Hinicio

Port of Antwerp Bruges

fluxys

economie
FPS Economy, S.M.E.s, Self-employed and Energy

HyBex

Webinar

19TH OF JUNE 2024

HyBex

With the support of the Belgian energy transition fund (ETF)

Welcome to the HyBex webinar on hydrogen market balancing

Your audio will be automatically muted. We can however unmute you if you have a question or remark during the Q&A session. Please use the "raise hand" functionality for this, after which we can grant you the speakership. The chat function can be used at any time.

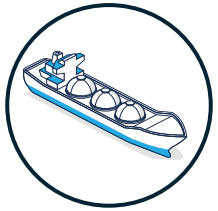
A limited Q&A is foreseen at the end of the webinar. Some chatbox questions will already be tackled throughout the session. Remaining or further questions can afterwards be addressed bilaterally, via our mailbox or by consulting our webpage.

The presentation of this webinar will be shared afterwards with all registrants.

Short recap on the concept and development of HyBex

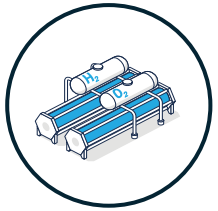
HyBex contributes to the establishment of Belgium as an import hub with a robust hydrogen market and a successful ecosystem

Belgian hydrogen strategy; strategic pillars



Pillar 1

Positioning Belgium as an import and transit hub for renewable molecules in Europe



Pillar 2

Expanding Belgian leadership in hydrogen technologies

Pillar 3

Establishing a robust hydrogen market

Pillar 4

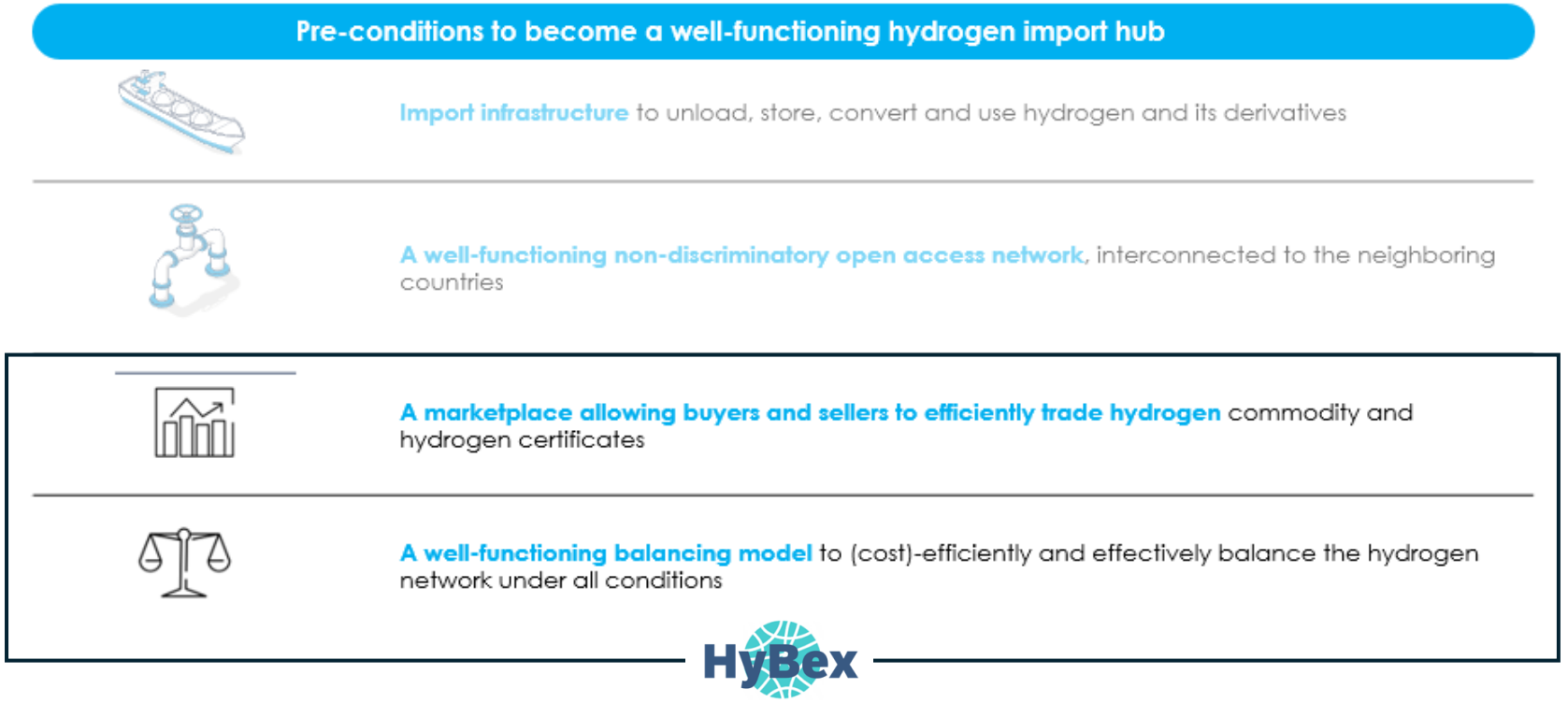
Investing in cooperation as a key success factor

HyBex

The Belgium authorities, PoAB, Fluxys and Hinicio decided on the need to further study and pilot a marketplace and balancing model

Description

- Early 2023, the Federal authorities, PoAB, Fluxys and Hinicio concluded on the need to further study and develop the marketplace and balancing model
- Project HyBex was set up, funded by the federal Energy Transition Fund, to study and pilot a one-stop shop for hydrogen commodity, balancing products and certificates



Hinicio fluxys Port of Antwerp Bruges economie

FOD Economie, K.M.O., Middenstand en Energie

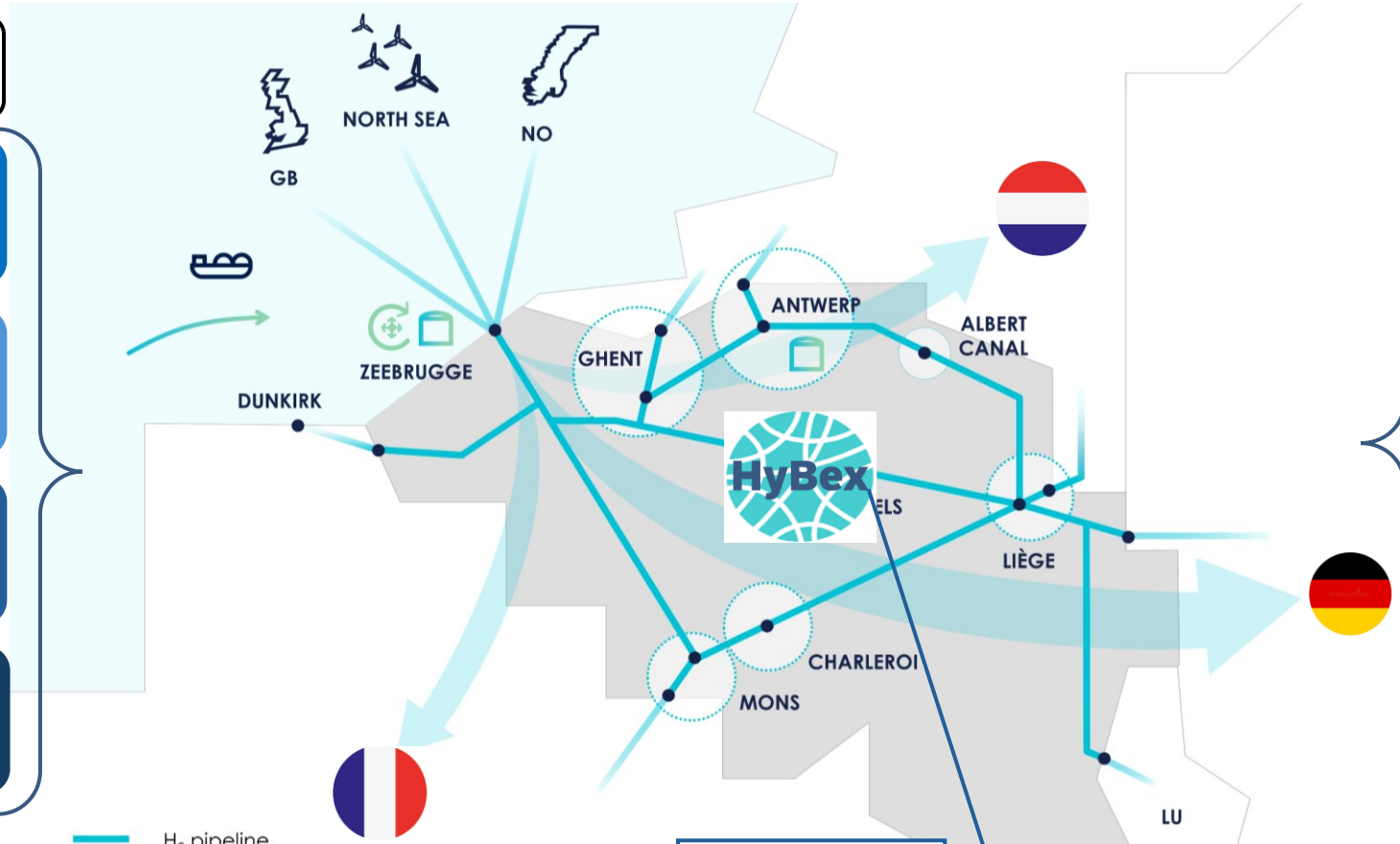
HyBex

HyBex marketplace will bring together the producers, consumers, importers and exporters to exchange certificates, commodity and balancing products

Market players | Infrastructure provider & Exchange platform | Market products

Different technologies and flexibilities

- Producers
- Importers
- Consumers
- Exporters



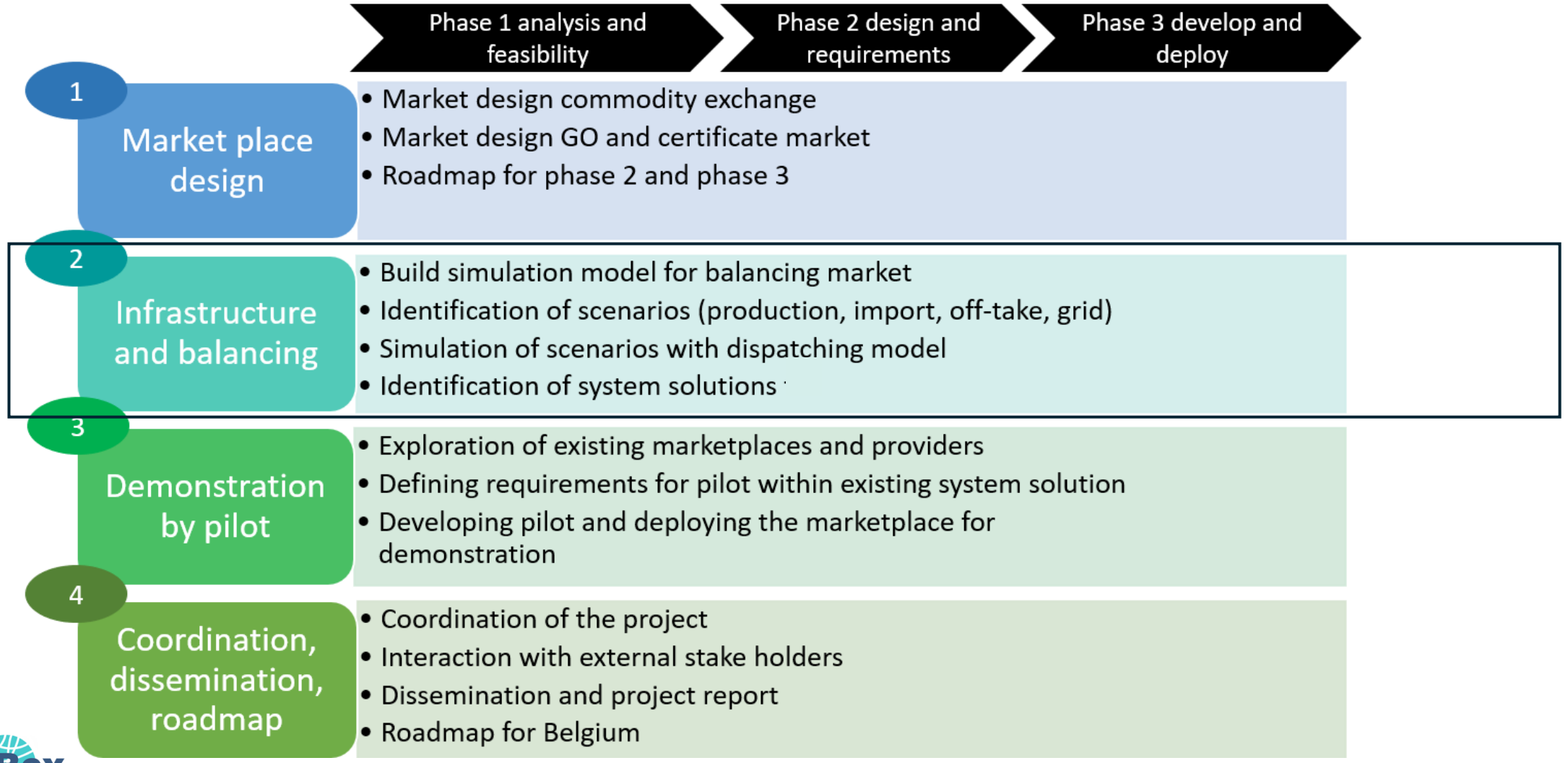
One stop shop for Hydrogen products

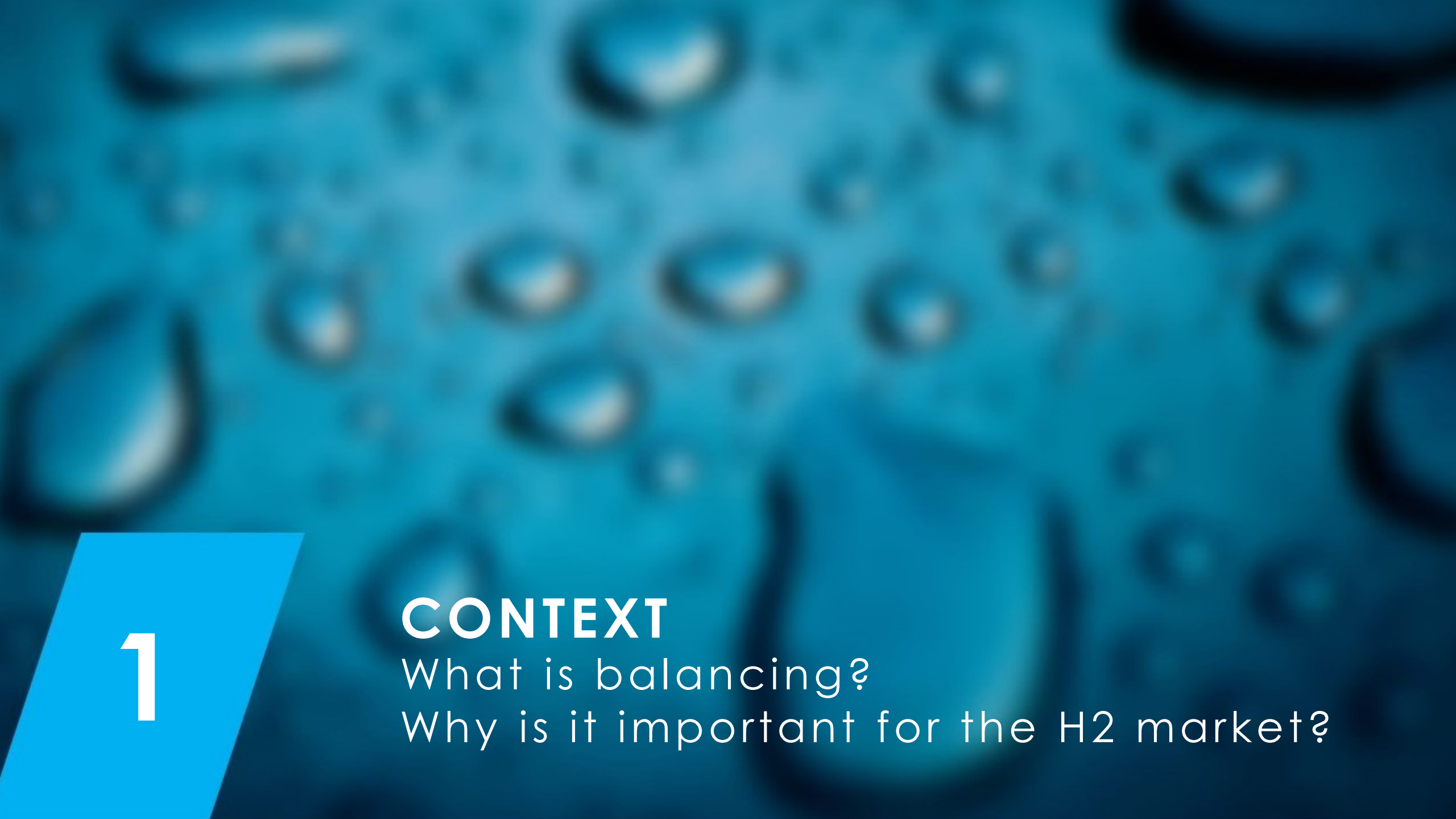
Different products and valorizations

- Commodity H2
- Certificates H2
- Balancing H2 products

HyBex is currently in the study phase; after summer a pilot will be set up to test the marketplace

Project Methodology and Scope





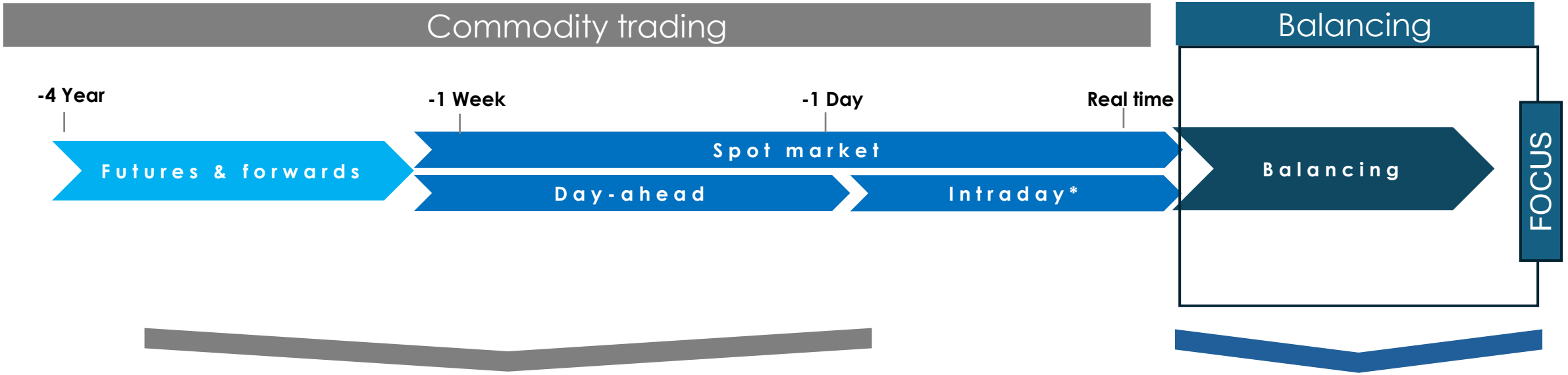
1

CONTEXT

What is balancing?

Why is it important for the H2 market?

Hydrogen suppliers and off-takers need to nominate a balanced portfolio of demand and supply. Balancing may be needed in case of deviations

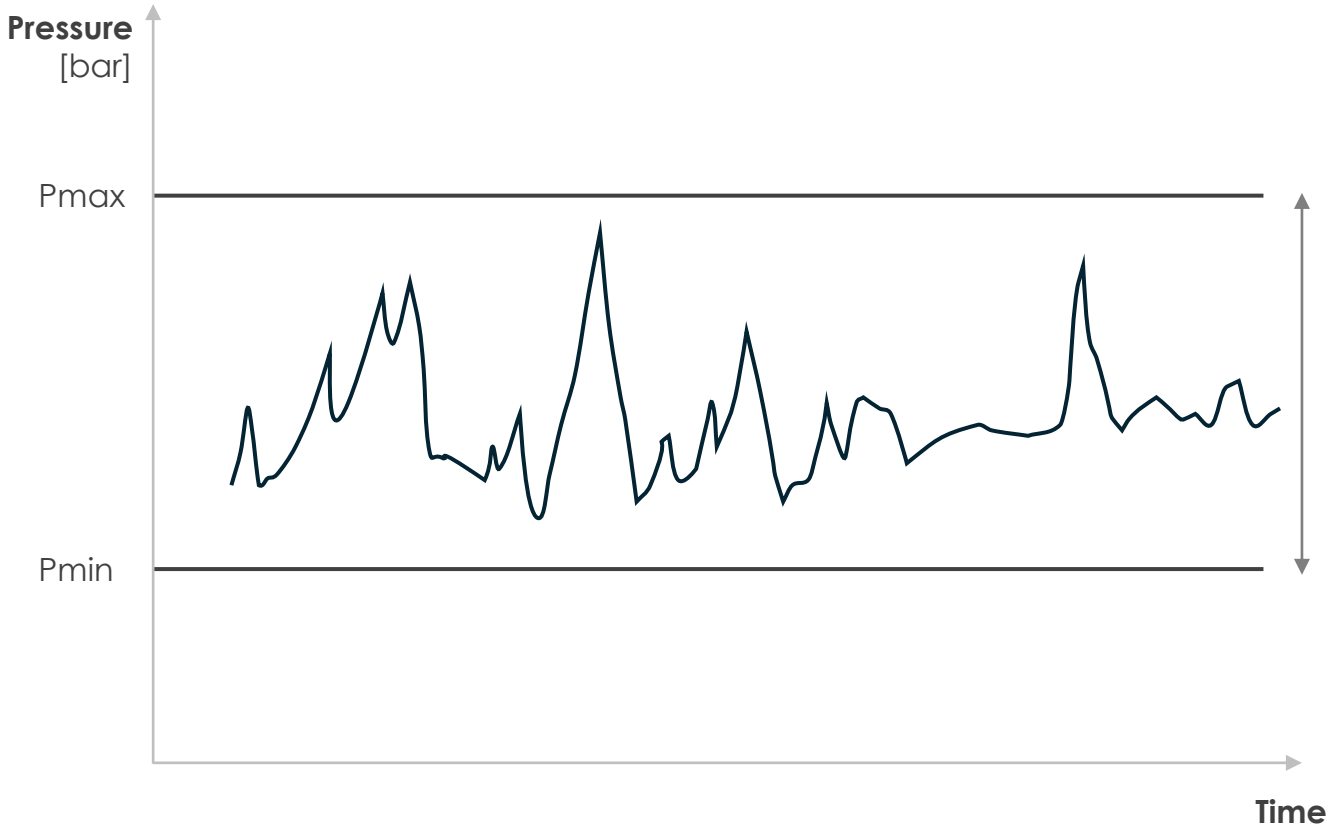


Before delivery, buyers and sellers trade hydrogen. The market supply and demand schedule ("nominations') should be balanced at all times…

…In real-time, there are deviations from the traded volumes (nomination) and balancing may need to take place

In case of deviations from the nominated capacity, the H2 linepack and hydrogen pressure will be impacted.

Hydrogen market



In case **hydrogen injection and supply are not balanced**, the linepack (gas storage in the pipeline network) and pressure evolve.

In case injection > off-take, the linepack and pressure increase

In case injection < off-take, the linepack and pressure decrease

The HNO needs to ensure that the pressure remains within **acceptable pressure band**, i.e. "**balanced**"

The Hydrogen network will be more sensitive to imbalance events than the natural gas network

Properties important for balancing	Natural gas network	Hydrogen network	Power network
Stability of supply	**Stable** (pipelines, LNG regasification)	**Mixed** mix of stable (*cracking of* ammonia, *SMR*) and **unstable** (*electrolysis*) sources	**Unstable** Mix of intermittent renewables and baseload assets
Storage	**Lot of storage** for geostrategic reasons 9,1 TWh in BE, 1139 TWh in the EU (1/4 of the annual EU consumption)	**Medium storage** mainly linepack, no large-scale scheduled in the short-term in Belgium	**Limited storage** Pumped storage and batteries
Size of the linepack (volume of gas in the network that can serve as buffer)	**Large linepack** 4000 km + distribution network	**?** (unspecified but less than 4000km, and a much smaller distribution network)	**No linepack**
Energy density (volume, atmospheric pressure, HHV)	**10,1 kWh/m³**	**3,3 kWh/m³**	**N.A.**
	✕ **No balancing assets or mechanisms are needed.** Every 24h, offsets between injections and nominated volumes are compensated the next day (by the causer)	? **The balancing mechanism needs to be investigated**	**Ancillary services (balancing services) are in place to ensure that supply and demand remain balanced**

Several questions need to be further investigated for hydrogen network and its security of supply

Open questions

- What are the imbalance events that may occur on the hydrogen network?
- What are the solutions that could be leveraged to keep the linepack within acceptable boundaries?
- What is the impact of imbalance events on the hydrogen market for different scenarios?
- …

Methodology

- Identification of different type of imbalance events
- Identification of solutions to balance the network
- Simulation of the impact of imbalance events on the future hydrogen network and the different solutions to rebalance the system

When an imbalance event occurs, the linepack will decrease in case there is no reaction from the market or the HNO

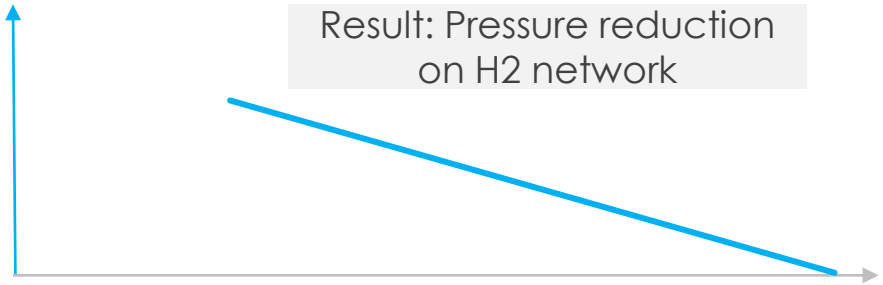
Several types of imbalance causes were identified…

Deviations from production & demand profiles	• Deviations from planned production and consumption • Forecast errors
Power market price signals	• Power market price signals triggers decrease or increase of consumption of electrolysers and other assets
Unplanned outages	• Offtaker shutdown due to incident • Producer shutdown due to incident
Grid incidents	• Pipeline leak or saturation of a pipeline between two clusters • Interruption of cross-border flow

…some of these may impact the linepack

Production cracker (MW)

Linepack (MWh)

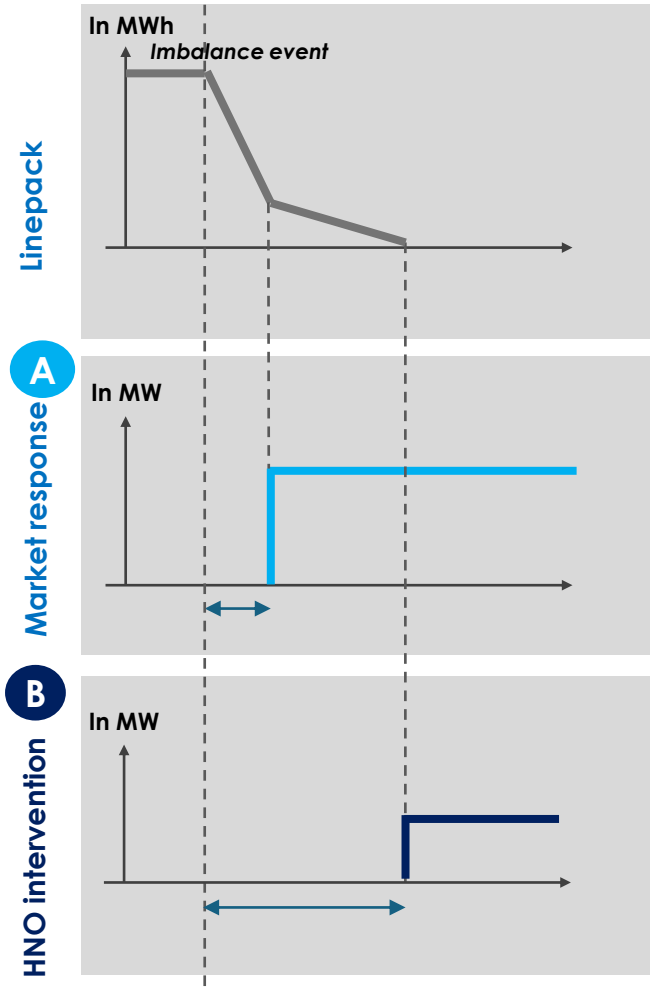


… and several solutions were identified to tackle these incidents.

Several types of possible solutions were identified…

Market response (flexibility)	• Production or demand response (flexibility)
Storage	• Linepack, geological storage, neighboring countries
Market rules	• Regulations at interconnection points or producer/offtakers
Balancing market	• Incentives for helpers • Penalties for causers • Balancing services (ancillary services)

…the most important ones were simulated to assess their efficiency



- **Market reaction**; the market reacts and helps solve an imbalance to capture incentives
  - Production increase or decrease
  - Consumption increase or decrease
  - Storage
- **HNO intervention**: the HNO requests assets to help solve the system imbalance. Different type of assets are possible:
  - HNO own assets
  - HNO reserves assets from the market (reserve market)

2

Hinicio simulation model

Imbalance events were simulated in 4000 different situations, all varying according to several parameters:

3 Phases of deployment

1) 2026-2027
2) 2028-29
3) 2030-2035

4 types of Imbalance events

- Electrolysers forecast error
- Power market price signal: electrolysers follow the power imbalance prices instead of nominations
- Outage of a large producer
- Outage of a large consumer

Market & event conditions

- Dynamic power prices
- Dynamic natural gas prices
- Period of the week (different consumers & producers load profiles)
- Duration before activation of market flexibility and/or HNO intervention (if any)
- Total duration of the event

Each scenario was simulated 250 times under different conditions

3 possible HNO responses

- No market intervention
- Minimum HNO intervention to preserve the security of supply
- Minimum HNO intervention to ensure a complete linepack recovery after the event

3 possible market responses

- No market response
- Some flexibility of consumers is activated
- Some level of flexibility of the producers is activated

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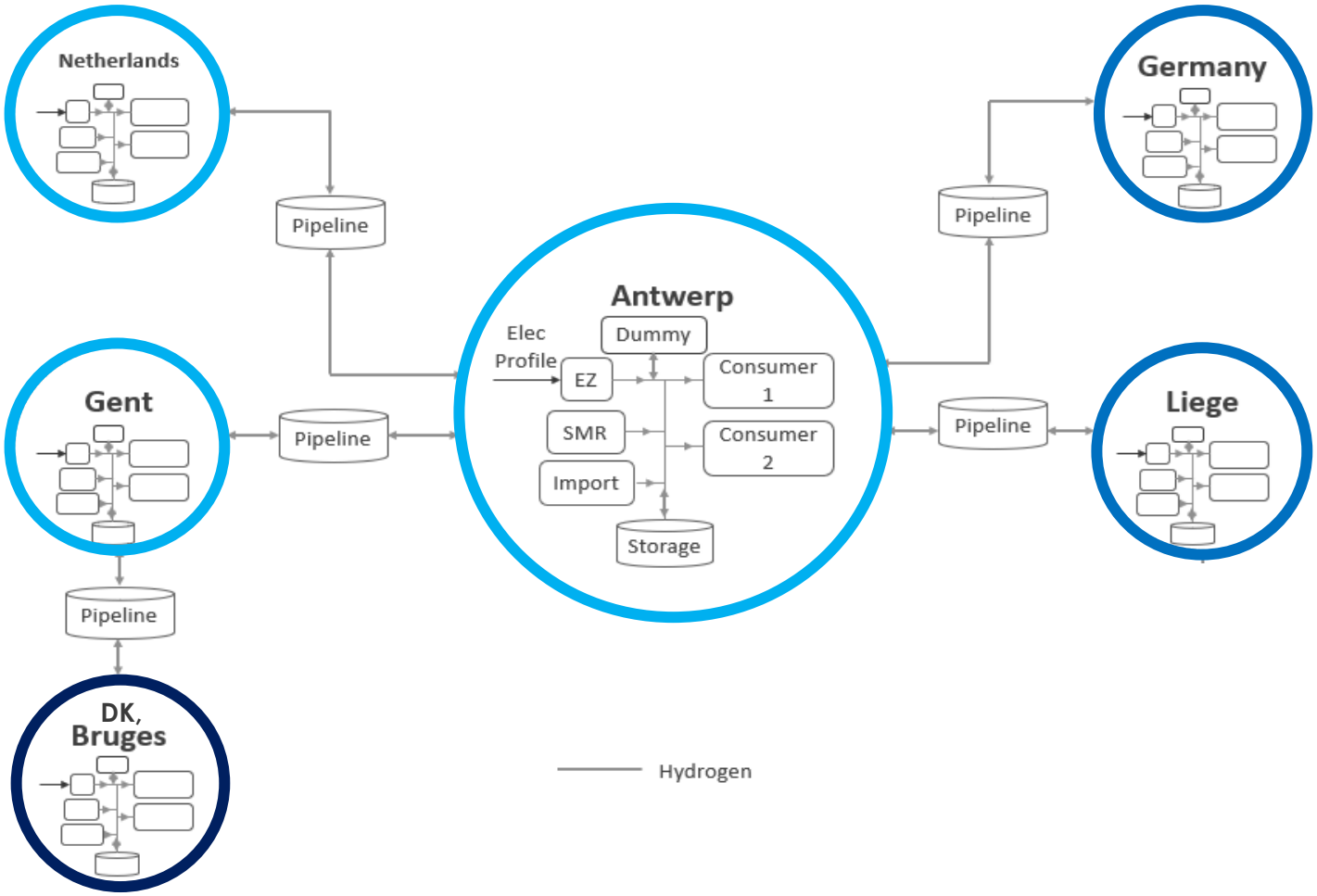
Topology for the modelling in 3 phases in line with expected indicative timeline

Virtual model of Belgian Hydrogen network topology



Phase 1 (2026 – 2027):
Antwerp – Ghent,
Connection to the Netherlands

Phase 2 (2028-2029):
+ Liege
+ import/export Germany

Phase 3 (2030-2035)
+ Bruges
+ Dunkirk connection

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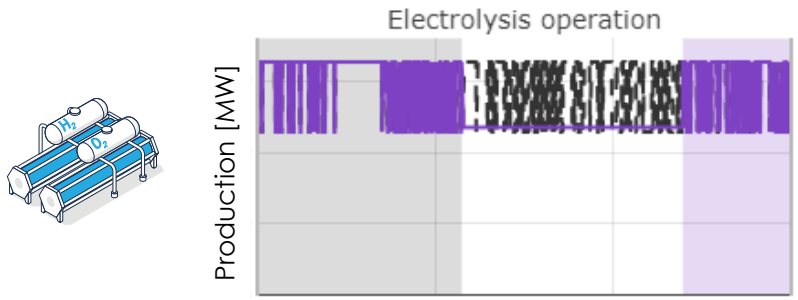
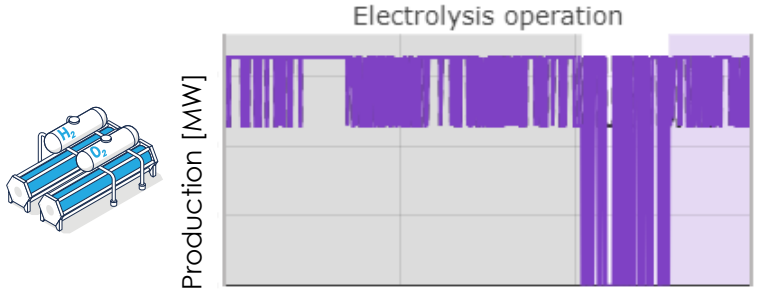
When an imbalance event occurs, the linepack will be impacted in case there is no reaction from the market or the HNO

- Electrolysers forecast error



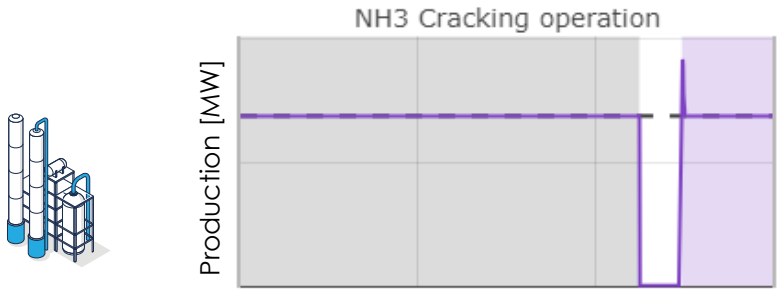
Assuming some electrolysers are working in baseload, and others following a wrongly forecasted RES curve

- Power market price signal



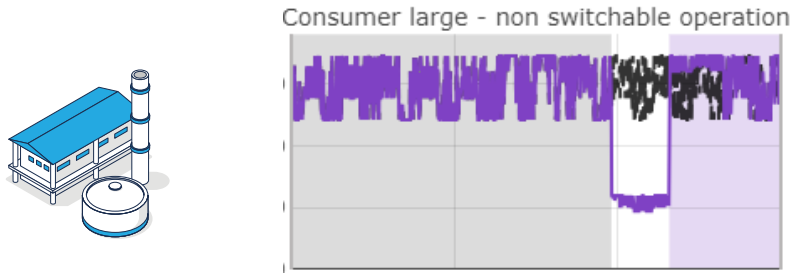
Assuming all electrolysers shift between 0% and 100% load following an imbalance power price signal (instead of their nominations, i.e. planned injections)

- Outage of a large producer



Assuming the largest producer (in this case, an ammonia cracker) has an unexpected shutdown

- Outage of a large consumer



Assuming the largest consumer (in this case, a chemical plant) has an unexpected shutdown

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Market & event conditions (1/2)

Different load profiles are possible on the H2 network

BASELOAD
Constant consumption/ production

VARIABLE
Consumption profile is variable (depending on activities) but fixed (inflexible)

FLEXIBLE
Profile is either constant or flexible (can switch in part to natural gas)

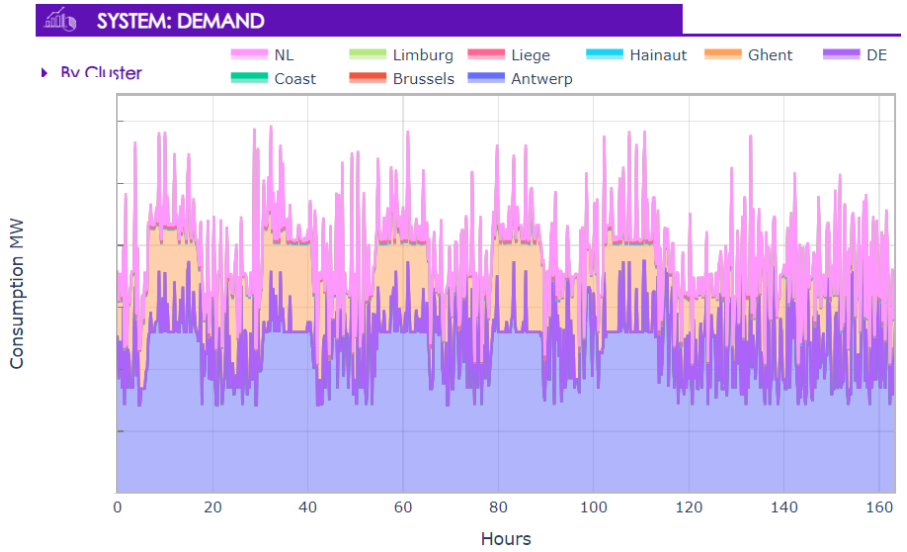
All producers & consumers have been appointed a specific profile depending on their activity

CONSUMERS	
Chemicals	**Mix baseload/variable**
Refineries	**Mix baseload/variable**
Iron & Steel	**Mix baseload/flexible**
Others	**Baseload** *(small volumes)*
Non-ferrous metals	
Waste	
Non-metallic minerals	
Food & Beverages	
Paper & Pulp	
Mobility	

PRODUCERS	
Power production	**Mix baseload/flexible**
SMR/ATR/pyrolysis	**Baseload**
Electrolysis	**Mix baseload/variable**
NH3 cracking	**Mix baseload/flexible**

As a result, the impact of an event highly depends on when it happens

… *(next slide)*



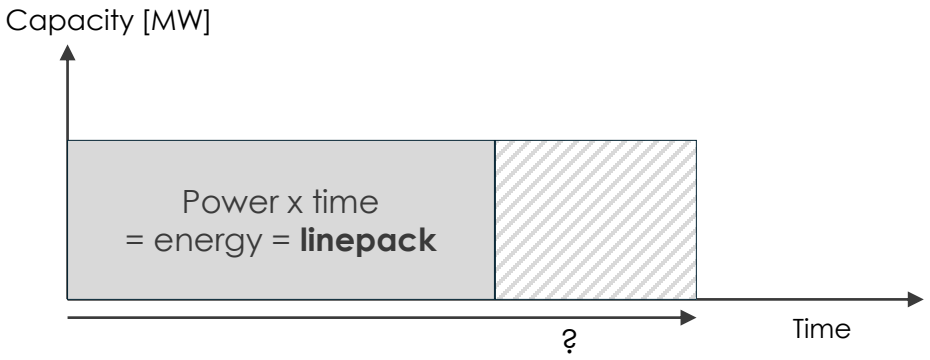
Depending on the period of the week, conditions are different

Note: **geographical distribution** (clusters), **start date**, **capacity** [MW_{eq}], and **type of activity** were determined by Fluxys through a Request For Interest with market players (data gathered in mid 2023).

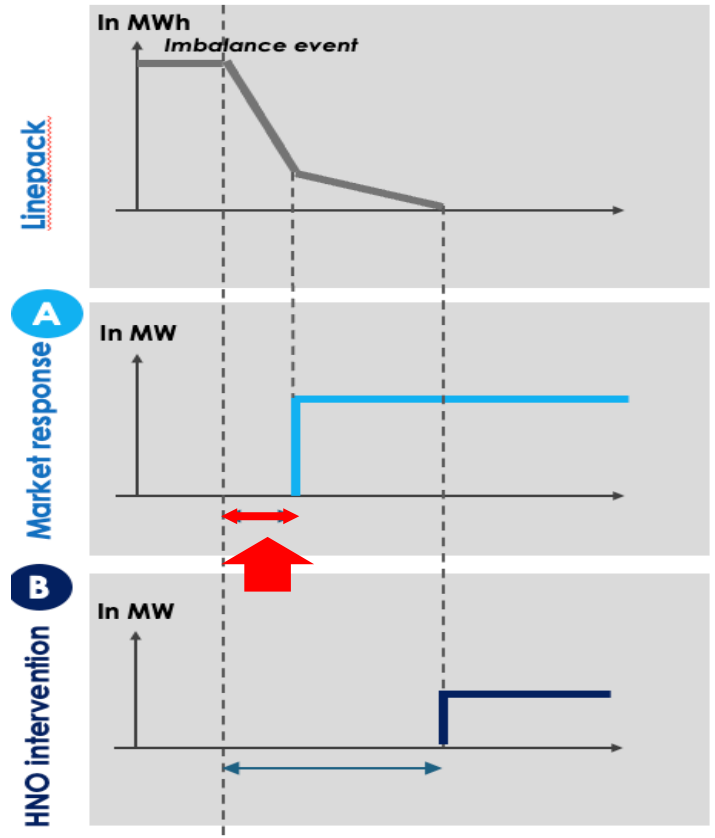
Market & event conditions (2/2)

The duration of an event highly impacts the missing/excess energy content

Event duration plays a particular importance for power price arbitrage events



The time to react when an intervention is activated will impact its required strength



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Zoom on system solutions

3 possible HNO responses

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3 possible market responses

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The HNO and market players could both play a role in balancing the network

Flexibility could help balance the network in a cost-efficient way. There are two types of flexibility in the system :

1

Market intervention

The market reacts and helps solve an imbalance to capture incentives sparked by the imbalance price. In other words, players are remunerated by the HNO imbalance price to deviate from their nominated trades.

3 possible types of intervention from market players

No market response
Business as usual: no deviation from nominations

Market response from one or more consumer(s)

In case of downwards imbalance (not enough H2 in the grid), a consumer will consume less than its nominations.

In case of upwards imbalance, a consumer will consume more.

Market response from one or more producer(s)

In case of downwards imbalance (not enough H2 in the grid), a producer will ramp up its production.
In case of upwards imbalance, a producer will ramp down

2

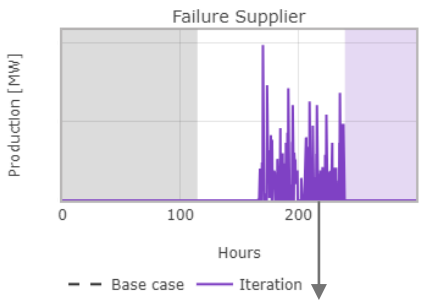
HNO intervention

The HNO requests its own assets and/or its contracted market assets to help solve the system imbalance. Different type of assets are possible:

- HNO own assets
- HNO reserves assets from the market (reserve market). This could be one or multiple dedicated reserve assets

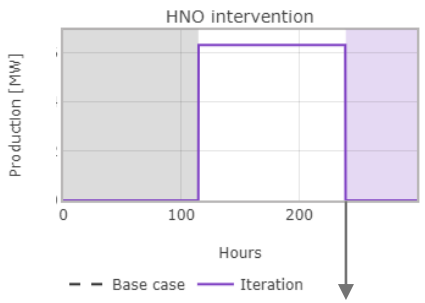
3 possible types of intervention from the HNO

No HNO intervention



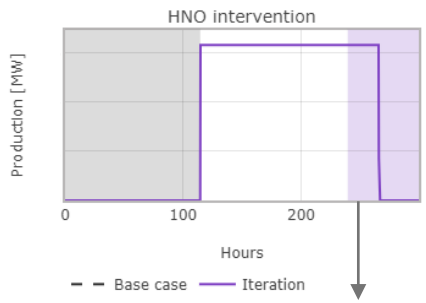
This volume of hydrogen represents the delta that is missing to keep the minimum acceptable pressure

With HNO intervention



Intervention stops after the event has ended

With HNO intervention, AND HNO refills the linepack to initial levels



Intervention continues after the event has ended to restore linepack

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- Some level of flexibility of the producers is activated

All these different configurations lead to a pool of 108 different scenarios, all running in different market & event conditions.
→The 16 worst-case scenarios were selected, and each of them was run under 250 times under different conditions.

A dedicated simulation tool (ANDREA) was developed to capture this complexity and help build up an understanding of the network's intricacies

ANDREA by HyBex

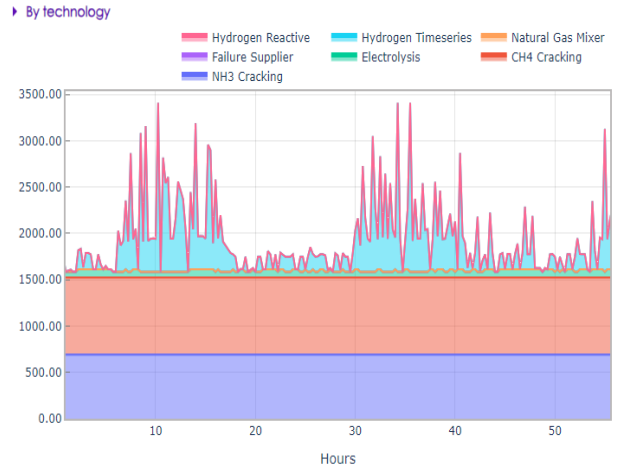
Adv **A** nced
a **N** alytical
mo **D** eling of
ene **R** gy
syst **E** ms and
sust **A** inability

ANDREA is a MILP-based tool (Mixed-Integer Linear Programming Definition) created by Hinicio to model and optimise complex multi-energy systems. An extension was developed specifically to simulate the balancing needs of the Belgian hydrogen grid, in its 3 phases of development (2026-2035).

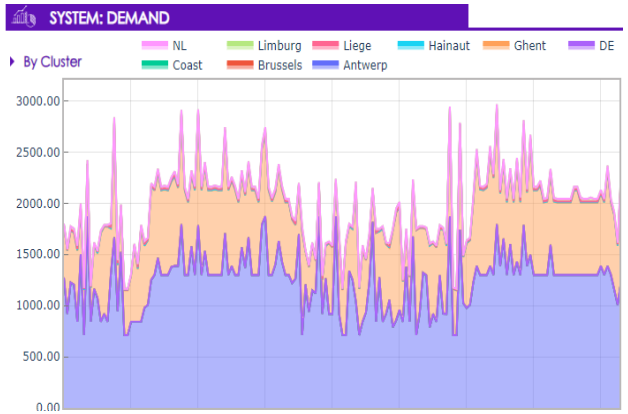
Modelling of the supply demand balance related to the topology (incl. linepack) and events: **4000 simulations**

4000+ simulations of network conditions, imbalance events, and balancing solutions

Complex modelling of supply sources
(each with their own type, capacity, load profile, localisation, year of deployment)

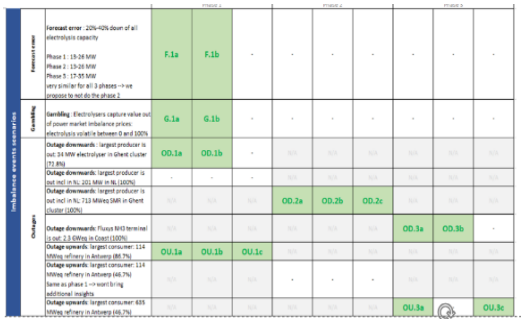


Complex modelling of offtakers
(each with their own type, capacity, load profile, localisation, year of deployment)



IMBALANCE EVENTS

Selection of the worst-case scenarios



ANDREA by Hinicio

Adv **A** nced
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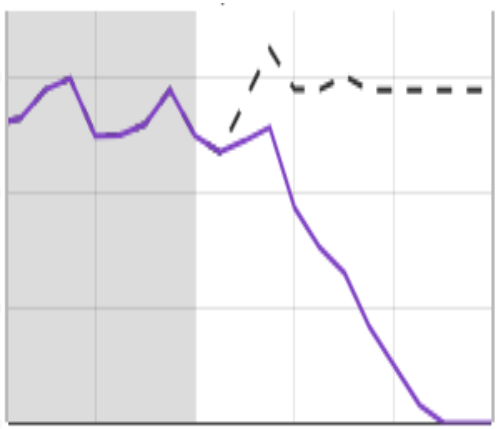
System boundaries: linepack

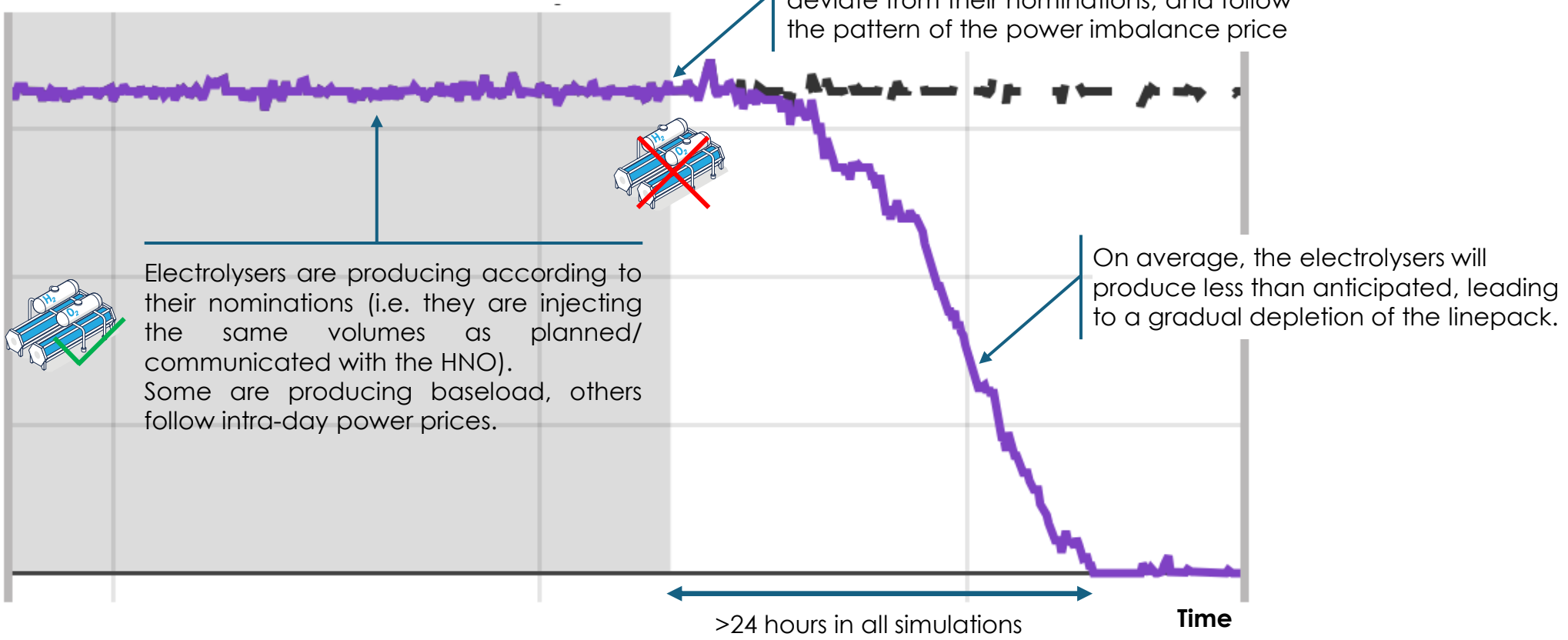


Modelling of complex imbalance cases:
what happens if a producer has a shutdown? What if an electrolyser deviates from its nominated trades?...

3 Preliminary results

Example n°1: The hydrogen network is likely able to cope with reactions from electrolysers on power market price signals

Linepack State of Charge [%, starting at 50%]

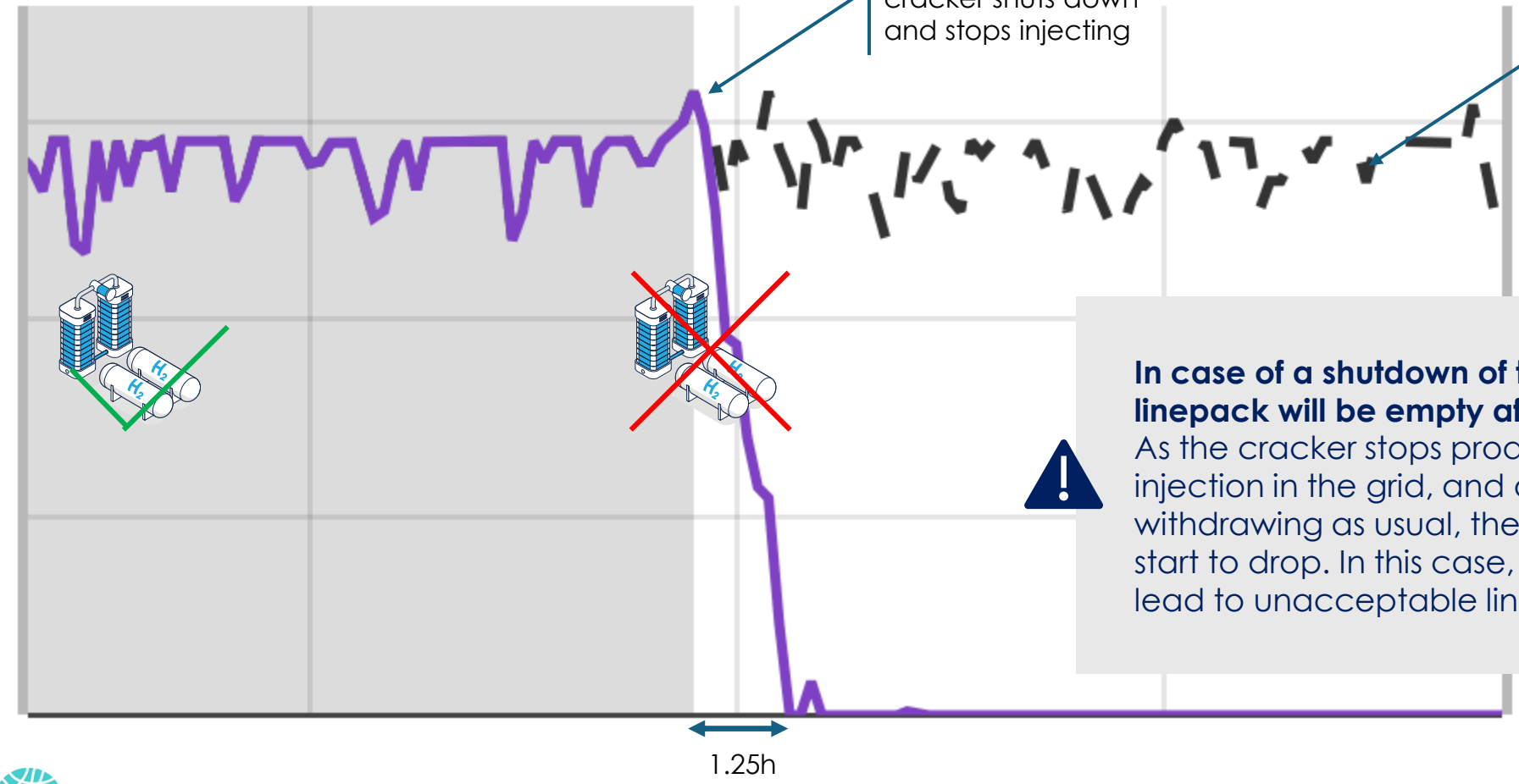


This simulation shows that the linepack is able to cope with unexpected events

Before event After end of event

Example n°2: Without any market flexibility, an outage of the ammonia cracking unit can lead to a system failure within **1 hour and 15 minutes**

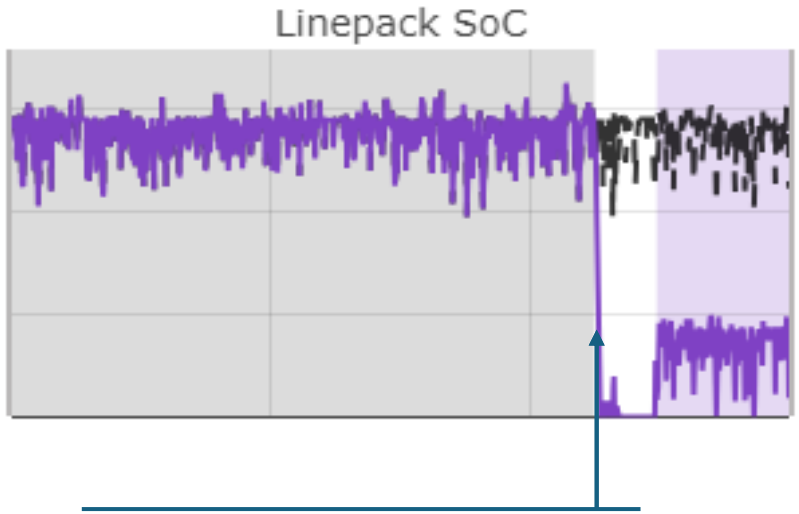
Linepack State of Charge [%, starting at 50%]



In case of a shutdown of the largest cracking unit, the linepack will be empty after only an hour.
As the cracker stops producing hydrogen and stops its injection in the grid, and other consumers keep on withdrawing as usual, the pressure on the network will start to drop. In this case, the event is severe, and could lead to unacceptable linepack levels within ~1 hour.

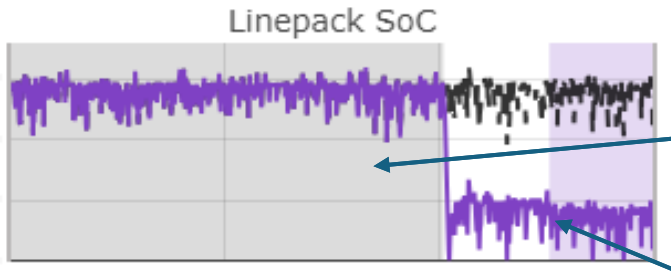
Example n°3: outage of an ammonia cracking unit, with an intervention of a large consumer of similar size

No market response



Without any intervention, linepack crashed rapidly after the shutdown of the producer

Market response from offtakes a large consumer is activated



1 When the cracker shuts down, pressure starts to plunge rapidly

3 The consumer's response stabilises the linepack until the end of the producer shutdown

Intervention of the consumer, i.e. the difference between initial nominations and real consumption
[negative MW]

2 After a moment (different in every simulation) the market response from the large consumer starts

This simulation shows that market response is an effective way to stabilise the linepack in case of an extreme event.

Linepack SoC = State of Charge in percent (starts at 50%)

The hydrogen network will require flexibility to ensure security of supply

Insights

Simulation 1: Power market signals	**The system can handle, to some extent, forecast errors and reactions from electrolysers to power market signals** The network is still able to withstand some level of imbalance induced by electrolysers reacting to power market signals
Simulation 2: Cracker outage	**A disruptive imbalance event could jeopardize the security of supply (SoS)…** The unexpected outage of a large consumer or producer (e.g. a cracker) will have a major impact on the system linepack
	…short-term reactions and data-provision will be needed to ensure SoS Pressure needs to be closely monitored in order to enable quick reactions. A shorter trading timestep (e.g. 1 hour) on the intraday market could also help prevent imbalances.
Simulation 3: Market response	**Flexibility from market players can effectively help balance the network in an effective way** Simulations have shown that market responders can effectively help to correct imbalances, provided that 1) the market response is available, 2) proportional to the imbalance and 3) it can be activated on time To trigger this flexibility, players would need financial incentives and a dedicated remuneration mechanism should be set up

Key insights for the H2 network

- **Electrolysers can potentially leverage and monetize part of their flexibility on the power market**
- **Bilateral contracts** with large players for flexibility activation **may be required to ensure security of supply**
- **Low granularity monitoring systems are needed to quicky detect issues**
- **Short trading timestep** (e.g. 1 hour) **& fast time to react help the market to react**
- **Balancing market** to reserve and activate flexible players (long term)
- Small **fees** for deviations inside a safe band
- **Possible penalties** for causers and incentives for helpers outside a safe band

4 Evolving towards a balancing model

Evolving towards a balancing model for hydrogen in Belgium

Upcoming task for the HNO

Fluxys has been appointed as HNO in May 2024 for the hydrogen back bone with third party open-access

Hence it has been given the task to write a **Code of Conduct integrating balancing principles**

This Code of Conduct will be **consulted with the market and submitted to the CREG**

Approach towards Code of Conduct

- Further **elaborate the result of the model** and possibly run more scenario's
- Develop **evolutive answer to the basic question** relevant for balancing
- Discuss the proposal **with the regulator for approval and consult with market**
- Set-up the necessary tools and systems for balancing a.o. **a balancing market**

Choosing suitable building stones for the hydrogen balancing model (1/2)

Evolutive balancing model adapted to the needs of a nascent hydrogen market

Balancing Period	Hourly or less	Daily with within-day obligations	Daily
	Network users are incentivized to balance theirs inputs & offtakes within the time period of an hour or less Need small flexibility means able to cover imbalance events of at least the defined period	Network users are incentivized to balance inputs & offtakes within the time period of a day Additionally, to safeguard the system integrity hourly constraints can apply Need medium flexibility means able to cover important imbalance events of at least one hour but not always one day	Network users are incentivized to balance theirs inputs & offtakes within the time period of a day Need large flexibility means able to cover important imbalance events of at least one day

Allocation Period (binding data)	5 minutes	15 minutes	Hourly	Daily
	The allocation granularity determines which figures will be used to calculate market positions and incentives. The Allocation Period is equal or shorter than the Balancing Period			

Within Day Obligations	Entry/Exit point	Individual/portfolio	System-wide
	Network users are incentivized to limit the gas flow or the gas flow variation under specific conditions at specific entry-exit points	Network users are incentivized to keep their individual position during the balancing period within a pre-defined range Every time the network user exceeds these individual tolerances, a balancing charge will result Timely binding individual information provision	Network users are incentivized to commonly keep the transmission network within its operational limits Once these system-wide obligations are exceeded, the causers will be penalized by paying the balancing charge pro rata their share Timely binding individual & system-wide information provision, sharing market behavior

Information Provision Frequency	5 minutes	15 minutes	Hourly	Daily
	Increased investment for data repatriation needed	Increased investment for data repatriation needed		

Choosing suitable building stones for the hydrogen balancing model (2/2)

Evolutive balancing model adapted to the needs of a nascent hydrogen market

Balancing trigger	Physical Balancing	Commercial Balancing
	Residual balancing actions of the balancing operator are based on the linepack position of the grid using a pressure signal More broadband flexibility allocated to market due to physical correlation, and taking only daily constraints into account Fit to real situation: no balancing action if not physically needed Faster reaction time for HNO to intervene Allocated balancing costs less predictable for Users	**Residual balancing actions of the balancing operator are based on the balancing positions of the Network users** Less broadband flexibility allocated to market due to uncertainties due to scenario constraints and physical decorrelation HNO does not intervene as long as commercial boundaries are not reached More predictable for Network Users

Settlement (correction physical position)	None	Kind	Cash
	Park & Loan Tolerances and fall-back	**Position settled to zero at Balancing Period closure** Quantity added in the next Balancing Period(s) Tolerances and fall-back	**Position settled to zero at Balancing Period closure** Compensation in € Price Index
Balancing Tools	**Dedicated Flexibility Provider**	**Dedicated Balancing Platform**	**Exchange Platform**
	In exchange for financial compensation, companies agree to adapt temporary their profile (consumption and/or production) **Max quantity and capacity are agreed upfront** **Activation on request by HNO** Tender (auction) for flexibility services	**The balancing operator notifies when balancing actions will be undertaken** **Market participants can post anonymously bid and offers (ex-ante or upon notification by the balancing operator)** **Identity of counterparty is disclosed to the balancing operator upon conclusion of transaction** **Balancing Operator is always a counterparty in every transaction** Bid ladder, auction platform, reservation & activation, …	**The balancing operator places bids and offers based on the imbalance signal on the exchange platform** **Anonymous trading (with clearing)** **Possibility to develop balancing operator specific products with obliged physical delivery** Exchange & liquid spot market

Next steps: set-up and roll-out of the pilot exchange platform

Hinicio fluxys Port of Antwerp Bruges

economie
FOD Economie, K.M.O., Middenstand en Energie

HyBex

Discussion and Q&A

- **In order to foster strong stakeholder engagement with the HyBex model for a Belgian hydrogen network, we open the floor for your suggestions, remarks and questions.**

For additional queries, you can contact us on: info@hybex.be or consult www.hybex.be

HyBex

With the support of the Belgian energy transition fund (ETF)