

HYCLICX-NL February 2024

Hydrogen cost indicator for the Netherlands

HYXCLICX is a product developed by HyXchange. This indicator is an instrument to estimate marginal production cost of hydrogen in the Netherlands.

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1. The HyXchange Initiative

Introduction: Hydrogen is increasingly attracting interest as an important part of the energy transition. No greenhouse gas is released when hydrogen is used. Hydrogen is therefore regarded by many as a climate-neutral energy carrier for the future.

Due to the position that hydrogen will occupy in the future and the many ways in which it can be produced and used, with a variety of producers and users, the development of the trade in hydrogen will become important.

As a result, parties from the sector have started the “HyXchange” Initiative. HyXchange is supported by Gasunie, Port of Rotterdam, Port of Amsterdam, Groningen Seaports, North Sea Ports and a large growing number of interested market parties involved in meetings, pilots, simulations and/or other activities.

Key objectives: For the functioning of a hydrogen exchange it is important that the underlying conditions for market forces in hydrogen are met:

- Firstly, an openly accessible transport infrastructure for hydrogen is important condition; this will be facilitated with the establishment of the backbone & storage facility.
- Secondly, a diverse supply of hydrogen is important (incl. import and low-carbon hydrogen from industrial processes). This also contributes to the security of supply.
- Thirdly, a dependable and transparent trading platform greatly enhances market access, pools liquidity and reduces transaction costs and trading risks.

The HyXchange platform is expected to catalyse an increasing demand for climate-neutral hydrogen produced by an expanding asset base, driving optimal balancing of supply and demand through transparent pricing.

2. Introduction HYCLICX (1/2)

Introduction: On June 7th (2023) HyXchange published its first issue of the hourly HYCLICX spot market indicator for hydrogen based on lowest-priced electricity hours during its EU Green Week event in Brussels. The indicator is an instrument to estimate marginal production cost for renewable hydrogen from electrolysis in the Netherlands.

Approach: The renewable HYCLICX indicator is linking the marginal cost component of hydrogen to the hourly electricity spot market, reflecting the electrolysis as a source for green hydrogen. By selecting the lowest set of volatile hourly power prices - mostly occurring in two varying blocks per day in the Netherlands - hydrogen can be produced in the cheapest way. The hours are largely coinciding with a high share of renewable electricity production from wind and solar, also providing alignment with certificate rules and the EC Delegated Act on hydrogen.

Selected indicators: HYCLICX publishes on a monthly interval a selection of relevant indicators for hydrogen:

- **HYCLICX green (daily 2x 6 hour blocks):** The marginal cost price for the cheapest (fixed) 12 hours of electricity each day: hours 1-6 and 12-17 (0.00-6.00 and 11.00-17.00)
- **HYCLICX green best 50% (month):** The marginal cost price for the lowest-priced 50% of hours of electricity each month.
- **HYXCLICX blue (daily):** The marginal cost price for blue hydrogen, to allow for comparison.
- **HYXCLICX grey (daily):** The marginal cost price for grey hydrogen, to allow for comparison.

The HYCLICX methodology, at the moment calculated for the Netherlands, can also be readily applied to other countries with a transparent hourly electricity price. Interested countries are invited to contact us to discuss options.

2. Introduction HYCLICX (2/2)

Frequency: The HYCLICX will be published on a monthly basis, showing both in detail the hydrogen production price for the previous months as well as the development dating back 1 year. In addition, a weekly update will also become available on our website.

Further analysis: The pre-defined 2x6 hour operating approach is a possible operational pattern. Alternative (equally good) operational options exist. Any market party can apply a different operational pattern in its own individual way by using the hourly HYCLICX data. Available on demand.

Please contact the HyXchange team directly to obtain the dataset for HYCLICX to allow for further computation.

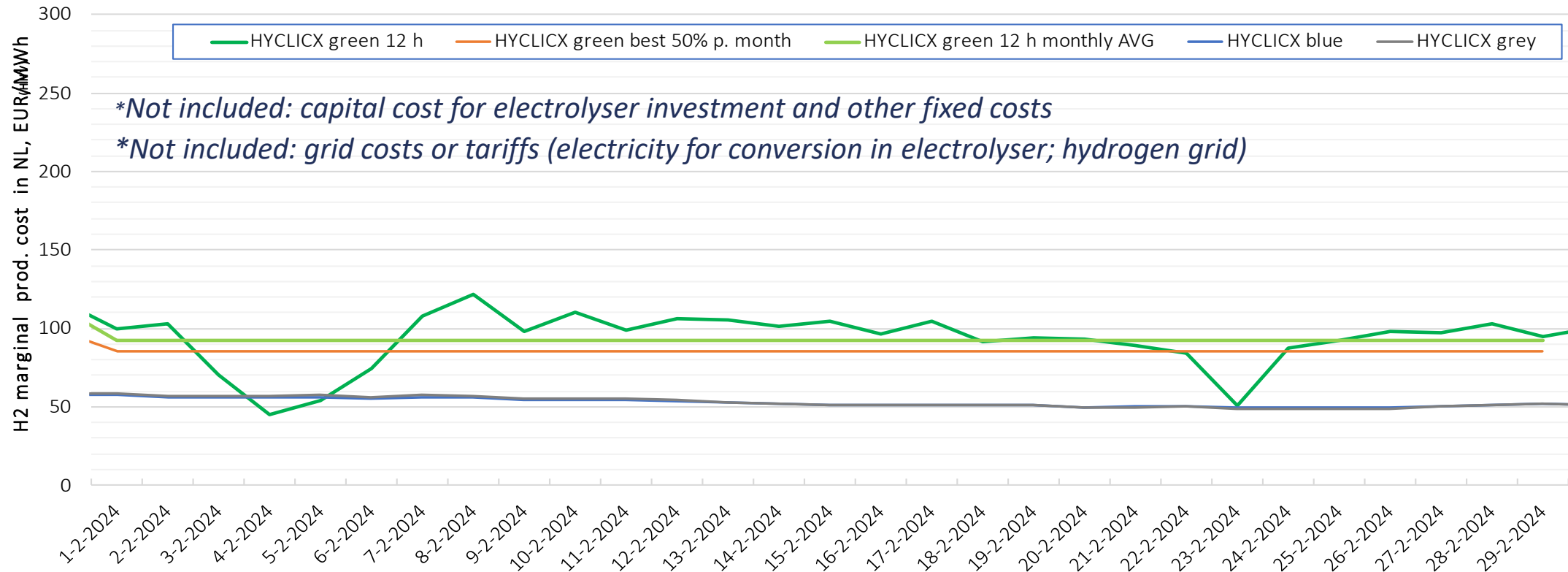
Additional information: Insight in the cost price of hydrogen makes it possible to start hydrogen trading more quickly. Hence, HyXchange with its price indicator is contributing to the growth of trade in hydrogen produced through renewable energy as a main commodity in the energy transition and at the same time reducing overall natural gas dependence.

The HYCLICX indicator was inspired by the HyXchange spot market simulation of the future hydrogen market, optimizing the spot market outcome on marginal cost. A total of 25 market parties participated in these simulation meetings.

See also: www.hyxchange.org

3. HYCLICX marginal H2 production cost NL: Feb 2024

Prices in €/MWh HHV (higher heating value)



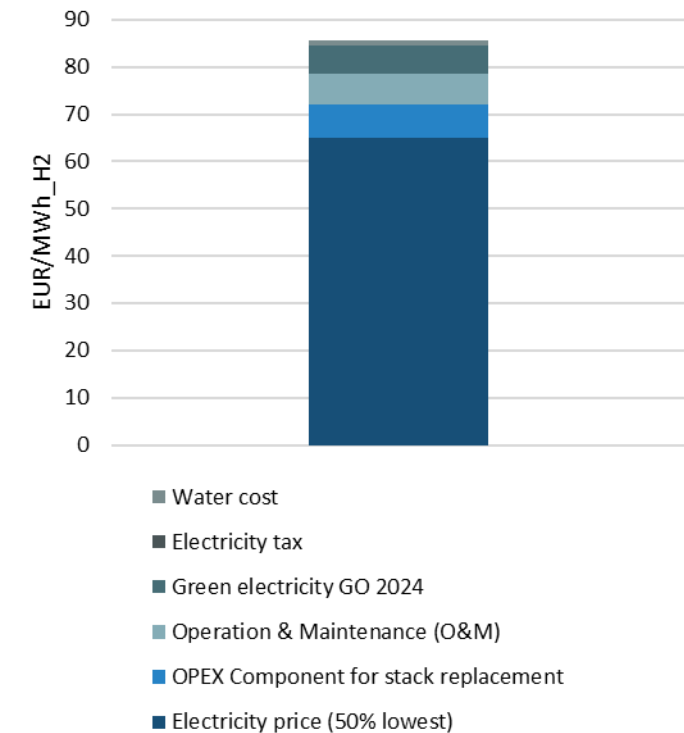
3. HYCLICX green best 50%: Feb 2024

Month of 2023	HYCLICX Green best 50% €/MWh HHV marginal cost	HYCLICX Green best 50% €/kg marginal cost	HYCLICX Green best 50% €/MWh LHV marginal cost
January	97.15	3.83	114.84
February	85.62	3.37	101.21
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			

- Prices primarily in Eur/MWh HHV higher heating value. full H2 energy content
- Aligned with indexes for natural gas (e.g. TTF). rules of Dutch H2 grid and green G.O
- Conversion factor P/MWhHHV to P/kg: 0.03939 ~ 4 / 100
- Conversion factor MWhHHV to MWhLHV: 1.182

**Marginal price component (not included: capital cost for electrolyser investment and other fixed costs).*

HYCLICX variable hydrogen price cost components (February 2024)



3. HYCLICX green daily 12h: Feb 2024, €/MWh (HHV)*

Date*	HYCLICX green	HYCLICX blue	HYCLICX grey
01.02.2023	99.30	57.36	58.53
02.02.2023	103.11	56.08	56.94
03.02.2023	70.52	56.11	57.21
04.02.2023	44.71	56.11	57.21
05.02.2023	53.71	56.30	57.39
06.02.2023	74.52	55.03	56.06
07.02.2023	108.04	56.39	57.52
08.02.2023	121.56	56.04	56.94
09.02.2023	97.81	54.80	55.46
10.02.2023	110.09	54.76	55.01
11.02.2023	98.64	54.76	55.01
12.02.2023	106.30	53.86	54.17
13.02.2023	105.14	52.43	52.45
14.02.2023	101.61	52.04	51.99
15.02.2023	104.54	51.18	51.23
16.02.2023	96.49	50.99	51.32
17.02.2023	104.66	50.97	51.15
18.02.2023	91.55	50.97	51.15
19.02.2023	93.62	51.00	51.17
20.02.2023	93.01	49.61	49.13
21.02.2023	89.40	50.05	49.70
22.02.2023	84.33	50.26	49.95
23.02.2023	50.77	49.13	48.54
24.02.2023	87.41	49.12	48.40
25.02.2023	92.04	49.12	48.40
26.02.2023	97.89	49.37	48.64
27.02.2023	97.12	50.49	50.04
28.02.2023	102.68	51.25	51.10
29.02.2023	94.59	52.12	52.36

*Marginal price component (not included: capital cost for electrolyser investment and other fixed costs). In €/MWh based on the High Heating Value (HHV) of Hydrogen.

4. HYCLICX: marg. and total cost formula

The marginal costs for hydrogen production are determined according to the following methodology (hourly).

$$\text{HYCLICX} = \sum \text{fixOPEX} + \frac{\text{Elec Price} + \text{Elec tax} + \text{GO}}{\eta} + \frac{\text{Spec Water Cost} \cdot \text{Spec Water Demand}}{\text{HHV}}$$

Selected cost parameters*		HYCLICX Green	HYCLICX Blue	HYCLICX Grey
	Unit	Electrolysis	CH4 + CCS	CH4 (no CCS)
Operation & Maintenance (O&M), <i>fixed part</i>	EUR/MWh	13.72	7.51	6.06
Efficiency (UHV)	%	76.83	82.74	88.65
Electricity and gas levies (incl. Green GOe)	EUR/MWh	7.465	4.01	4.01
Water cost	EUR/m ³	4	-	-

**Basic calculation method and most parameters provided by consultant E-bridge. In line with their HYDEX index for hydrogen in Germany. Approach to assess green hydrogen product cost per hour (and select blocks of operational hours) for HYCLICX provided by HyXchange based on its hydrogen market simulation project and discussions with market parties.*

4. Detailed parameters for the calculation

Selected cost parameter	Unit	HYCLICX green	HYCLICX blue	HYCLICX grey
		Electrolysis	Reformer + CCS	Reformer w/o CCS
OPEX Component for stack replacement	EUR/MWh_H2	7.18	-	-
Operation & Maintenance (O&M)	EUR/MWh_H2	6.54	7.51	6.06
Lower heating value Hi / LHV	kWh/kg_H2	33.32	33.32	33.32
Higher heating value Hs / HHV	kWh/kg_H2	39.39	39.39	39.39
Efficiency (ref. to lower heating value Hi / LHV)	%	65.00	70.00	75.00
Efficiency (ref. to higher heating value Hs / HHV)	%	76.83	82.74	88.65
Full-load hours (12h. 2 6h blocks per day)	h/a	4380	7000	7000
Water cost	EUR/m ³	4	-	-
Water demand	m ³ /kg_H2	0.01	-	-
CO2 transport and storage cost (only operational part. no CAPEX)	EUR/t_CO2	-	35	-
CO2 emissions for natural gas	t_CO2/MWh_NG	-	0.201	0.201
Sequestration rate for CCS	%	-	90	0
Additional cost for electricity (Electricity tax and green electricity GO))	EUR/MWh_e	0.115 + 7.35	-	-
Additional cost for natural gas (Gas tax)	EUR/MWh_NG	-	4.01	4.01

HYCLICX: what is included

Marginal-price costs associated with producing additional MWh of hydrogen

- Electricity spot price (hourly variable)
- Green guarantee of origin for renewable electricity (monthly)
- Tax on electricity demand electrolyser not into stack (auxiliary power)
- Water cost
- O&M costs
- Stack replacement cost

For blue and grey hydrogen:

- Gas price (daily variable), CO2 price (daily variable) and/or CCS storage cost

What is not included

Costs that are independent of producing additional MWh of Hydrogen

- Capital cost of investment of Electrolyser
- Upfront project preparation cost
- Fixed administration and overhead cost
- One-time electricity grid connection fee or cost
- Yearly fixed electricity grid tariff, capacity related
- Hydrogen grid: all shipper tariffs, connection fees
- Cost for other transportation (by ship or trailer)
- Commercial margin

For blue and grey hydrogen:

- Same principles apply as above

4. Literature list

No.	Source
1a	Efficiency Electrolysis: IEA 2020/Platts Methodology and Specifications Guide Global Hydrogen Latest update: October 2020
1b	Reformer with CCS: IEA 2020/ Platts Methodology and Specifications Guide Global Hydrogen Latest update: October 2020
1c	Efficiency Reformer without CCS: IEA 2020/Platts Methodology and Specifications Guide Global Hydrogen Latest update: October 2020
2a	OM Electrolysis 2.2 % of invest: Reuß et al. (2017) Seasonal storage and alternative carriers: A flexible hydrogen supply chain model. Applied Energy
2b	OM Reformer with CCS: IEA 2020/ Platts Methodology and Specifications Guide Global Hydrogen Latest update: October 2019
2c	OM Reformer without CCS: IEA 2020/ Platts Methodology and Specifications Guide Global Hydrogen Latest update: October 2020
3a	Invest Electrolysis: Fraunhofer ISE (2022) Cost Forecast for low temperature electrolysis. S. 56
3b	Invest Reformer with CCS: IEA 2020 Platts Methodology and Specifications Guide Global Hydrogen Latest update: October 2020 (EUR/\$ = 1.15)
3c	Invest Reformer without CCS: Platts Methodology and Specifications Guide Global Hydrogen Latest update: October 2020 (EUR/\$ = 1.15)
4	Benutzungsstunden für Elektrolyse und SMR nach Prognos-Studie (Kosten und Transformationspfade für Strombasierte Energieträger S. 88; https://www.bmwk.de/Redaktion/DE/Downloads/Studien/transformationsspfade-fuer-strombasierte-energietraeger.pdf?__blob=publicationFile)
5	Sequestration rate of CCS: IEA 2020/ Platts Methodology and Specifications Guide Global Hydrogen Latest update: October 2022
6	Electricity tax - Tabellen tarieven milieubelastingen. https://www.belastingdienst.nl/wps/wcm/connect/bldcontentnl/belastingdienst/zakelijk/overige_belastingen/belastingen_op_milieugrondslag/tarieven_milieubelastingen/tabellen_tarieven_milieubelastingen?projectid=6750bae7%2D383b%2D4c97%2Dbc7a%2D802790bd1110
7	Gas tax - Tabellen tarieven milieubelastingen. https://www.belastingdienst.nl/wps/wcm/connect/bldcontentnl/belastingdienst/zakelijk/overige_belastingen/belastingen_op_milieugrondslag/tarieven_milieubelastingen/tabellen_tarieven_milieubelastingen?projectid=6750bae7%2D383b%2D4c97%2Dbc7a%2D802790bd1110
8	CO2 emission acc. BAFA (2021) Informationsblatt CO2-Faktoren. S.6
9	Porthos CCS - Cost for transport and storage. https://zoek.officielebekendmakingen.nl/blg-947442.pdf
10	Hourly electricity prices are taken from Nordpool. https://www.nordpoolgroup.com/en/Market-data1/data-downloads/historical-market-data2/



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