Nordic
Hydrogen Valleys
as Energy Hubs

Rally to the Valley

Establishing Hydrogen Value Chains for the Nordics

Nordic Energy Research

Tooraj Jamasb, Copenhagen School of Energy Infrastructure (CSEI)
05.10.2023

Project Background

The decarbonization of the energy system will be highly dynamic in the years to come

- Fossil fuels are phased out, electrification manifests where possible, and energy efficiency increases.
- **Hard-to-abate sectors face problems in electrification.**
  - Impossible due to process or economic infeasibility.
  - Need for sustainable fuels but currently only small, sustainable quantities are available.
- **Renewable e-fuels** based on hydrogen are required.

1. The **current use of hydrogen** (mainly as feedstock and for fertilizer production) must become renewable.
   - Requires a massive amount of additional renewable energy.
   - These sectors may become the main driver for the allocation of hydrogen infrastructure.
2. The (long-haul) **maritime sector** is a potential application area due to the lack of better alternatives. Currently, it remains unclear which fuels will prevail for this.

- The **Nordics are a frontrunner** in renewable energy technology roll-out:
  - **High potential** of renewable energy sources.
  - **Existing know-how** and expertise.
- Represent a promising location to explore the **future of a hydrogen value chain**.
  - The region may evolve as a hydrogen valley with e-fuel **exports,**
  - be largely **self-sufficient,**
  - or become a **net importer**.
- **What are the implications of these scenarios for the pathway of the energy transition in the Nordics?**

Project Objectives

A joint pathway for a hydrogen value chain in the Nordics focusing on the maritime sector

- The project aims to **extend energy system models** for the analysis of **hydrogen value chains:**
  - Global supply and demand mapping,
  - Local operation of specific facilities.
- The project provides **insights into**:
  - **Hydrogen, ammonia, and e-fuel** use in the global and Nordic energy systems.
  - **Specific operation** of energy hubs and ammonia facilities.
  - **Policy and regulatory** instruments to ensure a smooth pathway.
  - **The role of ports** to identify specific needs for technology and current barriers.
- The structure of a Nordic hydrogen valley is shaped by:
  - The **carbon-neutrality ambitions** of the Nordic maritime industry,
  - The **demand for renewable fuels**,
  - The **regional infrastructure,**
  - The **renewable energy potential**.
- The **market design and regulation** will determine economic viability and the need for public funding.
- The project uses **detailed cases** to analyze the value chain:
- **Rønne Havn** in Denmark,
- A mobile Power-to-X facility developed by **H2Carrier** in Norway,
- The fertilizer branch of **St1** in Finland.

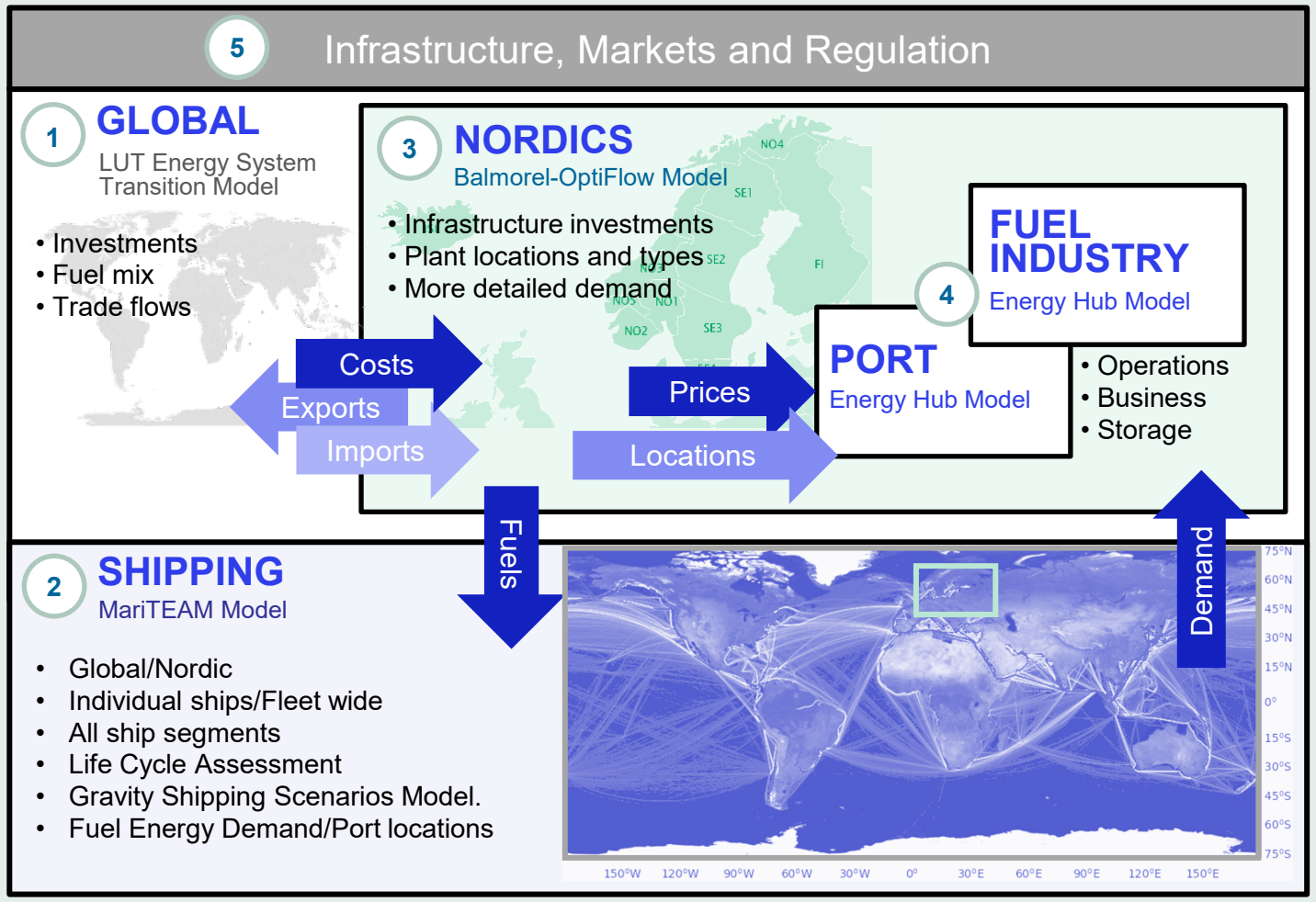
Project Partners

Scientific Partners

Industrial Partners

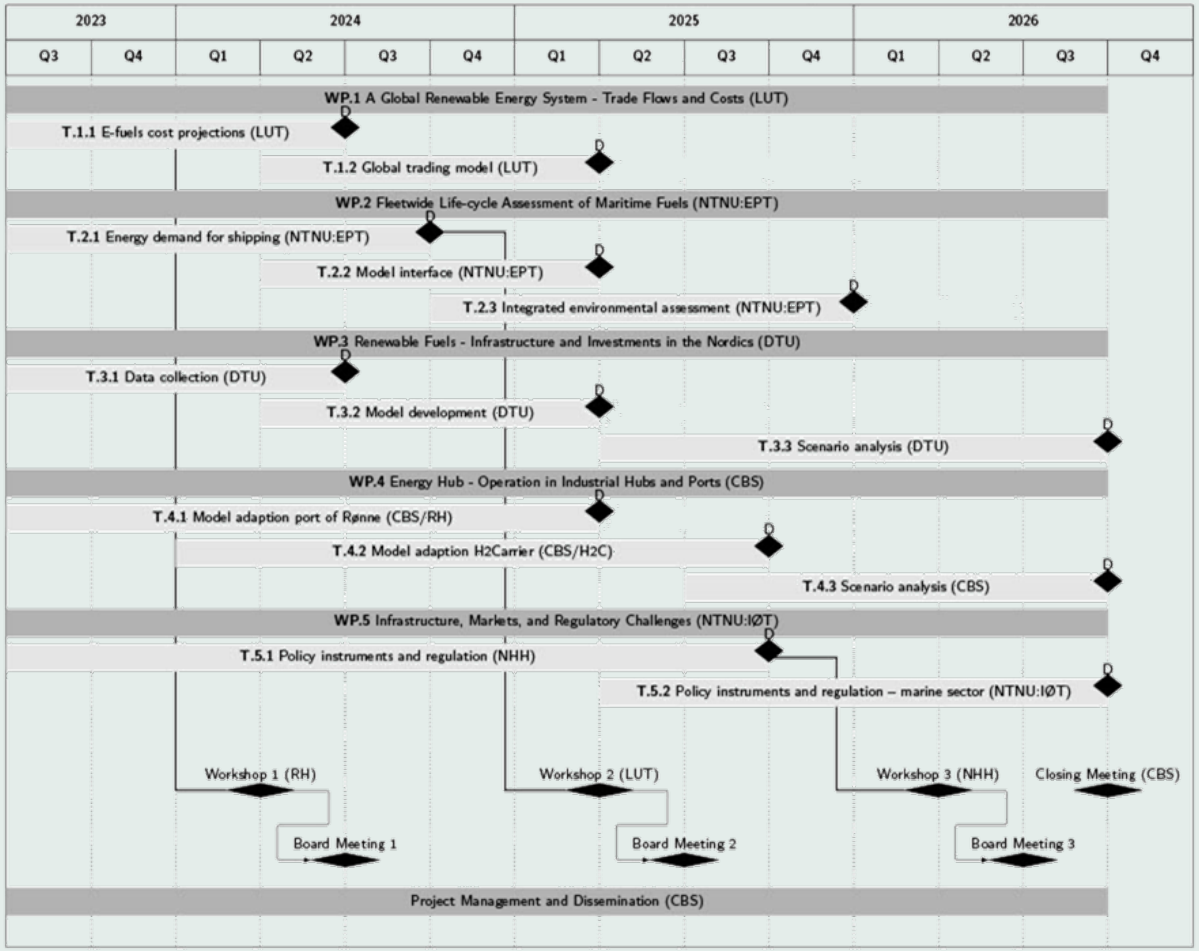
Observers

Project Structure



- **WP 1:** LUT, St1 FI
- **WP 2:** NTNU:EPT, St1 NO
- **WP 3:** DTU, LUT, NTNU:IØT, CBS, RH, H2C
- **WP 4:** CBS, DTU, RH, H2C
- **WP 5:** NTNU:IØT, NHH, CBS, St1 NO

Project Structure



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- **WP 3:** DTU, LUT, NTNU:IØT, CBS, RH, H2C
- **WP 4:** CBS, DTU, RH, H2C
- **WP 5:** NTNU:IØT, NHH, CBS, St1 NO

Work Package Structure

Global Perspectives

WP 1: A Global Renewable Energy System - Trade Flows and Costs

- The analysis addresses the background of electrofuels production options:
  - **Trade flows** for hydrogen-based e-fuels and e-chemicals using the LUT-ESTM model,
  - **Supply costs** in the Nordics, Europe, and the global level,
  - **Competition for resources** such as biomass between regions and sectors,
  - **Relative competitiveness** of Nordic e-fuels,
  - **Policy options** and their impact on infrastructure.
- The results will feed into the scenarios and costs used in the Nordics in WP 3.

WP 2: Fleetwide Life-Cycle Assessment of Maritime Fuels, Energy, and Ship Operation

- Modelling energy use and emissions in the maritime sector using the MariTEAM model:
  - Combination of data on **individual ship movements** on inter-Nordic, European, and global level,
  - Weather information, ship technical data,
  - **Geospatially explicit modelling** of ships and trade scenarios,
  - **Energy-emission models** across the whole fleet,
  - **Demand for different fuels** used in ports segmented by ship classes and destinations.
- The WP **links the global scenarios to a Nordic** scale
  - Perform fleetwide life-cycle assessments of hydrogen scenarios,
  - Comparison of conventional and alternative fuels.

Work Package Structure

Nordic and Local Perspectives

WP 3: Renewable Fuels - Infrastructure and Investment in the Nordics

- Focus on **locations for hydrogen-based fuels** covering:
  - Local resources,
  - Existing industrial, transport, and storage infrastructure,
  - Flexibility provided by renewable fuel solutions.
- **Considering scenarios** of
  - National self-sufficiency, imports and exports,
  - Decentralized vs. centralized fuel production,
  - Unique layouts of harbours.
- **Providing insights** into
  - Strengths and weaknesses of hydrogen value chains,
  - Prospective Nordic hydrogen valleys and their benefits, costs and environmental impact.

WP 4: Energy Hub - Operation in Industrial Hubs and Ports

- Analysis of **operation and business models of energy hubs** covers
  - The technical setup,
  - The interactions with the electricity market,
  - The regulatory framework,
  - Local resources.
- **Detailed modelling of the technical production process** enables
  - A realistic estimate of the needed flexibility,
  - Consideration of interdependencies between the production processes,
  - Representation of operational patterns of the hub.
- The **case studies of the industrial partners** will play a significant role in the analysis.

Work Package Structure

Infrastructure, Market, and Regulatory Perspectives

WP 5: Infrastructure, Markets, and Regulatory Challenges

- The analysis of the **development of hydrogen valleys** in the Nordic considers:
  - Input from WP 3 on timing and sizing of the construction of new power and gas infrastructure,
  - Ongoing plans and visions on the European level (e.g., the European Hydrogen Backbone by the gas TSOs),
  - Broader European initiatives towards large-scale hydrogen production, transport, and markets,
- The WP **investigates the hydrogen value** chain comparing
  - Options for hydrogen production include large-scale offshore wind,
  - Electrolysis offshore or onshore etc.,
  - Fossil alternatives.
- **Providing insights** into and **decision support** to:
  - Market designs for hydrogen trade,
  - Regulation of zero-emission fuels,
  - Regulatory and socio-economic challenges,
  - Aspects of public acceptance.

Thank you.

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www.csei.eu/nord_h2ub/

This project is part of the

Nordic Hydrogen Valleys as Energy Hubs Programme

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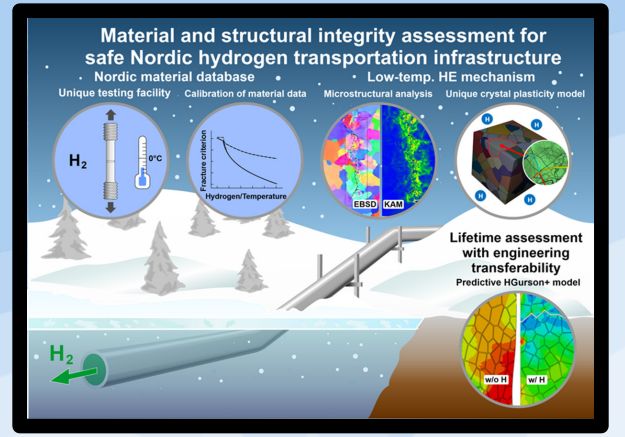
Nordic Hydrogen Valleys as Energy Hubs



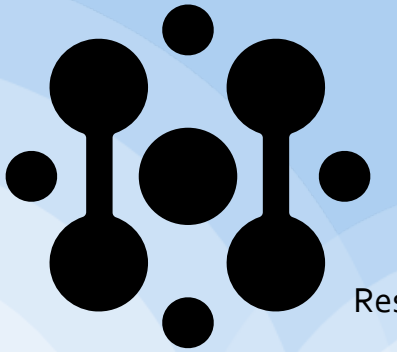
The MatHias project

- *Material and Structural Integrity Assessment for safe Nordic Hydrogen Transportation Infrastructure*

Nordic Energy Research

Vigdis Olden
The Nordic Hydrogen Valleys Conference 2023, Reykjavik, 4-5.10.23

The consortium



Research Partners

- SINTEF, Norway (Project Lead)
- University of Uppsala, Sweden
- VTT, Finland
- University of Oulo, Finland
- NTNU, Norway

Industry partners

- SSAB, Finland
- Equinor, Norway

Observers

- Gasgrid Finland
- Nordion Energi, Sweden

What does Material and Structural Integrity related to transport of H_2mean?

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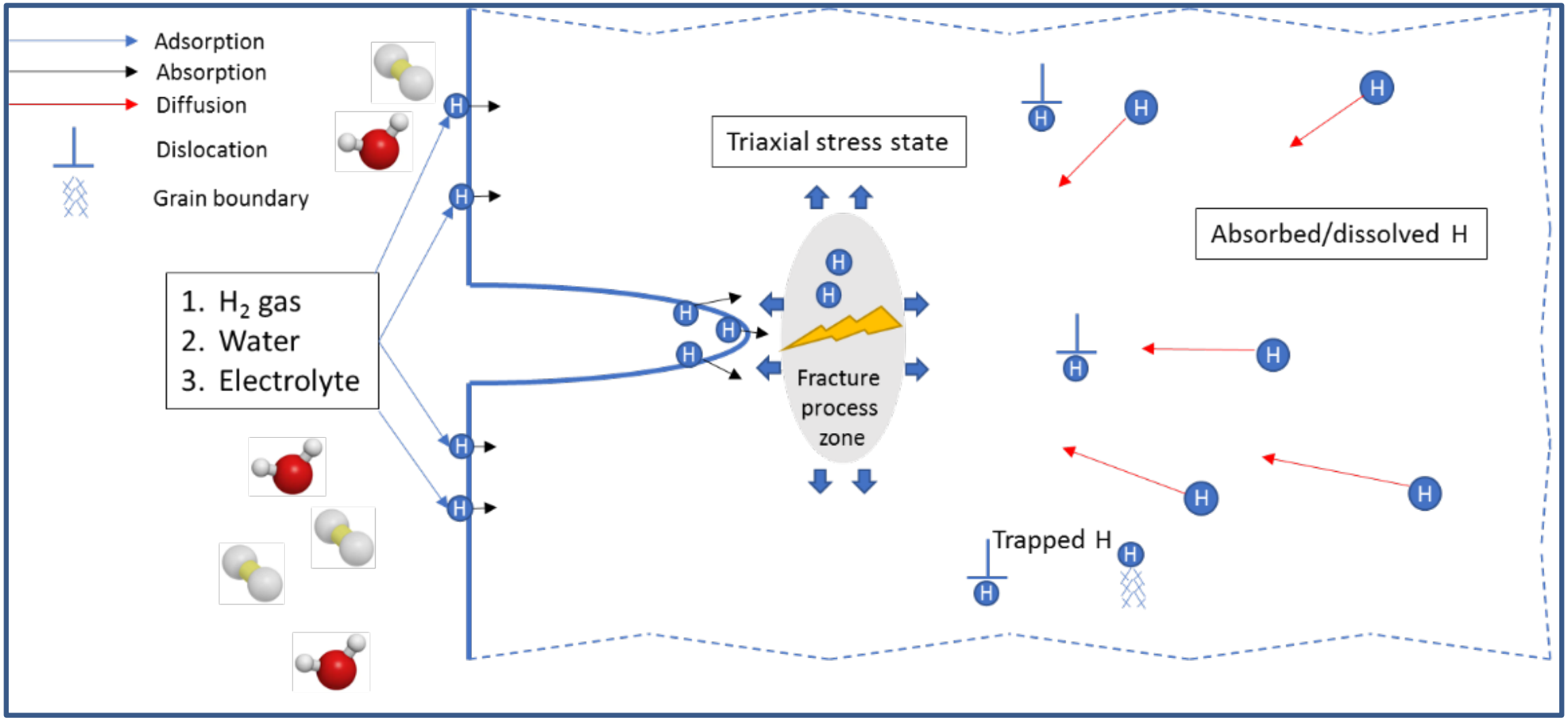
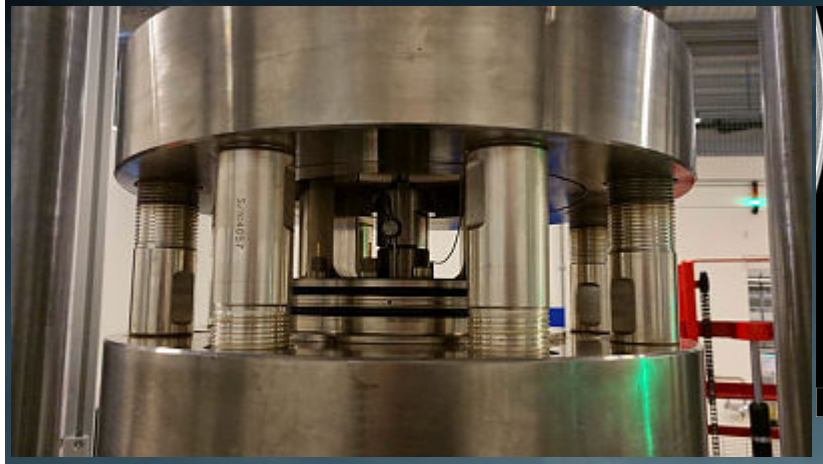
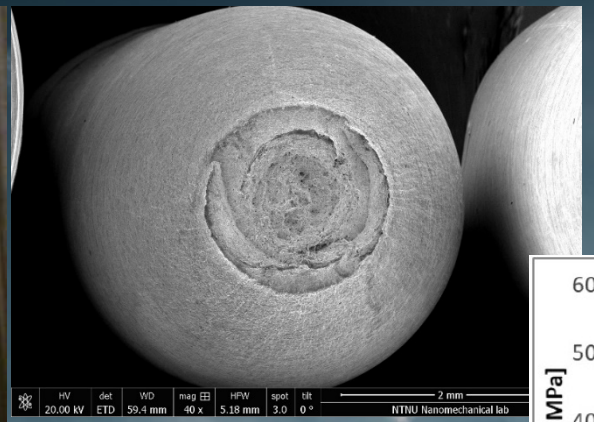

Adsorption
Absorption
Diffusion
Dislocation
Grain boundary
1. H_2 gas
2. Water
3. Electrolyte
Triaxial stress state
Fracture process zone
Absorbed/dissolved H
Trapped H

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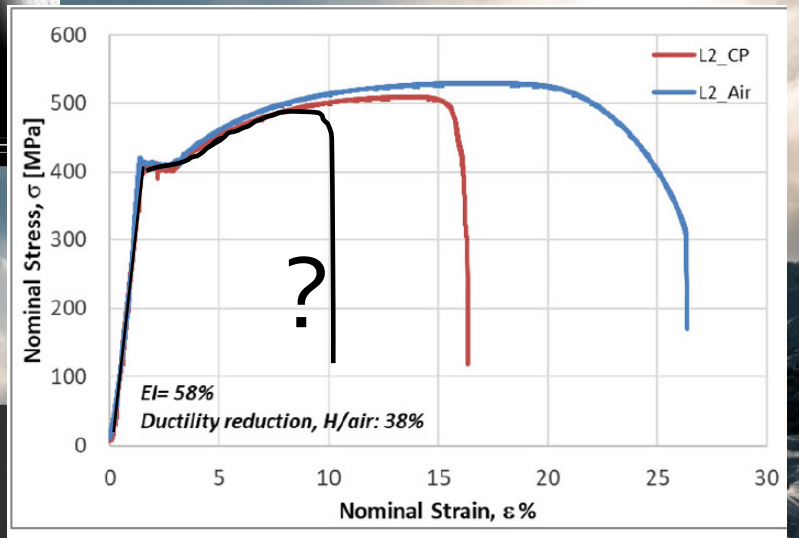
NTNU Nanomechanical lab


600
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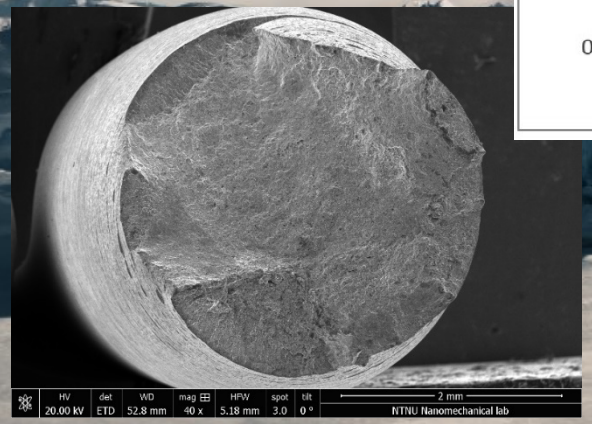
15
20
25
30
Nominal Stress, σ [MPa]
Nominal Strain, ε %
L2_CP
L2_Air
?
EI= 58%
Ductility reduction, H/air: 38%


HV 20.00 kV
det ETD
WD 52.8 mm
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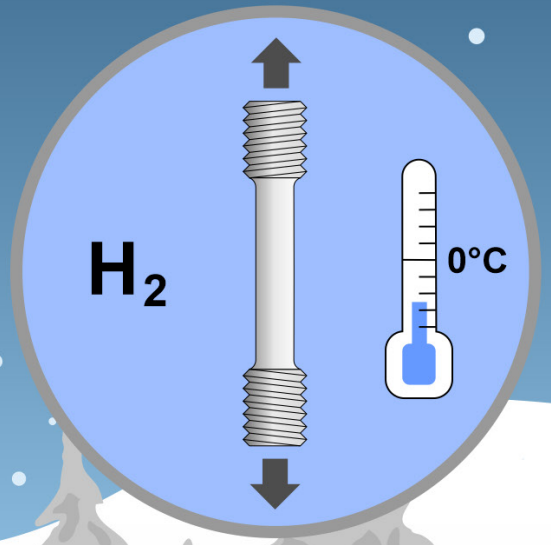
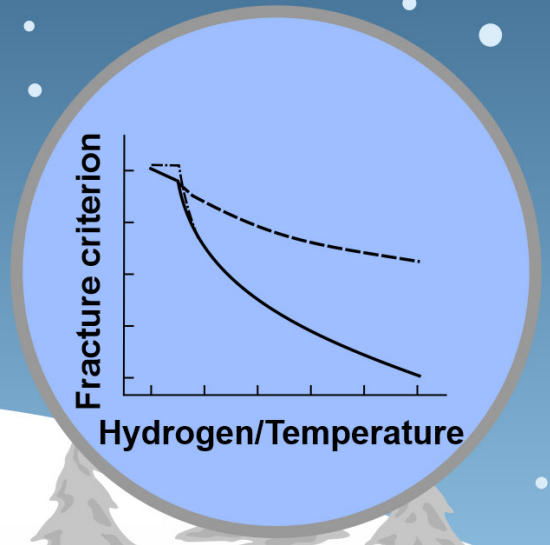
HFW 5.18 mm
spot 3.0
tilt 0 °
2 mm
NTNU Nanomechanical lab

Nordic material database

Unique testing facility

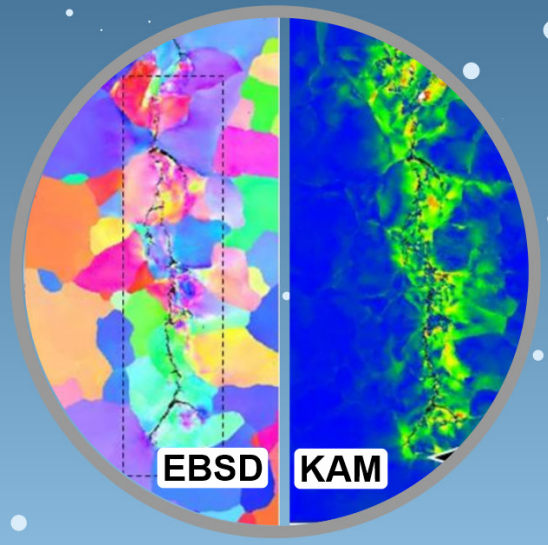


Calibration of material data

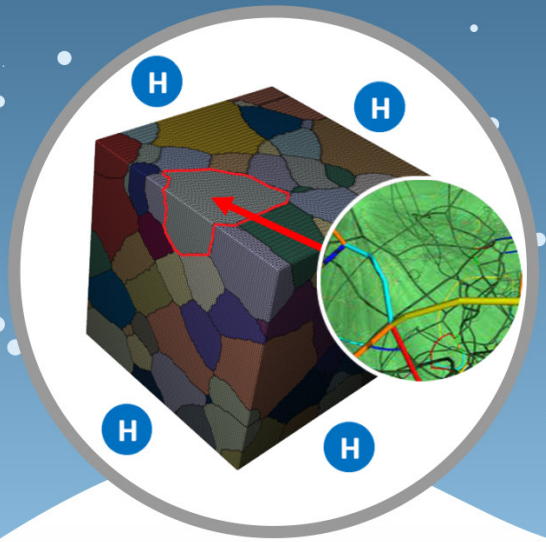


Low-temp. HE mechanism

Microstructural analysis

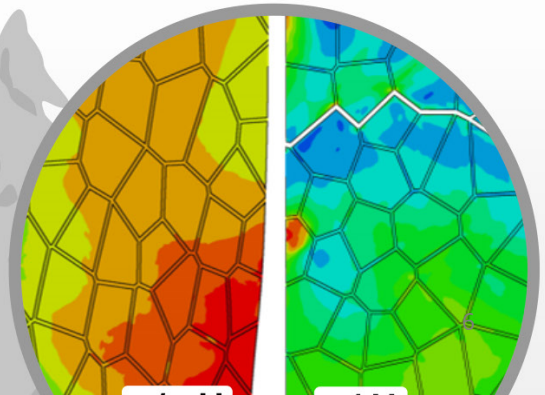


Unique crystal plasticity model



Structural integrity assessment with engineering transferability

Predictive Hgurson+ model



Nordic Energy Research

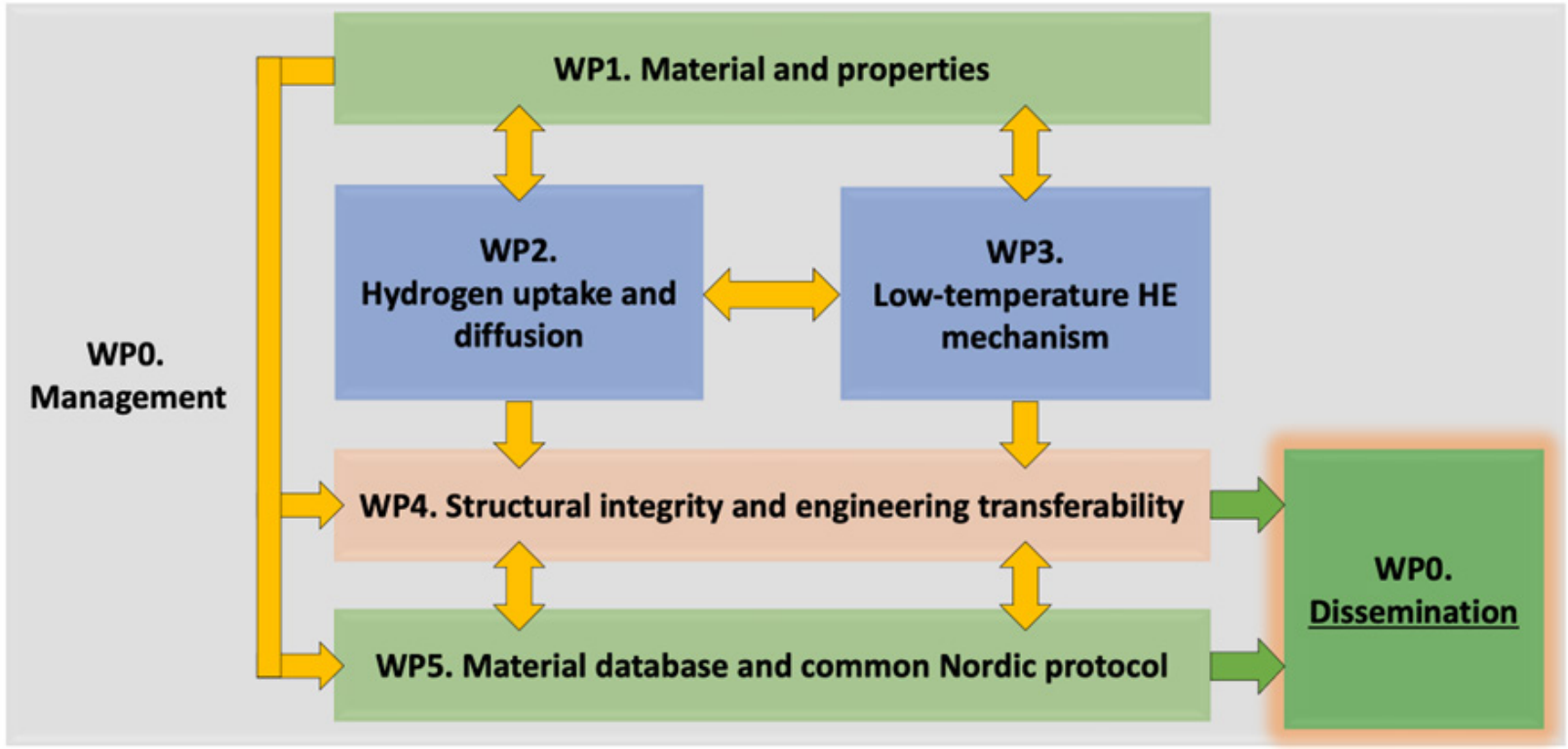
Nordic Hydrogen Valleys as Energy Hubs

MatHias

Objectives

- **Maintaining safe operation of hydrogen pipelines in the Nordic countries**
  - Providing tailored guidance on material selection for new pipelines.
  - Forming a knowledge base for future low temperature and hydrogen resistant steel development.
  - Developing a lifetime prediction tool for existing hydrogen pipelines.

Structure of MatHias

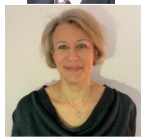


WP1: Uni. of Oulo (Sakari)

WP2: SINTEF (Bård)

WP3: Uppsala Uni. (Haiyang)

WP4: NTNU (Zhiliang)



WP5: VTT (Elina)

WP0: SINTEF (Vigdis)

For discussion

- Material and structural integrity are relevant in all situations where hydrogen is in direct contact with structural materials, and where safety and lifetime of components are important.
- Are there other parts of the H2 value chain where the structural integrity will be of relevanse?

Dr. Vigdis Olden

Senior Research Scientist

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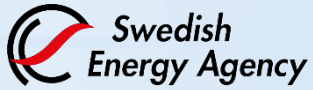
nordicenergy.org

Thanks!



This project is part of the

Nordic Hydrogen Valleys as Energy Hubs Programme

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Nordic Hydrogen Valleys as Energy Hubs

Hydrogen Safety and Improved Permit Processes

NORDIC HYDROGEN VALLEYS

Cecilia Wallmark, LTU and Marcus Runefors, LU. Iceland 5/10 2023

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Lund University
Aalto University
NTNU Norwegian University of Science and Technology
Luleå University of Technology

Hydrogen Safety and Improved Permit Processes

NORDIC HYDROGEN VALLEYS

Pathways to 2030 and 2040

We will develop strategies to delimit key barriers identified in recent work for the implementation of hydrogen in the Nordic countries:

1) permit processes
2) safety distance determination
3) social acceptance

H2S IPP Hydrogen Safety and Improved Permit Processes

NORDIC HYDROGEN VALLEYS

A consortia with long and widespread experience in hydrogen market and strategy development

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Nordic Hydrogen Valleys as Energy Hubs

Lund University

Aalto University

NTNU Norwegian University of Science and Technology

Luleå University of Technology

Frontrunners within the hydrogen industry, local hydrogen energy systems, pipelines, refuelling stations and public support

OBJECTIVES

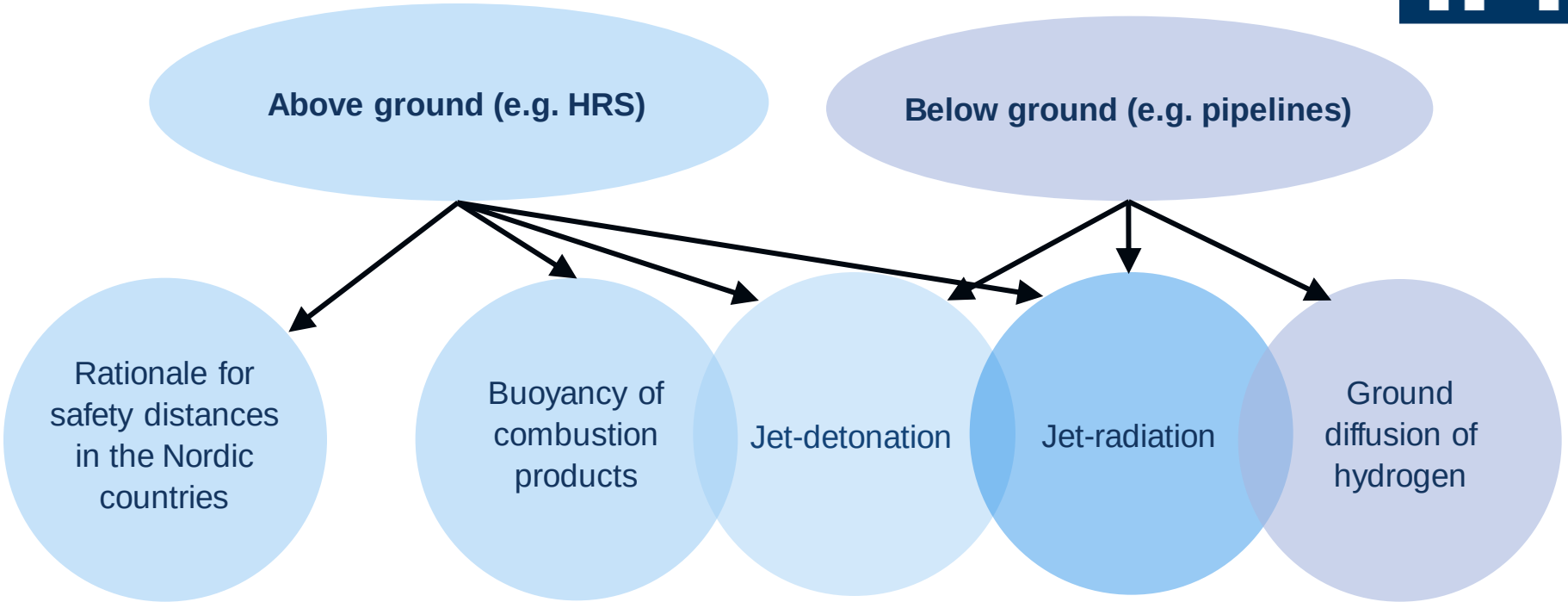
1. To suggest how to improve permit processes
2. To present ways of working to increase the social acceptance
3. To fill the gaps regarding safety calculations as decision material for regulations etc
4. To understand hydrogen leakage from underground pipelines
5. Increase stakeholder interaction between disciplines, countries etc

The overarching objective is to reach a more effective way of working regarding safety issues and permit processes, increase the acceptance for the use of hydrogen in society, and remove political and organizational barriers with respect to hydrogen safety.

A multidisciplinary and agile approach

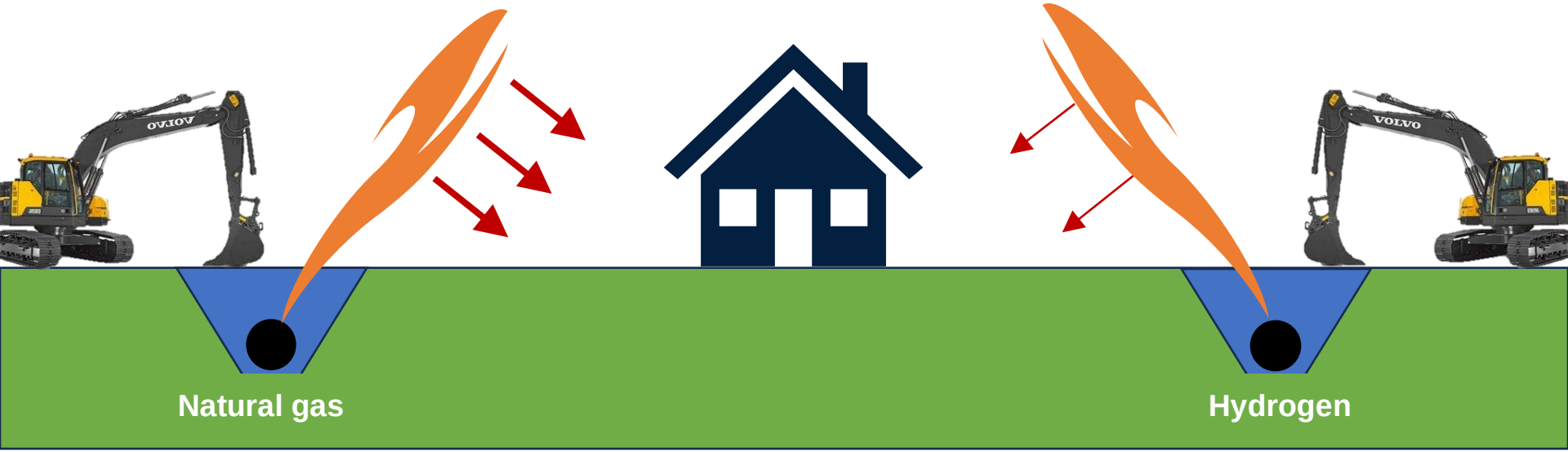
1. To suggest how to improve permit processes	2. To present ways of working to increase the social acceptance	3. To fill the gaps regarding safety calculations as decision material for regulations etc	4. To understand hydrogen leakage from underground pipelines	5. Increase stakeholder interaction between disciplines, countries etc
Analyse law, permit processes and stakeholders. Work on real cases, and comparing regions	By theoretical and empirical frameworks	Performing safety calculations and experiments	By calculations, experiment and development of theories	By delivering research based knowledge exchange and communication

WP3 – Safety distance



WP3 – Safety Distance – Pipelines

Jet-radiation

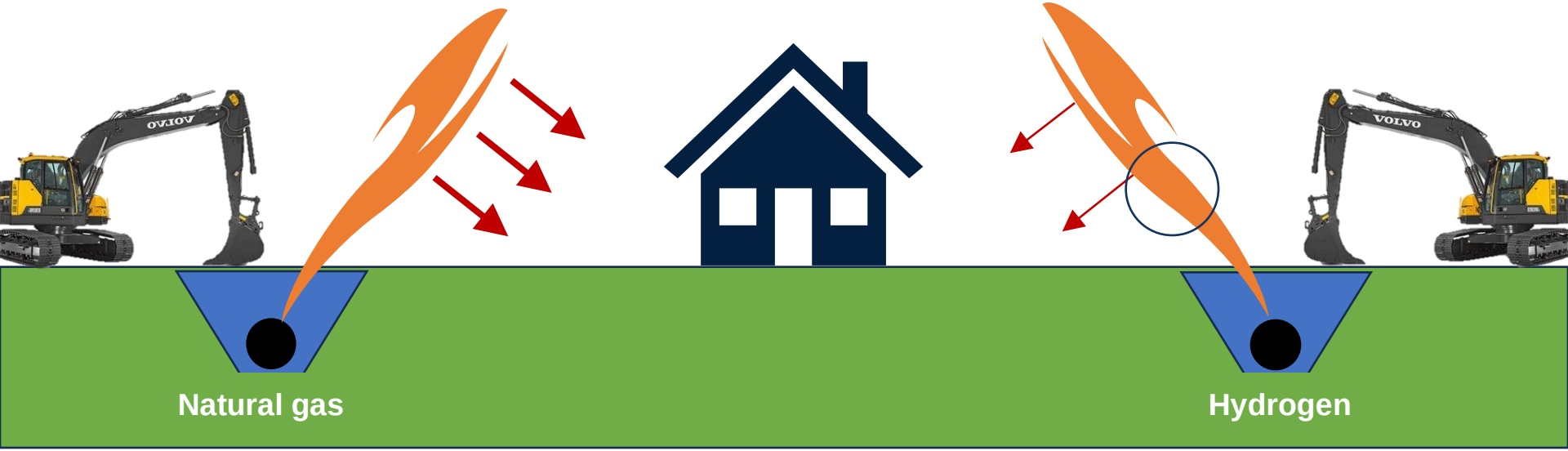


WP3 – Safety Distance – Pipelines

Jet-radiation

Jet-detonation

H_2S IPP



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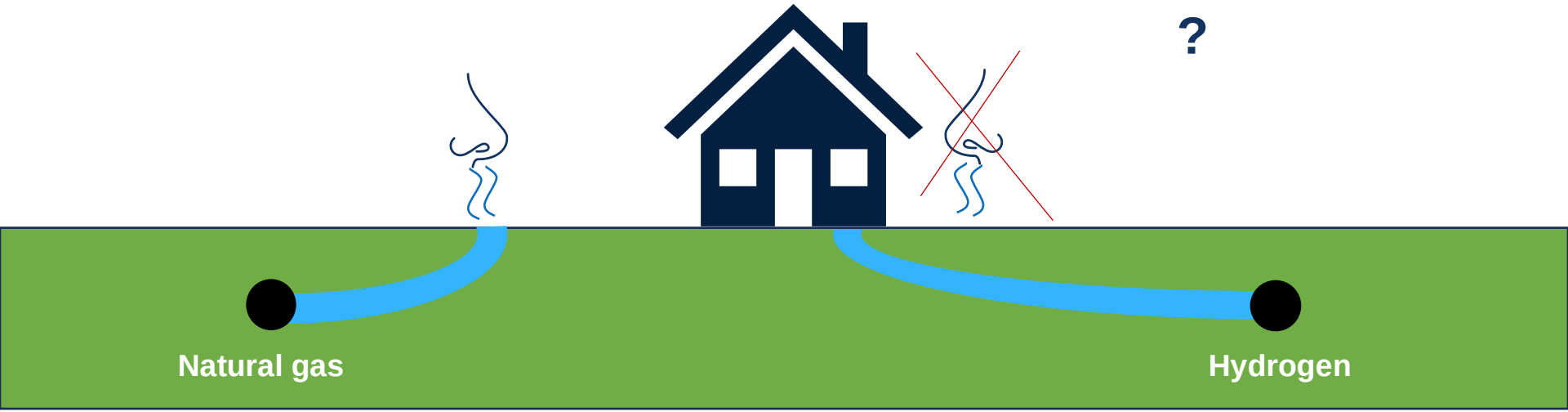
Aalto University

NTNU Norwegian University of Science and Technology

Luleå University of Technology

WP3 – Safety Distance – Pipelines

Ground diffusion of hydrogen



National, Nordic and global co-operation and communication to move faster forward.

Building the Nordic hydrogen economy, LTU, 24-25/1 2023

H2S IPP

Hydrogen Safety and Improved Permit Processes

NORDIC HYDROGEN VALLEYS

Participants 5/10 – with hope for further co-operation

Joakim Berg, Gen-H Oy, Hydrogen Energy System development

Björn Santana Arvidsson, Nordion Energi, Hydrogen pipelines

Cecilia Wallmark, LTU, Hydrogen implementation

Marcus Runefors, LU, Hydrogen safety and safety distances

Michael Försth, LTU, Fire and hydrogen safety

Fredrik Granberg, LTU Green Fuels, Permit case development

Pedro Vilaca, Aalto University, Material science

Maria Pettersson, LTU, Environmental law

Hydrogen Safety and Improved Permit Processes

NORDIC HYDROGEN VALLEYS

Welcome to follow our work on the web:
Hydrogen Safety and Improved Permit Processes, H2SIPP (ltu.se)

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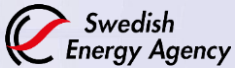
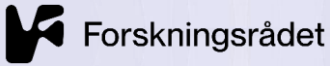
BUSINESS
FINLAND


Swedish
Energy Agency


nnovation Fund Denmark


Forskningsrådet

Hydrogen, Ammonia and Methanol in hydrogen hubs in the Nordic region

Joakim Lundgren, Project leader H2AMN
Professor, Deputy Director, CH2ESS
Div. of Energy Science, Luleå University of Technology

Nordic Energy Research

Reykjavik, October 5, 2023

Background

Ports serve multiple industries - energy, shipping, trucking, railways, fisheries, cruise-tourism, and manufacturing etc.

Central nodes for sector couplings and energy systems integration.

Ports will have a key role in the transition to a fossil free society.

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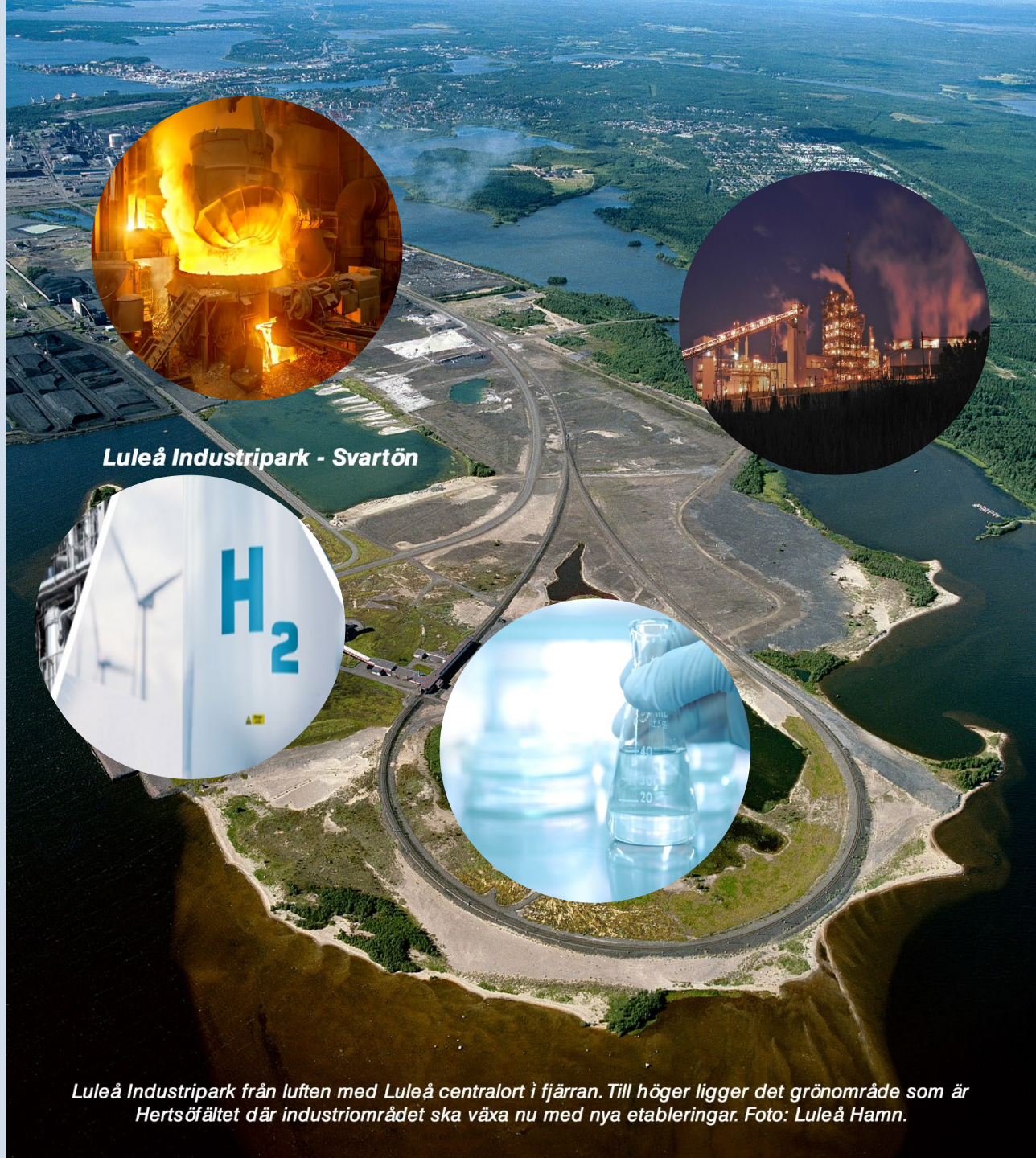
Nordic Hydrogen Valleys as Energy Hubs

H2AMN

Increased knowledge is crucial

- Logistics, scales and localizations of H2/H2-carrier-production
- Bunkering guidelines and storage possibilities.
- Uncertainties on demands and type of H2-carrier
- Business-related opportunities and challenges
- New sector couplings and use of by-products.
- National policies and international developments.
- …



Luleå Industripark från luften med Luleå centralort i fjärran. Till höger ligger det grönområde som är Hertsöfältet där industriområdet ska växa nu med nya etableringar. Foto: Luleå Hamn.

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Nordic Hydrogen Valleys as Energy Hubs

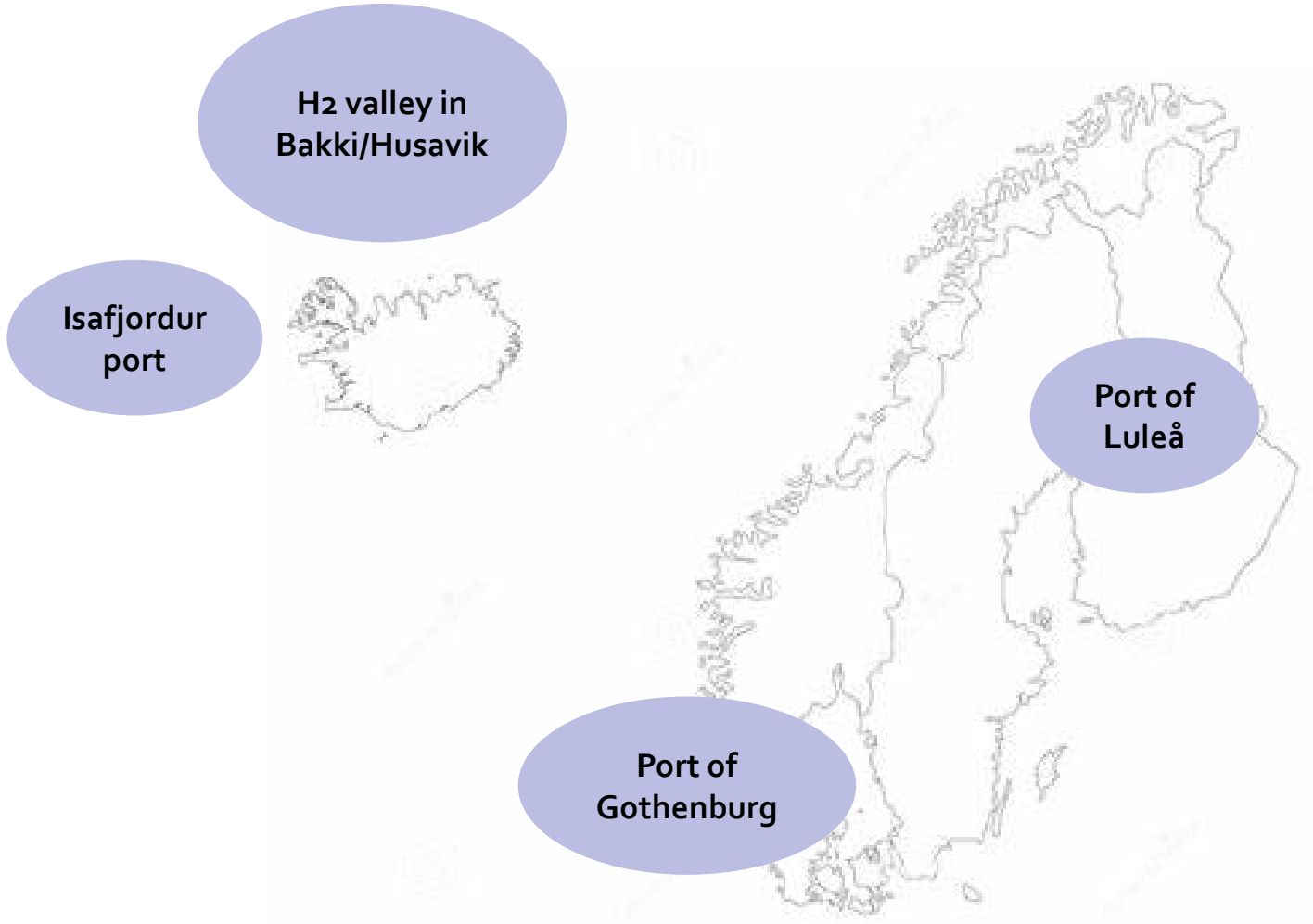
H2AMN

Aim & Objectives of H2AMN

Increase knowledge on hydrogen-based fuel pathways (hydrogen, ammonia, and methanol) centered around ports in the Nordic region.

- Assess techno-economic conditions for implementation of H2-based fuel pathways
- Assess drivers and barriers for demonstrating these pathways incl. policy gap analysis
- Assess opportunities for innovative sector couplings and energy systems integration
- Assess possibilities in of using existing underground rock caverns for hydrogen and ammonia storage
- Outline ambitious pathways and strategies/guidelines for the implementation of hydrogen-based value chains in ports in the Nordics by 2030/2040.

Four case studies in two countries



Tools and methods

- Mathematical linear programming
- Numerical modeling (LRC)
- Techno-economic assessments
- Scenario analysis
- Literature reviews

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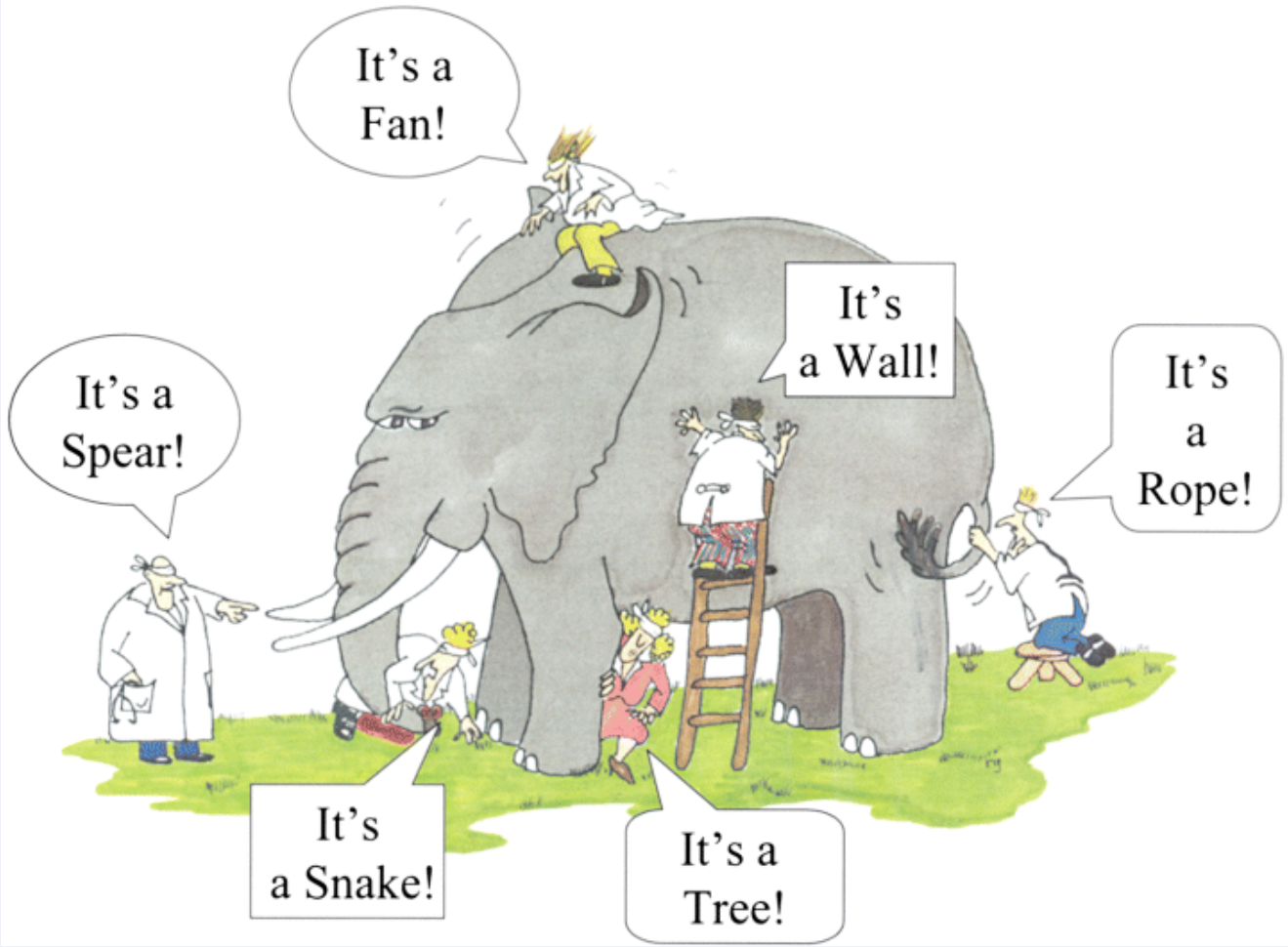
Nordic Hydrogen Valleys as Energy Hubs

Seeing the bigger picture is important…




ivl
Swedish Environmental
Research Institute


LULEÅ
UNIVERSITY
OF TECHNOLOGY


NTNU
Norwegian University of
Science and Technology


UNIVERSITY OF ICELAND


Blámi


Landsvirkjun
National Power Company of Iceland


Luleå
Energi


PITEÅ
HAMN AB


PORT OF
GOTHENBURG


SSAB


Statkraft


H2A
MN

Thanks.

NordicH$_2$ubs

Nordic Hydrogen Hubs – Roadmaps towards 2030 and 2040

Nordic Hydrogen Valleys conference

Nordic Energy Research

Sigrid Lædre
Reykjavik, October 5th 2023

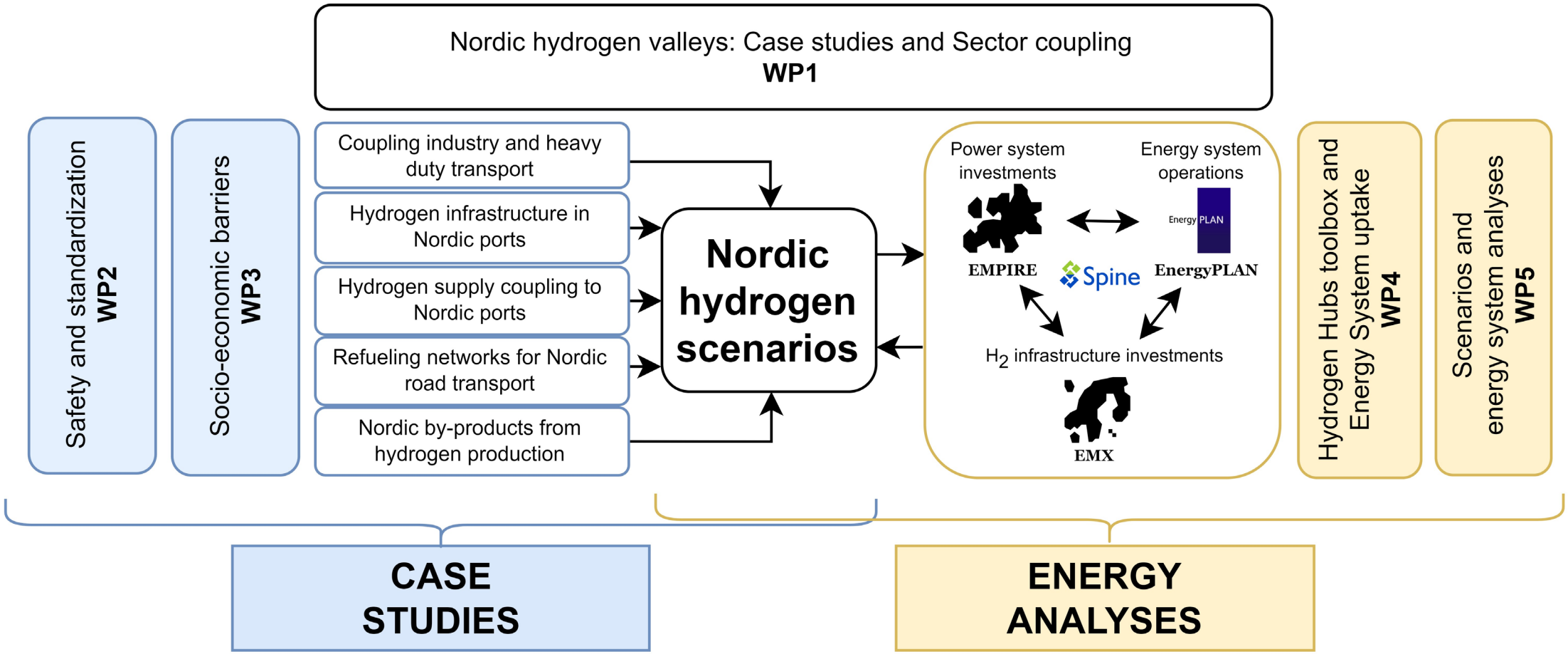
Project information

- Full name: Nordic Hydrogen Hubs - Roadmaps towards 2030 and 2040

- https://nordich2ubs.com/

- Duration: August 1st 2023 to August 31st 2026
- The project will:

  - Connect the Nordic countries
  - Cover multiple markets and sectors
  - Find synergies between both countries and sectors



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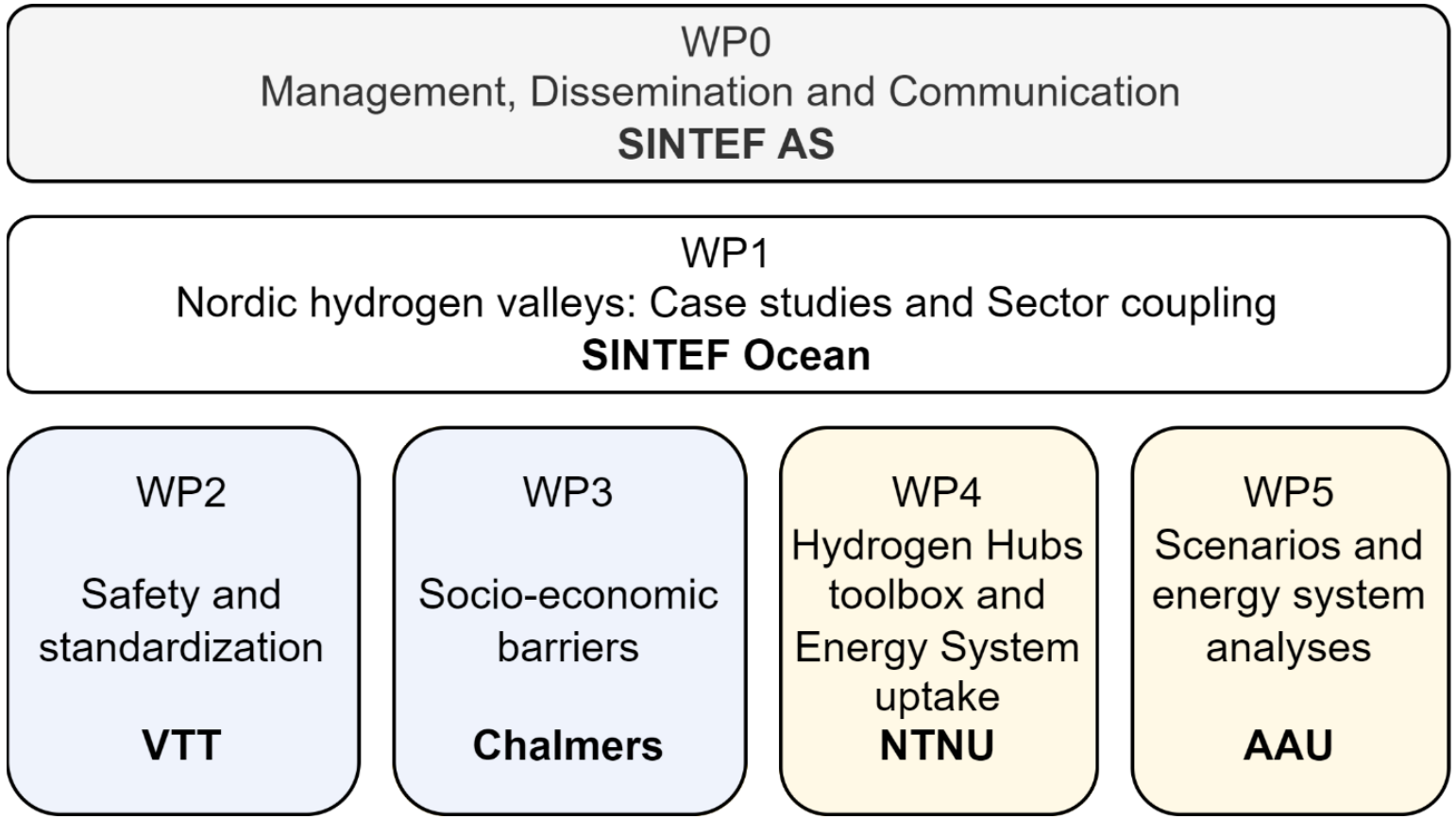
Nordic H2ubs

Work packages



Project partners

- 17 partners
- All the Nordic Countries represented
- Both Universities and Research institutes
- Industry partners within various sectors

Nordic H2ubs

WP 1: Nordic hydrogen Valleys- Case studies and sector coupling

Case study 1: Cross-sectoral hydrogen value chains in Finland

- Will analyze the H_2 availability for heavy duty (HD) transport and propose locations for H_2 refueling stations, based on the modelled optimized costs for dispended H_2 at HRSs.

Case study 2: Cross-sectoral hydrogen value chains in Sweden

- Connecting the planned hydrogen hub in Gävle port to the planned hydrogen production by local steel industry and other local actors planning to invest in hydrogen production or utilization

Case study 3: Hydrogen infrastructure at ports

- Connecting selected planned hydrogen production sites in Norway and Iceland to ports in other Nordic countries, with a focus on infrastructure and transport of hydrogen for maritime use

WP 1: Nordic hydrogen Valleys- Case studies and sector coupling

— Case study 4: Road Transport
  - Based on the Scandinavian-Mediterranean TEN-T network corridor from Oslo to Germany, the ongoing and necessary development for hydrogen deployment for HD transport applications will be evaluated.

— Case study 5: By-products
  - An investigation into further research market/opportunities for oxygen and surplus heat from green hydrogen production

— Partners: All

WP 2: Safety and standardization – three relatively independent tasks

- **Safety analysis of hydrogen refueling stations** with large (up to 2000 kg) or very large (> 2000 kg) gaseous and liquid hydrogen storage will be conducted by use of simulations of HTR
  - A model will be used to simulate the entire operation of a H_2 refueling station and identify challenges.
  - Methods for technical and operational mitigations in relation to inherent risks of fire and explosions in large H_2 storages will be developed.
- Premises for **maritime cascade bunkering,** container swapping and other storage solutions will be set as input for standardization work. Input from various projects in Norway, as well as from suppliers of storage and bunkering solutions will be gathered and governmental entities such as "Sjøfartsdirektoratet" will be involved as observers.
- The development of **H_2 purification and quality assurance** methods for hydrogen used **in transportation applications** in the Nordic countries will follow recommendations from ISO 14687:2019 standard.
- Partners: DBI, SINTEF AS, SINTEF Ocean, Greenstat, Everfuel, Norwegian Hydrogen, VTT and Kemira

WP 3 Socio-economic barriers

— Visualize **actor-networks** and associated **technological trajectories**
  - Publicly available data regarding, e.g., hydrogen projects, actors and public funding

— Analyse **competence needs** in emerging Nordic hydrogen value chains
  - Data mining of jobsites such as Platsbanken and Finn.no. Survey with actors to identify future competence needs and challenges.

— **Regulations** are identified through databases such as lovdata.no.

— Identify barriers and solutions to fostering **early market formation**
  - Interviews and workshops with partners and other hydrogen actors in the Nordics

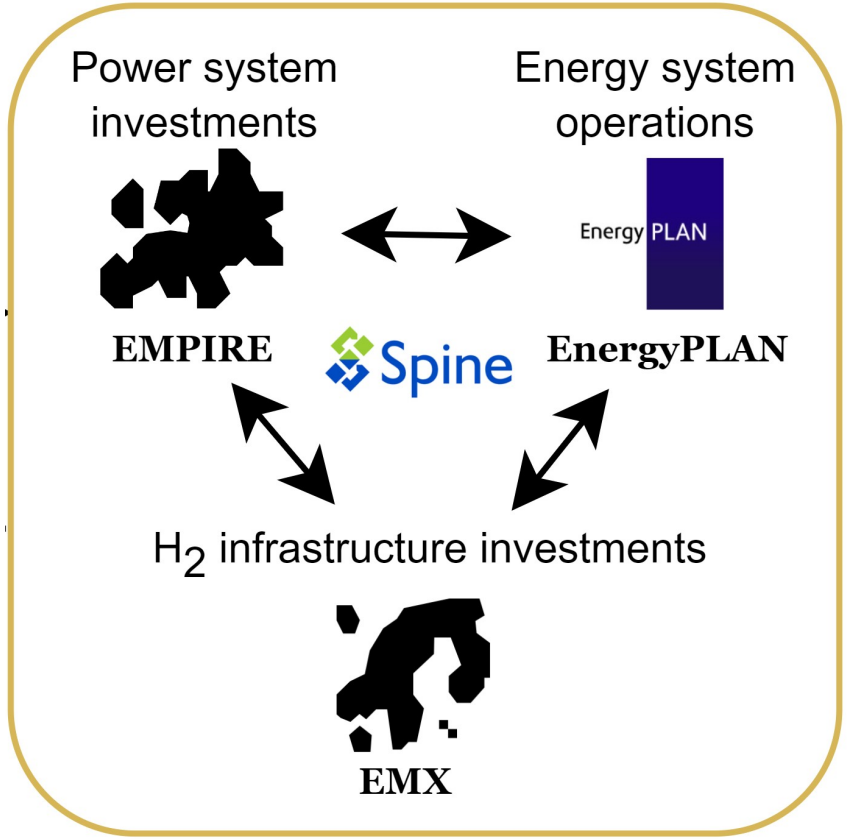
— **Inform policy** regarding measures to foster hydrogen valleys

Partners: Chalmers and SINTEF

WP4: Hydrogen hubs toolbox and energy system uptake

- **Adapt and extend existing energy system models** (EMPIRE, EnergyModelX and EnergyPlan) to include hydrogen hubs interaction to the Nordic energy system and relation to Europe.

- Create a **new open-source methodological framework** to investigate pathways in WP5. The modelling framework will analyze the H_2 uptake prospects based on case studies insights.



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Nordic Hydrogen Valleys as Energy Hubs

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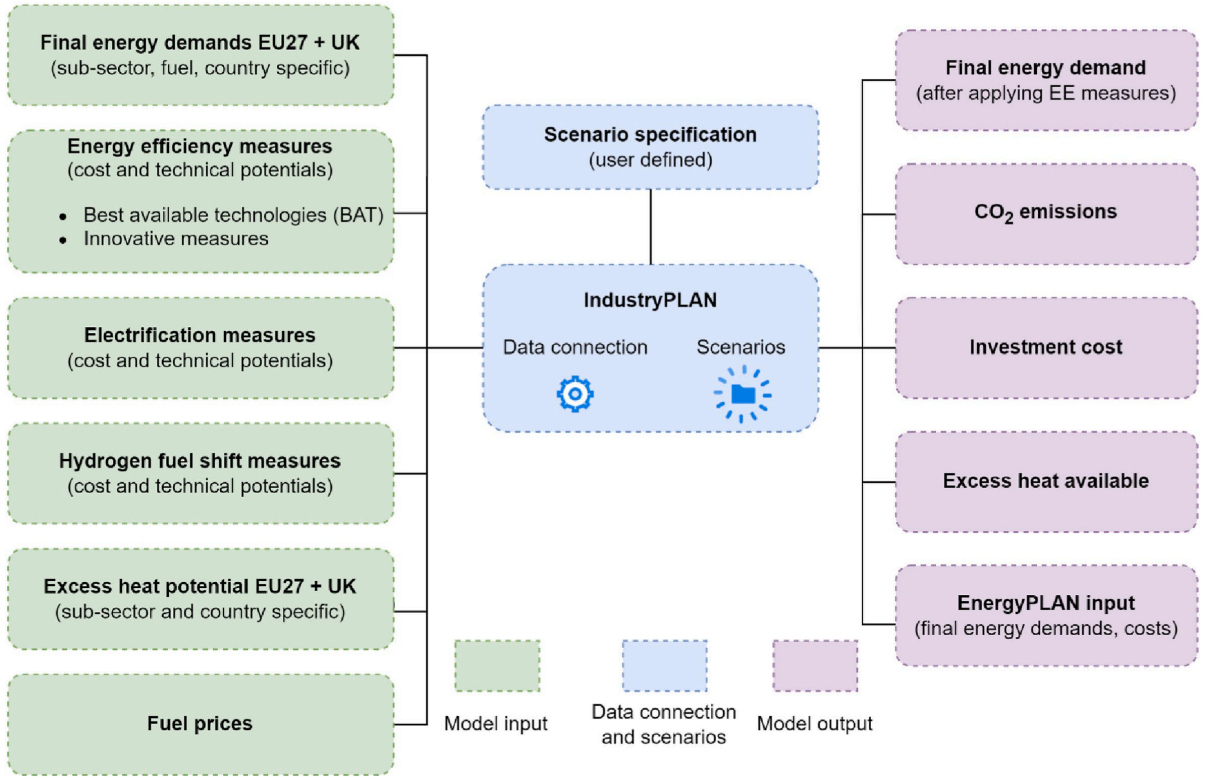
WP 5: Scenarios and energy system analyses

- Investigation of **cost-optimized investments related to hydrogen** infrastructure and the balance between various hydrogen production.
- **Simulations on operations** and short-term **cross-sectorial interactions and synergies between different energy sectors** will be investigated.
- **Transport demand development and industry energy demands** will be estimated, based on the gathered data, in the scenario tools **TransportPLAN** and **IndustryPLAN**. These scenario tools can use sector specific raw data to produce **scenarios towards 2030 and 2040.**



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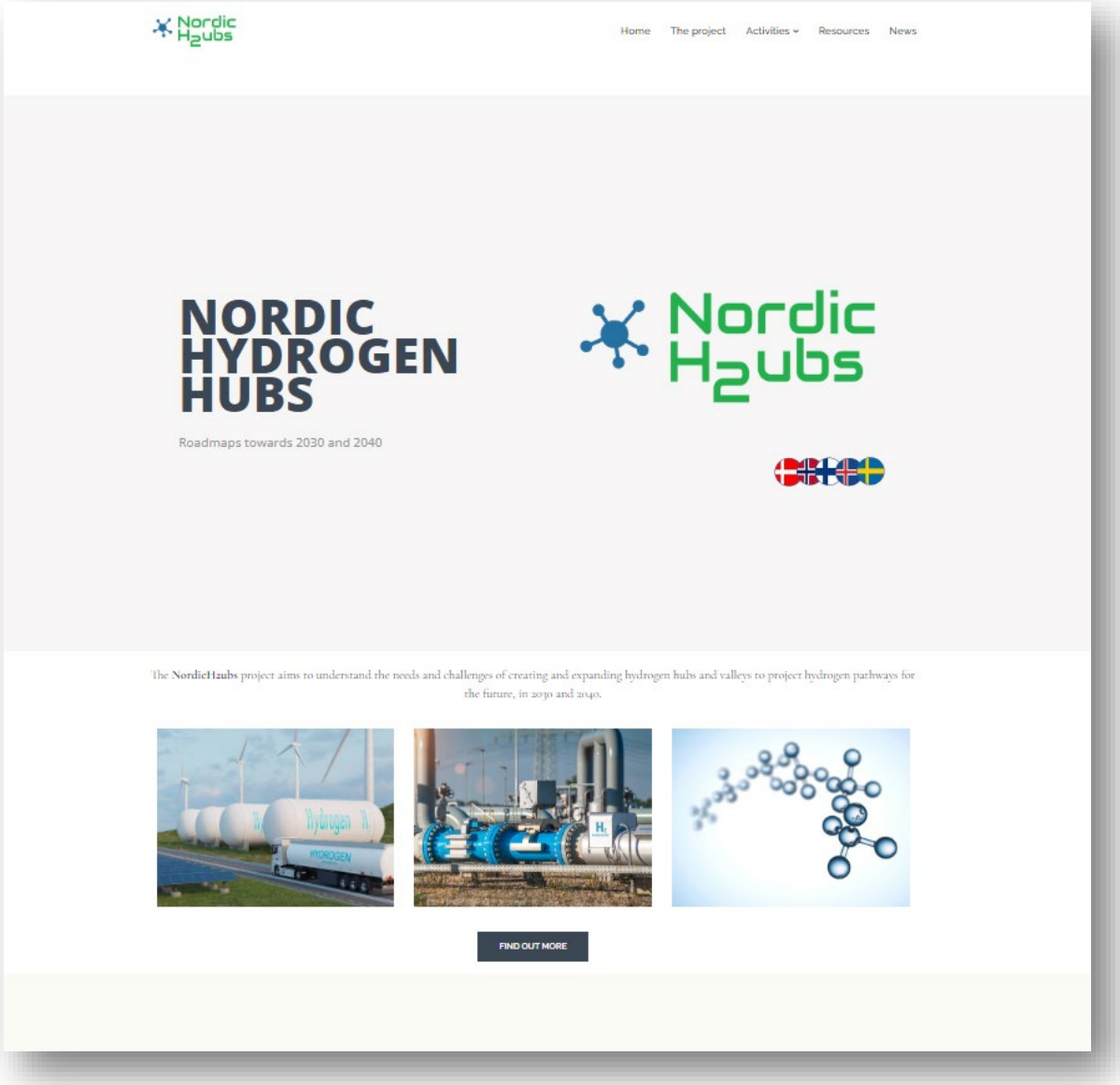
Communication and dissemination

- Website: www.nordicH2ubs.com
- Work shops for relevant stakeholders
- Publications, both scientifical and popular science
- Main contacts
  - Pedro Crespo del Granado (pedro@ntnu.no)
  - Sigrid Lædre (sigrid.ladre@sintef.no)



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Thanks

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This project is part of the

Nordic Hydrogen Valleys as Energy Hubs Programme

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