Hydrogen economy in Finland: opportunities and challenges ahead

H2Cluster Finland & HYGCEL project joint seminar

May 22nd, Oodi Central Library, Helsinki

Agenda

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Share Your Thoughts on Finland's Hydrogen Economy

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Hydrogen economy in Finland: the big picture

Simo Säynevirta
H2 Cluster Finland chair

Petteri Laaksonen
Research Director, School of Energy Systems, LUT

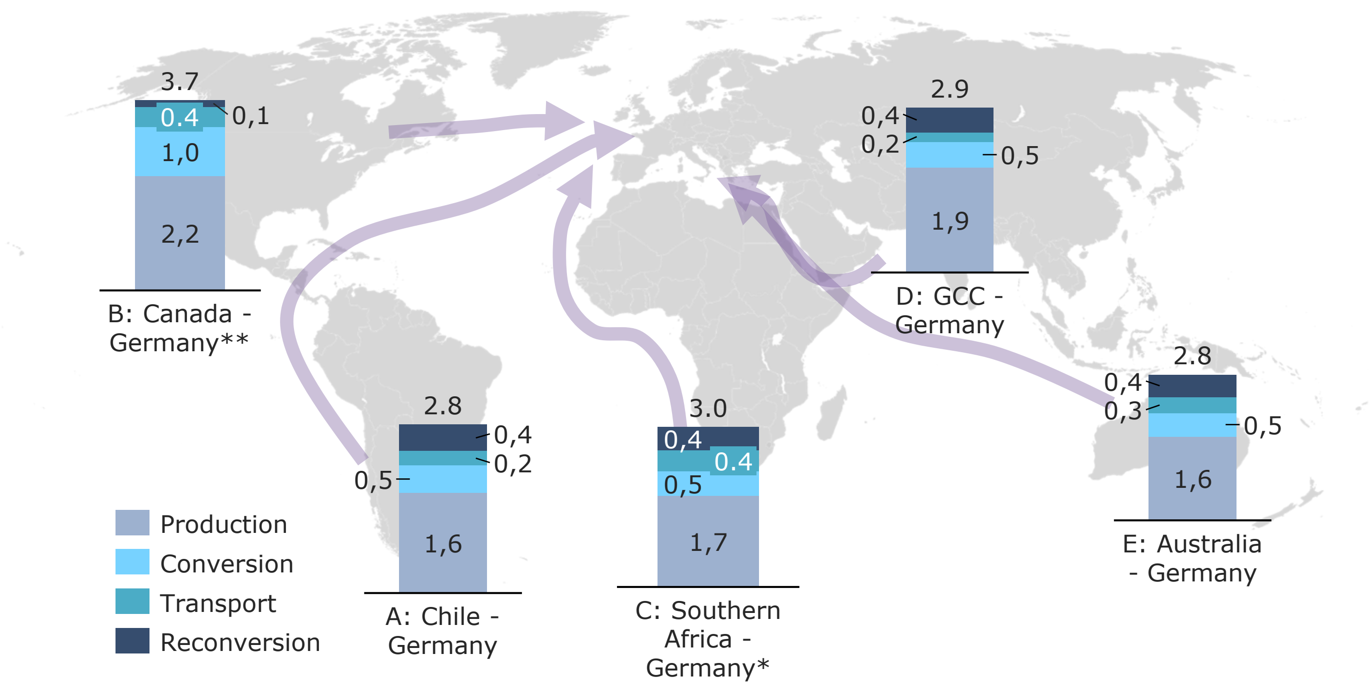
The northern way to a free industrious Europe

H2Cluster Finland & HYGCEL project joint seminar, 22.5.2024, Oodi

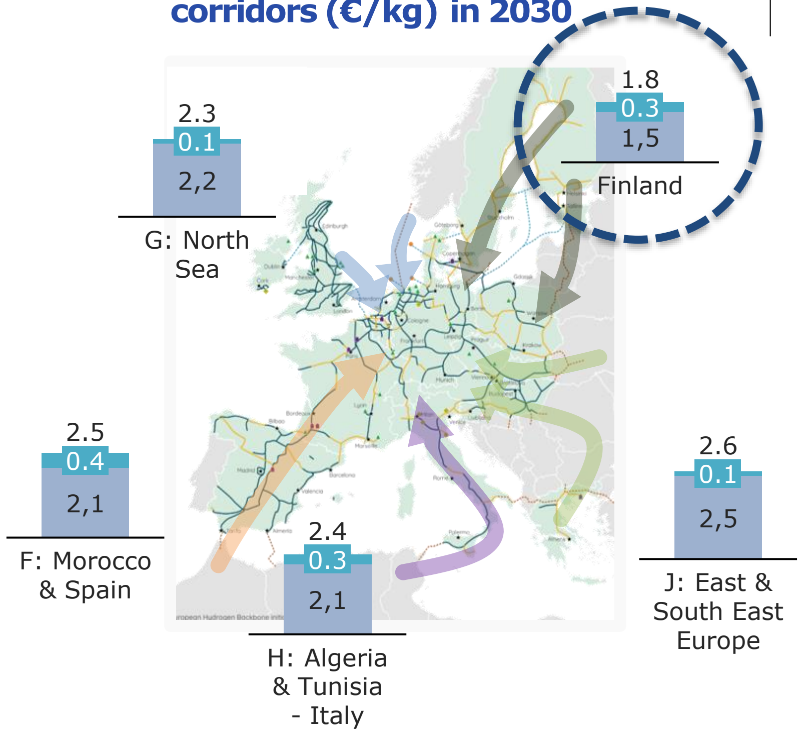
Europe needs a balanced approach that uses each region’s strengths to its fullest

Finland aims to produce 10% of Europe’s clean hydrogen, projected cost at €1.8-2.5kg

Levelized cost of hydrogen for shipping corridors (€/kg) in 2030



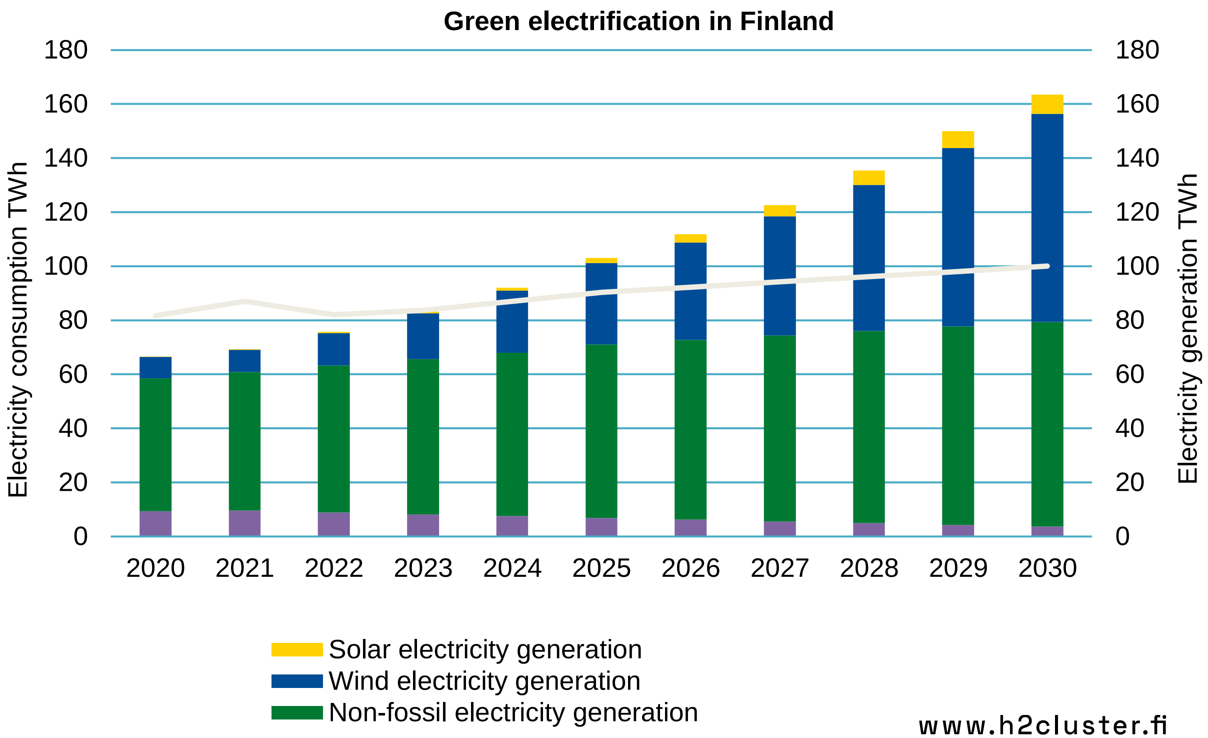
Levelized cost of hydrogen for pipeline corridors (€/kg) in 2030



H2 cluster FINLAND

Source: Guidehouse analysis based on: EHB; Ministry of Natural Resources, Hydrogen Strategy For Canada (2020); Ministry of Energy, Government of Chile, National Green Hydrogen Strategy (2020); UNSW Sydney, The Case for an Australia Hydrogen Export market to Germany (2021); Department of Science and Innovation, Hydrogen Society Roadmap for South Africa (2021); Qamar Energy, UAE’s Role in H2 Economy (2021). *Carrier undefined in strategy; assumption: ammonia, **Carrier undefined in strategy; assumption: LH2

Finland is a natural starting point for Europe to produce hydrogen



www.h2cluster.fi

We connect multiple pathways to secure and reinvent Europe’s most critical industrial and transportation value chains

More than 30
hydrogen projects under construction or planned

Annual hydrogen production of planned projects more than
700.000 tonnes

Trusting, yet prepared - we drive comprehensive security

2.4 GW

of wind power completed in just one year while detaching from Russian energy

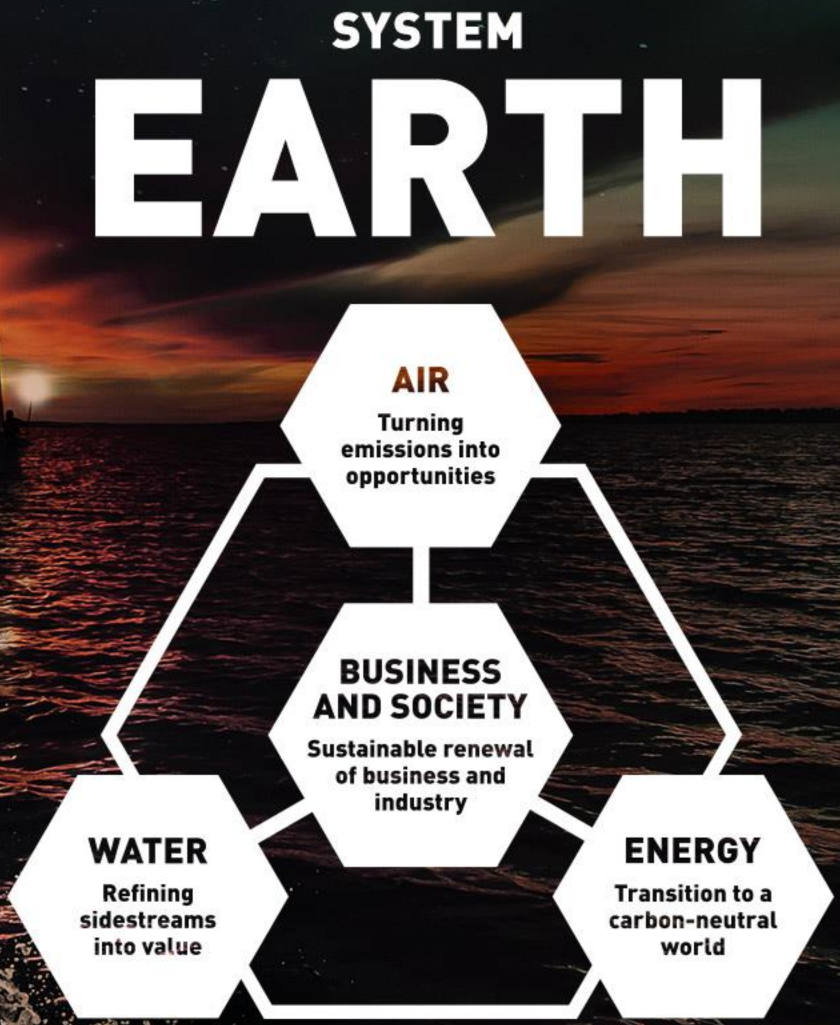
Connect a million ways
of hydrogen with

H2cluster FINLAND

LUT University

LUT UNIVERSITY STRATEGY 2030 • TRAILBLAZERS – Science with a Purpose

HYDROGEN CLUSTER & HYGCEL PROJECT JOINT SEMINAR



Helsinki, 22.5.2024

Petteri Laaksonen, D.Sc., Research Director

petteri.laaksonen@lut.fi

GREEN ELECTRIFICATION & P2X ECONOMY

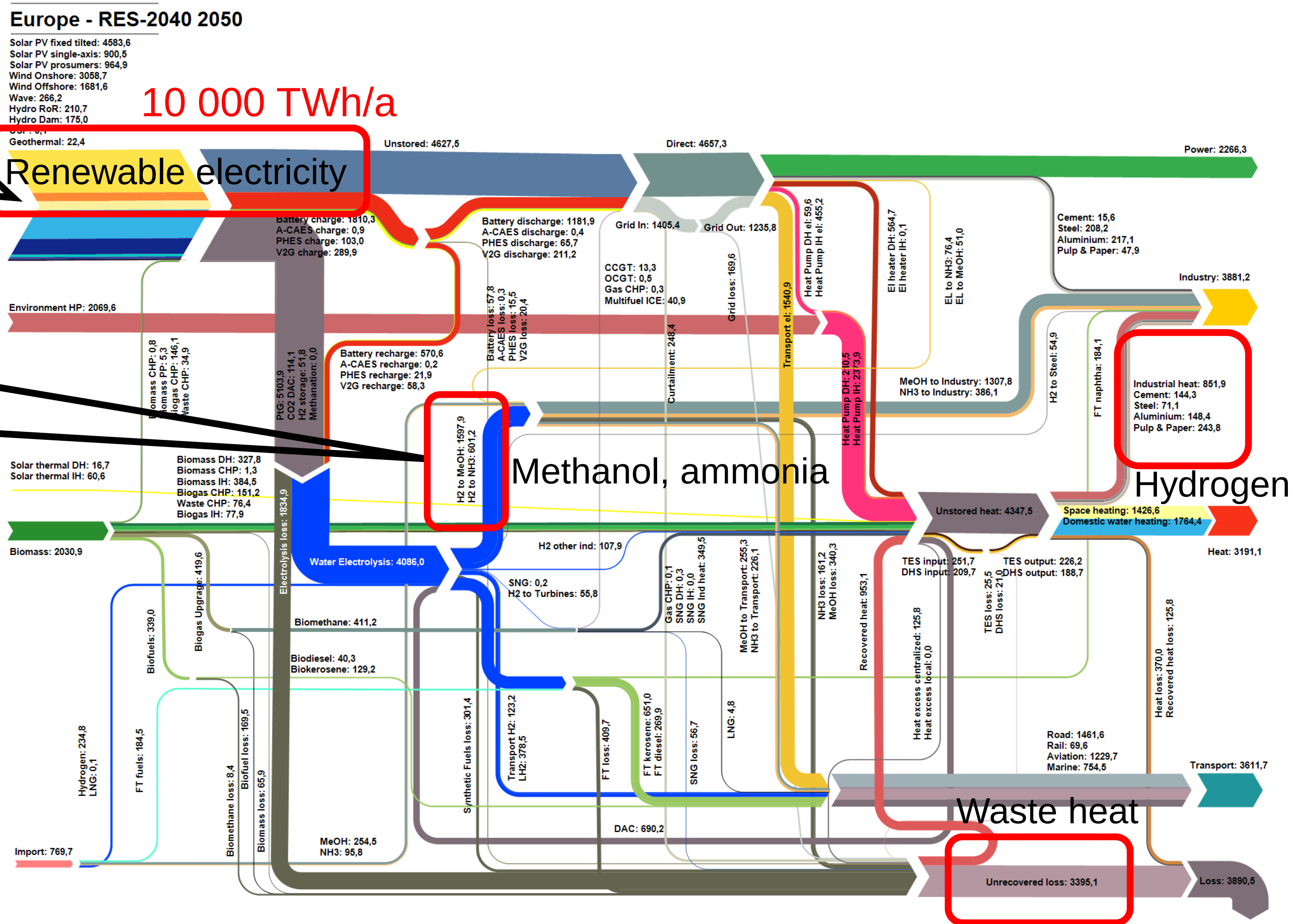
Big picture and conclusions from the research

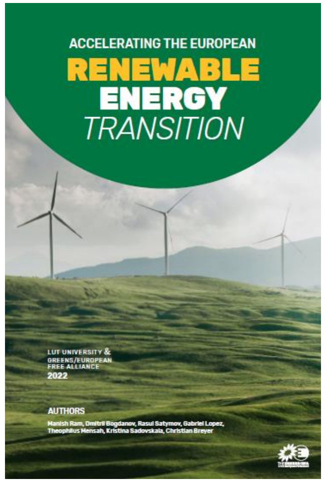
- **Zero CO_2 emission, low-cost energy system is based on renewable electricity (mainly solar PV and wind power)**
  - Demand of electricity will three to four-fold in Europe
  - Electricity will be always used directly whenever possible (electric vehicles, heat pumps, desalination, etc.)
  - Indirect electrification via hydrogen will take place by e-fuels (marine, aviation), e-chemicals, e-steel; power-to-hydrogen-to-X
  - 24/7 production in industries (like steel, chemical) with little flexibility is viable by flexibility hydrogen storages
- **Competitive advantage is based on the price of electricity**
  - Iberian peninsula and Nordic countries in Europe have competitive advantage
  - In Finland, the potential for affordable electricity production exceeds easily 1000 TWh's (in 2023 it was 79,8 TWh)
  - Competitive advantage of Finland (Sweden, Norway) is related to affordable and available electricity and bio-based CO_2
  - Nordic countries could represent 35-40% of the electricity demand in EU (3500 – 4000 TWh)
- **New industrial investments will locate to near affordable electricity production**
  - Transporting of hydrogen or electricity long distances is not competitive
  - Most cost competitive way of production of hydrogen and e-chemicals, is near to electricity production
  - Exporting chemicals, plastics and fuels is easy - logistics is in place
  - Based on the LUT modelling, methanol will be the biggest chemical by volume. Methanol and its derivatives will be used in chemical industry as well as a fuel in shipping and aviation (MTO to eKerosene)
  - Social acceptance of the change is crucial to achieve the positive impacts in society
- **Regulation plays a big role in market creation**
- **Resilience of Finnish energy system and welfare of the society will be remarkable improved due to electrification**

Energy system transition in Europe

Electrical energy

Hydrogen economy is a subset of power-to-x - economy

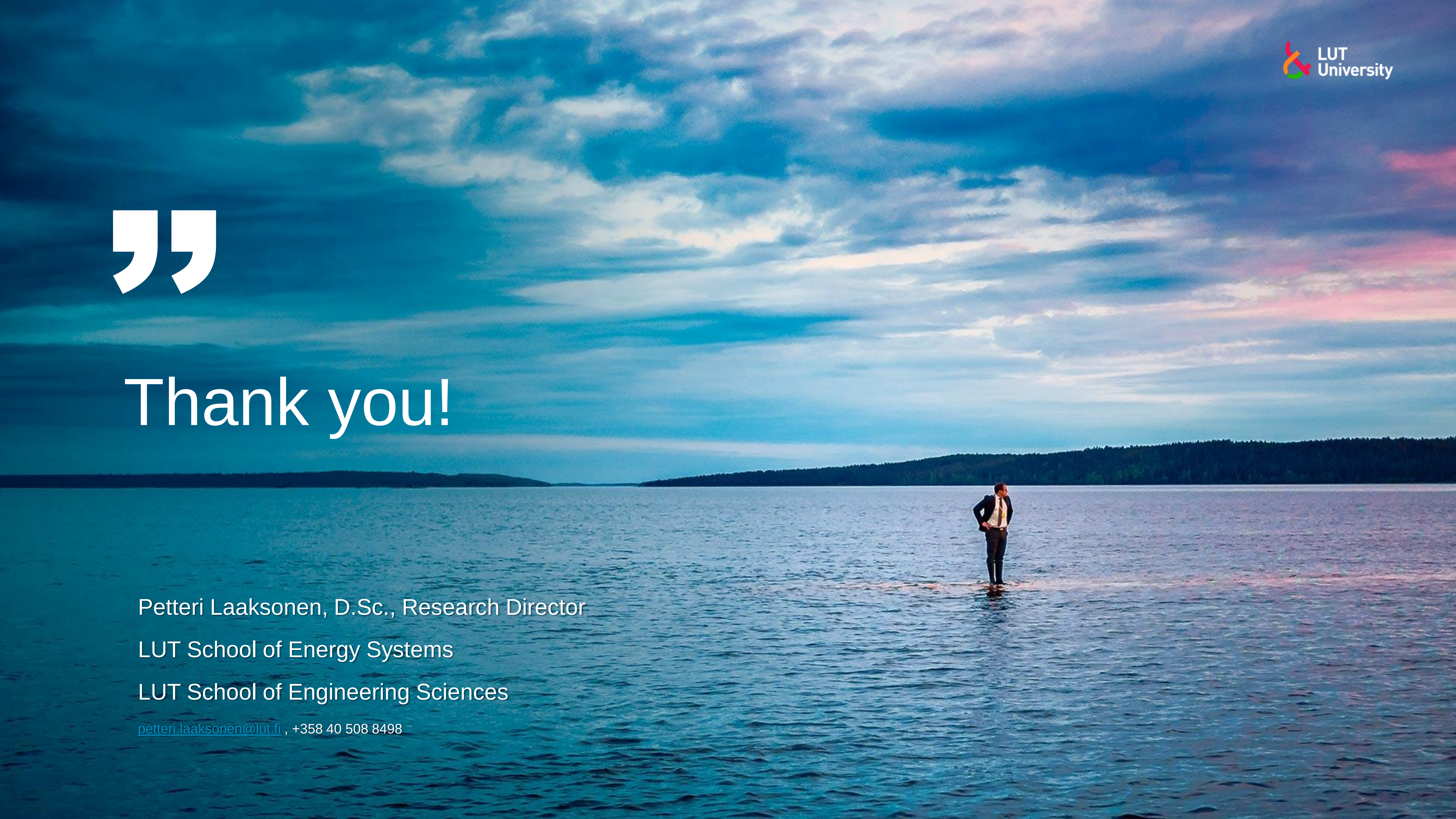




Greens/EFA, 2022

https://extranet.greens-efa.eu/public/media/file/1/7862

Authors: Manish Ram, Dmitrii Bogdanov, Rasul Satymov, Gabriel Lopez, Theophilus Mensah, Kristina Sadovskaia, Christian Breyer


LUT University
Thank you!
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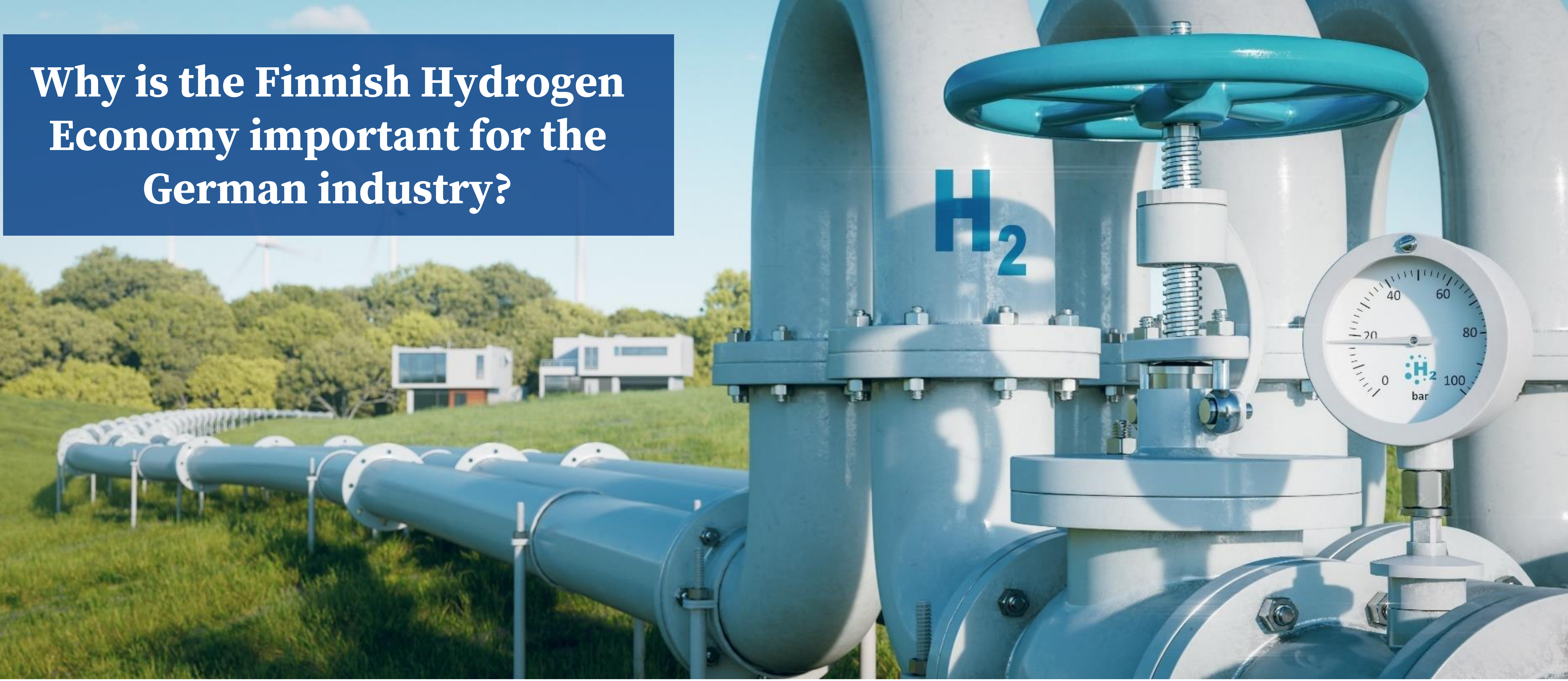
Why is Finnish hydrogen economy important for the German industry?

Lotta Westerlund
Deputy Managing Director

German-Finnish Chamber of Commerce

Why is the Finnish Hydrogen Economy important for the German industry?



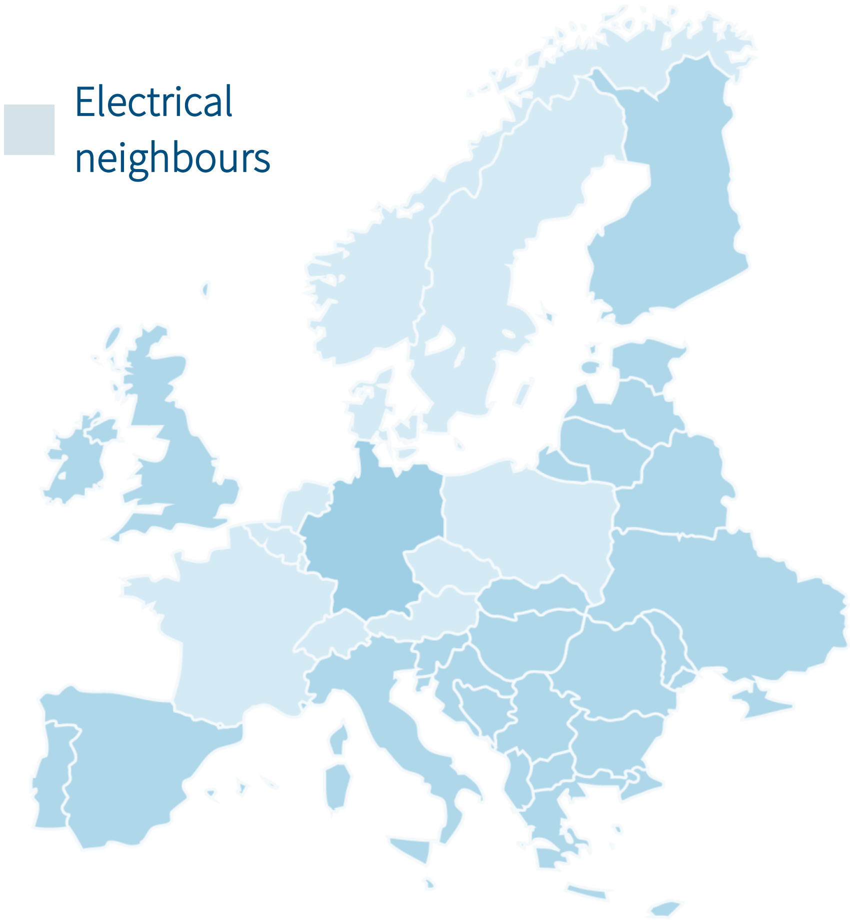
AHK
Deutsch-Finnische Handelskammer
Saksalais-Suomalainen Kauppakamari
Tysk-Finska Handelskammaren

AHK Finnland – the German-Finnish Chamber of Commerce

The AHK Network with over 150 locations in 93 countries across the world advises, assists and represents German and local companies worldwide to help them establish or expand their foreign business. With this aim, the AHK Finnland acts as institution to promote German and Finnish foreign trade and is subsidised by the German Federal Ministry for Economics and Climate Action (BMWK) as well as the Finnish Ministry of Economic Affairs.

We at the German-Finnish Chamber of Commerce work bilateral with both German and Finnish companies to find and support new connections and opportunities.

Germany is in a unique position to drive forward the transformation of the energy system in Europe



Economy

- Largest economy in Europe, 3rd largest in the world
- Population: **84.3 million**
- Gross Domestic Product per capita: **52,800 USD**

Energy sector

- Electricity consumption per capita: **6,204 kWh**
- Total Energy Consumption: **10,791 PJ**
- Total power capacity: **245 GW**, renewable: **167 GW**

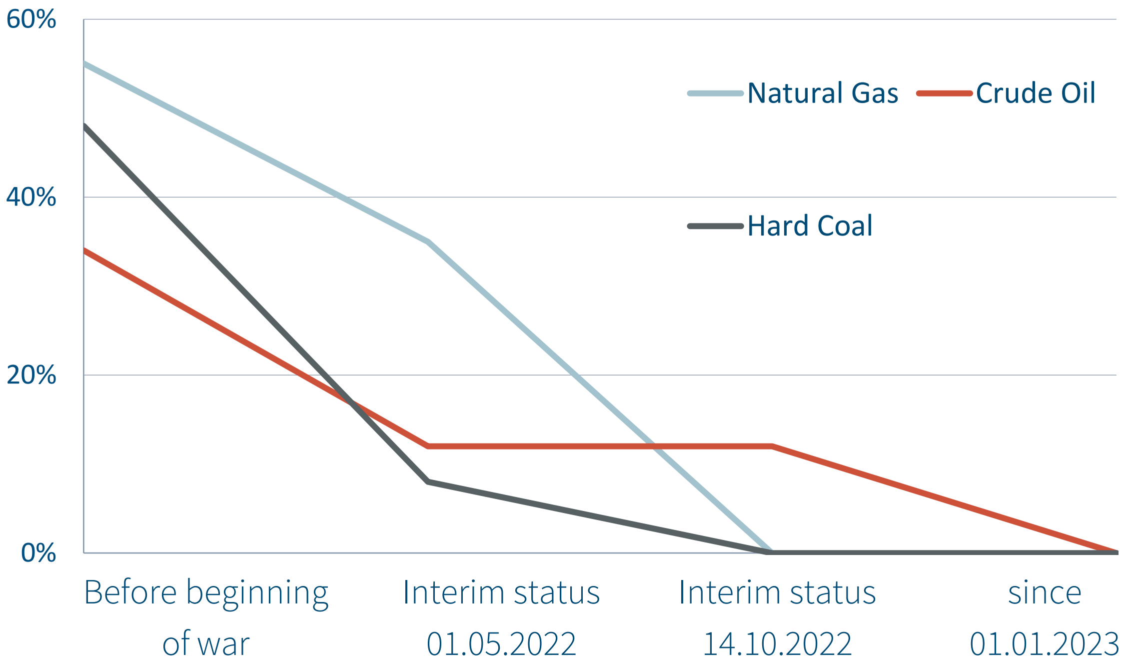
“Energiewende” x3

- Closing of the last nuclear power plants
- Replacing coal with renewables
- Independence from Russian gas

Source: Guidehouse, March 2024 based on Agora 2024, Destatis 2023 & UBA 2024

Germany restructured its energy imports in response to the Russian invasion of Ukraine

Development of energy imports from Russia



Diversification of energy supply

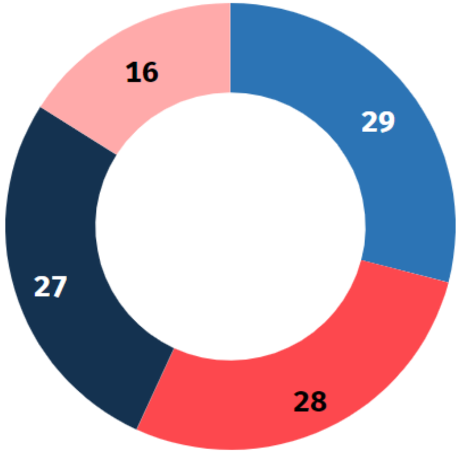
- Restructuring energy imports and thinking about the fossil-free future
- Temporary LNG infrastructure will be H_2-ready

Source: Guidehouse 2024 based on BAFA 2022a, BAFA 2022b, BMWK 2022b

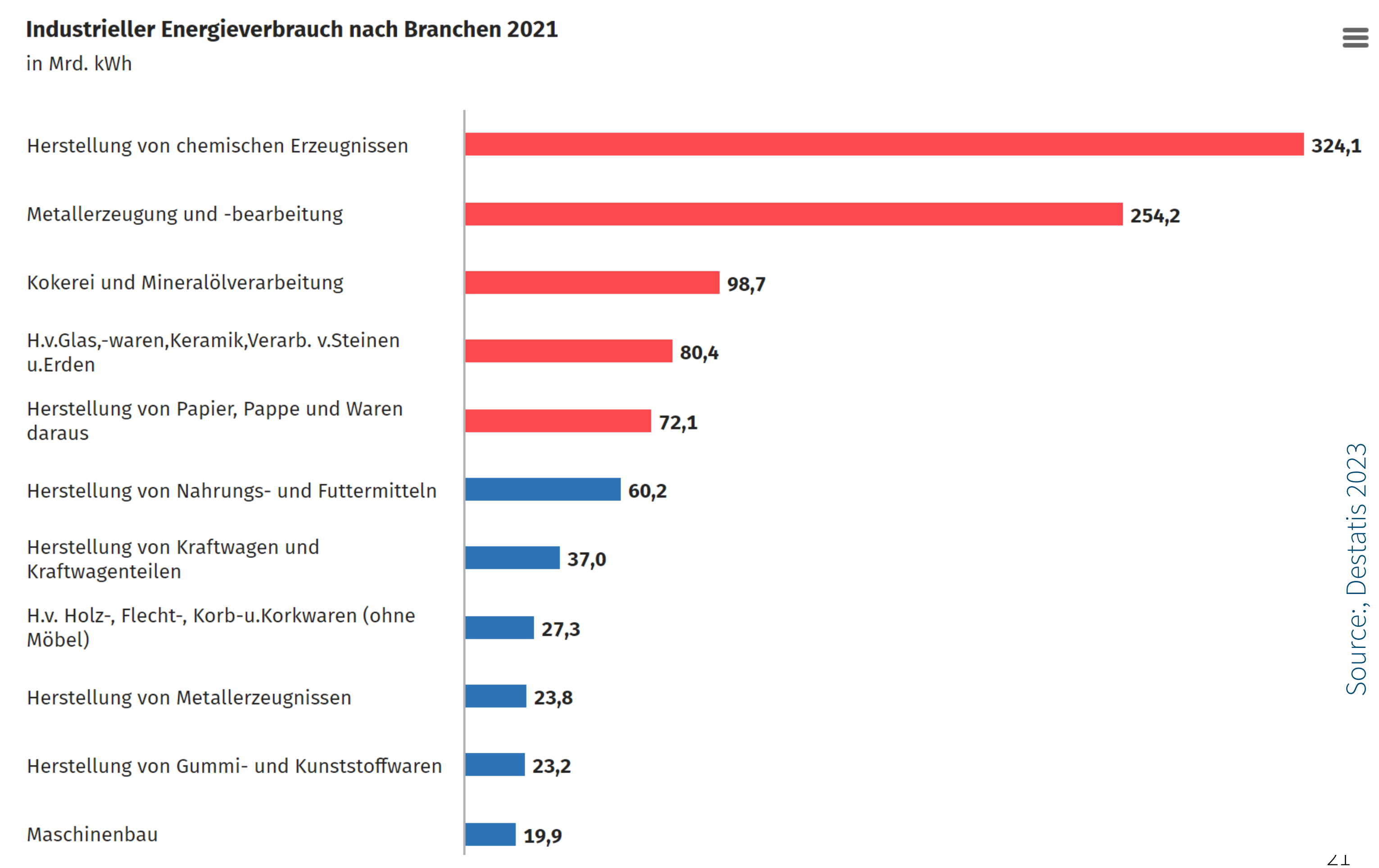
Energy consumption by sector and industry

Final energy consumption in Germany by sector

in % of the total amount of energy used



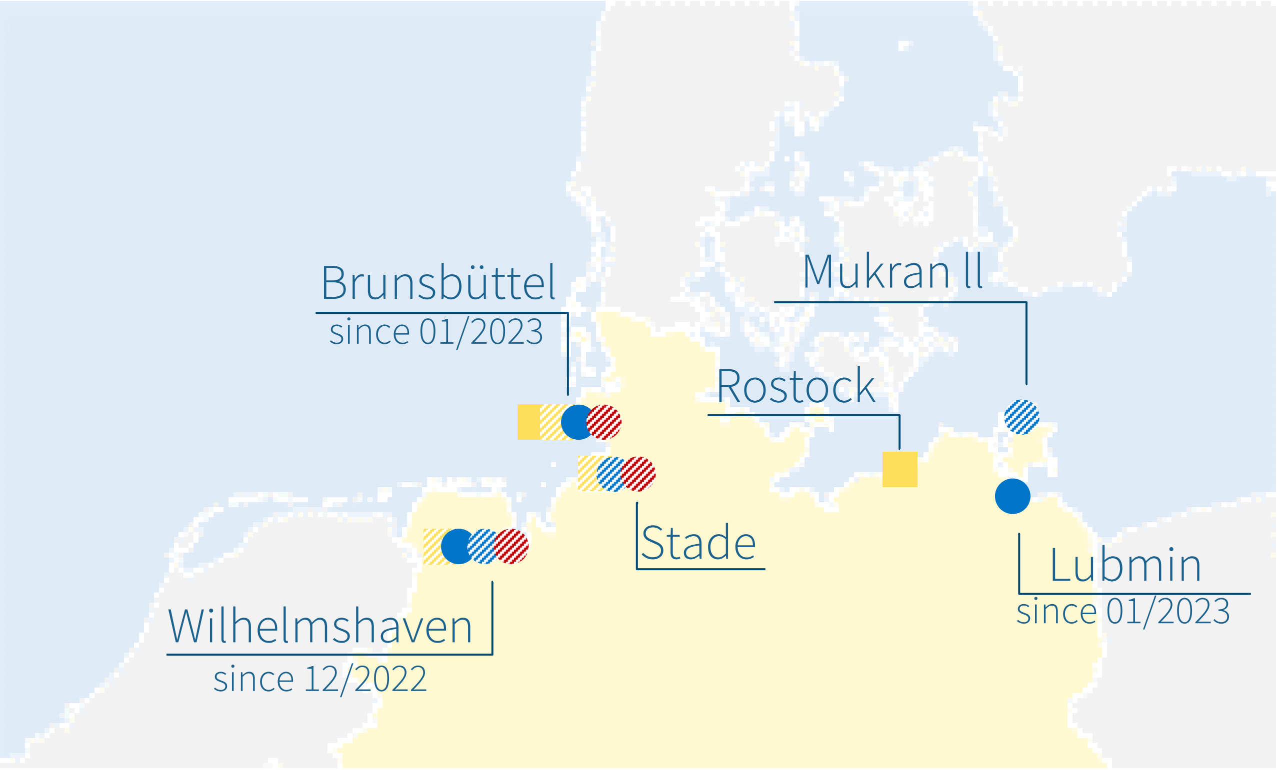
Industry (manufacturing and mining)
Business, Commerce, Services
Private households
Traffic



Source:, Destatis 2023

Germany is rapidly building up an infrastructure for the import of LNG and ammonia

Germany is securing its energy supply using a total of 14 LNG and ammonia import terminals

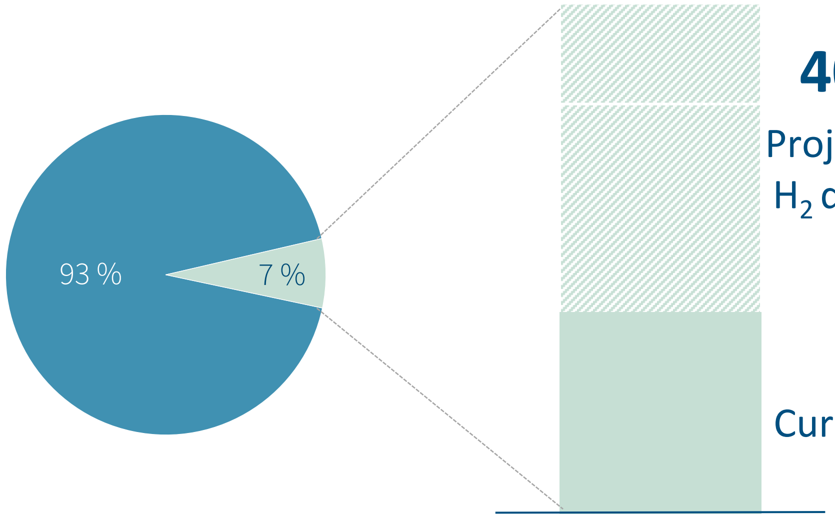


- Germany charters **five FSRUs** (plus one private FSRU) and plans to have **three land-based LNG import terminals**
- Next to the two existing ammonia import terminals, additional **two are planned**
- LNG infrastructure will be **hydrogen-ready**
- Rostock Port is building an ammonia cracker

FSRU in operation
Land-based LNG terminal in operation
FSRU not yet in operation
Land-based LNG terminal not yet in operation
Ammonia import terminal in operation
Ammonia import terminal not yet in operation

Source: Guidehouse 2024 based on BMWK 2022, Bundesregierung 2023, Uniper 2024, RWE 2024 & HEH 2024

Green Hydrogen will be one of Germany’s future energy sources



40-75 TWh
Projected additional H_2 demand by 2030

55 TWh
Current H_2 demand in 2024

45-90 TWh
Projected H_2 imports until 2030

1867 TWh
Targeted final energy demand in 2030

95-130 TWh
Projected total H_2 demand in 2030

Source: Guidehouse 2024 based on BMWK 2023; Icons from flaticon.com

Import and infrastructure

Finaler Entwurf für das deutsche Wasserstoff-Kernnetz
Stand: 14.11.2023

HANDELSBLATT
Quellen: Bundesministerium für Wirtschaft und Klimaschutz, fnb-gas

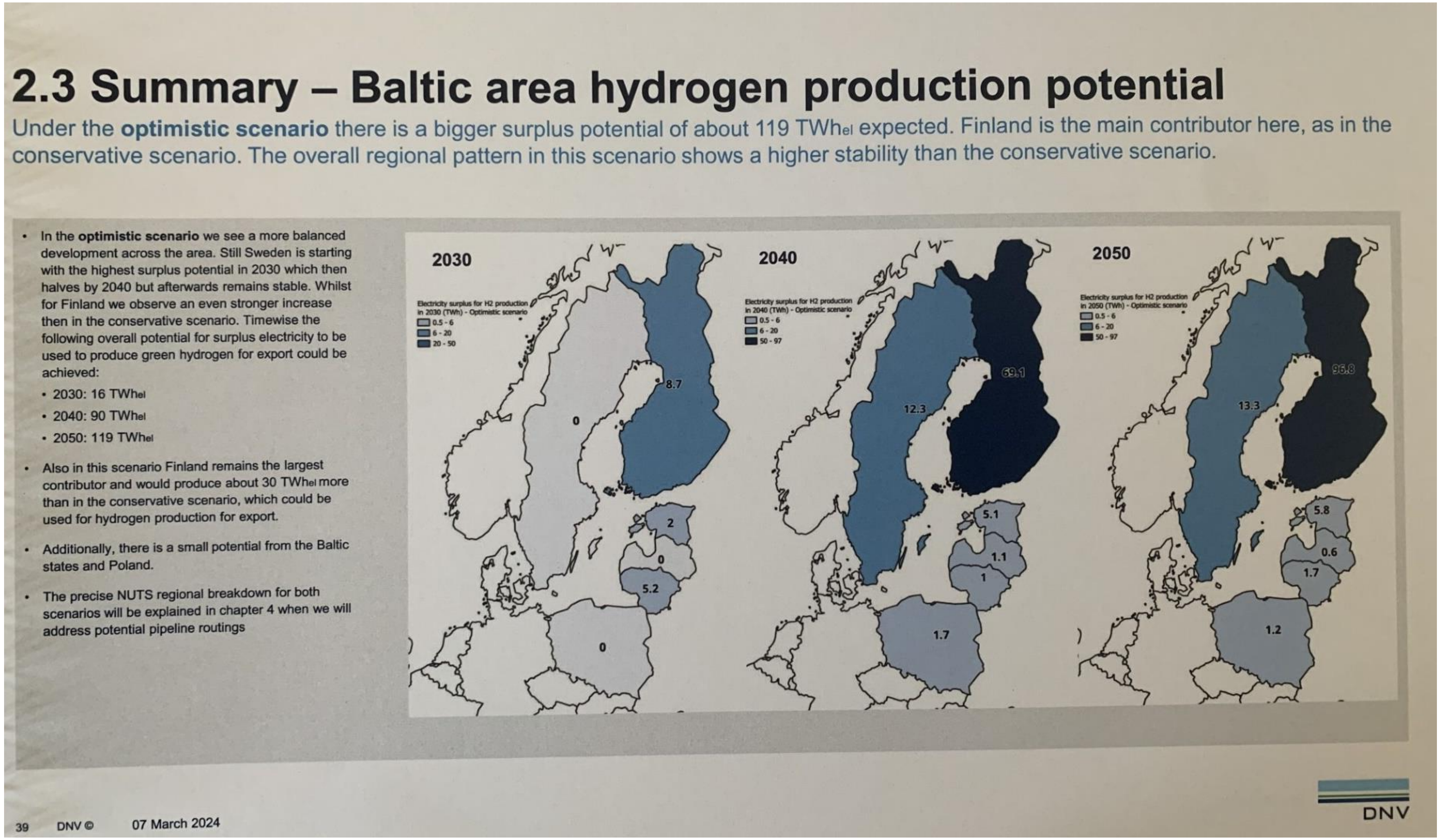
Import

- BMWK is currently preparing an import strategy for hydrogen and H_2 derivates
- Finland has been identified as high potential production area for green H_2

Infrastructure

- Germany has an existing infrastructure for gas, which will be partly converted to H_2 use and supplemented with new pipelines
- Midsize industry players will probably not be able to pay for the last mile of the pipeline to their production site -> the role of H_2 derivates like ammonia might stay relevant also long term

The Finnish green H_2 potential is recognized in Germany



2.3 Summary – Baltic area hydrogen production potential

Under the **optimistic scenario** there is a bigger surplus potential of about 119 TWhel expected. Finland is the main contributor here, as in the conservative scenario. The overall regional pattern in this scenario shows a higher stability than the conservative scenario.

- In the **optimistic scenario** we see a more balanced development across the area. Still Sweden is starting with the highest surplus potential in 2030 which then halves by 2040 but afterwards remains stable. Whilst for Finland we observe an even stronger increase then in the conservative scenario. Timewise the following overall potential for surplus electricity to be used to produce green hydrogen for export could be achieved:
  - 2030: 16 TWhel
  - 2040: 90 TWhel
  - 2050: 119 TWhel
- Also in this scenario Finland remains the largest contributor and would produce about 30 TWhel more than in the conservative scenario, which could be used for hydrogen production for export.
- Additionally, there is a small potential from the Baltic states and Poland.
- The precise NUTS regional breakdown for both scenarios will be explained in chapter 4 when we will address potential pipeline routings

39 DNV © 07 March 2024

DNV

DNV Study (ordered by Gascade) published on 16.5.2024

Germany provides targeted funding instruments to support green hydrogen projects worldwide

Germany's H_2 funding schemes

H2Global: Auction-based promotion of international green hydrogen projects

The Federal Ministry for Economic Affairs and Climate Protection is already providing 900 million euros for the first funding window. Further tenders are currently being prepared, with a volume of up to 3.5 billion euros.

H2Uppp: Provision of supporting services to small private-sector projects

Guarantee Instruments: to promote foreign trade and investment

Source: Guidehouse, November 2023 based on BMWK 2022 & BMWK 2023; Icons by flaticon.com

H_2 is one of the main topics in 2024 also for us @AHK Finnland

1. We are starting a bilateral working group for Finnish and German H_2 producers, off-takers and technology providers.
2. German-Finnish Business Forum on 30-31.10.2024 in Düsseldorf on the topic “post-fossil energy“

Thank you!
Kiitos!
Danke schön!

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Saksalais-Suomalainen Kauppakamari
Tysk-Finska Handelskammaren

Hydrogen and e-fuels in the maritime sector

Sören Hedvik
Senior Project Manager in R&D

Wärtsilä

Hydrogen and e-fuels in maritime

Hydrogen Cluster & HYGCEL Joint Seminar

Sören Hedvik, Senior Project Manager

22 May 2024

1 **Regulation**

2 **Sustainable fuels**

3 **Wärtsilä’s offering**

Regulation

Accelerated decarbonisation targets are shaping the shipping industry and reinforcing our strategy

INTERNATIONAL MARITIME ORGANIZATION

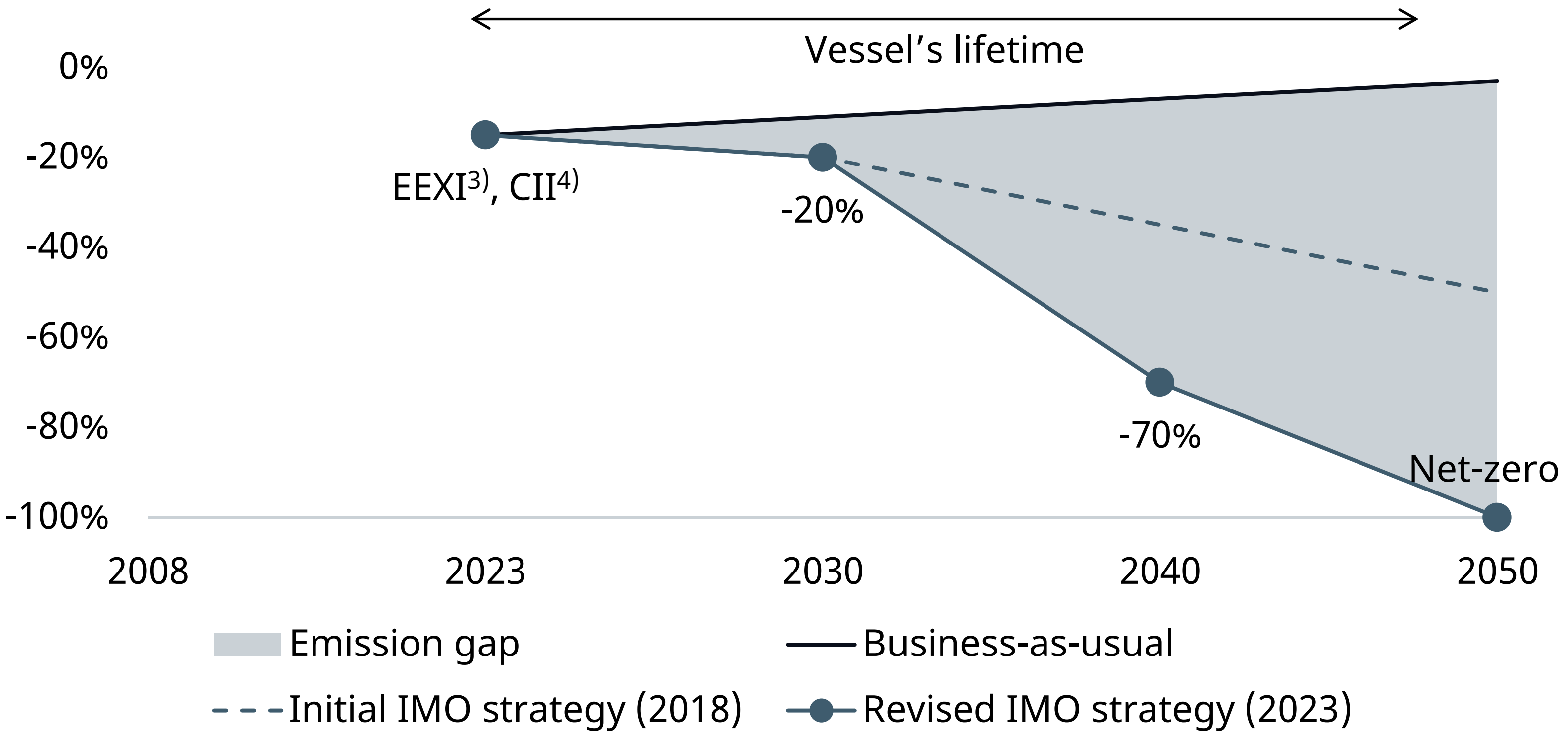
In 2023, IMO strengthened its GHG reduction targets, and now strives for **net-zero "by or around 2050"**

The total estimated investment in 2023-2050 is **USD ~5.0 trillion**[1)]

We can enable customers to reach intermediate and 2050 targets with our existing portfolio

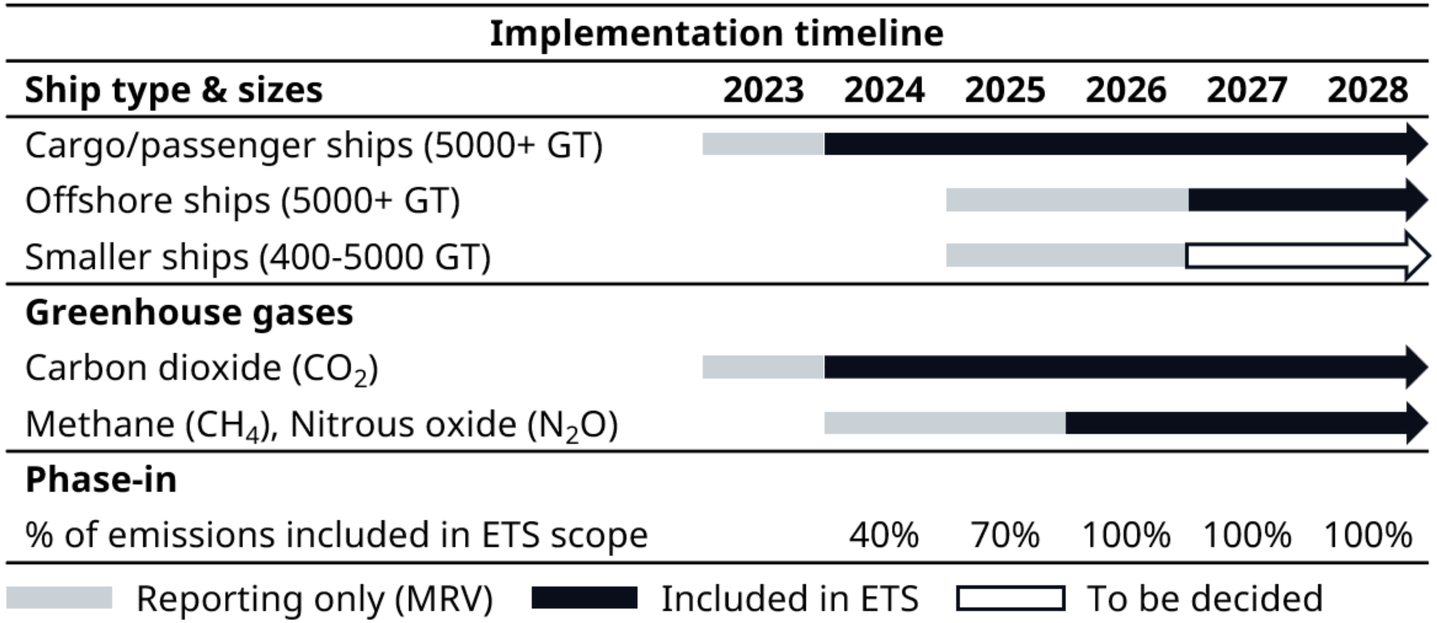
Ambitions and checkpoints in the revised IMO GHG strategy[2) 5)]

GHG emission reduction % vs 2008



1) Source: Clarksons; total newbuilding and equipment upgrades investment for fleet renewal in 2023-2050; 2) Source: DNV Energy Transition Outlook 2023; well-to-wake GHG emission reduction compared to 2008; 3) Energy Efficiency eXisting ship Index; 4) Carbon Intensity Indicator; 5) Decarbonisation trajectories used by the Poseidon Principles represent the 2023 IMO GHG Strategy ambition of reducing total annual GHG emissions to net-zero around 2050 in a well-to-wake CO2e perceptive.

EU Emissions Trading System (ETS) for marine



- Uses the existing EU MRV (monitoring, reporting and verification) tool
- 100% of GHG from voyages within EEA, 50% of voyages to and from EEA ports
- Based on Tank-to-Wake emissions.
- Sustainable biofuels will be considered as zero.

What are EUAs?

- EU Allowances (EUAs) are a permit to emit a certain amount of CO_{2eq}
- EUAs can be bought and sold on the market, and the variable market price of EUAs reflects the cost of reducing emissions
- **No free allowances in marine, only phase-in period**
- Revenue of 20 million allowances will be dedicated to maritime innovations

FuelEU Maritime pushes fuels to become less GHG intensive

- Focus on fuels, not efficiency. Well-to-Wake **GHG intensity** is using **unit gCO_{2eq} /MJ**
- 100% of GHG emissions from voyages within EEA, 50% of voyages to/from EEA ports
- **CO_2, CH_4 and N_2O** are calculated as CO2eq. Reward for using wind power.
- **Shore power** usage requirement for container and passenger ships from 2030
- Exceeding the limit results significant **financial penalty** (2400 €/”ton VLSFO emission”)
- **Pooling** = requirement applies to the average GHG intensity of the ships in the pool

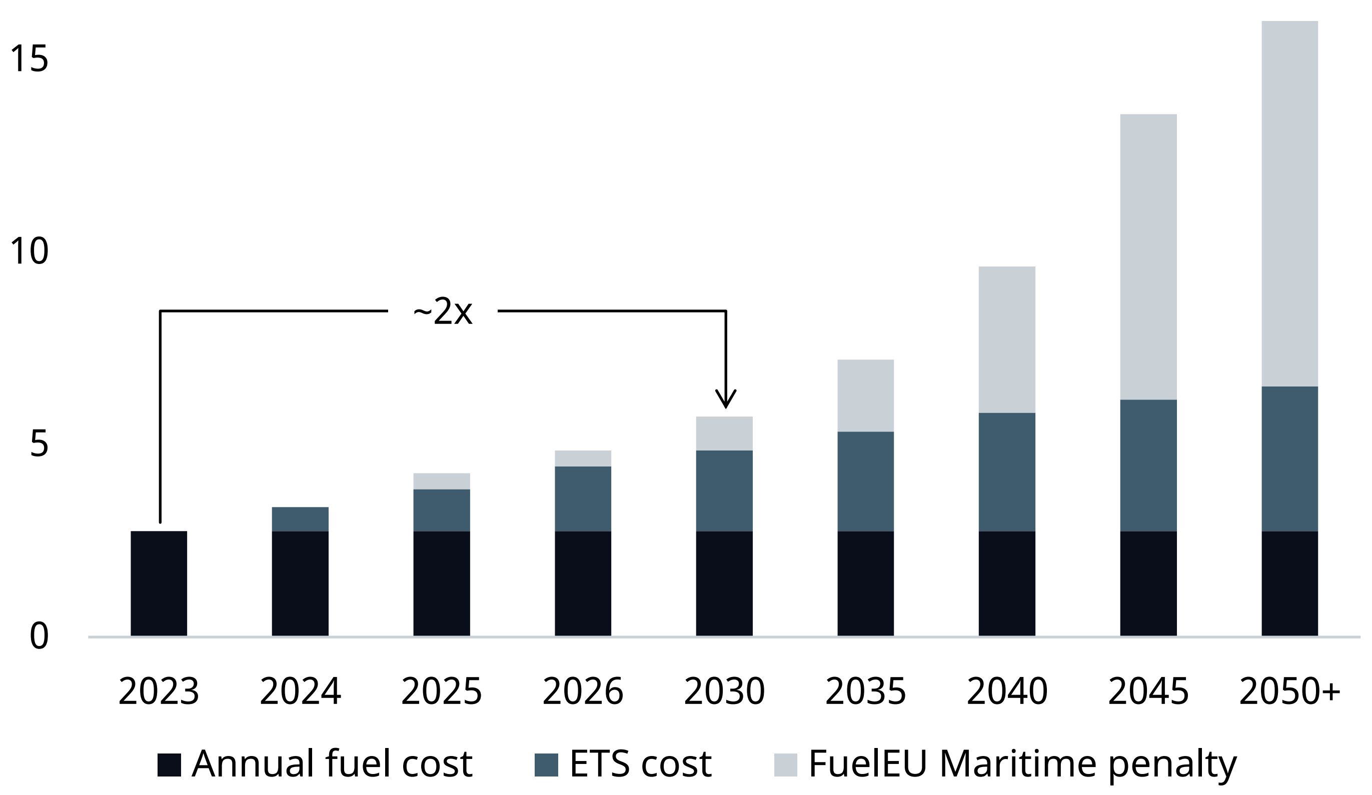
FuelEU Maritime

is setting tightening requirements on the Well-to-Wake GHG intensity for the fuel consumed on board compared to 2020 reference limit of 91.16 gCO_{2eq}/MJ

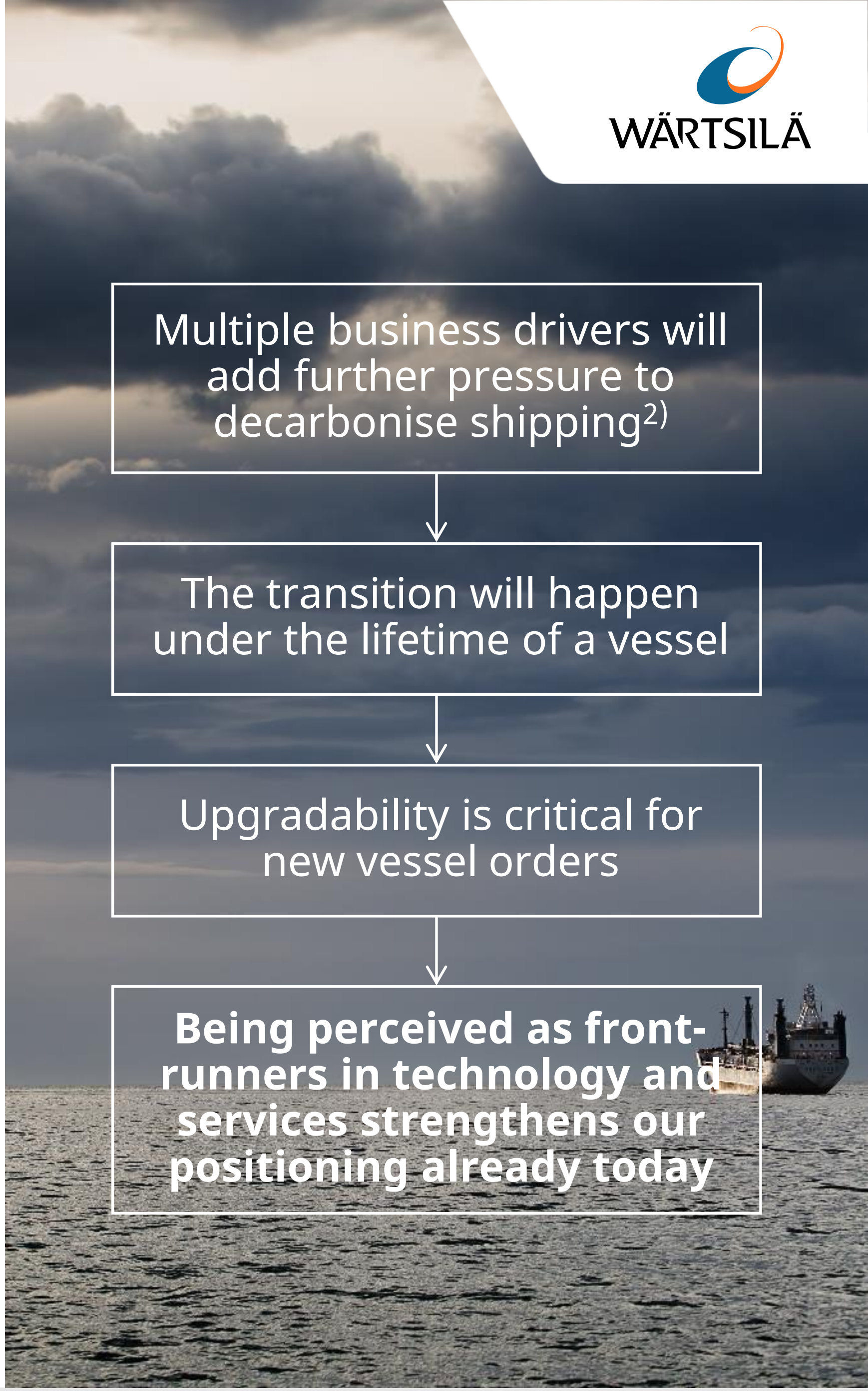
-2% from 2025
-6% from 2030
-14.5% from 2035
-31% from 2040
-62% from 2045
-80% from 2050

Up to 2030, fuel cost will double due to emission fees

Fuel-related costs for Handymax bulker operating in EU waters, EURm[1)]



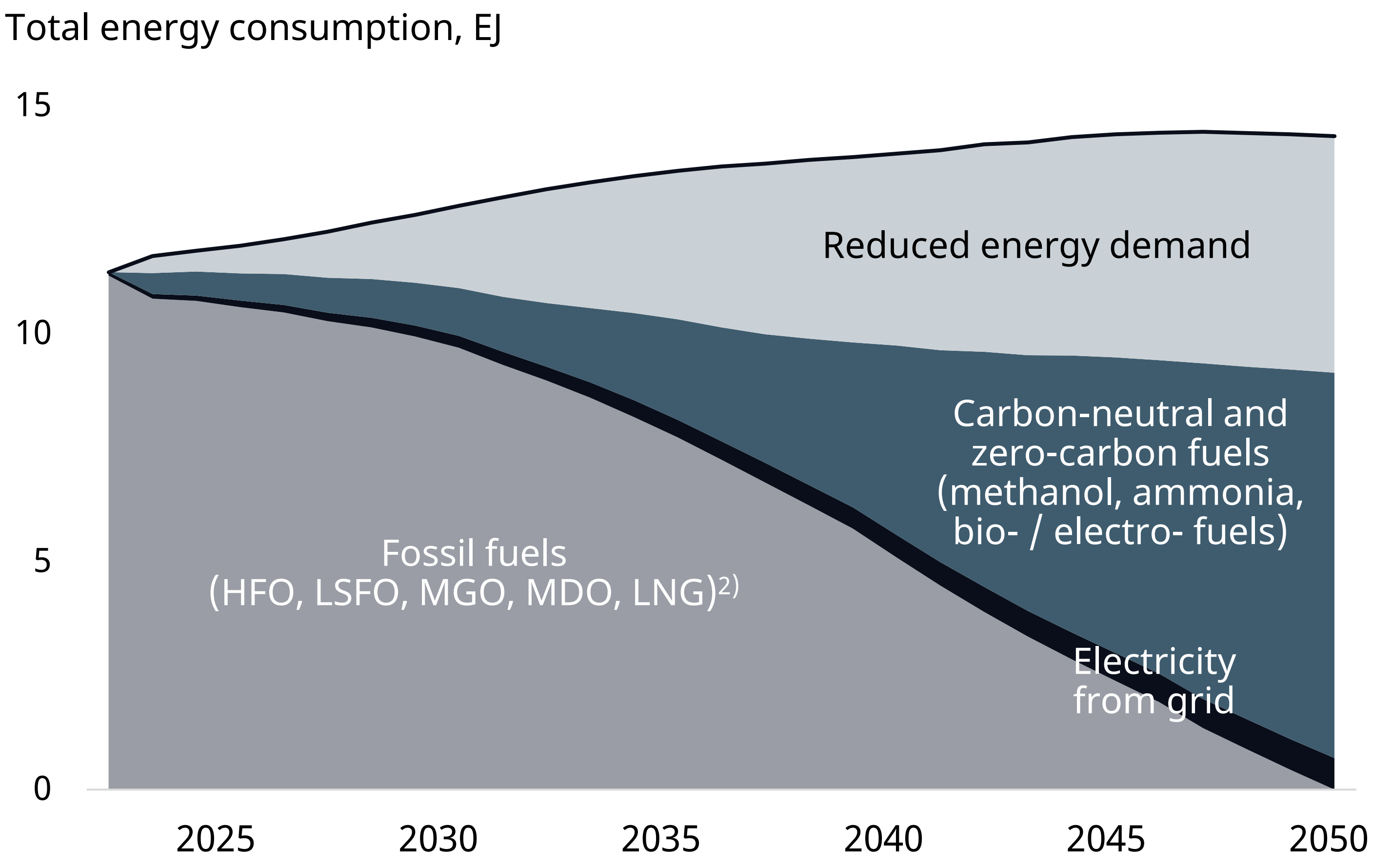
1) Assuming 5 000 tons/year VLSFO (Very Low Sulphur Fuel Oil) consumption subject to EU Fit-for-55, VLSFO at EUR 550/ton; EU allowances from EUR 100/ton today to EUR 230/ton in 2050 (source: Transport & Environment NGO); 2) E.g., local regulations and emission fees (EU Fit-for-55), green financing (Poseidon Principles), climate-linked chartering (Sea Cargo Charter), companies' ESG targets



Sustainable Fuels

A progressive switch to sustainable fuels is already under way

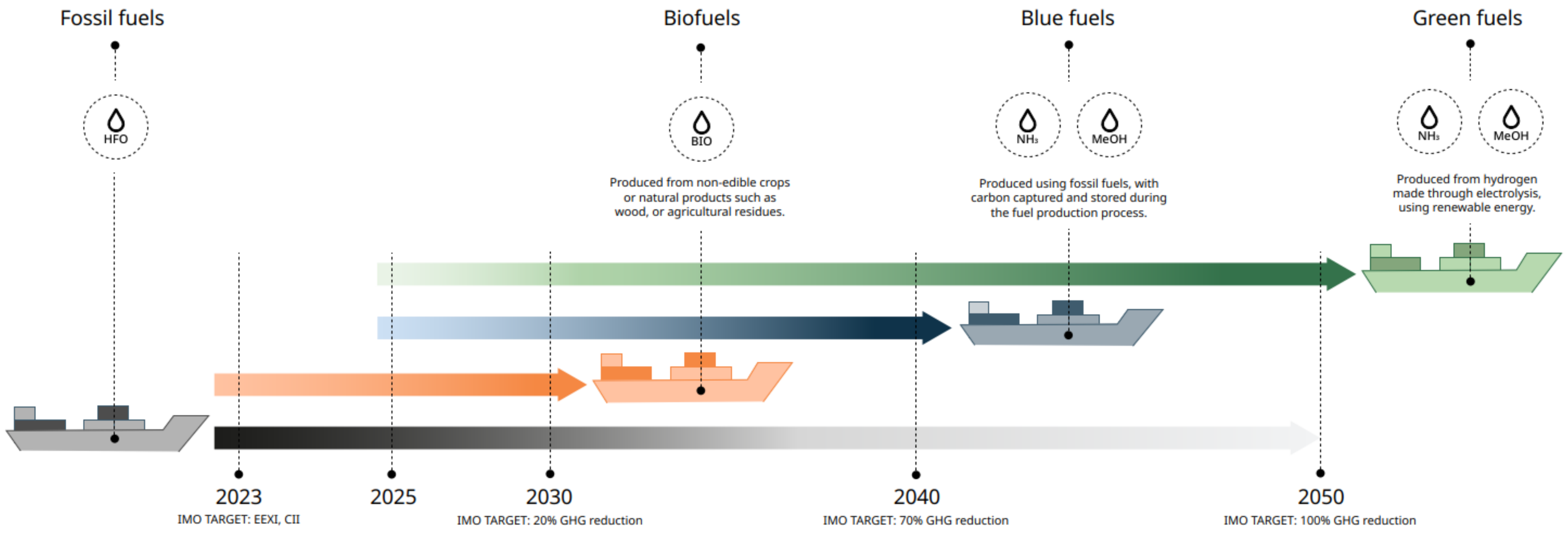
Sustainable fuel uptake scenario for net-zero in 2050[1)]



- **Fuel transition is under way**: 50% of tonnage on orderbook is set to use alternative fuels; long-term fuel mix is dependent on future fuel supply
- **LNG is still #1 alternative fuel**: 24% of tonnage ordered in 2023 is LNG fuelled
- **Methanol is gaining share**: 49% of boxship tonnage ordered in 2023 will run on methanol
- **Ammonia will pick up in the longer run**
- **Hybrids, batteries, ESTs[3)] are growing**:
  - 31% of the tonnage in current fleet is fitted with at least one EST
  - 42% of the tonnage on orderbook is fitted with at least one EST
  - 146 hybrid / full-electric 2000+ GT vessels were ordered in 2023 (102 in 2022, 55 in 2019)

1) Source: DNV Maritime Forecast 2050; 2) HFO – Heavy Fuel Oil; LSFO – Low Sulphur Fuel Oil; MGO – Marine Gas Oil; MDO – Marine Diesel Oil; LNG – Liquefied Natural Gas; 3) Energy Saving Technology

Sustainable fuels uptake roadmap to 2050

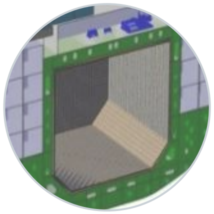
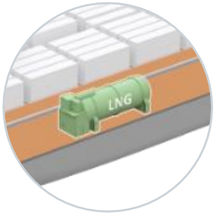
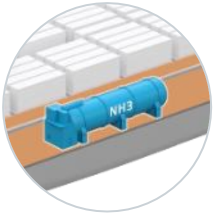
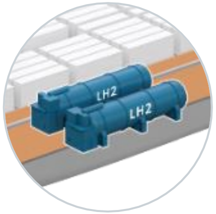
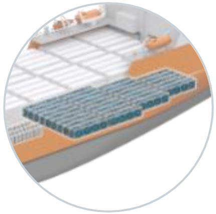
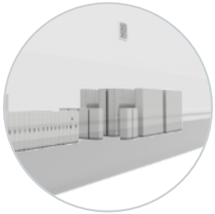


Targets based on latest MEPC80 regulation, referring to Well-to-Wake emissions

- LNG is well-placed to act as a transition fuel, followed by biofuels in the 2030s
- ‘Blue’ fuels such as blue ammonia will then act as bridging fuels
- Green synthetic fuels become widely available at scale as the ‘gold standard’ in the late 2030s and early 2040s

Source: Sustainable fuels for shipping by 2050 – the 3 key elements of success
Wärtsilä report on future fuels in the marine industry, 21.3.2024 link

Costs and design impact

Fuel type	**Low Sulphur Fuel Oil** @ 20°C	**Liquified Natural Gas** @ -162°C	**Methanol** @ 20°C	**Ammonia** @ -33°C	**Liquid Hydrogen** @ -253°C	**Compressed Hydrogen** @ 350bar	**Marine Battery Rack**
Fuel price factor (per GJ)[1]	1x	1.1x – 4.6x[2]	2.6x – 5.5x[3]	2.4x – 4.3x[4]	3.6x – 4.6x[4]	2.1x – 3.1x[4]	2.0x – 5.3x[8]
Fuel price factor in 2035, incl. carbon tax[1] [5]	1x	0.8x – 1.4[2]	0.8x – 1.6x[3]	0.7x –1.2x[4]	1.2x – 1.5x[4]	0.6x – 1.0x[4]	0.8x – 2.0x[8]
Gross tank size factor[6]	1x	1.7x – 2.4x[7]	1.7x	3.9x	7.3x	19.5x	~40x (~20x potential)

1) Fuel production cost estimate for 2025 and 2035; source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023; 2) Price range spans between fossil & electro- methane; 3) Price range spans between bio- & electro- methanol; 4) Price range spans between blue- & electro- ammonia/hydrogen; 5) Assuming 100% consumption subject to EU Fit-for-55, EU allowances at EUR 159/ton (source: Transport & Environment NGO); 6) Gross tank estimations based on Wärtsilä experience; 7) 1.7x membrane tanks, 2.4x type C tanks; 8) Shore energy price EUR 10-27/kWh

Wärtsilä’s offering

Our purpose

Enabling sustainable societies through innovation in technology and services

We are shaping the green transition in marine and energy with our advanced technologies, expertise in sustainable fuels and lifecycle service offering.

Uniquely positioned to drive global transformation in our industries

1 in 3 of the world's vessels

are equipped with Wärtsilä solutions. That's over 30,000 ships.

Over 180 countries

where Wärtsilä energy installations provide reliable power.

50% of sales come from services

and 90% of our lifecycle customers renew their service agreement.

Wärtsilä Marine: the right combination of solutions for each vessel and fleet

Engine optimisation & fuel flexibility

Electrification & hybrid systems

Energy-saving solutions

Abatement systems & carbon capture

Lifecycle solutions & services

Sustainable fuel engine offering

Milestones on low/zero carbon technologies in the pipeline

Methanol

- 2015: First engine conversion ZA40S to methanol onboard ship
- 2023: Delivery of first W32 methanol engines. Sales release of additional marine engines and engine conversion packages

Ammonia

- 2022: Combustion and performance testing, optimization with different engine concepts and different engines platforms
- 2023: Sales release of the first ammonia-capable W25 marine engine, delivery 2025.

Hydrogen

- 2021-2024: Combustion testing on H2 blends and 100% hydrogen
- 2023: Hydrogen blend capability offered for all SG-engines
- 2025: 100% Hydrogen concept ready
- 2026: W31SG - first industrialized 100% Hydrogen product ready

Pilot products enabling uptake of new fuels in the market

MeOH

Methanol: Wärtsilä 32M (2023)

- Methanol with diesel pilot
- Dual fuel with backup (diesel)

NH3

Ammonia: Wärtsilä 25 (2025)

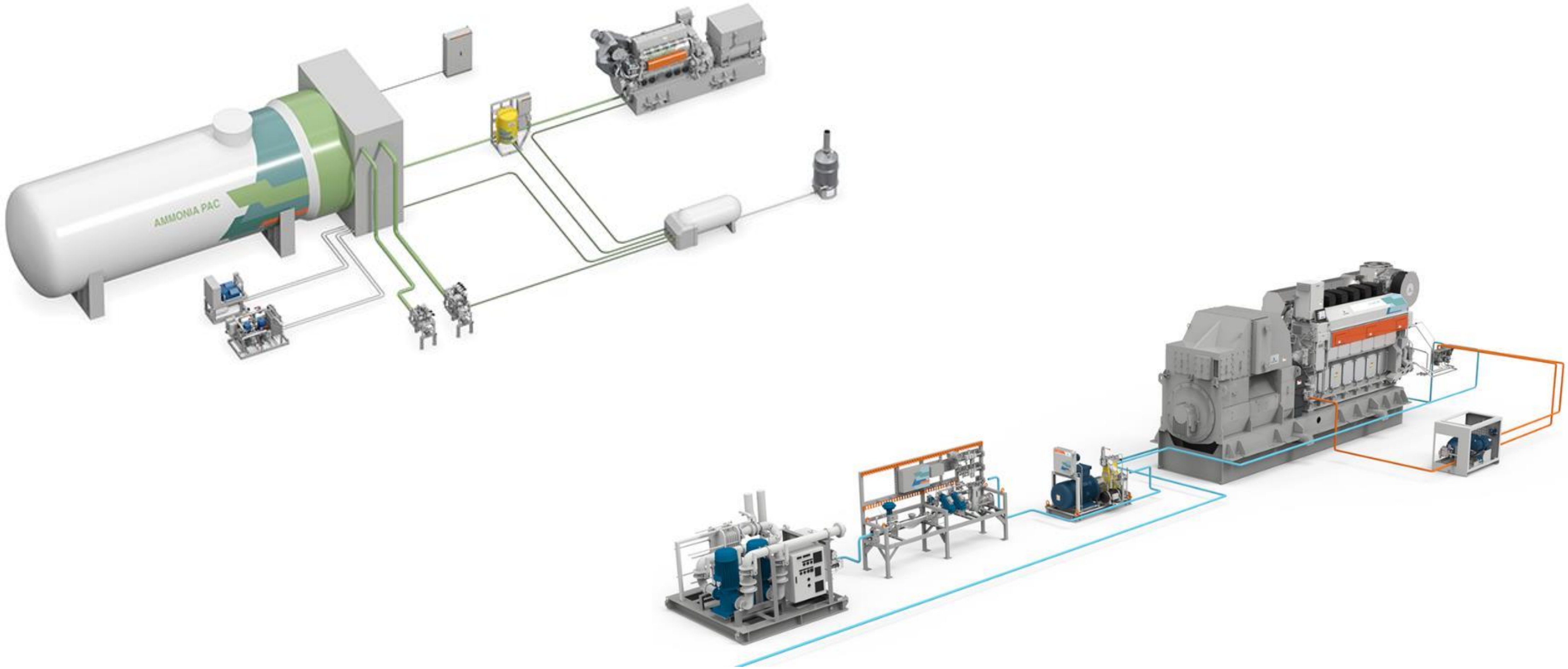
- Ammonia with diesel pilot
- Dual fuel with backup (diesel)

H2

Pure Hydrogen: Wärtsilä 31SG (2026)

- Pure hydrogen, spark ignited

Sustainable fuel solution offering



WÄRTSILÄ

Challenges in the EU approach to hydrogen markets and regulation

Regulation findings from HYGCEL

Kim Talus
Professor of Energy Law

UEF Law School and University of Helsinki

UNIVERSITY OF
EASTERN FINLAND

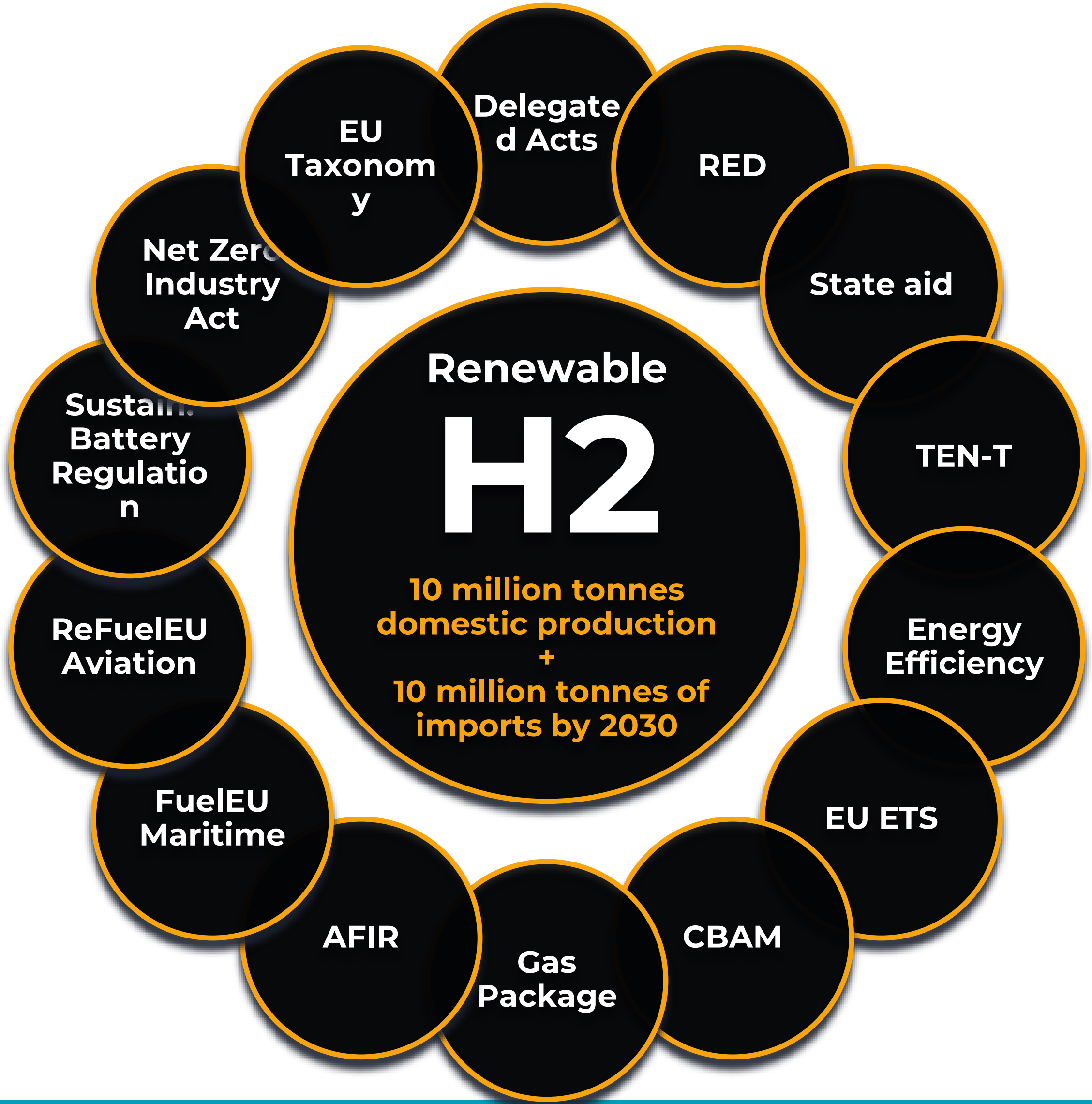
Challenges in the EU approach to hydrogen markets and regulation

Kim Talus

Key messages

- Regulatory framework for RFNBO is complicated
- Regulatory demand for RFNBO has now been established
- Imports of RFNBO are unlikely to amount to significant volumes in the short-term
- Regulatory framework has adjustments built-in and Member state role is critical

EU Regulatory framework for hydrogen



Green hydrogen production rules

- RED III + 2 DA’s + Q&A = RFNBO
  - Electrolysers must be powered by additional renewable electricity
  - Power purchase agreement with RE producer necessary in most cases
  - Additionality, temporal and geographic correlation requirements apply in most cases
  - Possibility of adjustments through future Delegated Acts

EU Sectoral Targets for renewable hydrogen/RFNBO

- **By 2030: 42.5% share of renewable energy** in EU overall consumption; additional indicative top-up of 2.5%, allowing to reach 45%
- **Industry** (42% RFNBO by 2030, 60% by 2035), **Transport** (advanced biofuels and RFNBO 1% by 2025, 5.5% by 2030), **Maritime** (RFNBO 1.2% by 2030, possibly 2% by 2034), **Aviation** (RFNBO 1.2% in 2030, 35% by 2050, and SAF 70% by 2050)

▸ The EU's regulatory obligations create **stable demand** that producers and exporters can rely on when making investment decisions

▸ Large-scale **production and imports are necessary** to get anywhere near the targets: **10 million tonnes** renewable hydrogen production and imports by 2030

RFNBO import rules – challenges for importers

- Same EU RFNBO rules apply to imports into the EU. Challenges for importers:
    - No subsidies for RE production is allowed (US IRA)
    - Recognition of guarantees of origins is currently not possible (US REC's)
    - Bidding zones and imbalance settlement rules require a certain type of market
    - 'Renewable energy producer' and role of intermediaries is unclear
    - CO_2 requirements for e-methanol production (effective carbon pricing mechanism; biogenic CO_2; direct air capture) can be difficult to meet
    - Carbon Border Adjustment Mechanism (CBAM) creates more work and costs
    - Plus: access to import infrastructure is uncertain

Long-term access to import facilities

- **Main rule**: Article 32 of the gas and hydrogen directive provides for a negotiated access regime, but access should be ensured (preamble 73)

- **Exemption**: Article 78 of the gas and hydrogen regulation may exempt hydrogen interconnectors, terminals and underground storage facilities

- Conditions (examples):
- **enhances competition** in hydrogen supply and enhance security of supply;
- contributes to decarbonisation and the achievement of the Union's climate and energy targets and was decided by applying the energy efficiency first principle;
- **not detrimental to competition** in the relevant markets which are likely to be affected by the investment, to the proper functioning of the internal integrated market for hydrogen, to the proper functioning of the regulated systems concerned, to decarbonisation or to the security of supply of the Union;
- the infrastructure has **not received Union financial assistance** for works under Connecting Europe Facility

RFNBO sector as a sub-sector in hydrogen market

- Compliance with the RFNBO criteria is not mandatory for producing or importing hydrogen

- But: RFNBO is likely to be a separate sector with its on price dynamic and the rules must be followed in order to count as RFNBOs towards EU legislative targets; not counting as RFNBO is commercially less attractive

Hydrogen market creation

- New framework builds on existing gas market rules and provide similar rights for various stakeholders. The framework allows for multiple adjustments (if the Member States so decides)

- Examples:

- Third party access for networks and underground storage before and after 31.12.2032
- Derogations subject to 7-year review: existing hydrogen networks, geographically confined hydrogen networks, horizontal unbundling
- Hydrogen networks in isolated regions (max 15 years and 2045)
- Capacity contracts: 20 years if operational before 2028, then 15 years but both subject to NRA market assessment
- Inter-temporal cost allocation with State quarantees (ACER recommendation on methodology)

Way forward and possible changes

- **Production of RFNBO**: number of delegated acts will be issued by the Commission on important details – but the demand targets are likely to remain unchanged

- **Market creation**: the Member State and National Regulatory Authorities are in key position – the real timeframe for market creation uncertain

- **State aid and EU subsidies**: time is of essense, if a market is to be created, subsidies are needed now

Way forward - Finland

RFNBO approach is beneficial for the Finnish industry, but:

- Adjustment opportunities need to be utilised
- State aid urgently needed if Finland is to position itself as a leader in the market
- Hydrogen transport infrastructure regulations and related permitting regulations are urgently needed
- Facilitation of permitting for the entire hydrogen value chain is urgently needed
- CO_2 transport infrastructure?

Conclusion – markets in the making

Internationally:

- Hydrogen market creation is a global challenge (nationally and in terms of trade)
- The EU is emerging as a global model for hydrogen production framework (the US approaching EU)

Within the EU

- Regulatory details for the production of RFNBO may still change
- Role and definition of low-carbon hydrogen is still unclear
- Demand for RFNBO has been created by regulation and it is unlikely to change
- Market rules have been set but adjustments are possible at national level

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Thank you

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Panel discussion: Challenges in the EU approach to hydrogen markets and regulation

Leena Sivill
Principal, Energy Management Consulting

AFRY

Outi Ervasti
Advisor, Innovation Business Platforms

Neste

Kimmo Järvinen
Head of EU governmental Affairs

SSAB

Kim Talus
Professor of Energy Law

UEF Law School and University of Helsinki

Tatu Hocksell
Regulatory Affairs Specialist

Helen

Lunch break until 12.40

H2Cluster Finland & HYGCEL project joint seminar

May 22, Oodi, Helsinki

Agenda

Scan the QR Code to access today's agenda!

Stay informed and keep track of all the exciting sessions and events happening today. Simply scan the QR code with your phone to view the full schedule and detailed information about each segment. Don't miss a moment of the action.

Presentations of results from the HYGCEL project across the themes

Introduction

Mari Tuomaala
HYGCEL research lead

LUT

Overall HYGCEL research presentation

Presentations of results from the HYGCEL project across the themes

Oodi, Helsinki, May 22, 2024

HYGCEL – Hydrogen and carbon value chains in green electrification

LUT University (LUT)
Tampere University (TAU)
University of Eastern Finland (UEF)

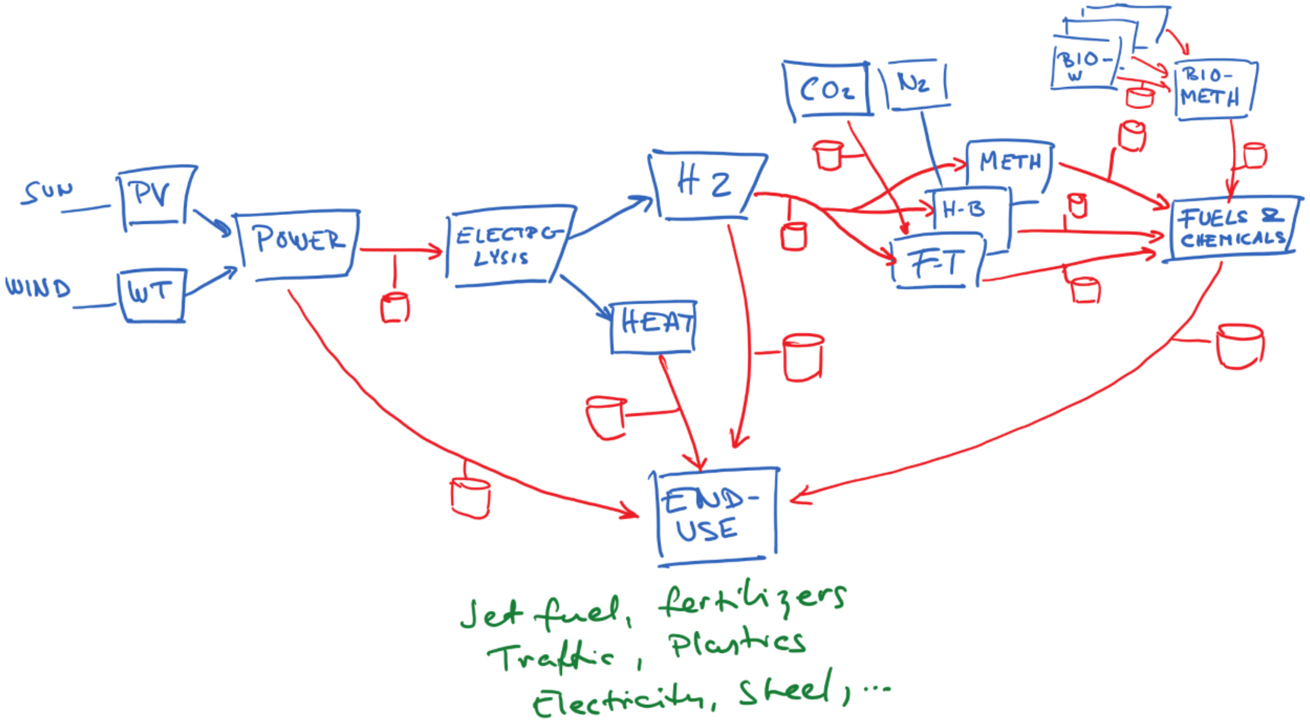
Project time 1.1.2022 – 30.10.2024
Financed by Business Finland

Research budget 4,5 M€
Co-innovation consortium budget 10,5 M€

Altogether 17 consortium partners
Almost 80 participating researchers

With in kind contribution:
5th Innovation, Ucont, Bakelite, FennoSteel

HYGCEL was studying what are the most optimal PtX value chains for Finland and it was developing guidance about how to build the electricity -based infrastructure in Finland.



HYGCEL results

Regulation	Challenges in the EU approach to hydrogen markets and regulation - 1 presentation	WP1
Techno - economy	Resource potentials and regional imbalances in infrastructure development - 3 presentations Modelling of electricity, hydrogen, CO_2, and end-products transportation - 2 presentations	WP2 WP3 WP4
Sustainability and safety	Perspectives to sustainability, safety and profit sharing in green hydrogen value chains - 2 presentations	WP6 WP1
Politics	Hydrogen value chains: Reflection of global policies for the Finnish Hydrogen economy - 1 presentation	WP1


LUT
University

Resource potentials and regional imbalances in infrastructure development

Hannu Karjunen
Post-doctoral researcher,
School of Energy Systems

LUT University

Sami Repo
Professor in Smart Grids

Tampere University

Tero Tynjälä
Professor in Engineering
Thermodynamics, Sc
hool of Energy Systems

LUT University

HYGCEL research presentation

Resource potentials and regional imbalances in infrastructure development

Oodi, Helsinki, May 22, 2024

Presentations in this session

1. Finland’s distributed PtX resources create unique production locations
   - Hannu Karjunen, post-doctoral researcher, LUT University

2. Finland’s distributed resources create regional energy imbalances and transportation needs
   - Sami Repo, professor, Tampere University

3. Value from PtX plant flexibility
   - Tero Tynjälä, professor, LUT University

Finland's distributed PtX resources create unique production locations

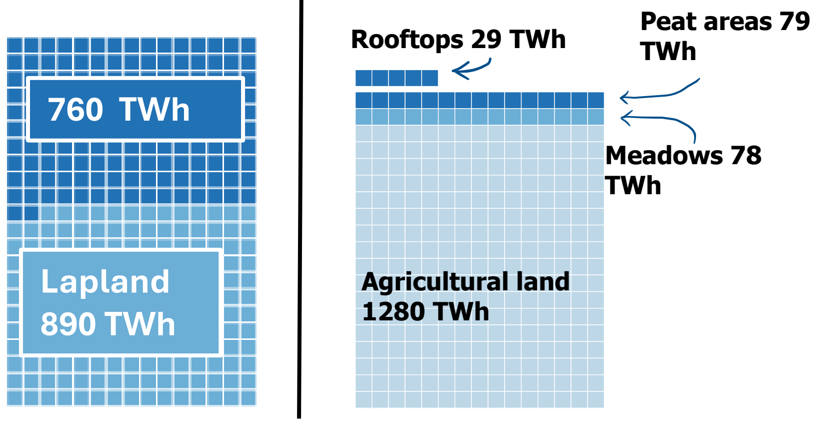
Topics of this presentation

- Finland's wind and solar potential and its distribution
- Distributed resources affecting infrastructure development

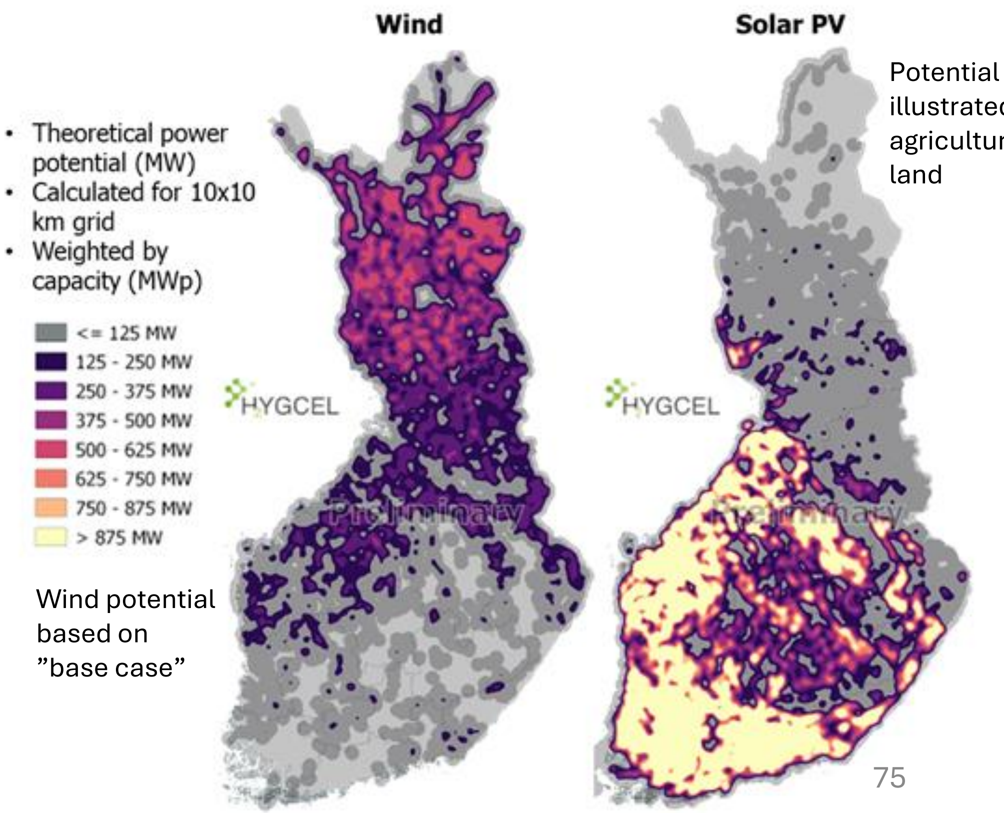
Finland could supply 10% of EU’s renewable electricity

- EU electricity demand ~3700 TWh by 2030, including hydrogen demand of 10 Mt_{H2} (530 TWh_{el})
- Available renewable potential exceeds Finland’s domestic energy needs → export strategy needed
- Finland’s renewable power supply will be determined by social acceptance, demand and techno-economics
- Production sites for wind and solar complement each other

	Wind	Solar PV
Current production	14.4 TWh	0.6 TWh
Theoretical potential	1650 TWh*	1300 TWh



= 5 TWh/a

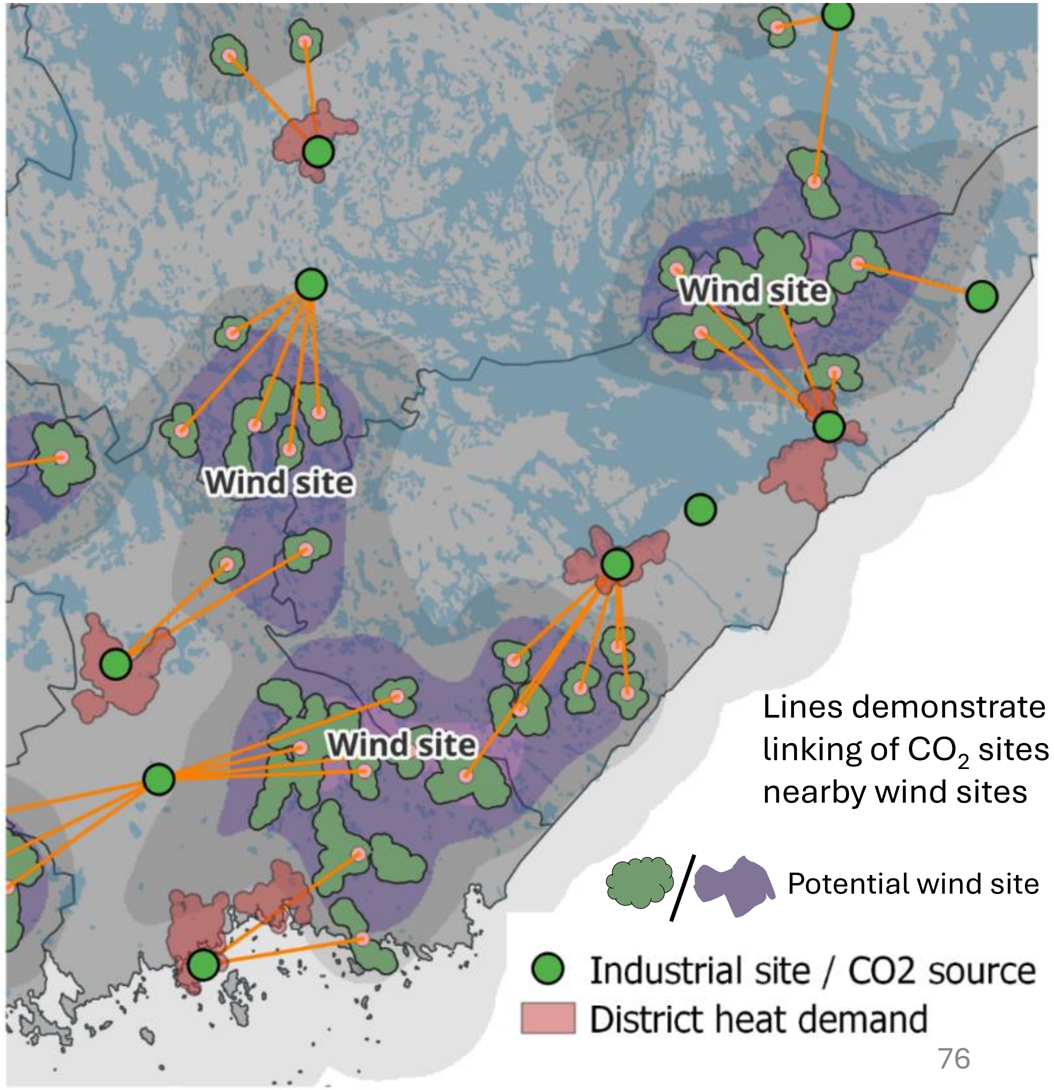


Potential illustrated for agricultural land

* based on our ”base case”-scenario land-use assumptions (potential in scenarios varied between 700 – 2500 TWh)

PtX is sensitive to local conditions

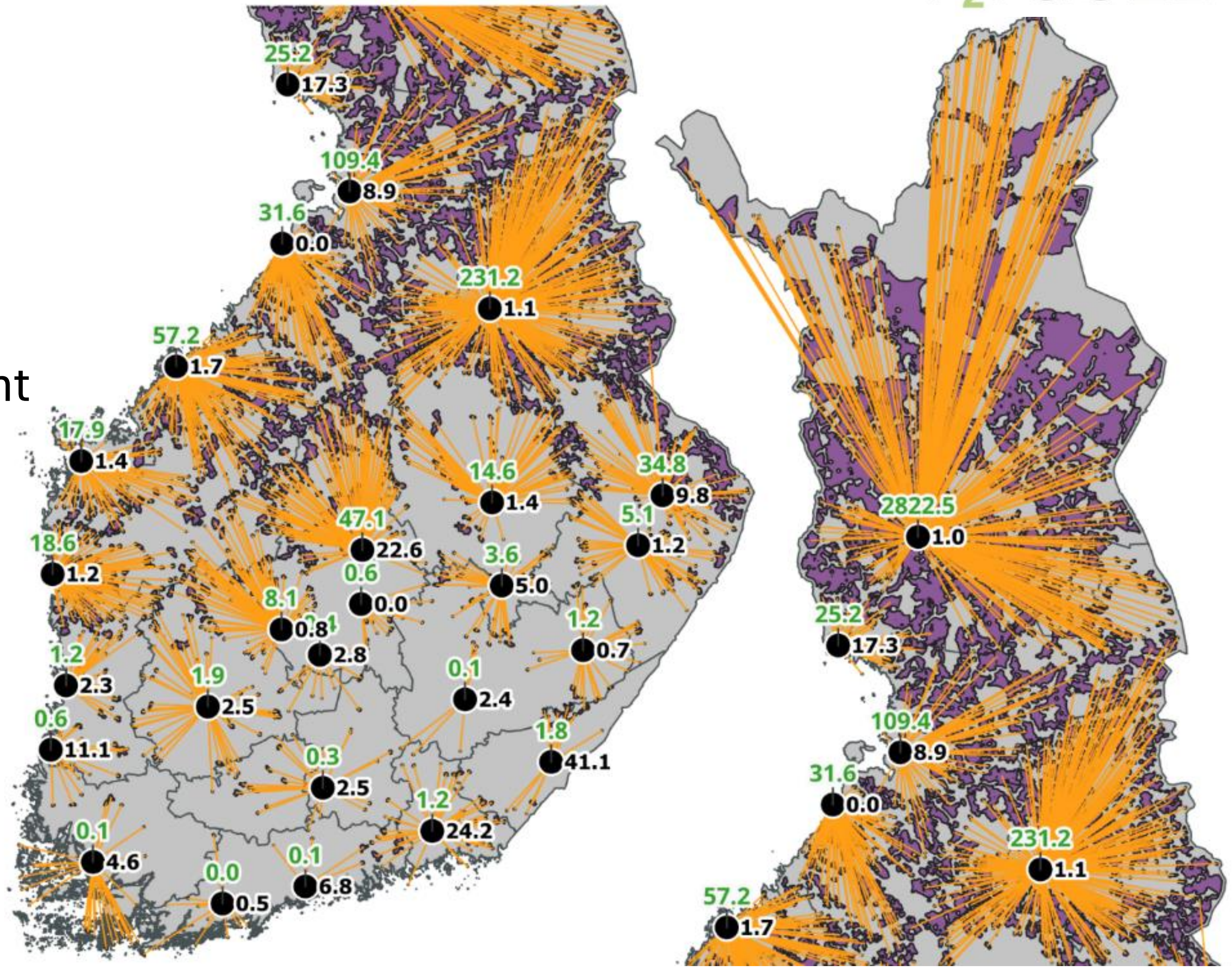
- Each location is unique: different constraints and opportunities
- Location and design of an PtX industrial cluster will depend on several factors, like the availability of renewable power or CO_2
  - Customized solutions for power supply, hydrogen storages and heat
  - Small production volumes are easier to place
- RFNBO regulation concerning connection requirements will be in a decisive role



Lines demonstrate linking of CO_2 sites with nearby wind sites

There are several ways to connect the resources

- Renewable power generation capacity is spread across large areas and unevenly
- A demonstration (orange lines in the figure) was made to connect wind sites and CO_2 point sources.
  - Regions of surplus and deficit areas are formed
  - Transport infrastructure is needed
  - Resources might need to be connected from far
- Time window is open for deciding the placement of industrial clusters:
  - National strategies needed to guide the development?



Green: Wind potential (TWh)

Black: CO_2 conversion electricity demand (TWh)

Finland’s distributed PtX resources create unique production locations

Key messages

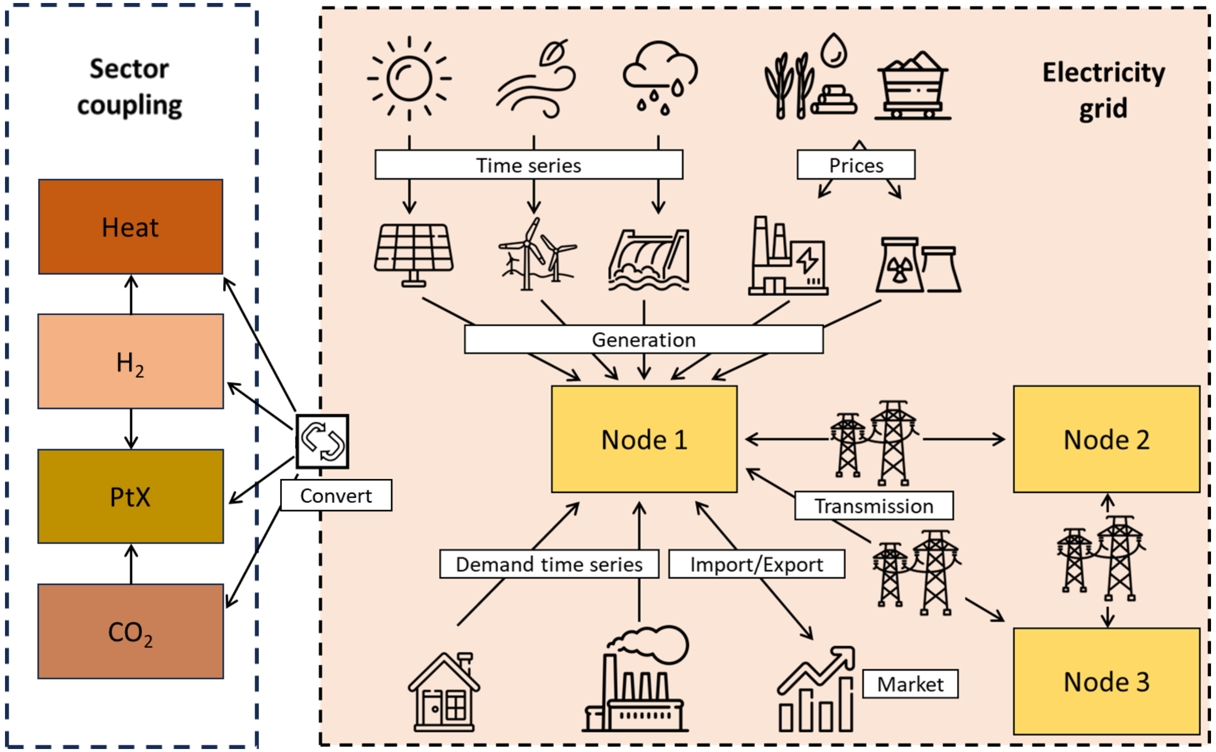
- Renewable power potential is significant, dimensions of sustainability
- Wind and solar resources provide balancing of regional differences
- Wind and solar resources provide temporal balancing
- Local resources are always different, requiring tailored solutions
- Transport of resources will be required, in one form or another

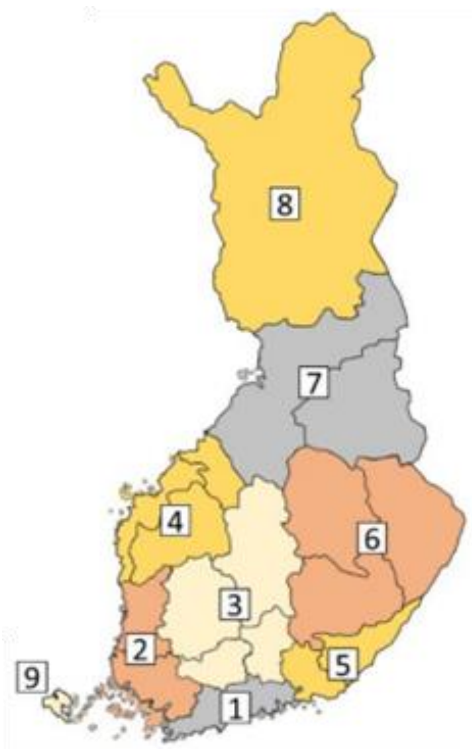
Finland’s distributed resources create regional energy imbalances and transportation needs

Topics of this presentation

- Distributed nature of resources and locational imbalances
- Energy transportation needs across areas of Finland.

An energy system model of Finland was developed to study future energy needs

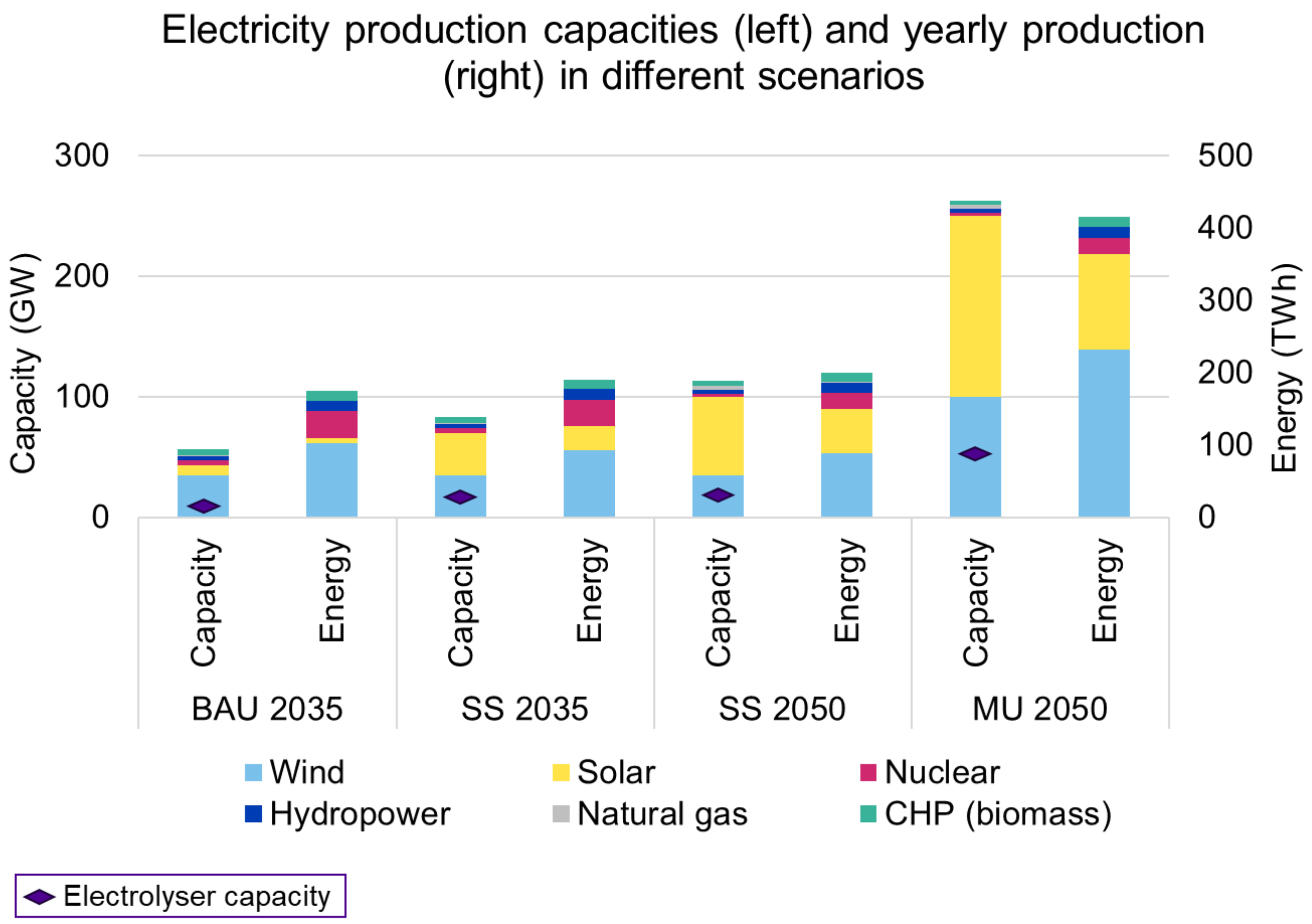




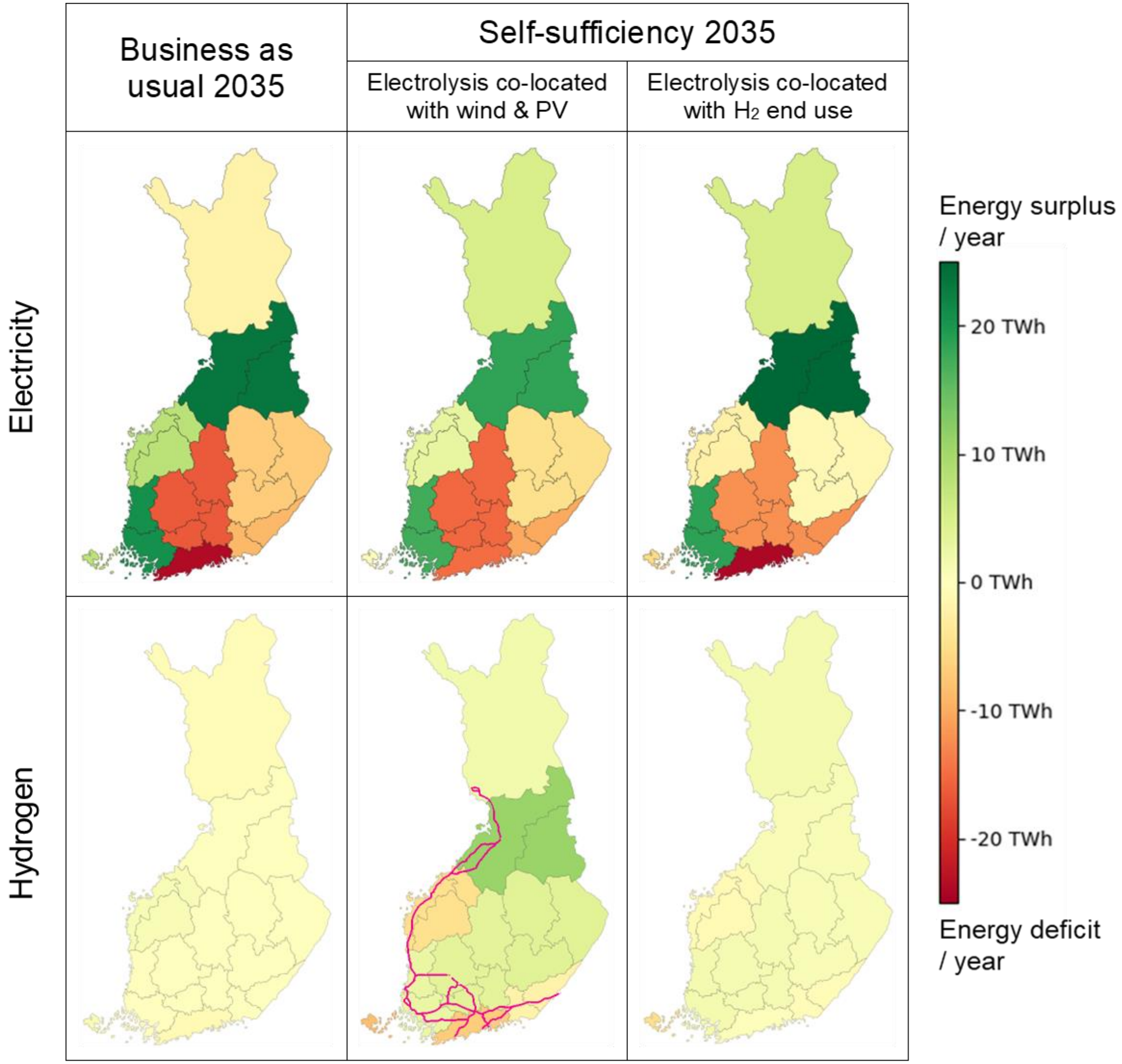
- Mathematical model representing the regional structure and operation of the energy system in Finland.
- In the model, Finland is divided into 9 regions.
- The model optimizes the cheapest way to produce the hourly energy demand. Storages and demand response is included.

Three scenarios were modelled

- **Business as usual** (BAU 2035)
  - Finland’s energy infrastructure develops by assuming the current publicly announced PtX development and extrapolating that to 2035.
- **Self-sufficiency** (SS 2035 and SS 2050)
  - All the consumed energy is produced in Finland
- **Maximal utilization** (MU 2050)
  - All the consumed energy is produced in Finland
  - Excess electricity is used for manufacturing PtX products for export



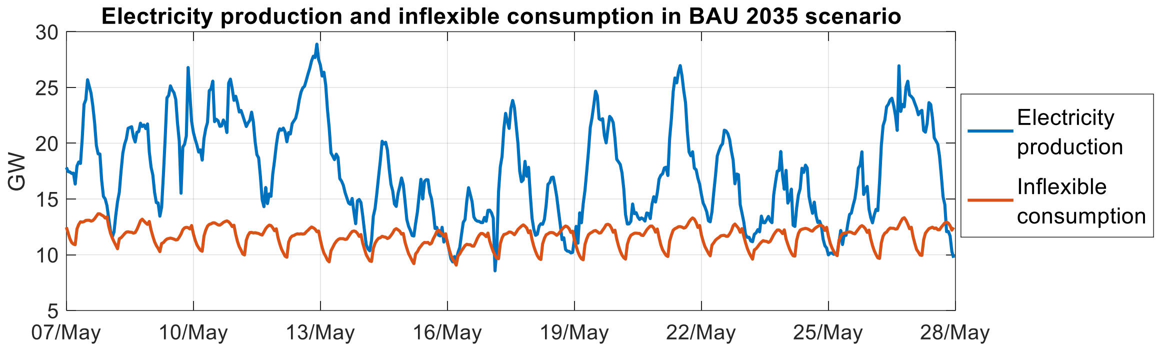
Modelling reveals regional imbalances

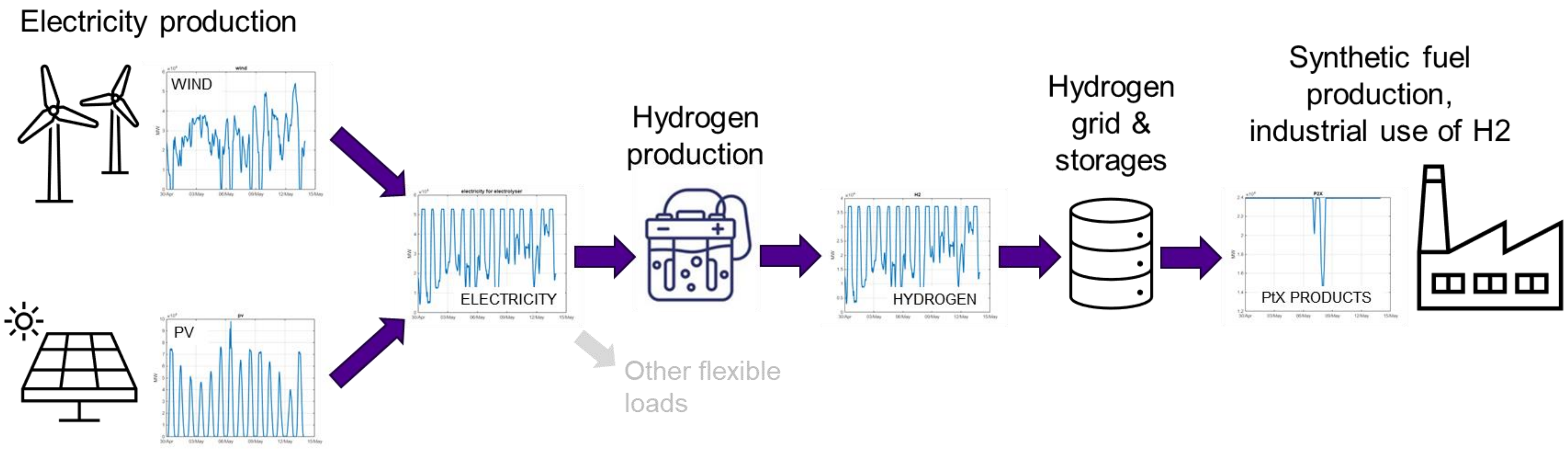


- The distributed nature of renewable energy resources and energy demand leads to regional imbalances: Finland has significant energy surplus and energy deficit areas.
- Modelled locations of production units (wind, PV, electrolysis, PtX) influence energy transport needs from one area to another
- Electricity grid reinforcement needs can be reduced by implementing a hydrogen transport infrastructure
  - This applies if electrolysis is regionally co-located with renewable electricity production

Flexibility needed in the value chain

- The energy system needs flexible loads (i.e., flexible consumption) to balance the high variability of renewable electricity production
- To utilize all variable green electricity production potential, hydrogen production must be flexible and **buffered with storages**.
- Insufficient buffer storage capacity reduces hydrogen production volumes (i.e., potential will be lost).
- The energy system needs buffer storage capacity to cope with the temporal variations of green electricity production and this will not depend on the locations of hydrogen production units.





Finland’s distributed resources create regional energy imbalances and transportation needs

Key messages

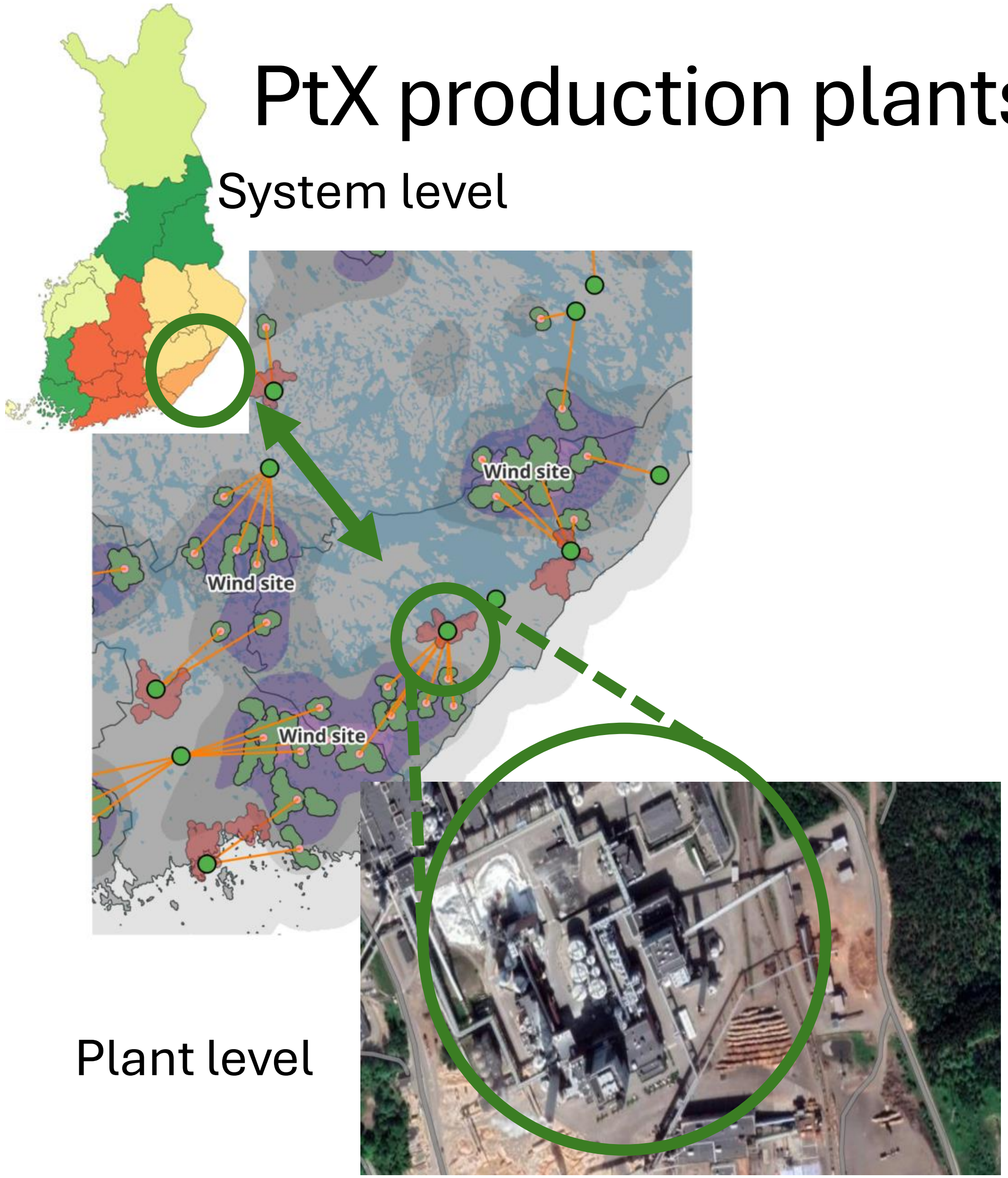
- Distributed nature of resources means that Finland has significant energy surplus and energy deficit areas.
- Electricity grid reinforcement needs can be reduced by implementing a hydrogen transport infrastructure
    - This applies especially if electrolysis is co-located with renewable electricity production.
- System level storage capacity and flexible electrolysis are needed in all scenarios, and it is not dependent on how hydrogen production will be located.

Value from PtX plant flexibility

Topics of this presentation

- Flexibility in as a requirement from the system level to the production plant level
- Results from a dynamic methanol production simulation case study
- Results from H_2 storage studies

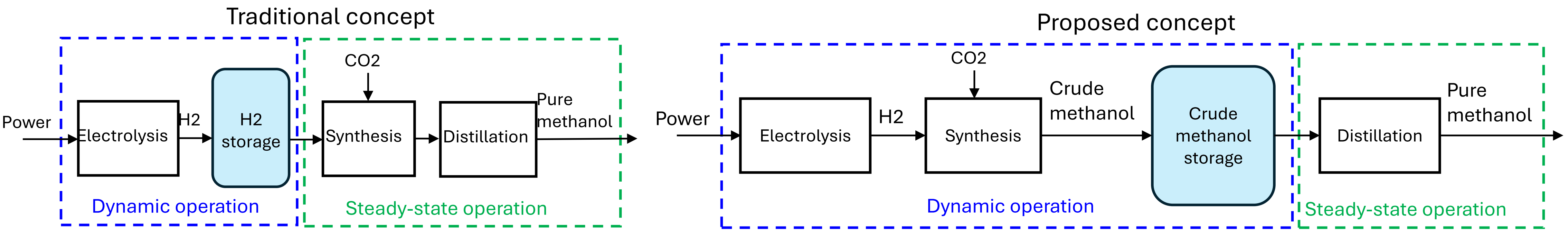
PtX production plants create value



- Distributed renewable electricity –based energy system is regionally and temporally imbalanced
- Flexibility is needed both at the system level and at plant levels
- Flexibility at plant levels provide both stability and added value

- Plant level flexibility is provided by:
  - Storages for H2, CO2, heat, and final products
  - Electrolysis, synthesis, CO2 capture processes

Results from simulation studies: Methanol processes can be modified to provide more flexibility and value



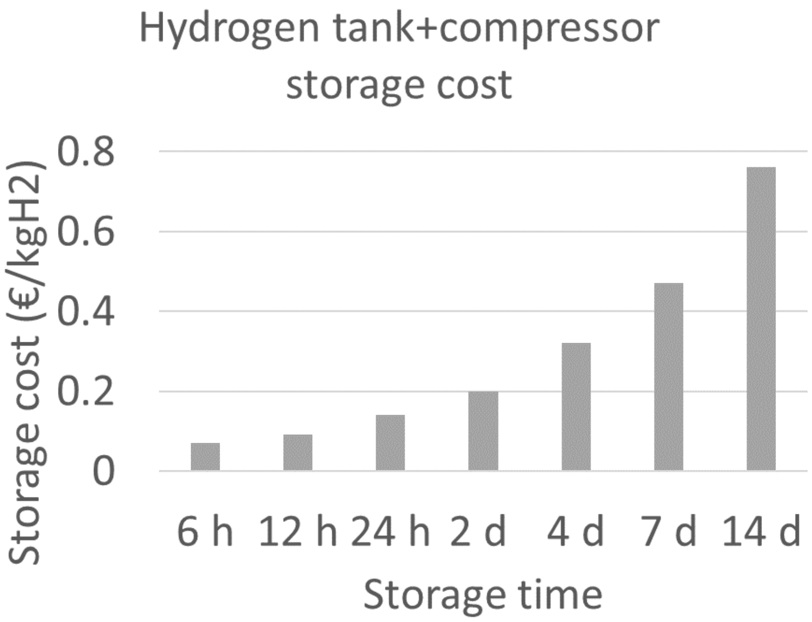
- Traditionally synthesis units and distillation processed are directly coupled
- Decoupling the process into dynamic production and steady state purification provides:
  - Shorter process start-up time
  - Faster process load changes, lower minimum load level
  - Storing of crude methanol is cheaper than storing of hydrogen

Source: Nguyen, Viet Hung (2022). HYGCEL results page https://www.lut.fi/en/hygcel

Findings related to hydrogen storages

- Optimal H_2 storage capacity varies between years and used electricity mix (Fig.1)
- H_2 tank storage cost increases H_2 production costs by 0.1-0.8 €/kg_{H2} (Fig. 2)
- Cost assumptions have a large effect on optimal unit capacities and full load hours

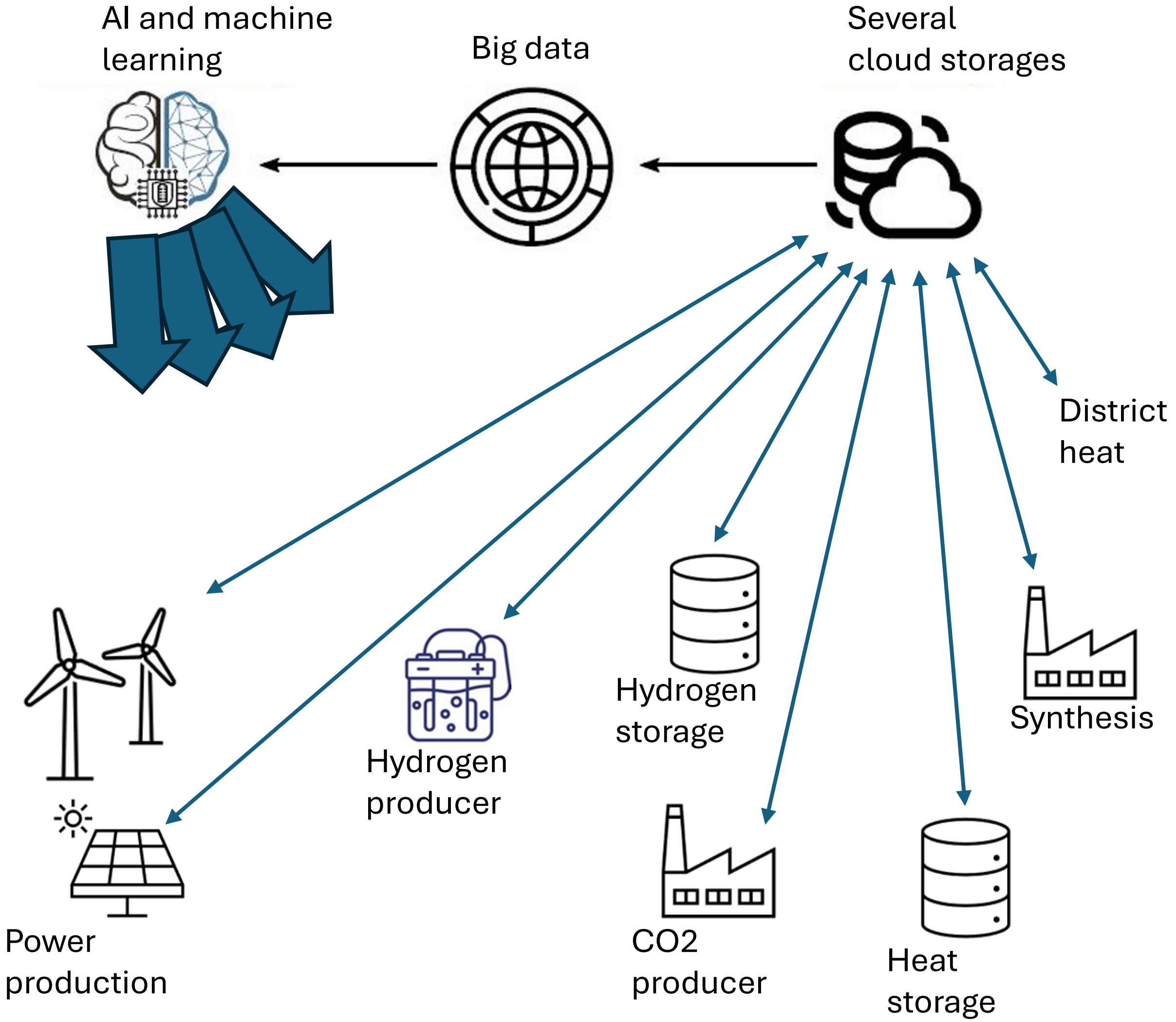
Source: Hyypiä, J. et al. (2023) HYGCEL results page https://www.lut.fi/en/hygcel



Source: Vilve, Sampo (2023). HYGCEL results page https://www.lut.fi/en/hygcel

AI and IoT in PtX operations

- AI and machine learning based solutions can provide efficient ways to simulate and forecast plant operation.
- Current practices doesn't support collecting storing and sharing big data between multiple actors.
- Industrial interfaces need development, standardization and new policies to guarantee secure and reliable data sharing.



Source: Ullah, M., et al. (2022), (2024). HYGCEL results page https://www.lut.fi/en/hygcel

Value from PtX plant level flexibility

Key messages

- Plant level flexibility provides added value for PtX plant operator.
- Optimal dimensioning of storages and process components is highly dependent on used electricity mix (wind, solar, grid) and operation conditions, such as annual price variations of electricity, heat and PtX products.
- Operation optimization can benefit from AI-based tools and data sharing IoT platforms.

Finland's competitiveness in hydrogen production compared to the other EU countries

Dario Nikzad
Senior Energy Analyst and Forecasting Lead

VaasaETT

Finland’s competitiveness in hydrogen production compared to other EU countries

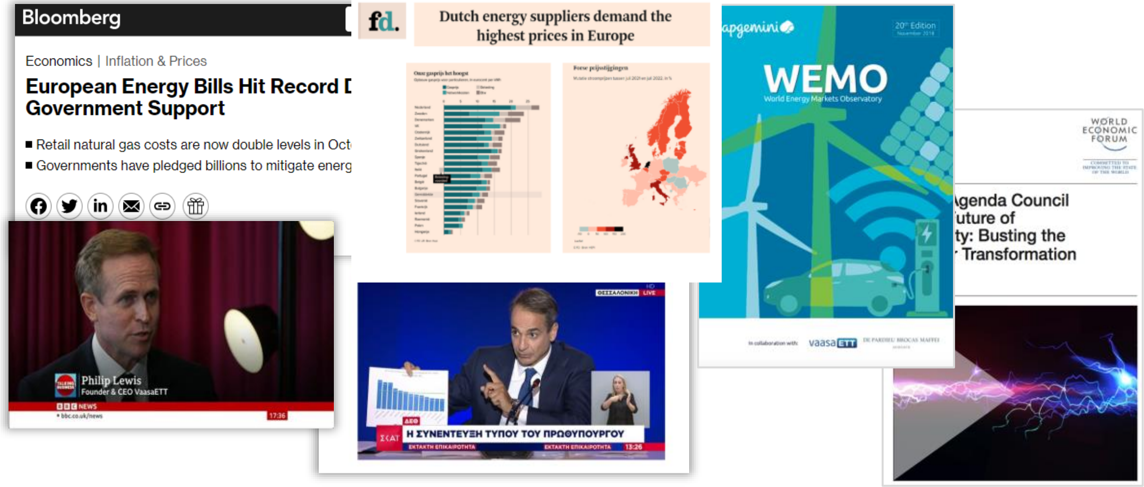
Focus on attractive power markets and optimal supply strategies for PtX

May 2024

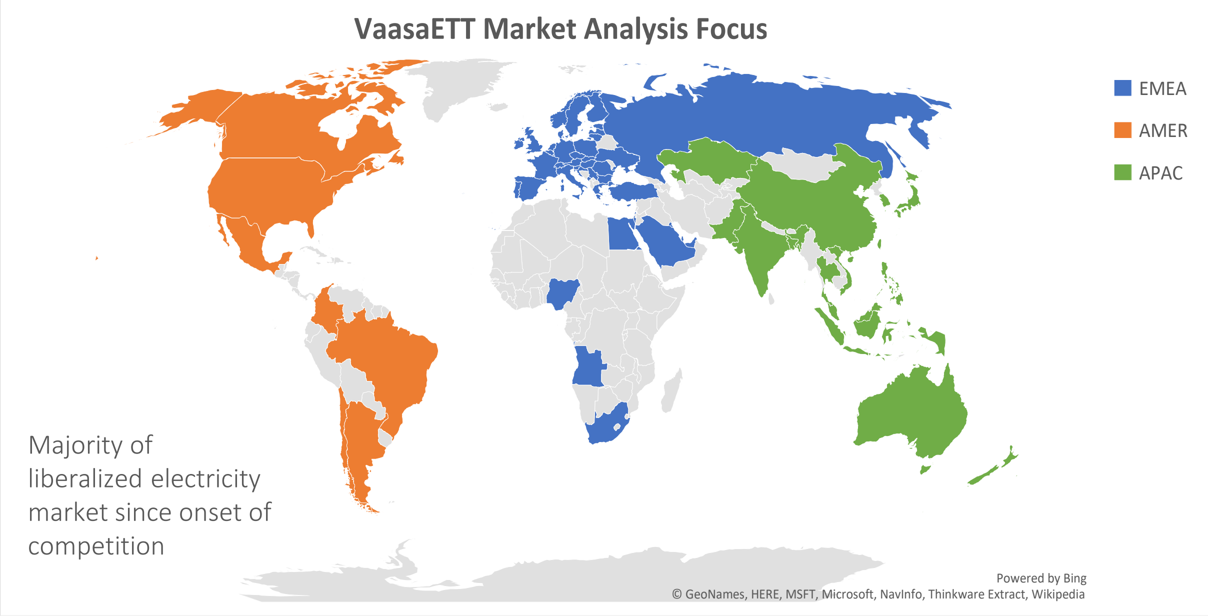
About VaasaETT in a nutshell

World-leading data analytics

20 Years of thought leadership



Nearly 90 markets analysed and tracked globally



Client Examples

IKEA, SwissLife, Norwegian Water Resources and Energy Directorate (NVE), FINGRID, European Commission, ENGIE, OMERS, ACCC Australian Competition & Consumer Commission, Microsoft, fortum, ovo energy, ofgem, Verbund, RECS International, Enerjisa, e.on

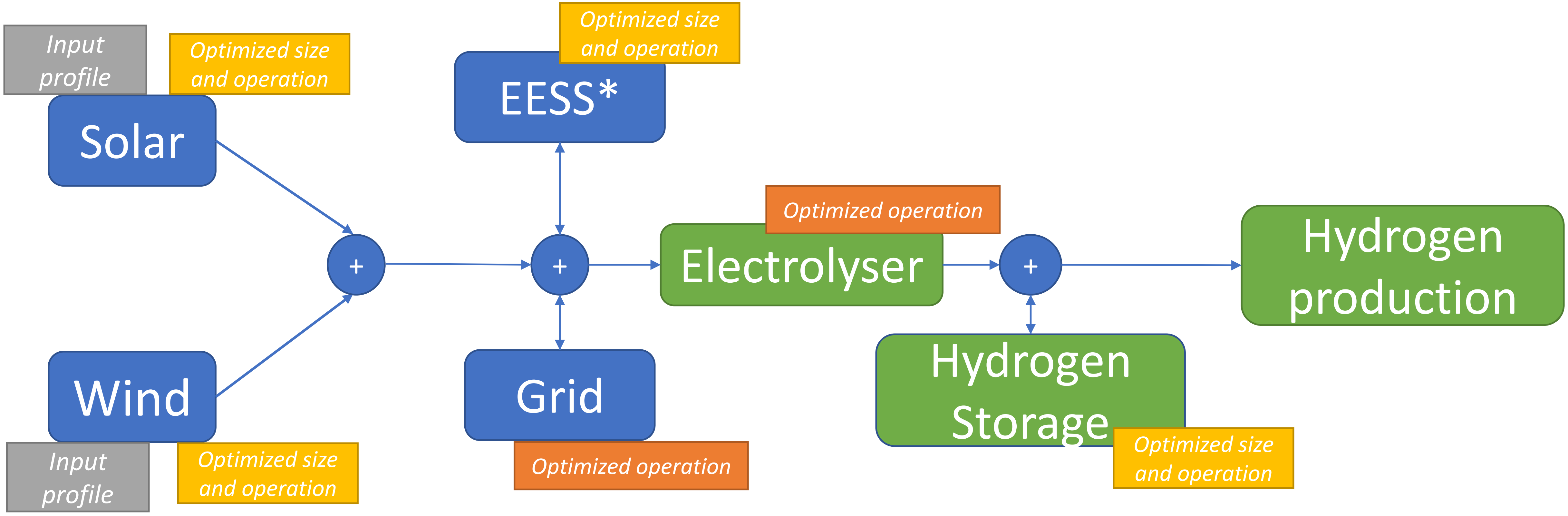
Power Procurement and PtX – Optimal markets and strategies

"Choosing the right market and power procurement strategy are two of the most important and underestimated factors determining the cost competitiveness of PtX plants"

Analysis of five different power procurement strategies through SATI optimization model

SATI-H_2, Model structure

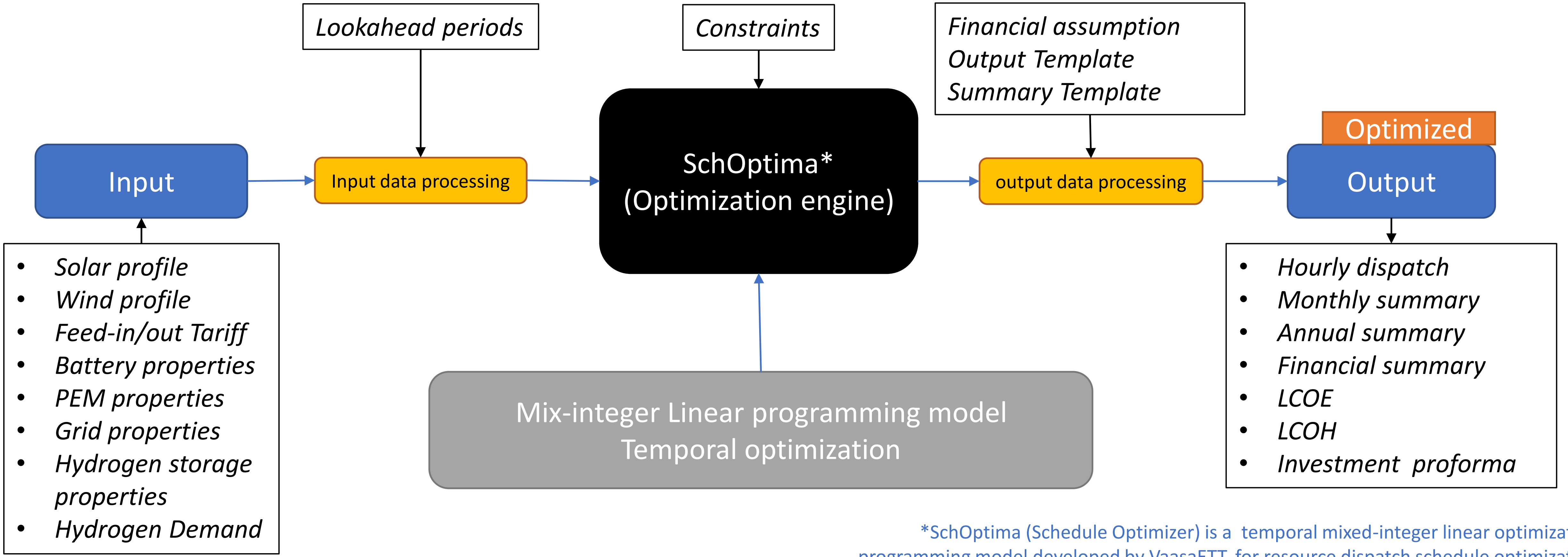
The model aim is to minimize the hydrogen production cost, by optimizing the system electricity supply to meet the electrolyser's operational target (highest-capacity factor). The model structure follows the figure shown below:



*EESS – Electrical Energy Storage system

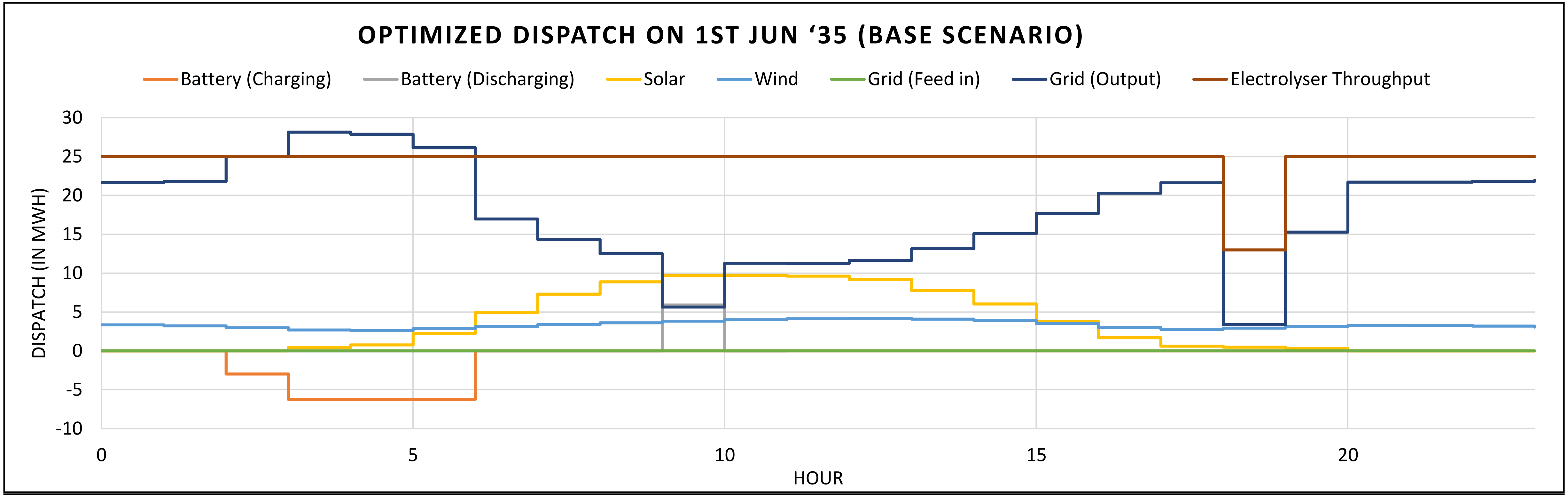
SchOptima – Optimization engine

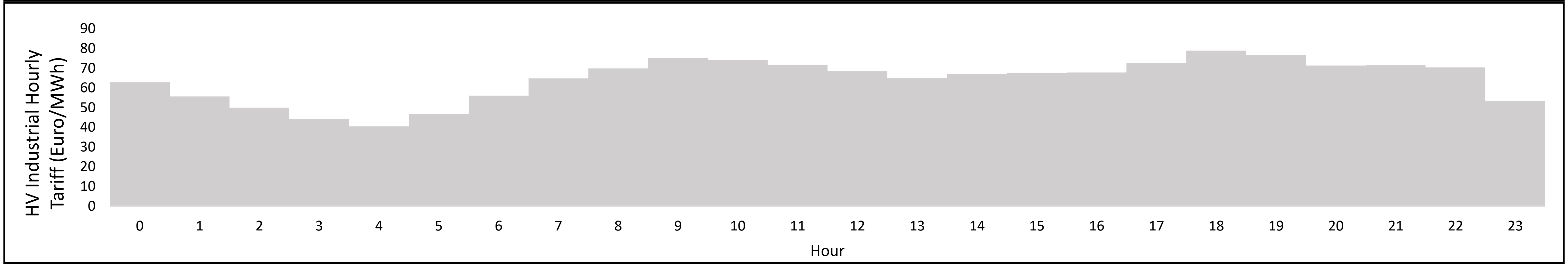
SATI model takes multiple inputs from a user friendly interface which is processed through a dedicated optimization engine to produce several high quality output files based on user specification and requirements. A brief flow chart is presented below. A simplified mathematical model for the optimizer (SchOptima) is presented in the next page.



*SchOptima (Schedule Optimizer) is a temporal mixed-integer linear optimization programming model developed by VaasaETT, for resource dispatch schedule optimization

Optimizad Dispatch with hourly granularity – Summer 2035 example





VaasaETT know-how on long-term bill forecast

VaasaETT has a long experience (since 2013) in storing historical full bill examples (from LV to HV customers) and providing long-term bill forecast in over 60 countries globally.

Energy charges

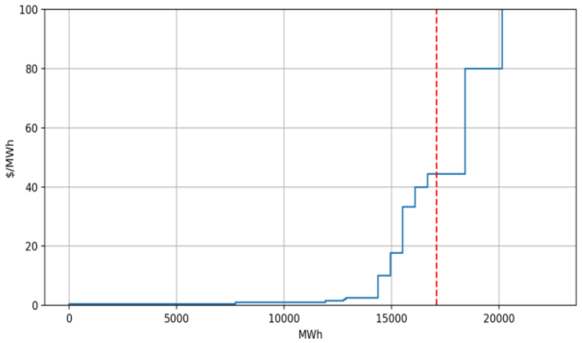
In-house Supply Stack Model (Merit-Order Model) for long-term power price forecast:

- ❖ Trained on historical supply/demand monthly data;
- ❖ Simulates marginal pricing mechanism at bidding zone level
- ❖ Highly sensitive to changes in demand, supply, energy mix and transmission constraints
- ❖ National Strategic Plans, IEA, ENTSO-E and national TSOs scenario are basis of scenario building

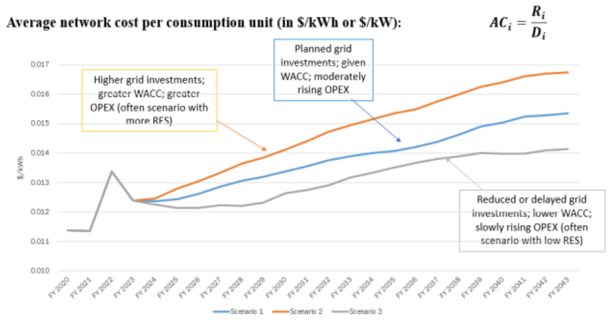
Network charges

Dedicated model focuses on:

- ❖ Short and long-term TSO/DSOs grid investment plans, regulatory asset base (RAB) of PP&E, historical transmission tariffs and changes in the regulatory framework.
- ❖ Sensitive to CAPEX, OPEX, depreciation and WACC
- ❖ Determines the all-in network price (USD/kWh) per consumer type (HV, MV and LV level)



Example of energy price formation following the supply stack methodology



Example of network charge forecast based on three scenario

Regulated charges

Regulated charges forecast include RES incentives, energy efficiency or environmental measures, system reliability and other country specific charges.

- ❖ For each market we analyse and reproduce the methodology behind the regulated charge allocation per consumer category.

Case studies: analysis of 5 different power procurement strategies

CASE 0 – Fully grid reliance, spot price-based contract (no green H_2)
- Power solely procured from the spot market

CASE 1 – Onsite Wind/Solar + Spot price contract
- Onsite RES generation and missing demand covered by spot price contract

CASE 2 – Onsite Wind/Solar + Battery + Spot price contract
- Similar to Case 2, but the battery allows less grid reliance and arbitrage opportunities

CASE 3 – Virtual RES PPA + Grid
- The PtX load follows the RES PPA's profile, while the remaining part is covered by a spot-price based contract

CASE 4 – Virtual PPA, 24/7
- Power demand fully covered by a Virtual PPA

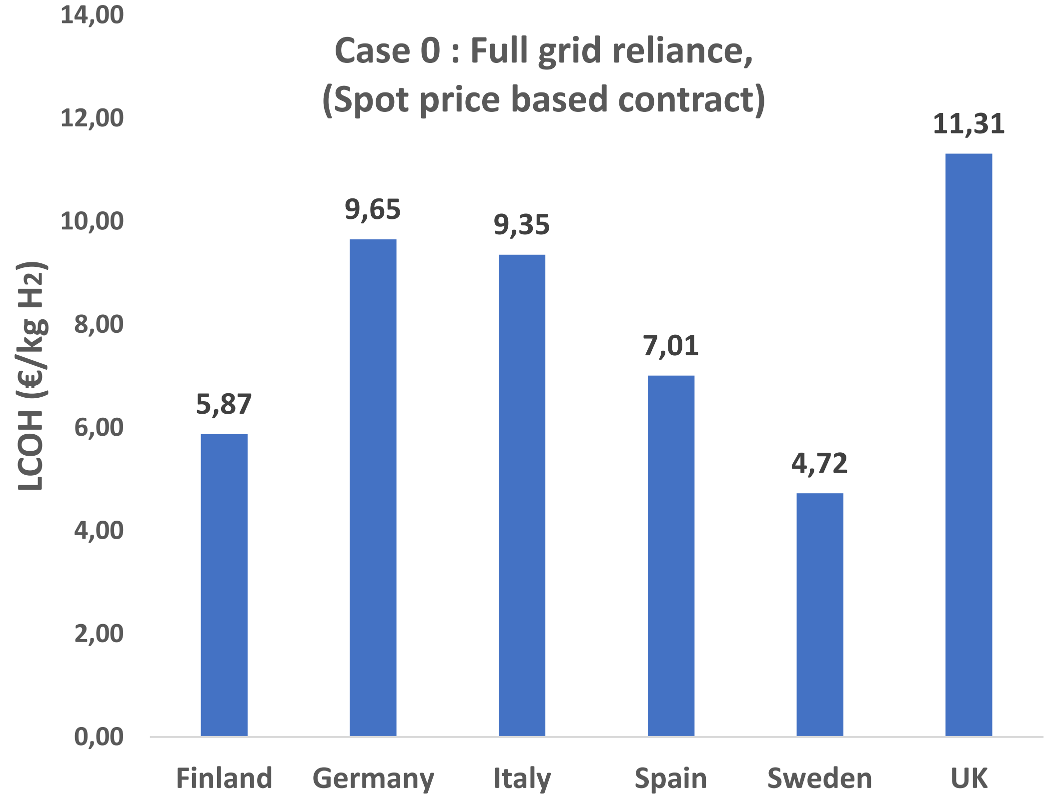
COUNTRIES ANALYSED
Finland, Sweden, Italy, Spain, Germany and Great Britain

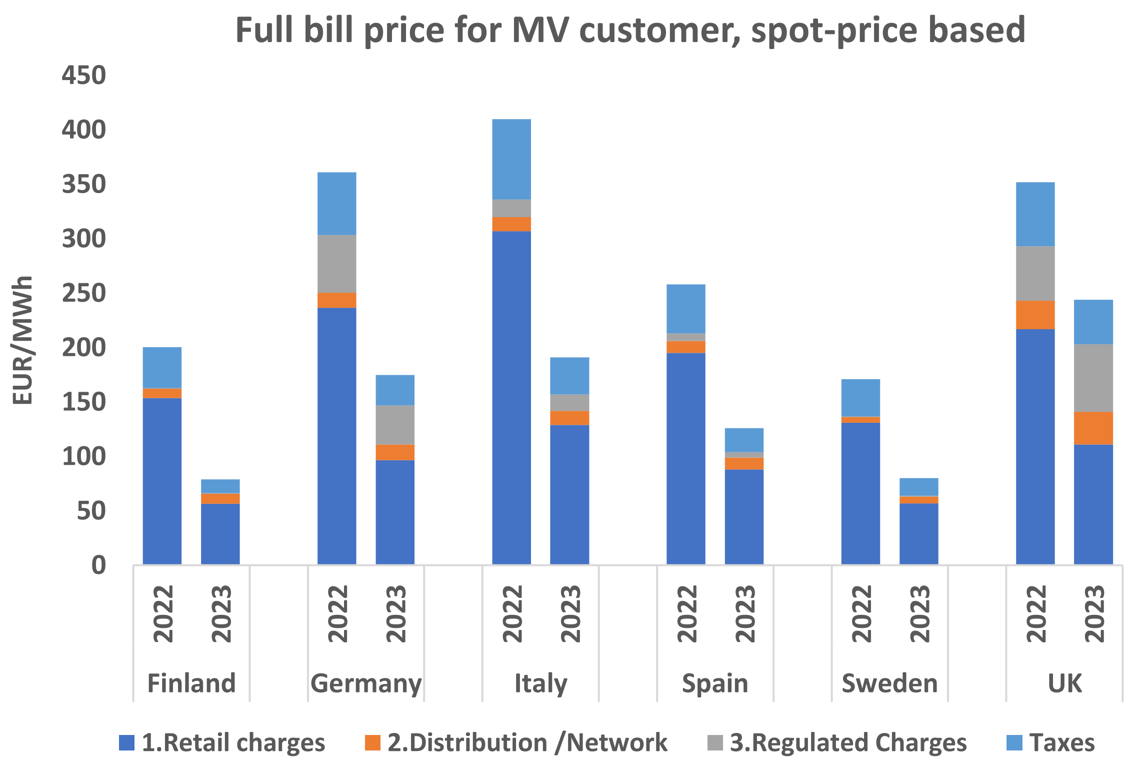
Main input parameters

All the input parameters are based on a set of official references related to countrywide datasets.
The hourly wind and solar profiles are taken at country level (10-years average profiles) from the 'European Meteorological Data Hub'.

Model Inputs	Unit	Value
PEM Electrolyser CAPEX	€/kW	1400
PEM Electrolyser OPEX	€/kW/yr	20
Electrolyser size	kW	5000
Onshore Wind CAPEX	€/kW	1300
Onshore Wind OPEX	€/kW/yr	39
Utility Scale Solar CAPEX	€/kW	600
Utility Scale Solar OPEX	€/kW/yr	12
Li-ion Battery CAPEX (4hr)	€/kWh	450
Li-ion Battery OPEX (4hr)	€/kWh/yr	4.5
Project lifetime	Yr	20
Customer connection level	Voltage	Medium Voltage (MV)
Debt to equity ratio	:	60:40
Project start	Yr	2024
Discount rate	%	3
Price Scenario	-	VaasaETT Base Scenario

CASE 0, Full grid reliance – “Reference case”, spot-price based contract





Ranking

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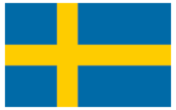
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3°

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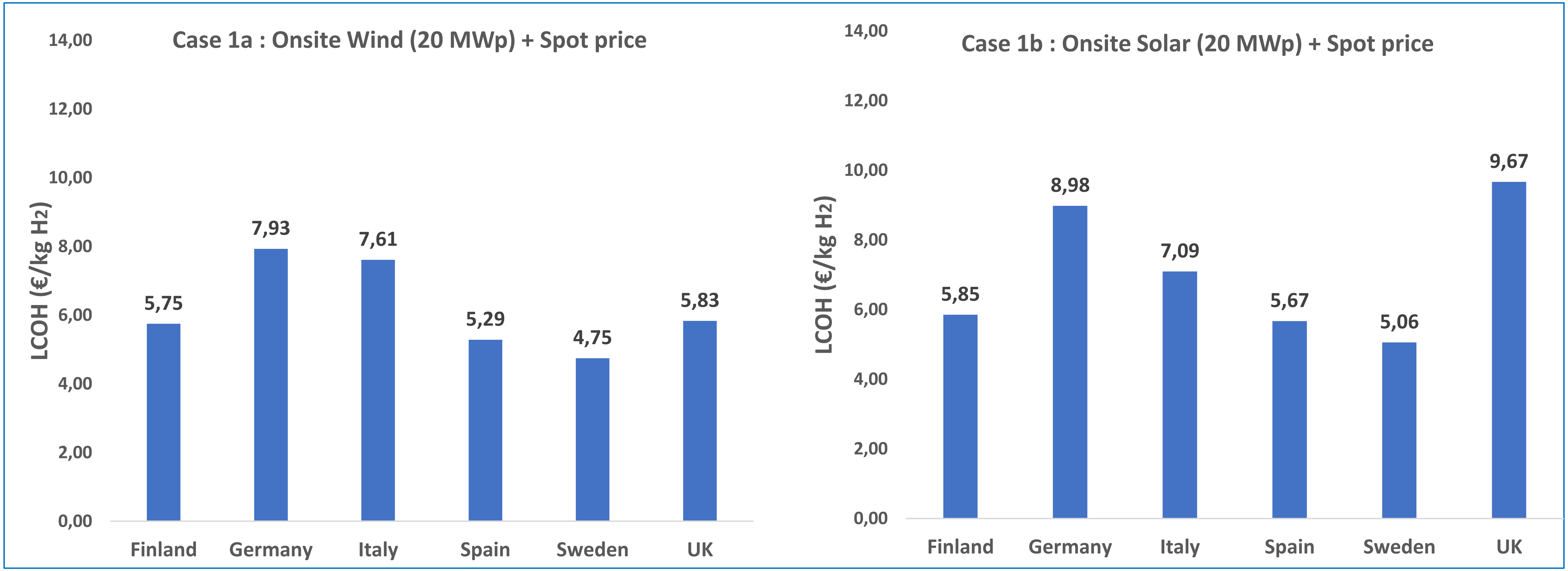
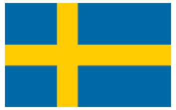
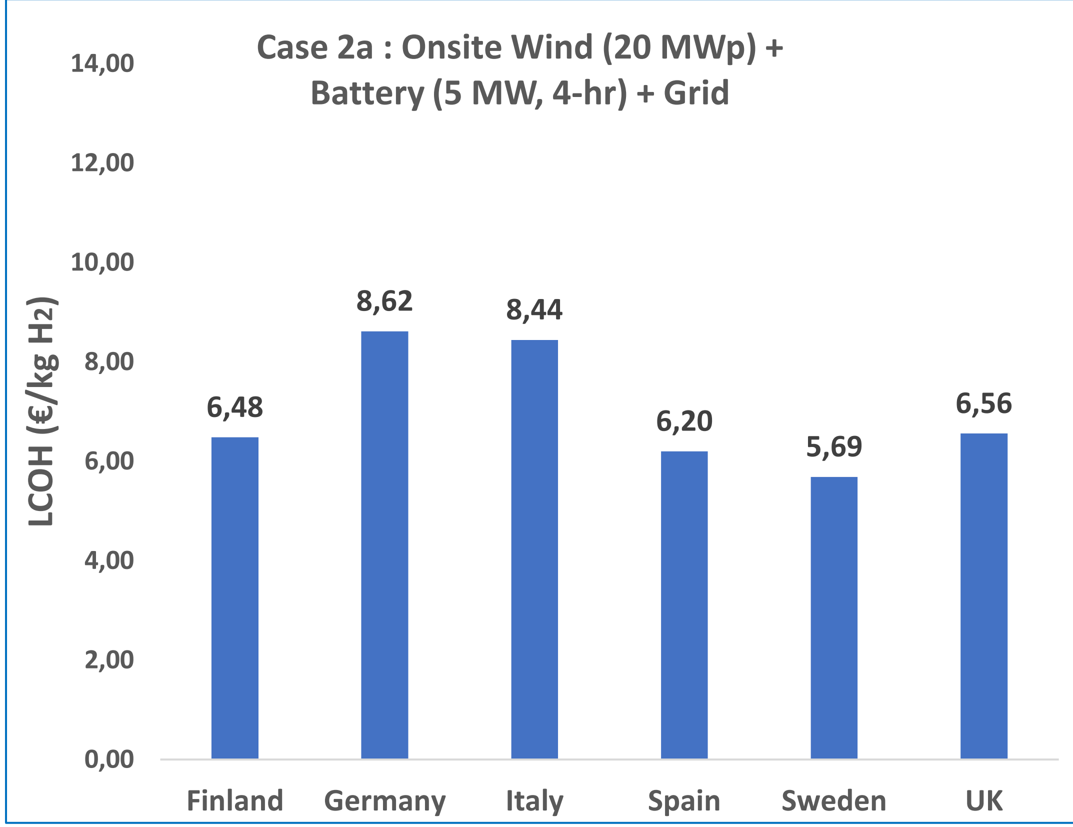
CASE 1 – Onsite wind/solar + Grid (spot price)

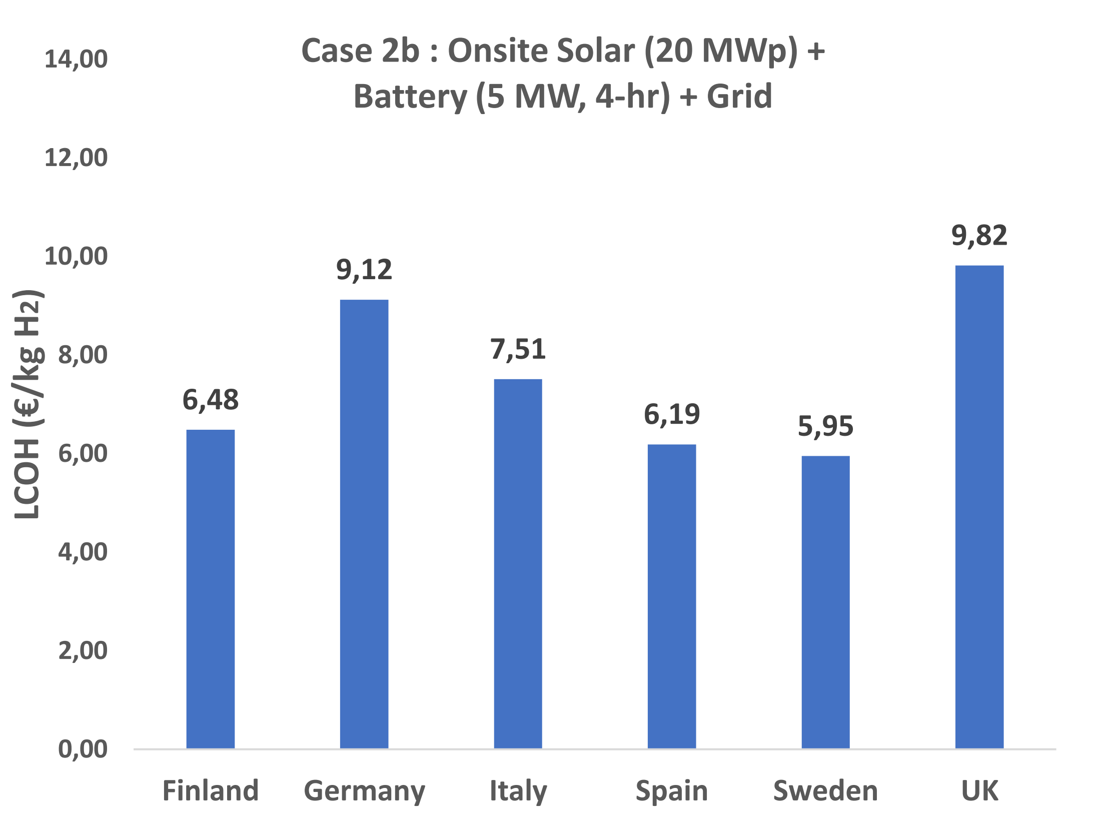


Ranking

1°  2°  3°  4°  5°  6° 

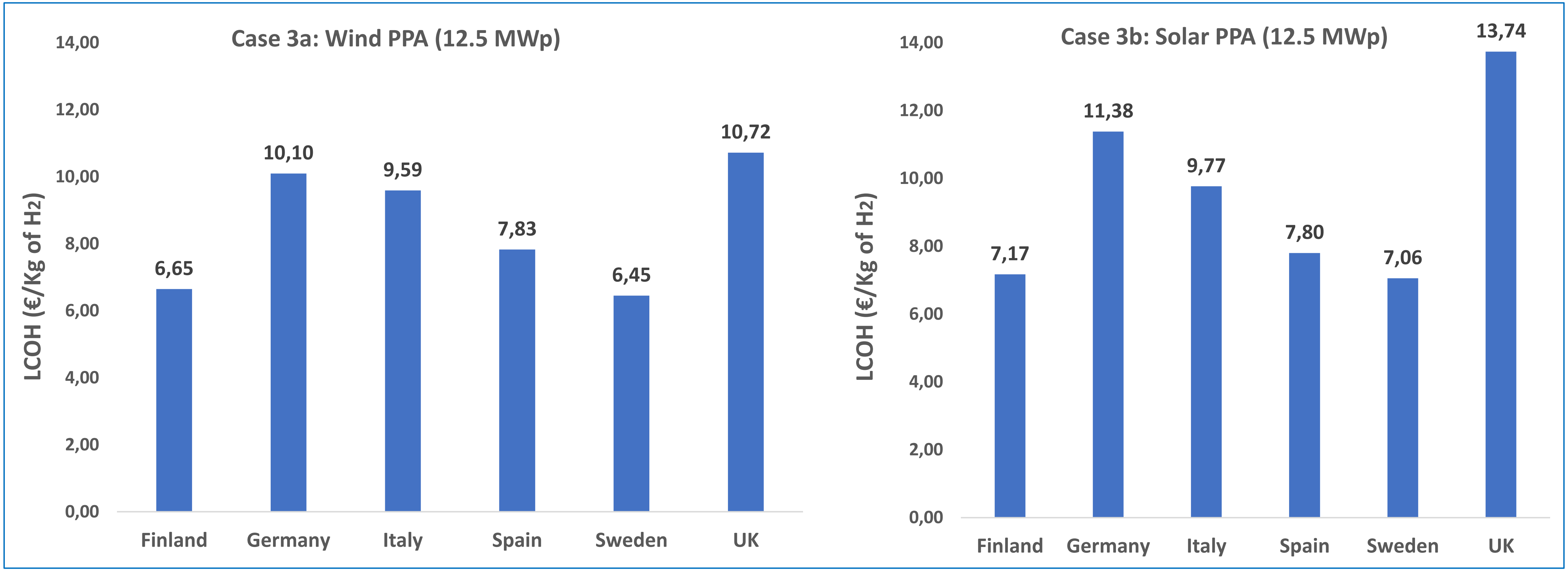
CASE 2 – Onsite RES + Battery + Grid (spot price)





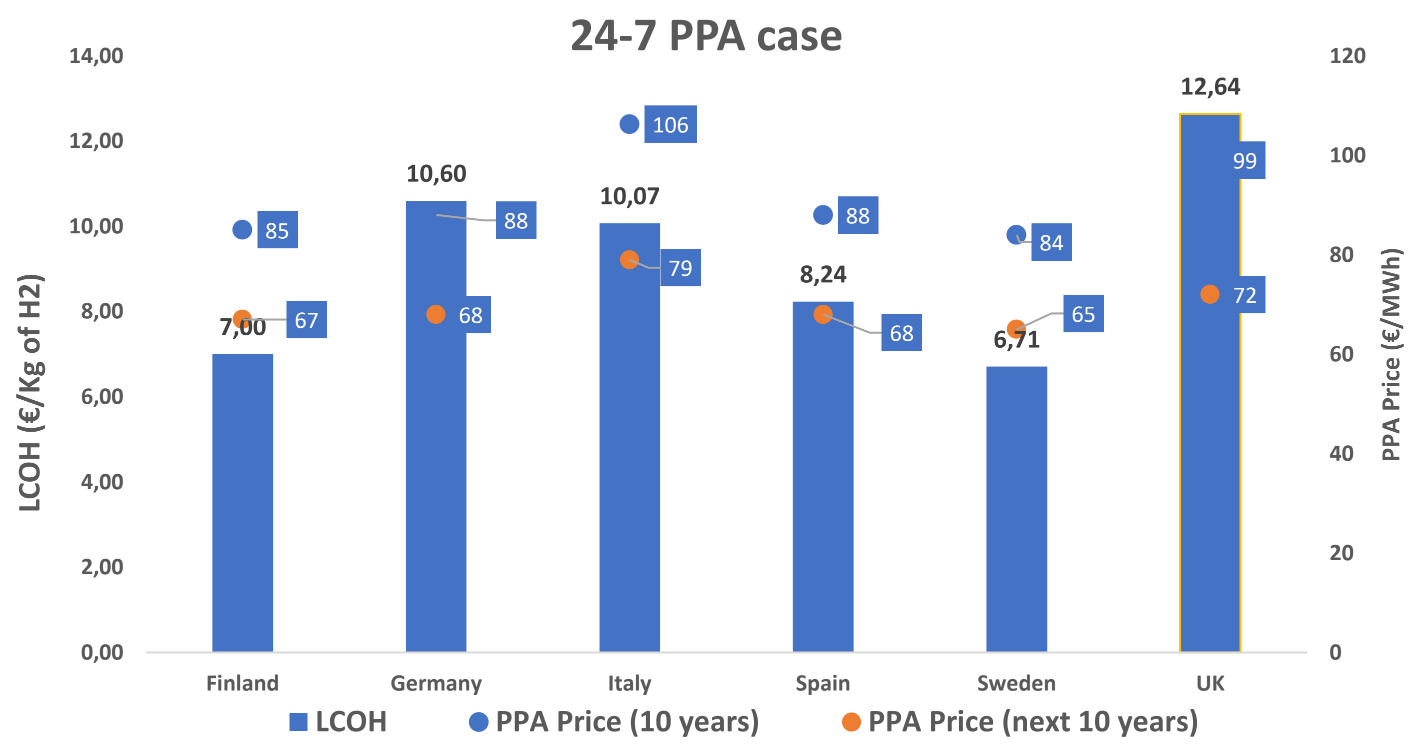
Ranking

CASE 3 – Virtual PPA adjusted to RES profiles



Ranking

CASE 4 – Virtual PPA, 24/7

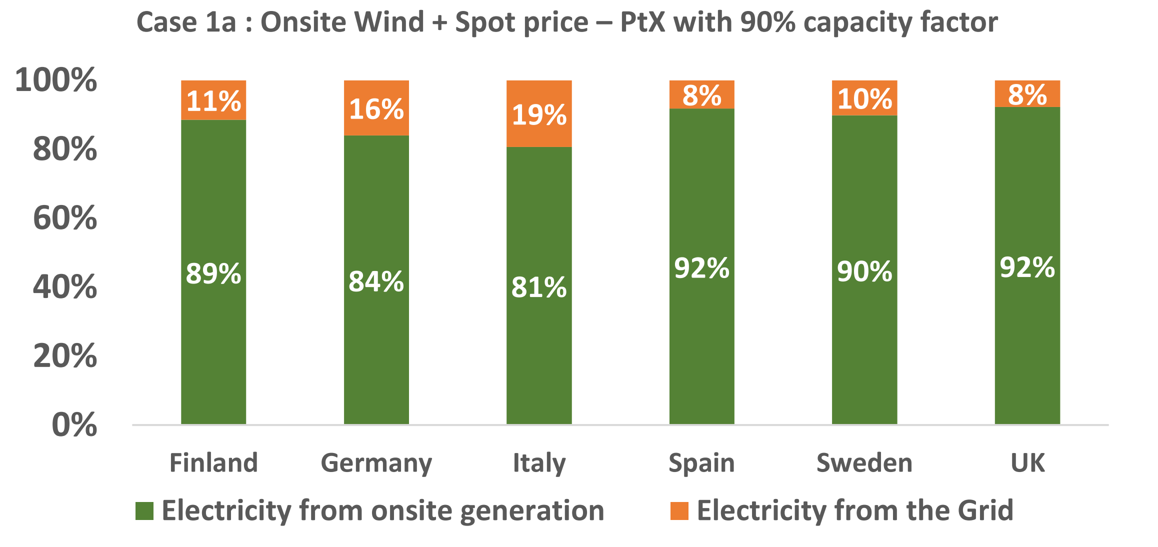


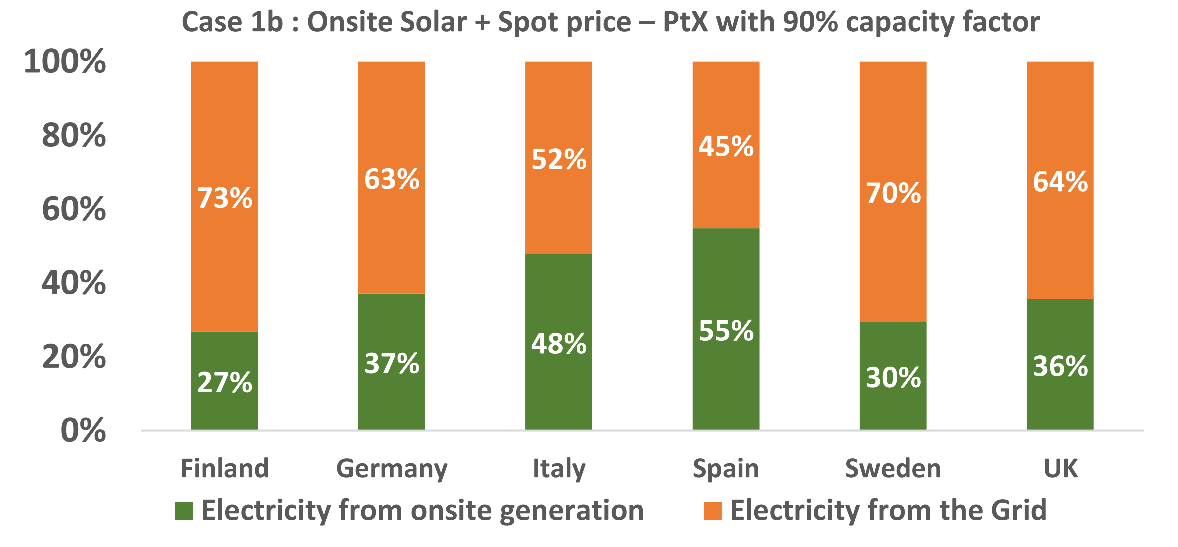
- Two 10-yr PPAs are considered, the first starting in 2024 and the second in 2034.
- 24/7 PPAs cover the PtX demand with green supply and hour granularity
- Final PPA price includes green certificate prices when needed

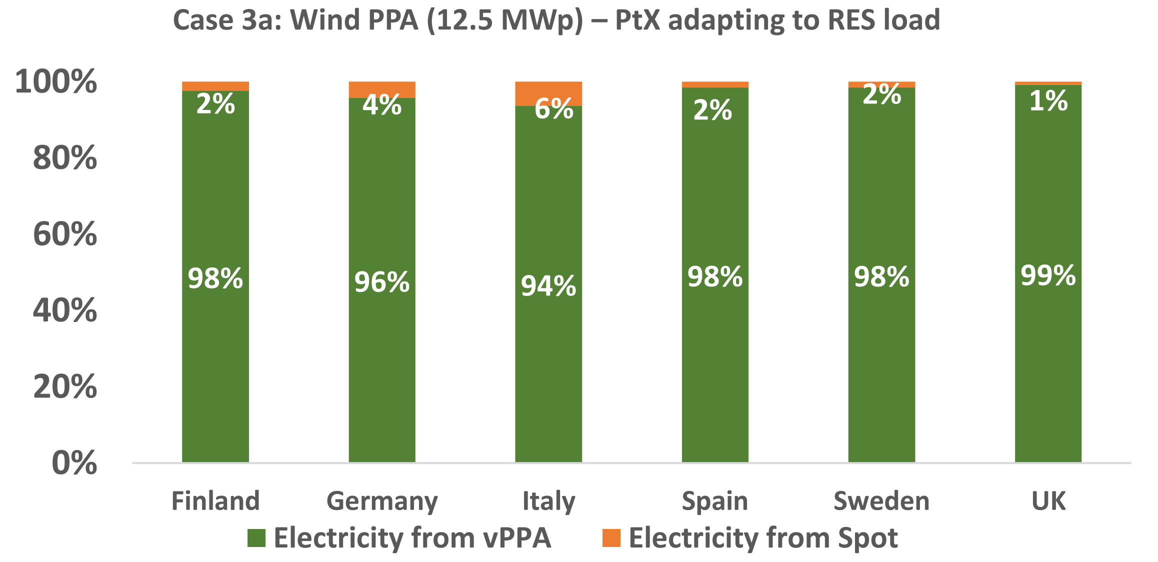
Ranking

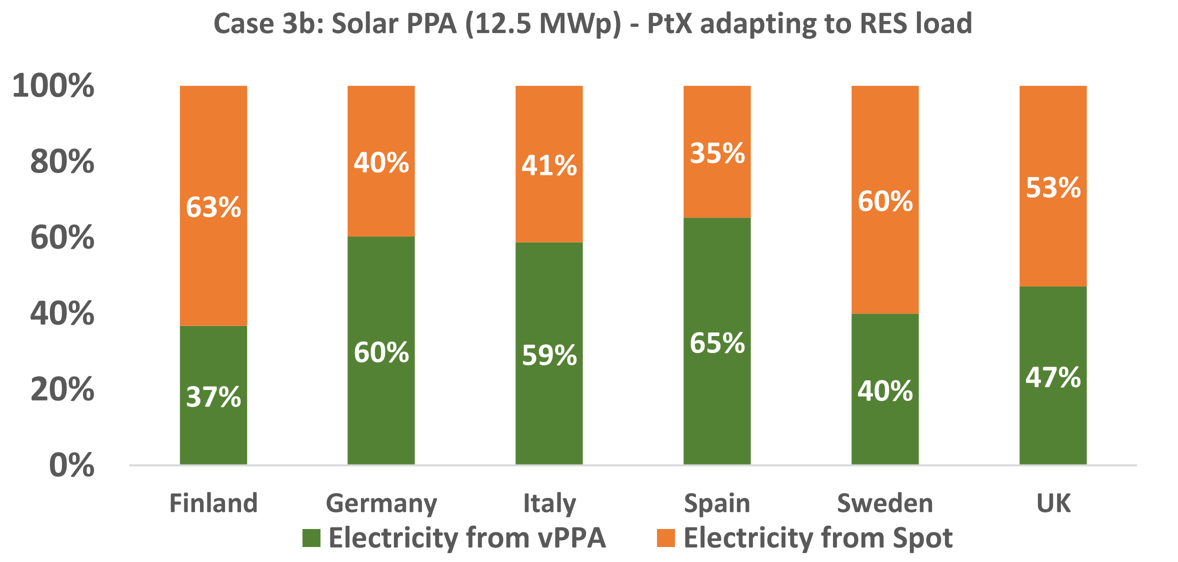
1°  2°  3°  4°  5°  6° 

Final overview – Which case can be considered Green?









Conclusions

- The right power procurement strategy will be a key factor determining PtX competitiveness
- Certain markets looks more attractive than others, thanks to RES potential, average low spot prices, average low bills
- Markets that look unattractive for PtX at first glance, might turn appealing by just choosing the right procurement strategy
- The right ancillary supply assets and the optimal interaction with the grid can determine the PtX project success.
- Based on this study, batteries are adding about 1 €/kgH2 to the system LCOH. At the same time, ancillary market revenues could completely turn this outlook.
- Further analysis is needed considering alternative market scenario and interaction with other revenue streams, such as heating, oxygen chain, ancillary markets, battery strategies.

Final Ranking

1°

2°

3°

4°

5°

6°


Thank you!

Dario Nikzad
Forecasting Lead, Senior Energy Analyst

May 2024

Reflections from Gasgrid and Fingrid

Venla Saarela
Head of Strategic Analysis and RDI

Gasgrid

FINGRID

GASGRID

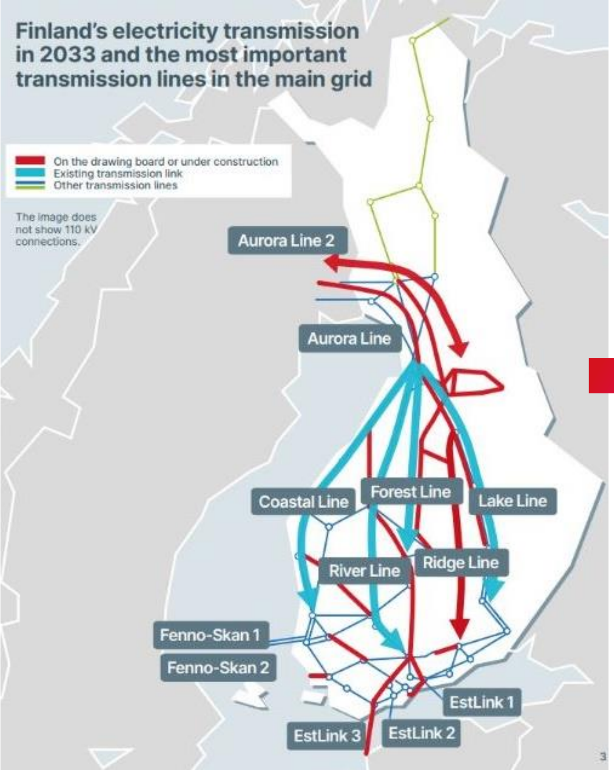
Gasgrid's and Fingrid’s joint hydrogen economy project

Venla Saarela, Gasgrid Finland

22 May 2023

Energy transmission networks as enablers of the hydrogen economy and the clean energy system

- Main goals of the joint project
  - Establish the energy infrastructure requirements for the implementation of a clean and cost-effective system
  - Support the co-design and co-development of the energy infrastructure, enabling investments in clean energy
- Joint project launched in 2021
  - Interim report published in spring 2022
  - Scenario consultations summer–autumn 2022
  - Scenarios published in spring 2023
  - Final seminar in Autumn 2023
- The joint project was part of the HYGCEL
  - Business Finland granted funding to both the joint project and the wider project series



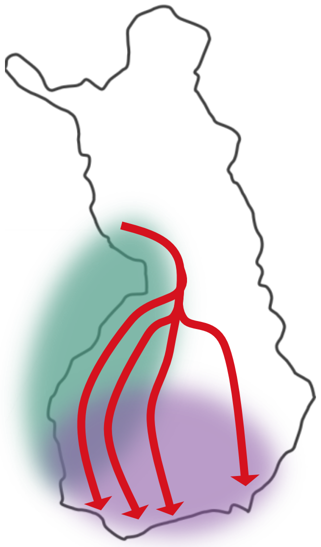
The competitive advantage of Finnish hydrogen production is based on affordable wind power

Finland has a historic opportunity to lead the way

Finland is particularly well positioned

Competitive wind power

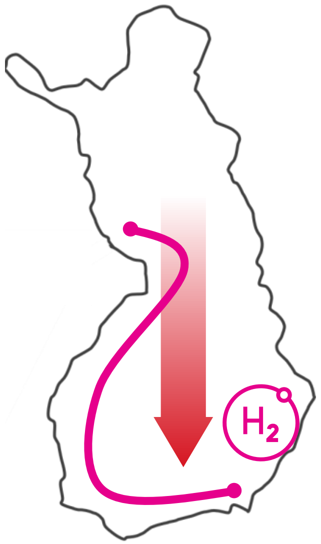
Solar power & biogenic CO2



A strong electricity infrastructure and well-functioning electricity market

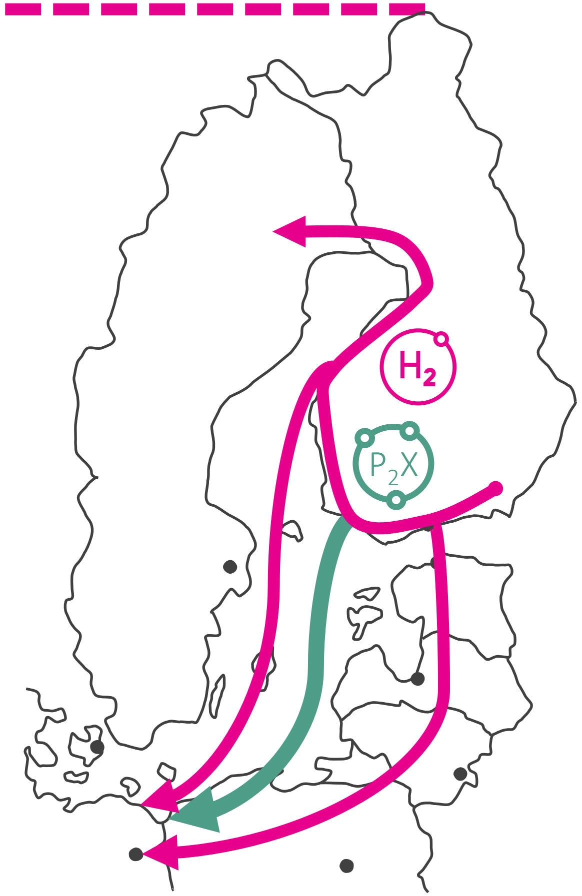
A strong energy infrastructure lets us realise our potential

Energy transmission as hydrogen between producers and consumers and balance created through storage



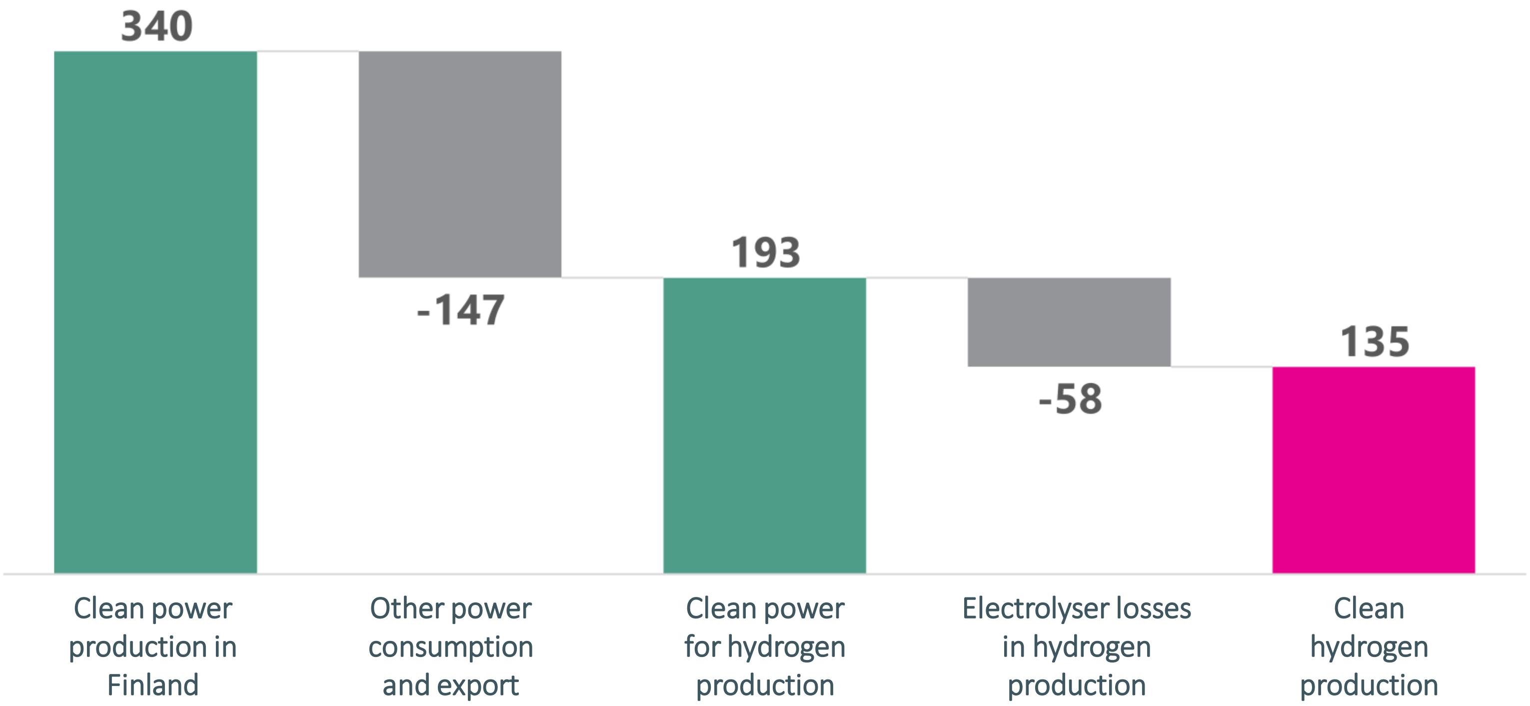
Reinforcing electricity transmission, especially on the north to south axis

Enables the birth of a new export industry



Finland has enormous potential to produce renewable electricity and clean hydrogen

Highest growth scenario prospects for Finland in 2040
(TWh electricity/hydrogen)



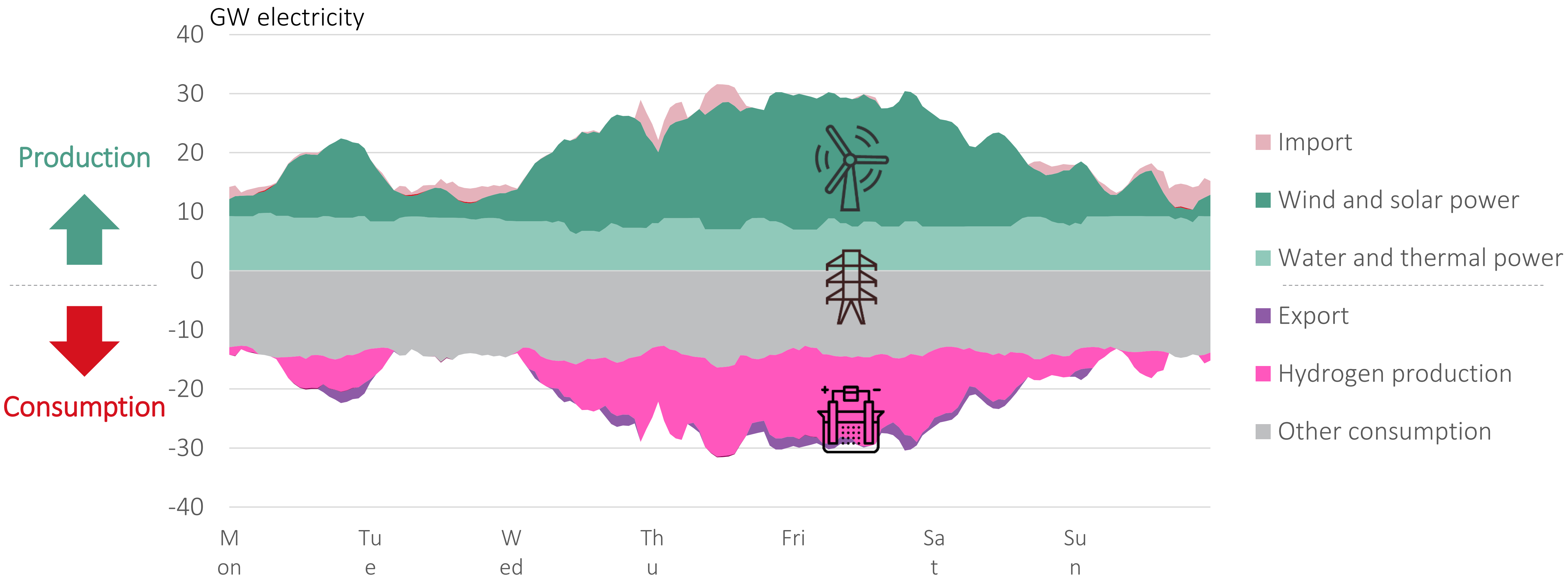
Wind power
will be the most significant form of electricity production

Hydrogen production
will be the largest application for electricity

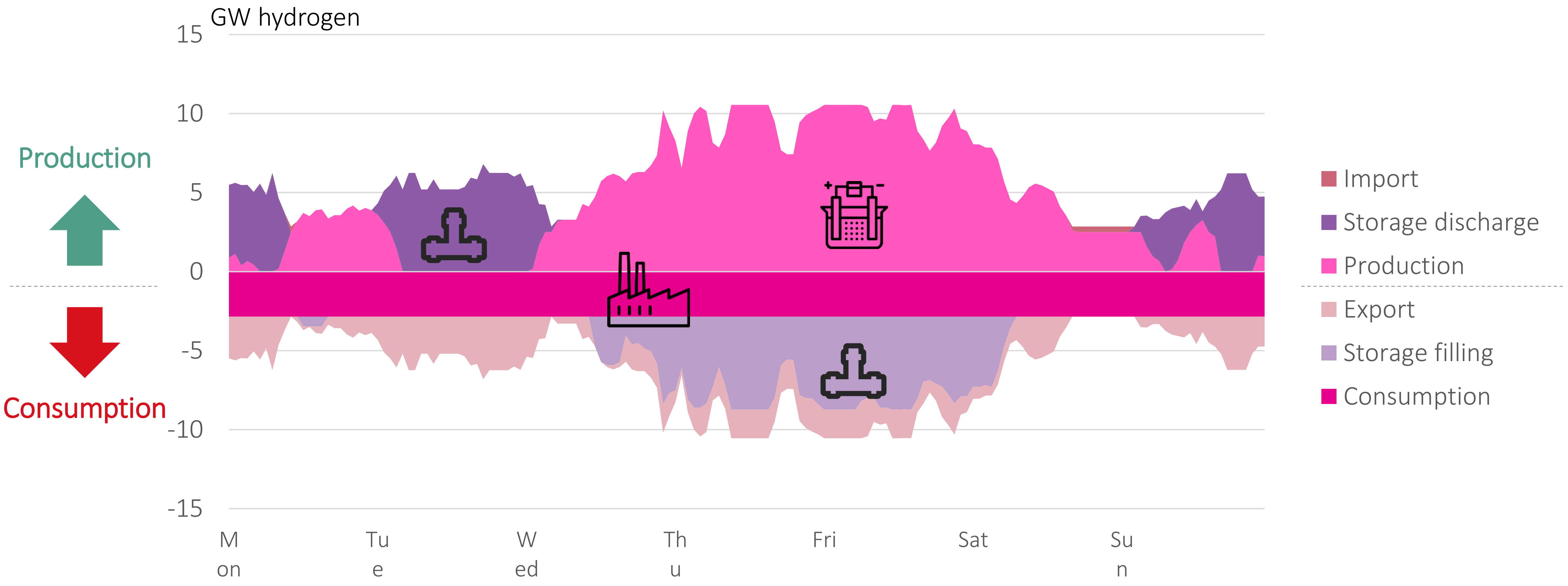
Hydrogen storages
will enable the maximal exploitation of affordable renewable electricity

Large-scale exploitation of wind power requires flexibility

Electricity is converted into hydrogen during windy hours, when there is plenty of cheap electricity on offer



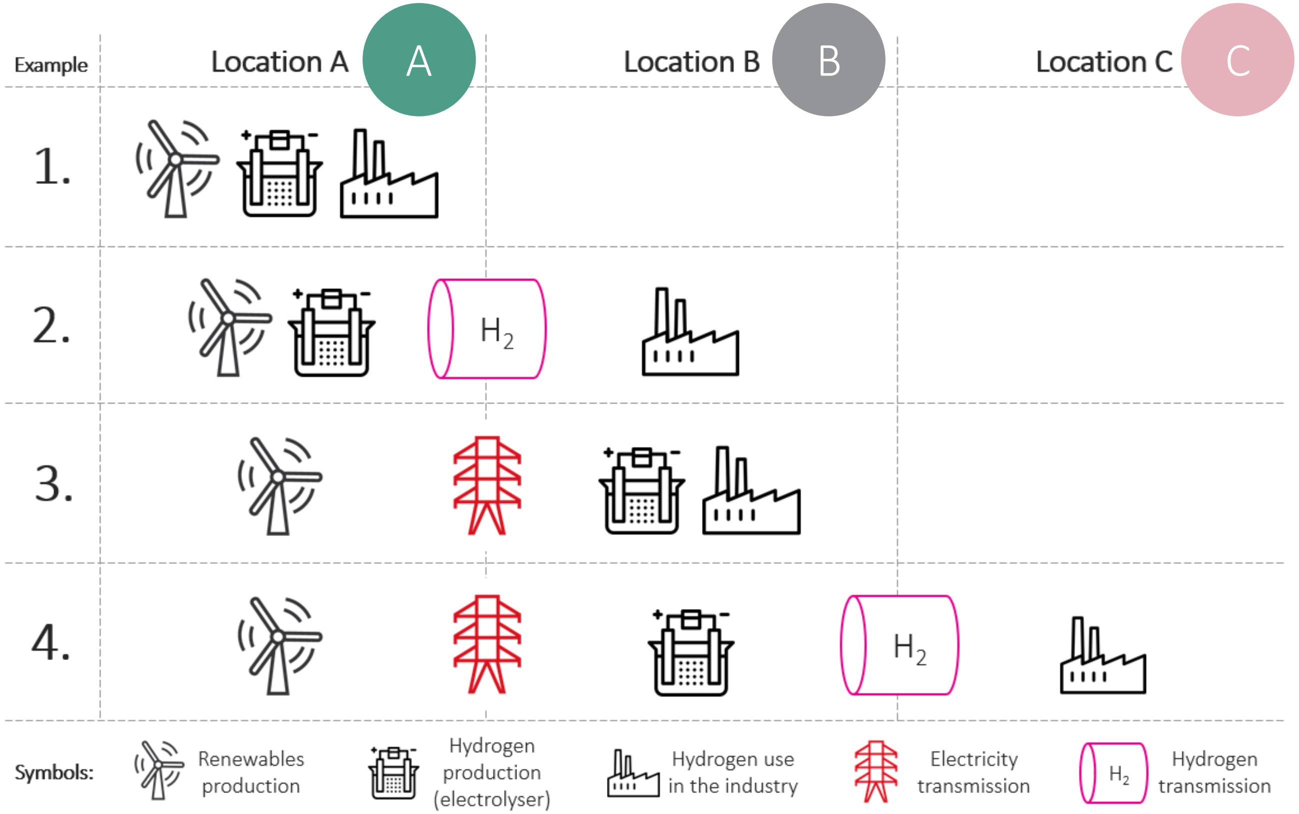
Hydrogen production is flexible, but end users receive a steady supply of hydrogen through transmission system and storages

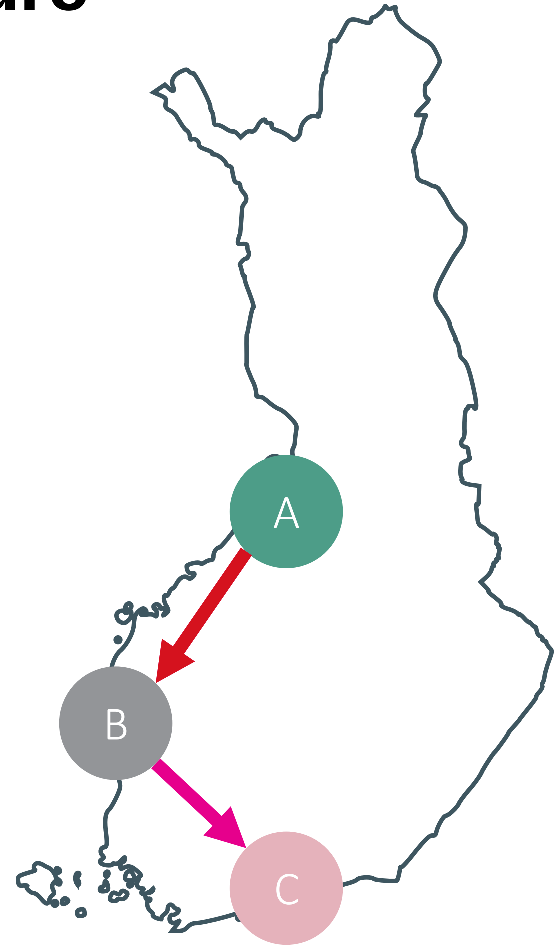


The integration of electricity and hydrogen balances the energy system

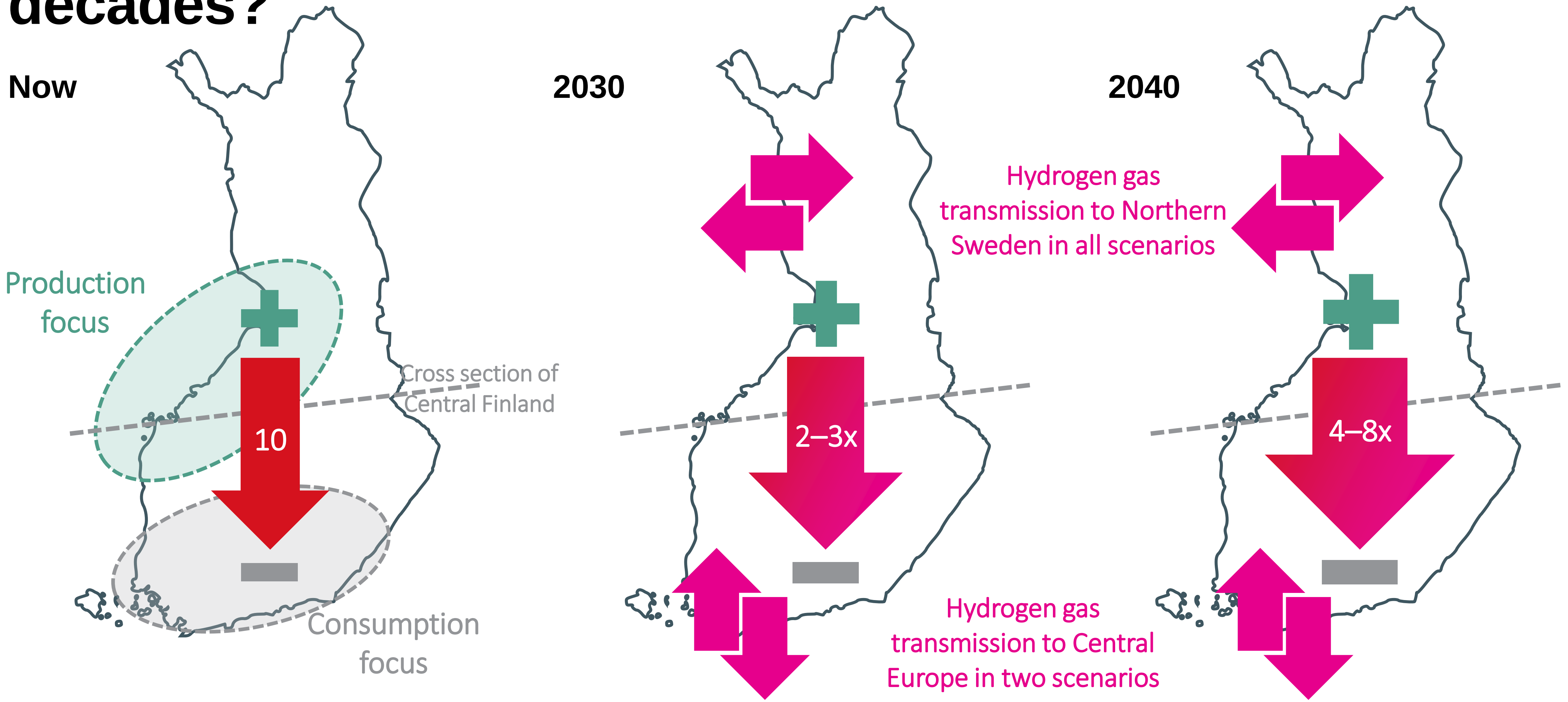
Identifying the energy transmission needs of industry actors is vital for the development of transmission infrastructure

Energy transmission needs will be determined by the relationship of renewable electricity production, hydrogen production and hydrogen consumption





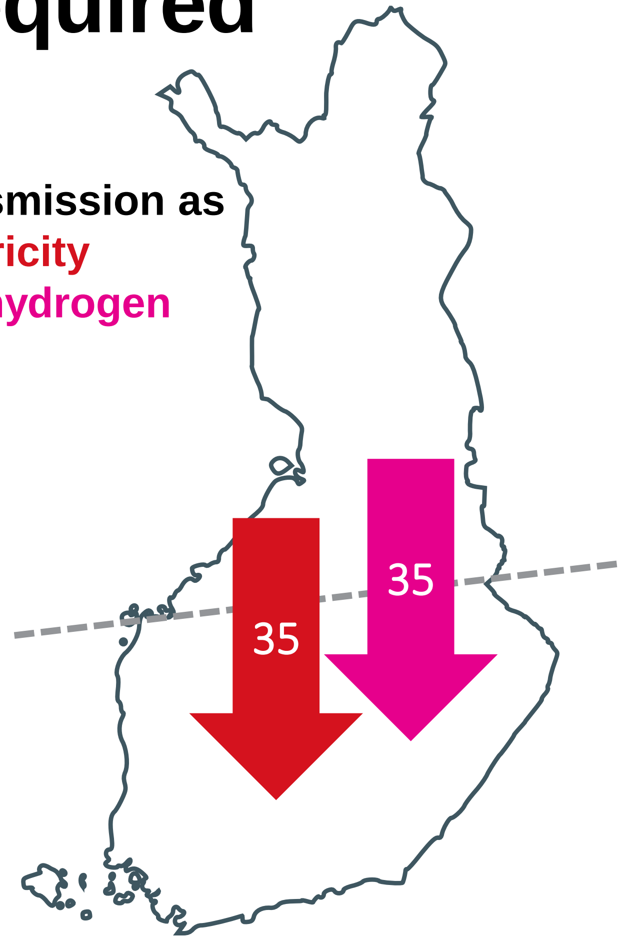
How will transmission needs develop in the coming decades?



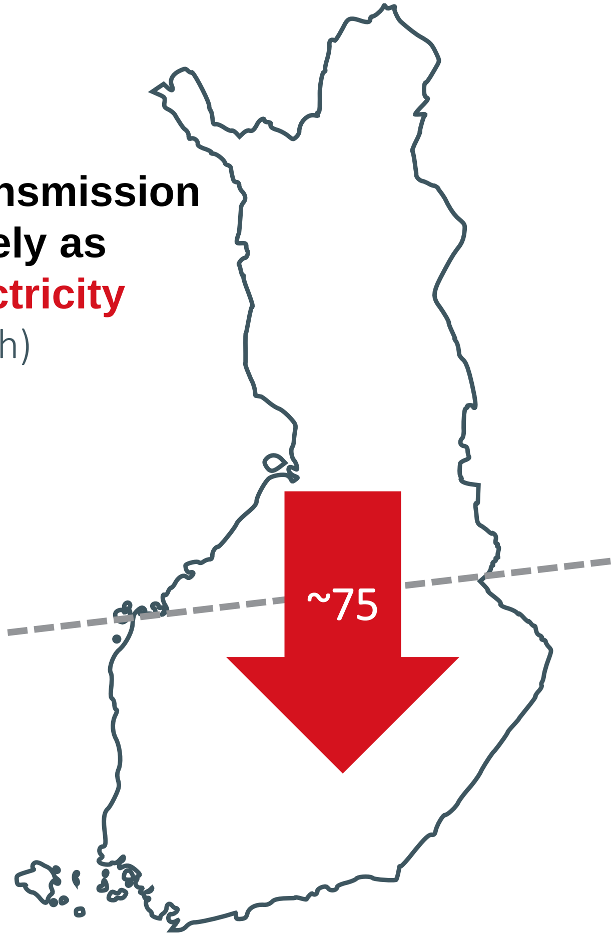
How to manage growing transmission volumes cost-effectively?

Efficient use of both transmission infrastructures is required

Transmission as electricity and hydrogen (TWh)



Transmission solely as electricity (TWh)



Transmission needs in the highest growth scenario in 2040

Transmission as electricity alone would require the construction of

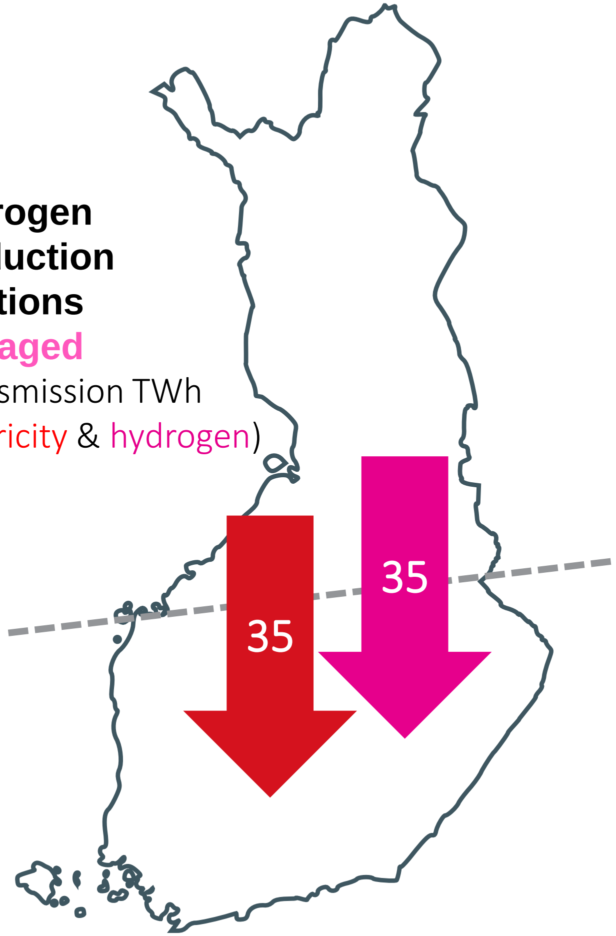
dozens of power lines

running from north to south

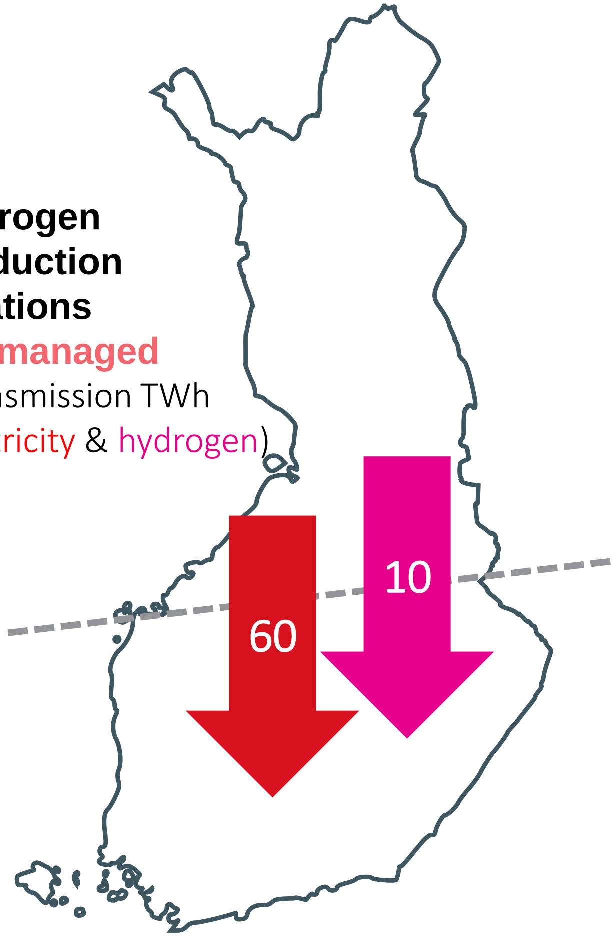
One hydrogen pipeline (DN1200)
can transmit as much energy as
~15 power lines (400kV)

Location matters in enabling growth

Hydrogen production locations managed
(Transmission TWh electricity & hydrogen)



Hydrogen production locations not managed
(Transmission TWh electricity & hydrogen)



Transmission needs in the highest growth scenario in 2040

For managing the system's **total costs** and leveraging its **growth potential,** it is important to encourage production and consumption sites:

- **to act flexibly in the market** and consider the status and transmission capacity of the electricity and hydrogen system
- to establish themselves in locations **that take electricity and hydrogen transmission investments into account**

Co-development of transmission infrastructures enables growth and responding to customer needs

The main conclusions of the hydrogen economy project

Finland has excellent potential to become a forerunner of the hydrogen economy

- Great potential in renewable electricity production
- Strong main grid
- Expert workforce and several companies for different parts of the value chain

Development of electricity and hydrogen infrastructures enables growth of the hydrogen economy

- Proactive development of the main grid and hydrogen transmission grid for customer needs
- Efficient leveraging of both transmission infrastructures is key – location matters!

FINGRID

THANK YOU!

GASGRID

Modelling of electricity, hydrogen, CO2, and end-products transportation

Christian Breyer
Professor for Solar Economy
School of Energy Systems

LUT University

Satu Lipiäinen
Post-doctoral researcher
Laboratory of Sustainable Energy Systems

LUT University

HYGCEL research presentation

Modelling of electricity, hydrogen, CO_2, and end-products transportation

Oodi, Helsinki, May 22, 2024

Presentations in this session

1. The role of hydrogen in the value chain and a transportation case example “Southeast-Ostrobothnia”
   - Christian Breyer, professor, LUT University

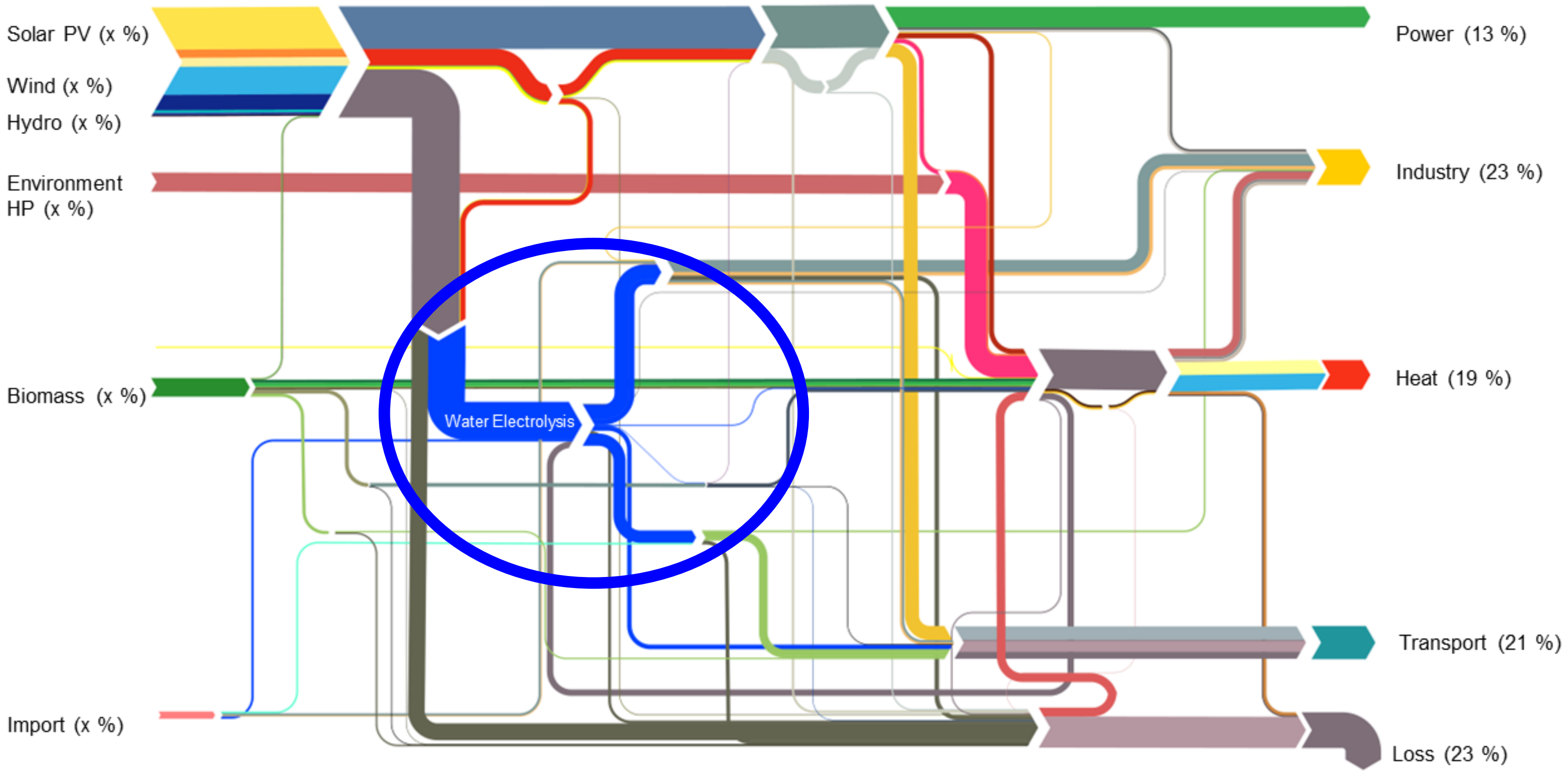
2. Case study: H_2 delivery to a steel mill
   - Satu Lipiäinen, postdoc researcher, LUT University

The role of hydrogen in the value chain and a transportation case example “Southeast-Ostrobothnia”

Topics of this presentation

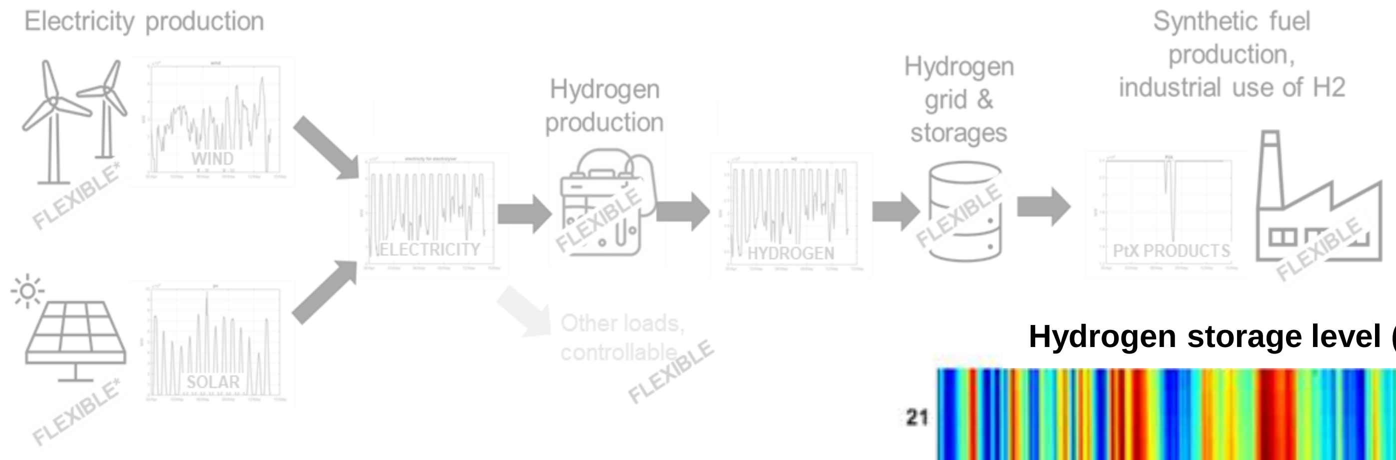
- The role of hydrogen in the energy system
- Feasibility of hydrogen transportation
- The transportation case Southeast-Ostrobothnia”

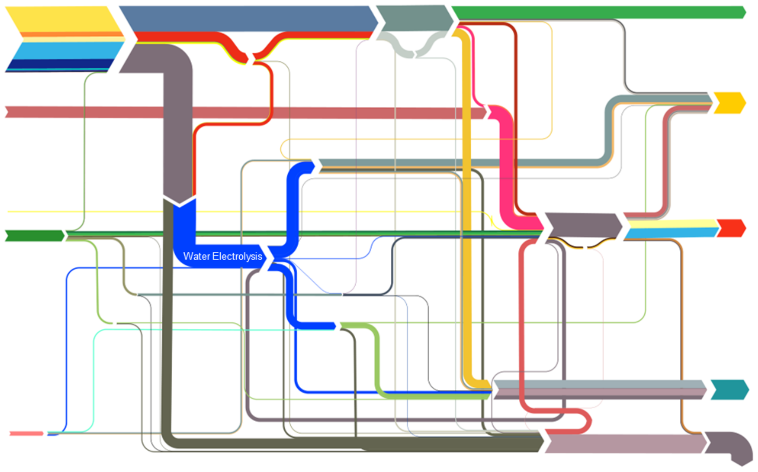
Role of Hydrogen in the Value Chain

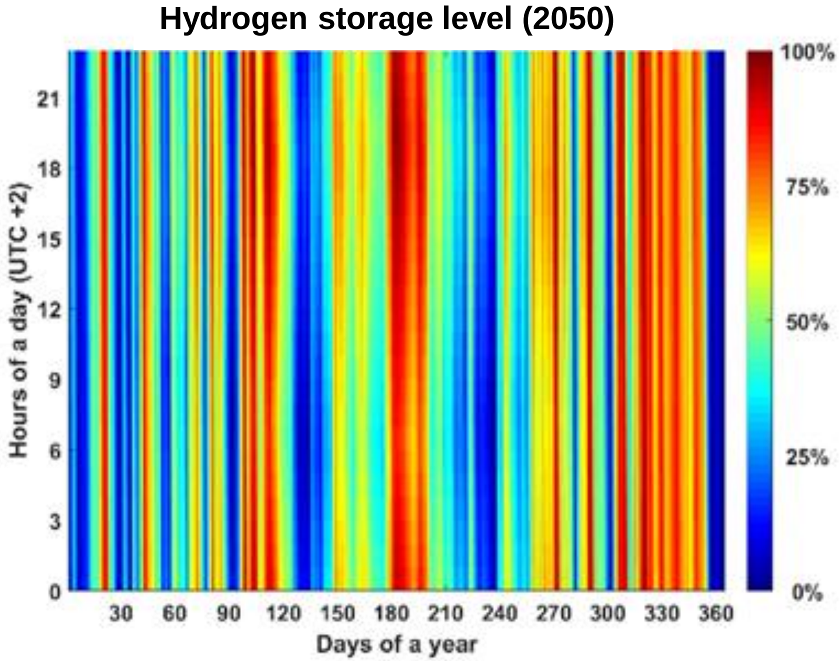


- **Hydrogen** is **important for applications** that cannot be directly electrified: e-fuels, e-chemicals, e-materials
- The **value chain** is complex and comprises several steps, such as electricity generation, transport, and **hydrogen** and final product production
- By far largest share of **hydrogen** is as an **intermediate** product for the **final** product, such as ammonia, methanol, kerosene jet fuel
- **Final products** are easier to transport as **hydrogen**

Flexibility provided by hydrogen storage



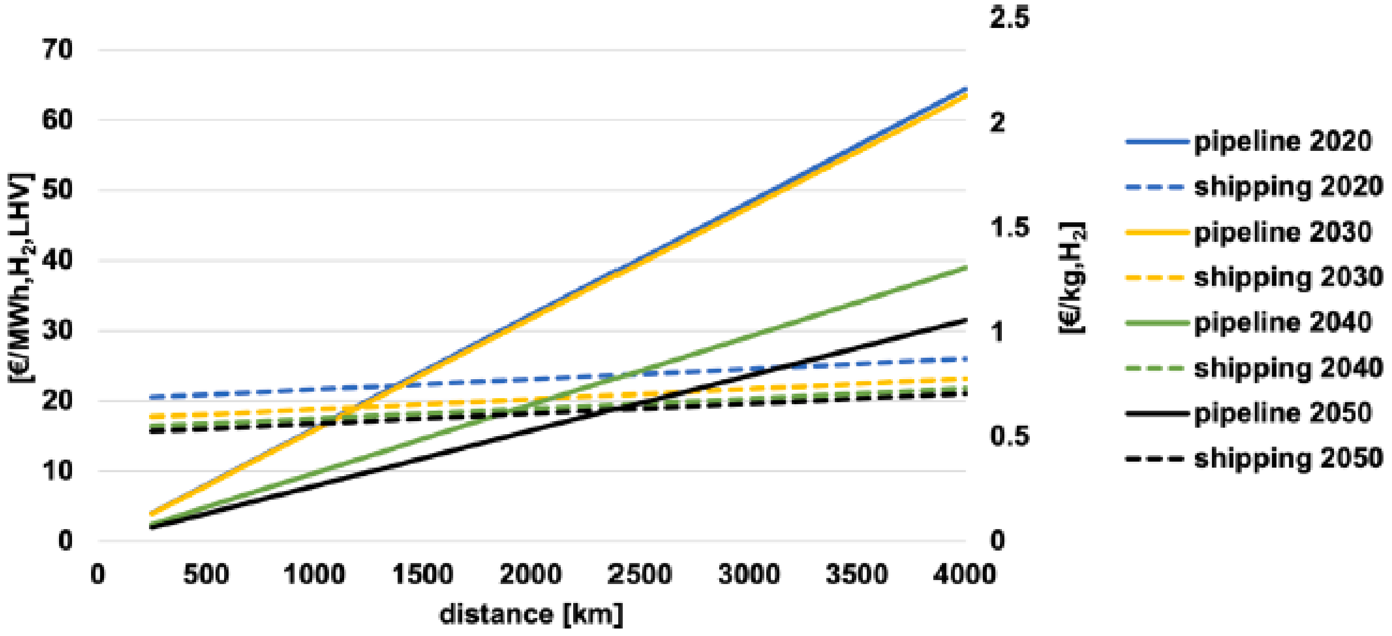




- Hydrogen storage **connects variable** renewable **electricity** with less flexible **demand** profiles such as PtX production
- Hydrogen storage **buffers** the low-cost renewable electricity for times of demand
- The **flexible** hydrogen storage for PtX production enables massive **additional benefits** for the **energy system**, avoiding inefficient and costly overdimensioning of renewable generation capacities.

Analysing transport costs

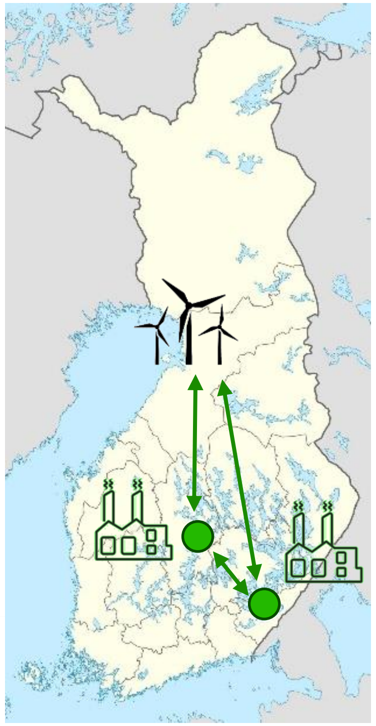
Cost of transporting H_2 by ship and pipeline



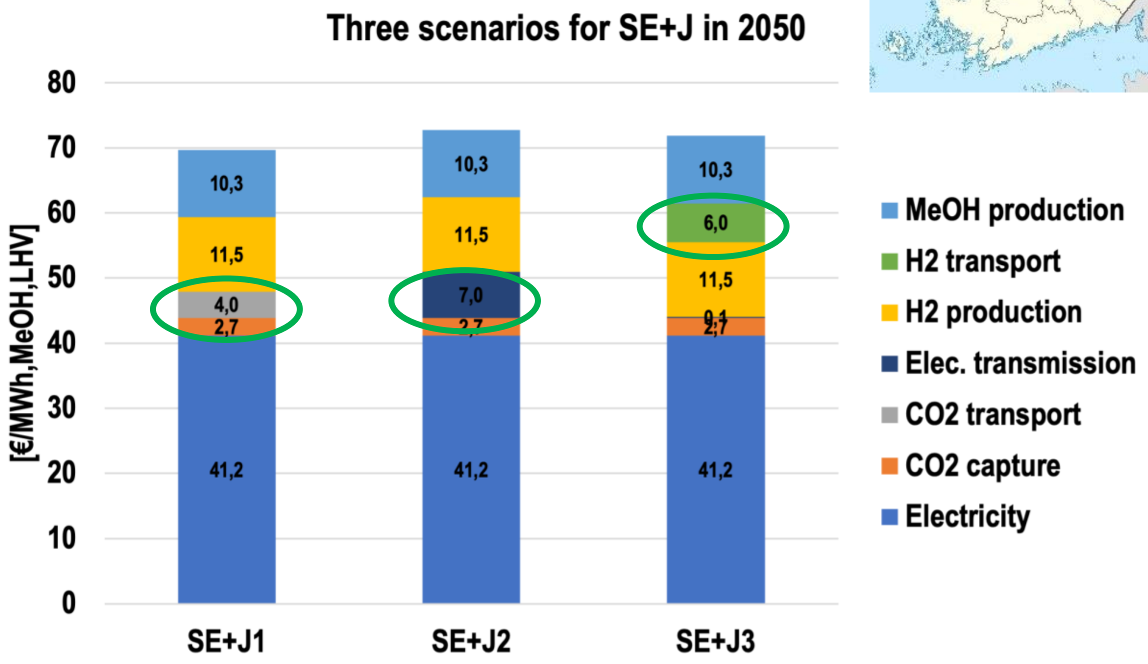
- **Transportation of final PtX products is more attractive than transportation of H_2**
  - 2000 km **hydrogen** transport by pipeline: about 15-20 €/$MWh_{H2,LHV}$
  - 2000 km **ammonia** transport by ship: about 1.5-2 €/$MWh_{NH3,LHV}$
- **Short distance** hydrogen transportation is **feasible**, whereas **long-distance** transportation might **not** be **attractive**
  - Short distance (several 100s km) transport is no cost burden
  - Long distance (> several 100s km) **transport** chains for hydrogen are **unlikely** due to high cost … it also means that Europe may not import hydrogen by ship from overseas

- Source: Galimova et al. (2023a; 2023b)
- Impact of international transportation chains on cost of green e-hydrogen: Global cost of hydrogen and consequences for Germany and Finland
- Feasibility of green ammonia trading via pipelines and shipping: Cases of Europe, North Africa, and South America

Transport case 1 – Southeast - Ostrobothnia



- Several **industrial cases involve** electricity and/or hydrogen **transmission** from wind sites to bio-CO_2 sites, or CO_2 transport from CO_2 sites to a wind site.
- We studied methanol production for the case of Finland combining **best wind resources in North Ostrobothnia** and **bio-CO_2 in the southeast**.
- **CO_2 transport** seems to be the **least cost** transport option.
- Transporting **H_2** or **electricity** cost almost the same, but **power lines** have **multiple valuable roles** in an **electrified energy system**.
- Despite slightly higher cost **sending the energy to Southeast Finland may be still attractive** for regional industry policy reasons.



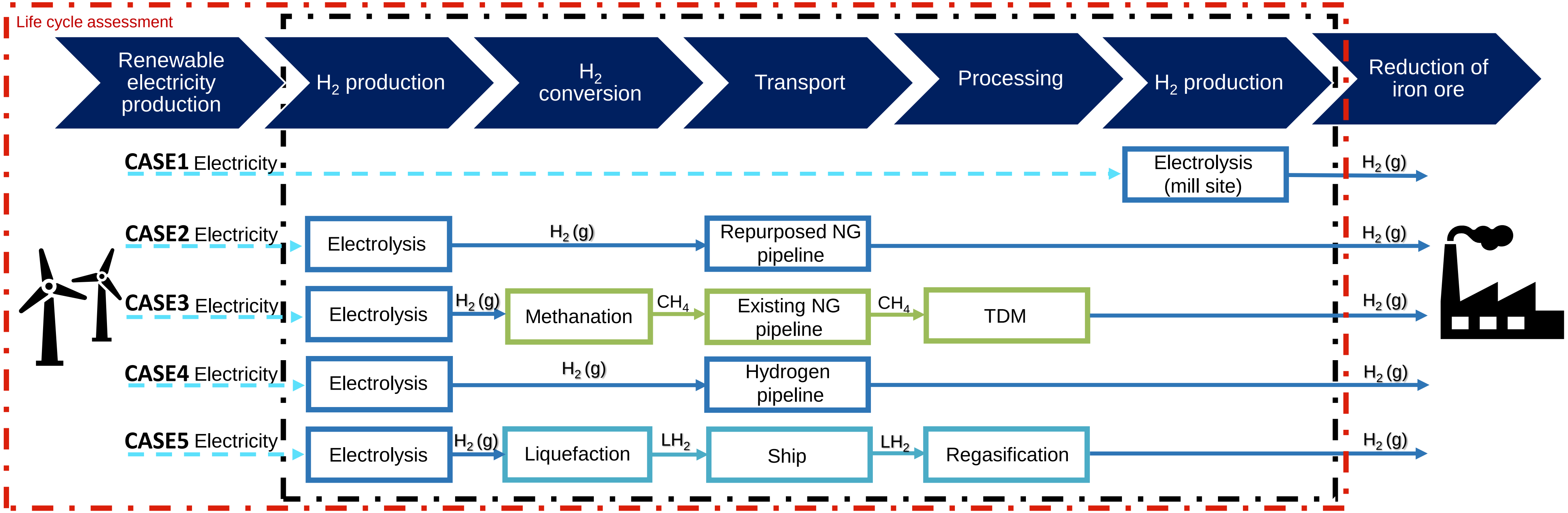
Case study: H_2 delivery to a steel mill

Topics of this presentation

- Evaluation of energy transportation options from three perspectives: investment costs, energy use and greenhouse gas emissions

Case study: H_2 delivery to a steel mill

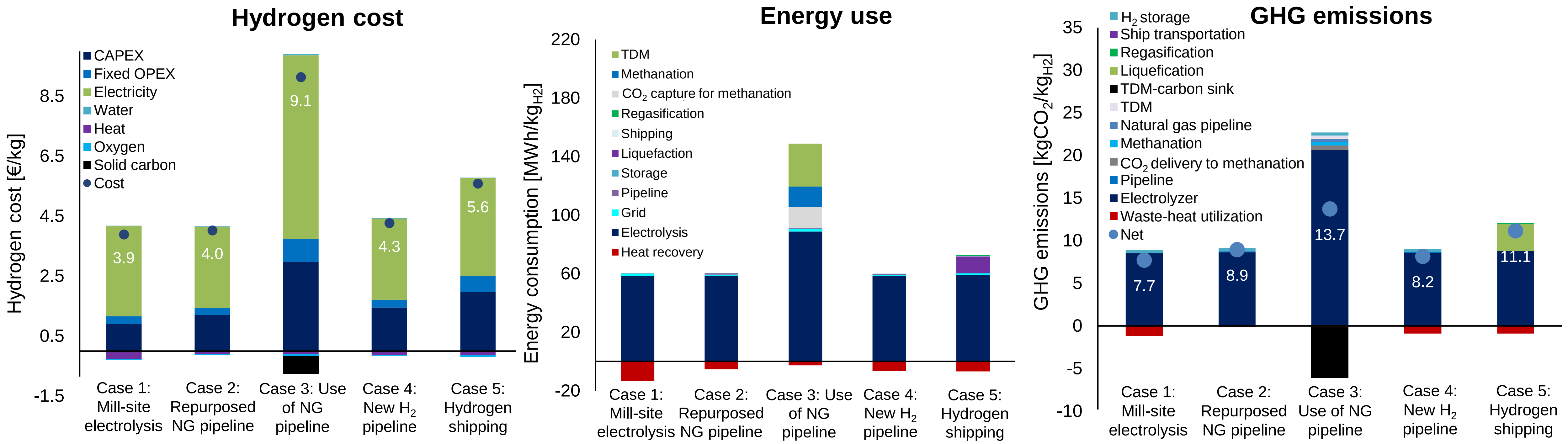
- The study evaluated 5 optional ways to provide hydrogen to a steel mill in Inkoo (144 000 t_{H2}/a / 5 TWh)
- Transport distance is 300 km cases except 500 km in shipping
- Three perspectives were studied: techno-economy, energy use, and greenhouse gas emissions



TDM = Thermal decomposition of methane
NG = Natural gas
LH_2 = Liquid hydrogen

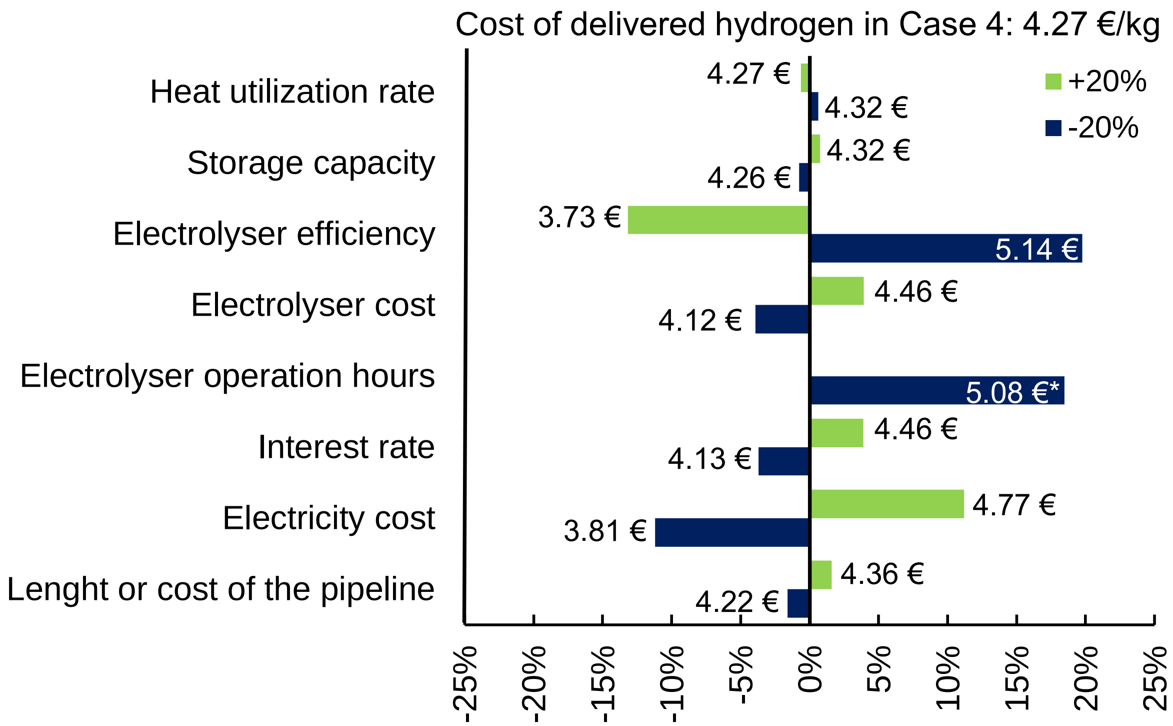
Lipiäinen, S., Sillman J., Vakkilainen, E., Soukka, R., Tuomaala, M. (2024) Hydrogen transport options for a large industrial user: Analysis on costs, efficiency, and GHG emissions in steel mills. Sustainable production and consumption. 441–13. https://doi.org/10.1016/j.spc.2023.11.021
Read more: https://www.lut.fi/en/hygcel

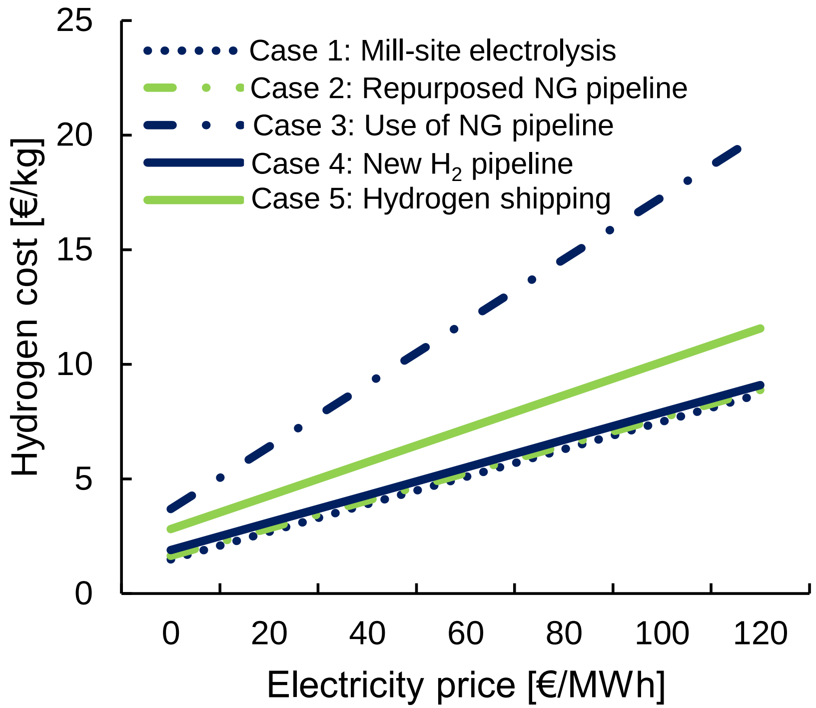
Complexity in the energy delivery increases costs and energy used in operations



1) Lowest cost is achieved in electricity transport (electrolysis at the mill) and in pipeline transport as hydrogen
2) Transport as liquid H_2 or methane requires additional unit operations, which increases costs and energy use
3) Despite the methanation route (Case 3) is expensive and inefficient, it would provide an opportunity to utilize NG infrastructure and provide a carbon sink (black bar in fig).
   - The emission benefit would require the use of fully renewable electricity

Evaluation from multiple perspectives provides a more comprehensive result





1) Results are sensitive to case-specific properties: H_2 volumes, transport distances, location of H_2 user and producer, available infrastructure, etc.
2) Especially the price of electricity affect the cost of transported H_2 very much
3) Open questions and uncertainties regarding hydrogen transport remain

Case study: H_2 delivery to a steel mill

Key messages

- There are notable differences among transportation options
  - Additional conversions need to be avoided when transporting inside Finland
- Each transportation case must be separately looked at

Coffee break until 14.30

H2Cluster Finland & HYGCEL project joint seminar

May 22, Oodi, Helsinki

Agenda

Scan the QR Code to access today's agenda!

Stay informed and keep track of all the exciting sessions and events happening today. Simply scan the QR code with your phone to view the full schedule and detailed information about each segment. Don't miss a moment of the action.

Hydrogen economy as a corner stone for Finland to achieve green transition

Kai Mykkänen

Minister of Climate and the Environment

VALTIONEUVOSTO
STATSRÅDET

Hydrogen economy as a corner stone for Finland to achieve green transition

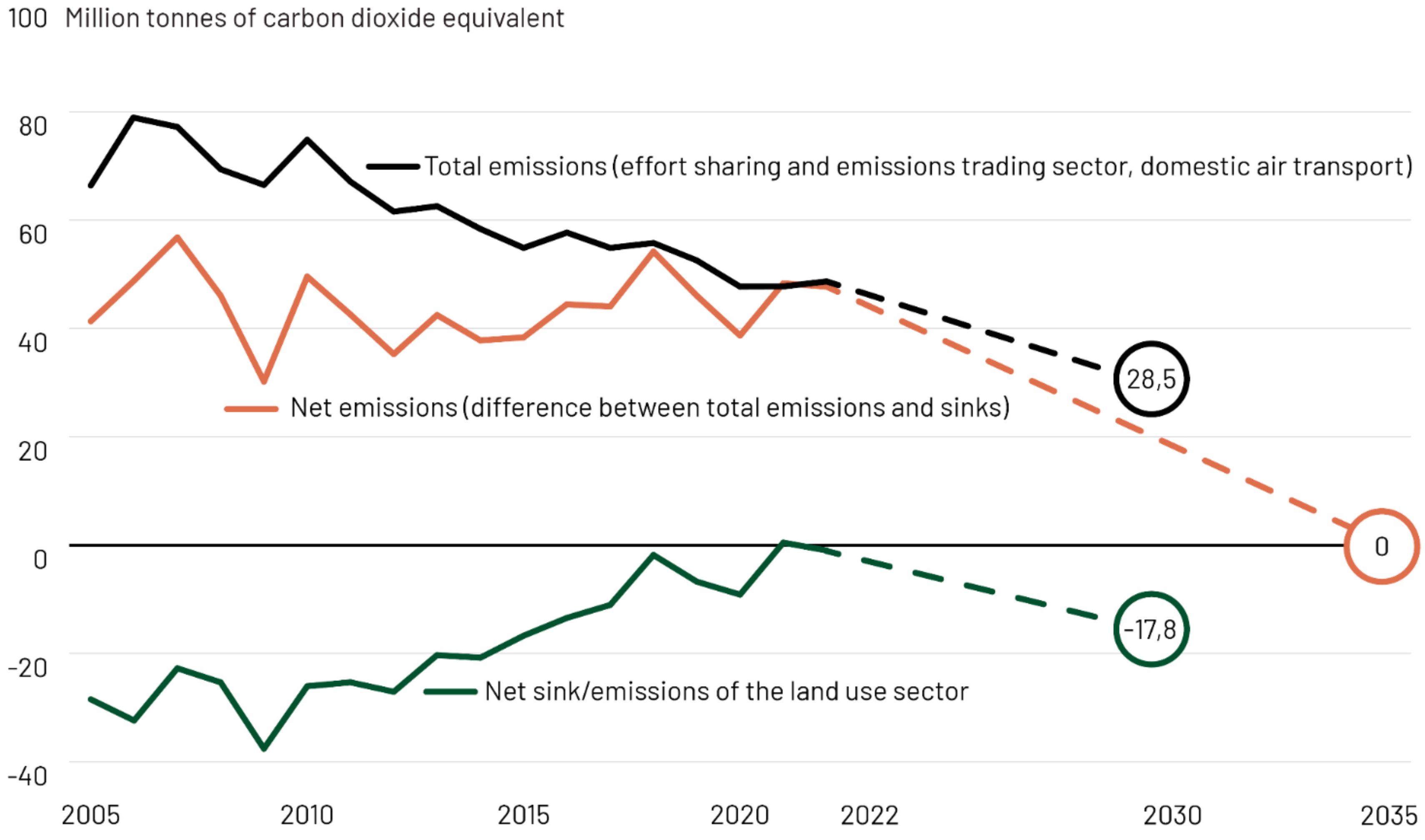
Kai Mykkänen, Minister of Climate and the Environment

H2 Cluster Finland – HYGCEL project joint seminar
22nd May. 2024

Climate and Energy policy

” Finland will use effective and sustainable means to increase its climate handprint and proceed towards carbon neutrality”

Finland’s greenhouse gas emission trends

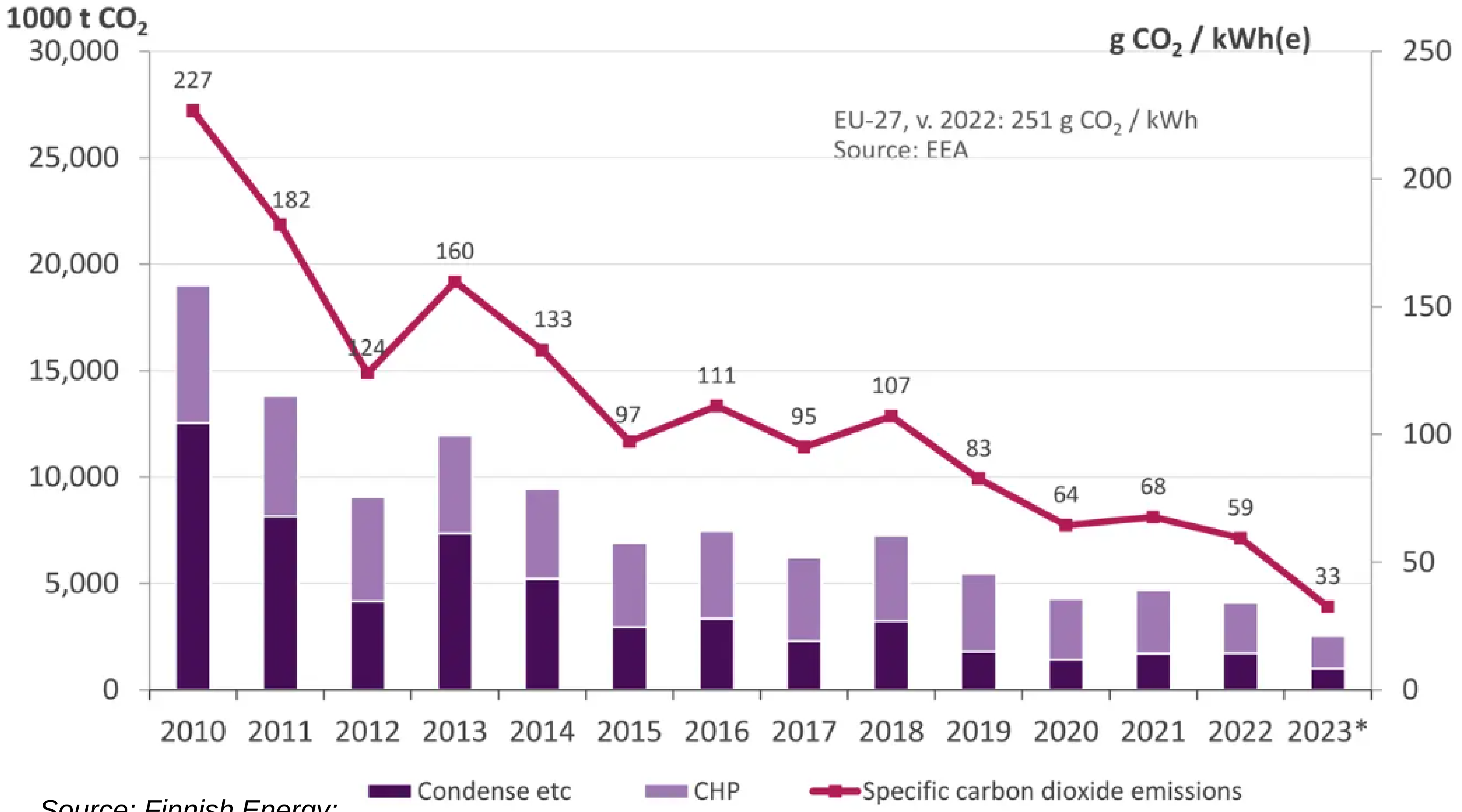


The emissions should be equal to the sinks by 2035 for Finland to achieve its climate neutrality target.

Annual Climate Report data for 2022 are based on Statistics Finland’s proxy estimates, which will be specified later.

How and why should we make Finland a clean energy superpower?

CO_2-emissions of power generation have collapsed



Source: Finnish Energy: Electricity Year 2023

CO_2-emissions of power generation:

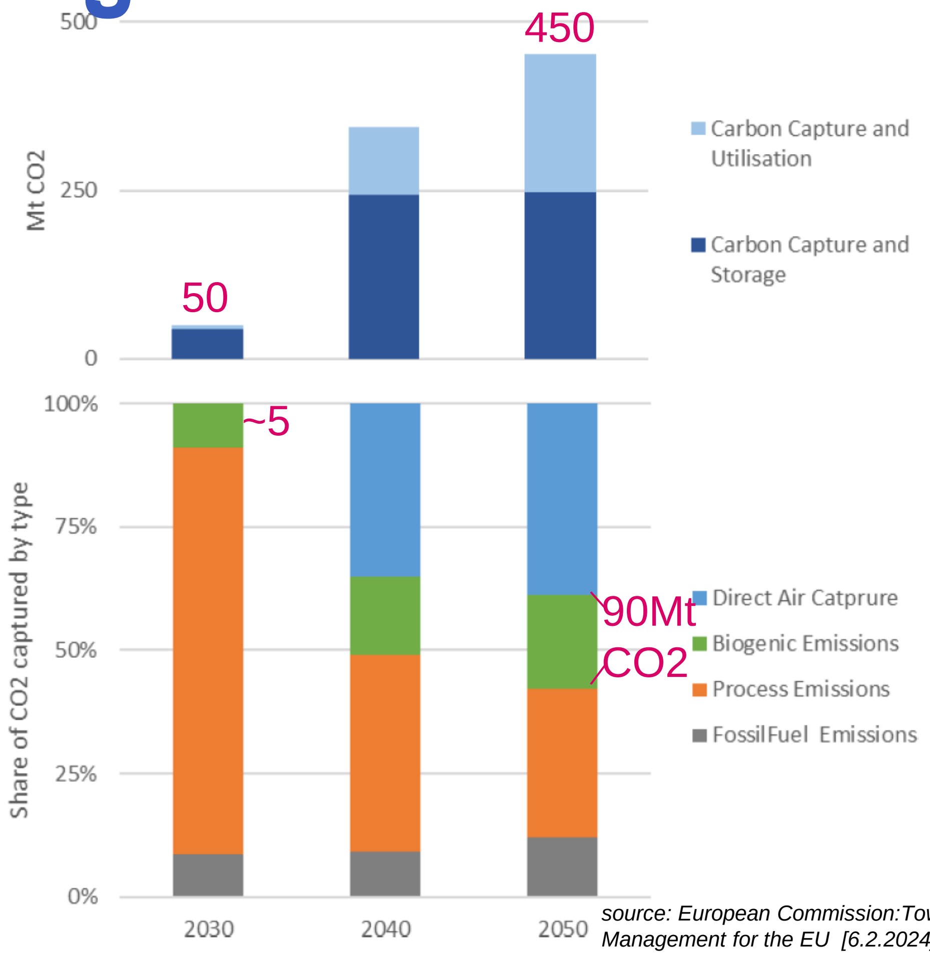
- 2.5 Mt in year 2023
- 4.1 Mt in year 2022
- 4.7 Mt in year 2021
- 7.5 Mt in year 2016
- 19 Mt in year 2010

→ 2023 vs. 2022 **-38 %**

→ Emissions **-65 %** in last 5 years

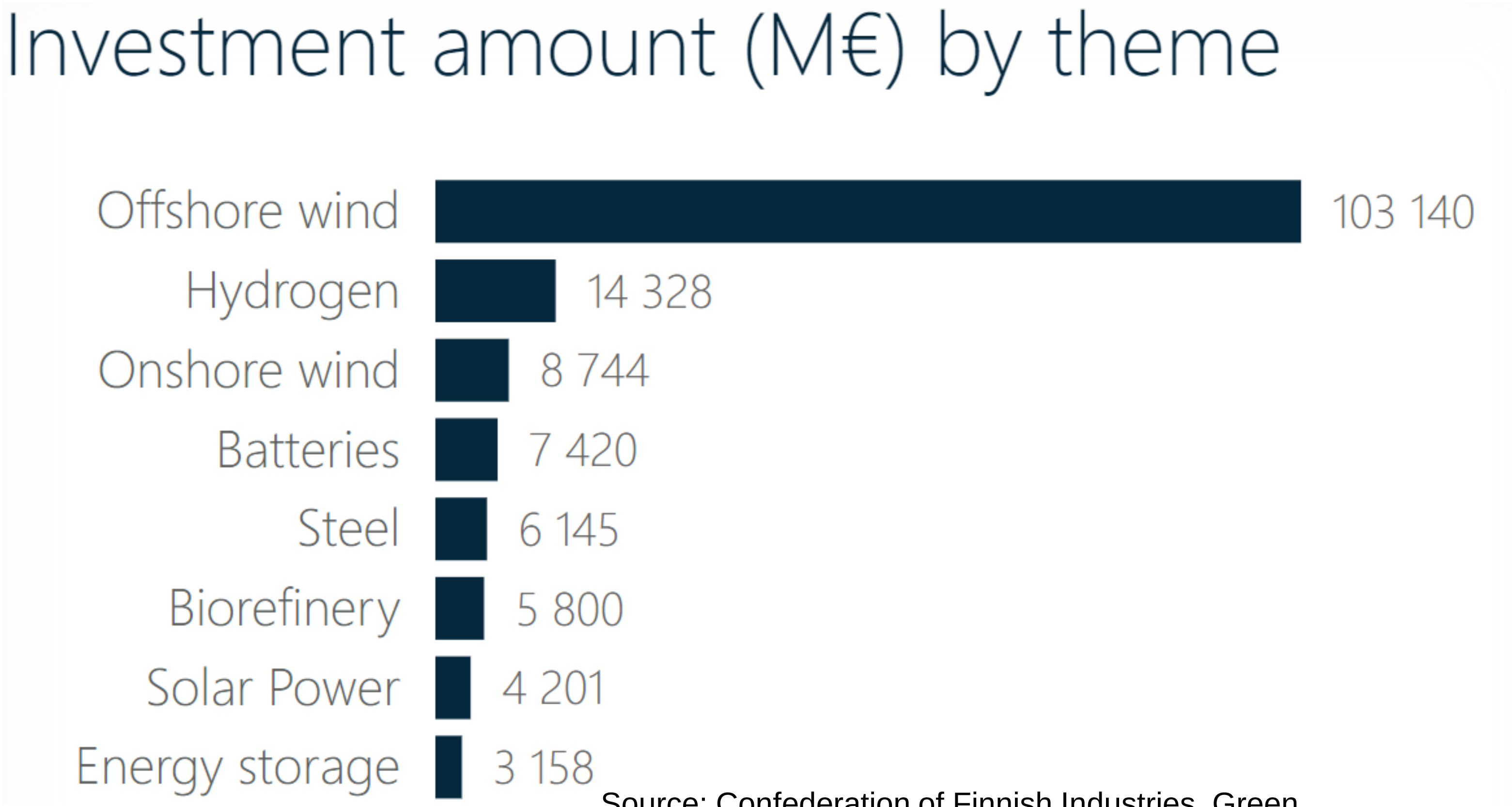
→ Emissions **-87 %** vs 2010

Volume of CO2 captured for storage and utilisation in the EU and share of the CO2 captured by origin:

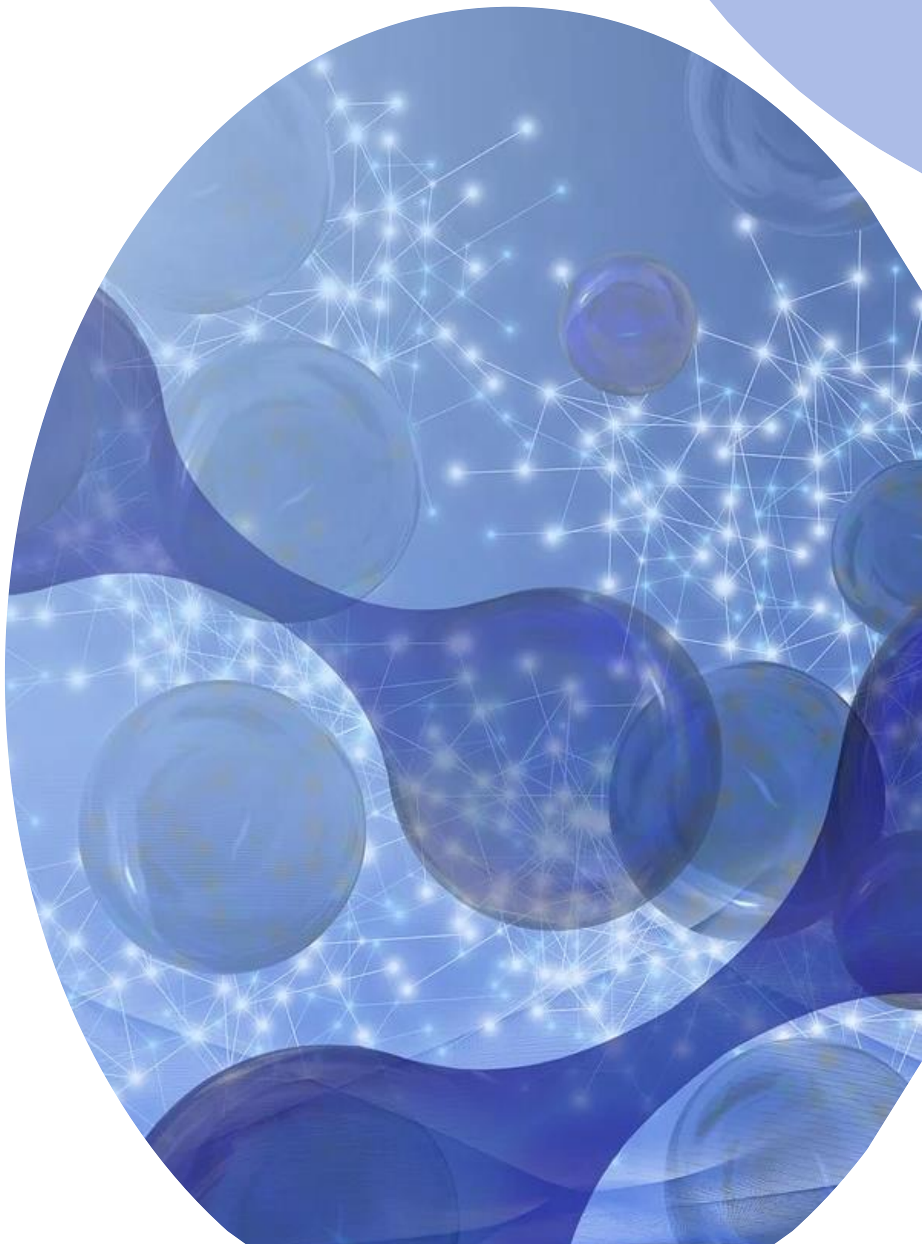


source: European Commission:Towards an ambitious Industrial Carbon Management for the EU [6.2.2024]

Green investments in Finland



Source: Confederation of Finnish Industries, Green Transition Data Dashboard (updated 26th April 2024)



Hydrogen Prospects in Finland

Nordic Ren-Gas Wins in the First EU Hydrogen Auction with EUR 45 million Bid

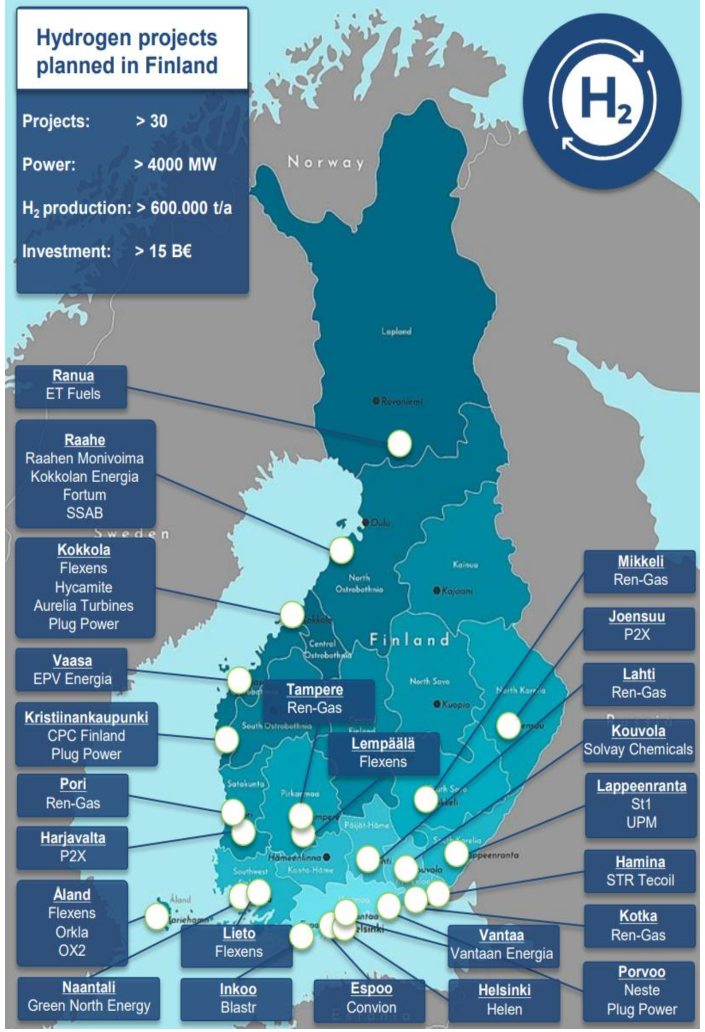
30.4.2024

Nordic Ren-Gas Lahti plant has been among selected winners with a EUR 45 million subsidy grant through the European Hydrogen Bank's first competitive bidding process. This significant financial support will enable Nordic Ren-Gas to scale up its renewable e-methane production in Lahti Finland, and to accelerate the development of the decentralized e-methane production network.

18.12.2023

Westenergy, CPC Finland and Prime Capital plan a large-scale carbon capture plant

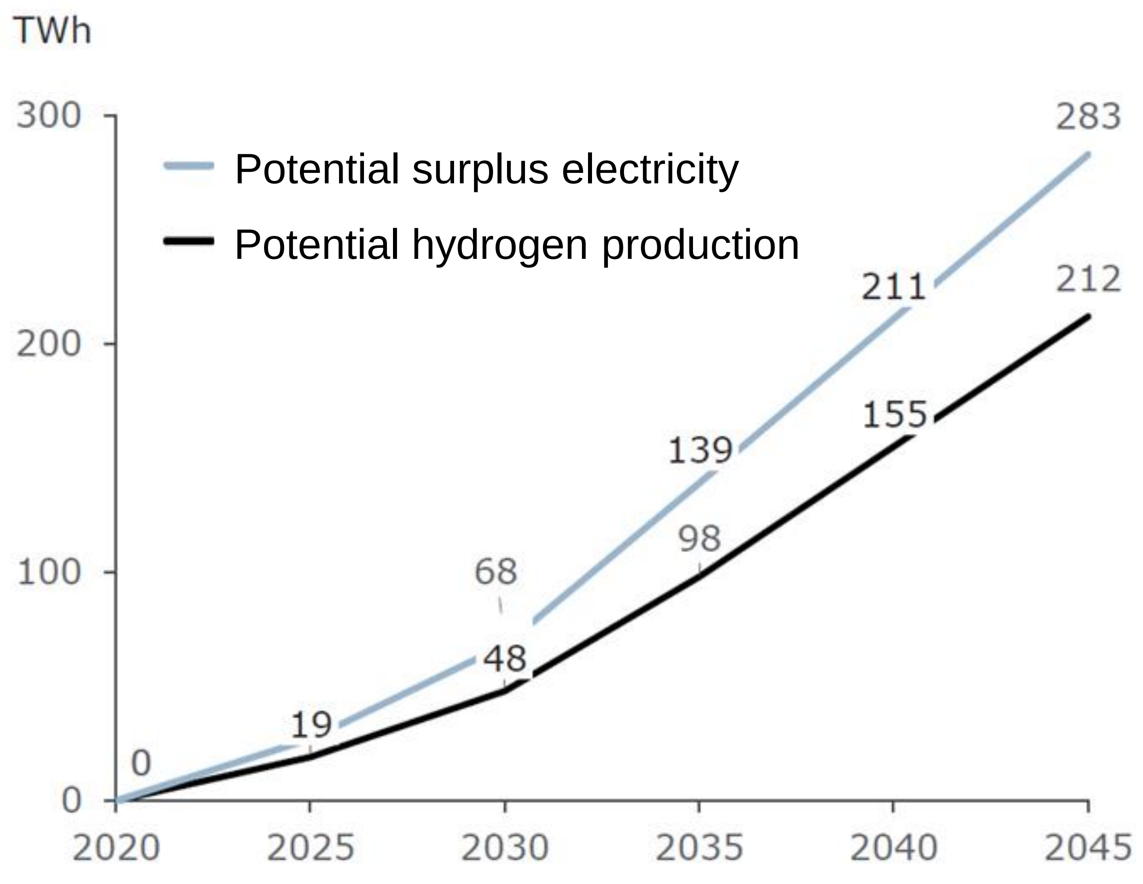
The parties entered into an agreement for the joint development, construction and operation of a carbon capture unit in the municipality of Mustasaari, Finland. The unit will capture CO2 from the flue gas generated by the existing Westenergy plant. The captured CO2 will be liquefied, and a large fraction will be transported to Kristinestad where it will be utilised at Prime Capital´s and CPC´s power-to-x site. The carbon capture operations will be managed by Westenergy. The total value of the investment is approximately EUR 138 million and the Ministry of Economic Affairs and Employment has granted a total of EUR 20 million of energy investment aid for the project.



source: H2 Cluster Finland

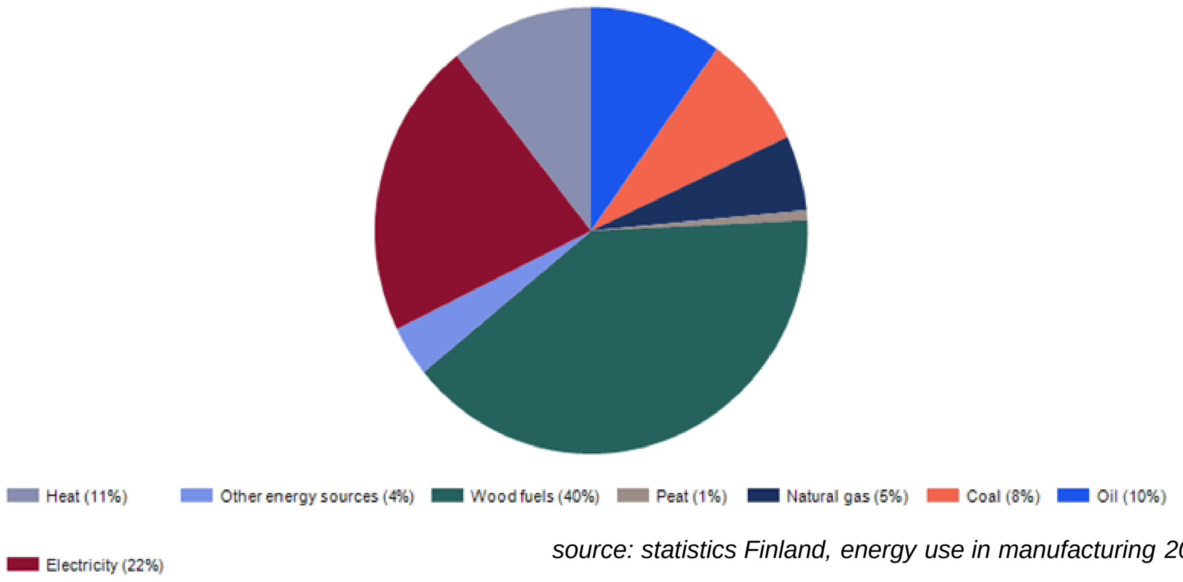
source: Gasgrid Finland

Clean electricity production is a solid foundation for a hydrogen economy



source: Gasgrid Finland

Energy use in manufacturing (128 000 GWh total)



source: statistics Finland, energy use in manufacturing 2022

Thank you!

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STATSRÅDET

Perspectives to sustainability, safety, and profit sharing in green hydrogen value chains

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HYGCEL

HYGCEL research presentation

Perspectives to sustainability, safety and profit sharing in green hydrogen value chains

Oodi, Helsinki, May 22, 2024

Presentations in this session

1. Profit sharing in PtX investment, case methanol value chain
   - Antti Ylä-Kujala, Post-Doctoral Researcher, LUT University

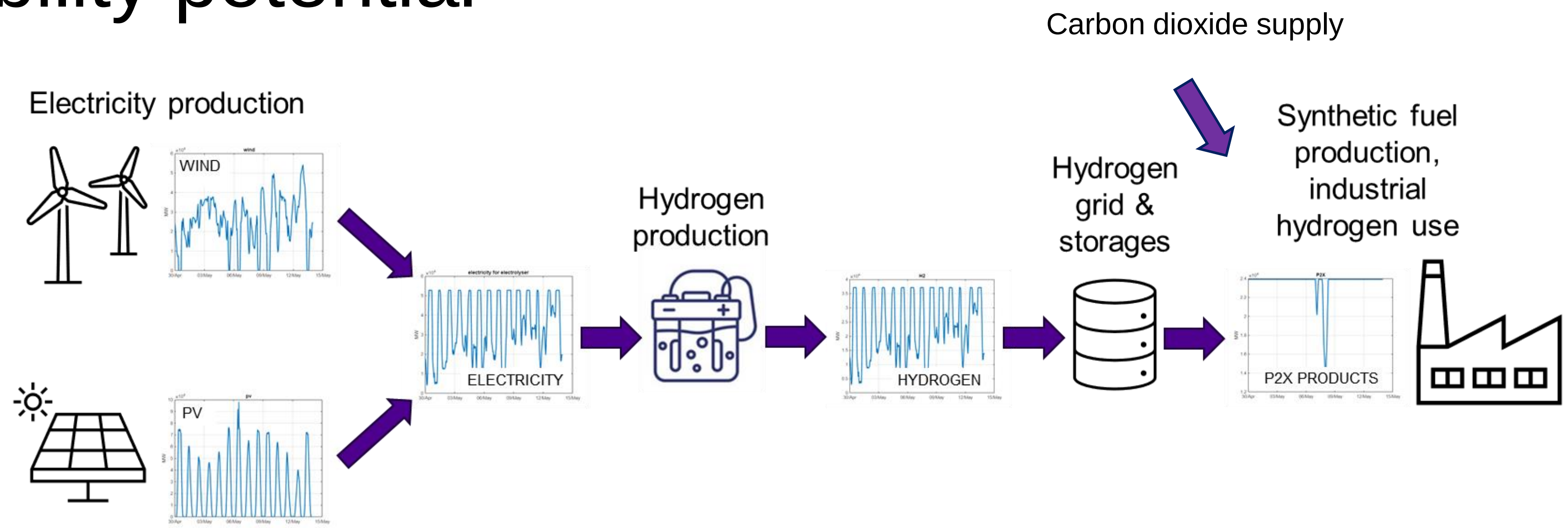
2. Sustainability and safety in PtX value chains
   - Jani Sillman, Post-Doctoral Researcher, LUT University

Profit sharing in PtX investment, case methanol value chain

Topics of this presentation

- The role of hydrogen provider in the value chain
- Assessment of economic uncertainties in the value chain
    - The impact of electricity price, subsidization and interest rates

Life cycle costing (LCC) was used to study profitability potential



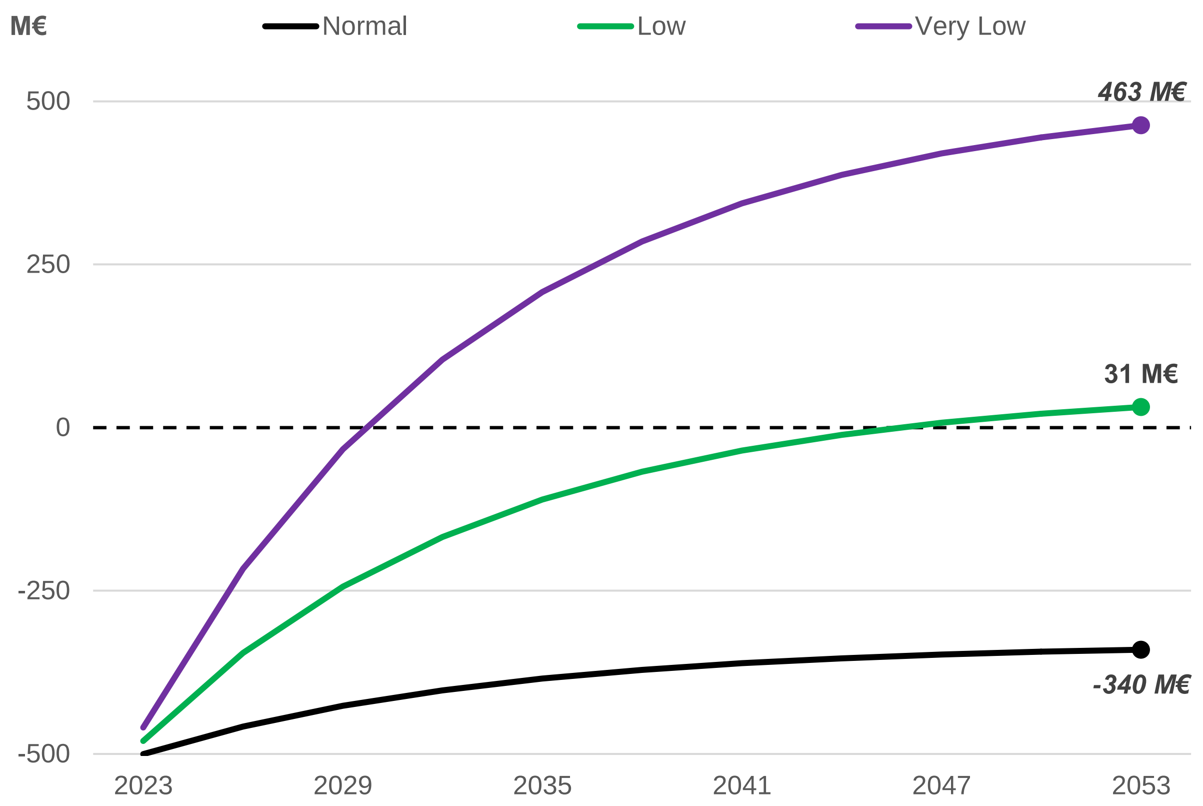
- Industrial PtX value chain is a complex chain of unit operations, and all entities are looking for profitable business.
- Case e-methanol was formed to estimate the profitability of individual operations in the value chain using fixed pricing.
- Life-cycle costing (LCC) approach based on the discounted cashflow method was used.

Positive net cash flow (NCF) for PtX methanol is difficult to achieve

NCF	Electricity price: Normal	Electricity price: Low	Electricity price: Very Low
Carbon Dioxide	76 M€	81 M€	88 M€
Hydrogen	-856 M€	-514 M€	-128 M€
Methanol	440 M€	464 M€	503 M€
Value Chain	**-340 M€**	**31 M€**	**463 M€**

NCF for the value chain is clearly positive only with very low electricity prices

NCF for the H_2 producer remains negative in all scenarios



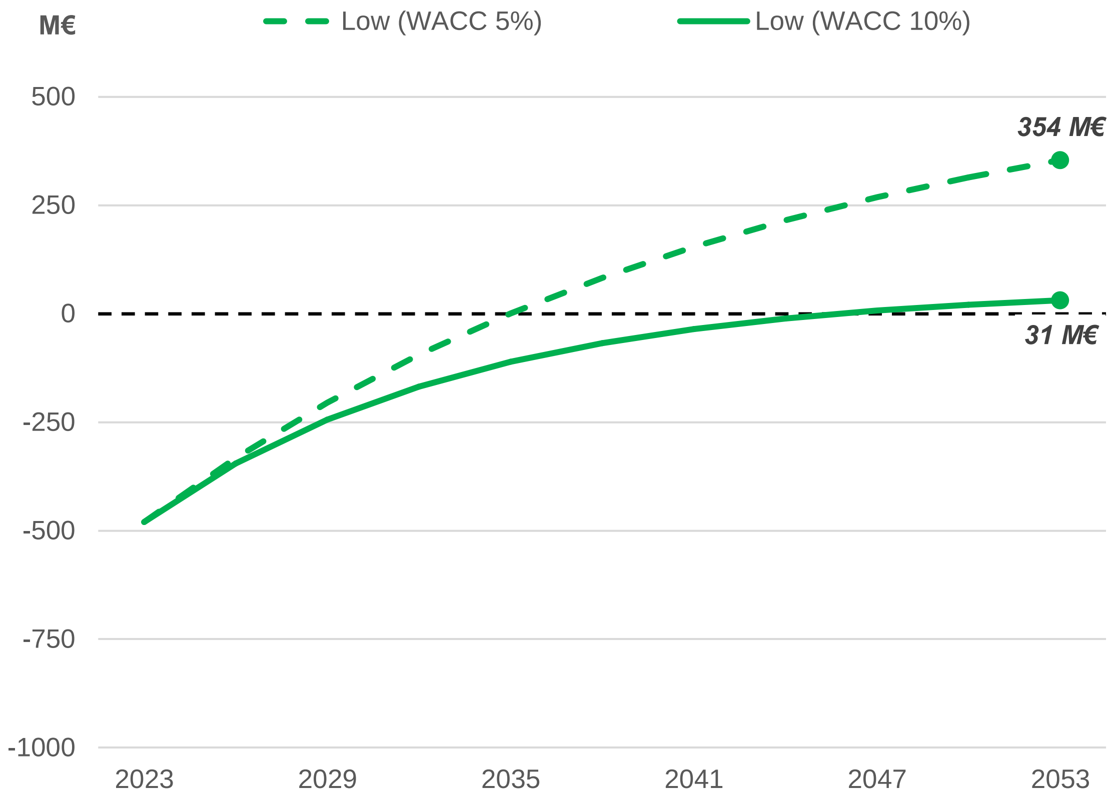
Sources: Ylä-Kujala et al., Silman et al. (both articles in review)
Prices: normal ~47 €/MWh, low ~ 37 €/MWh, very low ~ 27 €/MWh

Subsidies and interest rate are powerful mechanisms

NCF	Electricity price: Normal	Low	Very Low
Value Chain (Subsidy)	**-340 M€**	**31 M€**	**463 M€**
Total Investment	518 M€	518 M€	518 M€
Value Chain (No Subsidy)	**-631 M€**	**-258 M€**	**173 M€**
Total Investment	808 M€	808 M€	808 M€

Investment subsidy (here: 60%) to H_2 production improves profitability significantly

Lowering the interest rate, i.e., WACC, was found to have a significant effect



Profit sharing in PtX investment, case methanol value chain

Key messages

- The role of the H_2 provider is challenging, because profitability lies in value added products
- The value is created in the whole PtX value chains and therefore the value chain should be looked as one business entity instead of separate operations
- The value chain should be measured as one entity in which profits are shared
- Incentives (e.g., subsidization) and collaborative models (e.g., PPA or PPP) are key factors to start investment activity

Sustainability and safety in PtX value chains

Topics of this presentation

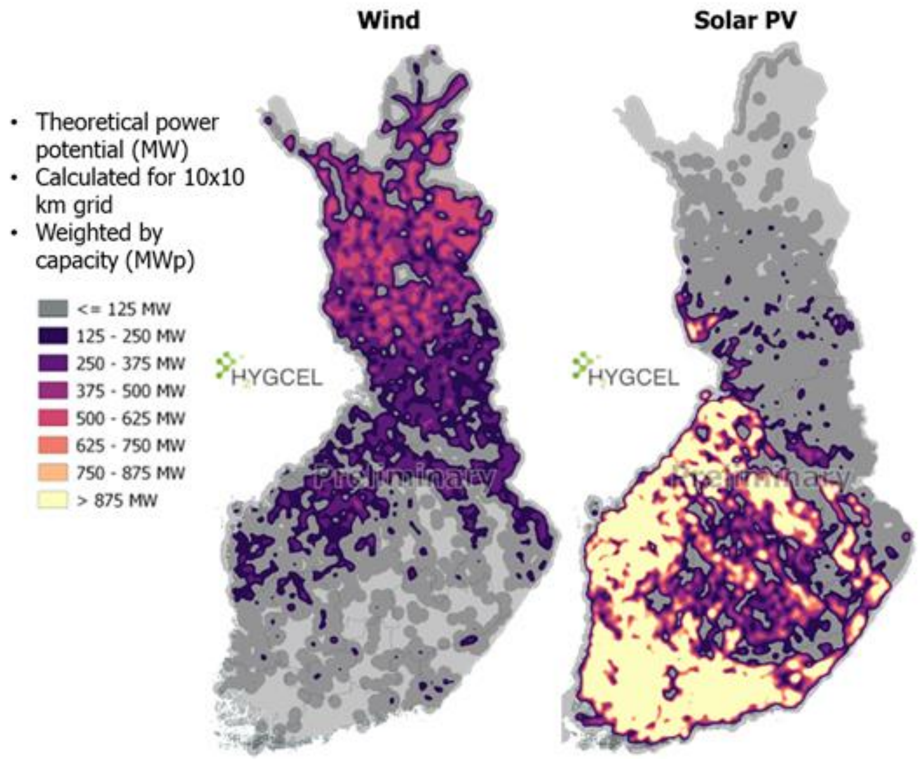
- Sustainable transition of PtX – what is it about?
- Results from safety study
- Potential climate benefits

The sustainable transition needed is about realizing benefits and managing risks

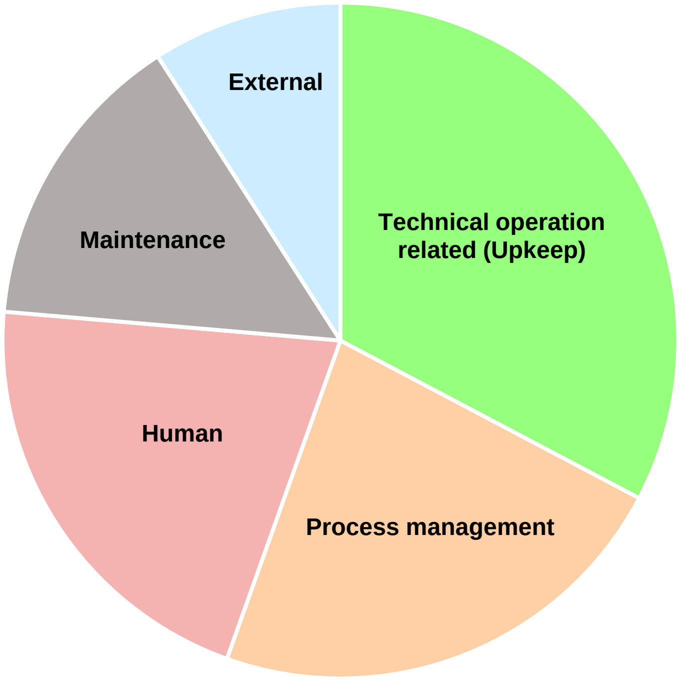
- Examples of benefits and risks on three pillars of sustainability:

  - Economic aspects 1)
    - Benefits through profitable business
    - Risks caused by, such as, regulation, new technology and material and energy costs
  - Environmental aspects
    - Benefits achieved through climate mitigation 2)
    - Risks caused by potential loss of biodiversity (forest land)
  - Social aspects
    - Benefits achieved by new jobs, tax incomes and knowledge
    - Risks caused by unsafe operations 3) and unfair transition

  - Examples provided in this session 1), 2), 3)



Human activity is the main cause for hydrogen incidents and accidents

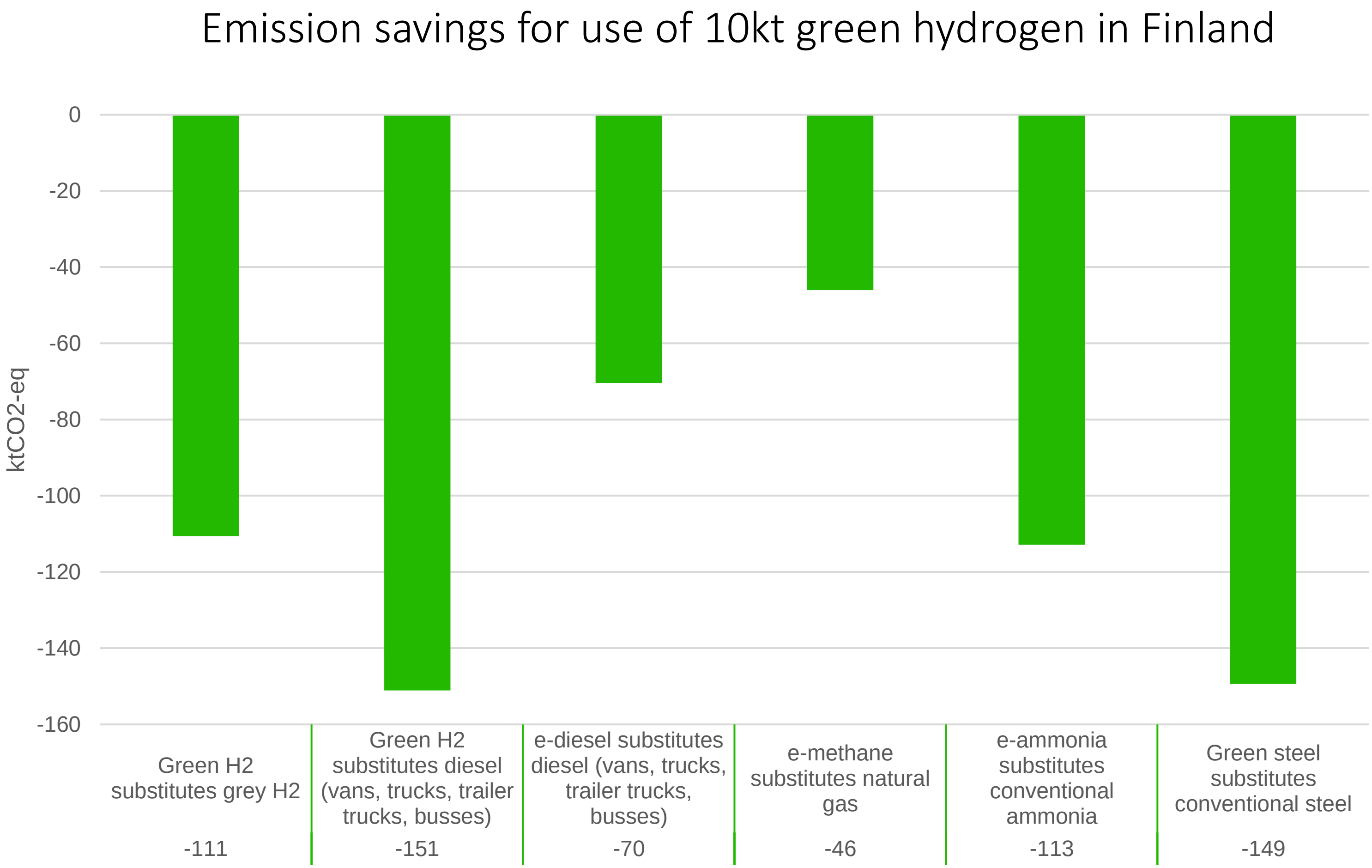


- Human factor is present in most of the root causes of hydrogen incidents and accidents
- Most of the hydrogen incidents and accidents are related to:
  - **Technical operation**
    - tools and equipment failures with pipes, valves, connection joints etc.
  - **Process management**
    - E.g., lack of protocols, procedures and guidelines to run the facility
  - **Human activity**
    - E.g., failure to follow procedures and training issues
- About half of the hydrogen incidents were related to organizational and managerial issues

Source: Alfasfos et al.2024 HYGCEL results page https://www.lut.fi/en/hygcel

PtX products provide low-carbon alternatives to fossil economy

- Emission savings modelled using LCA as a tool
- Typical conventional products used as a reference product
- Assumed final PtX product manufacturing and consumption in Finland
- Results show that renewable electricity based H_2 and PtX products are radically better than conventional fossil-based ones in terms of their impact to climate.



Source: Sillman et al. 2024 (article in review), HYGCEL results page https://www.lut.fi/en/hygcel

Sustainability and safety in PtX value chains

Key messages and findings

Safety

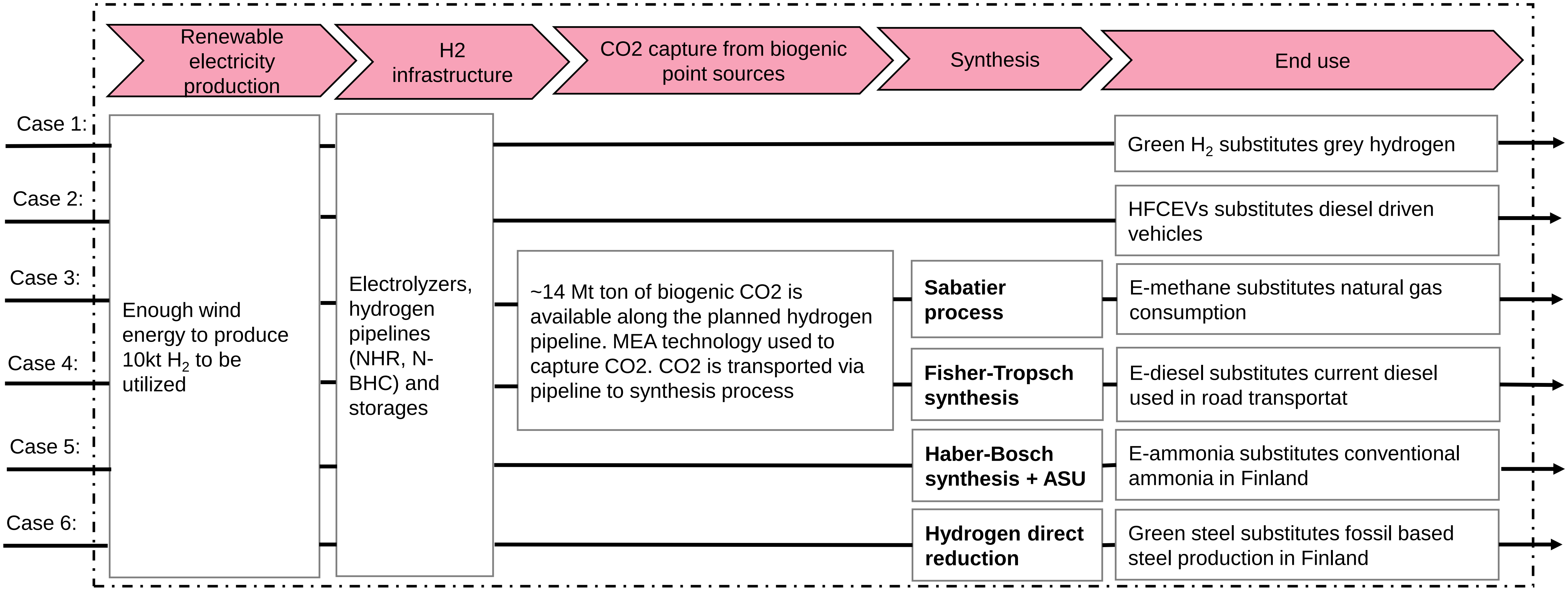
- H_2 has been used safely for decades
- **Larger** scale H_2 infrastructure increases the **accident probability** and/or the **consequences**
- With a careful **risk management** accidents can be prevented. Severe accidents can **prolong** PtX economy and cause reputational damage.
- Workforce training (**education**), better guidelines and improved regulation for H_2 handling are a key for success

Climate mitigation

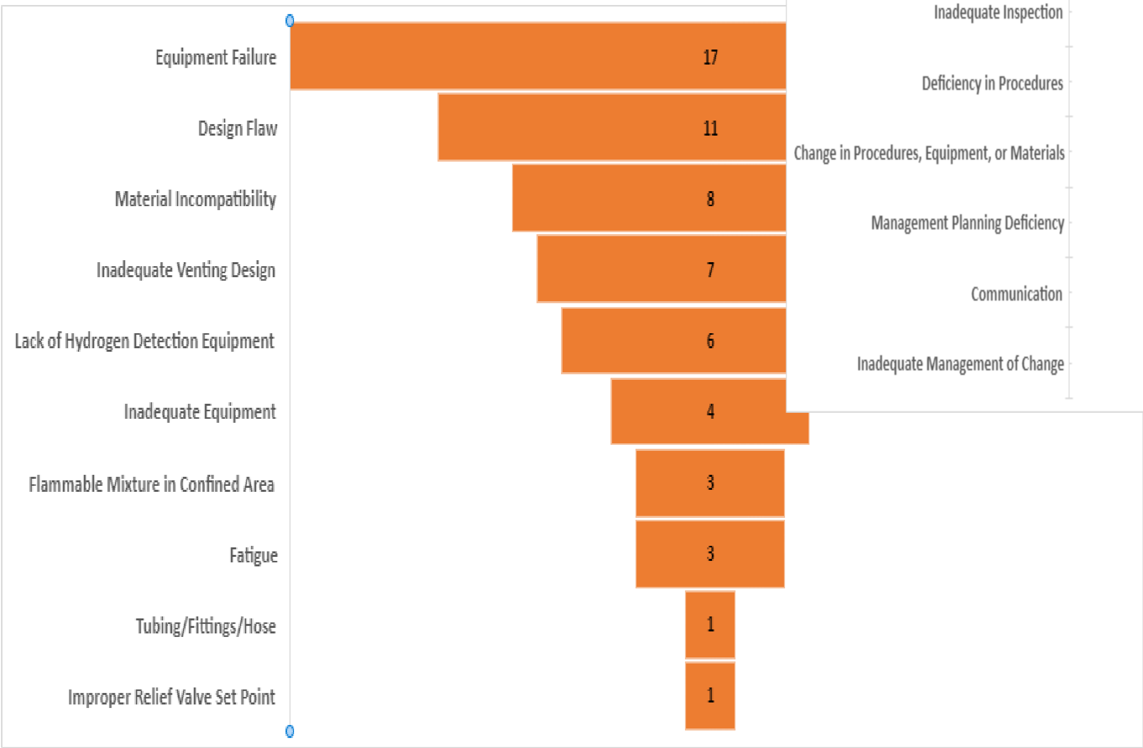
- PtX value chains can help to **achieve** national carbon neutrality targets
- Finland can help **other countries** to achieve their climate targets by providing PtX products (positive carbon handprint) creating also export potentials for Finland
- H_2 should be **first** utilized in those sectors that can achieve **the highest** emission reductions (steel, ammonia, grey H_2) or are, so called, **hard to abate sectors** (aviation fuel, steel)

Additional reading - LCA modell to assess climate benefits

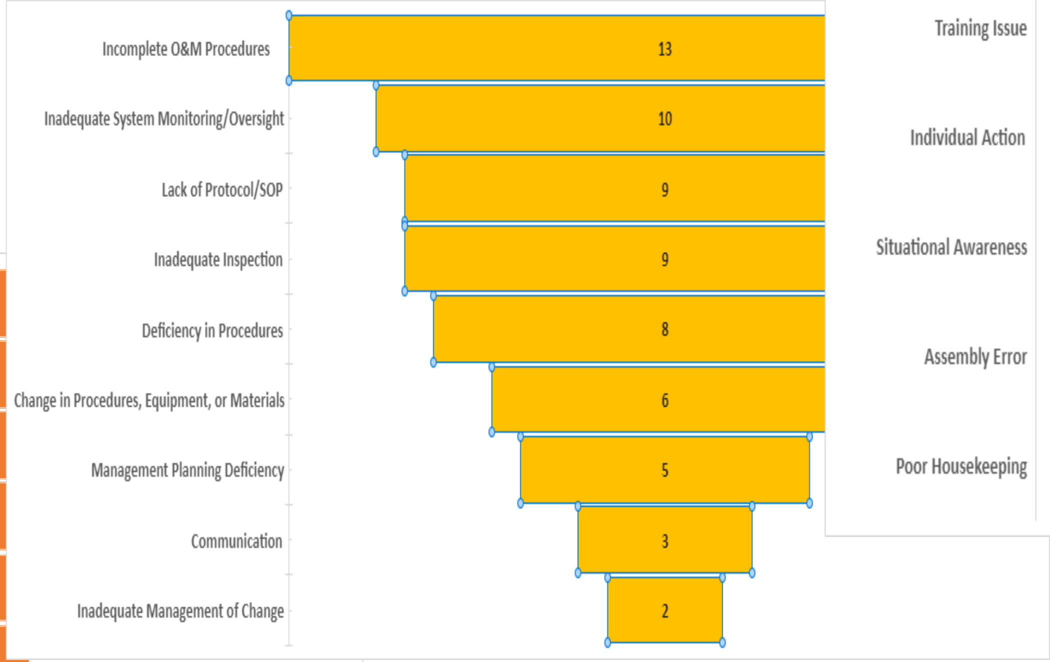
- Assumptions:
  - Hydrogen leakage 3% in Finland
  - 65% (LHV) electrolysis using 100% wind energy to produce H_2.
  - Average gridmix used in synthesis processes (green steel uses nuclear)
  - Input-output analysis values from literature
  - Cradle-to-use phase
  - Transportation considered



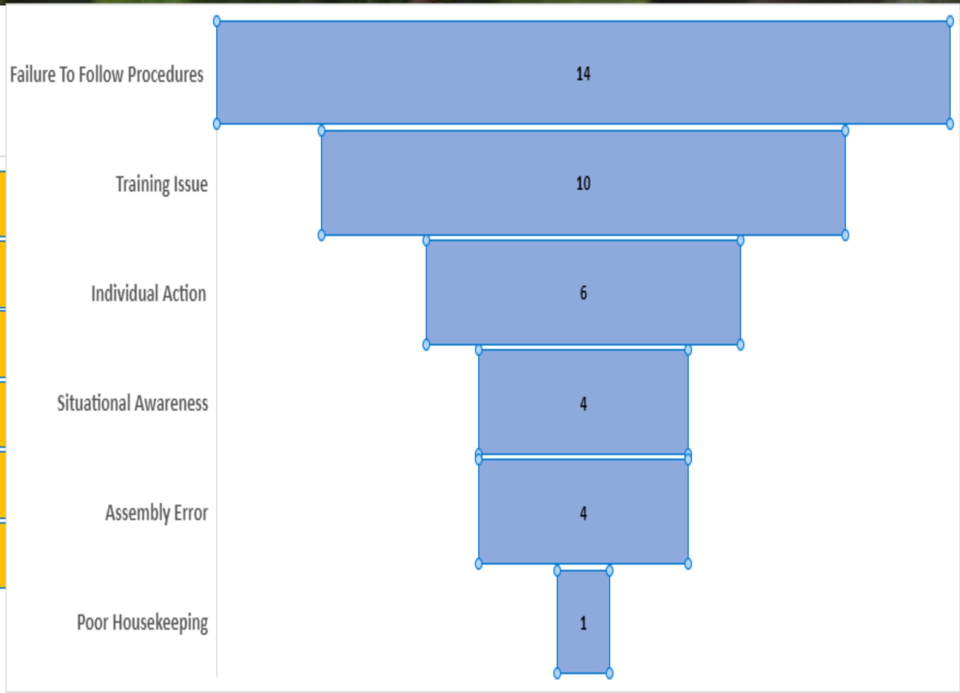
Additional reading - safety



Events caused by technical operation related (upkeeping operations).



Events caused by process management.

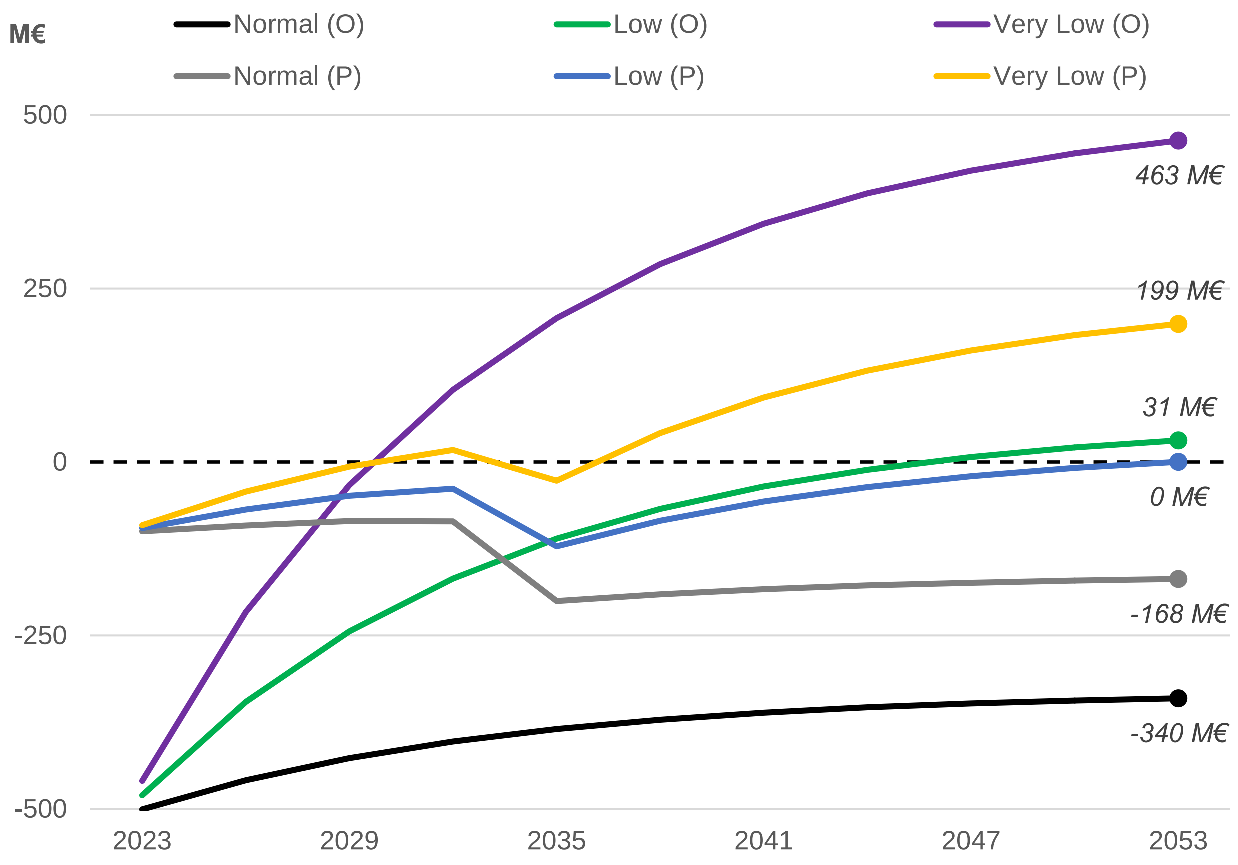


Events caused by human error.

Source: Alfasfos et al.2024 HYGCEL
results page https://www.lut.fi/en/hygcel

Additional reading: Economic vs. environmental goals

Discounted cash flow of one-time investment (O) vs investing in phases (P)



Cumulative emission reductions during 30-year operation

	PtMeoh		
Emission reduction (LCA, End use)	Normal	Low	Very low
One-time Investment [MtCO2-eq/30y]	-19,1	-20,2	-21,9
Investing in phases [MtCO2-eq/30y]	-13,3	-14,0	-15,0

Investing can be made in phases. A case study was made first to invest in 150MW electrolyzer, and then scaled up to 750 MW after 10 years.

Capital intensive one-time investments are challenging (economic uncertainty). Investing in phases reduces capital required.

However, the investing in phases reduces cumulative GHG emission savings.

If fast emission reductions are wanted, one-time investments to PtX value chains are desirable

Reflection to Hydrogen safety

Jari Sistonen
Chairman

U-Cont

Hydrogen and safety

How would the safety of hydrogen be a positive sales argument. What questions then need to be answered?

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- Leading supplier of distribution stations and fuel systems in Northern Europe
- Other main products: tanks, industrial fuel systems and design
- Located in Joroinen, Finland, and in Krakow, Poland

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PICTURE OF HYDROGEN SAFETY WEIGHT BALANCE?

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CASE NORWAY HYDROGEN CARS

CASE HYDROGEN NORWAY

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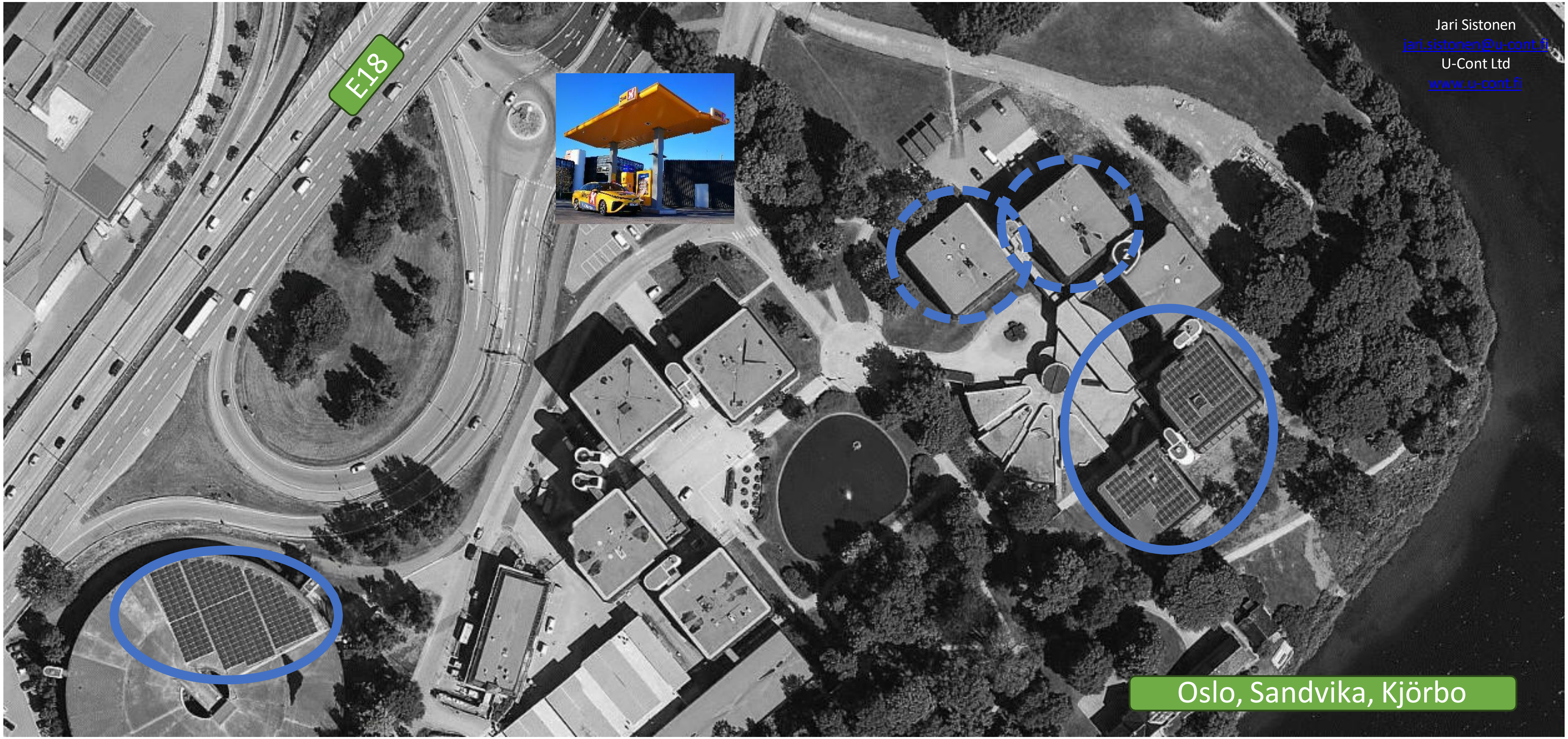
1 of 20: Lighthouse Project, Solar-to-H2

Collaboration With Asplan-viak & Entra, Supported By Enova & Akershus CC



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June 10.2019 Kjörbo Oslo hydrogen station explotion

- No human casualities
- Airbags nearby cars caused few hospital visites
- Hydrogen production & warehouse damaged
- Close highway closed for few hours
- Operator decided to stop hydrogen project after

=> NEL HYDROGEN INFORMATION OF REASON

1. High pressure flange torgue was not tightened enough / flange type was changed more triky to tight.
2. This caused a leakage after one operational year.
3. Finally, the high pressure expanded and caused a strong pressure shock to gravel, which in turn created a spark and explosion.

https://nelhydrogen.com/status-and-qa-regarding-the-kjorbo-incident/

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APPROVAL AND STANDARDISATION

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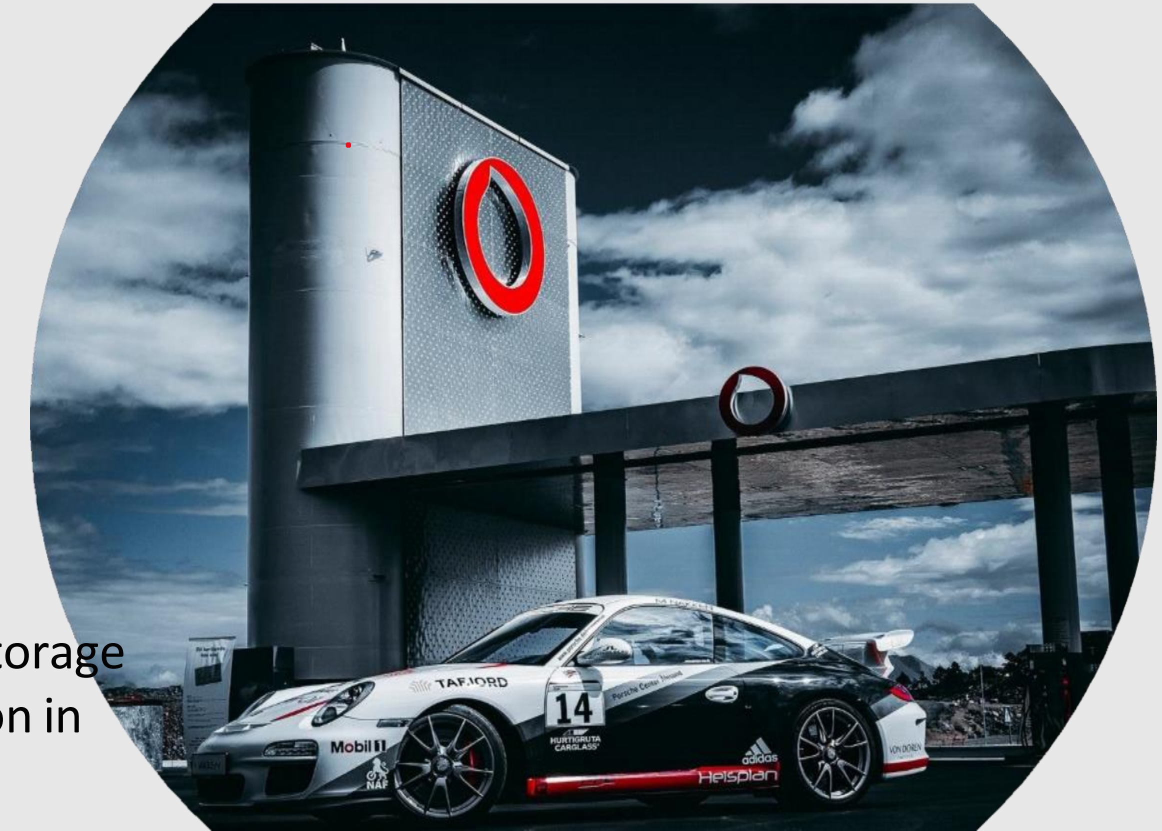
APPROVAL PROCESS IN FINLAND EXAMPLE

- Above ground gasoline storage with fire and bullet protected tanks TO PROTECT GROUND WATERS
- U-Cont made development investments and agreed fast approval process with TEM at 2008
- STILL WAITING APPROVAL BUT HELSINGIN SANOMAT SAID THAT ITS SOON IN PROCESS (HS 8.5.2024)
- SAFETY OF INNOVATION INVESTMENTS IN FINLAND?



Above ground storage gasoline station in Norway

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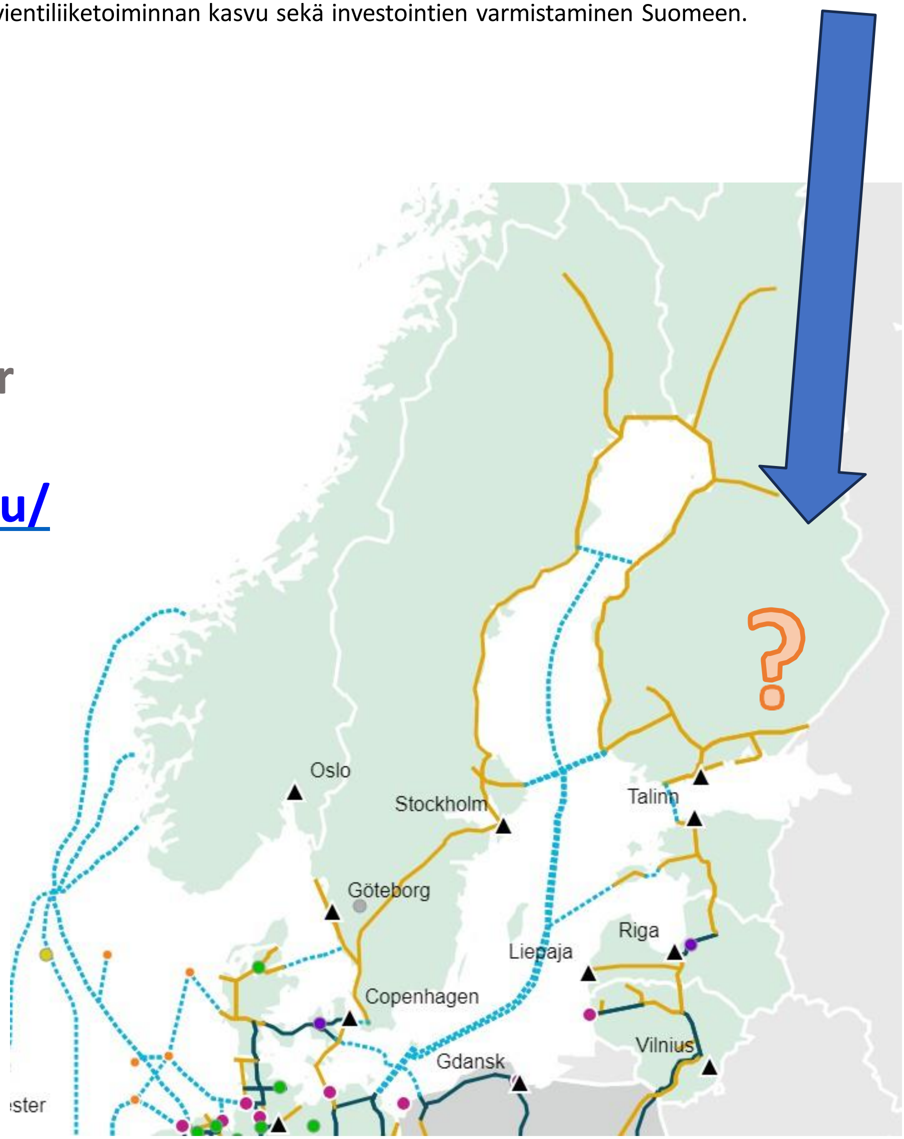
NATIONAL SAFETY RESILIENCE WITH HYDROGEN?

HYDROGEN / ENERGY NETWORK AND NATIONAL SAFETY

Valtioneuvoston periaatepäätös vedystä Valtioneuvoston julkaisuja 2023:19
Suomi tavoittelee Euroopan johtava asemaa vetytaloudessa läpi koko arvoketjun. Tavoitteina ovat puhtaan vedyn ja sähköpolttoaineiden valmistus kotimaisen teollisuuden, liikenteen ja energiajärjestelmän tarpeisiin, teollisuuden uudistuminen ja korkean jalostusarvon vientiliiketoiminnan kasvu sekä investointien varmistaminen Suomeen.

- Energy network planning safety means:
  - Alternative routs in case something happened
    - Inside Finland
    - Near by Finland
  - The ability to defend key routes in the event of a crisis
- Areal planning of this network means areal planning of most heavier branches of industry=> Means areal planning of indutrial wealth
- European level planning leaves big part of Finland out https://ehb.eu/



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HYDRGEN SAFETY 2024 QUESTIONS

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End product?
Methanol=> Ground water issues
Ammonium=> Work safety issues
Methane=> Climate issues

How to make better public view of H2 safety?

Warsafe H2 solutions from Finland?

Planning close to practice or theoretical with distance?

Is this infra set available to daily usage 2 or 20 years?

Fysics or religion?

Sulo Vilen or MacGyver at site?

Is this approval set 2 or 20 years?

Ready 2030?->

2 or 20 times of the old way?

Is it easy and safe?

Is Finland recilience better with fossil or with electricity together with H2?

What are the key questions to solve?

Safety storage & transport?

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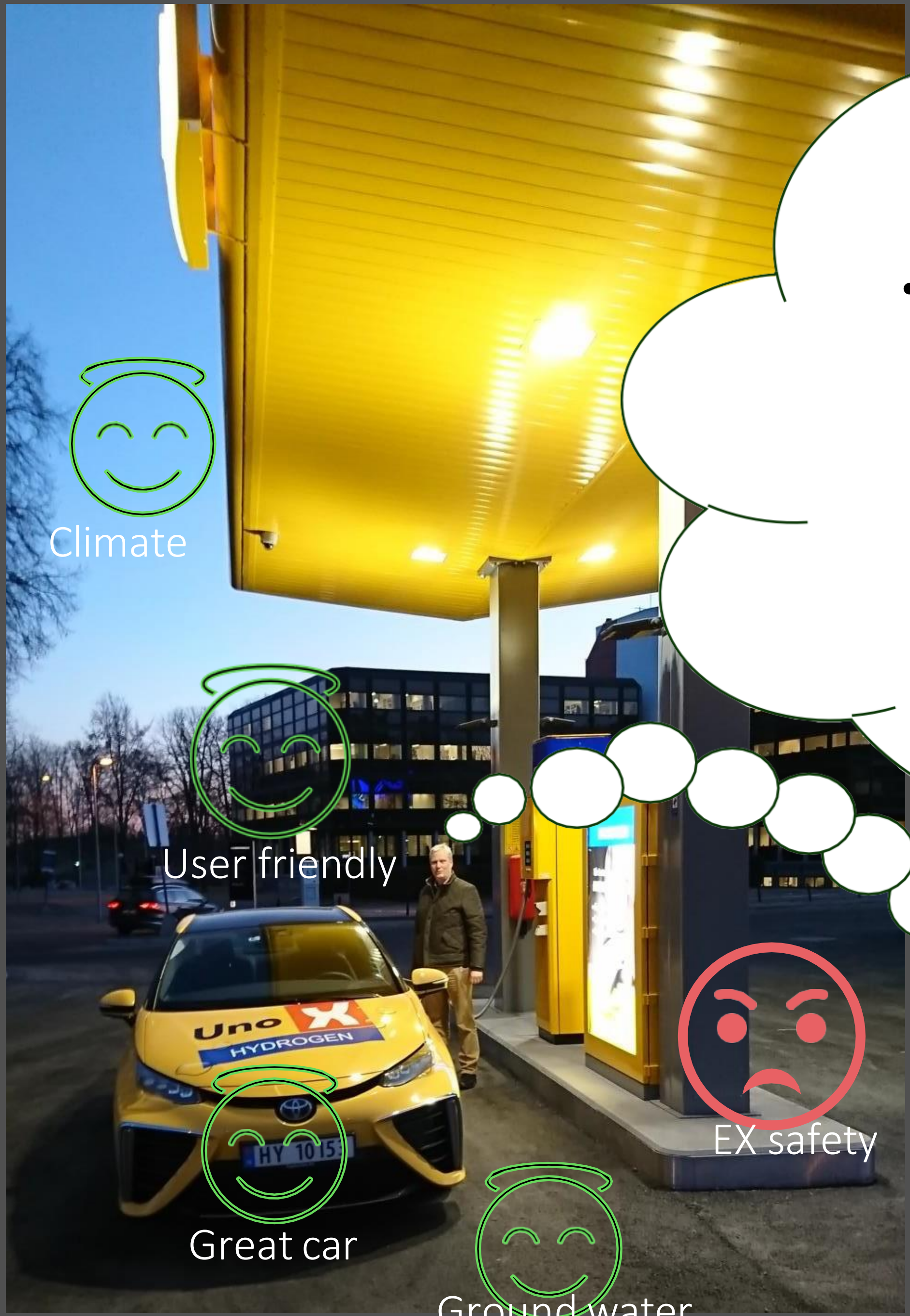

- Better to speak safety balance than only safety because then you have more truthful picture on table.

- Practical safety is often other than theoretical, thats why we should have strong practical role since beginning.
- Explosive safety is and will be the heaviest part of safety balance, thats why we have to focus on storage and transport when speaking or designing of safety. Thats why hydrogen pipe lines and –storages are so important.

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Thank You

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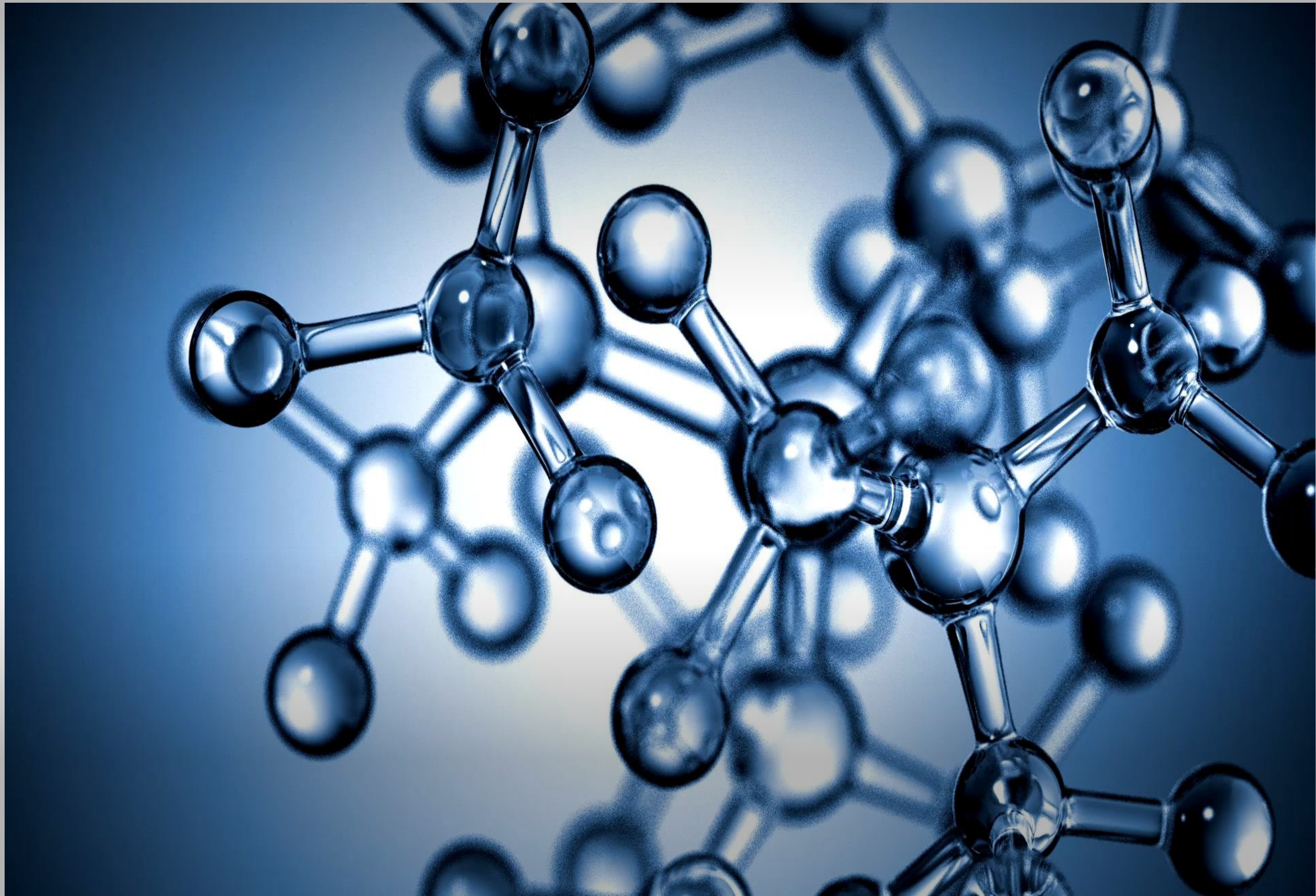
Hydrogen value chains: Reflection of global policies for the Finnish Hydrogen economy

Pami Aalto
Jean Monnet Professor in International Relations
Faculty of Management and Business

Tampere University

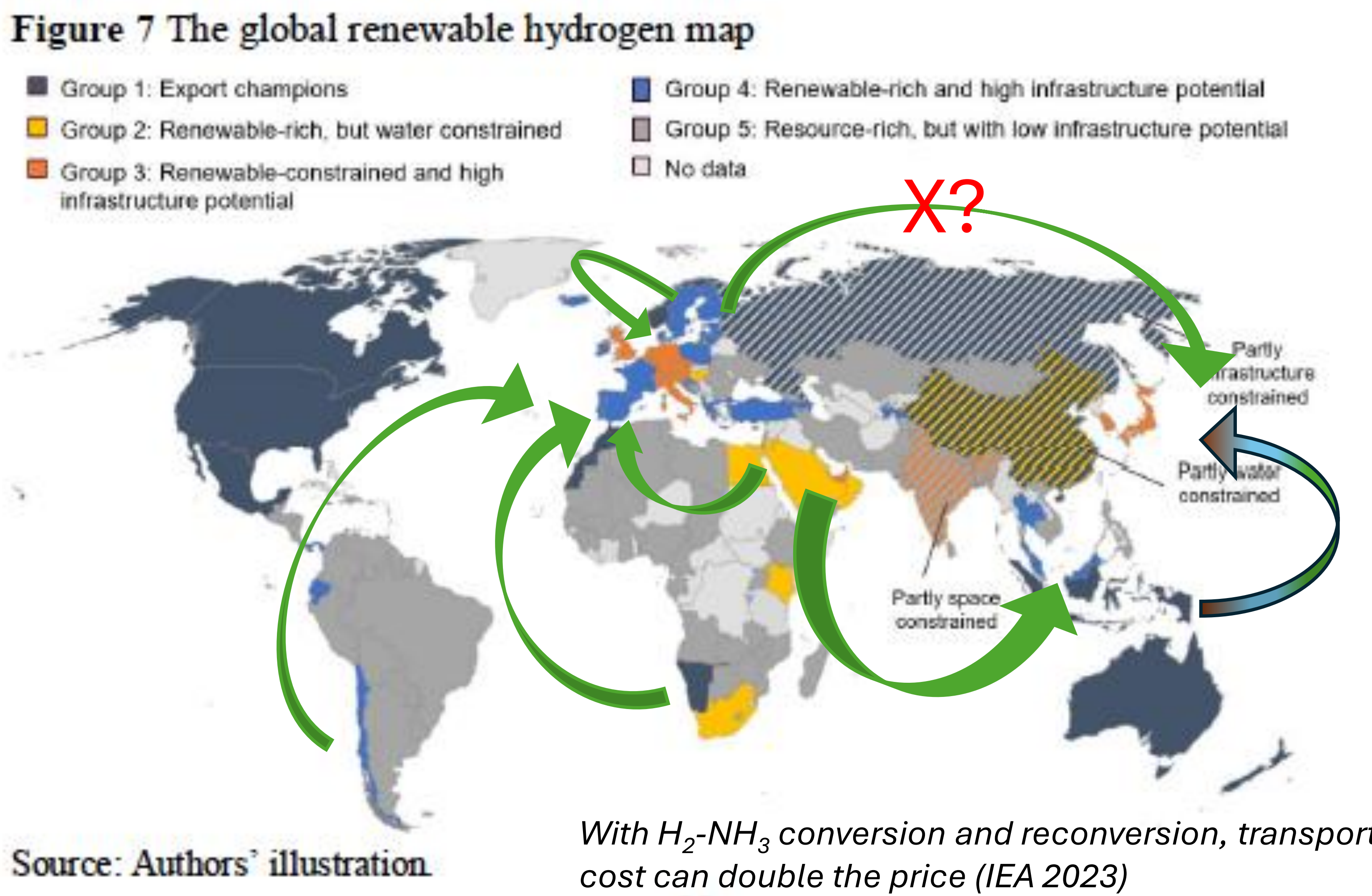
Hydrogen value chains: Reflections on global policies for the Finnish hydrogen economy



Prof. Pami Aalto
Tampere University/Politics unit
Business Finland HYGCEL consortium

Presentation 22.5.2024 Helsinki

The largest markets for **H2 fuels** produced in Finland will likely be in Europe – for chemicals etc., maybe the same case?



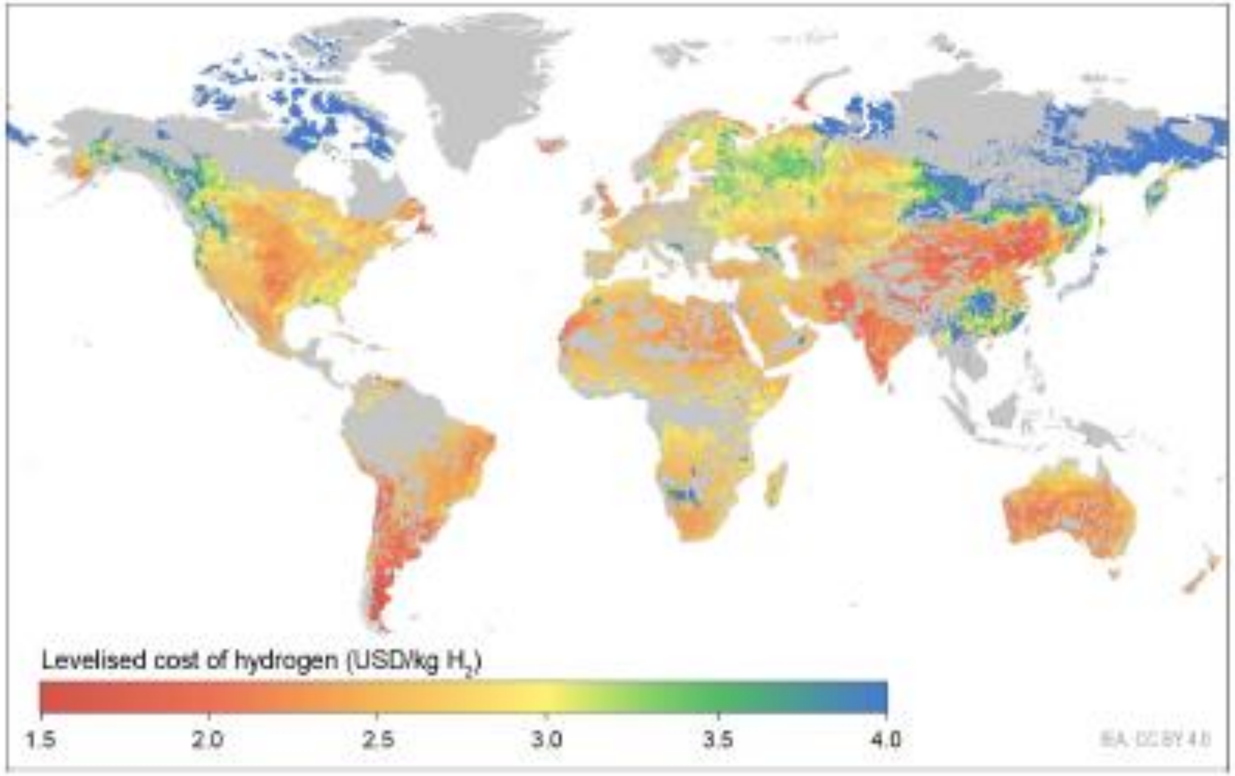
With H_2-NH_3 conversion and reconversion, transport cost can double the price (IEA 2023)

Source: Pflugman & DeBlasio (2020)

- CHN mostly domestically oriented?
- Large US potential, but uncertainties vis-à-vis exports due to the policies of the next presidential regime and possible domestic instability
- Persian Gulf: affordable CCUS fuel + large renewable H_2 potential
- AUS, IN, ID → Asian markets due to transport cost reasons?
- Northern Sea route unusable
- Finnish fuel exports to Asia uncertain due to transport costs & shrinking global commons character of the Seas
- Southern Europe to be supplied with Northern & sub-Saharan Africa

Competition is tough even in Europe both for price and policy reasons – but **competitiveness** has many components (one of them may be **strategic autonomy**!)

Figure 3.13 **Hydrogen production costs and share of solar PV from hybrid solar PV and onshore wind systems, 2030**



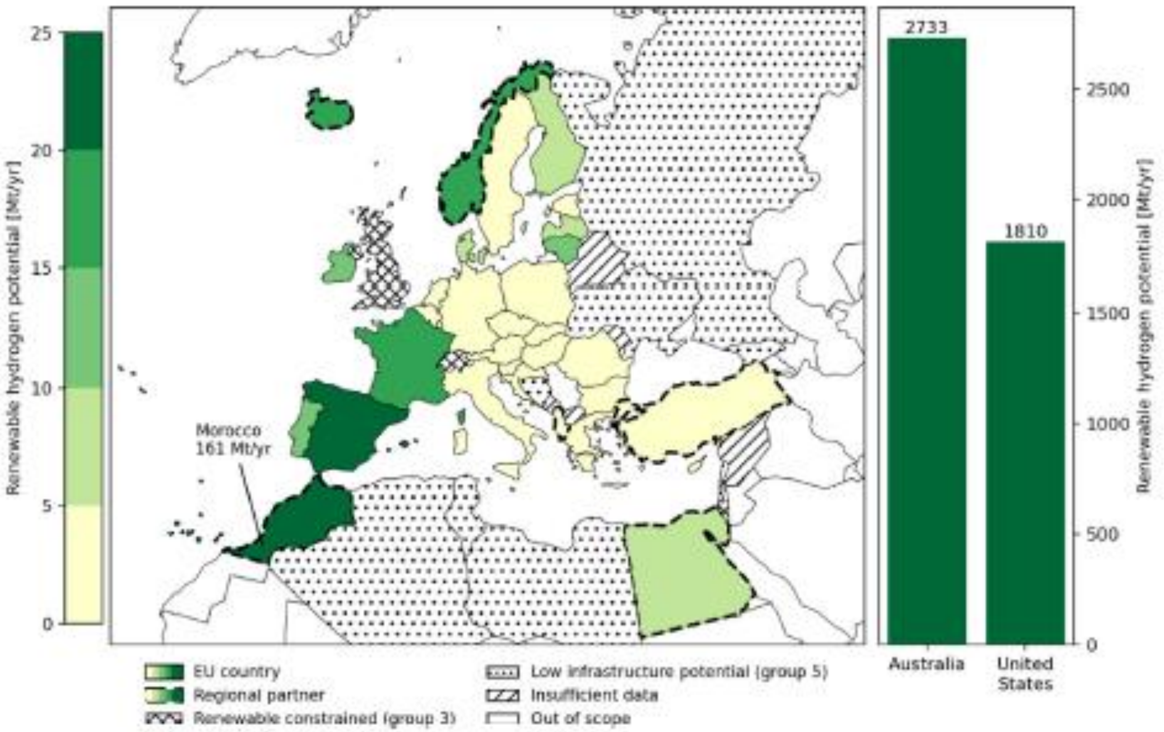


Fig. 1 – Renewable hydrogen potentials by 2050.

- Finnish production globally not among the most price competitive & transport cost to far away markets may be prohibitive
- In Europe, Finnish production competes with Norwegian, Baltic, Spanish, North African, sub-Saharan & Latin American production
- Many potential producer countries have strong policy push & incentives
- Economical pipeline transport ca. 1000-2000km

Finnish H2 fuel production can compete with connectivity & diversified infrastructure

- Poor connectivity to otherwise lucrative Asian markets as Northern searoute and Russian land transit unavailable
- Although only few Finnish projects are operational, those operational in central Europe will not satisfy all demand there
- Finnish ‘project pipeline’ comparable to that of most potential suppliers to Europe
- H2 transport through pipeline & H2 fuel transport via tankers both have vulnerabilties
- Connection to Barents Sea and/or Sweden to address vulnerabilities
- Destinations: UK, BE, NET, DE?

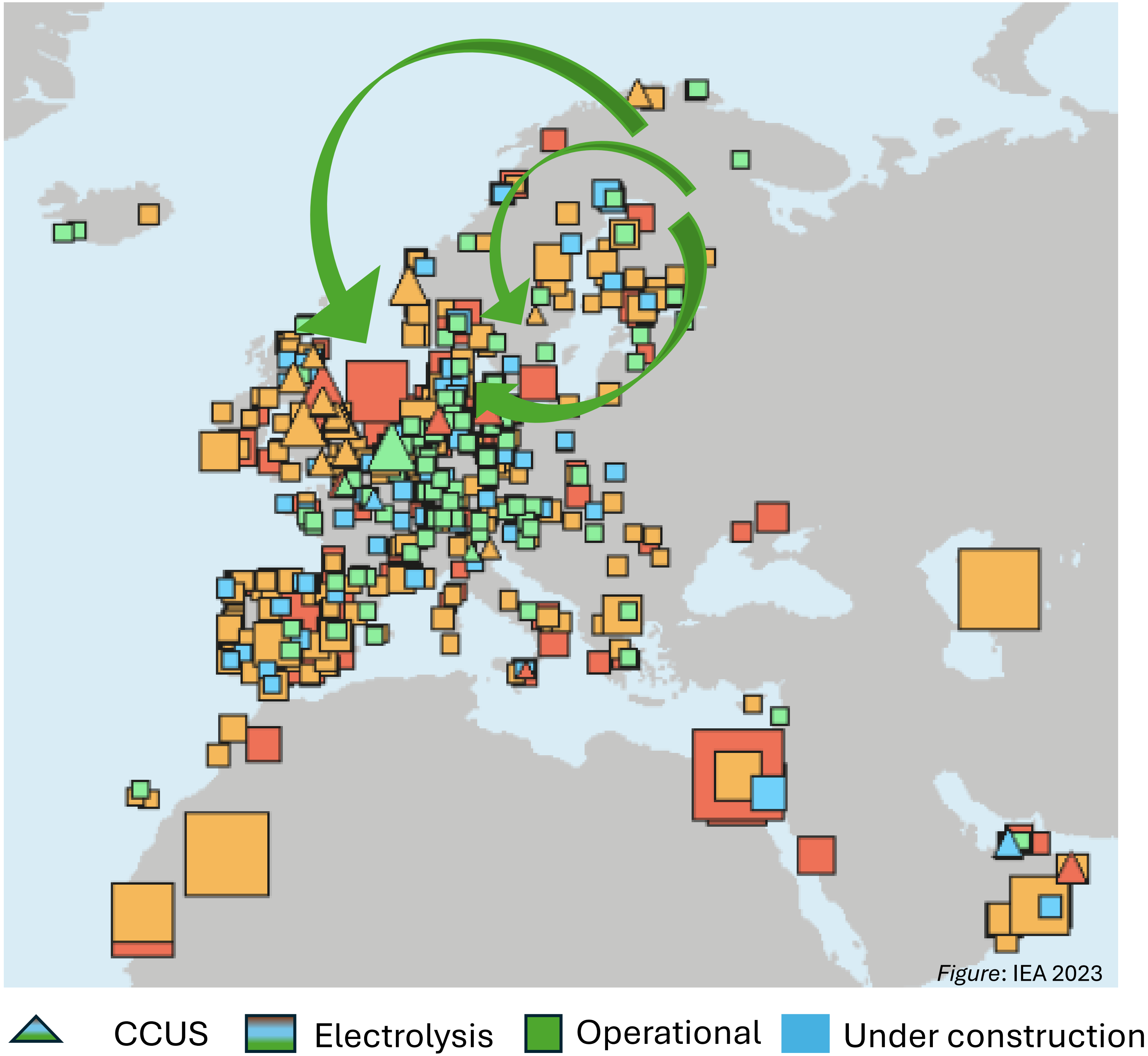
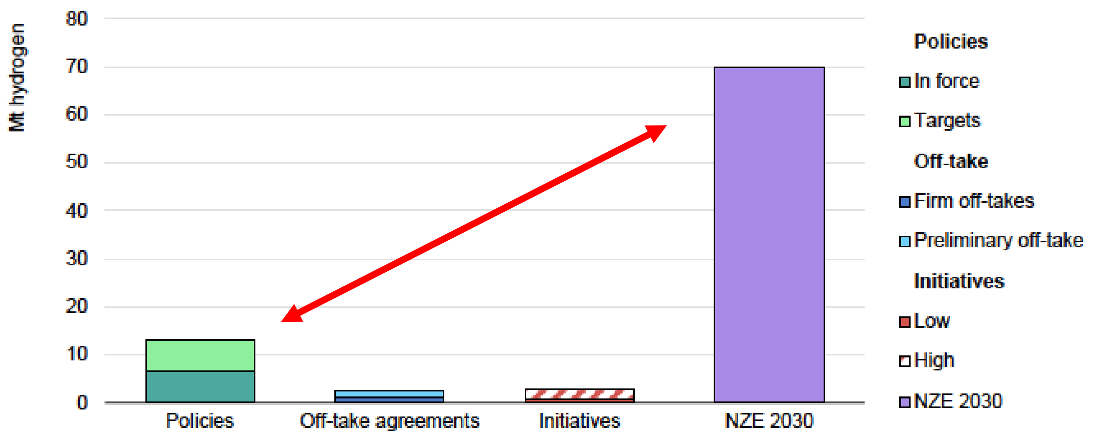


Figure: IEA 2023

What did the Finnish forestry industry once do?
It is possible to offshore some production

→ (yet unknown) demand will exist
→ production closer to demand diminished transport cost
→ investment into 'safe' (?) allied/NATO countries (USA, JPN, AUS)
→ or to riskier (Namibia? Chile? Morocco? India?)
→ competitive advantage with policies
→ just like RES deployment was kicked off with policies
→ invest in countries with proper policies

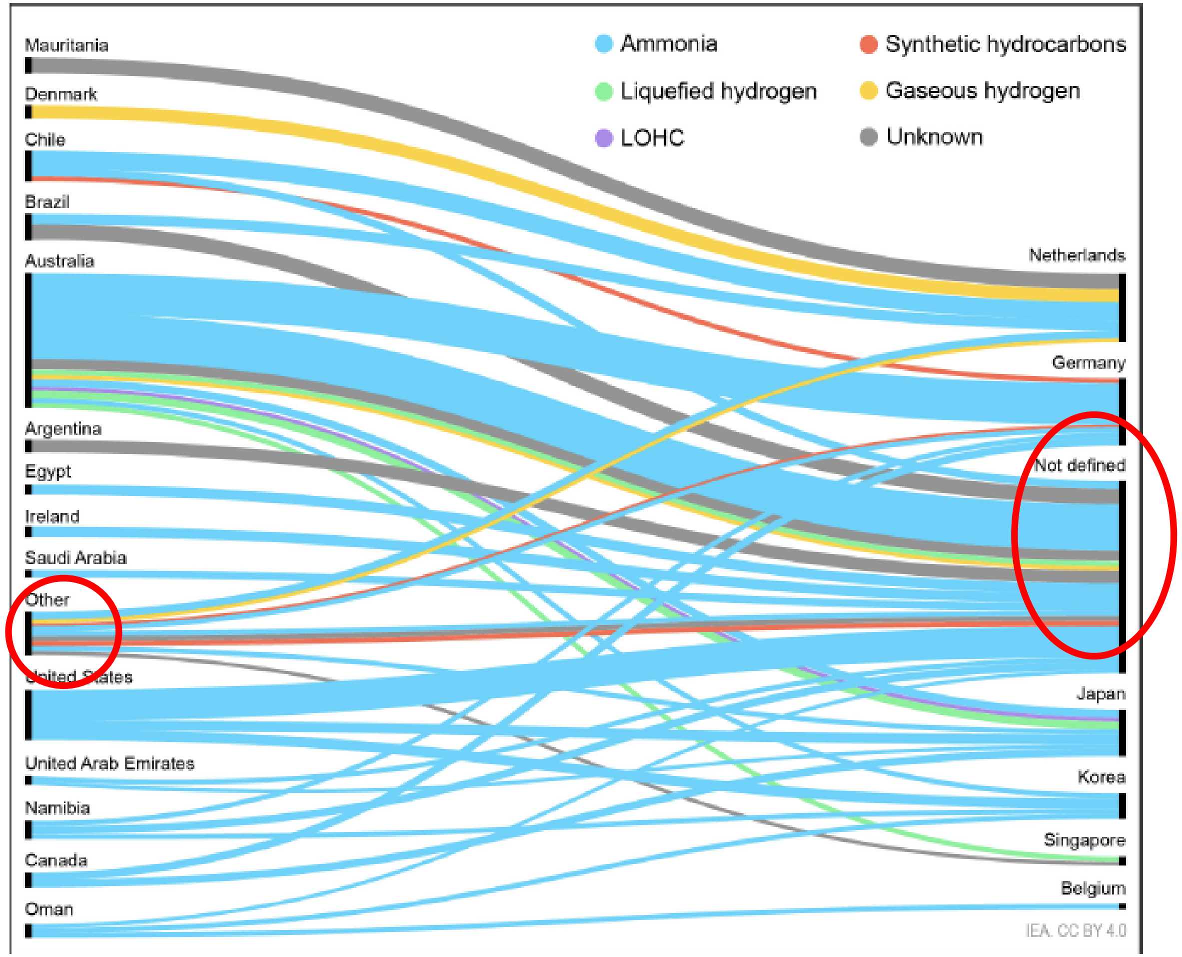
Figure 2.15 Potential demand for low-emission hydrogen from announced policies and targets, private off-take agreements, commitments of international co-operation initiatives and the Net Zero Emissions by 2050 Scenario, 2030



Notes: NZE = Net Zero Emissions by 2050 Scenario. In "Initiatives", the dashed area corresponds to the range between the most conservative (low) and boldest (high) estimates of the demand that can be generated by international initiatives.

Source: IEA (2023)

Figure 4.3 Potential low-emission hydrogen trade flows based on announcements, 2030



Notes: LOHC = liquid organic hydrogen carrier; UAE = United Arab Emirates; Mt = million tonnes. In million tonnes of hydrogen equivalent, only flows larger than 150 kt H_2 equivalent per year are shown.
Source: IEA analysis based on multiple sources, including company announcements.

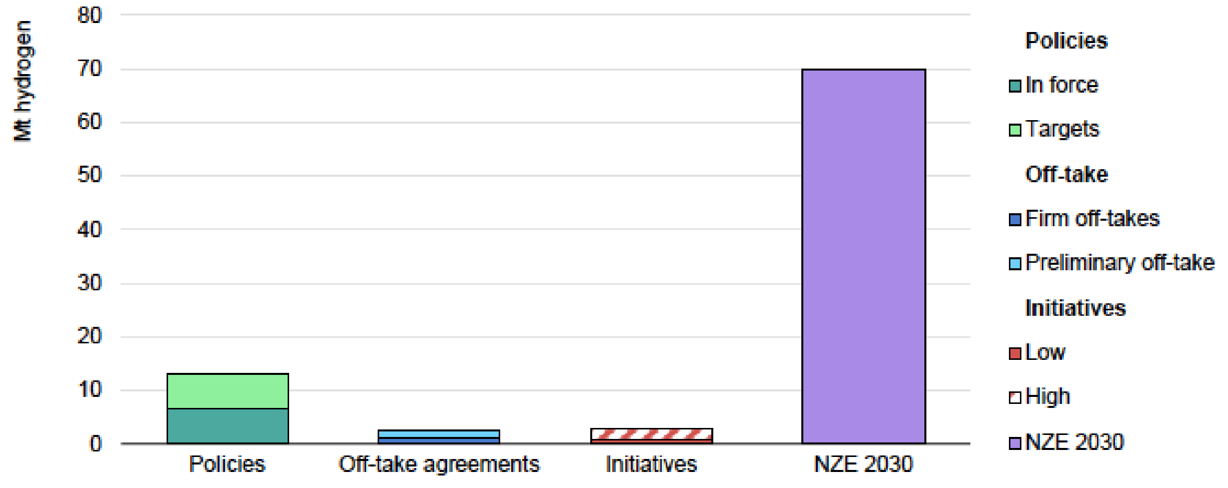
Several trade projects are under development, with Australia, Central and South America, North America and Africa as key exporters, while only a few importing countries have been identified.

Policy push required to create demand

→ redirected fossil fuel subsidies & expenses that so far have went to buying fossil fuels from abroad

→ in 2022, the EU imported energy worth € 604bln...

Figure 2.15 **Potential demand for low-emission hydrogen from announced policies and targets, private off-take agreements, commitments of international co-operation initiatives and the Net Zero Emissions by 2050 Scenario, 2030**



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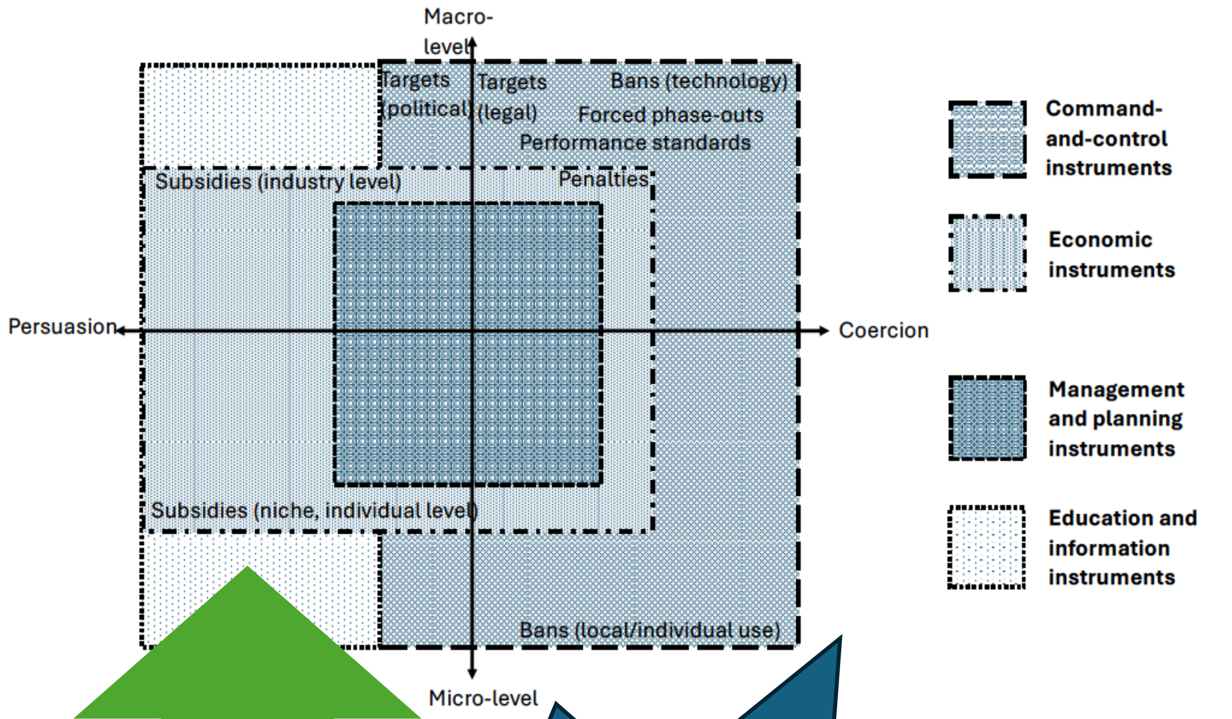


How does one achieve a major transition fast? Analogy from Norway's EV transition → the whole menu of policy instruments in use!

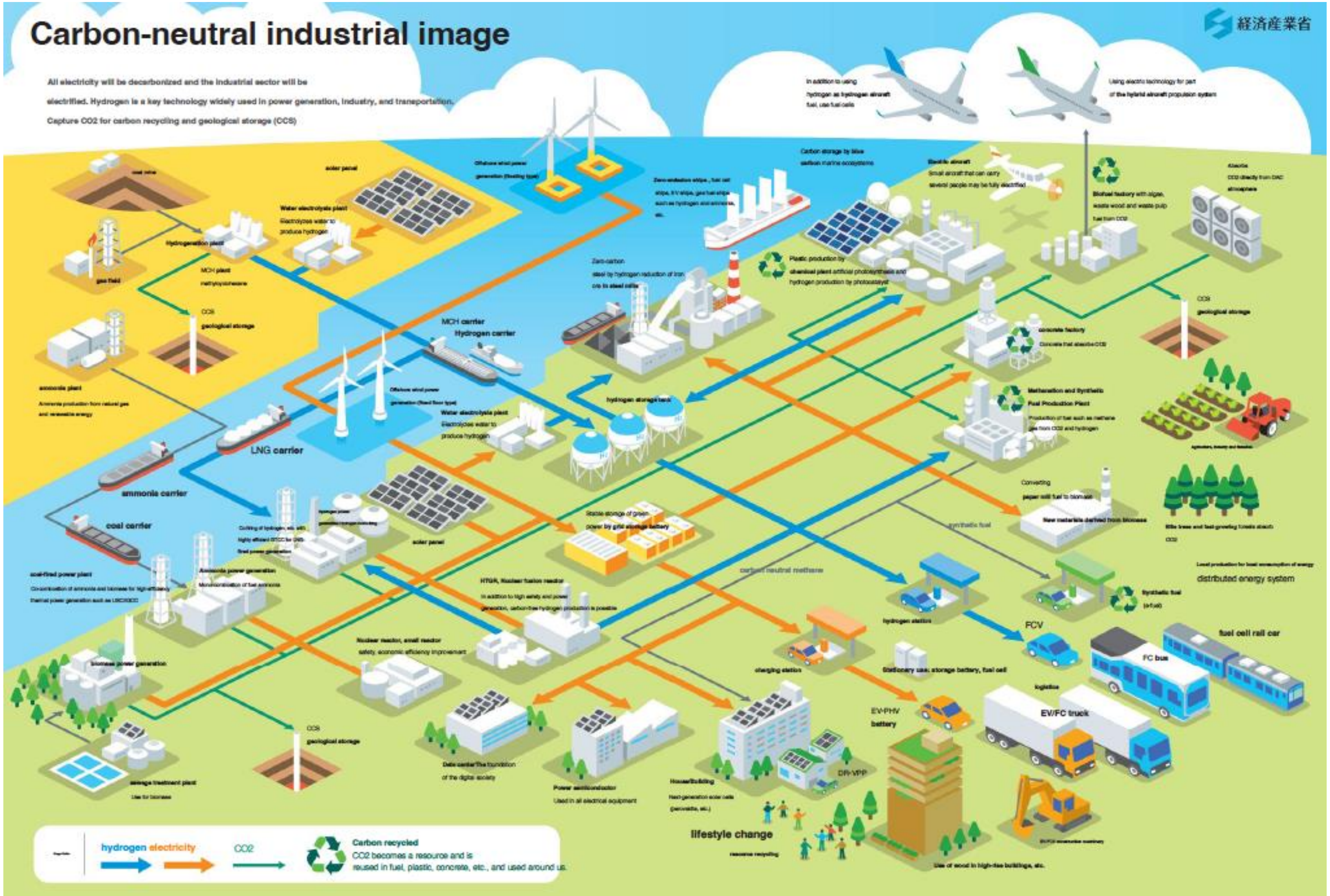
So how does the EU policy mix look like? **Gruyere** or **Maasdam**?

Command-and-control	**Example**	**Notes**
Targets		
EU gas and hydrogen package (2023/2024)	42.5% of H2 renewable by 2030 (RFNBO) = 4Mt; 60% 2035	Where is the 2040 target?
	1.2% of aviation fuel renewable H_2 by 2030 (RFNBO) = 92.000t + 460.000t CCUS	The industry's own actions are slow…
	1% road transport fuels renewable H_2 by 2030 (RFNBO) = 360.000t	Hopefully this goes to heavy traffic, but competing solutions exist
Performance standards	RFNBO	Eligibility: 3.4kg of CO_2e/kg H_2
Blending obligation	Natural gas pipeline operators to accept 5% H_2 1.10.2025→ 75% tariff discount for H_2	Primarily targeting industrial sector's emission reductions Hollanti (2026)
Incentives		
Hydrogen Bank	720Me on first round (CfD type), 1.58Mt in 10 years, 7 projects (1 to Finland) → **2Mrd+ €**	+ MS incentives for projects not receiving EU funding, e.g. DE 350M€; EST 39Me
RDI support	Clean Hydrogen Partnership, 190M€ 2024	+ MS 10M€+ projects: BR, NET, DE, DK

What about the competitiors? India's renewable H2, NH3, MeOH boost

Command-and-control	**Examples**	**Notes**
Target	'Self-reliant India' scheme (2020)	Energy independence by 2047
Performance standard	Green Hydrogen Standard for India (2023)	Eligible RES incl. biomass; < 2.0 $kgCO_2e/kg$ of H_2 (12m average); methodology TBA
Incentives		
Production subsidy	USD 25mln →5 Mt of 'renewable' hydrogen by 2030 (with 125GW RES capacity additions)	May reach 10 Mt/yr incl. exports
Competitive bidding scheme, 2.2bln USD	Subsidy for electrolyser development	Part of SIGHT programme
Competitive bidding scheme, 2.2bln USD	Subsidy for RES based H_2 production	Part of SIGHT; USD 0.64/kg) for 1^{st} year, USD 0.51/k) for 2^{nd} year; USD 0.38/Kg) for 3^{rd} year
Waiver	Electricity transmission charge waiver	Until 2030/2036
Management instruments	Manufacturing zones for green H_2	Spatial planning policy
	H2 safety certification programme	
Sources: e.g. IEA (2023); Pal et al. (2024); Government of India (2023)	H2 fuel quality control system	

Japan's hydrogen society vision proposed to do it a bit differently



Some key leftovers from Japan's Hydrogen Society vision, on top of impressive H_2 supply chain development

Transport – *heavy competition with other technologies*

6427 FCV

FC bus deployment
106 FC buses

FC train demonstration

FC train

FC Truck development

ISUZU HONDA The Power of Dreams HINO TOYOTA

FC Truck

District & residential heating + CHP → *best applied where?*

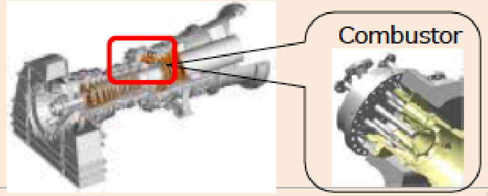
Stationary Fuel Cells at home

FC CHP* for home use: More than 400,000 units installed

Sources: METI (2021, 2022)

R&D for large-scale thermal power generation (500 MW class)

Development of technology for hydrogen co-firing in existing large-scale thermal power plants, <u>achieving a hydrogen co-firing rate of 20% by 2018.</u> → Technology development for hydrogen single fuel power generation is in progress from 2020.

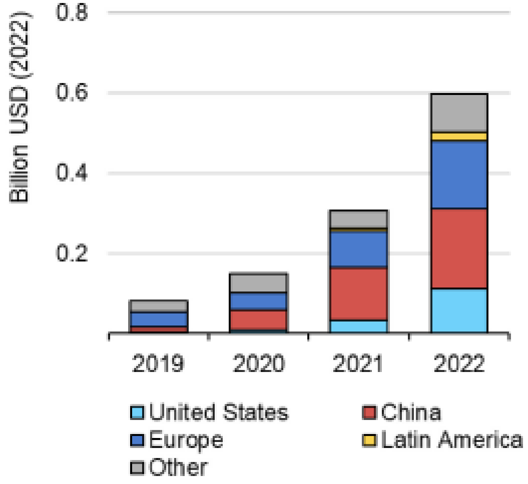


R&D for cogeneration for supplying heat and electricity (1MW class)

We have developed a technology that can freely co-fired hydrogen with natural gas from 0 to 100%. <u>In 2018, we will be the first in the world to achieve combined heat and power supply to urban areas using hydrogen exclusively.</u> → From 2019, technology development for high-efficiency dedicated <u>hydrogen single fuel power generation</u> is in progress.

Hydrogen power generation facility (hydrogen CGS) constructed on Port Island in Kobe City

What about the global competition in electrolyser manufacturing?



Electrolyser investments, 2021-22

Sources: IEA (2023); METI (2021, 2022)

Selected active hydrogen R&D programmes

Country	Programme	Funding and duration
Australia	ARENA's R&D Programme CSIRO Hydrogen Mission	AUD 22 mln (~USD 15 mln) – 5 yr AUD 68 mln (~USD 47 mln) – 5 yr
European Union	Clean Hydrogen for Europe	EUR 1 bln (~USD 1. bln) – 10 yr
France	PEPR Hydrogène	EUR 80 mln (~USD 91 mln) – 8 yr
Germany	National Innovation Programme for Hydrogen and Fuel Cell Technology	EUR >250 mln (~USD 285 mln) – 10 yr
	Wasserstoff-Leitprojekte	EUR 700 mln (~USD 800 mln) – n.a.
Japan	NEDO innovation programmes	JPY 699 bln (~USD 6.5 bln) – 10 yr
Spain	Misiones CDTI	EUR 105 mln (~USD 120 mln) – 3 yr
United Kingdom	Low Carbon Hydrogen Supply	GBP 93 mln (~USD 119 mln) – n.a.
United States	H2@Scale M²FCT – H2New Consortia DOE Hydrogen Program	USD 104 mln – 2 yr USD 100 mln – 5 yr USD 285 m/yr

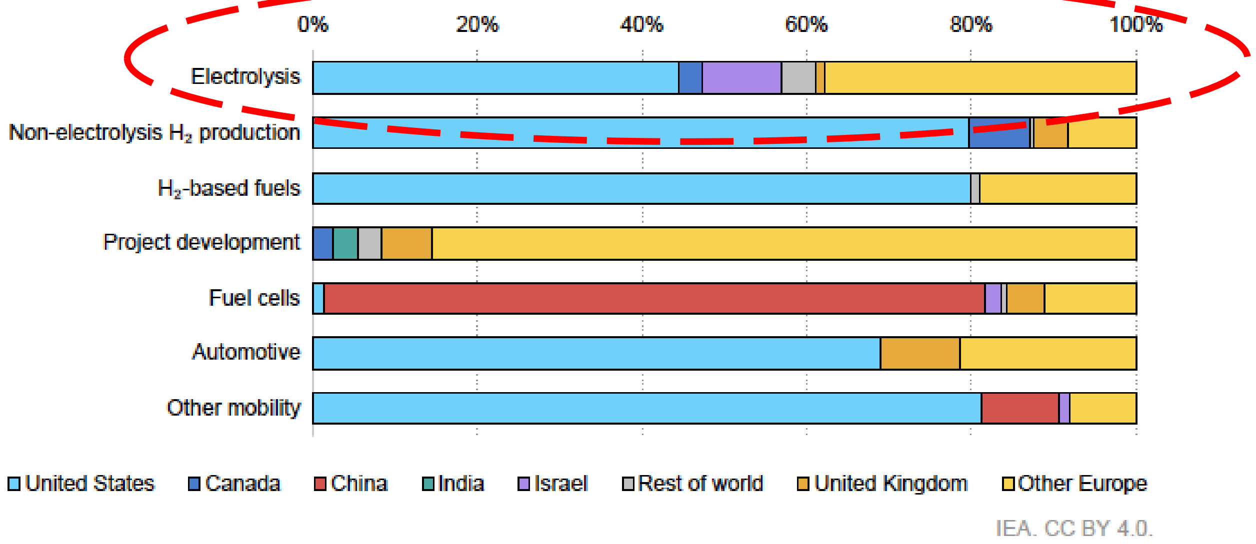
→ Japan invests some 450mln USD public money for electrolysers to bring cost to 1/6!

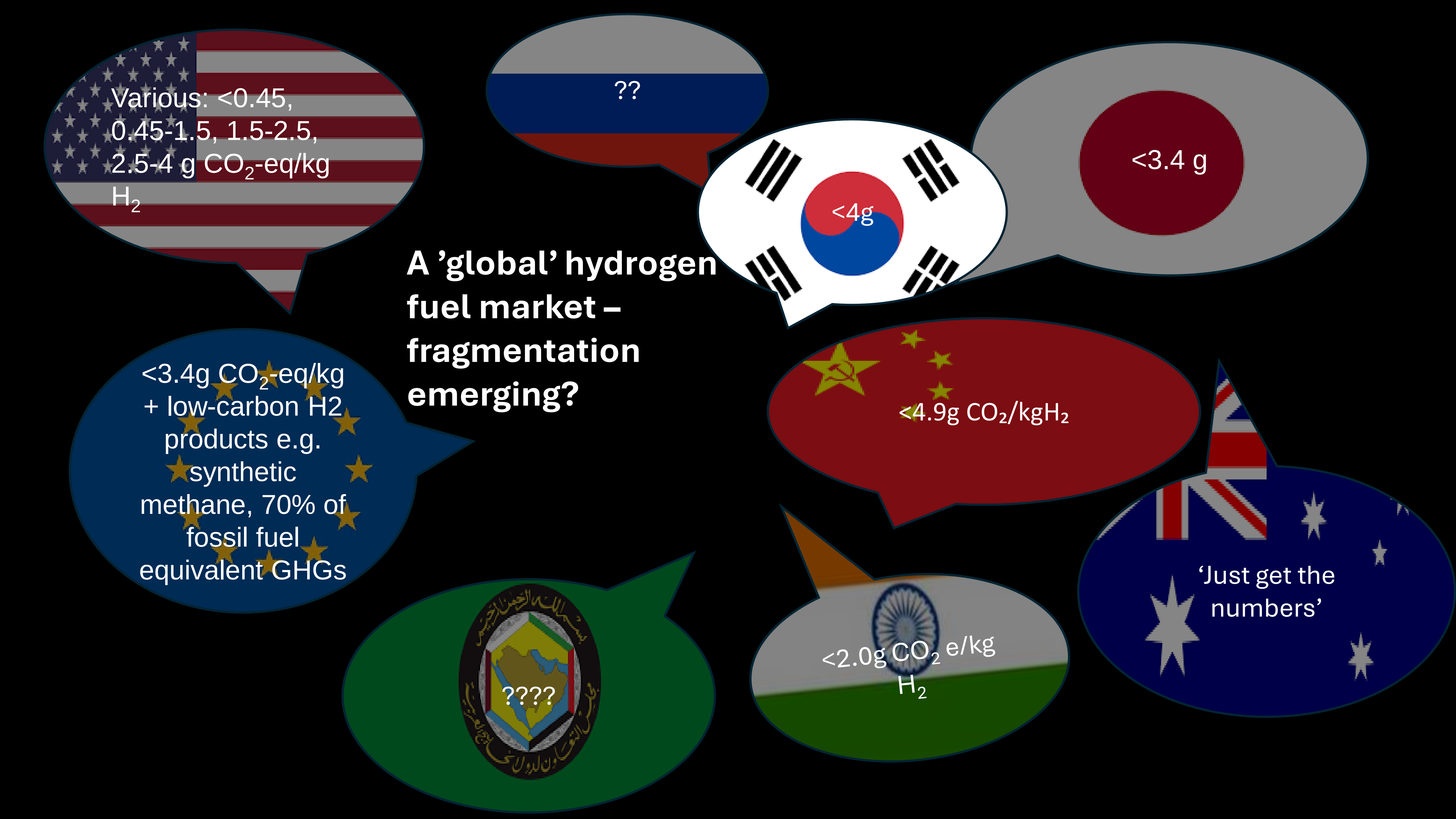
GI Fund Project② : Scaling up Electrolysers

- To further reduce the cost of electrolysers, Japanese government will support demonstration projects for 1) scaling up electrolysers, 2) implementing superior components and 3) system optimization with several demands(**~70 Billion Yen**)
- The goal of this project is to establish a strong technological base to attain the cost of electrolyer **(up to 1/6 of the current system cost)**

→ But USA & Europe lead investment in electrolyser start-ups

Figure 5.6. Early- and growth-stage equity investment in energy start-ups in hydrogen-related areas by region, 2018-2022




A 'global' hydrogen fuel market – fragmentation emerging?
Various: <0.45, 0.45-1.5, 1.5-2.5, 2.5-4 g CO_2-eq/kg H_2
??
<4g
<3.4 g
<3.4g CO_2-eq/kg + low-carbon H2 products e.g. synthetic methane, 70% of fossil fuel equivalent GHGs
<4.9g CO_2/kgH_2
????
<2.0g CO_2 e/kg H_2
'Just get the numbers'

A ‘global’ policy landscape?

- Not so much in terms of actual ‘global’ policies yet but predominantly national + EU-based
- Some international standardisation efforts
  - European Clean Hydrogen Alliance (standardisation)
  - European Hydrogen Safety Panel, ISO (work on fuelling stations & protocols)
  - SAE International [USA] (hydrogen refuelling stations)
  - International Electrotechnical Commission (standards on performance testing in fuel cell/battery systems in excavators + power-to-methane, fuel cells in trucks)
- Several ‘agent’ organisations & platforms working on knowledge accumulation, sharing & dissemination

Where is Finland?

- Even though Finnish H_2 fuel production will not be the cheapest, strategic autonomy policies & friend-shoring to create opportunities within NATO/EU
- But Finland’s own H2 policies are not much to be seen…
- Some risks in transition period CCUS solutions based on natural gas extraction
- And in CO_2 in methanol solutions → how long will biological origin CO_2 be considered climate neutral?
- **For a value-added, resilient niche, invest in ammonia + SWE/NO transport connection?**

HYDROGEN INITIATIVE
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

IPHE

MISSION INNOVATION

IRENA
International Renewable Energy Agency

Finland as part of the global hydrogen economy – what should be done to become a leader?

Marko Janhunen
Vice President, Public Affairs

Gasgrid

Riitta Silvennoinen
Circular economy and Energy transition lead

Deloitte

Jukka Ruusunen
Industry Professor

LUT University

Pami Aalto
Jean Monnet Professor in International Relations
Faculty of Management and Business

Tampere University

Simo Säynevirta
Chair of H2Cluster Finland, Head of ABB Green Electrification Ecosystem

Petteri Laaksonen
Research Director, School of Energy Systems

LUT University

Share Your Thoughts on Finland's Hydrogen Economy

Scan the QR code: Use your phone to scan the QR code and join the conversation.

Enter the Code: Alternatively, go to www.menti.com and enter the code **8484 9571** to participate.

Q&A and conclusion

Simo Säynevirta

H2Cluster Finland chair

Head of ABB Green Electrification Ecosystem