Powering the future: Integrating clean hydrogen into the power system

Dr. Cecilia Wallmark
Director of CH2ESS
Within the hydrogen area since 1999

CH2ESS
Centre for Hydrogen Energy Systems Sweden
AT LULEÅ UNIVERSITY OF TECHNOLOGY

Centre for Hydrogen Energy Systems Sweden

AT LULEÅ UNIVERSITY OF TECHNOLOGY

1) Education

2) Excellent, demand driven research

3) Accelerating hydrogen

Sweden decarbonises hard-to-abate sectors with green hydrogen

- Hydrogen has been identified as a key component of human society's response to climate change, enabling decarbonisation of hard-to-abate industrial and transport sectors (IEA, 2023).

- This has translated into forecast global demand for green hydrogen (electrolytic hydrogen from renewable sources) of 0.5—2 TW by 2050 [McKinsey, 2023] with capacity in Sweden forecast to rise to 15 GW by 2045 [Swedish Energy Agency, 2021].

- Already, we see the world's largest electrolytic hydrogen production facility (>700 MW) under construction in northern Sweden as the frontrunner project for fossil-free steel production and this is placing significant pressure on the electricity transmission grid to expand to facilitate this transition [SvK, 2024].

- IEA (2023), Global Hydrogen Review 2023. Accessed: Mar. 12, 2025. [Online.] Available: https://www.iea.org/reports/global-hydrogen-review-2023.
- McKinsey (2023), Global Energy Perspective 2023: Hydrogen Outlook. Accessed: Mar. 12, 2025. [Online.] Available: https://www.mckinsey.com/industries/oil-and-gas/our-insights/global-energy-perspective-2023-hydrogen-outlook.
- Energimyndigheten (Swedish Energy Agency) (2021). Förslag till Sveriges nationella strategi för vätgas, elektrobränslen och ammoniak. Accessed: Mar. 12, 2025. [Online.] Available: https://tinyurl.com/5ds2t773
- Svenska Krafnät, Grid Development Plan 2024–2033. Accessed: Mar. 12, 2025. [Online.] Available: https://www.svk.se/siteassets/om-oss/rapporter/2024/grid_development_plan_2024-2033.pdf

Hydrogen related development in Sweden, selection [CH2ESS @ LTU]

Renewable power, biomass, distr. heating, green CO_2, H_2O, capital

Early network of HRS
>60 stations accepted for public financial support

Heavy-duty FCV
- Volvo
- Scania

Front runners in fossil-free green iron and steel etc
- SSAB
- LKAB
- Stegra
- Ovako
- Power2Earth

Hydrogen based fuel production
- Liquid Wind
- St1
- Vattenfall
- Uniper
- …

World class fuel cell material, components, stacks and systems
- PowerCell
- Alleima
- Cellimpact
- Permascand…

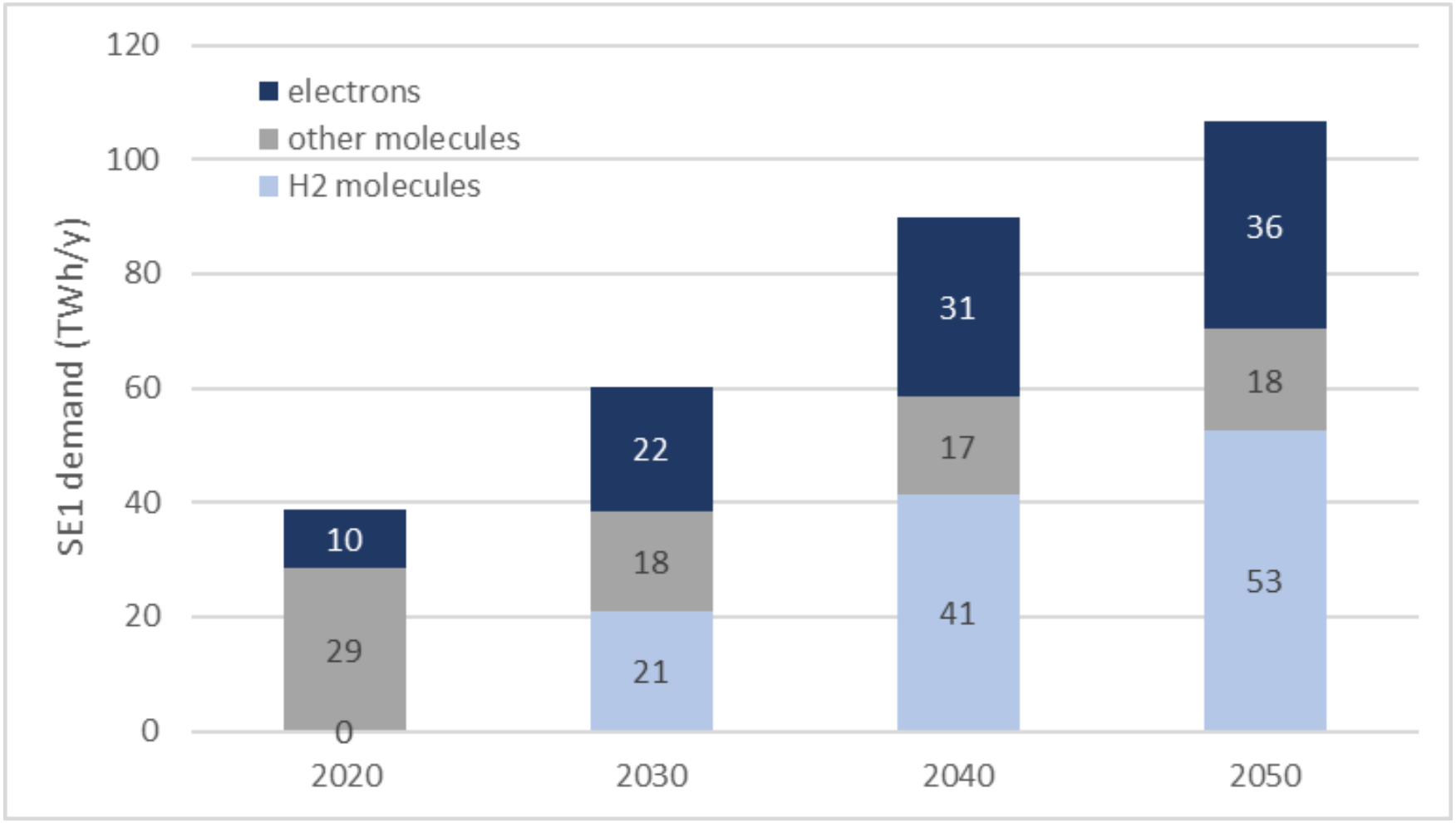
World class hydrogen research
- KTH
- Umeå
- Chalmers
- Lund
- Uppsala
- LTU
- RISE

World leading steel and metallurgy research
- LTU
- KTH
- Swerim

Hybrit in Luleå – Proven fossil-free steel production

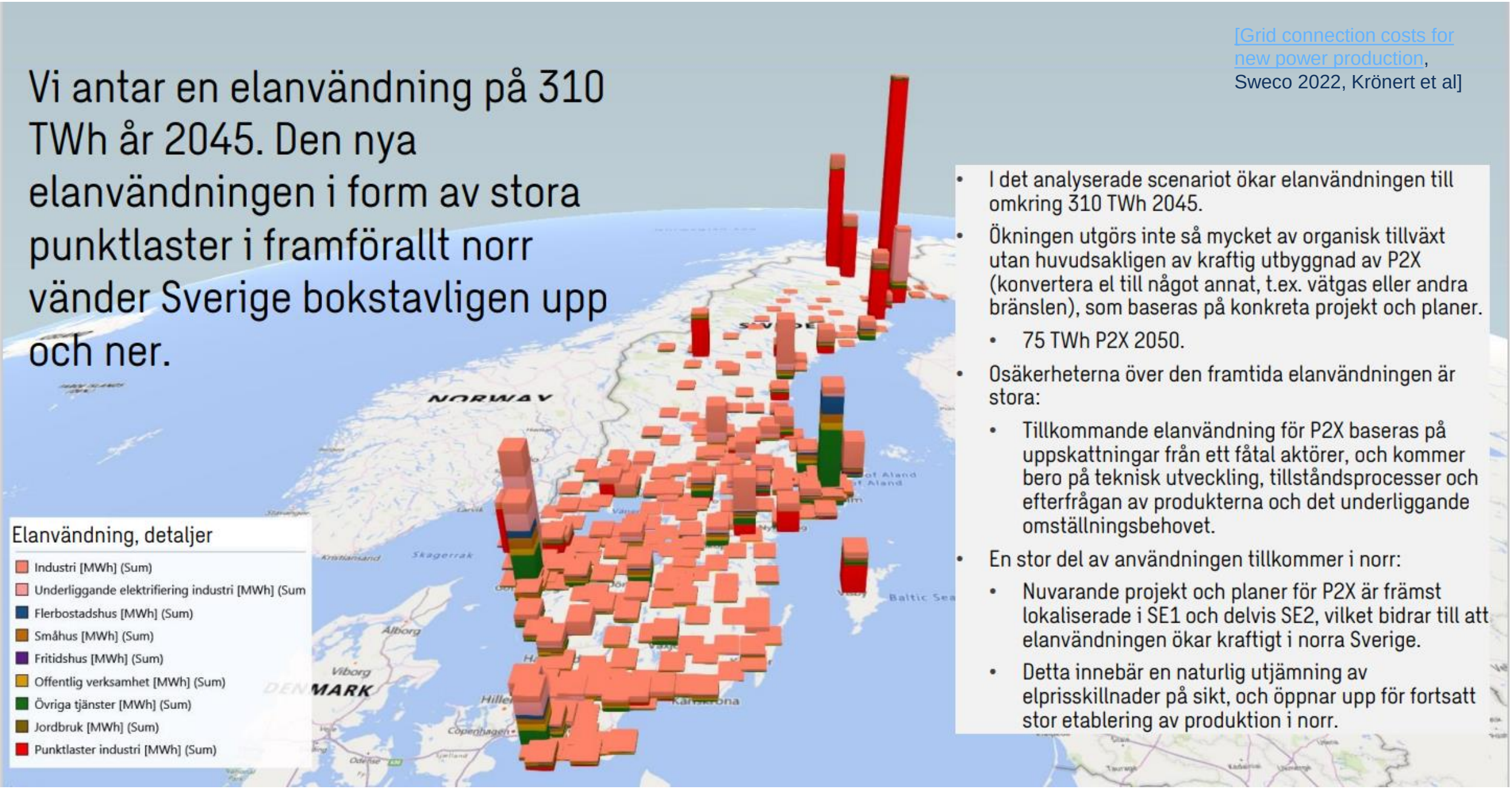
Stegra in Boden - Green steel production start 2026

“Three to six times today's energy demand for electricity and hydrogen by 2050” SE1 = Northern part of four [H2ESIN 2022]



Vi antar en elanvändning på 310 TWh år 2045. Den nya elanvändningen i form av stora punktlaster i framförallt norr vänder Sverige bokstavligen upp och ner.

[Grid connection costs for new power production, Sweco 2022, Krönert et al]

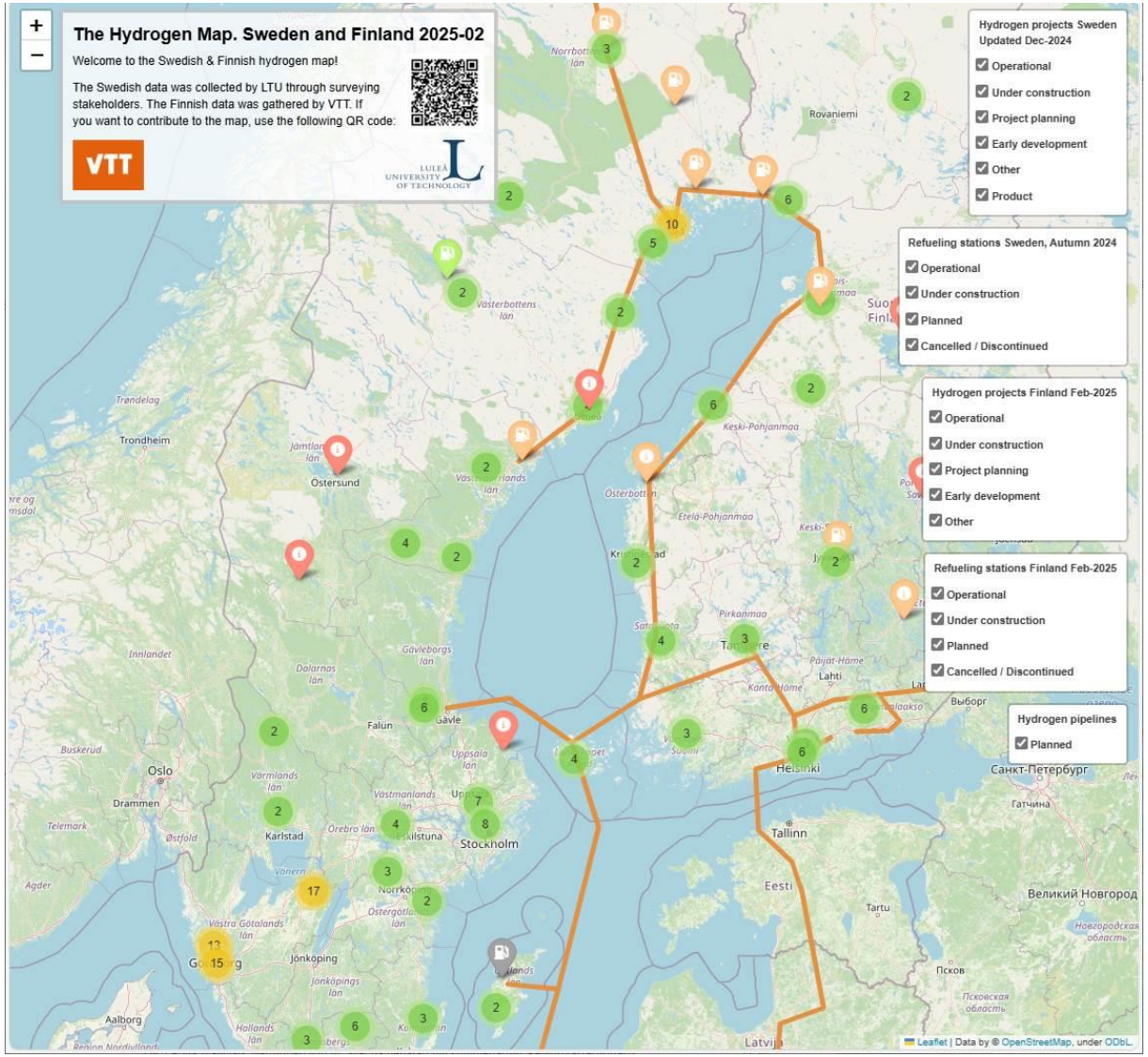


- I det analyserade scenariot ökar elanvändningen till omkring 310 TWh 2045.
- Ökningen utgörs inte så mycket av organisk tillväxt utan huvudsakligen av kraftig utbyggnad av P2X (konvertera el till något annat, t.ex. vätgas eller andra bränslen), som baseras på konkreta projekt och planer.
  - 75 TWh P2X 2050.
- Osäkerheterna över den framtida elanvändningen är stora:
  - Tillkommande elanvändning för P2X baseras på uppskattningar från ett fåtal aktörer, och kommer bero på teknisk utveckling, tillståndsprocesser och efterfrågan av produkterna och det underliggande omställningsbehovet.
- En stor del av användningen tillkommer i norr:
  - Nuvarande projekt och planer för P2X är främst lokaliserade i SE1 och delvis SE2, vilket bidrar till att elanvändningen ökar kraftigt i norra Sverige.
  - Detta innebär en naturlig utjämning av elprisskillnader på sikt, och öppnar upp för fortsatt stor etablering av produktion i norr.

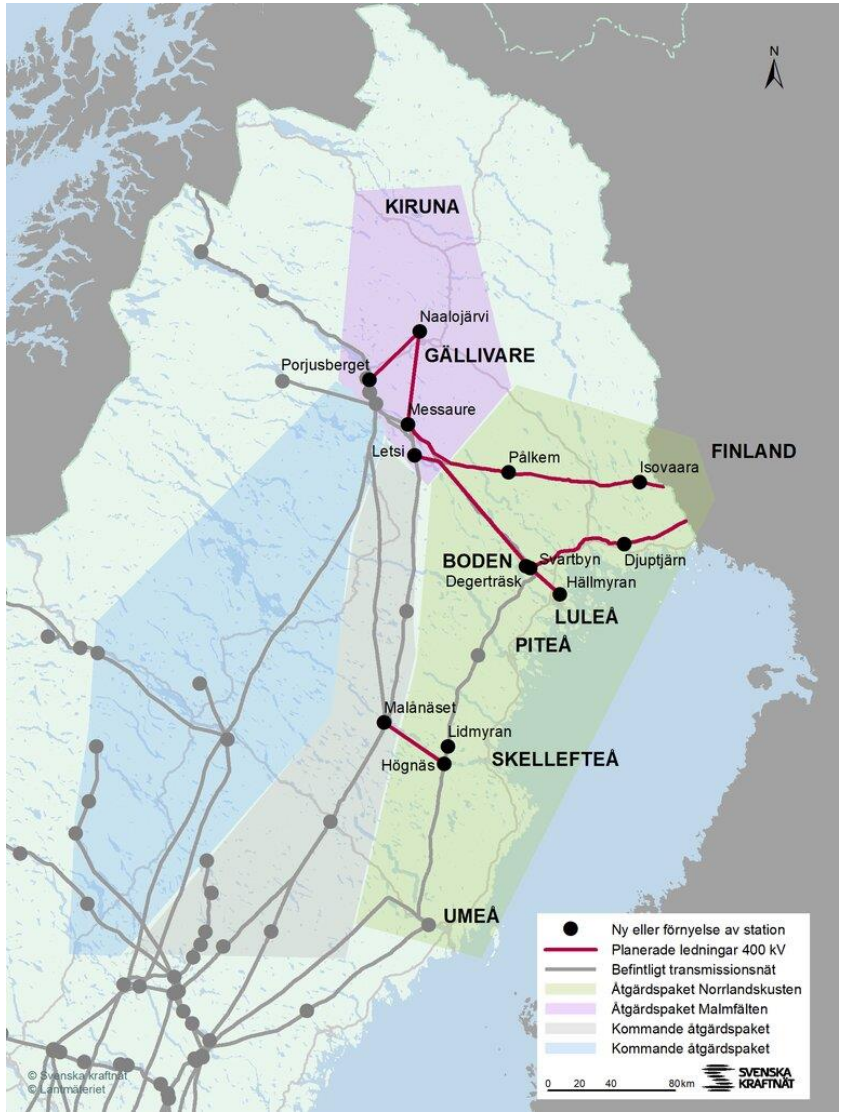
The Hydrogen Map | Luleå tekniska universitet

Region Nord | Svenska kraftnät

The Hydrogen Pipelines plans



New Power Lines



The governmental task to the national power grid TSO on co-planning for hydrogen piplines

Regeringskansliet

Sök på regeringen.se

Sveriges regering | Regeringens politik i Sverige & EU | Dokument & publikationer | Så styrs S

Pressmeddelande från Klimat- och näringslivsdepartementet

Svenska kraftnät ska samplanera el- och vätgasinfrastruktur i norra Sverige

Publicerad 28 juni 2024

I Norrbottens och Västerbottens län sker flera historiskt omfattande företagsetableringar och företagsexpansioner. Till följd av detta pågår också omfattande planering av ny el- och vätgasinfrastruktur i båda länen. Regeringen ger därför Svenska kraftnät i uppdrag att föreslå hur el- och vätgasinfrastruktur kan samplaneras i norra Sverige. Uppdraget är en del av regeringens strategi för nyindustrialiseringen och samhällsomvandlingen i norra Sverige.

Combined planning of Power Grids and Hydrogen Pipelines

- Future needs?
- Huge investments, large local impact!
- The differences between the two energy carriers!
- Include safety and security!
  - Safety distances.
  - Risk evaluations.
  - Coallocation implies higher risk scenarios.
- Local use, or export?
- The importance of type of owners! State/investor.

Exemplifying drivers and barriers

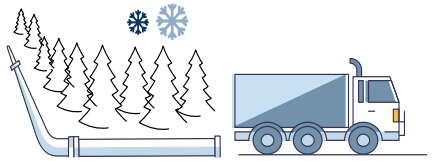
[LTU CH2ESS, addresssing the barriers]

Drivers, examples	Cathegory	Barriers, examples
Long term support	Organisation	Lack of stakeholder types.
GHG targets	Politics	Short term thinking
Funding	Economy (market)	Missing introduction support
Requirements to reach targets	Regulations	Excludes new innovations
Sales	Technology (TRL and MRL)	Limited life time or weak target fulfilment. Missing manufacturing capacity
Availability	Infrastructure	Could be necessary
Understand the new possibilites	Knowledge	Slow permit processes
Demand improved solutions	Social sustainability and acceptance, public engagement	Stops investments
Demand more sustainable solutions	Ecology	Limited natural resources

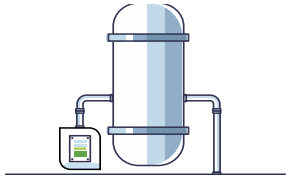
The CH2ESS research portfolio

Addressing the barriers

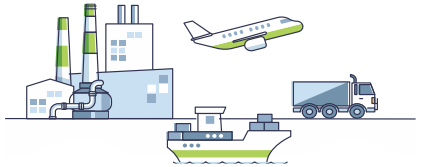
Production



Distribution



Storage



Usage

Energy & Fluid mechanics

Electrocatalytic production of liquid organic hydrogen carriers (LOHC) and chemicals from lignin

Power grid connections

Hydrogen from biomass

1 MW electrolyser (H2LABS)

Formic acid as hydrogen carrier

Pipeline flows x2

Methanol as a storage

Oxygen in iron oxide process

Carbon capture, storage and use

Green Fuels

Material & Safety

Condition monitoring - pipelines

Polymer for H2 tanks

Lined rock caverns

Ammonia – storage materials

Laser welding for stationary storage

Bearing performance

Fossil-free steel (FINAST)

Safety, permits & acceptance (H2SIPP)

Industrial symbiosis, energy & storage in rock caverns (H2AMN)

Law & Economics

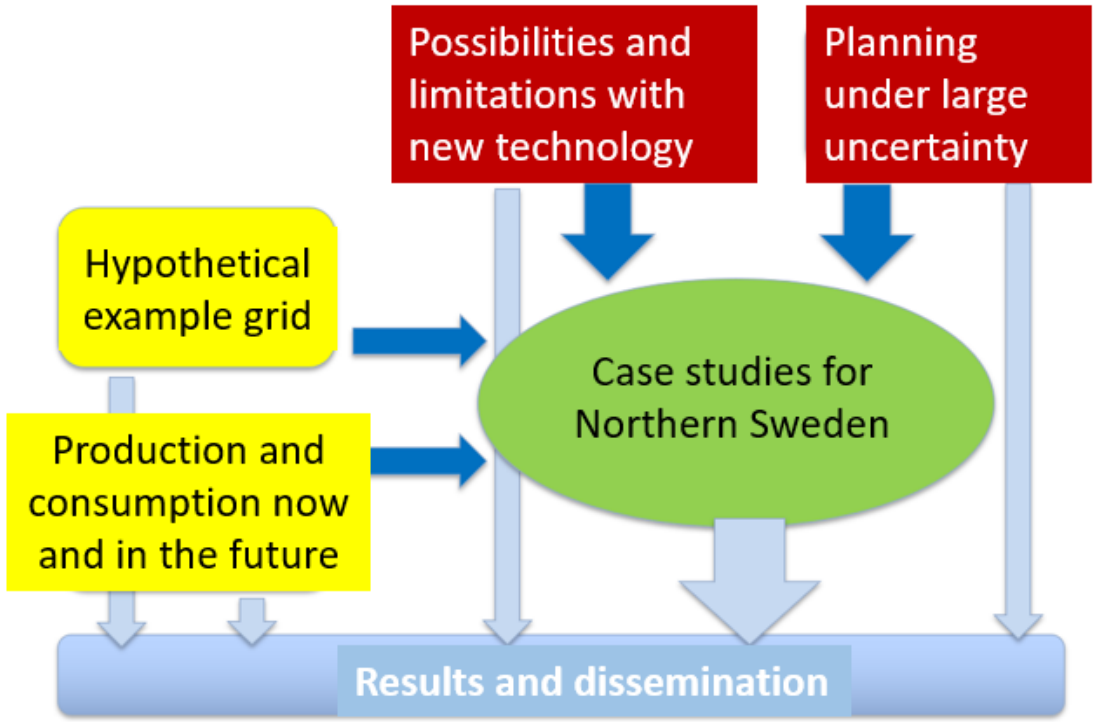
Heavy duty vehicles

Socio-technical challenges, stakeholders

Increasing the power grid hosting capacity, LTU research

Research on finding and increasing the hosting capacity of the existing transmission grid - without the need for new lines or substations.

- **Operational Risk:** risk-based operation and stochastic transmission expansion planning.
- **Smart-Grid Solutions:** new technologies on the network such as dynamic line rating and power flow control.
- **Energy Storage:** cross-vector storage and storage as congestion solutions.
- **Flexibility:** flexible hydrogen production, non-firm connections and flexibility markets as enablers of increased hosting capacity.



[Prof Math Bollen, Peter Haigh, Cecilia Wallmark, et al., LTU]

Modelling flexibility to increase the power grid hosting capacity

- Flexibility is valuable to the grid and that value can be passed on to the hydrogen production project through ancillary service market revenue and through accelerated connection timescales.

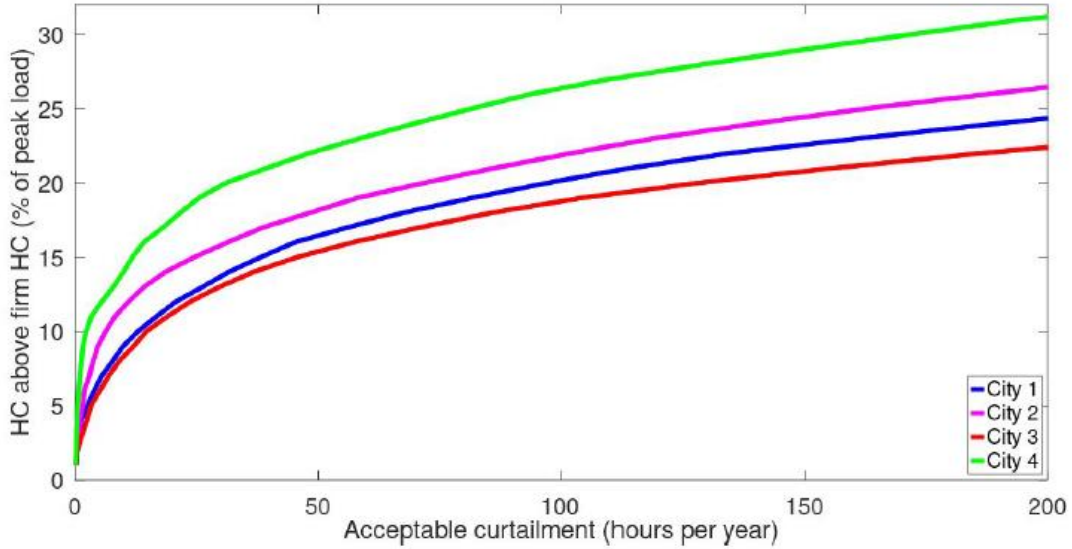


Figure 1. Hosting capacity as a function of the acceptable curtailment, for four Swedish cities.

An electrolyser sized no larger than 10% of peak load can be connected if only a few hours of curtailment per year are acceptable. If curtailment is acceptable for 100 hours per year, then installations sized at around 20% of peak load become viable. The figure also shows that there is an apparent difference between the four cities.

[Azarnia, M.; Bollen, M.J.; Haigh, P.; Katal, F.; Kudahetti, R.; Mousavi, M.; Nazir, Z.; Tavares de Oliveira, T.; Wallmark, C.; Westerlund, Zhong, Jin. Hosting capacity of meshed distribution grids with and without smart solutions, IET Conf. Proc., vol. 2024, no. 5, pp. 138–141, 2024, doi: 10.1049/icp.2024.1906.]

Overall research and implementation gaps - A selection

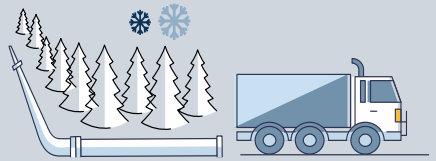
- Support the political decisions and public stakeholders.
- How to keep the sustainable development?
  - Support and develop attractive societies.
- The long-term vision: local energy and hydrogen production.

Hydrogen! Shaping a Sustainable Future - with Dr Wallmark Feb 2025

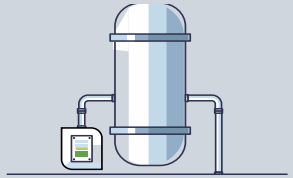
Centre for Hydrogen Energy Systems Sweden

AT LULEÅ UNIVERSITY OF TECHNOLOGY

Production



Distribution



Storage

Usage

Energy & Fluid mechanics

Material & Safety

Law & Economics

Policy

Environment, Health & Society

IT & Digitalization

Research, education and collaboration to support sustainable implementation of hydrogen


LULEÅ
UNIVERSITY
OF TECHNOLOGY