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HYDROGEN TRANSMISSION NETWORK DESIGN IN FINLAND – MATERIAL CHALLENGES AND RESEARCH NEEDS

New Research Infrastructure for Hydrogen Technology for Industry and Academia

Hanna Kinnunen, 19.5.2026

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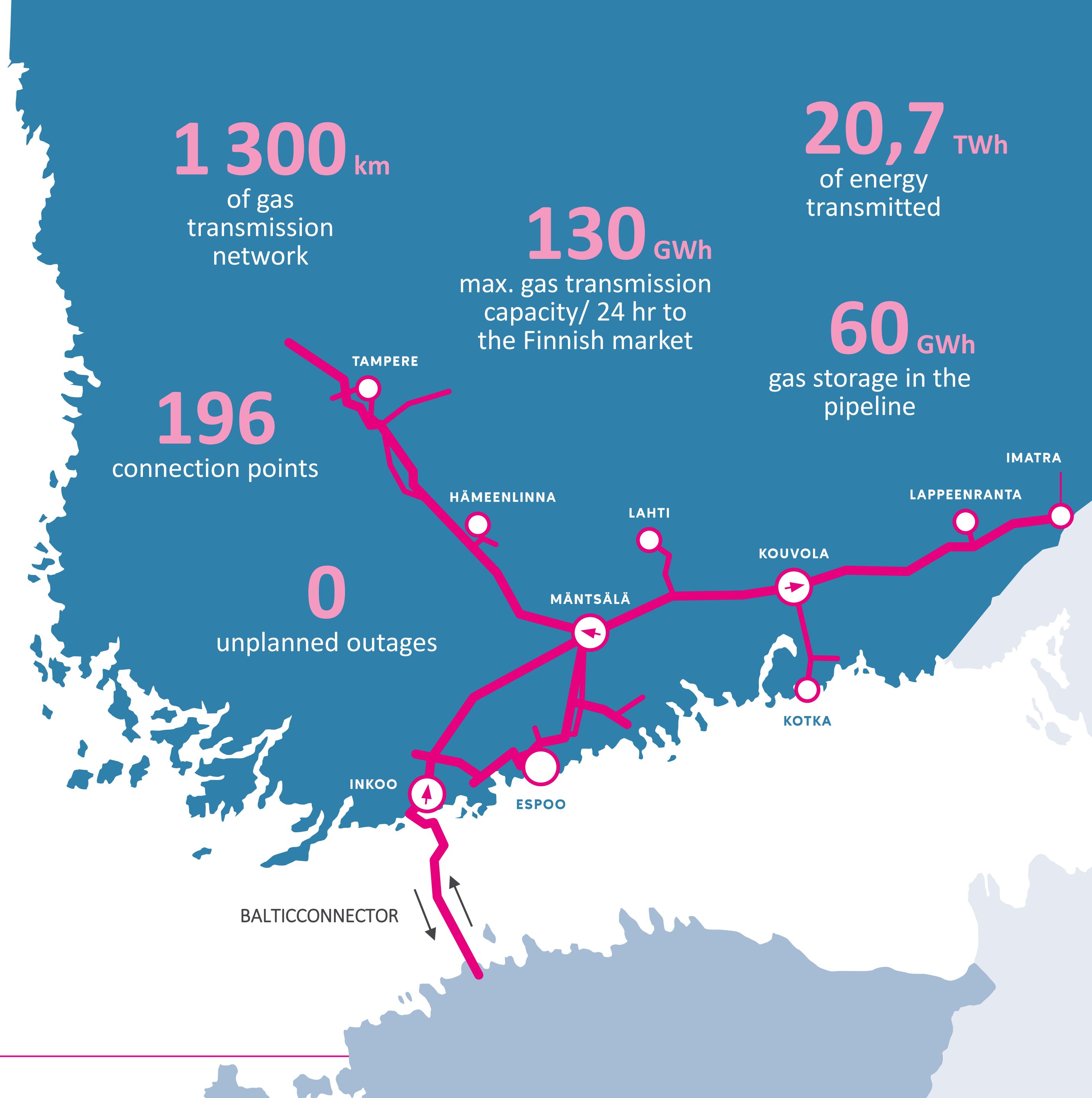
Gasgrid in brief

Gasgrid is the network operator responsible for gas transmission and the transmission system as well as the builder of the national hydrogen infrastructure.

We provide Finnish industry and companies with safe, reliable and cost-effective gas transmission. We safeguard Finland's security of supply and energy independence.

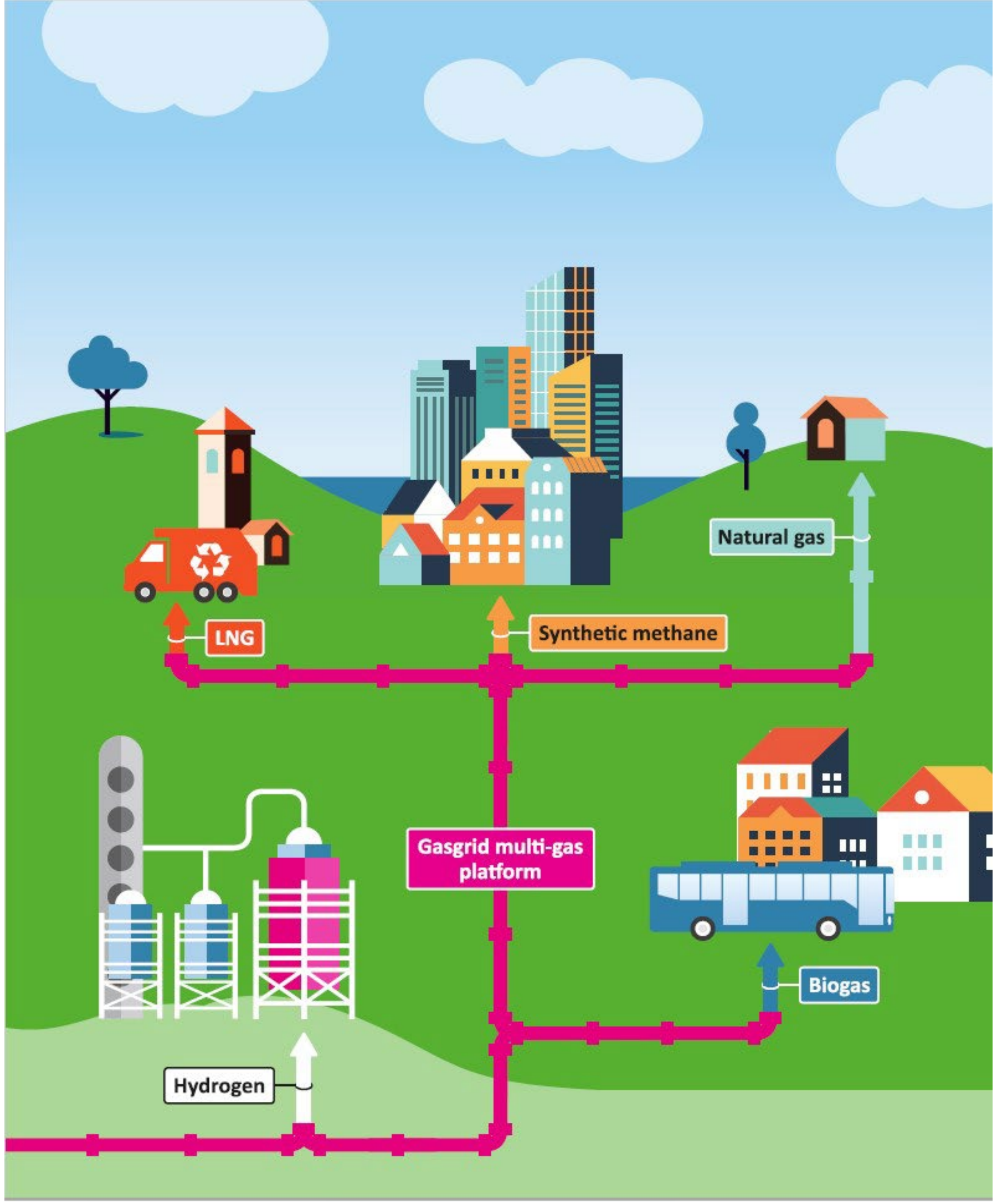
Mandated by the Finnish government, we are building a national, cross-border hydrogen infastructure.

Gasgrid is owned by the State of Finland.



Multi-gas platform supports the green transition and security of supply

- We are building a multi-gas platform **to respond to** the **energy needs of an electrifying society**, and it will enable the realisation of carbon neutrality goals.
- **Finland aims for carbon neutrality** by 2035, and society is switching to **emission-free forms of energy.** The platform **enables the growth of clean gases**.
- The multi-gas platform also safeguards Finland's **security of supply** and **energy independence**.
- Going forward, besides traditional **natural gas, biogas and liquefied natural gas** (LNG), Gasgrid's multi-gas platform will be used for the transmission of **hydrogen** and **synthetic methane**, which are low- or zero-emission gases.




HYDROGEN HAS A KEY ROLE IN THE EUROPEAN ENERGY TRANSITION

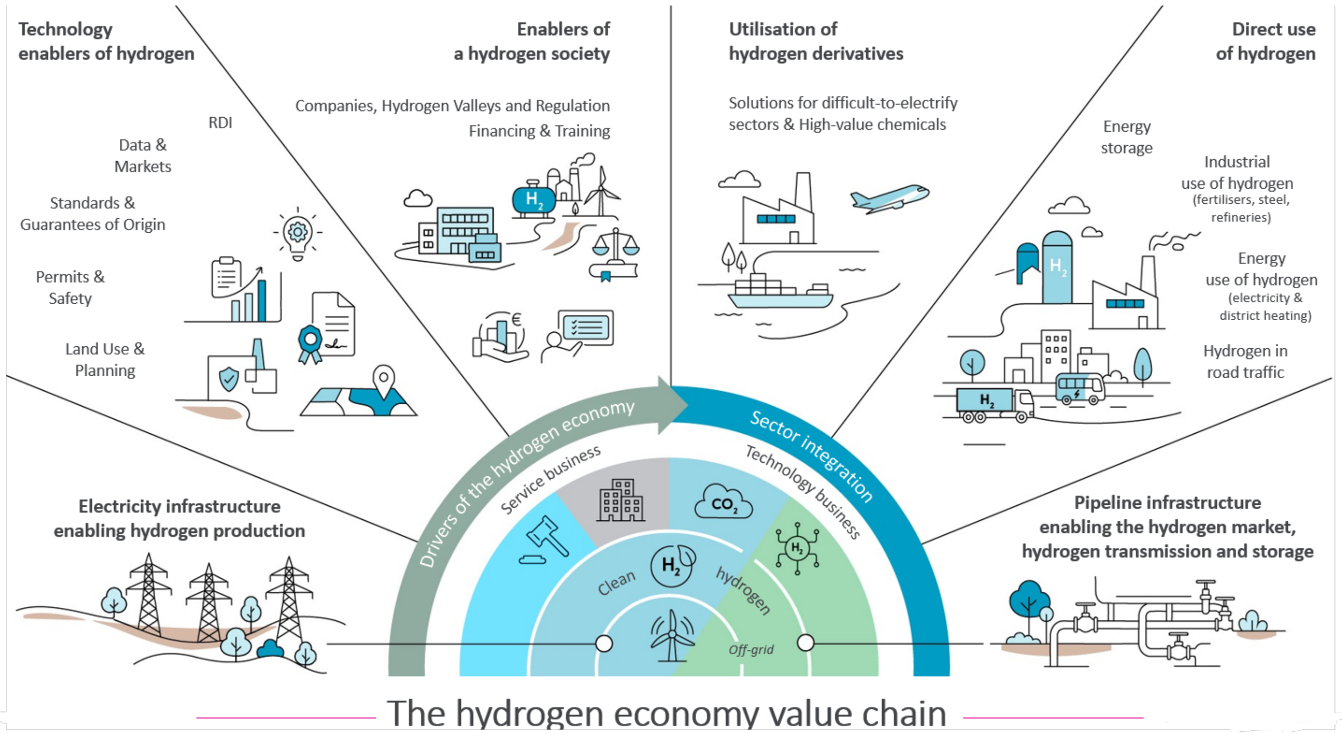
Finland can play a significant role in the energy transition of Europe

- The REPowerEU Strategy of 2022 set out the aim of producing 10 million tonnes (333 TWh) and importing 10 million tonnes of renewable hydrogen in Europe
  - Finland could produce 10% of this EU's hydrogen target

- Finland also aims to have a significant role in producing high-value products based on renewable energy and hydrogen to enable economic growth, strengthen industrial competitiveness, and support the green transition across Europe

- Finland's hydrogen potential lies in:
  - Excellent renewable energy resources
  - Cost competitive electricity and hydrogen production costs
  - Availability of land and water
  - Strong electricity grids and continuous investments to the development of the electricity grid
  - Availability of biogenic CO_2 for production of synthetic fuels or chemicals
  - High-level technological know-how from energy and biorefining industries

Hydrogen infrastructure as an enabler



- Transmission pipelines enable:
  - *Efficient energy transportation*: One 13 GW hydrogen pipeline corresponds in energy transfer capacity to approximately 15 high-voltage power lines
  - *Broader utilization of wind power* potential and Finland's entire energy system
  - Establishes *connection* between multiple H2 producers & end users and creates an open market for hydrogen
  - Transferring large amounts of *energy as hydrogen is more land-use efficient* than transferring it as electricity: Hydrogen pipeline does not impose restrictions on agriculture during its operation
  - Gives *short- and long-term flexibility* through storage (linepack & availability of European cavern storages through pipeline)
  - *Creates new business opportunities* for different actors through the development of new value chains, products and services

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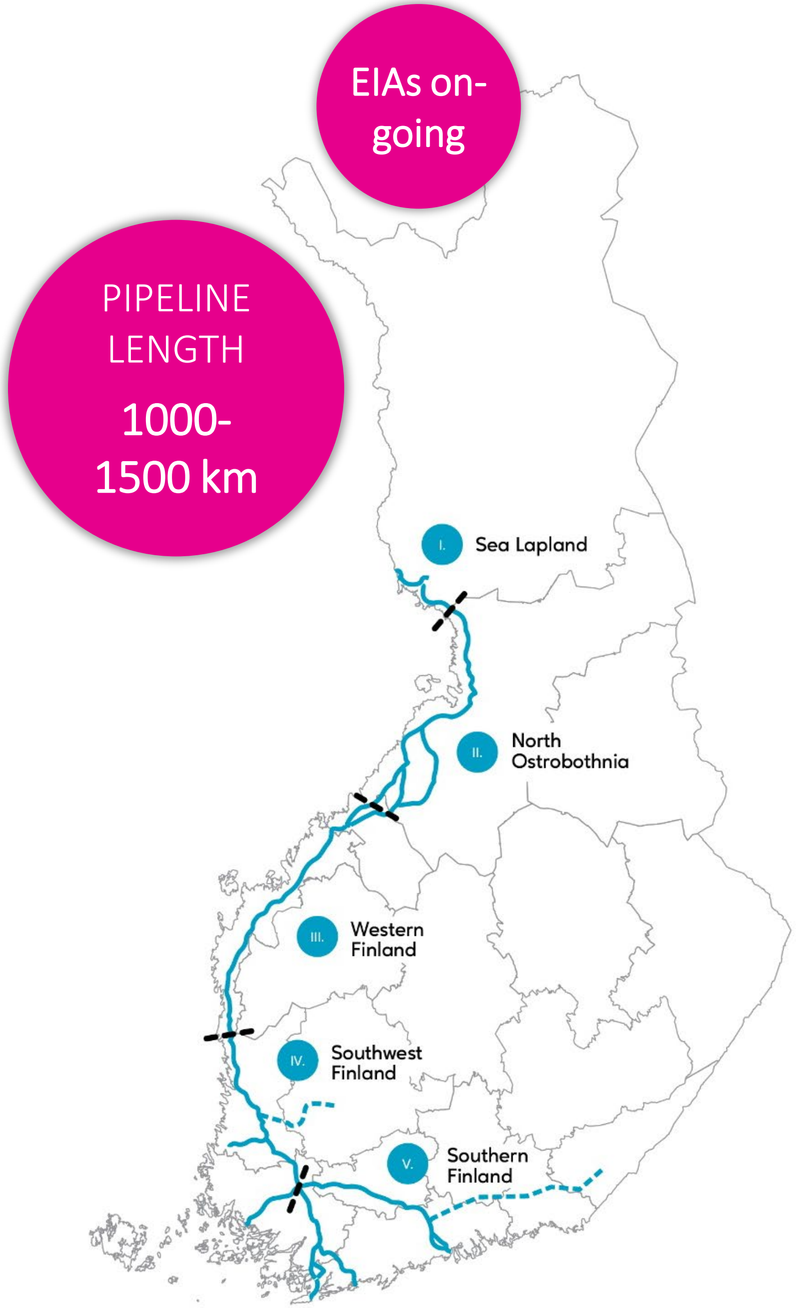
Finland's hydrogen transmission network is progressing

- Route planning has progressed with the help of **a market consultation** and an analysis of **the development of the hydrogen projects**, **in a dialogue with cities, municipalities, and hydrogen producers and users**.

- **The criteria for the routing of the pipeline include, among other things, safety as well as land use and environmental factors**. The routing aims for a permanent solution to avoid modifications in the future when, for example, housing and transportation routes expand.

- **The Environmental Impact Assessment (EIA) procedure** was launched in 2025 and is expected to be completed by 2027.
  - Comperehensive studies on the current state of the environment, including nature, archaelogy, land use, and landscape
  - Assessment of environmental impacts
  - Public hearing and public events conducted in two phases

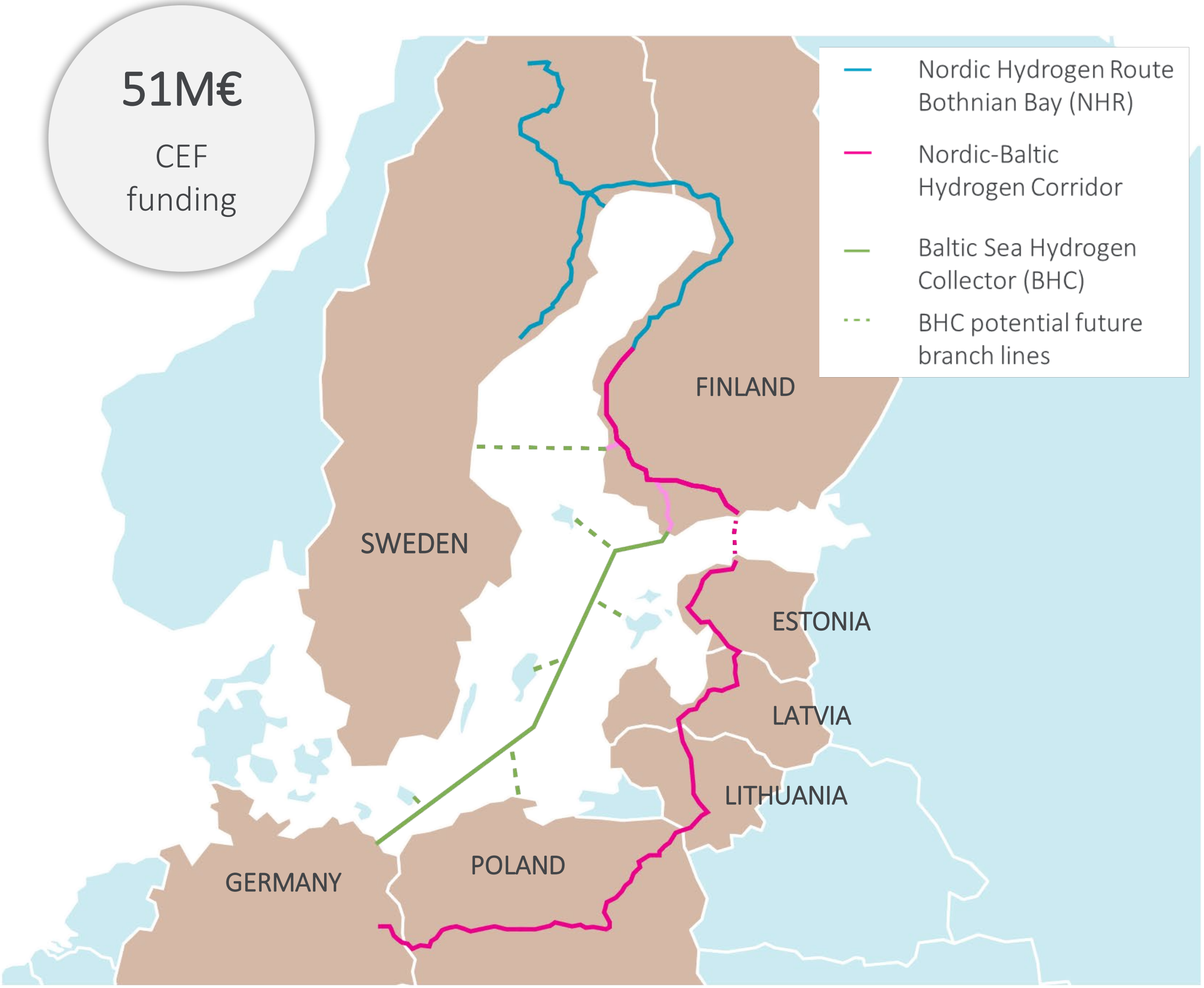


International connections and EU funding for the hydrogen pipeline

- Finland participates in three Projects of Common Interest (PCI), which are **NHR**, **BHC** and **NBHC**. The projects support the development of national hydrogen infrastructure.

- **International projects connect Finland with other European countries**, such as Sweden, the Baltics and Central Europe, enabling a broader market and collaboration.

- **The EU's CEF funding programme provides significant financing opportunities** for hydrogen economy investments and development projects.



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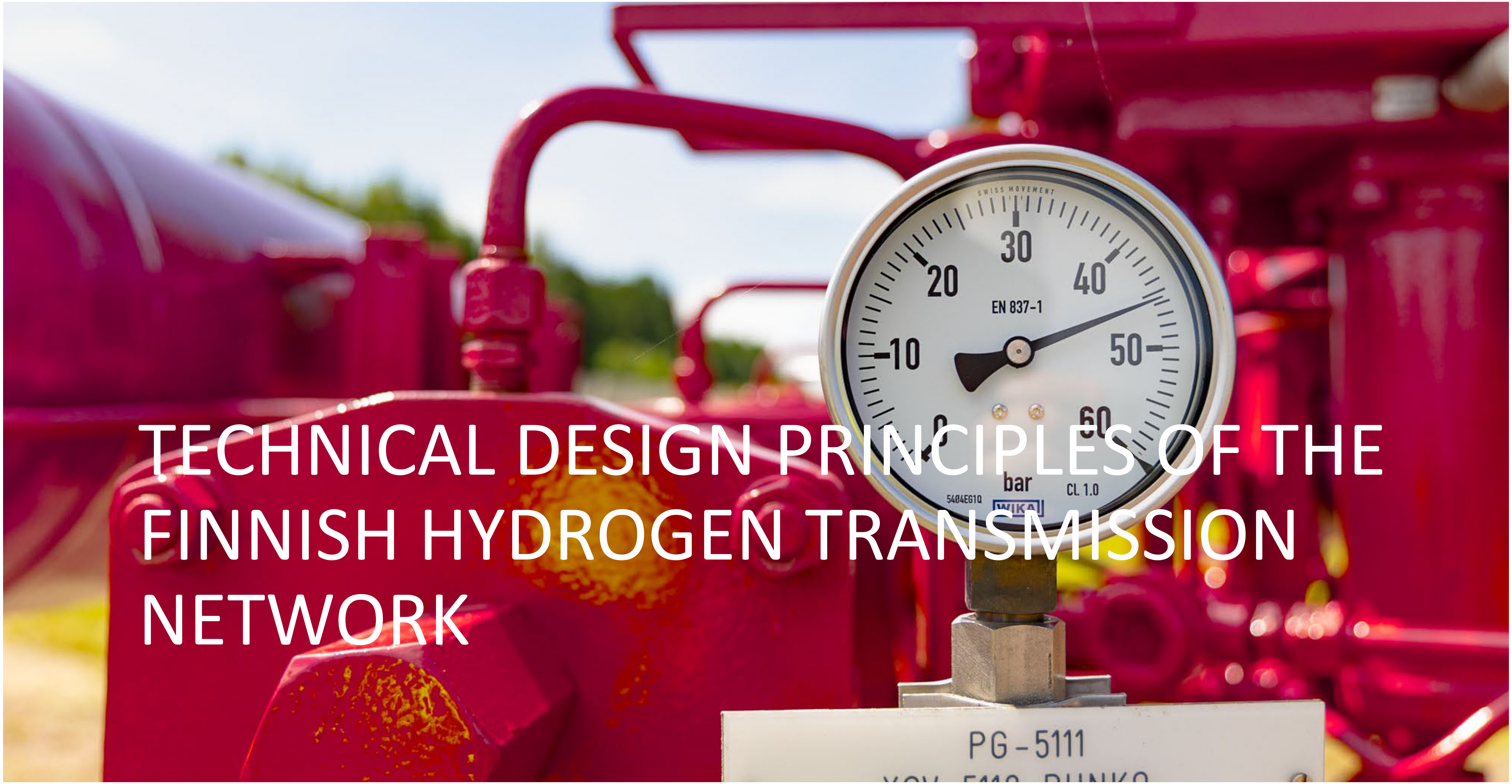


TECHNICAL DESIGN PRINCIPLES OF THE FINNISH HYDROGEN TRANSMISSION NETWORK

Finnish hydrogen network is primarily planned as a new-built infrastructure

- Typically, repurposed pipelines should be operated at lower pressure levels and with lower pressure fluctuations compared to new pipelines.
- To be considered:
  - Material compatibility
  - Pipeline condition
  - Operational history
  - Safety considerations
- Finnish hydrogen network is primarily planned as a new-built infrastructure
- Blending hydrogen into the methane infrastructure is not considered as a viable solution to transport hydrogen in Finland. Hydrogen content at interconnection points between Member States is limited to 2%.

Pipelines are placed underground, protected and marked

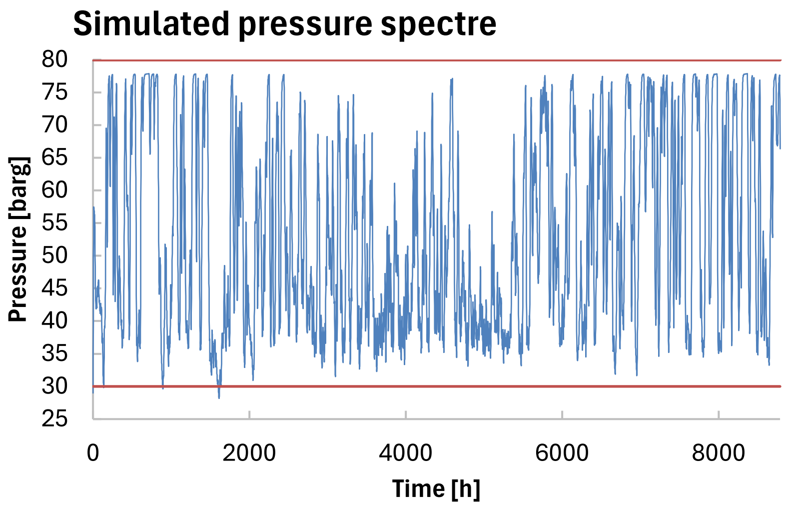
- The design maximum allowable operating pressure (MAOP) is currently 80 barg for onshore pipelines
- In addition, there can be distribution networks at lower pressure
- Steel pipes are coated with e.g., polyethylene to protect pipes from corrosion.
  - In addition, electro-chemical cathodic protection system is used
- Linepack capacity (storage of hydrogen in the pipelines, largely) depends on the pipeline dimension and the minimum and maximum pressure levels.

Cyclic operation of pipelines

BalticSeaH2

HYDROGEN PRODUCTION

- Electrolytic hydrogen production based on renewable energy sources leads to pressure fluctuations in pipelines, which challenge material durability
- These fluctuations can cause fatigue, accelerated by hydrogen embrittlement.



- On average, the pressure varies between 35 barg and 78 barg, with occasional drops to around 30 barg level during periods of reduced linepack

HYDROGEN UTILISATION

Four main off-taker types:

- Current oil refining industry – Low flexibility potential due to steady-state processes
- Hydrogen Direct Reduction of Iron (HDRI) – Moderate flexibility, HDRI is P2X product by itself.
- E-fuels and chemicals – Moderate to High flexibility
  - Methanol (and methane) synthesis reactors may have high flexibility.
  - eSAF production based on Fisher-Tropsch synthesis may have moderate flexibility
- Export (most of the hydrogen exported) — flexibility is hard to evaluate
  - Could be controlled with salt cavern storages located in Central Europe

Storage can help reduce pressure variations

Related work: J. Jauhola, Master's Thesis, Dynamic Modelling of Hydrogen Transmission Pipelines, Assessment of Durability and Effect of Storages, 2026, https://urn.fi/URN:NBN:fi:tuni-202602102420

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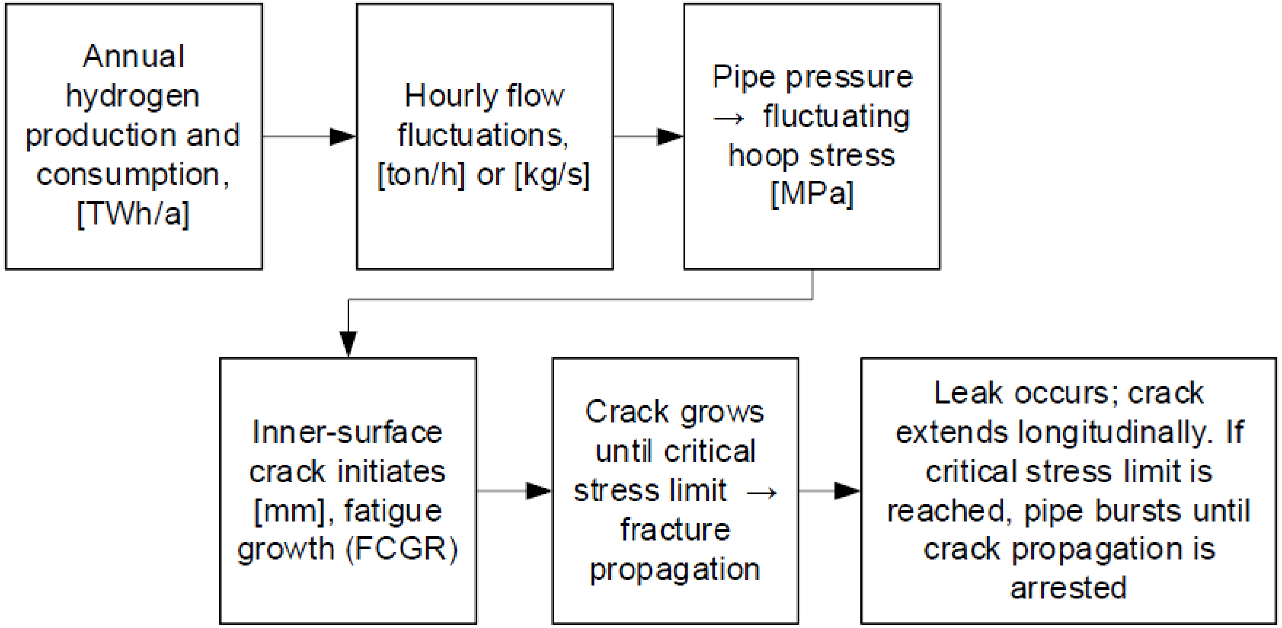
The durability assessment

The durability assessment process for hydrogen transmission pipelines is illustrated here:



The driving questions:

- What kind of hydrogen production and consumption system is emerging in Finland?
- What factors influence the durability of hydrogen pipelines?
- Can transmission lines operate within durability-related boundaries?
- What is the effect of storage size on pipeline durability and usability?

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Modelling scenarios and key design principles

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- A dynamic model was developed using the Simone software for representing a simplified example of planned Finland's backbone network
- The model included five hydrogen valleys where hydrogen is produced and consumed. 3 modelling scenarios based on off-taker flexibility evaluation
- The simulation produced pressure fluctuation spectra for the entire year at different pipe-line locations under all three scenarios.

Summary of scenarios studied

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

Key design principles assumed:

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

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

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

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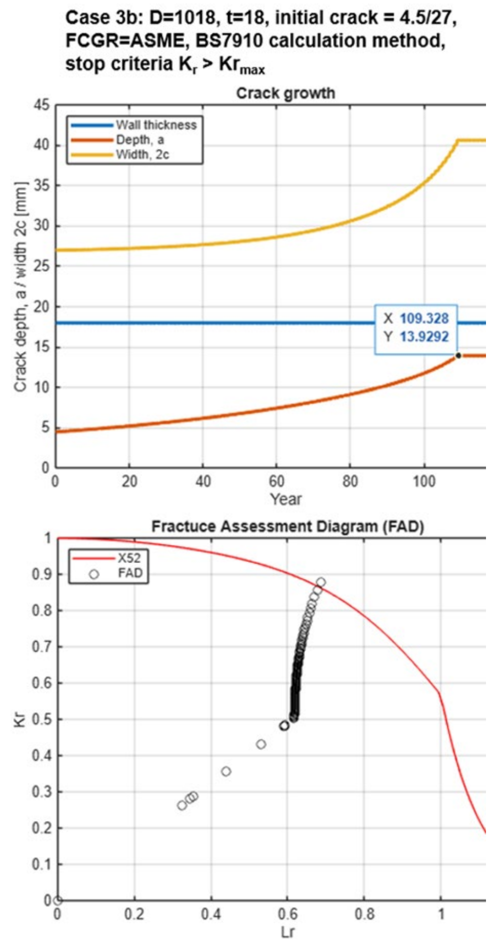
Fracture and fatigue assessment



- The structural assessment examined the properties of materials suitable for hydrogen transmission and the depth of manufacturing defects that act as crack initiation points.
- Two standardised fatigue crack growth rate (FCGR) models (ASME B31.12 and IGEM) were compared for fatigue assessment, and a Fracture Assessment Diagram (FAD) was used for fracture evaluation.
- The pressure fluctuation spectrum was used as input for fracture mechanics and fatigue models, with stress cycles calculated using the Rainflow method.
- A crack growth and fracture assessment model was developed in MATLAB. The analysis included multiple cases, resulting in calculated service lives for all scenarios.

The results showed that the factors influencing service life, in order of importance, are initial crack depth, magnitude of pressure fluctuations, selected crack growth calculation method, use of storage, consumer flexibility, and pipe wall thickness. ***Initial crack depth proved to be the most critical factor***, controllable during manufacturing and inspection. Storage improved service life by up to 82% but requires very large storage capacity.

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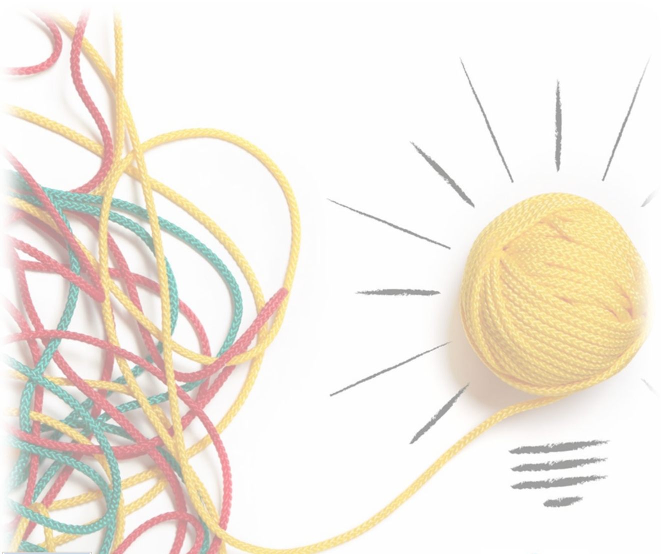
Collaboration needed in R&D activities to promote the hydrogen development



- Gasgrid's R&D projects support the development of the hydrogen infrastructure and economy
- Further research is needed e.g. to understand
  - the effects of thermal cycles, bending, and residual stresses on fatigue assessment and material selection
  - testing procedures and definition of testing environment, validation of simulation and testing
  - welding procedures
- Collaboration is a key to achieve concrete results

KEY TAKEAWAYS

Key takeaways

Hydrogen economy & infrastructure

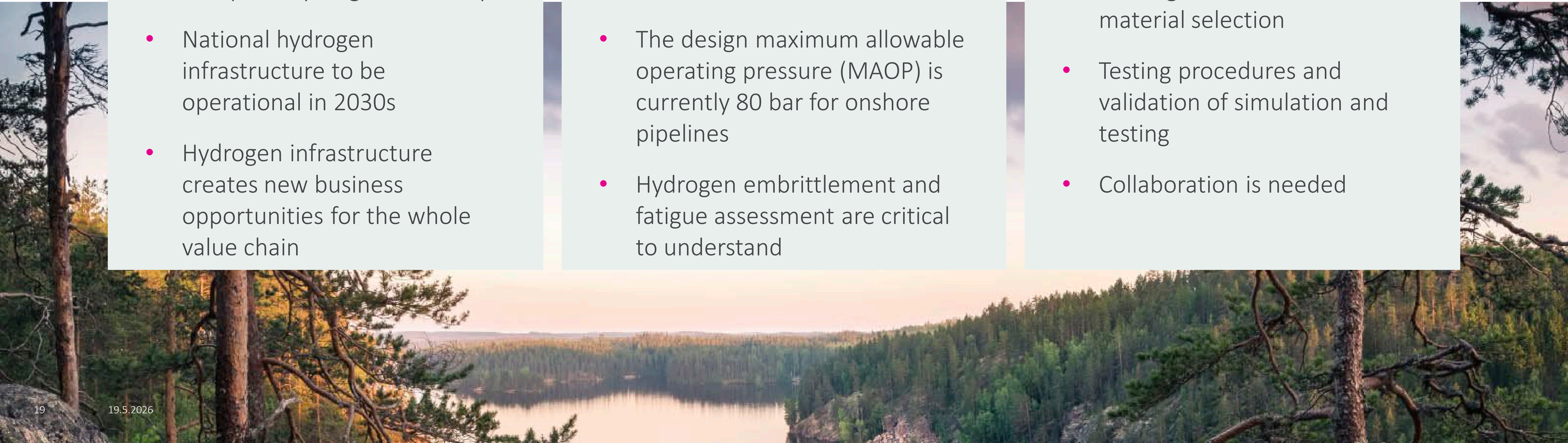
- Finland has an opportunity to achieve a leading role in the European hydrogen economy
- National hydrogen infrastructure to be operational in 2030s
- Hydrogen infrastructure creates new business opportunities for the whole value chain

Technical design principles

- Finnish hydrogen network is primarily planned as a new-built infrastructure
- The design maximum allowable operating pressure (MAOP) is currently 80 bar for onshore pipelines
- Hydrogen embrittlement and fatigue assessment are critical to understand

Research needs, examples

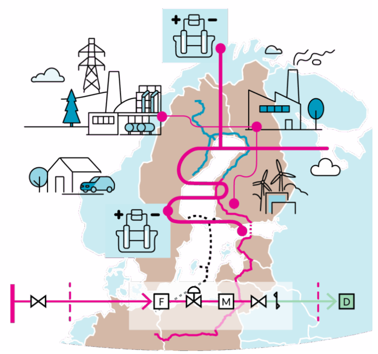
- The effects of thermal cycles, bending, and residual stresses on fatigue assessment and material selection
- Testing procedures and validation of simulation and testing
- Collaboration is needed



Further reading

Gasgrid's first hydrogen information package

H2 Information Package



TUKES's updated hydrogen guide

Safety of hydrogen handling and storage

EIA Programme, Meri-Lappi

(in Finnish only)

Suomen kansallinen vedyn siirtoverkko, osa I, Meri-Lappi

Gasgrid's map service for the preliminary hydrogen pipeline route plan

Gasgrid hydrogen transmission network

Further listening

Gasgrid's The Changers podcast is shaping the future

Some of Finland's most impactful changemakers – innovative influencers who actively drive economic growth and a better tomorrow – dive into inspiring conversations on what it takes to make a different with Olli Sipilä. Finland needs growth, and growth requires change. The bold steps towards a more productive future are taken together!

Join us to hear how change affects our lives and gain valuable insights to help you navigate it. Whether you're looking for inspiration, fresh perspectives, or concrete tips, The Changers brings you the voice of change.

The episodes are available on Spotify, Supla and YouTube.
(in finnish only)

Why does hydrogen matter now, and what will decide whether it really scales?

The Hydrogen Valley Podcast focuses on the practical conditions shaping the hydrogen economy, including technology readiness, regulation, infrastructure, investments, and system-level choices. The aim is to bring clarity to a discussion that often moves faster than implementation.

The first episodes are now available on Spotify and Apple Podcasts.

More information and listening links:
🔗 https://balticseah2valley.eu/podcast/

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