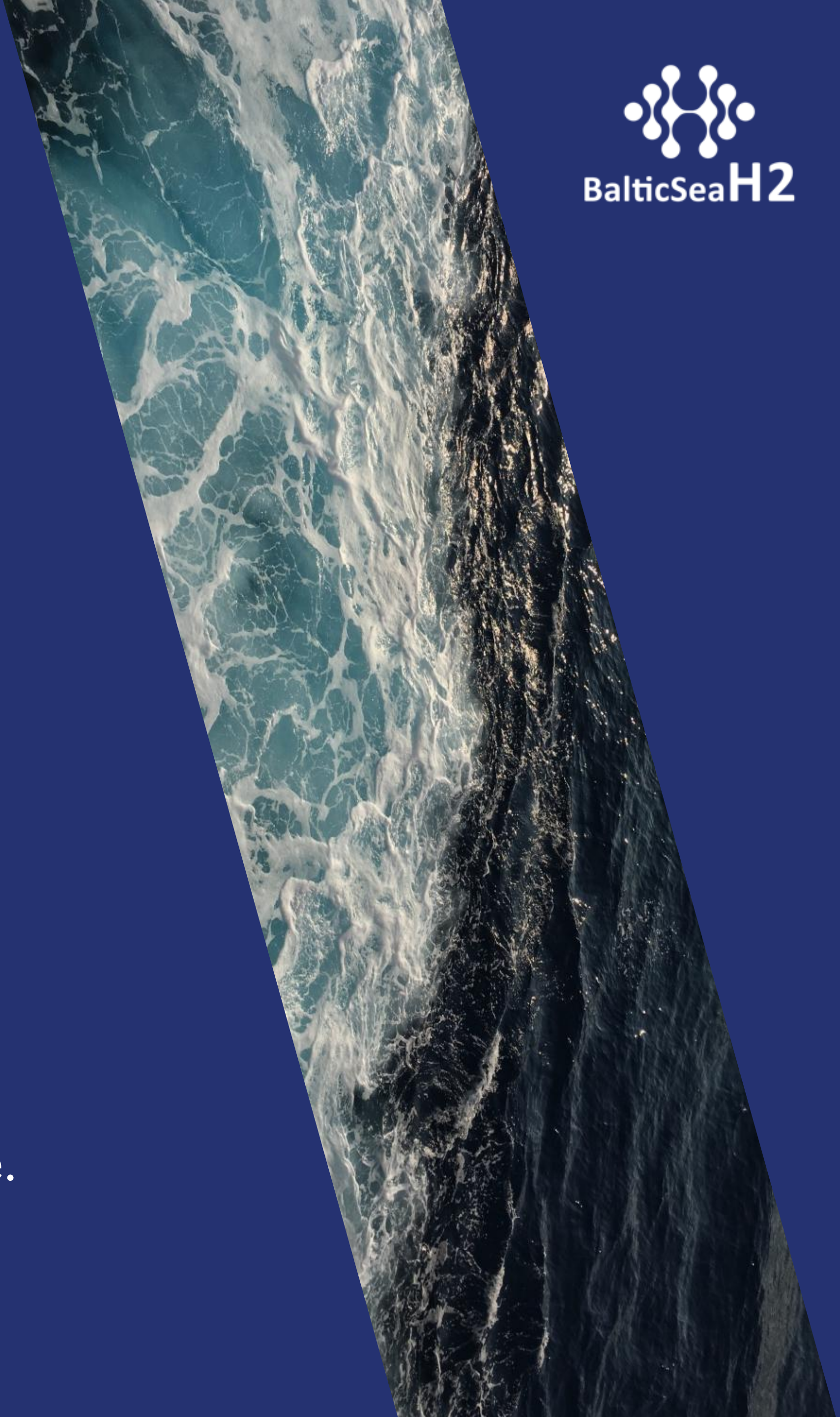
BalticSeaH2

Energy system flexibility in hydrogen valleys

May 7, 2026, 12:00-13:30 CEST



Please note that this webinar will be recorded.
Recording and presentations will be made available at BalticSeaH2 website.

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ENERGY SYSTEM FLEXIBILITY IN HYDROGEN VALLEYS

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Opportunities of sector integration in an integrated hydrogen valley
Antti Lukkari, ABB

Assessment of power and hydrogen sector integration: Insights from case studies
Göran Koreneff, VTT Technical Research Centre of Finland

Flexibility through hydrogen networks
Suvi Veräjänkorva, Gasgrid

The role of large-scale hydrogen storage in integrated energy systems
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Hydrogen Valley dynamics and policy recommendations in the Baltic Sea region
Kimmo Karhu, Aalto University

Ecosystem perspectives: Reflections from BotH2nia Hydrogen Valley and Hydrogen Cluster Finland
Sari Kola, BotH2nia Hydrogen Valley & Riitta Silvennoinen, Hydrogen Cluster Finland

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Opportunities of sector integration in an integrated hydrogen valley

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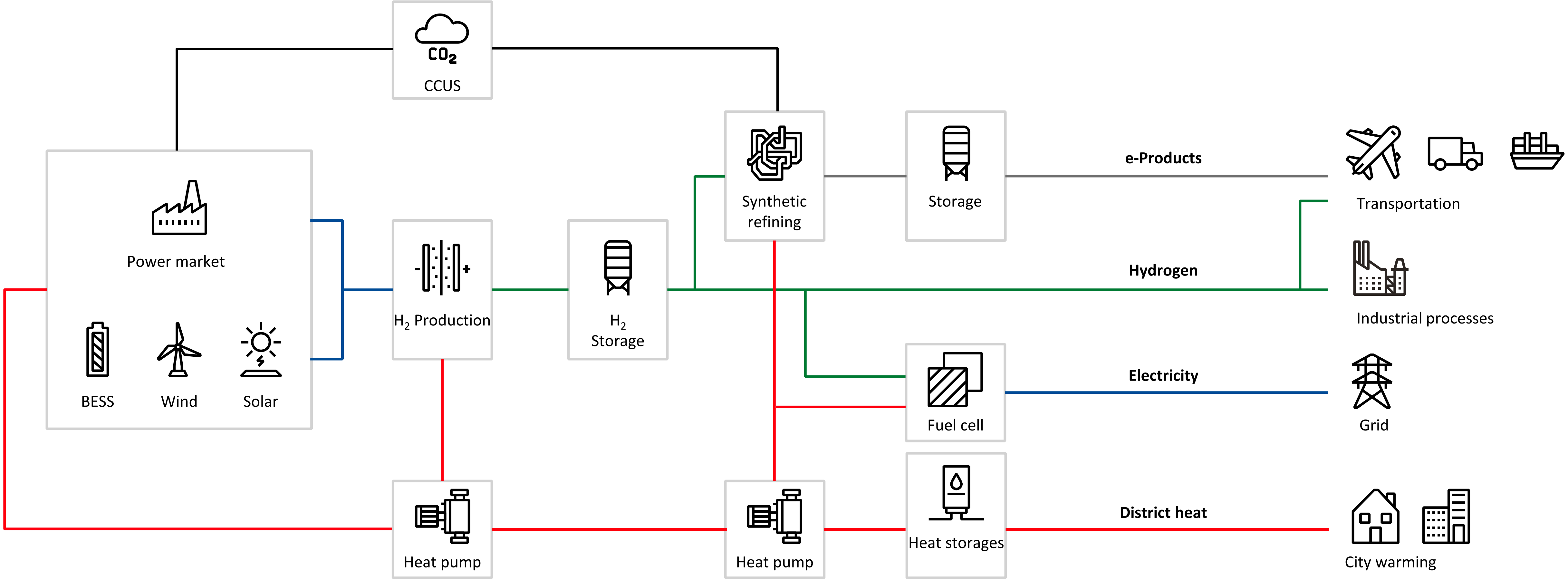
Sector integrated energy system



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Why sector integration matters?
Value drivers for sector integrated energy systems

System-level cost effectiveness

- Hydrogen assets are capital-intensive and rarely optimal in isolation
- Sector integration allows sharing infrastructure across power, heat, transportation, and industry
- Waste heat, oxygen, and flexibility become value streams instead of losses
- Integrated systems reduce total system cost (CAPEX & OPEX)

Resilience & security of supply

- Integrated systems provide multiple energy pathways and back-up options
- Hydrogen links electricity, heat, fuels, and storage into one resilient system
- Local, even off-grid production of electricity, hydrogen, and derivatives and cross-sector flexibility improve security of supply
- Automation and control enable fast response to disruptions

Sector integration creates resilient, cost-effective and optimized energy systems

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BalticSeaH2 Use Case Map

The use cases span a wide area and are not all connected to production cases. Some use cases are still far from implementation, but they are being explored to assess feasibility and identify potential challenges.

- P — H2 Production
- S — H2 Storage
- T — End Use: Transport
- I — End Use: Industry
- E — End Use: Energy
- O — Other

CH_3OH, H_2, CH_4, NH_3 — Products & derivatives

H2 trading

Use Cases not linked

Use Cases linked

T, I, E — End Users outside the consortium

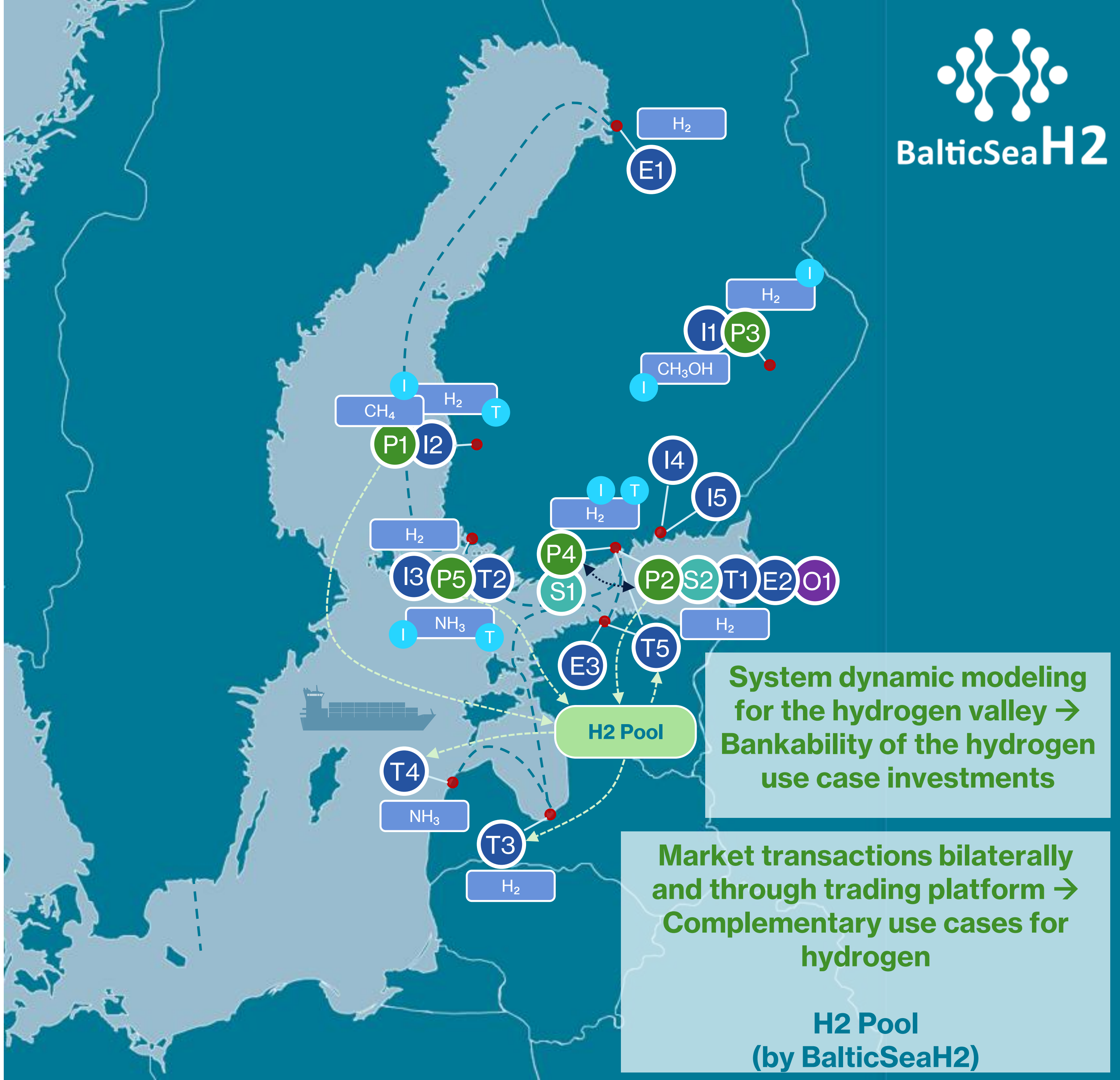

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ABB Marine fuel cell eHouse

- PEMFC-based technology
- +1MW rated power
- 40-ft standard high cube container
- Marine fuel cell modules with integrated balance of plant
- Cabling for the fuel cells, auxiliaries and control systems
- Control, safety, and piping systems
  - ✓ Auxiliaries control
  - ✓ Safety systems with instrumentation
  - ✓ Ventilation and air conditioning
  - ✓ Piping for the hydrogen, cooling, ventilation and exhaust

- **Sector integration opportunities:**
  - Heat: integration into the local district heating network
  - Electricity: reserve market asset and back-up power supply for critical ICT infrastructure and assets (resilience)
  - Transportation: off-grid charging station for electric vehicles (road & marine)

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BalticSeaH2 fuel cell demonstrator

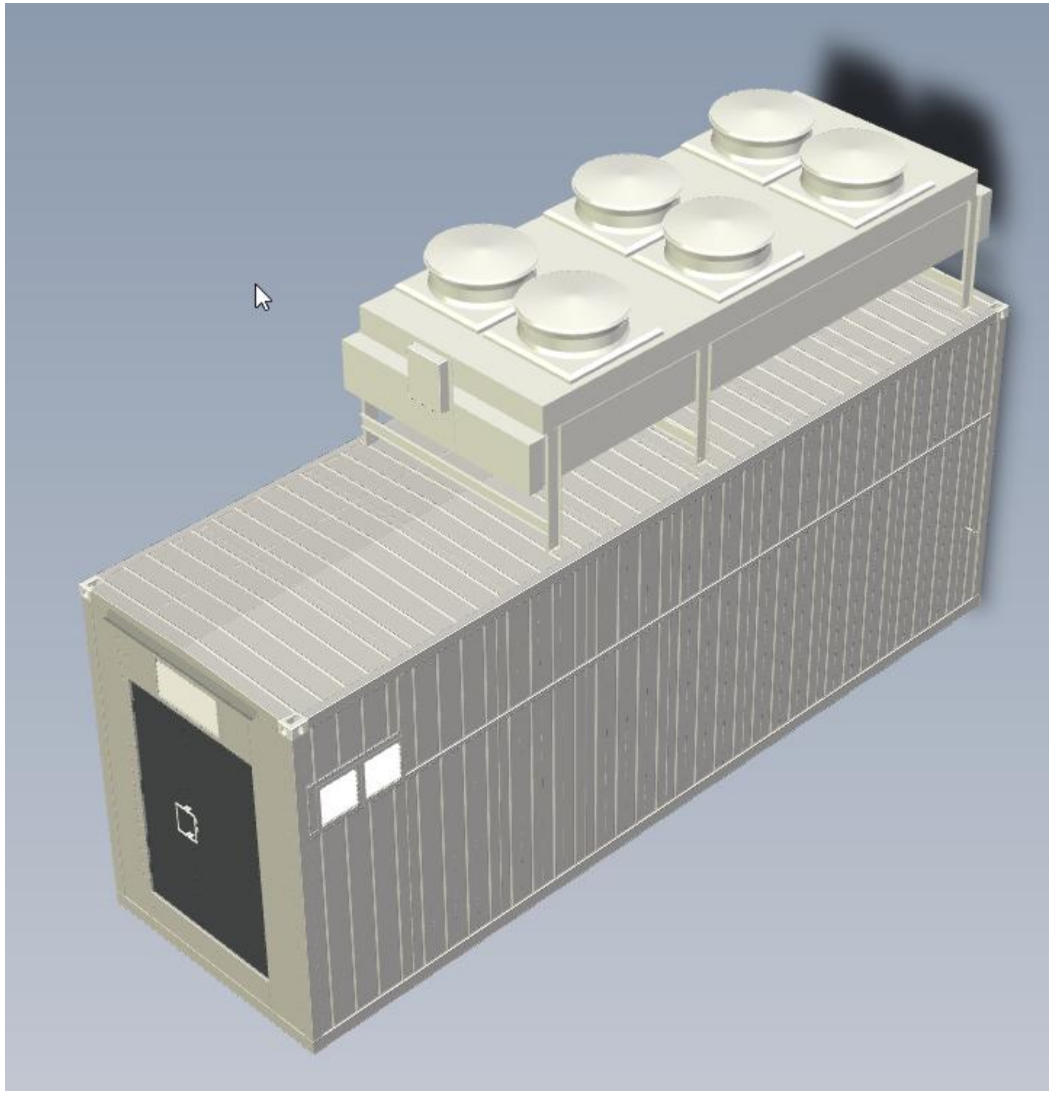
Land based piloting of marine solution

BalticSeaH2 fuel cell demonstrator serves as a proof of concept and test bed for components and subsystems

- Marine certified fuel cell modules (2 x 200kW Ballard FCWave)
- ABB Marine compliant ACS880 power converters
- Experimental converter solutions to enable scaling up to multi-MW scale installations
- Thermal management to enable operation in cold climate
- Safety automation solutions for marine fuel cell rooms

Land based pilot offers cost effective alternative with easier accessibility and availability of hydrogen.

End-user in Oulu, Finland with plan to harness the unit as reserve market asset after BalticSeaH2 R&D project completed.



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New wind and PV

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Wind and solar are the most cost efficient ways for new electricity, and

Wind and solar potential is high in Finland, but

Production is intermittent:

~40% capacity factor (CF) for onshore wind power[1],

~10% capacity factor for large scale PV[1]

New wind and PV production will mainly be tied to new demand (mostly via Power Purchase Agreements, PPA), as cannibalisation of wind and PV is already quite far gone in Finland:

Market value factors	Wind	PV
2022:	71%	126%
2023:	72%	90%
2024:	66%	85%

[1] Depends on location, weather conditions and design

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Finnish power system is already quite strained and has very volatile market prices - and market price is highly dependent on wind and solar production

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Upregulation is costly at times of low wind production, as available upreg. capacity is scarce

Not much condensing power capacity available

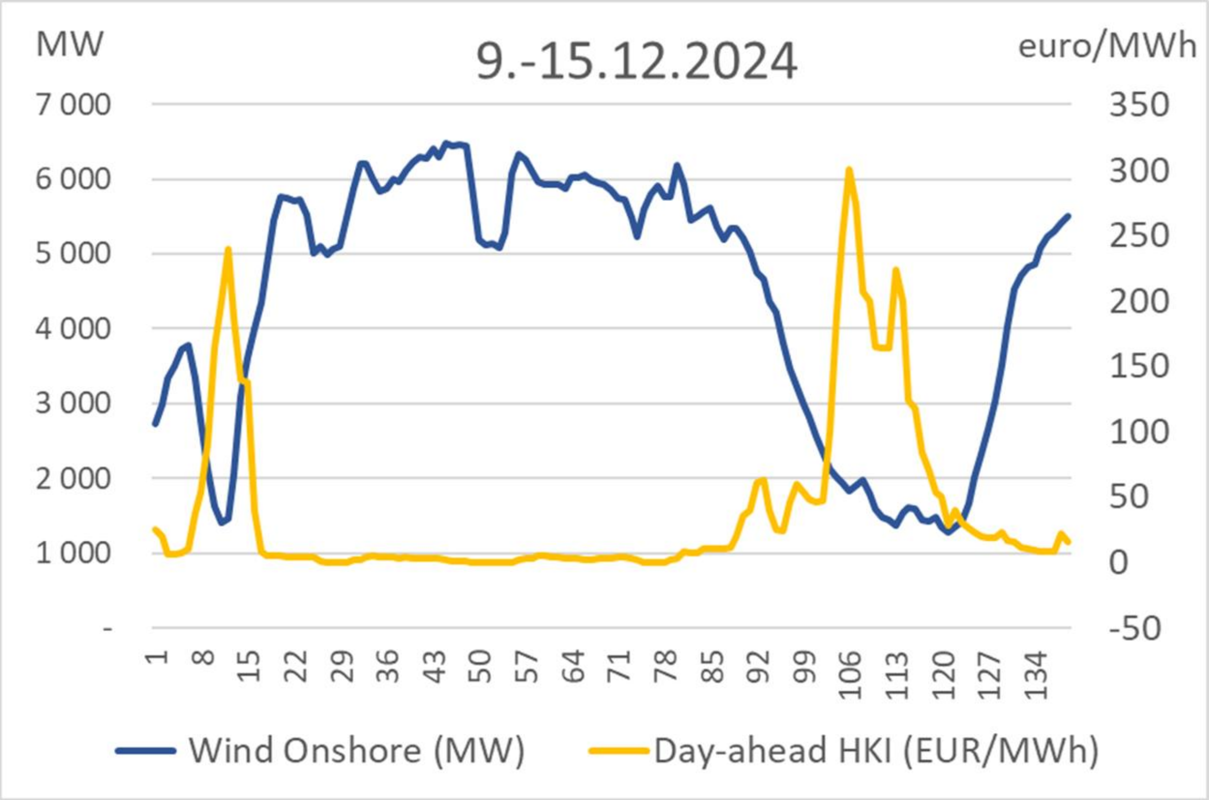
- E.g. Meri-Pori 565 MW is not in market use

Hydro power already in max flex use

Demand response is already in use extensively

New demand will not ease the situation; quite the opposite, if it is not flexible

- Normal data centres will have an inflexible constant load as they serve an immediate IT need
- AI data centres might offer a bit, but only a bit more flexibility
- Inflexible hydrogen production is no better than data centres from a system point of view



Data from ENTSO-E
Data centres load behaviour: Podcast/ **Fingrid Oyj. Kantaverkon pulssilla, Osa 3.Datakeskukset ja kantaverkko.**

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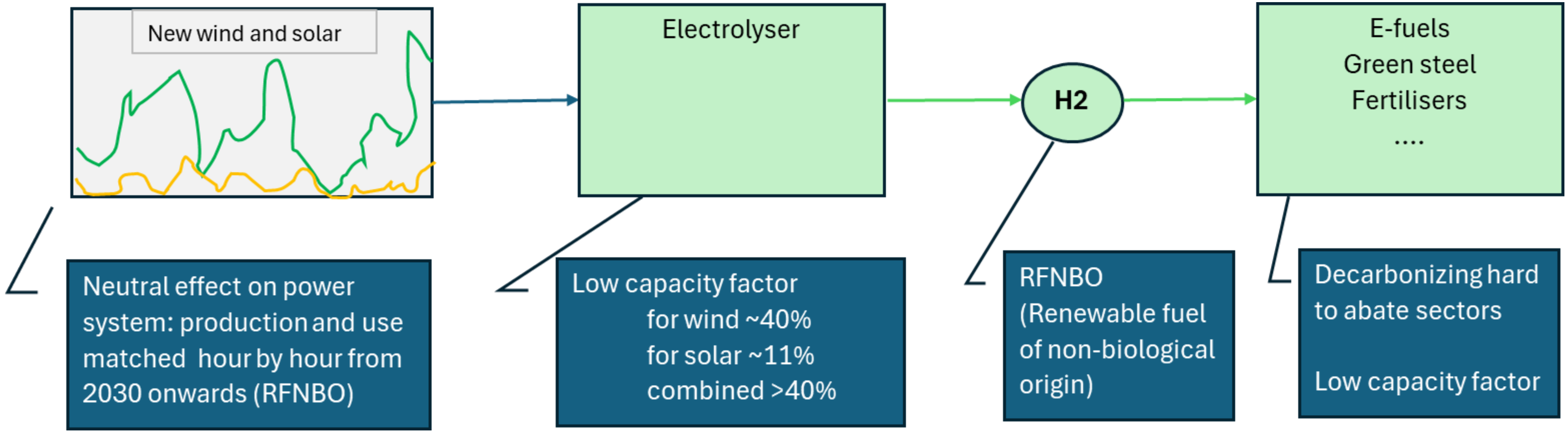
Sector integration aspects of new wind and PV –the role of the hydrogen sector from 2030 onwards

- Intrinsic EU view based on additionality of procured wind and solar production and
- H2 production following hour by hour wind and solar production
- Without storages: low capacity factors for electrolysers and hydrogen end users



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1 Mt H_2 production utilising new wind power

- The Finnish official target for clean hydrogen in 2030 is 1 Mt_{H_2} ==> presumes 50-55 TWh of electricity
- ➔ if from new onshore wind, 17 500 MW is needed (2024 production data)
- If we want to restrict adverse effects on the power system, we need an electrolyser capacity of 17 500 MW
- If we want a constant hydrogen production, an electrolyser capacity of only 5 700 MW is needed, but
  - surplus wind production 15.8 TWh, as well as deficit energy
  - a lot of batteries and pumped hydro[1] would be needed, or
  - use of **H_2 motors** for balancing (upreg), but
    - wind => H_2=> Power => H_2 makes no sense!
    - Lots of losses and price of H_2 up three or fourfold compared to original H_2 price
  - use of NG CCGT (for upreg), but
    - NG => Power => H_2 is more expensive and inefficient than NG => H_2
    - Finnish emissions would increase by 5,3 MtCO2 per annum

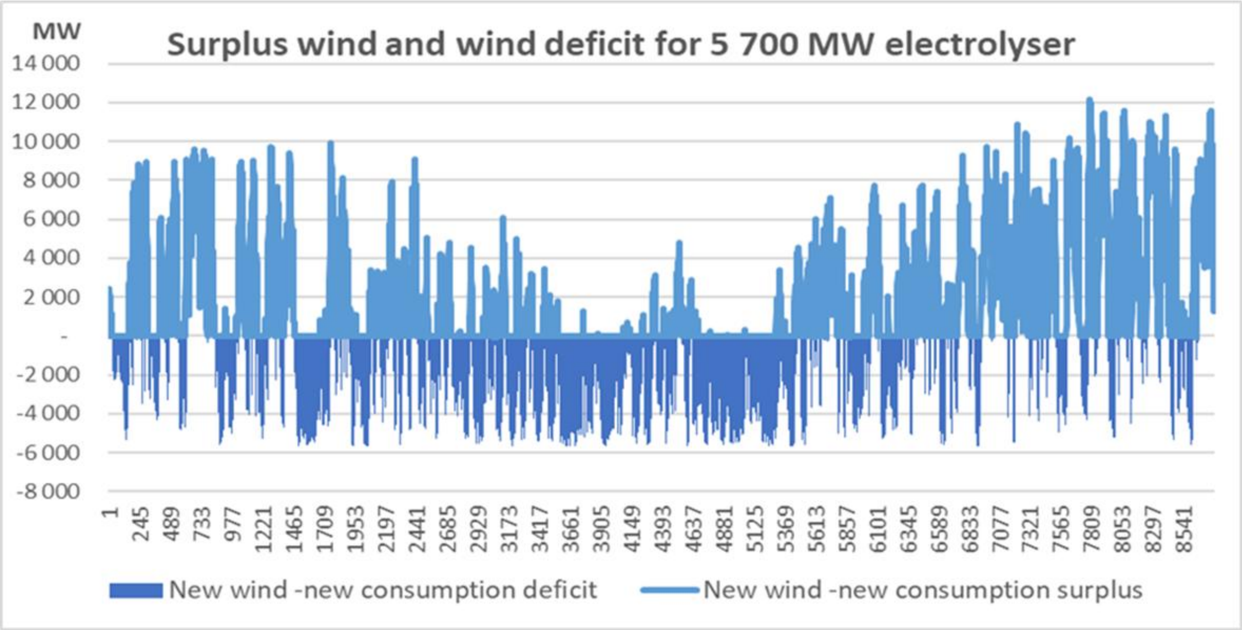

Fig.: Data source ENTSO-E, calculations own.

[1] Large scale 4 hour batteries are around 0.5 M€/MW (Ember 2025). 6 000 MW = 3 000 M€
The plans for large scale Finnish pumped hydro were all planned at Kemijärvi. Kemijärvi council has recently decided they won't allow pumped hydro in their municipality.

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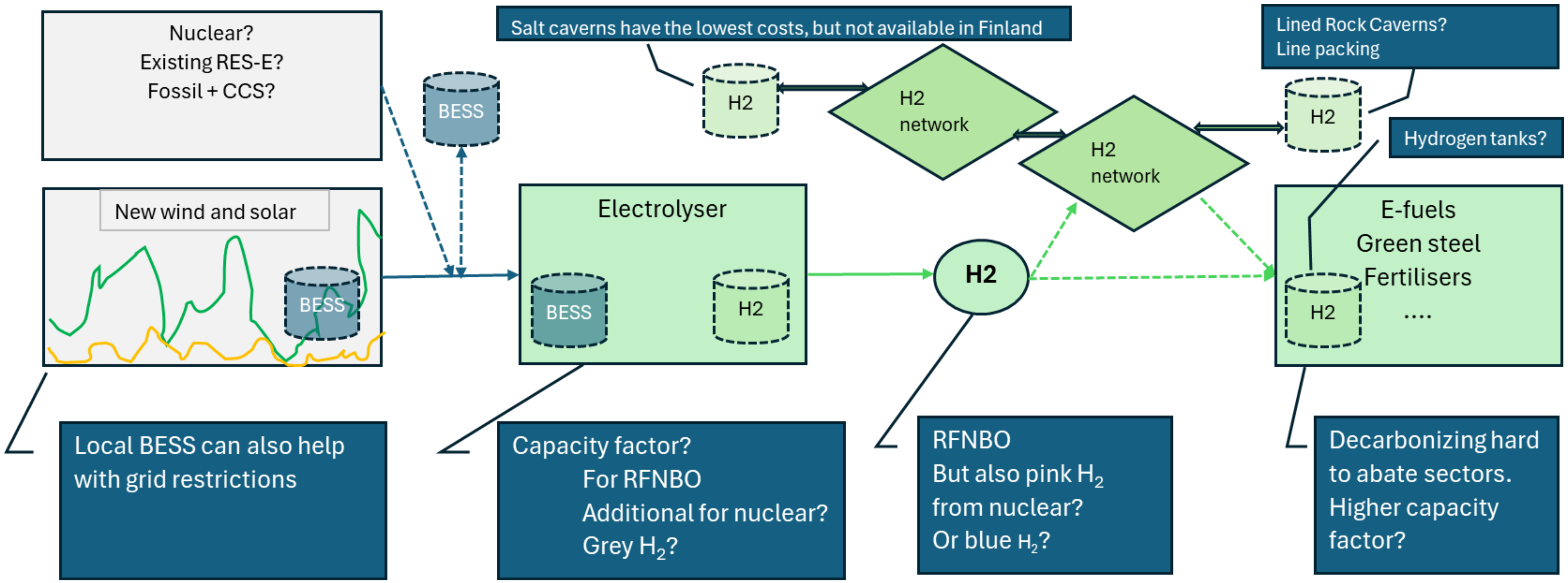
Sector integration aspects of new wind and PV –the role of the hydrogen sector from 2030 onwards

- Improving capacity factors is possible with storages (and different coloured H_2 production).
- Storage has a cost: what kind, where will it be employed, and how costly will it be to use?
- If we have enough H2 storage capacity, it is somewhat OK to have a more intermittent H2 production seen from side of the H2 user .
- If we have enough BESS on the electricity side, or alt.power, H2 production can be constant and H2 storage capacity is not much needed.



BESS (Battery Energy Storage System). In daily cycle use, LCOS could be as low as 60-70 €/MWh (Ember 2025, BloombergNEF 2026)

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Example: ammonium production cost as function of peak load hours and cost of electricity

The lower the procurement price of electricity, the less peak load hours (and storage) are needed

Hours of ≤0 €/MWh prices in Finland:

Year	Negative price hours	Null price hours	Sum/≤gratis hours
2024	750	150	900
2025	465	138	603

Data source ENTSO-E 2025, ET 2026

➔ Average price of 3000 cheapest hours:

below or above 20 €/MWh?

Data exists, find out!

But we also need to know the future, not only the past! => We need modelling results etc.!

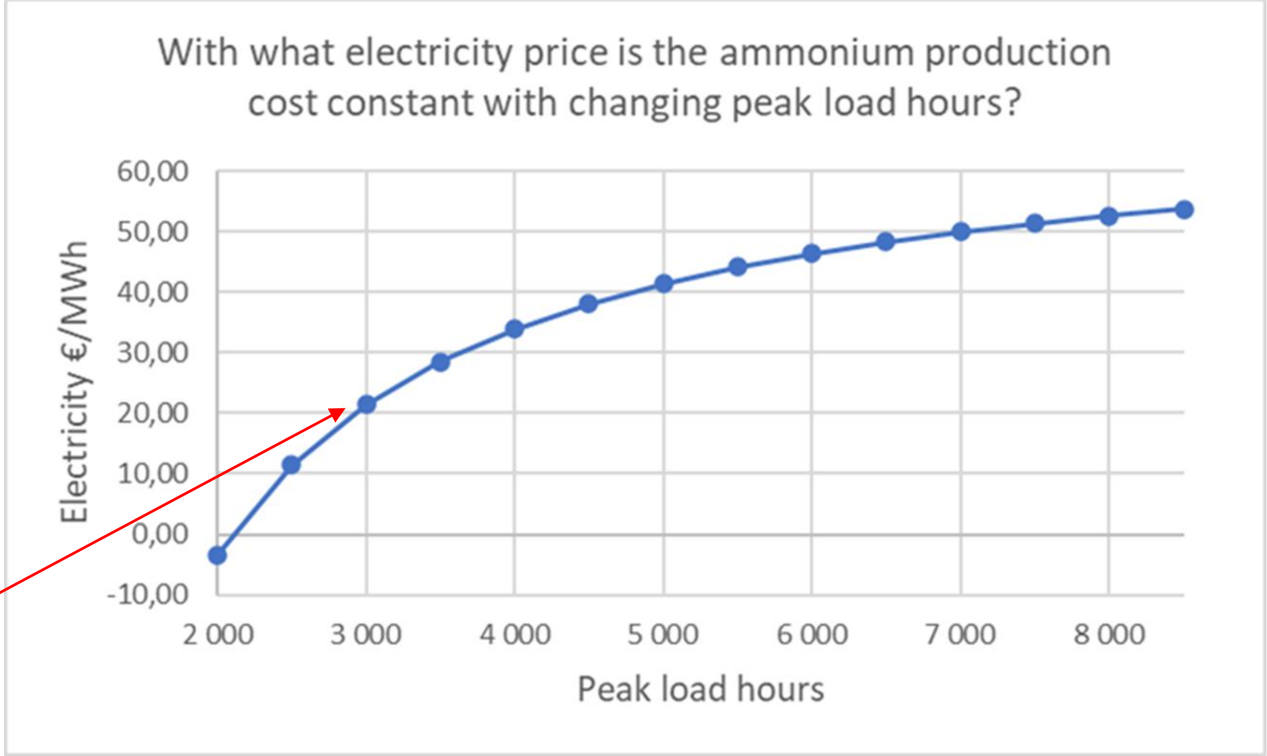

Fig. source: Koreneff et al. 2024. EU sähkömarkkinasääntelyn ja valtiontukien kilpailukykyvaikutukset. VTT Asiakasraportti VTT-CR- 00106-2. https://teknologiateollisuus.fi/metallinjalostajat/innostu-alalle/metallien-maailma/
Base case for example with constant cost: power price 50 €/MWh, electricity forms 70 % of total costs with 7000 peak load hours

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Energy system flexibility in hydrogen valleys

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Flexibility through hydrogen networks

Suvi Veräjänkorva & Janne Jauhola, Gasgrid

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Introduction

- System level study examined what kind of hydrogen transmission network could emerge in Finland, considering structural durability for such a network.
- Initial part of the work reviewed future scenarios, hydrogen production methods, and identified different consumer types and their flexibility.
- Dynamic model was developed using the Simone software for network simulation.
- Model represents a simplified example of planned Finland's backbone network, including five hydrogen valleys where hydrogen is produced and consumed.
- This presentation focuses on the results for hydrogen network flexibility.

Related Master's Thesis: Dynamic Modelling of Hydrogen Transmission Pipelines: Assessment of Durability and Effect of Storages, Janne Jauhola (2026)

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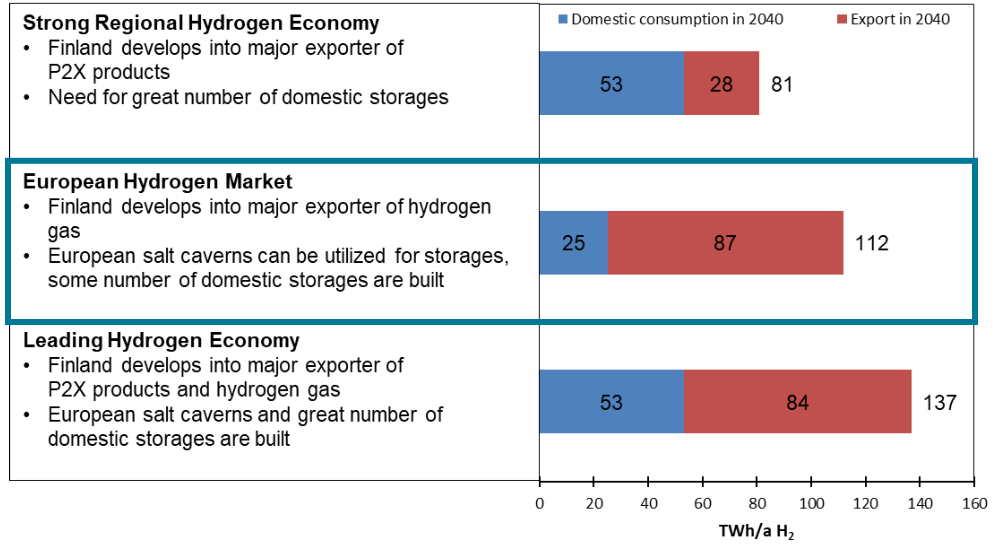
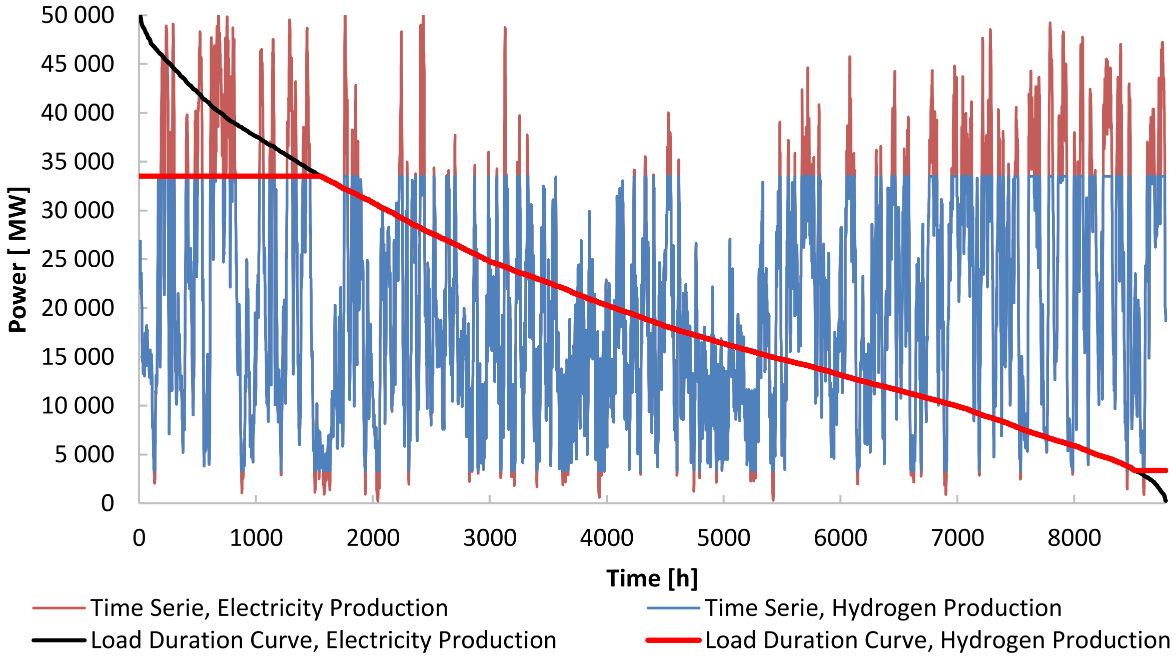
Electrolytic hydrogen production profile based on renewable energy sources

- European Hydrogen Market scenario was used from the earlier published Gasgrid-Fingrid joint research project.
- Renewable production profile was generated from 2024 production data by minimizing LCOH.
  - 20% wind offshore, 70% wind onshore and 10% solar.





Energy transmission infrastructures as enablers of the hydrogen economy and clean energy system, Final report of the joint project by Fingrid and Gasgrid Finland (2023)

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Characterization of hydrogen off-takers
flexibility potential for hydrogen intake

Four main off-taker types:

- Current oil refining industry – Low flexibility potential due to steady-state processes
- Hydrogen Direct Reduction of Iron (HDRI) – Moderate flexibility, HDRI is P2X product by itself.
  - Recent VTT case study [1] presented a techno-economic P2X optimization model, introducing concept of virtual storage for both H2 and DRI pellets.
- E-fuels and chemicals – Moderate to High flexibility
  - Methanol (and methane) synthesis reactors may have high flexibility.
  - eSAF production based on Fisher-Tropsch synthesis may have moderate flexibility [2]
- Export (most of the hydrogen exported) — flexibility is hard to evaluate
  - To be controlled with salt cavern storages located in Central Europe

[1] R. Weiss and J. Ikäheimo, "Flexible industrial power-to-X production enabling large-scale wind power integration: A case study of future hydrogen direct reduction iron production in Finland," *Applied Energy,* vol. 365, no. 123230, p. 23, 2024
[2] V. Dieterich, A. Buttler, A. Hanel, H. Spliethoff and S. Fendt, "Power-to-liquid via synthesis of methanol, DME or Fischer–Tropsch-fuels: a review," Energy & Environmental Science, vol. 13, no. 10, pp. 3207-3252, 2020.

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Modelling scenarios and key design principles

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3 modelling scenarios based on off-taker flexibility evaluation:

- Main scenario: Finnish off-take has no flexibility at all
- Full flexibility: Finnish off-take has 100% flexibility
- Storage scenario: Finnish off-take has no flexibility, but storages included

Key design principles:

- Hydrogen valleys at 30 barg, backbone network at max 80 barg and storages have max 150 barg pressure.
- 1,000 km long pipeline transfer system (984,000 m^3) has theoretically 3,936-ton linepack capacity between min. and max. design pressure. In practise, the pressure cycles will be smaller to secure the long lifetime of the pipe.
- Storage scenario has five 200,000 m^3 storages (approx. 9,000-ton capacity), increasing the total storage capacity in the system by over three times.
- The distances between valleys are chosen randomly as well as the production and domestic off-taker share, but so that the full capacity of pipeline is utilized during high production periods.

Summary of scenarios studied

Research scenario	Consumption	Storages
Main scenario	Flat, non-flexible	No
Flexible consumption scenario	Flexible	No
Storage scenario	Flat, non-flexible	Yes, 9,000 tons

Volume and theoretical minimum, maximum and difference of hydrogen mass in the system

Parameter	Value	Unit
System volume	984,000	m^3
Hydrogen mass at 30 barg pressure	2,563	ton
Hydrogen mass at 80 barg pressure	6,499	ton
Difference	3,936	ton

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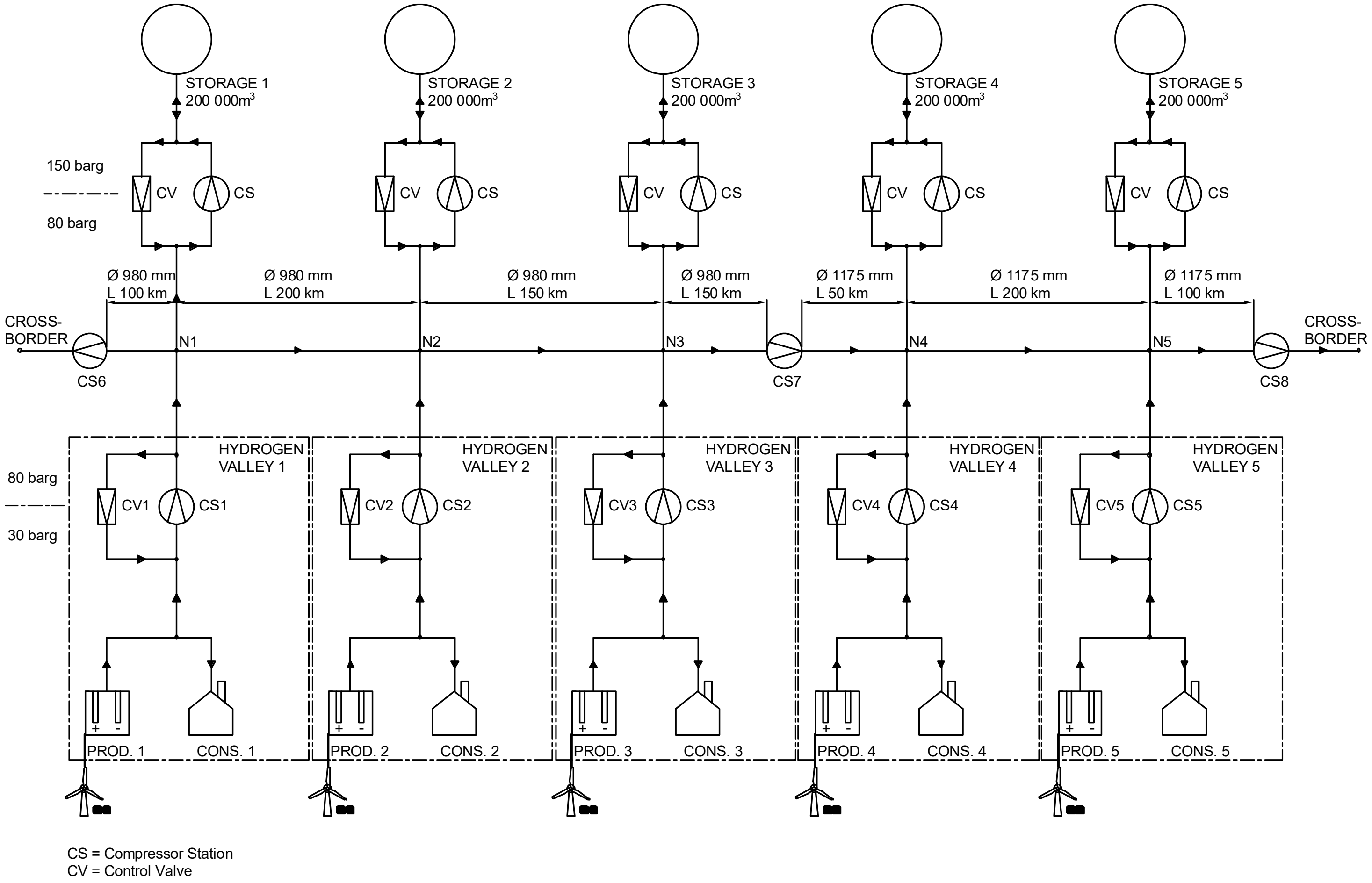
Simplified hydrogen network system model



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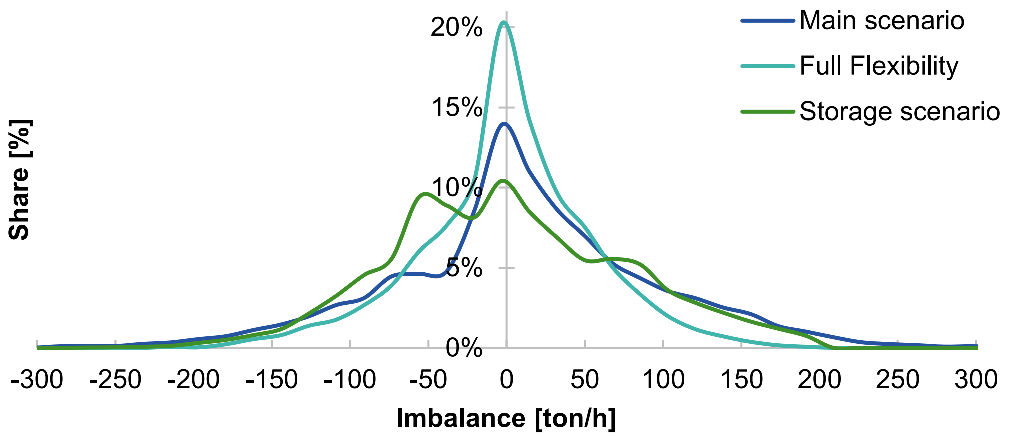
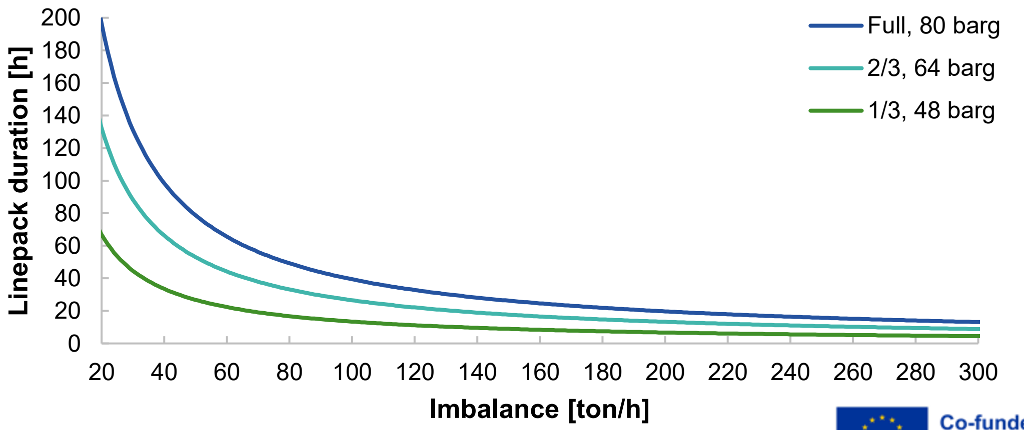
System imbalance and linepacking

- **System imbalance** is generated by:
  - Long distances (e.g., gas travels 1,000 km with 20 m/s speed in ~14 hours)
  - Off-taker flexibility vs. production
- Max imbalances were between -300 to 300 ton/h, but mostly between -100 and 100 ton/h in different scenarios.
- **Linepacking capabilities** were tested with different initial stage capacities: 1/3, 2/3 and full. E.g., 13 to 39 hours of linepack capacity with 100 t/h imbalance depending on the pressure level.
- **Pipeline can act as a short-term storage** for daily fluctuation, when the transfer is at the full capacity.
- In the early market phases or **at low volumes, there is more linepack capacity**.

Probability density of imbalance in all scenarios



Linepack duration for three initial stage capacities



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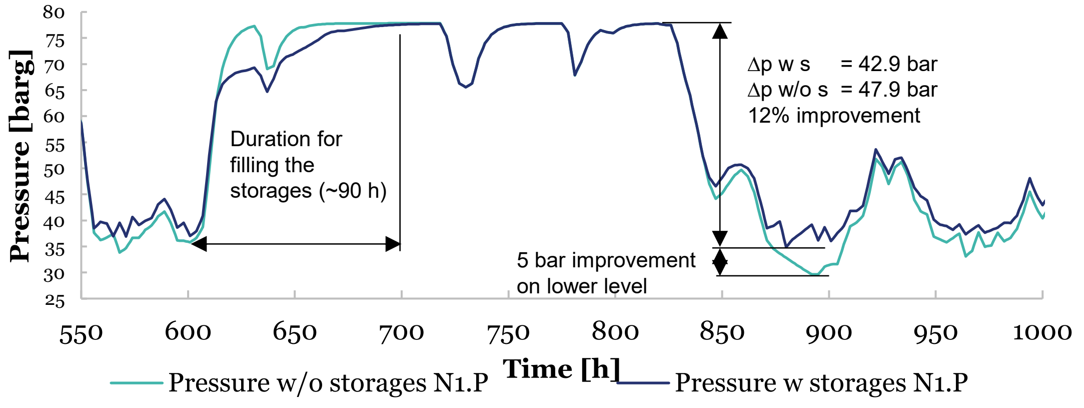
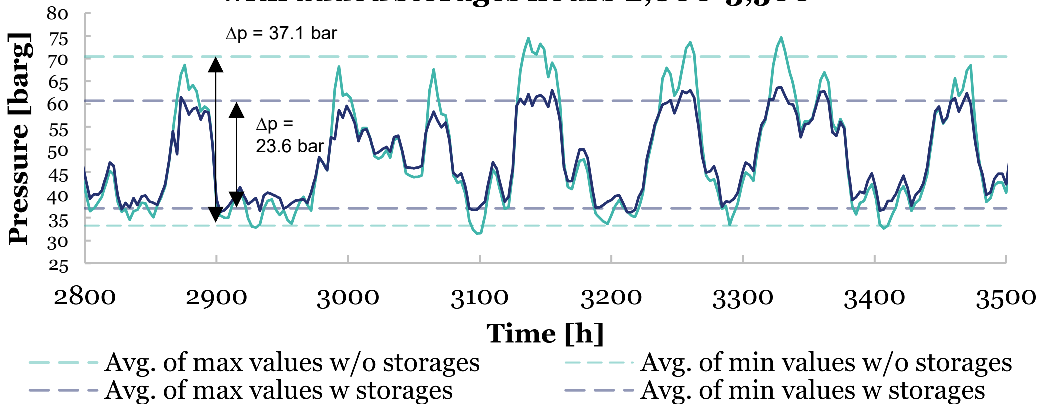
Impact of storages to transmission system

- Big storages are required to balance the fluctuation.
- Even with the 9,000 ton and 1 million m³ total storage volume, they are full in 90 hours when the full production period starts (upper figure).
- However, the modelled **storages can handle shorter production cycles very well** (lower figure).
- Storages reduce the pipeline pressure variation and increase the lifetime of pipeline with 82% in durability assessment.

Pressure in Node N1, comparison between original scenario and with added storages, hours 550 – 1,000, longest energy production cycle 610-826



Pressure in Node N1, comparison between original scenario and with added storages hours 2,800-3,500



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Conclusions

- Simulated hydrogen transfer pipeline system has **considerable amount of linepack capacity**.
- Long transportation distances generate imbalance to the pipeline system that linepack can and need to handle.
- When the market reaches **its maximum capacity, the pipeline can act only as an intraday buffer** securing operational safety.
- The **full-scale renewable fluctuation requires big storage volumes.**
  - Lined rock caverns (LRC) are seen one of the possible solution, but technology requires further development.
  - The use of salt rock caverns in the Central Europe for seasonal storage highlights the importance of multinational hydrogen system to stabilize the fluctuation from renewable sources.
- The **feasible system requires combination of off-take flexibility and storages** at the mature market.

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The role of large-scale hydrogen storage in integrated energy systems

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The role of large-scale hydrogen storage in integrated energy systems

Nobian

Louwrens op de Beek

PLATINUM Top 1% 2022 ecovadis Sustainability Rating

PLATINUM Top 1% 2023 ecovadis Sustainability Rating

PLATINUM Top 1% ecovadis Sustainability Rating SEP 2024

PLATINUM Top 1% ecovadis Sustainability Rating DEC 2025

Our company key numbers

Nobian has 3 salt production sites,
5 chlor-alkali plants,
and 1 chloromethanes plant
across 7 locations.

Head office in Amersfoort
and R&D centre in Enschede.

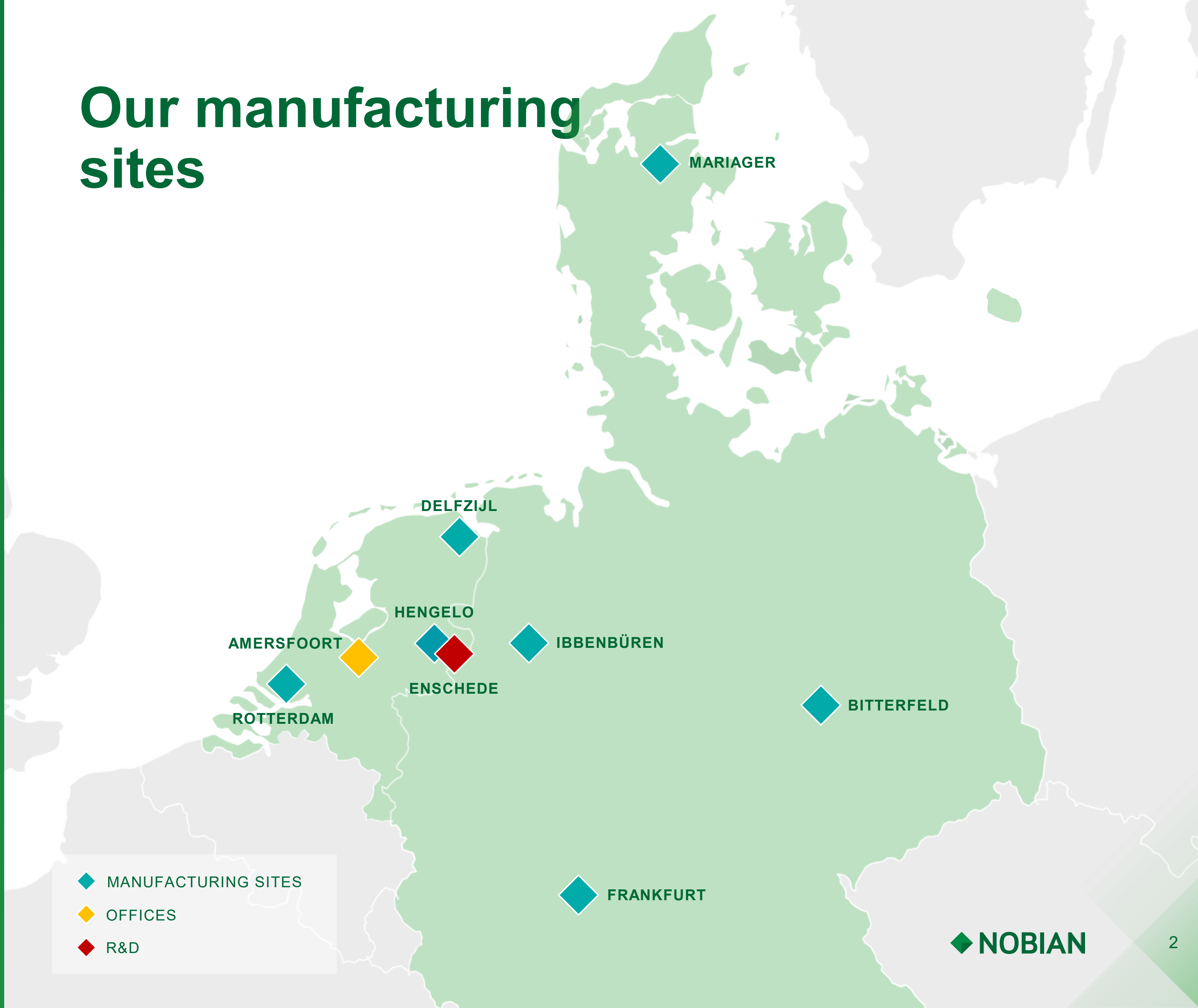
~1,600
People

1040 | 450 | 60

7
Manufacturing sites,
1 innovation centre

>€1.2 bln
Revenue

Our manufacturing sites



NOBIAN

Our value chain

delivers strategic independence of Europe for key materials.
Salt caverns to become cornerstone of hydrogen infrastructure.

85%

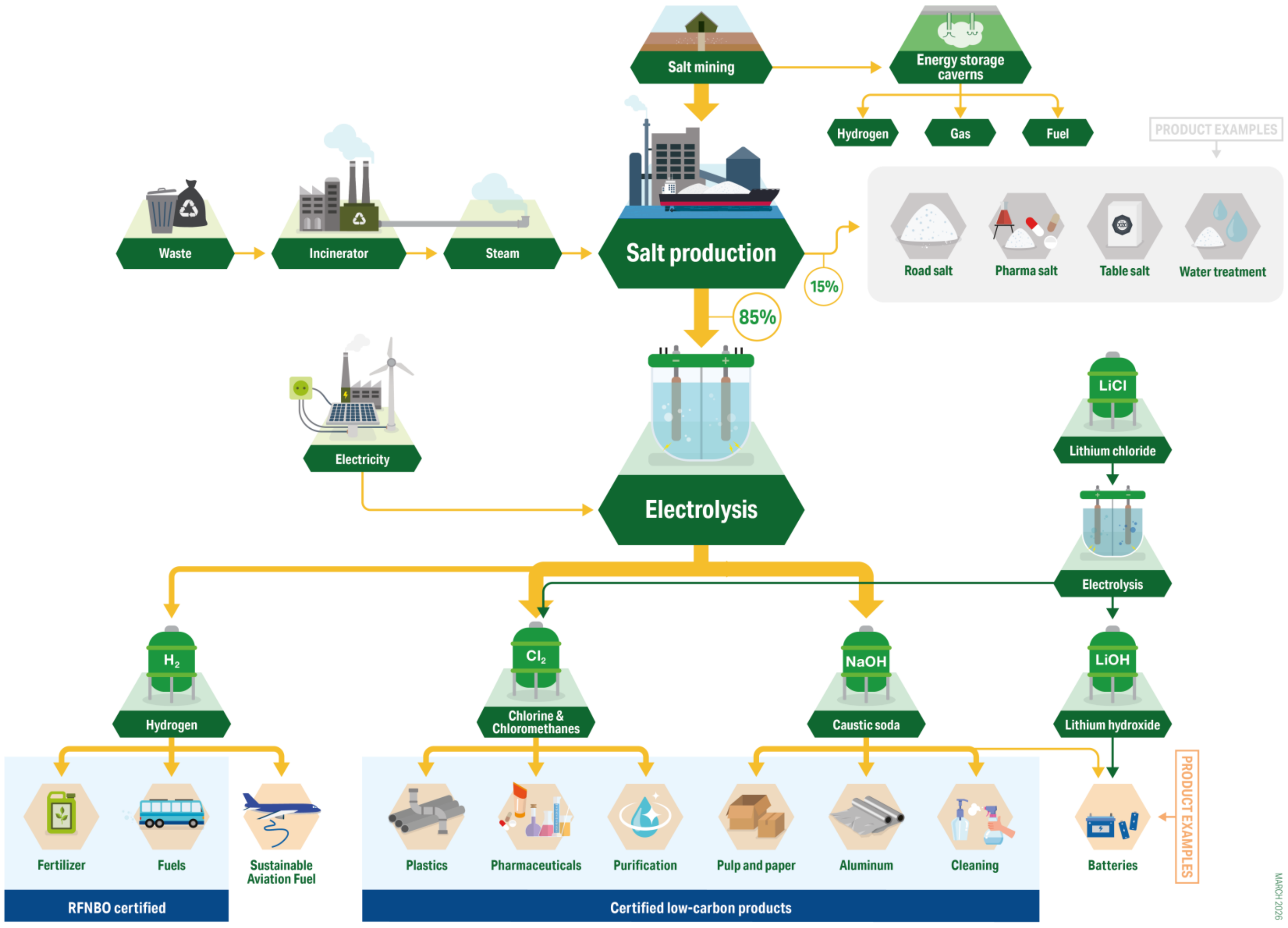
of Nobian's salt is sold to the chemical industry.

40%

of all products produced by the chemical industry is derived from salt.

100%

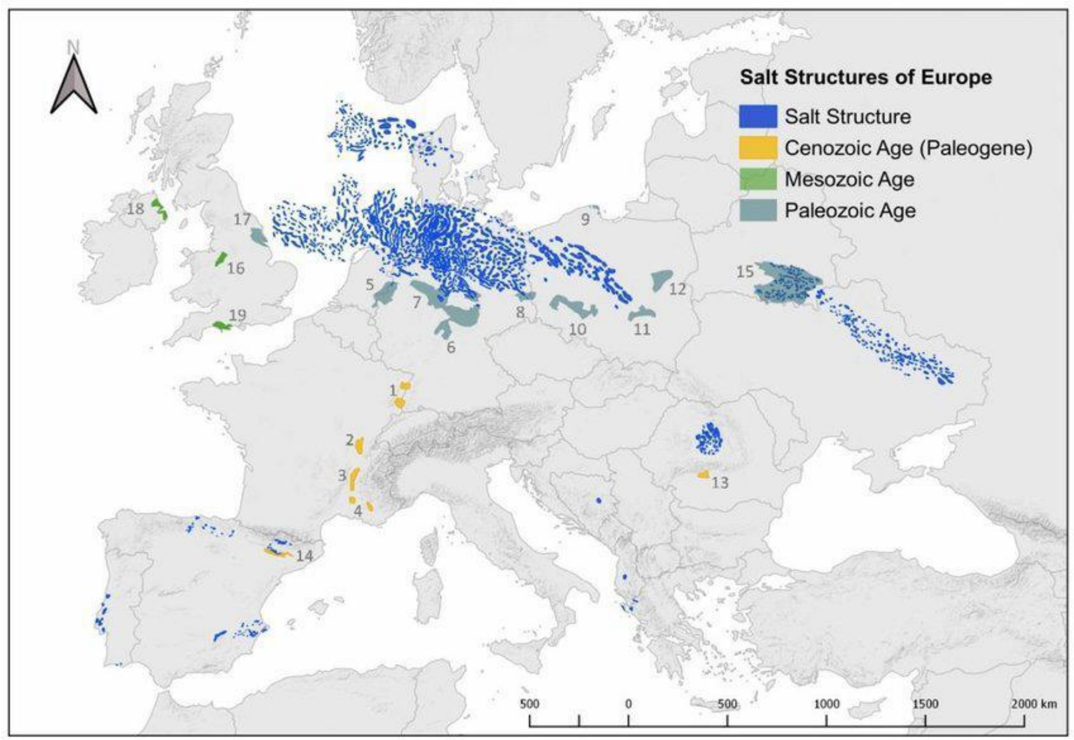
of the salt used in the chlor-alkali clusters Delfzijl, Rotterdam and Frankfurt, and a significant share of the salt used in other major chlor-alkali clusters in North-Western Europe is produced by Nobian.



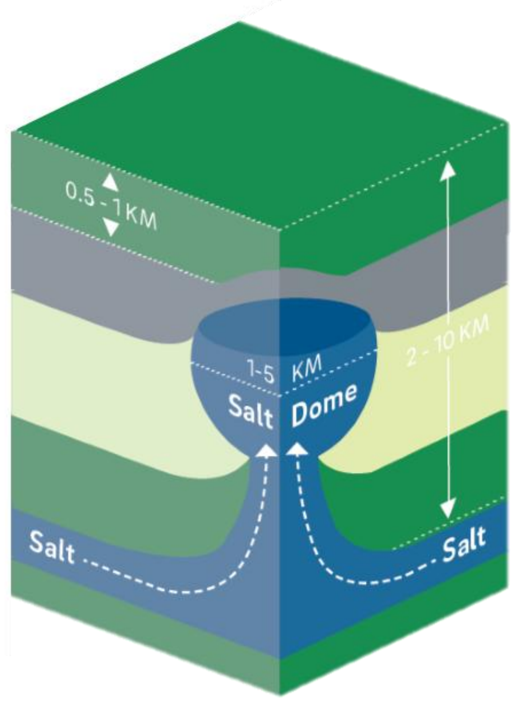
MARCH 2026

Europe has access to high purity salt deposits in Northwest Europe, but only a few are suitable for storage

Majority of high purity salt deposits are found in the Netherlands, Germany and Denmark



Salt domes are areas where salt has been pushed up by their lower density vs. surrounding rock



Source: Technical Potential of Salt Caverns for Hydrogen Storage in Europe, Dilara Caglayn et al. (2019)

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Salt caverns are the only proven and available technology for large-scale hydrogen storage

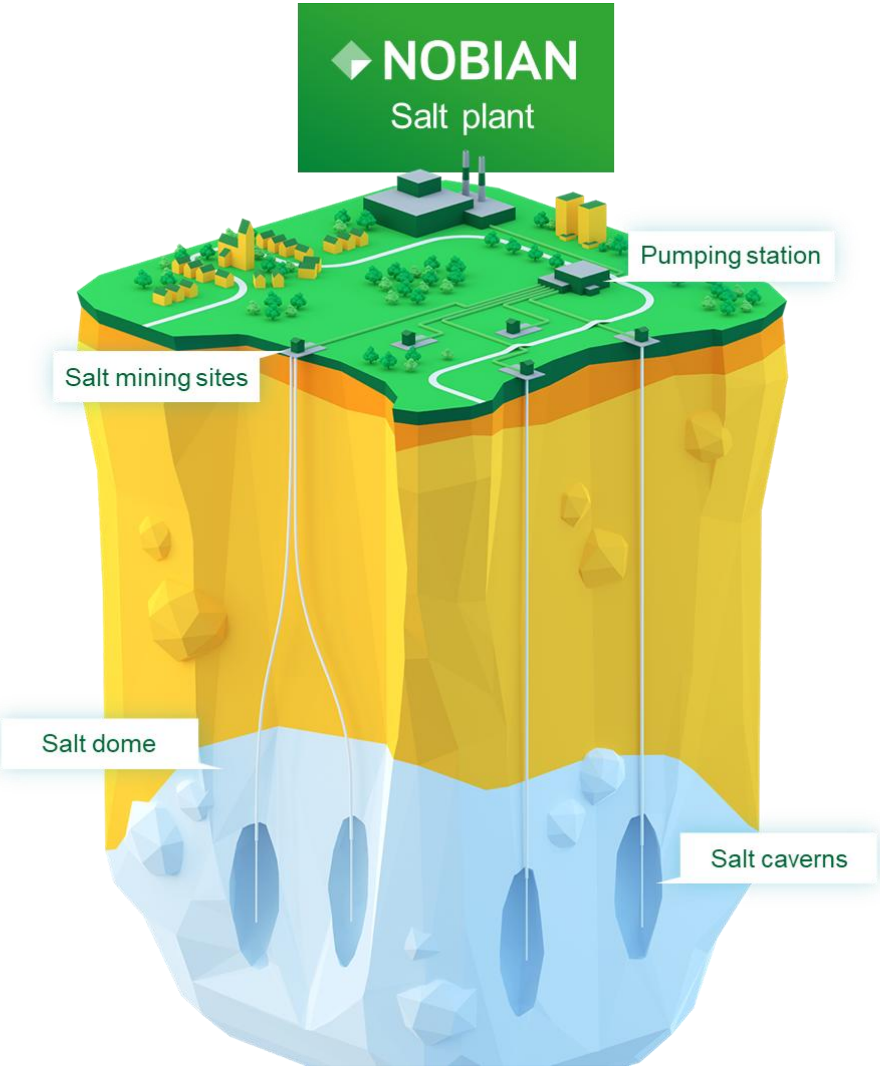
	Pressurized containers	Salt caverns	Depleted gas fields	Rock caverns
Main usage (volume and cycling)	◆ Small volumes (<1 GWh)[1] ◆ Storage cycling frequency: ***Daily*** ***Weekly*** *Seasonal/Strategic*	◆ Med/large volumes (130-260 GWh) ◆ Storage cycling frequency: ***Daily*** ***Weekly*** ***Seasonal/Strategic***	◆ (Very) large volumes (>3 k GWh) ◆ Storage cycling frequency: *Daily* *Weekly* ***Seasonal/Strategic***	◆ Medium volumes (20-30 GWh) ◆ Storage cycling frequency: *Daily* ***Weekly*** ***Seasonal/Strategic***
Technical feasibility	Technological feasibility is proven in practice	Sites in the US indicate the potential with high pressure and volume	Significant possibilities of contamination (currently testing only 10% purity)	Proven in practice with pure hydrogen at a low pressure and volume
Economic feasibility	Small scale Med/large scale Only economically feasible for small-scale H2 storage	Small scale Med/large scale Allows medium/high volume of hydrogen storage at limited cost	Small scale Med/large scale High extraction costs, but infrastructure is already well set up[2)]	Small scale Med/large scale Not economically feasible for large scale storage (high CAPEX)
Advantages ⊕	◆ Established storage technology ◆ Valuable option for many storage cycles (e.g. intra-day and daily)	◆ Risk of hydrogen contamination minimized ◆ Broad range of storage cycling frequencies	◆ Large storage volume potential across many locations in EU ◆ Well set-up infrastructure	◆ Allows for higher pressure storage ◆ Little cushion gas volumes needed
Disadvantages ⊖	◆ Suitability constrained to storage of small volumes ◆ Relatively high investment costs	◆ Geographical availability of salt domes dictates cavern location(s) ◆ Post abandonment risk (e.g. soil subsidence) needs to be mitigated	▪ Technical feasibility not yet proven ▪ Increased risk of hydrogen contamination ▪ Geographical availability of gas fields dictates storage locations	◆ High CAPEX costs ◆ Long-term exposure to steel (steel embrittlement due to hydrogen)

Source: TNO, BloombergNEF, Roland Berger
1. Assuming spherical pressure vessels are not utilized due to their limited storage pressure possibilities | 2. Can become more economically feasible at very large scale (pending technical feasibility)

NOBIAN

Development of energy storage caverns by Nobian

- Well-positioned to develop, operate and maintain energy storage caverns and infrastructure due to its longstanding experience and extensive capabilities
- Existing experience with the development of salt caverns to store various gasses/ liquids such as, hydrogen, natural gas, nitrogen and diesel-oil
- Two projects running in Zuidwending, the Netherlands:
  - **HyStock (Gasunie):** 4x H_2 storage caverns
  - **Zuidwending Oost (Nobian):** 9x H2 storage caverns
- Additionally, Nobian is exploring multiple energy storage opportunities in Northern Denmark

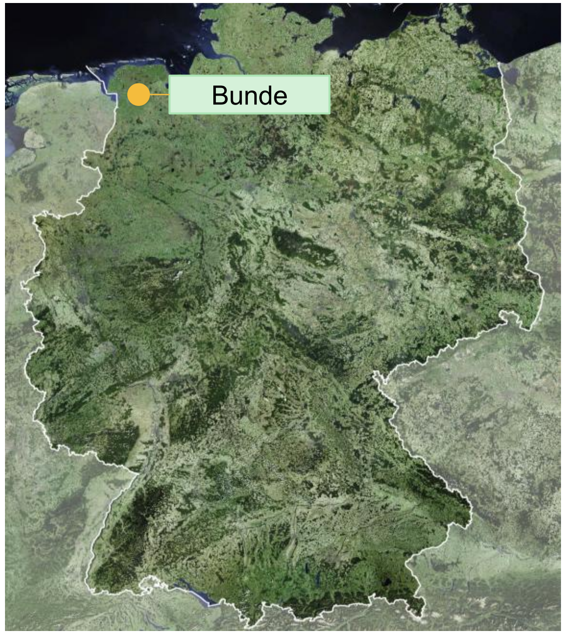


Nobian has access to suitable concessions and critical brine infrastructure for H2 storage caverns

The Netherlands

Denmark

Germany



Nobian is uniquely positioned and has the ambition to play a long-lasting role in hydrogen storage in North-West Europe

Salt processing plant | Salt concession | Business Development

NOBIAN

Development of hydrogen storage caverns takes time (min. 10 years)

Estimated lead time for H2 storage caverns[1]

~2 years — Preparations and permits

1 year — Engineering & drilling

4-8 years — Salt extraction via solution mining

1 year — Cavern filling with H2

Total lead time: ~8-12 years

Energy storage caverns need **to be developed on purpose** (existing caverns cannot be used)

Given lead time, essential to start development of H2 storage caverns **as soon as possible**

Multiple caverns can be **developed in parallel**, but limited by brine processing capacity

1. Timeline applies to the development of salt caverns for hydrogen storage in existing salt mining concessions. Development of greenfield locations takes more time

Netherlands: First 4x H2 storage caverns (HyStock) are under development, Nobian started drilling activities in '26

- Nobian will develop and leach the 4x salt caverns for Gasunie in Zuidwending
- Brine will be processed in Nobian's salt plant in Delfzijl

- One cavern leached (1 mln m3), three new caverns to be developed in the coming years
- In 2025, preparations started for two evaluation well drillings

- Drilling of first evaluation well started in February '26
- Drilling of second evaluation well and second borehole for existing cavern will follow shortly

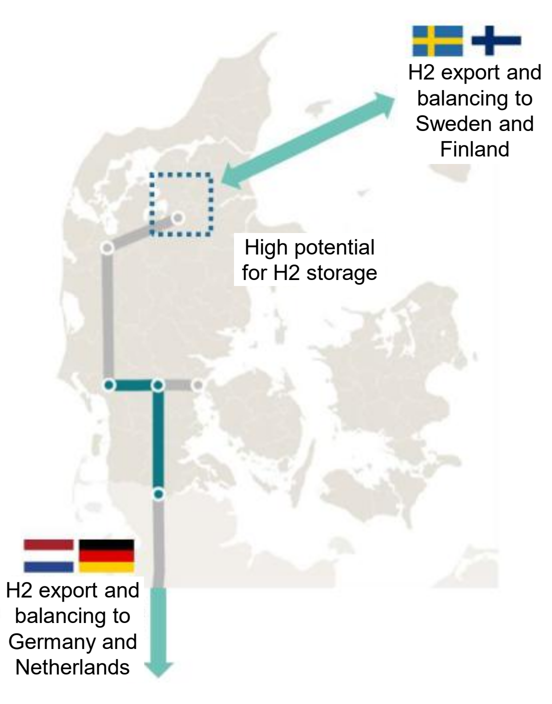
Denmark: High potential for hydrogen storage

Hydrogen storage will play a key role in future energy system across Denmark and other Nordic countries

- Renewable energy supply/ demand balance
- Energy system costs
- Security of supply
- Strategic autonomy and societal resilience

Denmark can unlock multiple H2 storage opportunities:

1) Hvornum (Nobian)
   - Existing salt mining area with potential for energy storage
2) Suldrup (Nobian):
   - Greenfield concession with potential for ~40 storage caverns[1]
3) Lille Torup (Gas Storage Denmark)
   - Existing natural gas storage facility; Nobian signed MoU to explore joint development of hydrogen storage caverns



Nobian salt processing plant | Nobian salt concession | Gas Storage DK concession

1. Additional research required with studies, modeling and fieldwork (incl. exploration drilling)

Source: Recommendations for an updated Danish Power-to-X strategy, Dansk Industri & Green Power Denmark (2026)

NOBIAN

NOBIAN

Salt | Essential Chemicals | Energy | Storage Caverns

www.nobian.com

www.linkedin.com/company/nobian

Energy system flexibility in hydrogen valleys

BalticSeaH2

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ENERGY SYSTEM FLEXIBILITY IN HYDROGEN VALLEYS

Hydrogen Valley dynamics and policy recommendations in the Baltic Sea region

Kimmo Karhu, Aalto University

BalticSeaH2

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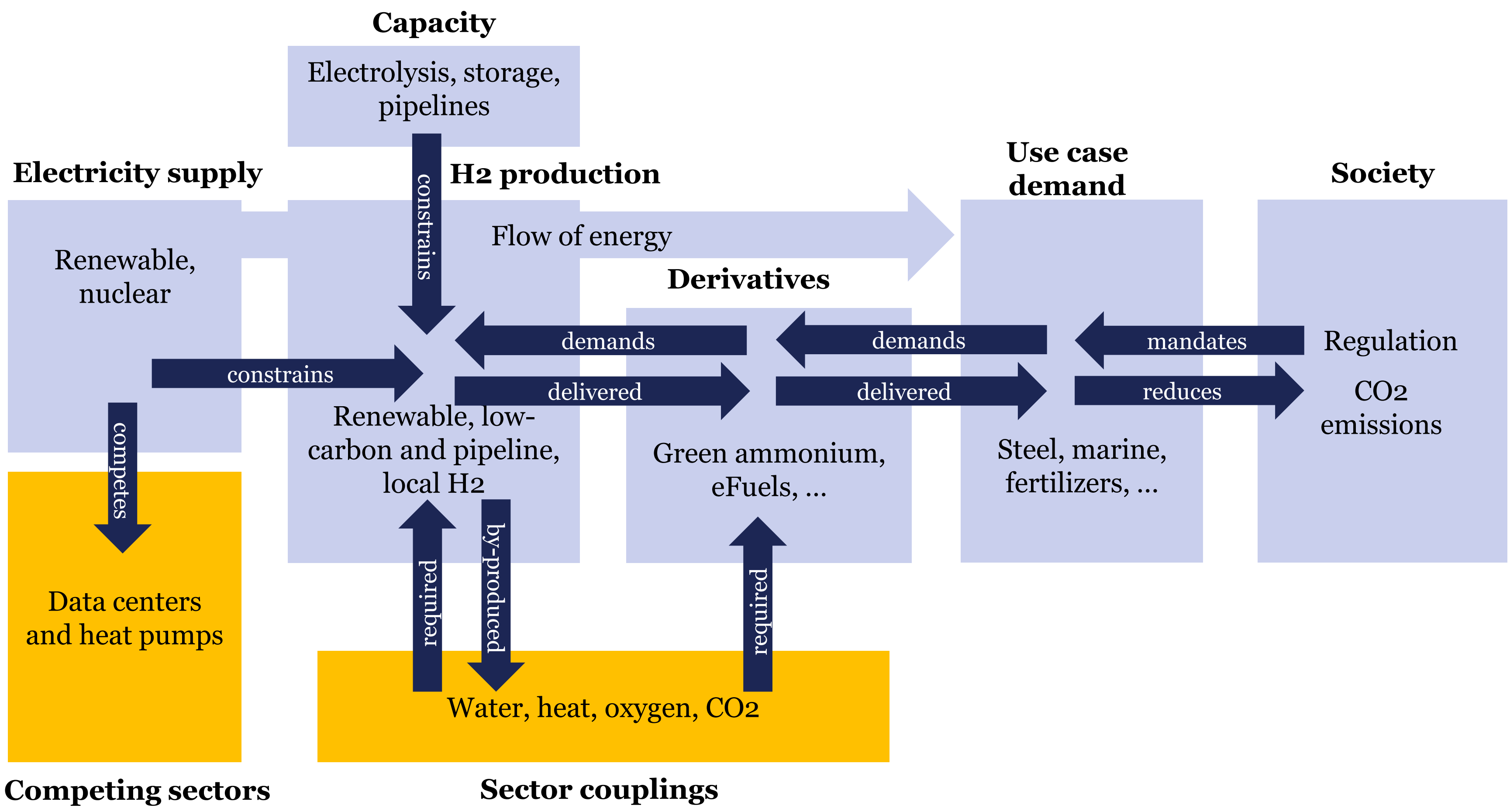
System Dynamic Model of the Valley

- Models the potential development of green hydrogen and derivative production in the future (until 2050)
- Model is driven by investments into production capacity
- Resource availability constrain the model (e.g., renewable electricity, pipeline capacity)
- Does not currently take prices into account
- Different scenarios can be tried by varying supply and demand



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Using Finland’s Green Investment Dataset

EK dataset

314	05-17-2023-Renewable Power (	17/05/2023	Energy sto	Renewabl	Uusikaupu	0	0	0	0	2. Inve	2025	50	ht	/www.ibvsuomi.fi/kalannin_sahkovarasto/
315	03-25-2025-Merus Power-Lemp	25/03/2025	Energy sto	Merus Pov	Lempäälä	0	0	0	0	3. Sta	2025	1	ht	/news.cision.com/fi/merus-power-oyj/r/merus-power-rakensi-
316	03-27-2025-GreenStack-Loppi	27/03/2025	Energy sto	GreenStac	Loppi	0	0	0	0	3. Sta	2025	5	ht	/news.cision.com/fi/eltel-networks/r/greenstack-ja-eltel-toteut
317	02-08-2023-Taaleri Energia-Len	08/02/2023	Energy sto	Taaleri Ene	Lempäälä	20	0	0	0	3. Sta	2024	30	ht	/www.arvopaperi.fi/porssitiedotteet/merus-power-oyj-sisapiirit
318	11-23-2023-PVO-Vesivoima-Ou	23/11/2023	Energy sto	PVO-Vesiv	Oulu	0	0	0	0	3. Sta	2025	3	ht	/www.sttinfo.fi/tiedote/70060915/pvo-vesivoiman-ensimmaisel
319	02-15-2023-Lempäälän Lämpö-	15/02/2023	Energy sto	Lempäälä	Lempäälä	0	0	10	0	1. Pla	2026	0	ht	/www.lempaalanlampo.fi/content/fi/36/35137/Ty%C3%B6-%20
320	11-20-2024-Lehto Group-Siikajc	20/11/2024	Energy sto	Lehto Grou	Siikajoki	0.5	0	0	0	2. Inve	2025	0	ht	/www.kaleva.fi/lehto-groupilta-uusi-aluevaltaus-rakentamassa-
321	02-17-2025-Alu-Relecon-Riihim	17/02/2025	Energy sto	Alu-Relec	Riihimäki	0	0	0	0	3. Sta	2025	0.1	ht	/www.tekniikkatalous.fi/uutiset/riihimakelaisen-pintakasittelijar
322	08-08-2024-UPM Energy-Kouvol	08/08/2024	Energy sto	UPM Ener	Kouvola	0	0	0	0	2. Inve	2025	6	ht	/www.upm.com/fi/tietoa-meista/medialle/tiedotteet/2024/08/u
323	11-19-2024-Helen-Lohja	19/11/2024	Energy sto	Helen	Lohja	0	0	0	0	2. Inve	2025	5	ht	/www.helen.fi/uutiset/2024/helenin-uusiutuvan-sahkon-kapasit

Year + MW/Ton

Model Excel

0.5	tons(H2)/ton
CO2 emissions avoided coefficient for emethane	
6	tons(CO2)/ton
CO2 use coefficient in emethane production	
5.5	tons(CO2)/tc https://www.
H2 per MW	
150	tons(H2)/MW

time	tons(emthane)/ye
0	0
48	900
60	8466
72	44466
84	63966
96	183966
108	341866
120	512866
132	782866
360	2135089

Year	Tons(emethane)	Tons(H2)	MW	ID	Link	Comment	equiv Tons(emethane)
2020							
2024			3	02-15-2023-F	https://www.kokkolanener		900
2025			0.22	12-15-2023-I	https://www.sss.fi/2023/12		66
2025			5.00	12-12-2024-\	https://vireor	FROM RAW	1500
2025			20.00	02-02-2022-F	https://p2x.fi/en/project/		6000
2026			20	01-19-2022-F	https://ren-g	second	6000
2026			100	03-21-2024-I	https://yle.fi/	2026 (100 mw	30000
2027			25	12-22-2022-F	https://yle.fi/a/74-2008001		7500
2027	12,000			09-07-2023-F	https://ren-gas.com/ajank		12000
2028			50	12-05-2024-I	https://valtio	in the draft de	15000
2028			50	02-14-2024-(	https://www.	50% split em	15000
2028			300	05-04-2022-F	https://ren-gas.com/ajank		90000
2029			333	01-14-2025-\	https://vetya	split 3 ways	99900
2029	58,000			01-22-2025-F	https://yle.fi/a/74-2013849		58000
2031			900	03-21-2024-I	https://yle.fi/	2026 (100 mw	270000
2030			50	01-01-2025-\	https://vetya	50% split em	15000
2030			500	09-04-2024-\	https://yle.fi/	50 % slpit em	150000
2030			20	01-19-2022-F	https://ren-gas.com/ajank		6000

Sum of equiv Tons(emethane)	
Year	Total
2020	0
2024	900
2025	7566
2026	36000
2027	19500
2028	120000
2029	157900
2030	171000
2031	270000
2050	0
Grand Total	782866

Model Input

Data Input

BalticSeaH2

Aalto University
School of Science

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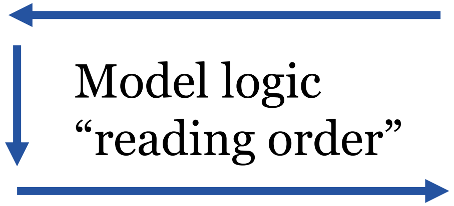
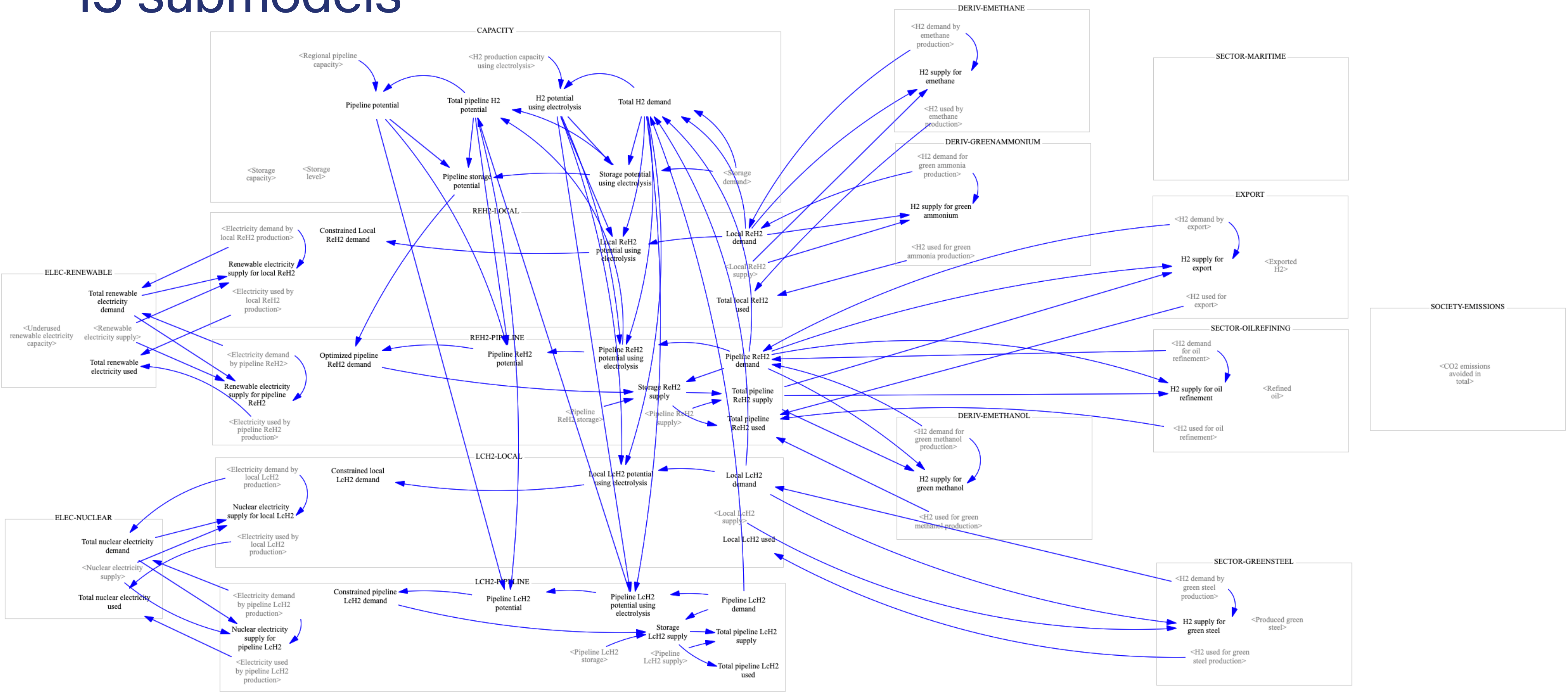
A modularized model with similar production logic in each ~15 submodels





Main policy observations concerning development of green hydrogen market in **Finland**

1. Renewable electricity becomes a bottleneck
2. Sector couplings: CO_2 demand and heat supply match with national supply and demand
3. Significant potential for reducing CO_2 emissions
4. Data center investments significantly hinder CO_2 emission reduction potential of green hydrogen

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Please note that all results in the following slides are based on a tentative analysis and forward-looking information that is linearly projected until 2050. We have purposefully used aggressive maximalist scenario to stir discussion.

For these reasons, please be cautious in interpreting the results.

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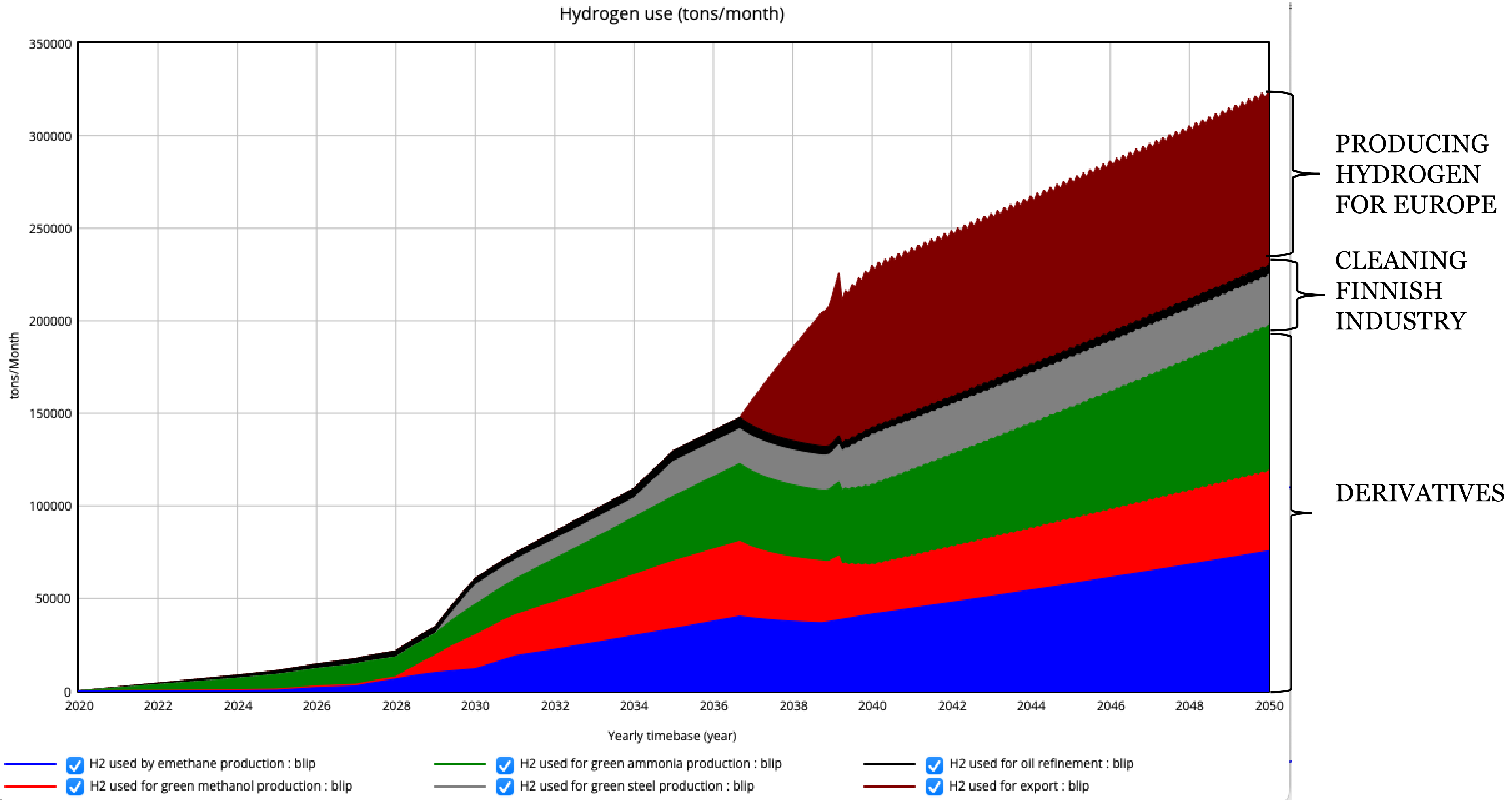
Overall hydrogen production and use

Annual Hydrogen production of 3.7 Million tons annually by 2050



- Green steel uses low-carbon H2 (nuclear) and others use renewable H2
- Of domestic use, roughly half is pipeline H2 and half local H2
- Hydrogen production for European demand is not based on investments but just assuming the the whole pipeline capacity is produced

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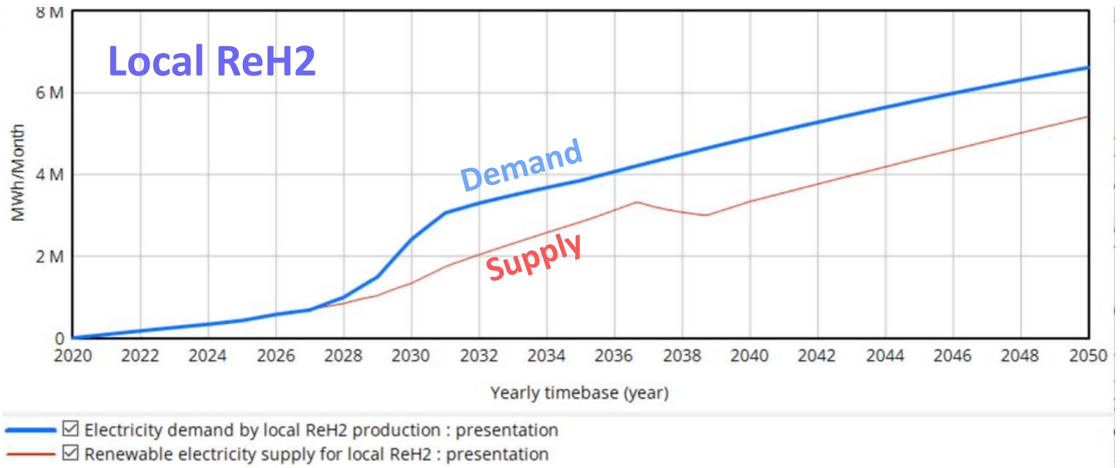
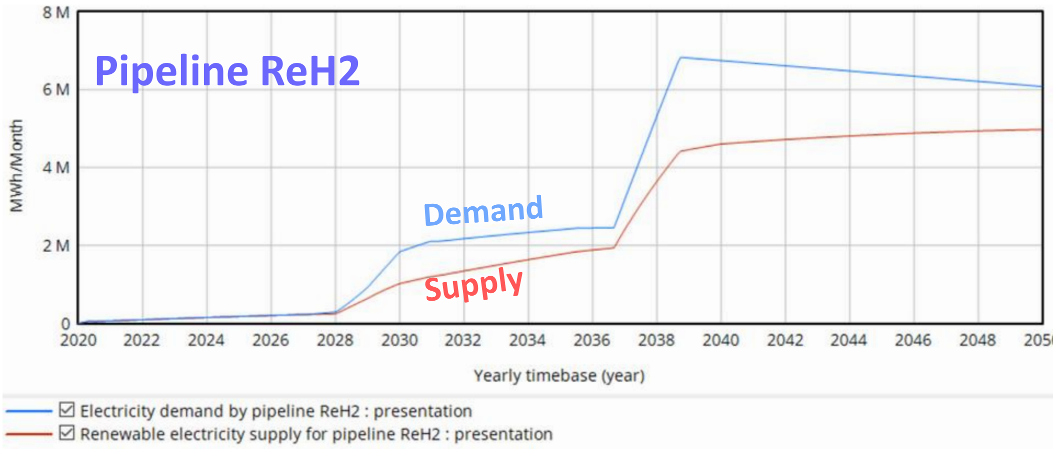
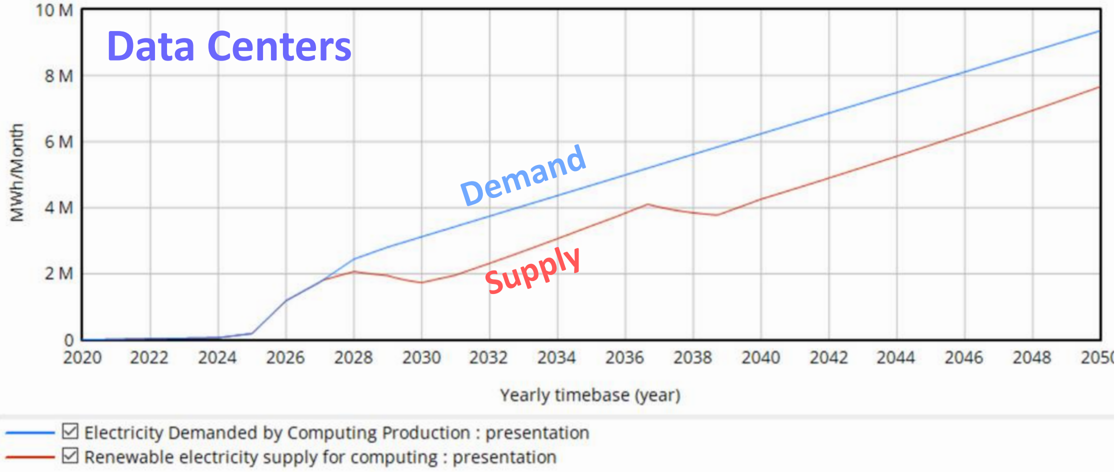
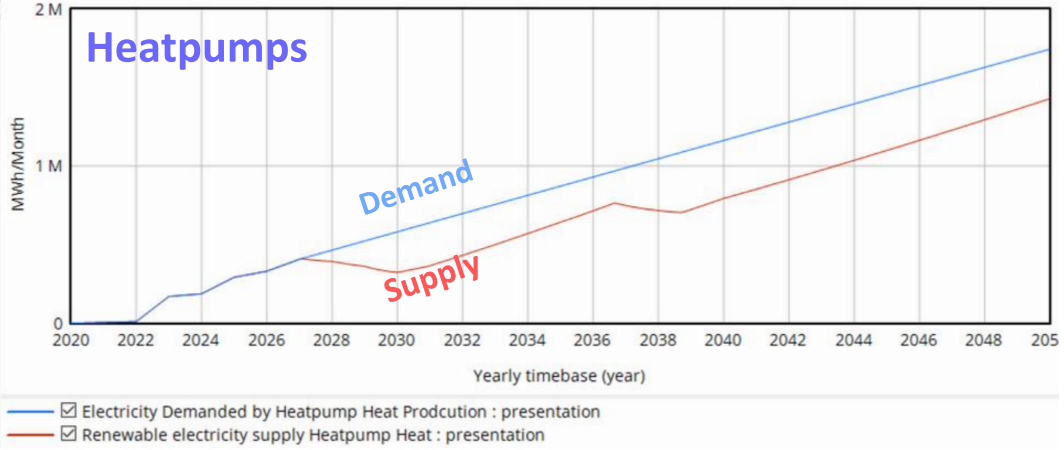
1. Renewable electricity becomes a bottleneck









Demand in all sectors is more than supply that is constrained by available renewable energy

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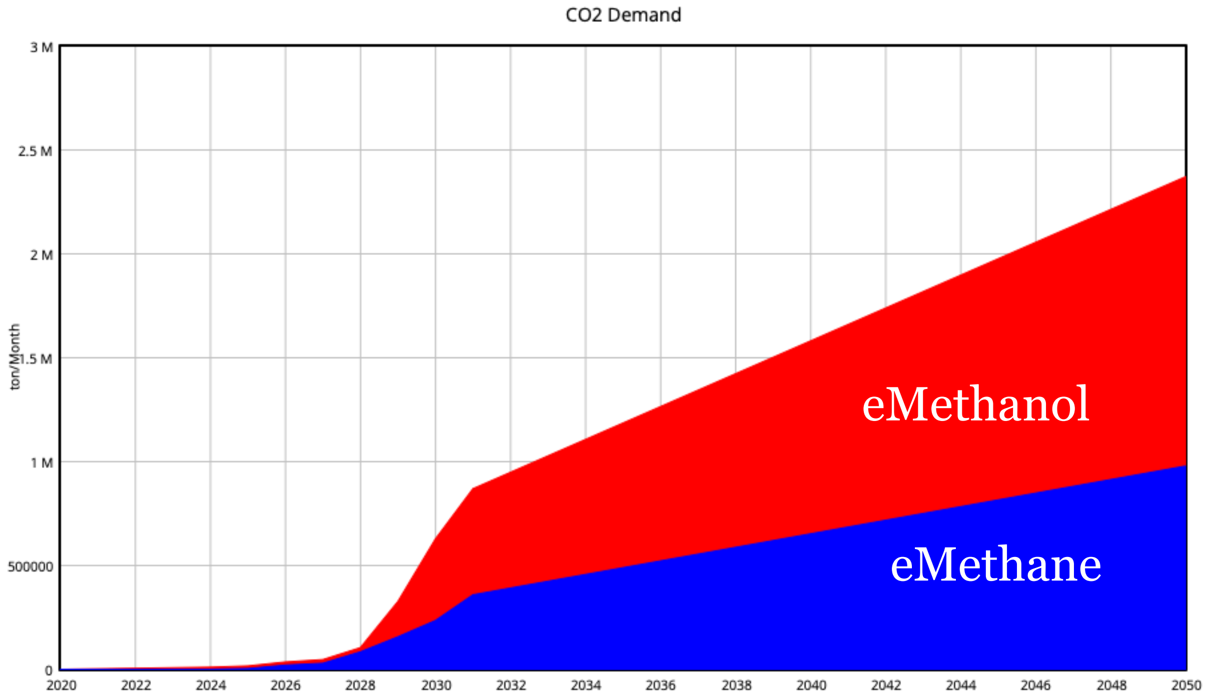
2. Sector couplings: CO2 demand and heat supply match with national supply and demand

CO2

- CO_2 use by eMethane and eMethanol production grows to ~2.4Mtons/month → 28.8Mtons/year
- Estimated CO_2 emissions from forest industry in Finland are around 24Mtons/year

Heat

- Assuming that 15% of electrolysis input electricity can be utilized for district heating (Roest et al., 2023), potential heat production grows to ~37,5TWh/year
- As a competing source, heat pumps amount to ~7TWh/year
- The annual demand for district heating in Finland is ~38TWh and industrial heat ~50TWh (note! high-temperature heat that is not directly exploitable from electrolysis)



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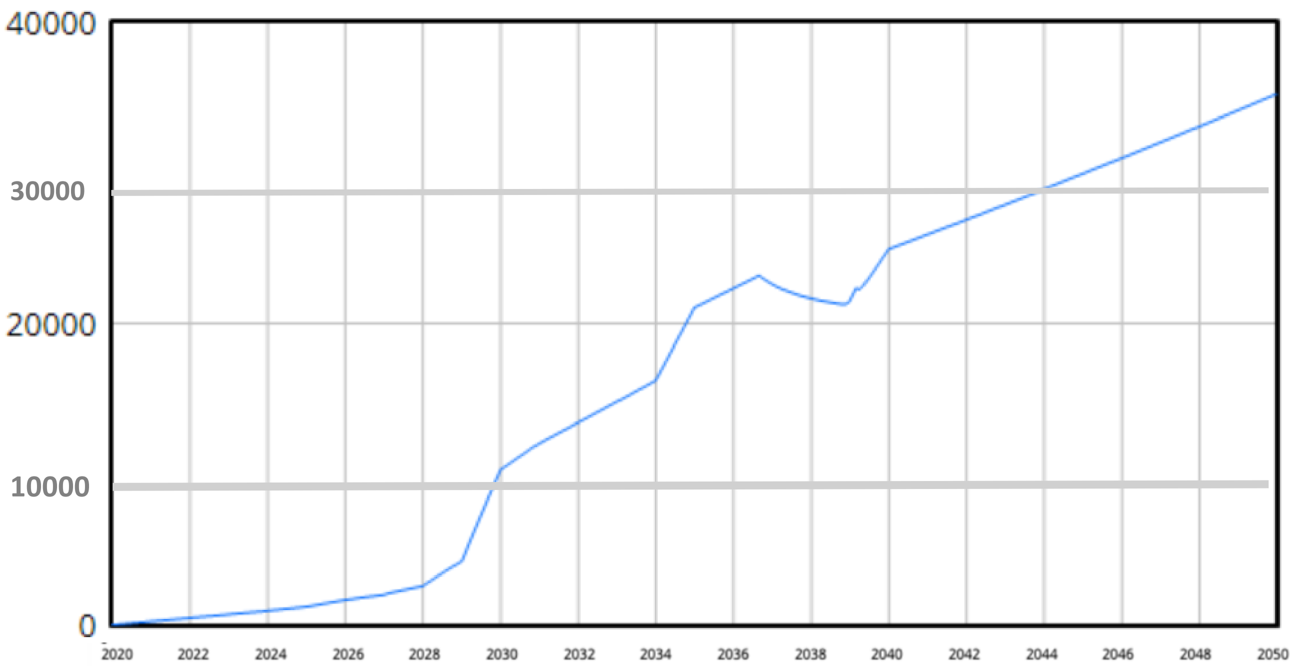
3. Significant potential for reducing CO2 emissions

- By 2050 hydrogen and derivative production in Finland will enable avoiding ~35Mtons CO2 emissions that roughly equals with what Finland currently produces annually
- H2 export to EU will add ~30% on top
- In addition, heat sector coupling can potentially replace ~9TWh of fossil-based heat production (and avoid ~3Mtons of CO2)
    - Wood-based fuels +15TWh

CO2 Emissions avoided (Ktons Co2/Year)



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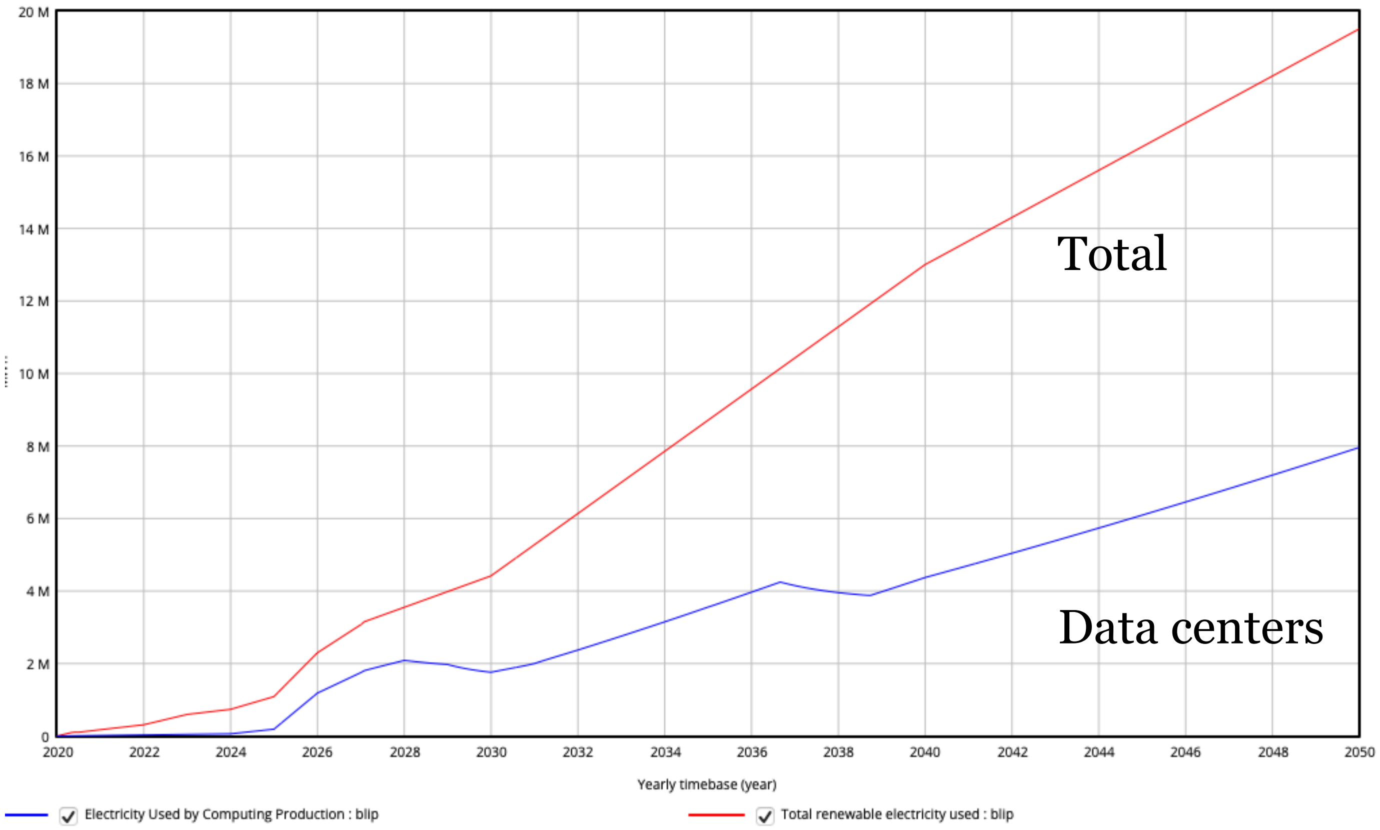
4. Data center investments significantly hinder CO2 emission reduction potential of green hydrogen

1. Compete for the same renewable energy
   - If current investment rate is extrapolated until 2050, data centers will consume ~100TWh/year (of 250TWh/year)
2. **Significant Co2 emission reduction opportunity is missed (~40%)**
3. Hinder heat production sector coupling by competing with it
   - Around 70% of data center input energy can be utilized for district heating → ~70TWh/year

However, in the short term, data centers may positively drive renewables development before hydrogen kicks off and also in their part help to replace fossil-based heat production

Renewable energy use (MWh/month)



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Energy system flexibility in hydrogen valleys

BalticSeaH2

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Thank you!

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