

Market Parties Meeting 17-12-2024

- a) Hydrogen market developments
- b) Book & claim opportunity & plans
- c) HYCLICX development plans

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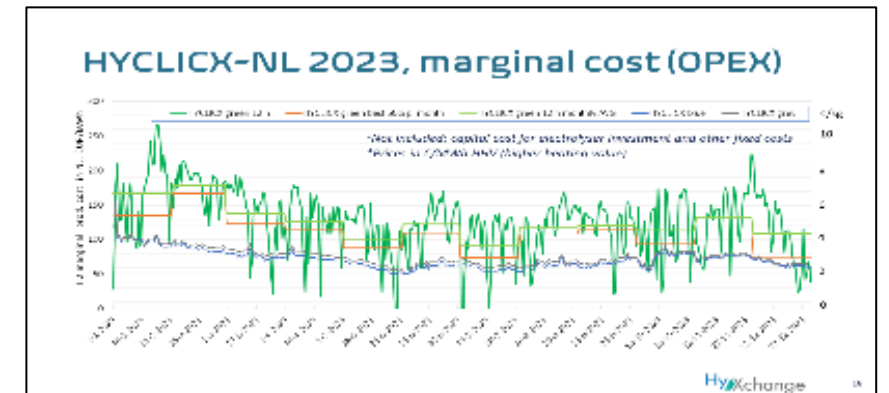
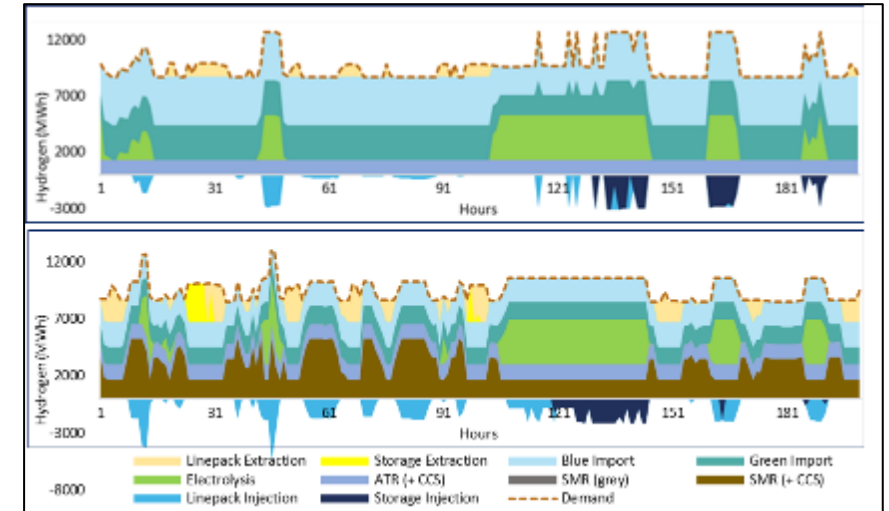
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a) Hydrogen market developments

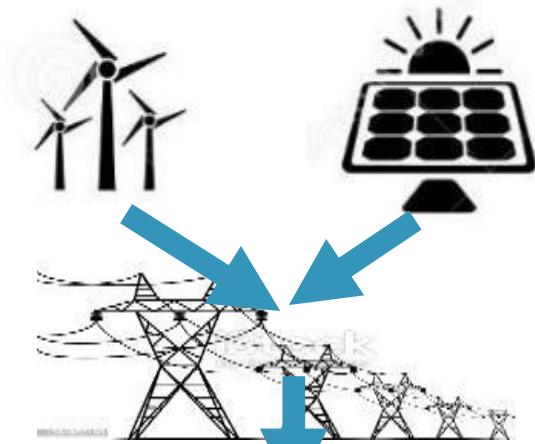
Development activities HyXchange 2022-2024, so far

- Hydrogen Certification pilot:
Dutch system of Green H2 Guarantees of Origin
- NL Spot market simulation including balancing: Spot market needed, due to intermittent output of electrolyzers. Simulate the market dynamics, grid balancing and storage.
- Index : HYCLICX variable cost index of hydrogen produced in NL at low-priced hours (high renewable) in co-operation with E-Bridge (HYDEX)

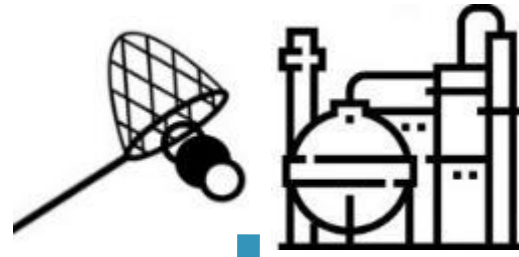


HyXchange spot market simulation: find out about H2 market dynamics, balancing, security of supply

1. Renewable

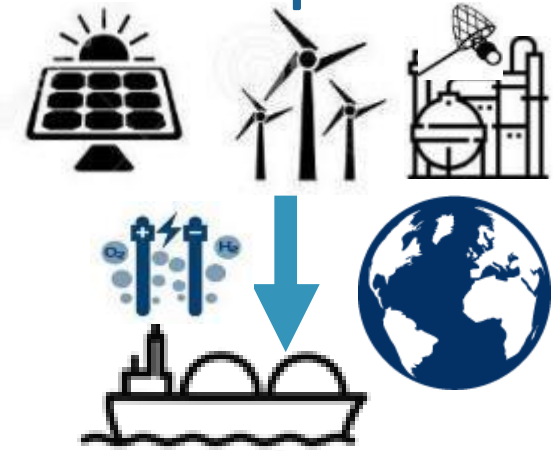


2. Low carbon+byproduct



Somewhat flexible

3. Import



Ammonia, H2 carrier
Terminals



Intermittent

Flexible

Limited Capacity



Storage and line-pack H2



Demand: Baseload Climate Neutral Hydrogen



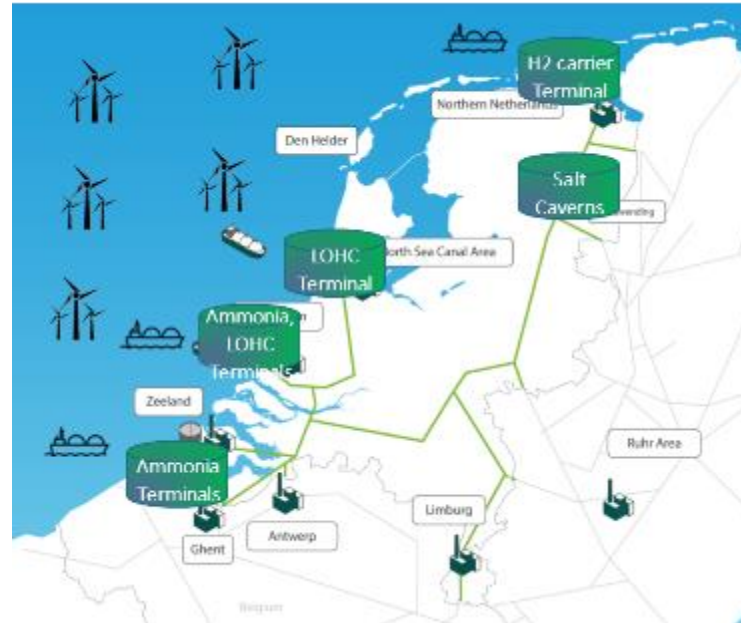
Original points of departure simulation year 2030

Some of these POD have shifted since publication

Main assumptions

Supply	18 GW
Seaborne ammonia import & cracker	7.7
<ul style="list-style-type: none"> Blue ammonia (Henry Hub) Green ammonia (MENA) 	
Gas reforming	6.4
<ul style="list-style-type: none"> SMR SMR/CCS ATR/CCS 	3.5 1.6 1.3
Electrolysers (PEM)	4

Storage	10 GW
4 caverns & line pack	9.5



Market & policy	
Green hydrogen obligation	42%
PEM full load hours (subsidy)	>4200 hours/y**
Support target offshore wind	

NL Backbone in 2030

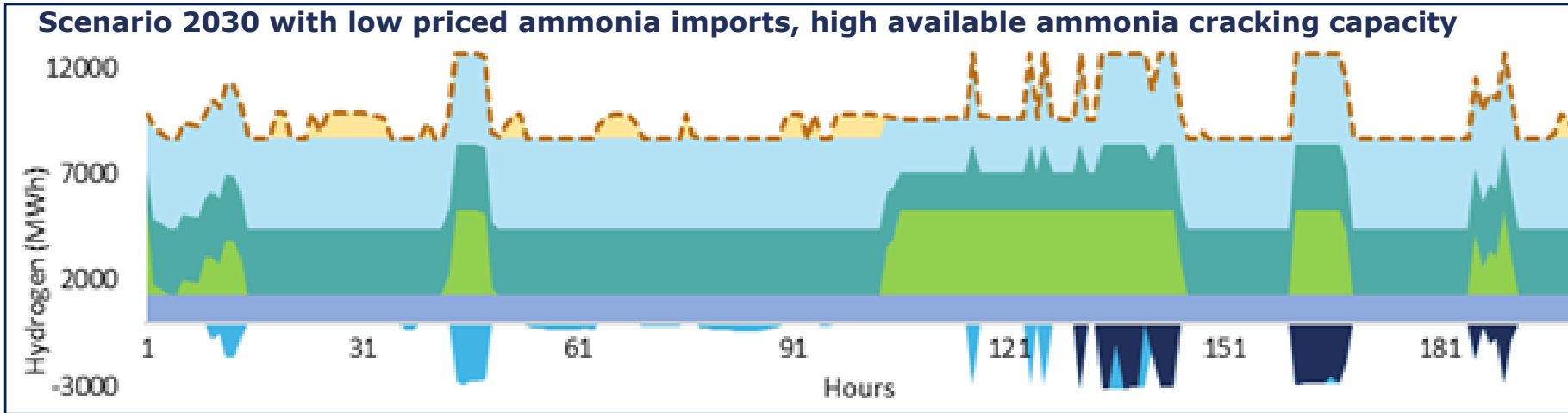
H2 Demand *	72 TWh / 8 GW
Netherlands	59 / 6.7
Belgium /Gent	0.5 / 0.1
Germany/NRW	12 / 1.4

* Assumed that half of current ammonia demand is imported directly in 2030, so not produced in NL from H2: H2 demand decrease. Assumed increase H2 demand from others including steel industry

** Assumed as a base case: the operation time of electrolysers is 4200 hours (subsidy criterion 2022)
As a variant we have also simulated fully free (market-based) dispatch

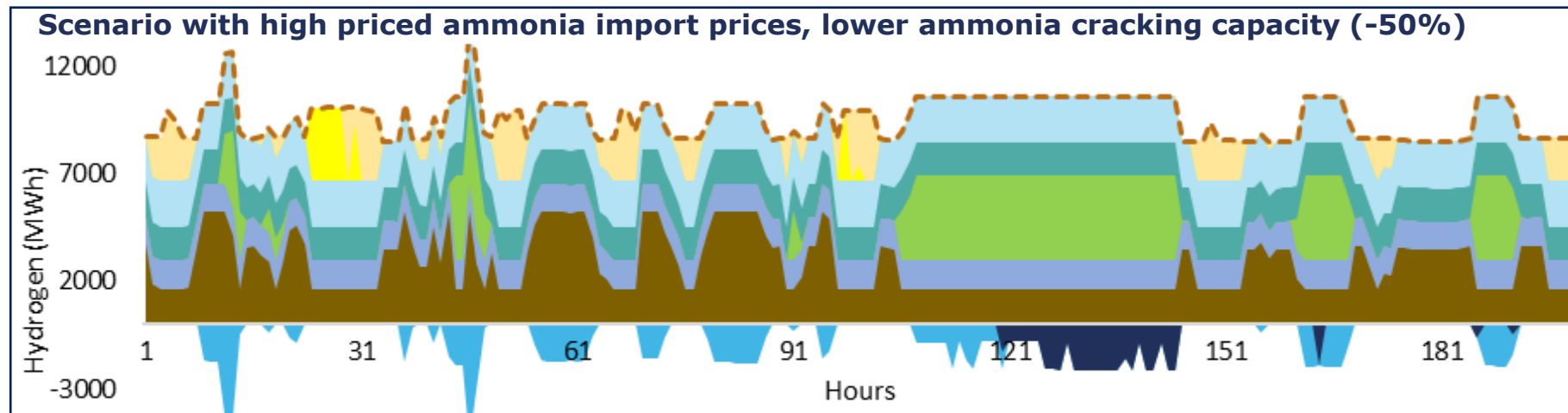
H2 market simulation 2030 example : October week

Weekly hydrogen balance for a example week in October. Stacked plot showing hydrogen dispatch per hour.

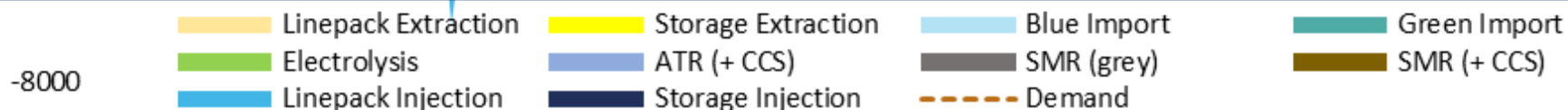


Dynamic (hourly) variation pattern by domestic renewable + electrolysis.

Demand is mostly baseload. The gaps in renewable are mostly filled by ammonia imports + cracking and/or gas reforming, depending on price levels of import ammonia and gas.



This also influences H2 storage and line-pack.



Key findings of project

As learned from market simulation and market parties input in Sim sessions

Time unit of the spot, intra-day market: to be hourly

- Hourly volume volatility for individual units, driven by weather and storage
- Price volatility much slower: “storage” sources tend to be price-setting (import ammonia cracking or SMR/ATR + CCS)

Variations and flexibility: multiple Hydrogen sources needed for 24/7 supply

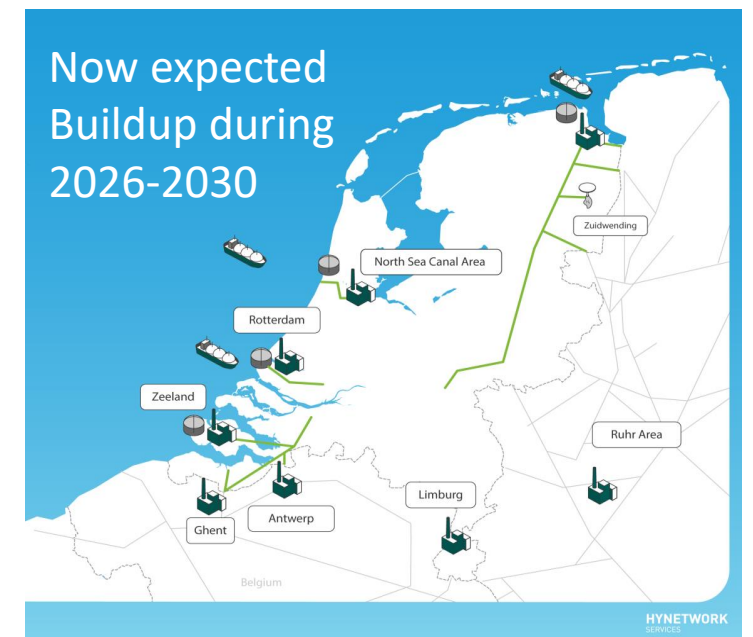
- Varying renewable output of electrolyzers must be supplemented by other sources (H2 storage, import ammonia cracking, SMR/ATR + CCS,) for constant 24/7 delivery.
- A balancing role for electrolyzers on electricity market is well possible. The resulting H2 volume variations exceed line-pack: salt cavern storage or other flex are needed.

Recent delays in infrastructure

- June this year: delay DRC announced until 2032 or later
- Now re-decided: priority for DRC for H2, CO2: 2031-2033
- Other connections between regions: also later than 2030

Infrastructure delay causes market issues until DRC readiness:

- Less benefit from nation-wide market optimization
- Balancing, 24/7 supply, not national (many flex sources) but regional (with few flex sources per region)
- No access to salt cavern storage for most regions until DRC
- **Consequences in national green H2 certificates trading and compliance target due to mass balancing character**
→ see further





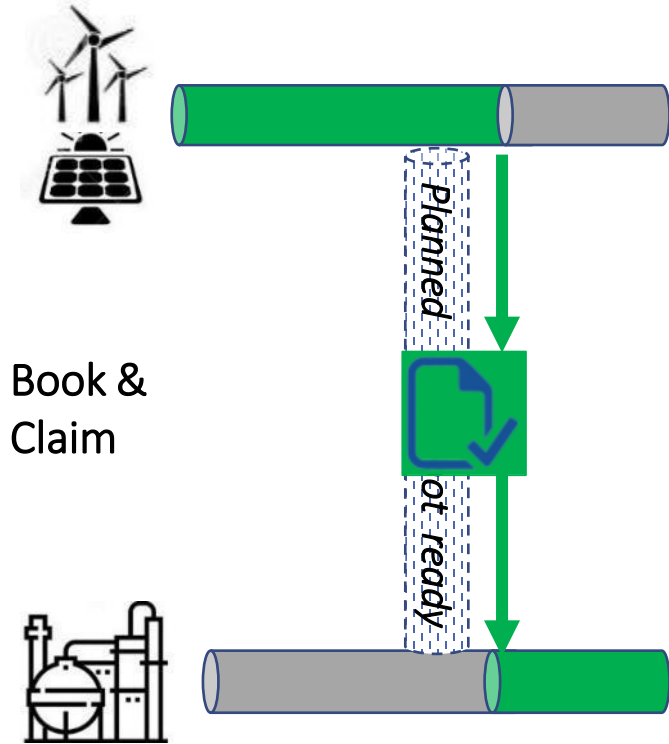
b) Book & claim opportunity & plans

HyXchange

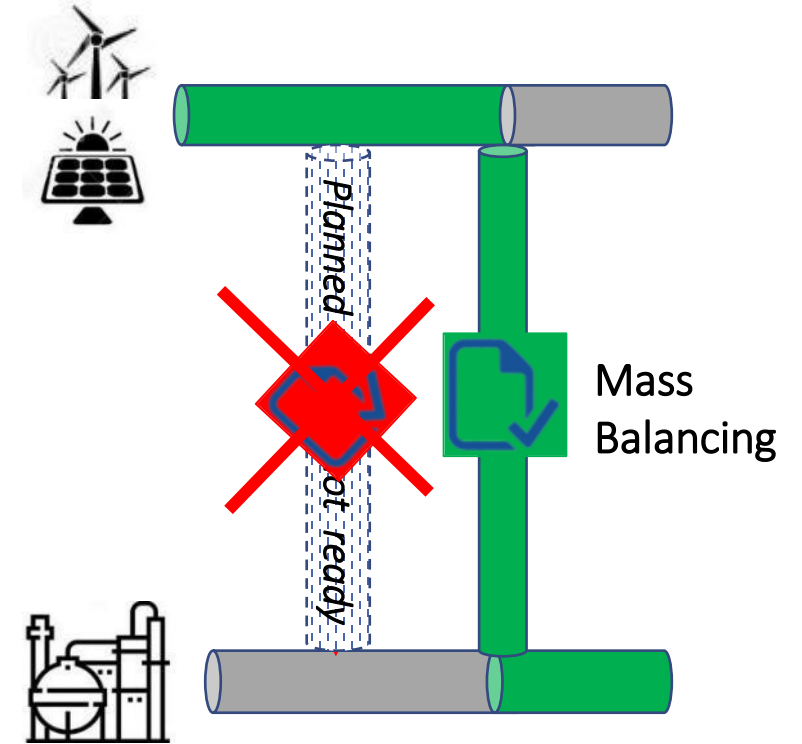
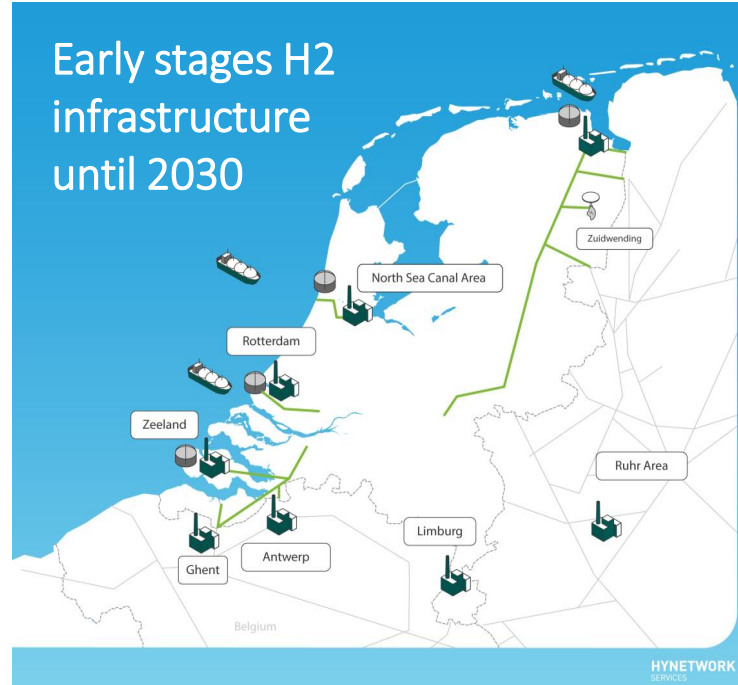
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Guarantee of Origin: can be separate from commodity

EC "Mass balancing": RFNBO only with physical commodity



Book & Claim



Mass Balancing

As long as there is no (complete) H2 infrastructure, Mass balancing principle is an obstacle:

- No connection between Green H2 producers (and imports) to all green H2 consumers
- Can't find offtakers with willingness-to-pay:
- Obstacle for market optimization (lowest price):
- No real opportunity for a successful H2 market

Hence, no offtakers

Hence bad price formation

Hence EU target unachievable

Temporary relaxation of RFNBO booking rules for parts of the H2 backbone not yet ready (as presented by RVO): Book-and-Claim



Tijdelijke versoepeling inboekregels onder RFNBO verplichting industrie

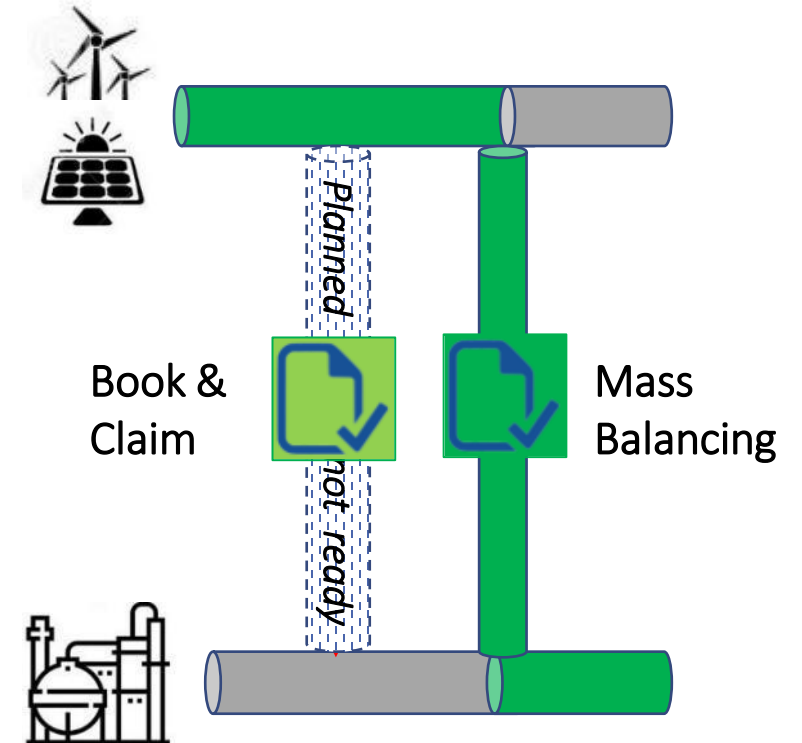
- Wat houdt deze versoepeling in?
 - Versoepeling leidt tot verkoop (book-and-claim) van "RFNBO status" (in onderstaande figuur van P naar A) los van verkoop van fysieke product (van P naar B)



- Dit betekent dus:
 - Waterstof wordt fysiek aan de ene partij geleverd, en de duurzaamheid administratief aan een andere partij
 - Er vindt dus scheiding plaats tussen "fysiek" en "administratief"



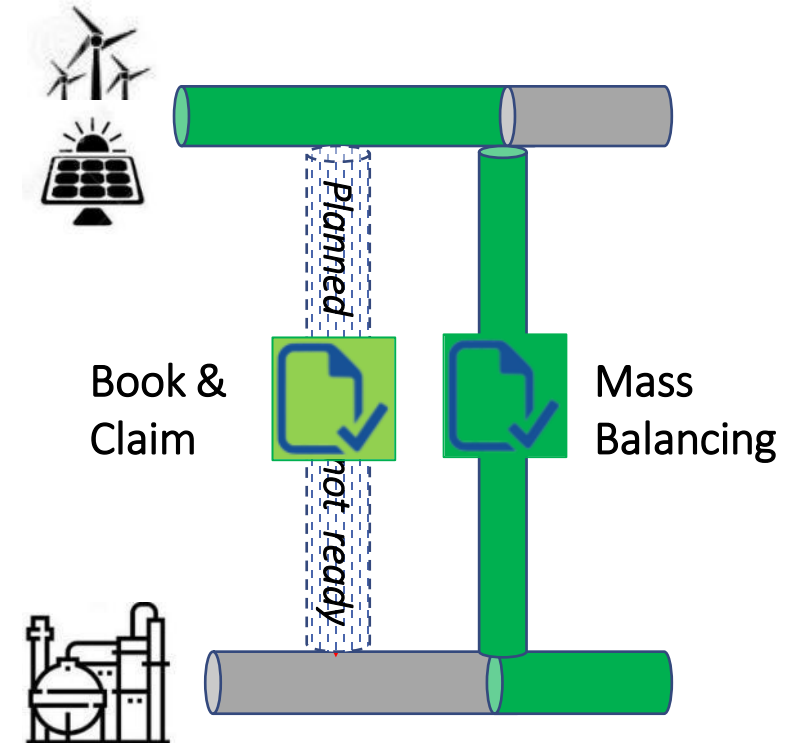
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→ "Ministry KGG re-creates a temporary "book and claim" solution

→ Consultation NL Ministry KGG on industrial H2 targets 2030 (including this relaxation)

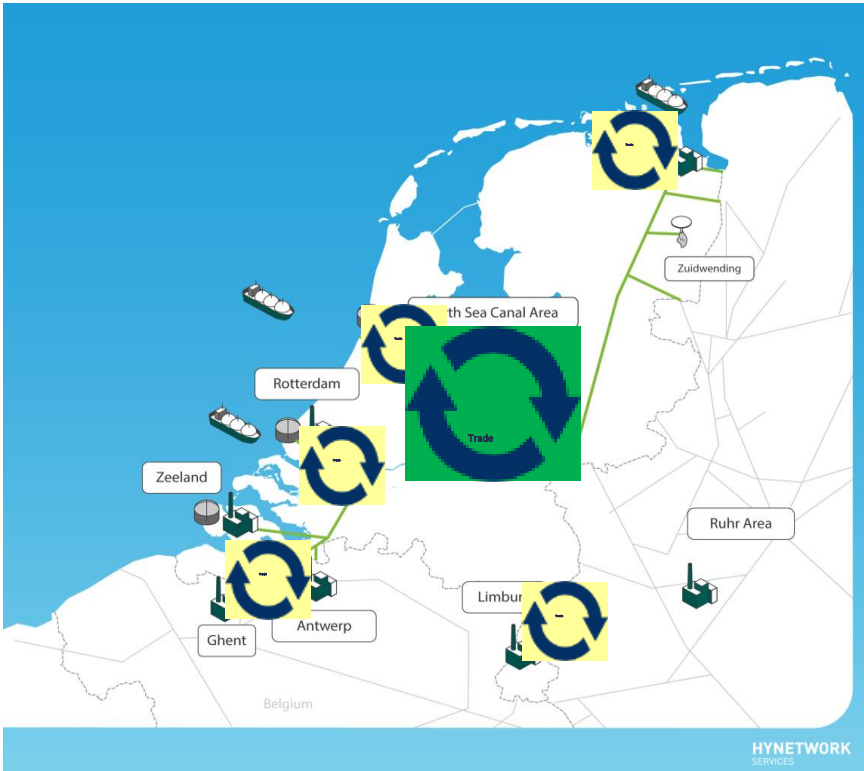
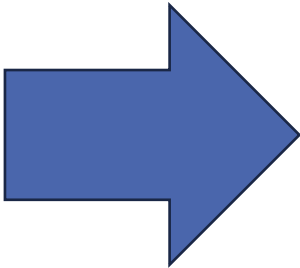
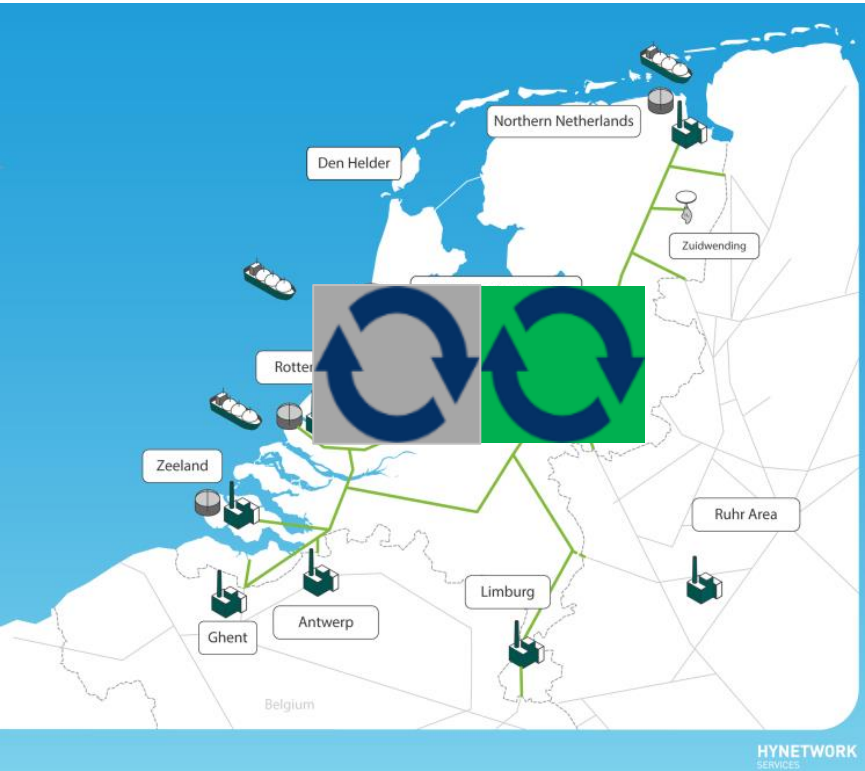
Two ways to exchange green hydrogen certificates in NL



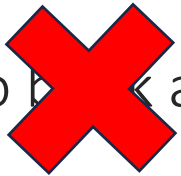
As long as there is no (complete) H2 infrastructure, this Temporary Relaxation of RFNBO booking rules makes transfer still possible within the Netherlands – including imports

- Easier to connect Green H2 producers (and imports) to green H2 offtakers
- Better market optimization
- Real opportunity for a successful H2 market

Differences with earlier thoughts of market start-up



Market Situations

(No Backbone, no book and claim) 

Everything within regions: physical H2 balancing and green balance



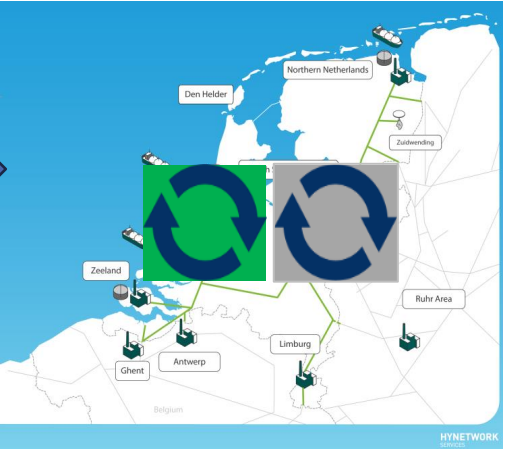
1. No Backbone, with book and claim (2026-2030)

Physical H2 balancing in the region, interregional transfer of green;



2. Backbone (2032)

Everything national: National physical H2, National green balance



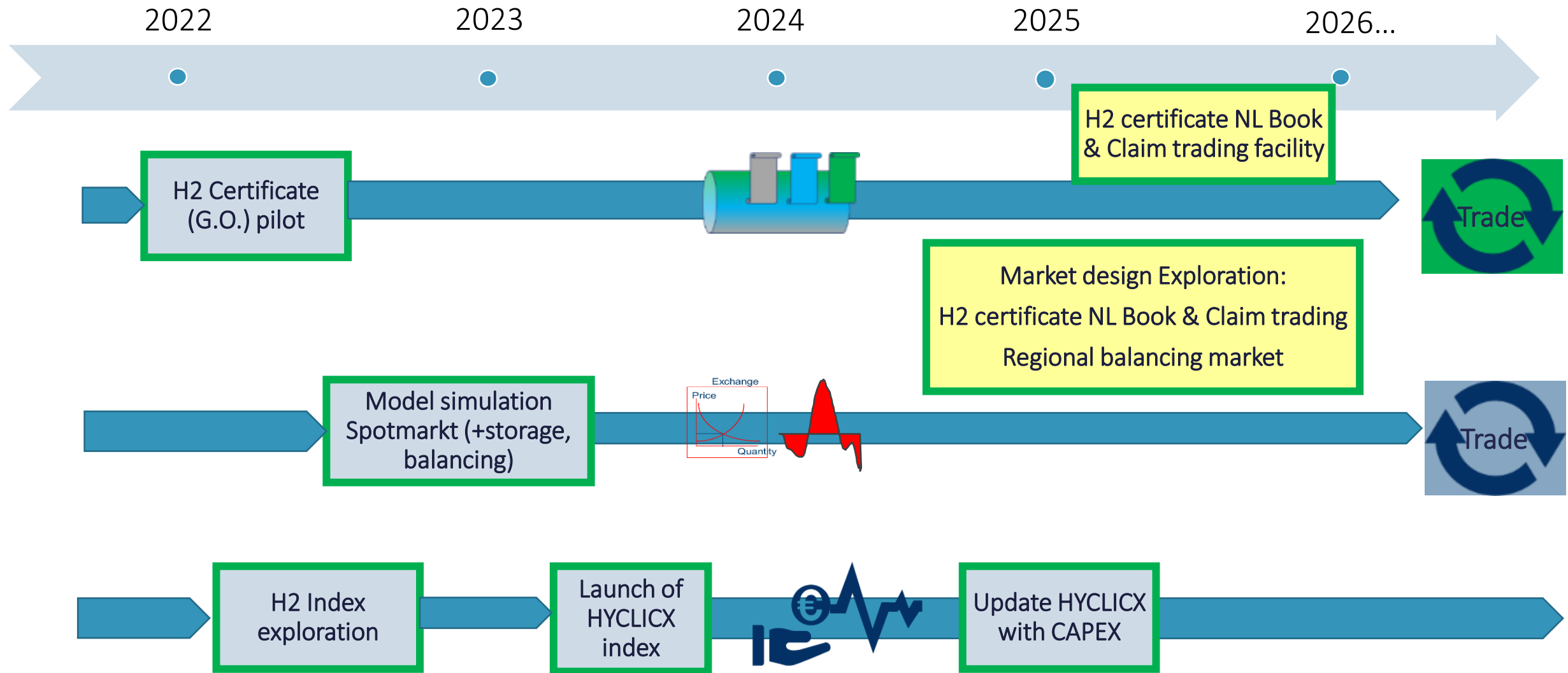
3. Backbone + larger storage (2035)

New Market set-up in 2030: Physical flex regional, Green National



- Physical Market start up in 5 industrial regions separately in 2026-2030.
- In each region: electrolysers with variable production. Demand is largely baseload.
- So there has to flexibility on a regional basis. Flex from:
 - reforming + CCS,
 - ammonia-import +cracking,
 - storage (1 region), flexible H2 demand.
- This flexibility also to enable electrolysers response on E-market (daily, intraday, balancing)
- National book-and-claim market for green H2 character/value, based on year obligation

HyXchange exploring products to develop this H2 market



Market exploration: how does this market work?



Explore together with “market design committee” from participants:

- Balancing / flexibility market in regions.
 - National book-and-claim market for green H2 character/value
- Market design for bilateral, OTC, traders, exchange
- Market facilities (settlement, auctions, re-trading, exchange) to be considered

Next step: survey sent to market parties

Also asking for taking part in committee (structural, bimonthly meetings)

Regional start of the market: Blue balancing Green?



- Market start in 5 regions. Each a “Virtual hub”
- In most regions: electrolyzers with variable production. Demand is largely baseload.
- So there has to flexibility on a regional basis. reforming (SMR or ATR)+CCS, ammonia-import + cracking, storage (once connected), demand flex?
- Also flexibility needed to enable electrolyzers response on E-market
- How do the (flex)contracts work in the region with the pipeline flexibility service? (bilateral, OTC, with traders, exchange)
- Is there need for a market? Possibilities:
 - flex capacity auction
 - Daily day-ahead and/or within-day market

How does this combine with the green H2 certificates, B&C?

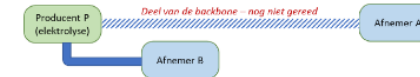
Book-and-Claim set-up & Market



Tijdelijke versoepeling inboekregels onder RFNBO verplichting industrie

> Wat houdt deze versoepeling in?

- Versoepeling leidt tot verkoop (book-and-claim) van "RFNBO status" (in onderstaande figuur van P naar A) los van verkoop van fysieke product (van P naar B)



> Dit betekent dus:

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- Er vindt dus scheiding plaats tussen "fysiek" en "administratief"

- More detailed drafts of regulation upcoming in 2025: market involvement
- Promote trade and liquidity
- How do the contracts work in this market? Standard contract agreement. (bilateral, OTC, with traders, exchange)
- Need for a market? Possibilities:
 - Monthly or quarterly auction
 - Continuous trade?

DECEMBER 2024

c) HYCLICX development plans

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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:

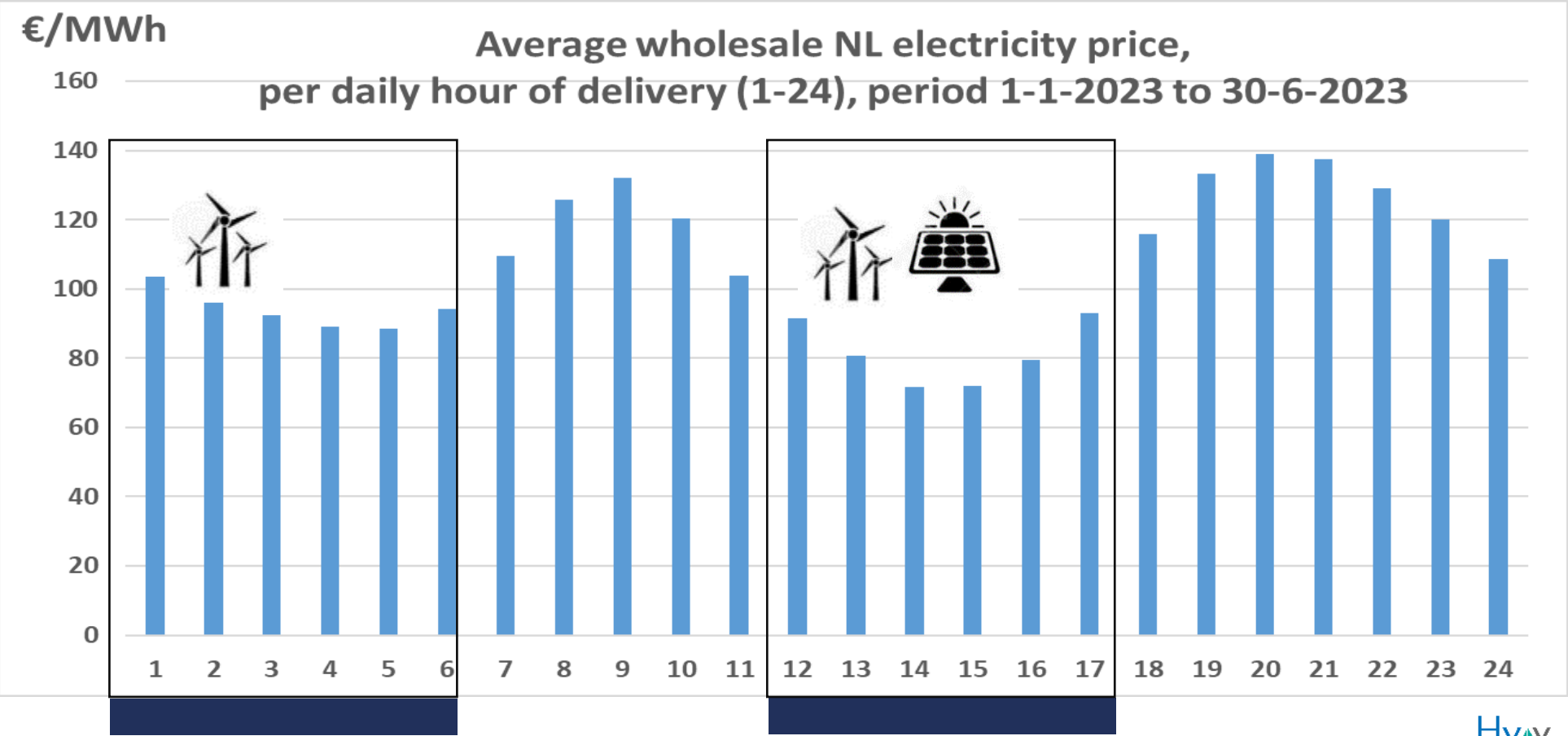
- **HYCLICX green (daily 2x 6 hour blocks):** The marginal cost price for the cheapest (fixed) 12-h of electricity each day: hours 1-6 and 12-17 (0.00-6.00 and 11.00-17.00)
- **HYCLICX green best 50% (month):** The marginal cost price for the lowest-priced 50%-h of electricity per month.
- **HYXCLICX 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](#).

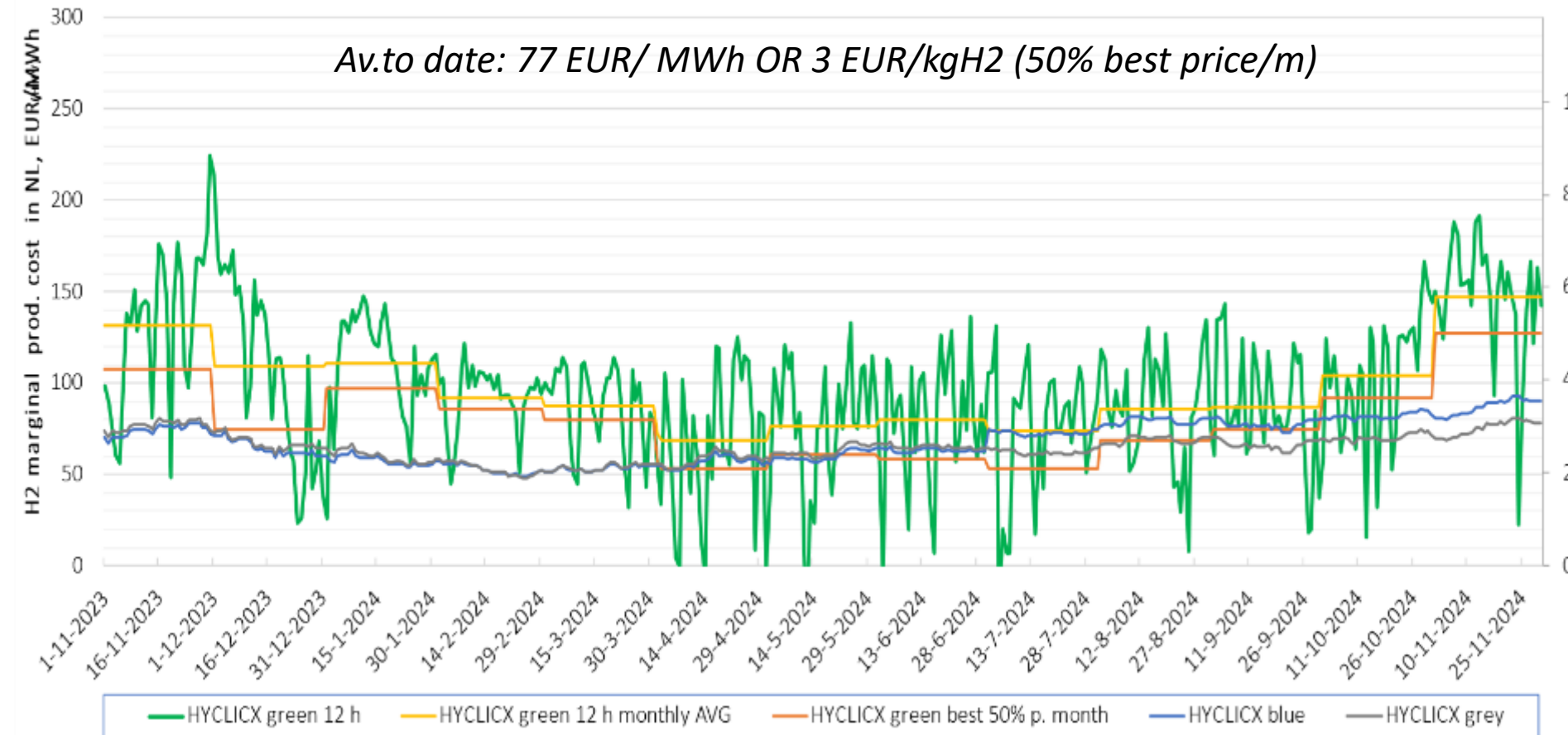
HYCLICX: hours with lowest power prices

Calculate marginal cost for each hour, work together with E-Bridge (HYDEX index Germany)

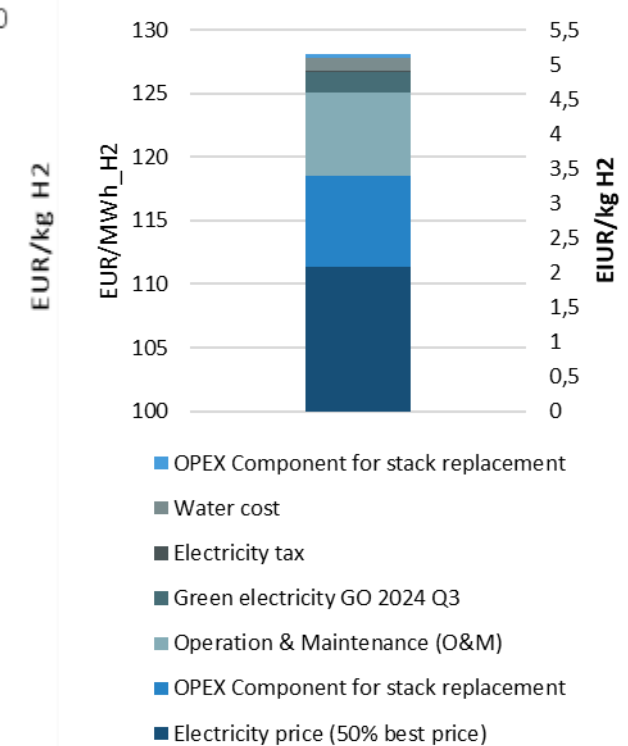
- **Daily: average lowest-prices 2x6 hour blocks (fixed, see below)**
- **Monthly: lowest priced 50% of hours in that month (varying monthly pattern)**



HYCLICX-NL 2024 01-11 (OPEX)



HYCLICX variable hydrogen price cost components (November 2024)





HyXchange

2. HYCLICX+-NL

2B. HYCLICX – proposal for including CAPEX

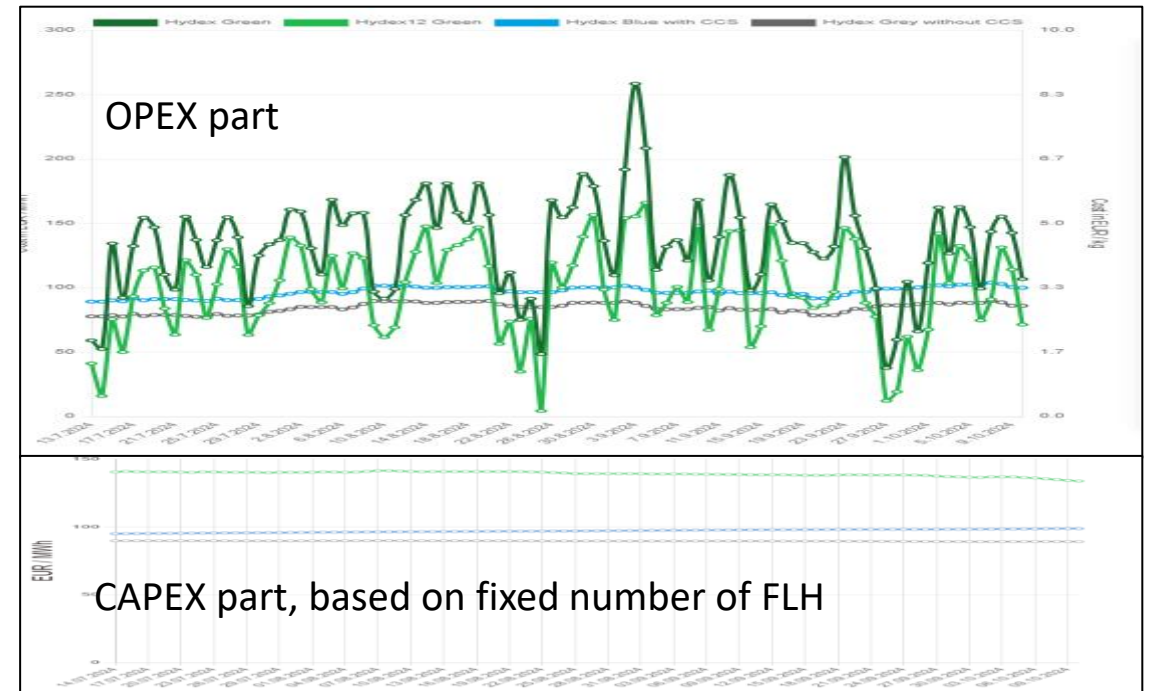
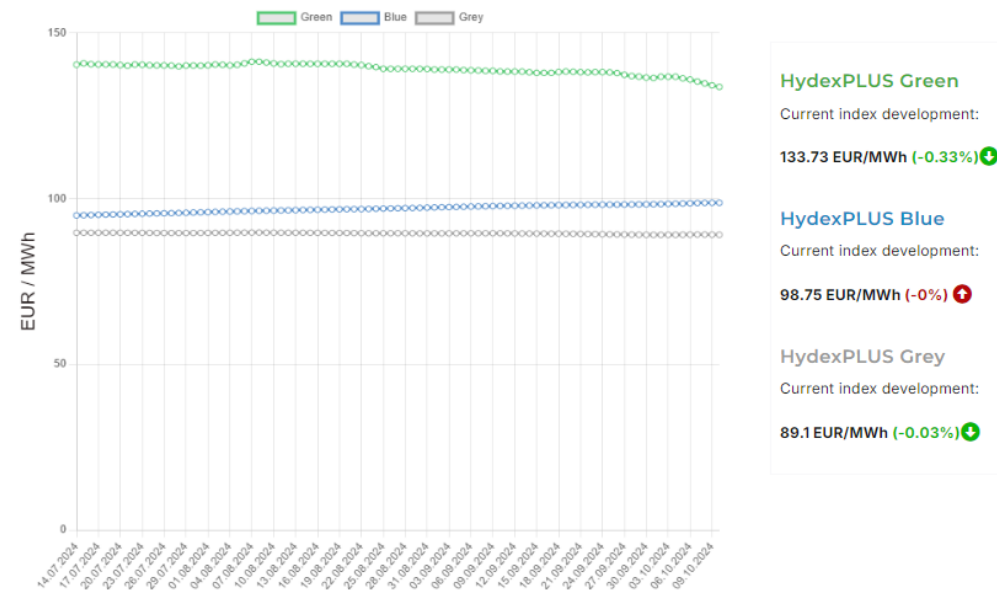
Current HydexPLUS (DE)

(<https://e-bridge.com/competencies/energy-markets/hydex/PM>)



Our planned HYCLICX+: OPEX part + CAPEX part

Current HydexPLUS

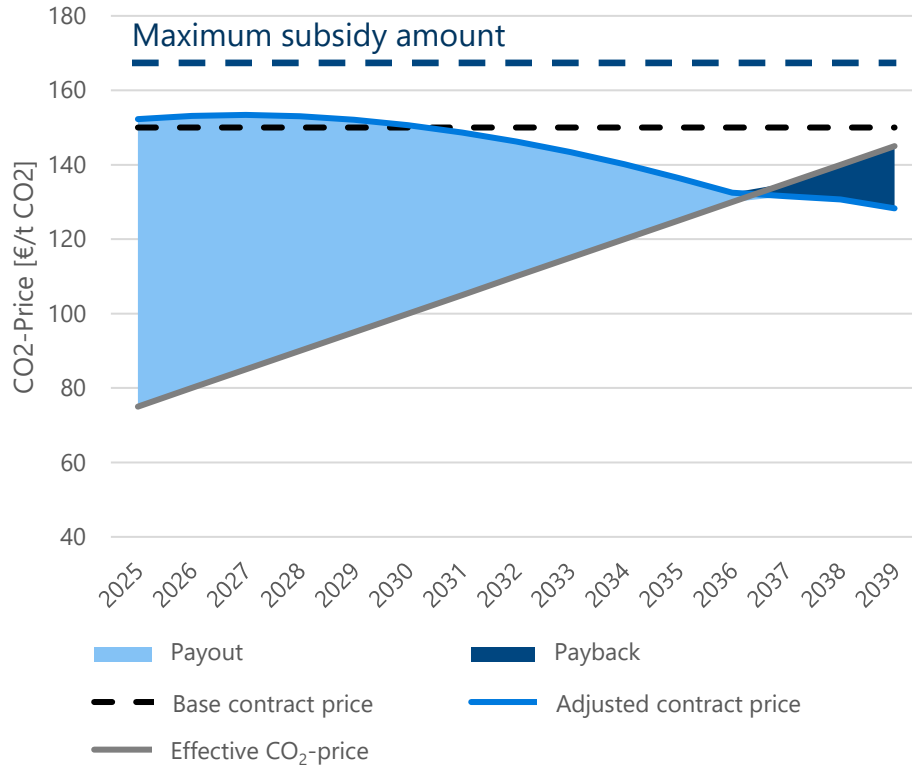


HYDEX+ includes CAPEX based on 1200 €/kW (current)
Request National H2 council (Deutsche Wasserstoffrat):
adjust upwards from 1. Jan 2025 after market consultation
https://www.klimaschutzvertraege.info/news/habeck_ueber_reicht_klimaschutzvertraege

Possibilities:

- one value or range for fixed cost green H2?
- Integrated OPEX+CAPEX, Separate graphs or Both?

HydexPLUS as reference for German CCfD scheme



Payout and payback between receiver und state

Pos. difference:



Neg. difference:



Base contract price (base price)



Amount estimated by applicants to be covered per ton avoided CO₂ (low-carbon hydrogen technology)

Dynamic contract price



Base contract price adjusted to the real development of market prices – between old technology and low-CO₂ technology

➤ **Indexing and adjustment of the contract price with HydexPLUS (annual value) for green hydrogen technologies**

The maximum funding amount depends on:



Eff. CO₂-Price



Dynamization component



Price indices of energy sources



Share of dynamisation

What is additionally included in H2+ index?

HYCLICX+: what is included?:

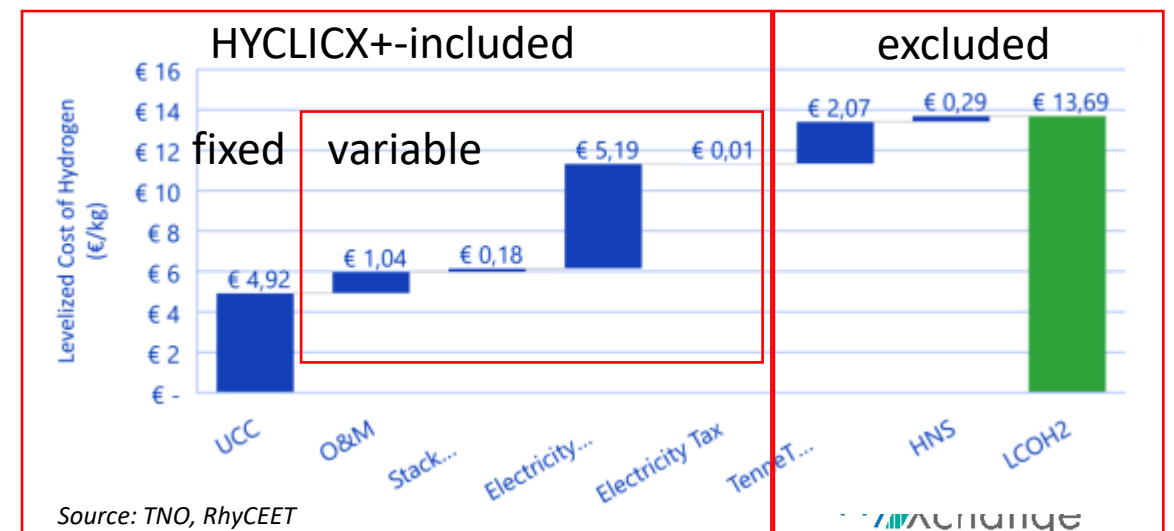
- Capital cost of investment of Electrolyser
- Upfront project preparation cost (EPC)
- Electricity spot price (hourly variable)
- Green guarantee of origin for renewable electricity (monthly)
- Tax on electricity demand electrolyser not into stack (auxiliary power)
- Water cost
- O&M costs
- Opex component for stack replacement

For blue and grey hydrogen:

- Gas price (daily variable), CO2 price (daily variable) and/or CCS storage cost
- Approach similar for green

What is not included?:

- 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



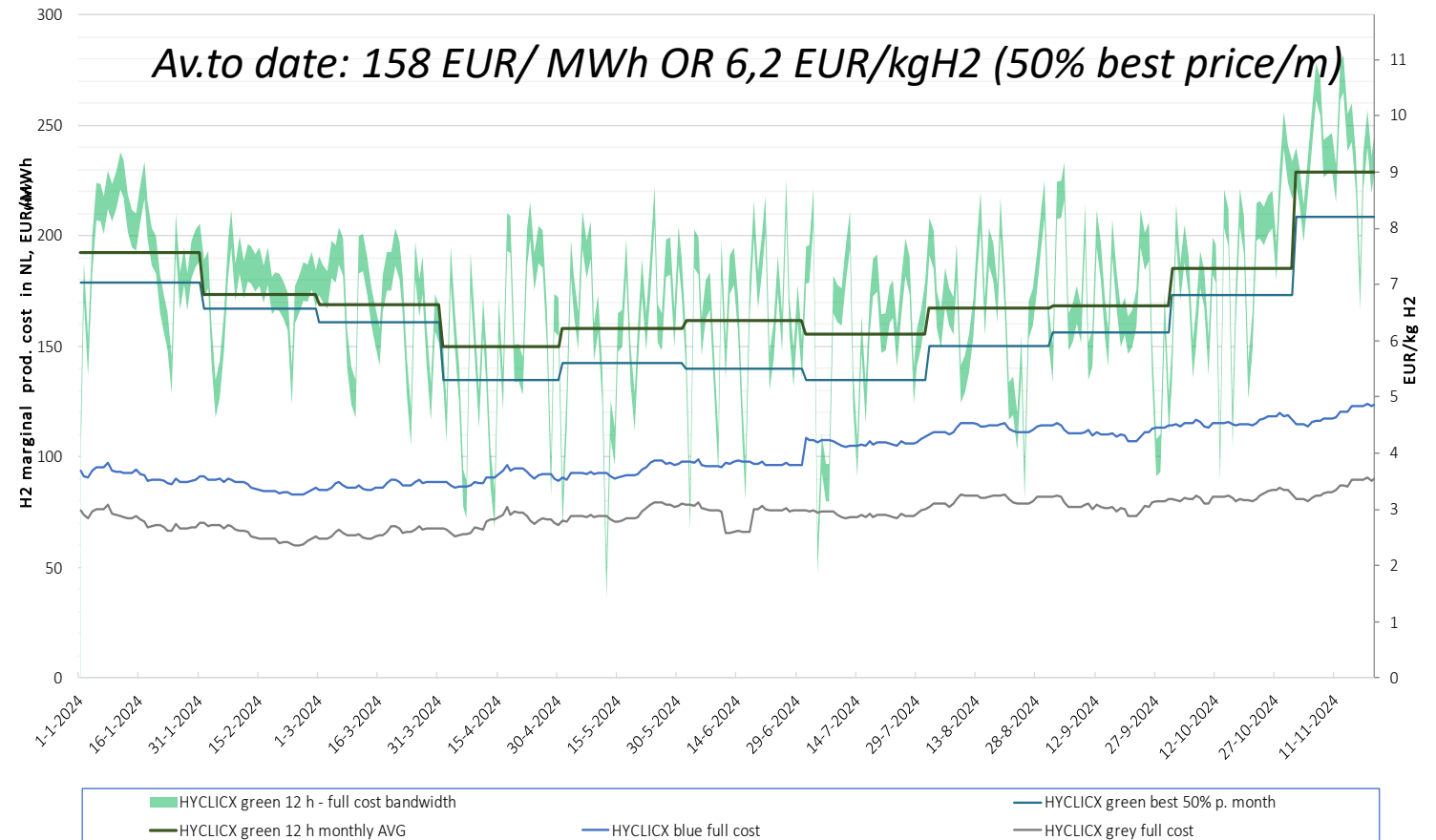
HYCLICX+, 2024 tot date (including CAPEX)

Uncertainty regarding PEM; we propose a bandwidth: 1970 EUR/kW (source: European Hydrogen Observatory) TO 2531 EUR/KW (source: TNO, RhyCEET excl. 17% contingency)

WACC 8% and 20yr lifetime

Findings (11/12 months 2024):

- Resulting marginal prod. cost:
 - Green: 158 EUR/MWh; 6,2 EUR/kg
 - Blue: 101 EUR/MWh; 3,9 EUR/kg
 - Grey: 75 EUR/MWh; 2,9 EUR/kg
- In 2024 green hydrogen +- 1.5 times more expensive vs blue and +-2 times more expensive vs grey (from marg. prod. cost perspective); 12/12 larger dif.



Earlier requests additional PPA based H2-index (incl forward)

1. Possible additional development is index based on PPA e-prices
2. Relevant because of EU DA requirements
3. Current HYCLICX only historical: PPA gives also forward opportunity

Issues with PPA handling in delegated act: partly solved, still ongoing discussions?

Still significant uncertainty regarding PPA contracts, three possible approaches:

1. Fixed minimum PPA e-price (75 EUR/MWh, source: TNO RhyCEET)?
2. Fixed mark up (18 EUR/MWh, difference PPA and yearly av.spot)?
3. Reliable PPA references (price vendors)?

Suggestions/ideas regarding possible integration of PPA in index?

Implementation effort subject to Steering Committee approval

Best wishes for 2025!

- The slides and a short survey will be shared beginning next year.
- Any final questions/remarks?
- Merry Xmas and we hope to see you again in 2025!





Jubiläum

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Jubiläum

Thank you for your attention

HyXchange

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