

JANUARY 2025

HYCLICX-NL report over year 2024

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

For questions regarding HyXchange and HYCLICX please contact j.schellekens@hyxchange.org or b.denouden@hyxchange.org

HYCLICX: Key insights

In 2023 HyXchange published its first issue of the hourly HYCLICX spot market indicator for hydrogen based on lowest-priced electricity hours.

- HYCLICX estimates marginal cost for renewable hydrogen from electrolysis during cheapest half of electricity hours, mostly coinciding with high share of renewable power.
- It links the marginal cost component of hydrogen to the hourly electricity spot market, reflecting green electricity as source for green hydrogen. Capital costs for electrolysis (substantial but situational) are not included.
- The indicator is calculated for the Netherlands. The method would be also applicable to other countries.
- This report provides insights looking back at prices in 2024, and further analysis and explorations for 2030.

Average marginal H2 production costs NL 2024 (OPEX), excluding capital and other fixed cost.

HYCLICX green best 50%:	79 €/MWh; 3.1 €/kg
HYCLICX green 2x6h:	96 €/MWh; 3.8 €/kg
HYCLICX blue:	69 €/MWh; 2.7 €/kg
HYCLICX grey:	64 €/MWh; 2.5 €/kg

Cost in €/MWh is based on upper heating value of hydrogen (HHV)

Key insights 2024 (HYCLICX NL green best 50%):

- Average marginal cost was 3.1 €/kg for green hydrogen at lowest 50% of hours (mostly 2 varying blocks per day).
- This is a significant reduction compared to 2023, which averaged at a price of 4.3 €/kg, or 28% lower.
- There is substantial variation in green hydrogen marginal cost due to varying wind and solar input.
- Most production hours correlate with a higher share of Dutch renewable electricity production than average.
- The cost of green hydrogen was between April and July below the marginal cost of grey hydrogen.
- The cost of blue hydrogen increased, due to a new insight on the cost of carbon capture and sequestration (CCS).
- In 26% of production hours the exemption criterion for temporal correlation condition is met (was 20% in 2023).

Planned update for 2025

- The CAPEX of hydrogen production facilities will be added to the HYCLICX monthly publication. The production hours for green will follow the 2x6h and 50% best hours patterns.

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The background of the slide is a photograph of an industrial facility. In the foreground, several large, silver-colored metal pipes with bolted flanges are visible, extending from the bottom left towards the center. In the background, there is a power plant or refinery with various structures, including a tall orange crane and several tall chimneys or towers. The sky is clear and blue. The overall scene is brightly lit, suggesting a sunny day.

HyXchange

1. The HyXchange Initiative & HYCLICKX-NL

The HyXchange Initiative

Introduction: Renewable and low-carbon hydrogen are 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 who participate in meetings, pilots, simulations and/or other HyXchange 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 open and accessible transport infrastructure for hydrogen. This will be facilitated with the establishment of the Dutch Hydrogen backbone & storage facility.
- Secondly, a diverse supply of hydrogen: green hydrogen from electrolysis of renewable power, low-carbon hydrogen from industrial processes, imports from various countries. This contributes to the security of supply.
- Thirdly, a dependable and transparent trading platform. This greatly enhances market access, pools liquidity and reduces transaction costs and trading risks.

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

HYCLICX: introduction

Introduction: In 2023 HyXchange published its first issue of the hourly HYCLICX spot market indicator for hydrogen based on lowest-priced electricity hours. HYCLICX acts as an instrument to estimate marginal production cost for renewable hydrogen from electrolysis (for now in the Netherlands, could also be applied in other countries).

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 with cheapest cost. 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 [EU COM 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-h 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%-h of electricity per 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. HYCLICX development is supported by experts from [E-Bridge](#) and [Berenschot](#).

HYCLICX: publication frequency

Frequency: The HYCLICX is published on a monthly basis, showing in detail the hydrogen marginal cost for the previous months. Additionally, we also publish an annual publication and various thematic publications.

Further analysis: The pre-defined 2x6 hour operating approach and the monthly 50% best are possible operational patterns. 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.

Please contact the HyXchange team directly to obtain the hourly dataset for HYCLICX-NL-2024 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 marginal cost 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 various simulation meetings.

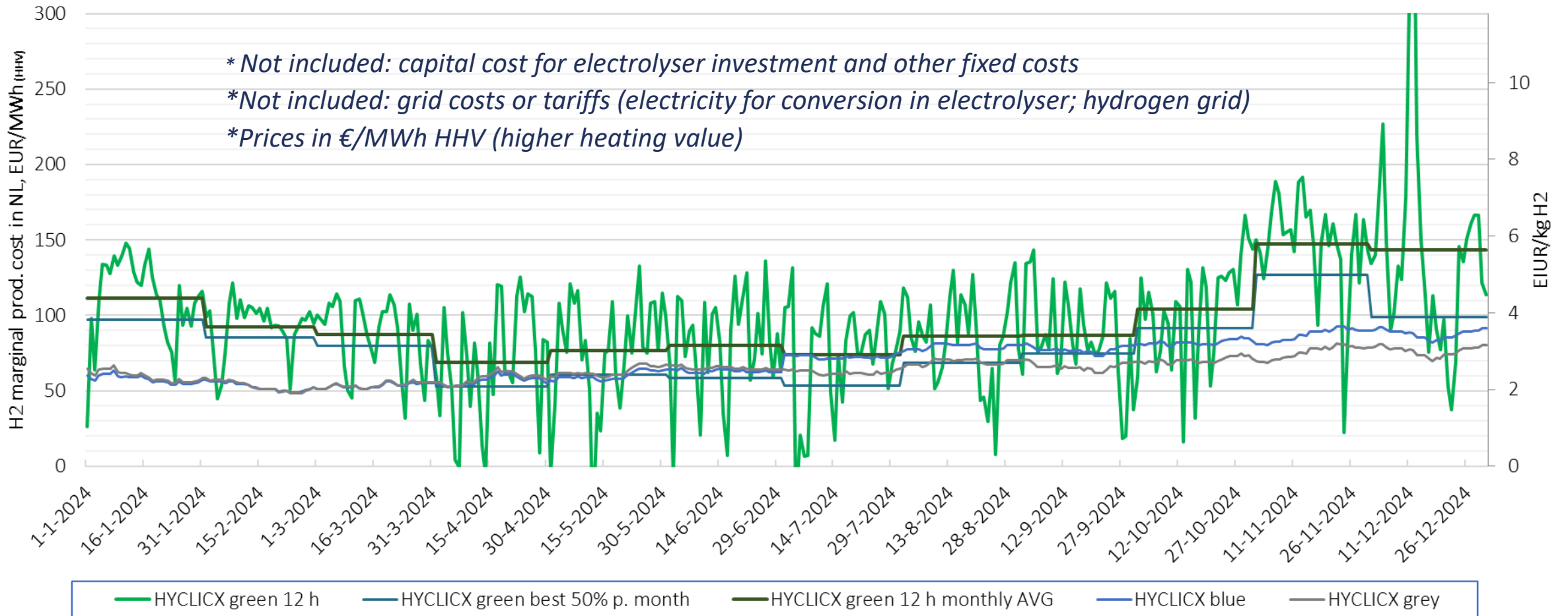
See also: www.hyxchange.org



HyXchange

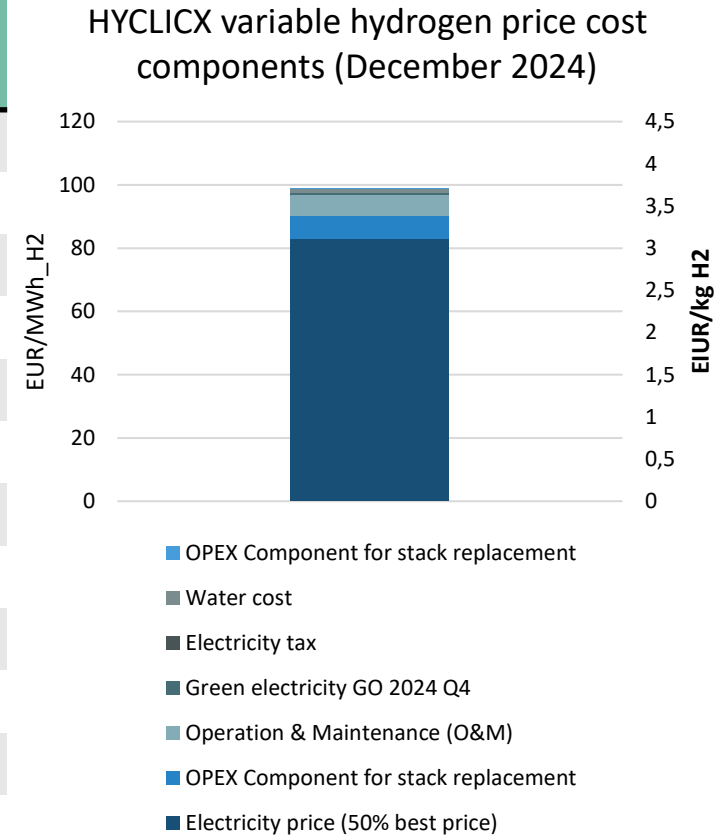
2. Insights HYCLICX-NL, findings 2024

HYCLICX-NL 2024, marginal cost (OPEX)



3. HYCLICX green best 50%: 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	79.68	3.14	94.19
April	53.11	2.09	62.78
May	60.90	2.40	71.99
June	58.50	2.30	69.14
July	53.36	2.10	63.07
August	68.61	2.70	81.10
September	74.65	2.94	88.24
October	91.96	3.61	108.38
November	127.05	5.00	150.18
December	98.70	3.89	116.67



- 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: $0.03939 \sim 4 / 100$
- Conversion factor MWhHHV to MWhLHV: 1.182

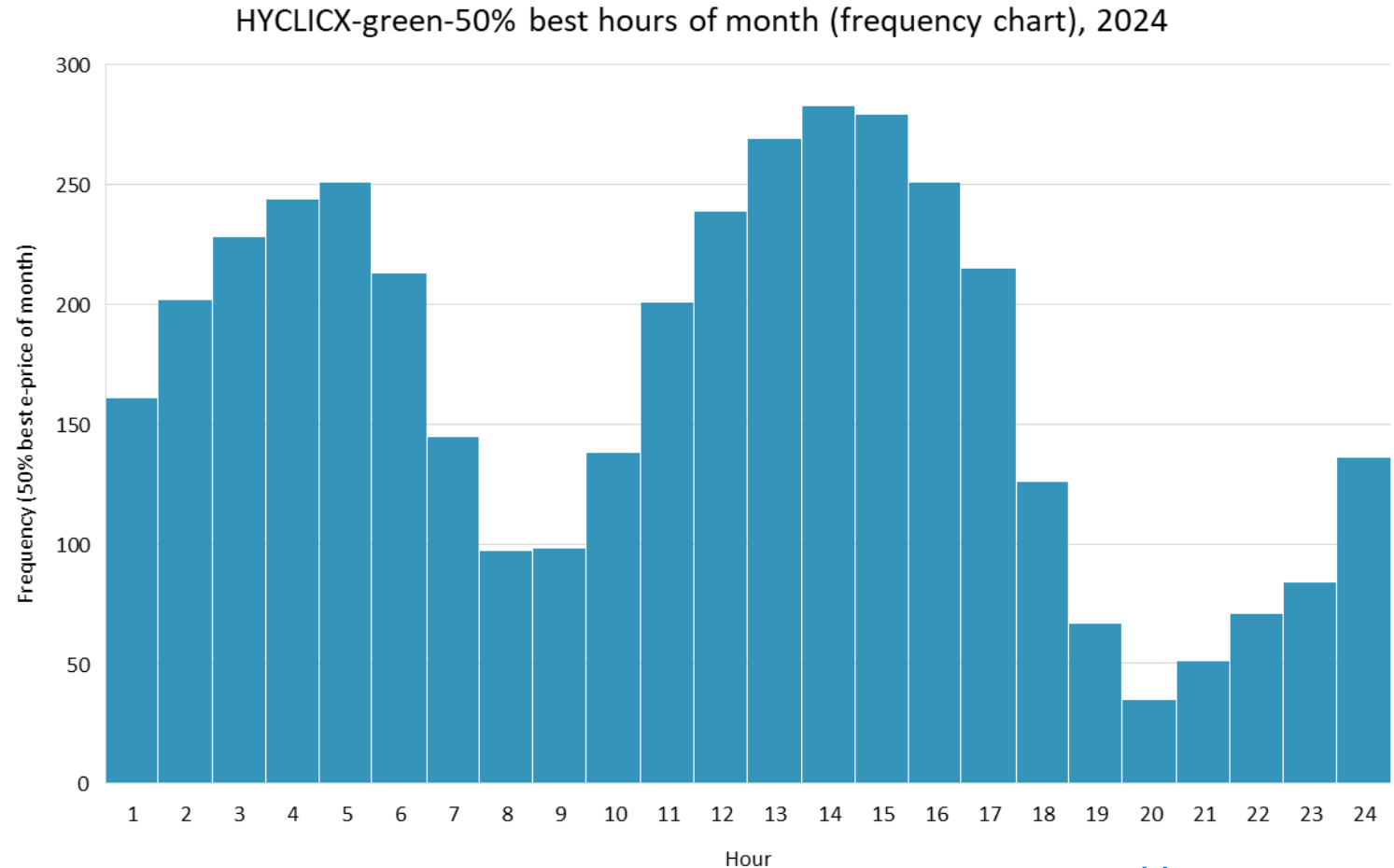
*Marginal price component (not included: capital cost for electrolyser investment and other fixed costs).

HYCLICX-NL 2024, production pattern

It makes a lot of sense to produce hydrogen when the average market price for using electricity is low. The electricity price fluctuates based on demand, global fossil fuel prices and local renewable production.

The graph on the right shows the 50% of hours with lowest electricity cost. It clearly shows why we think a 2x6h production plan yields cheap hydrogen.

In 2024 the cheapest hours are between 0.00-6.00 and 11.00-17.00. This result is similar to 2023.



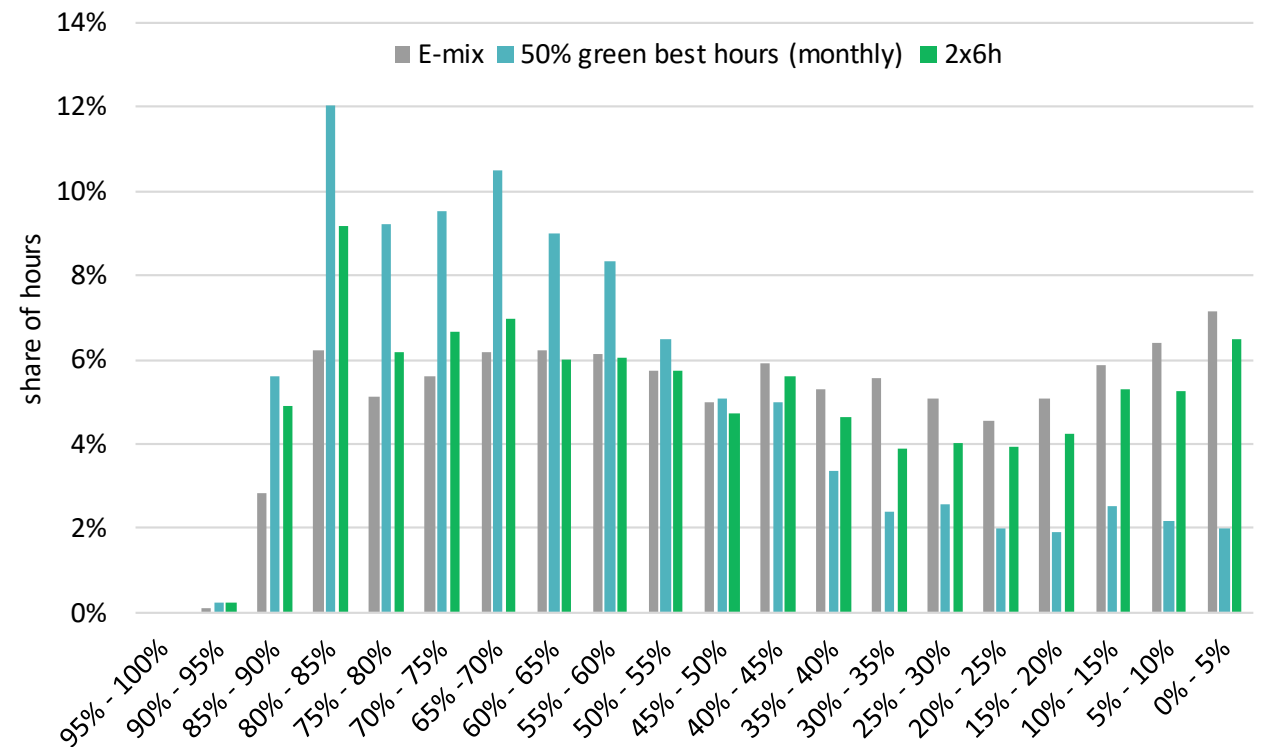
**the number of selected hours in the 50% lowest priced hours provides 4.390 hours; this is because some months multiple hours have an equal 'low' prices and hence are both selected. This means slightly more production hours than 4.380 (which would be exactly 50%)*

HYCLICX-NL 2024, e-renewability share

Green hydrogen has to meet the EU DA criteria: renewability of power input. We compared electrolyser production hour patterns for the HYCLICX 2x6 and best 50% per month, with hourly wind and solar production as share in total national demand. We find that:

- In 2024 the renewability of production hours is 59%, which is an increase compared to 2023 (54%*).
- The HYCLICX 50% per month is good at identifying hours with a high share of renewables: out of the 803 hours with more than 80% wind and solar, 785 were included in the HYCLICX.
- The HYCLICX 2x6 includes less favourable hours, but with an average share of 48% renewables it does outperform the national energy mix average of 44% wind and solar.

Renewables (wind, solar) in electricity mix and HYCLICX

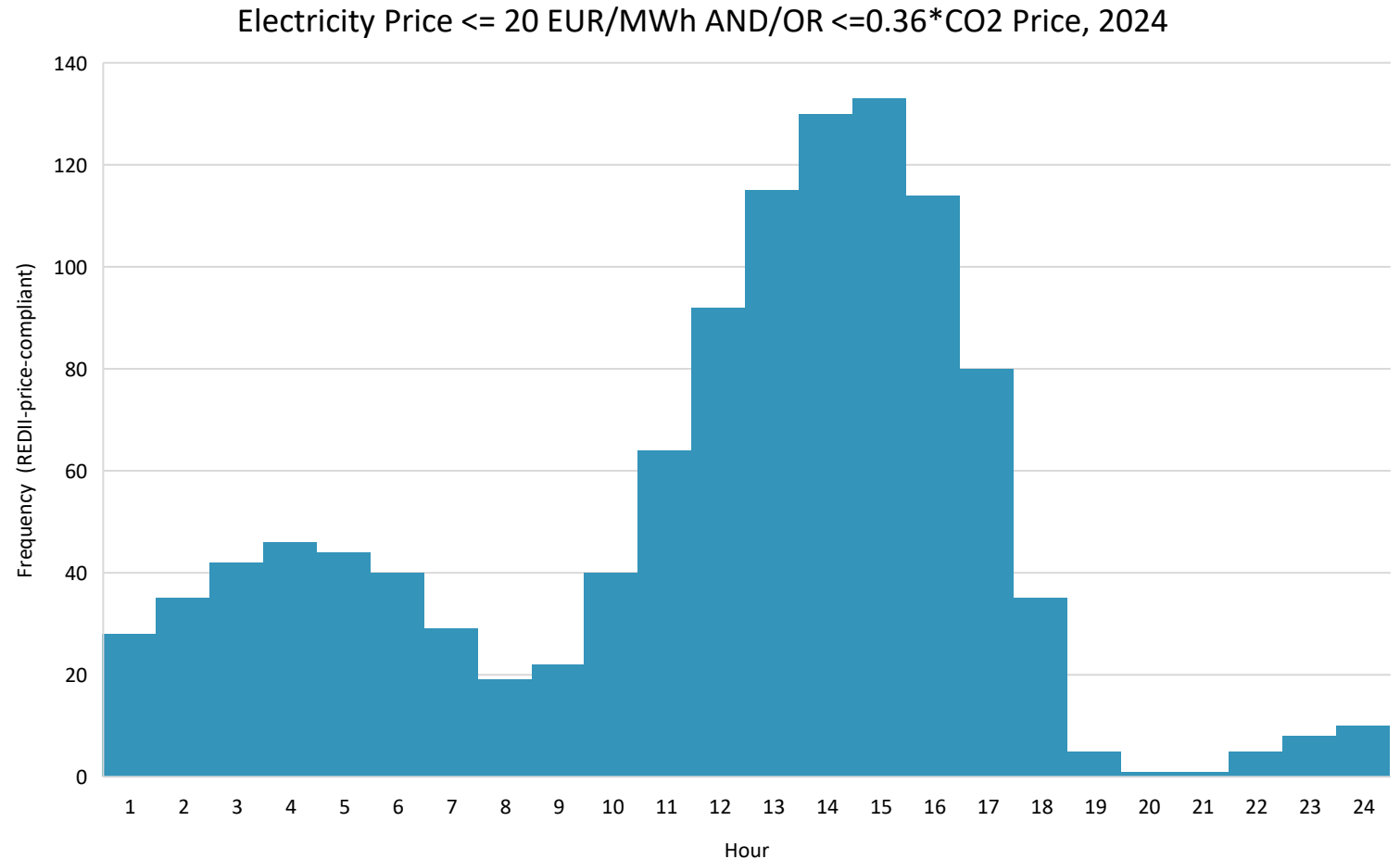


Source: *Samen slimmer met energie* | Nationaal Energie Dashboard. Plz note that results for 2023 have been adjusted due to changes made in the source file.

HYCLICX-NL 2024, production pattern

The EU Delegated Act requires the condition of temporal correlation to be met. This can be achieved using 1) a PPA or 2) an e-price that is below 20 EUR/ MWh OR $< 0.36 * \text{the CO}_2\text{-price}$ (136 EUR/t). The figure shows which HYCLICX hours meet the latter. We find that:

- The exemption condition is met in **1138 hours** in 2024.
- An increase of 252 hours compared to 2023.
- The criteria is met most often during the second time block 11.00-17.00.
- When more offshore wind comes online, we expect that also during the night the hours will increase.





HyXchange

Appendix: parameters and sources used by HYCLICX-NL

HYCLICX: marginal 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 (HHV)	%	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.*

HYCLICX: what is included in marginal index

HYCLICX: what is included?:

- 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
- Opex component for stack replacement

For blue and grey hydrogen:

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

→ Costs that are associated with producing additional MWh of hydrogen (marginal-price)

HYCLICX: what is not included?:

- 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
- Min. load that an electrolyser should operate at

For blue and grey hydrogen:

- Same principles apply as above

→ Costs that are independent of producing additional MWh of Hydrogen

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	-	90.6	-
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 + 1.24	-	-
Additional cost for natural gas (Gas tax)	EUR/MWh_NG	-	4.01	4.01

* The cost of CCS has been updated from 01-07-2024. The old value was 35 EUR/T_CO2. No backward calculation is performed

**Green electricity GO is updated at a quarterly interval. For 2024 Q2 the value was EUR 1.7/MWh_e

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/transformationspfade-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/

The logo for HyXchange features the word "Hy" in blue, a stylized green and white graphic element, and "Xchange" in grey. The background of the slide is a photograph of large industrial pipes in a field, with a green embankment on the left and an industrial facility in the distance.

HyXchange

For more information contact:
j.schellekens@hyxchange.org
or b.denouden@hyxchange.org