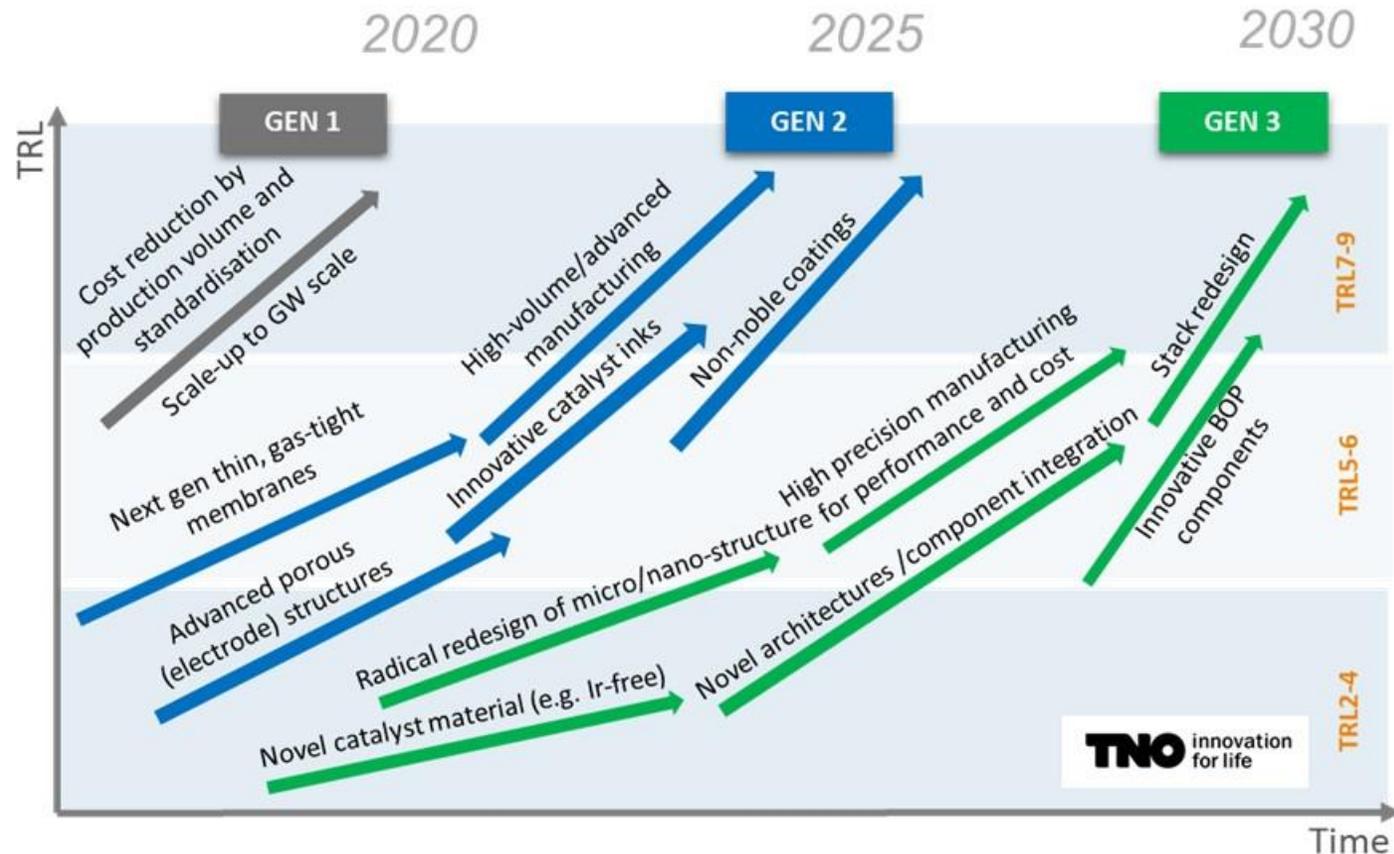
System innovation

- › Developing next generation Electrolyzer technology (become an OEMer for specific application i.e. offshore)



Concept of electrolyser generations – PEM

Our view on innovations & role of TNO



Note: Figure does not provide a full overview of activities, but a number of representative examples

1st generation

- › Current technology used by OEM's. Substantial cost reduction possible by simply scaling-up

2nd generation

- › Development of improved components (membranes, electrodes, coatings) including high volume manufacturing

3rd generation

- › Radically new architecture of cell and stack, leading to breakthrough in performance and use of scarce materials

Role TNO

Integration support

Shared Research

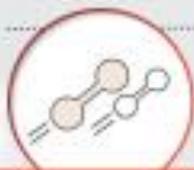
Create new Inventions



Groene H₂: kansen voor NL

Ambitie GroenvermogenNL

Stappen op weg naar een goed werkende groene waterstofmarkt



Versnellen

Ondersteunen
bestaande
initiatieven

Concreet doen
realiseren van
MW-schaal
projecten



Opschalen

Realiseren ca
500MW gebruik
van groene
waterstof aan
import/ productie
elektrolyse
projecten



Kostereductie

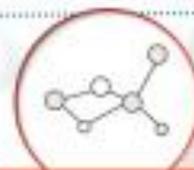
Ambitie richting
€ 2,50 per kilo
waterstof in 2030
(prijspeil 2021)



Toekomst- bestendige industrie

Demonstratie van
industriële gebruik
van groene waterstof
in een viertal
waardekens:

- Groen staal
- Groene chemie
- Groene kunstmest
- Groene brandstoffen



Innovatie ecosysteem

Samen met
topsectoren het
innovatie
ecosysteem voor
groene waterstof
in NL versterken



Inspiratie talenten

Zorgdragen voor
voldoende
opgeleide
mensen om de
ca 15.000
vacatures in NL
rond groene
waterstof te
kunnen
vervullen

Vier instrumenten



Demo support
€ 500 mln

Demonstratie van > 100MW projecten aan gebruik van groene waterstof in 3 – 4 waardeketens als:

- Groen staal
- Groene chemie
- Groene kunstmest
- Groene brandstoffen



Pilot support
€ 100 mln

Pilots en demonstratie door de hele waardeketen van productie, transport, opslag en gebruik van groene waterstof



R&D
€ 168 mln

7 werkpakketten:

- Productie CO₂ neutrale H₂
- Transport en opslag
- Gebruik groene waterstof
- Koolstof chemie
- Stikstof chemie
- Gespecialiseerde chemie
- Sociaaleconomische aspecten en implementatie



Human Capital
€ 50 mln

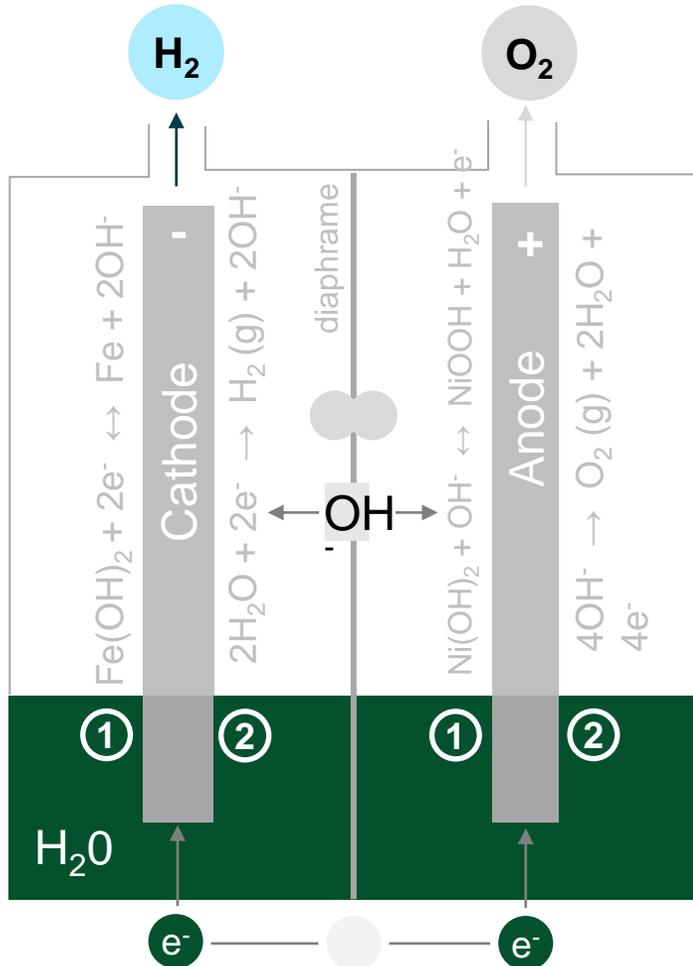
Nationale human capital agenda

- Regionale learning communities
- Digitaal platform
- Nationale coördinatie

GroenvermogenNL zorgt voor verbinding
Portfoliobenadering



Battolyser is the next generation electrolyser..



Source: Battolyser Systems analysis, Battolyser Systems data

How does it work?

- 1 In a first electrochemical reaction, the electrodes are charged and store electrons
- 2 When overcharged, hydrogen and oxygen are formed in a subsequent reaction

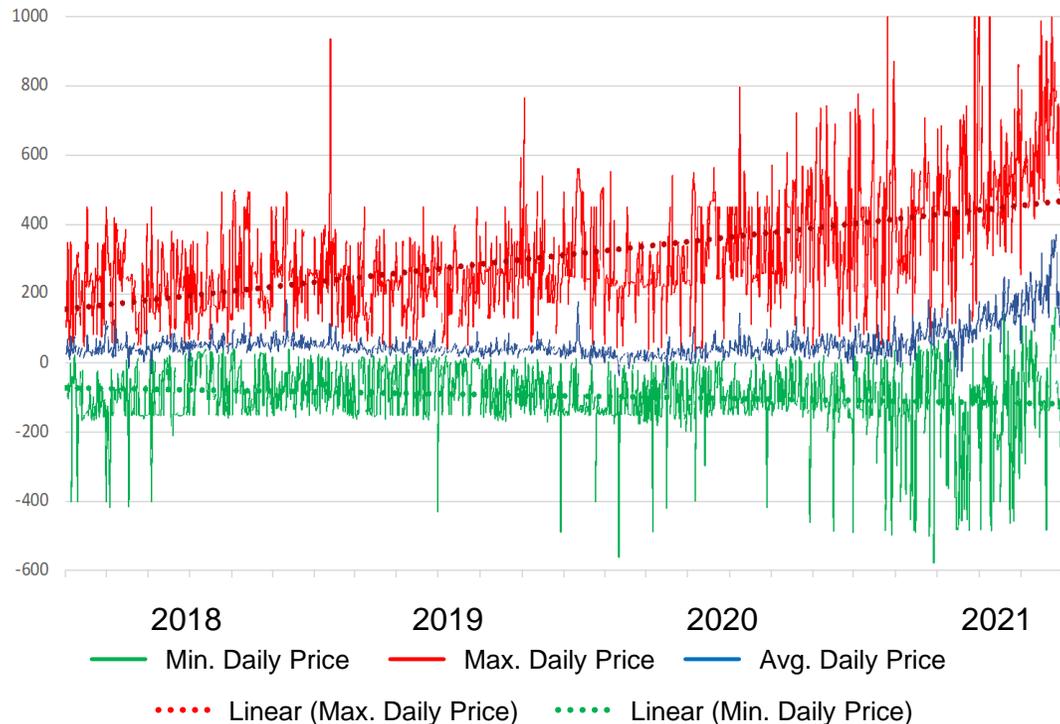
Advantages of the technology

 Flexible	Battolyser can instantly switch back and forth between charging and discharging
 Efficient	Stack is 80-90% energy efficient thereby using less electricity
 Sustainable	Technology is using only abundant active materials – i.e., Nickel (Class 2) and Iron – largely abundant
 Robust	Battery allows deep discharging and no risk of overcharging (electrolysis) with little-to-no degradation allowing a long lifetime (20+ yrs)
 Versatile	System can arbitrage between power and hydrogen markets

Battolyser's flexibility makes it a real systemic solution

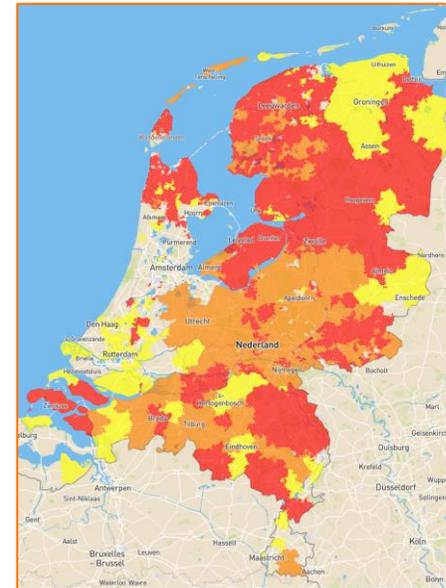
Electricity price volatility is increasing, improving flexible asset business cases

Imbalance prices in the Netherlands (€/MWh)



Source: TenneT data analysed by 

Grid congestion is increasing, limiting the ability to develop new solar and wind parks



Legend

- No electricity transport scarcity (yet)
- Threat of transport scarcity, adjusted supply regime
- Announcement of structural congestion by ACM
- Structural congestion, new transport request not accepted

Battolyser enables new renewable developments in congested grids by:

1. Buying electricity when there is a surplus, selling electricity when there is a deficit
2. Selling H₂ to local captive customers, inject in the H₂ backbone (when available) or distribute via tube trailers
3. Fully following grid load thanks to its high flexibility

The rest of the world is accelerating....

Germany grants Sunfire \$68m to build up gigawatt-scale H2 electrolyser production

Electrolyser developer and partners to use funding for serial production of high-temperature electrolysers and boosting alkaline electrolyser manufacturing capacity

10 January 2022 14:42 GMT UPDATED 10 January 2022 14:42 GMT

Four electrolyser gigafactories to be built in France as part of €2.1bn state-aid hydrogen push

Electrolyser makers McPhy, Genvia, Elogen and John Cockerill to receive funding from French government as it aims to make nation 'the world leader in carbon-free hydrogen'

30 September 2022 14:12 GMT UPDATED 30 September 2022 14:12 GMT

Cheap Chinese hydrogen electrolysers 'likely to become popular worldwide during 2025-30': BNEF

Alkaline electrolysis systems made in China are a quarter the price of those manufactured in the West, says analyst

22 September 2022 2:33 GMT UPDATED 22 September 2022 2:37 GMT

Europe risks losing green hydrogen funding to US, industry leader says

'Clean' fuel investors will favour Biden plan unless Brussels improves incentives, Fortescue chief claims



Scrapped | EU's controversial 'additionality' rules for green hydrogen are history after European Parliament vote

The requirements for hourly proof of dedicated renewable energy supply will no longer apply, reducing the risk of a potential 'mass exodus' of developers to the US — but not everyone is pleased

14 September 2022 17:23 GMT UPDATED 15 September 2022 12:51 GMT

Nel bags order for 200 MW of electrolyser equipment for US project

July 18 (Renewables Now) - Norwegian hydrogen solutions company Nel ASA (OSE:NEL) has received an order to deliver a 200-MW alkaline electrolyser system for an industrial green hydrogen project in the US.

The firm deal is valued at over EUR 45 million (USD 45.7m) and is the largest order for alkaline electrolyser equipment by Nel, the company said on Monday. The contract was placed with Nel Hydrogen Electrolyser AS by an unnamed US client.



Nel's M Series Proton PEM Electrolyser. Image by Nel (www.nelhydrogen.com)