Vetytutkimus Oulun yliopistossa

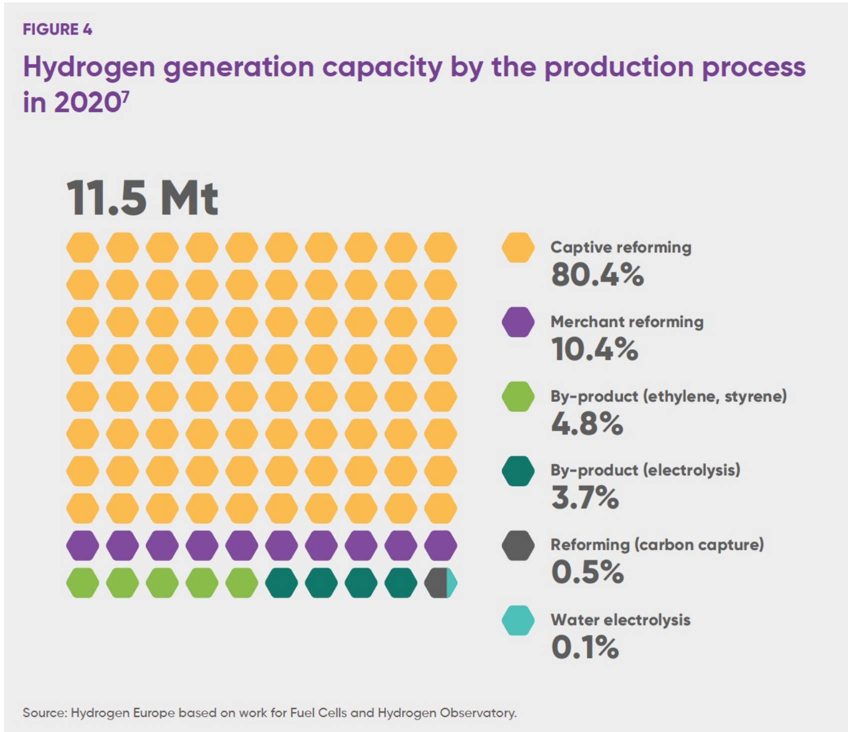
Samuli Urpelainen, yliopistotutkija

Nano- ja molekyylisysteemien tutkimusyksikkö
Luonnontieteellinen tiedekunta

11.10.2023

Vety osana hiilivapaata yhteiskuntaa

- Vetyä on käytetty teollisuudessa jo pitkään – mutta valmistettu pääasiassa maakaasusta höyryreformoinnilla
- Euroopan nykyinen tuotantokapasiteetti vuodessa on noin 11.5 Mt, josta 99.3% perinteisin menetelmin
- Vety voi korvata mm. maakaasun useissa teollisissa prosesseissa energialähteenä – ja sitä voidaan jatkojalostaa polttoaineiksi
- EU (esim. European Green Deal, "Fit for 55") on tunnistanut puhtaan vedyn avainteknologiaksi Euroopan hiilineutraaliuden saavuttamiseksi sekä energiahuoltovarmuuden kannalta (REPowerEU)
- Tavoite on 10 Mt/a vuotuinen puhtana vedyn tuotanto Euroopassa sekä 10Mt/a tuonti vuoteen 2030 mennessä – joka yksin vähentää hiilidioksidipäästöjä n. 140 Mt/a pelkästään tuotannon osalta

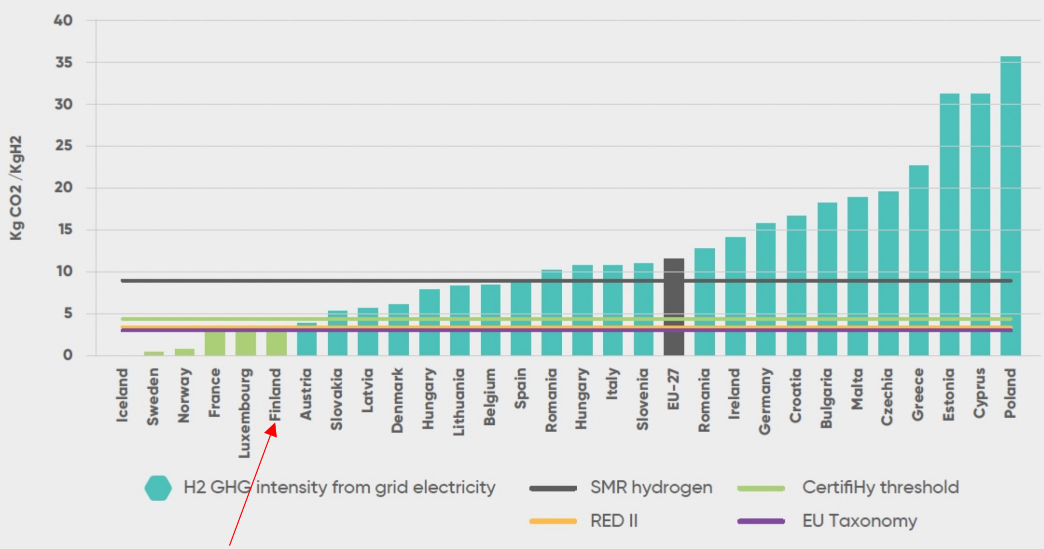


From Clean Hydrogen Monitor 2022 (Hydrogen Europe)

Suomen asema uusiutuvan vedyn suhteen?

FIGURE 7

Carbon intensity of hydrogen produced from grid electricity, compared to selected benchmarks



Source: Hydrogen Europe, based on EEA data

Note: SMR Hydrogen: 9.0 kg CO_2 / kg H_2 (75.0 gCO_2/ MJLHV), EU Taxonomy threshold for sustainable hydrogen manufacturing: 3 kg CO_2 / kg H_2 (25 gCO_2/ MJLHV), CertifHy threshold for low carbon hydrogen: 4.4 kg CO_2 / kg H_2 (36.4 gCO_2/ MJLHV), RED II threshold for RFNBO: 3.384 kg CO_2 / kg H_2 (28.2 gCO_2/MJLHV).

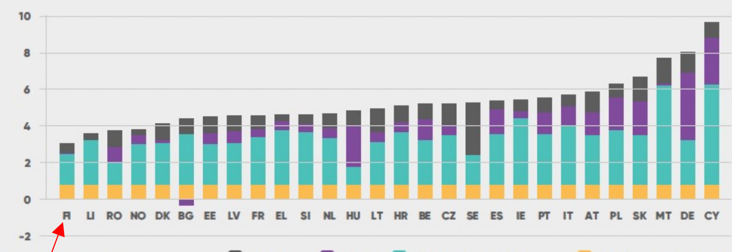
FIGURE 1

Total hydrogen production capacity by country.[4]

Source: Hydrogen Europe based on work for Fuel Cells and Hydrogen Observatory.

FIGURE 5

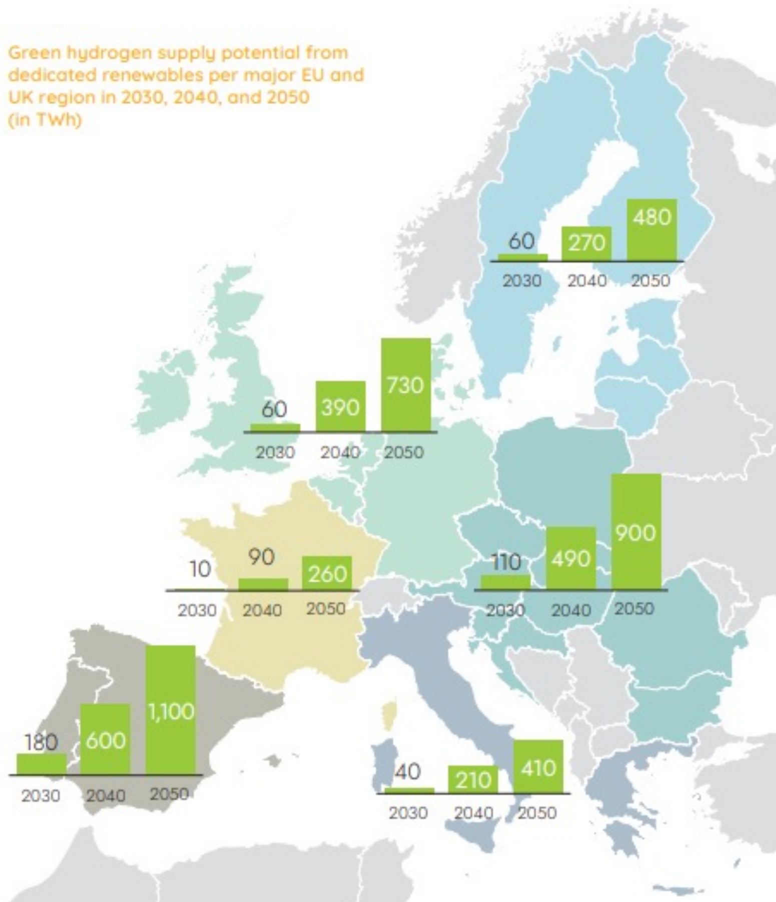
Grid-connected electrolysis hydrogen production costs in the EU in 2021 (in EUR/kg)[2]

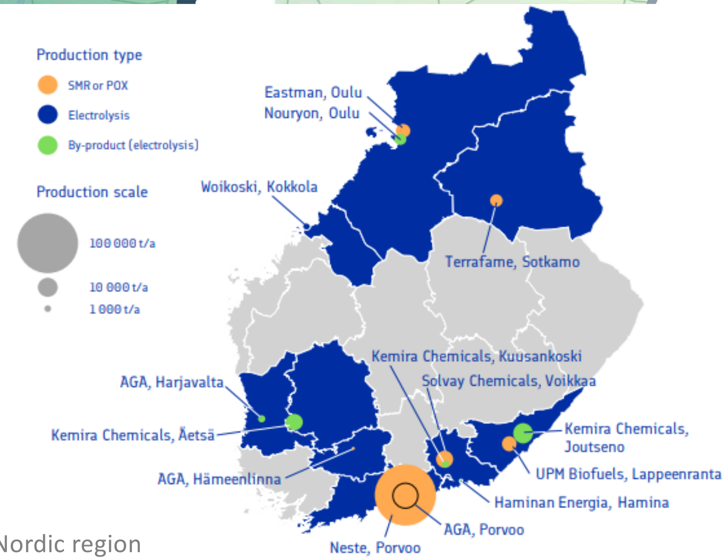


Source: Hydrogen Europe.

From Clean Hydrogen Monitor 2022 (Hydrogen Europe)

Euroopan ja Suomen vetytiekartat





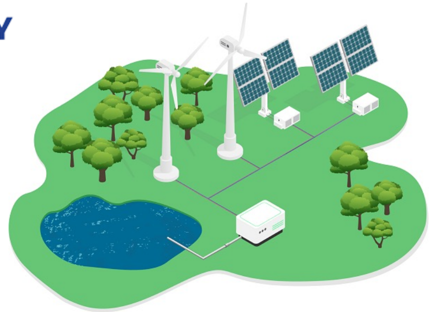
n yliopisto

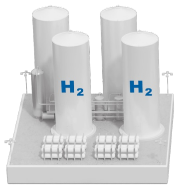
European Hydrogen Backbone NATIONAL HYDROGEN ROADMAP for Finland LTU, Boden a hub for hydrogen in the Nordic region

Multidisciplinary and intersectoral research on H_2

Holistic knowhow in clean hydrogen transition

UNIVERSITY OF OULU





Production

- (Photo)catalysis, methane pyrolysis, CCS & CCU, distributed production methods
- Business Finland, Academy of Finland, EU-ERC-CoG*

(* European Research Council funding

Transport and storage

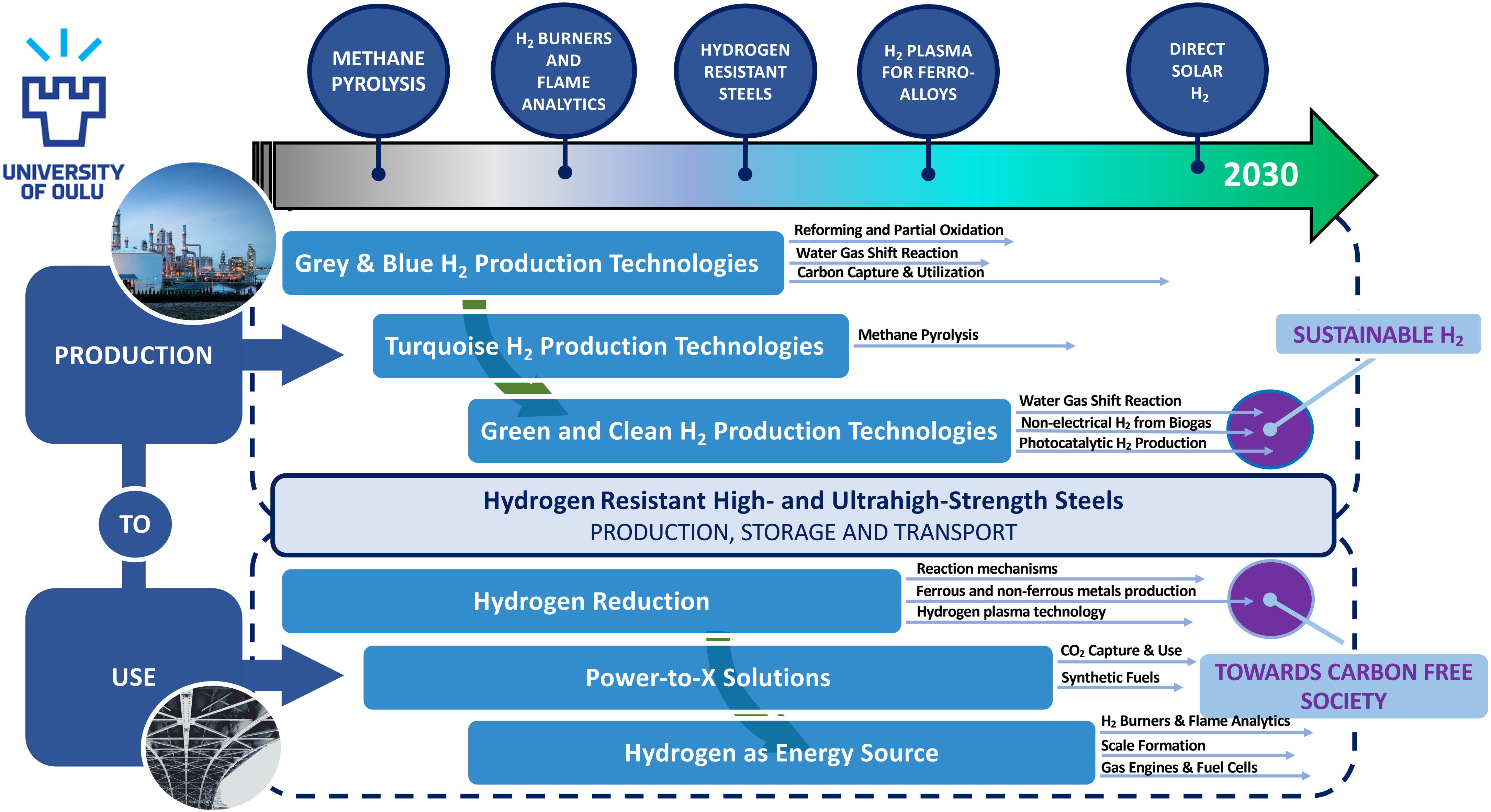
- Steels in storage, transport and use of H_2
- Business Finland, Academy of Finland
- Unique infrastructure and MAX IV FIRI

Usage

- Hydrogen reduction, Power-to-X
- Business Finland, Academy of Finland, EU
- Strategic cooperation with metals production industry

Impact: ESTEP (European Steel Technology Platform), EERA (European Energy Research Alliance), **ECHA (European Clean Hydrogen Alliance)**, **HER (Hydrogen Europe Research)**, **EIT Raw Materials**, RFCS (Research Fund for Coal and Steel, member TGA3), EN (European Standards), BEPA (Batteries European Partnership), IIW (International institute of Welding)

erc MAX IV CASR | Centre for Advanced Steels Research SSAB

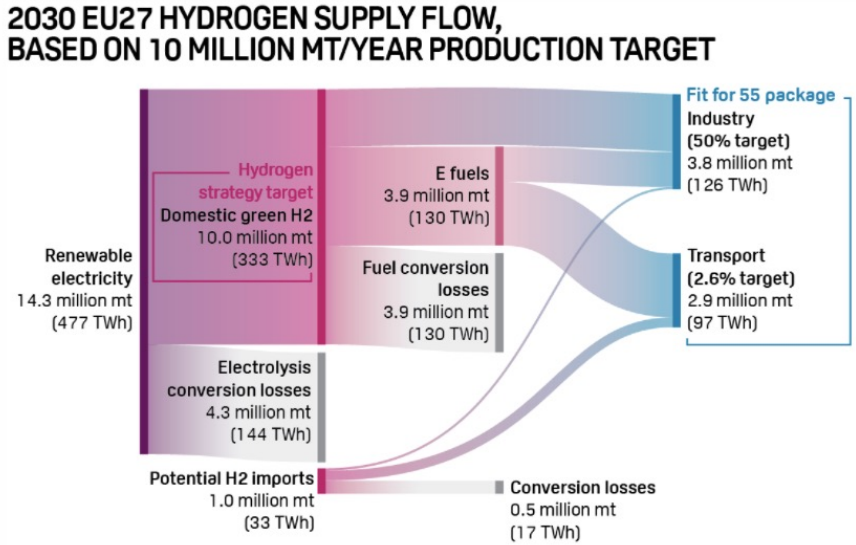


Grey & Blue: natural gas as raw material with CCS (blue) or without (grey); Turquoise: solid carbon as a by-product; Green and Clean: sustainable energy, CO2 emission free

Suuri haaste 2023 eteenpäin!

- Elektrolyysiin pohjautuva strategia nojaa edullisen sähköenergian hyvään saatavuuteen
- Arvioitu vedyn tarve EU:ssa 2050 on n. 2800 TWh/a (European Hydrogen Backbone, 2021)
- Sähkaöenergiassa mitattuna tämä on jopa ***4670 TWh (= 330 ydinvoimalaa tai 250 000 – 460 000 tuulivoimalaa)***
- Suomen sähköntuotanto 2021 oli n. 69 TWh, 2022 alijäämäinen n. 95% ajasta

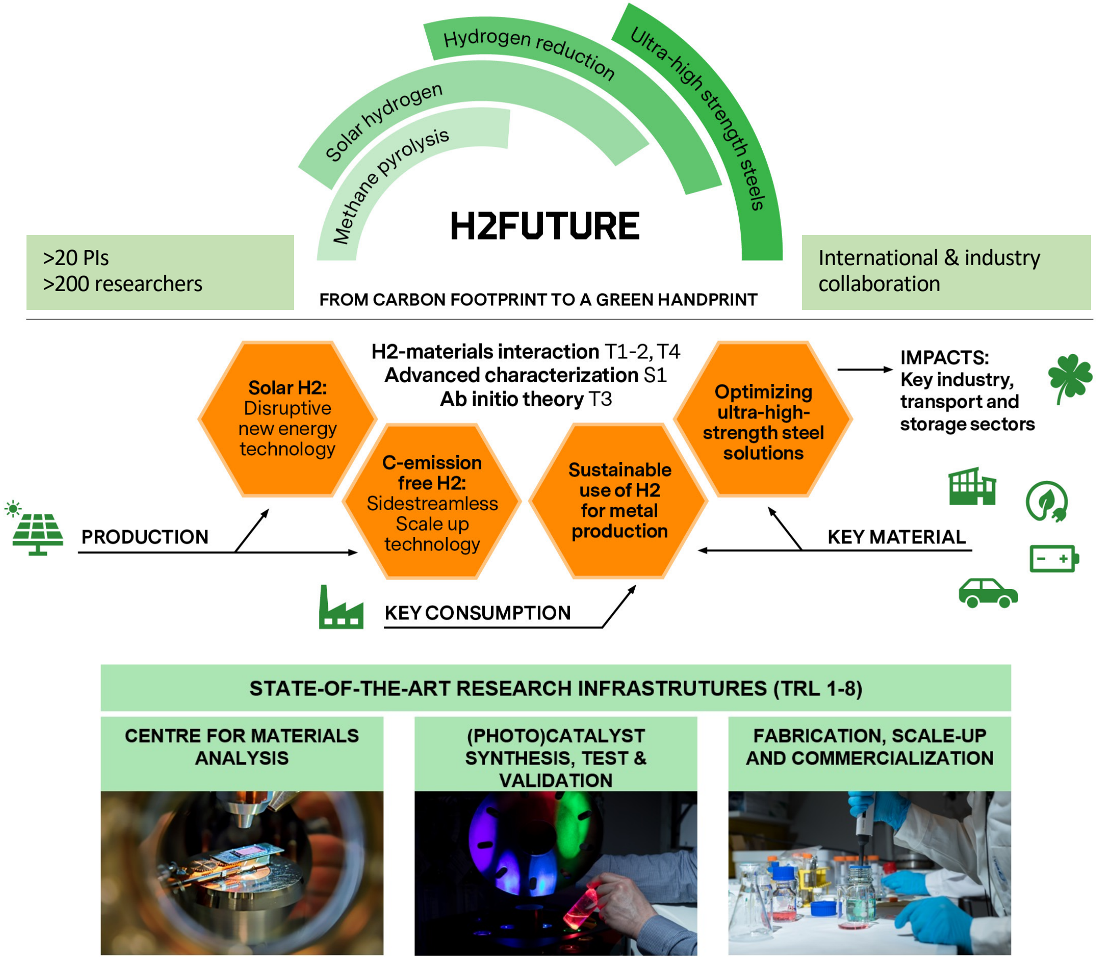
Sähkön kysyntä ja hinta kasvaa, kun vetyä tuotetaan elektrolyysillä



Source: Future Energy Outlooks, S&P Global Platts Analytics; EU Fit for 55 package

TUULIVOIMA 2022	Tuotannot kuukausikeskiarvona (MW)		
	Alle 500	Alle 1400	**Tehokkuus**
Tammikuu	13,7	35,0	**51,6**
Helmikuu	17,2	46,6	**43,2**
Maaliskuu	15,8	44,5	**43,9**
Huhtikuu	36,3	76,4	**25,0**
Toukokuu	27,6	64,9	**30,3**
Kesäkuu	35,6	80,8	**21,2**
Heinäkuu	36,6	89,1	**19,2**
Elokuu	21,4	60,9	**30,1**
Syyskuu	23,4	68,8	**25,4**
Lokakuu	14,8	36,9	**39,7**
Marraskuu	52,9	81,1	**17,5**
Joulukuu	18,3	46,4	**33,9**
Vuosi	**26,1**	**61,0**	**31,8**

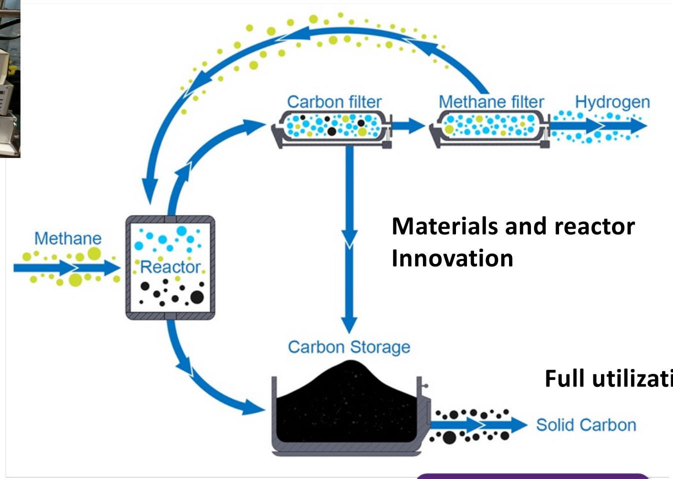
H2FUTURE - Multidisciplinary Research and Education as a Foundation of the Green Transition



- National profilation project **H2FUTURE** 2023-2028
- CO_2 free and energy efficient H2 production methods: ***solar H2 and (bio)methane pyrolysis***
- Energy materials research: electroceramics
- Solar panels and nanocoatings
- Coordination of Hydrogen Research Forum Finland (9 research organization members): Research based view on hydrogen transition
- **National graduate school on H2 transition under construction**
- I4WORLD EU-Horizon MSCA docotoral program focusing on UN SDG themes
- Offering courses on energy technology and systems, **minor** on sustainable development
- Open university and continuous learning, **education on H2 transition** (FiTech) and UNIC collaboration

I4WORLD UNIVERSITY OF OULU
Co-funded by the European Union
erc
BUSINESS FINLAND
SUOMEN AKATEMIA

Vaihtoehtoiset vedyntuotantomenetelmät: (Bio)metaanin termokatalyyttinen hajottaminen (TDC)



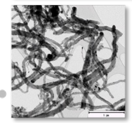
Materials and reactor Innovation

			Direct CO_2 emissions in kg CO_2/kg hydrogen	Minimum energy demand in kJ/mol hydrogen*
State-of-the-art	Steam reforming of natural gas	$CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$	8.85	27
Option 1	Water electrolysis	$2H_2O \rightarrow 2H_2 + O_2$	0	286
Option 2	Methane pyrolysis	$CH_4 \rightarrow 2H_2 + C$	0	37

Daloz, W., Frederik Scheiff, Kai Ehrhardt, Dieter Flick and Andreas Bode,The quest for CO2 -free hydrogen – methane pyrolysis at scale, ARPA-E Methane Cohort Kickoff, Houston (US), Dec 10, 2019.

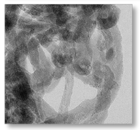
Full utilization of side streams

CNT, CNF



- **Battery industry**
- **Electric vehicles (supercapacitors)**
- **Catalysts**

Graphite



- **Battery industry**
- **Lightweight materials for automotive and aerospace industry**

Activated carbon

- **Water treatment**
- **Pharmaceutical purification**
- **Industrial applications**

hycamite

RESEARCH UNIT OF SUSTAINABLE CHEMISTRY
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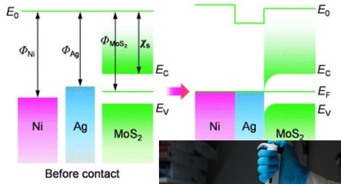
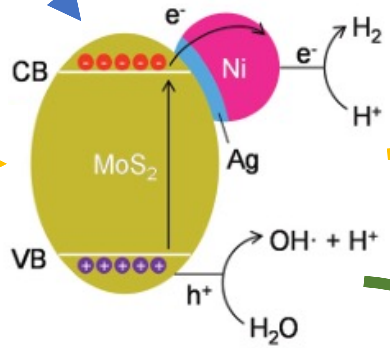
Vaihtoehtoiset vedyntuotantomenetelmät: valokatalyysi

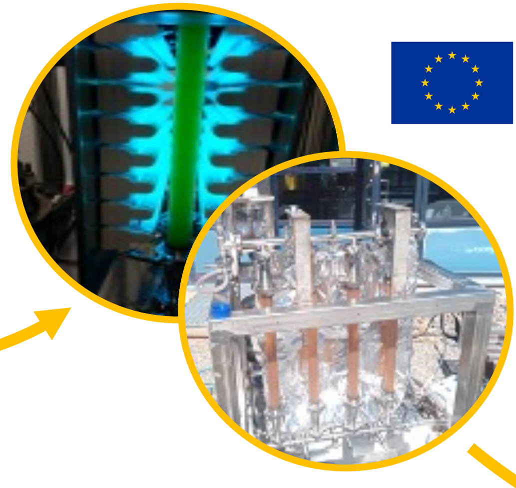


Catalyst design
& synthesis

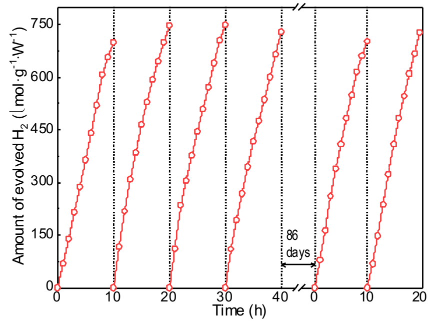
1 hour global sunlight
=
1 year mankind energy needs



Reactor
development



European Union
European Regional
Development Fund



Materials
characterization

Technology
validation

- Hydrogen evolution
- Water purification

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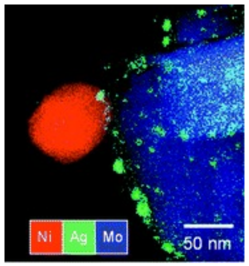
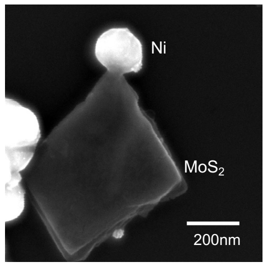
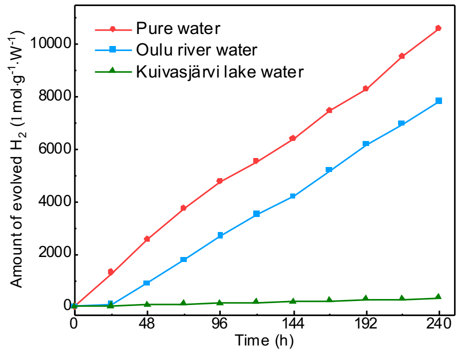
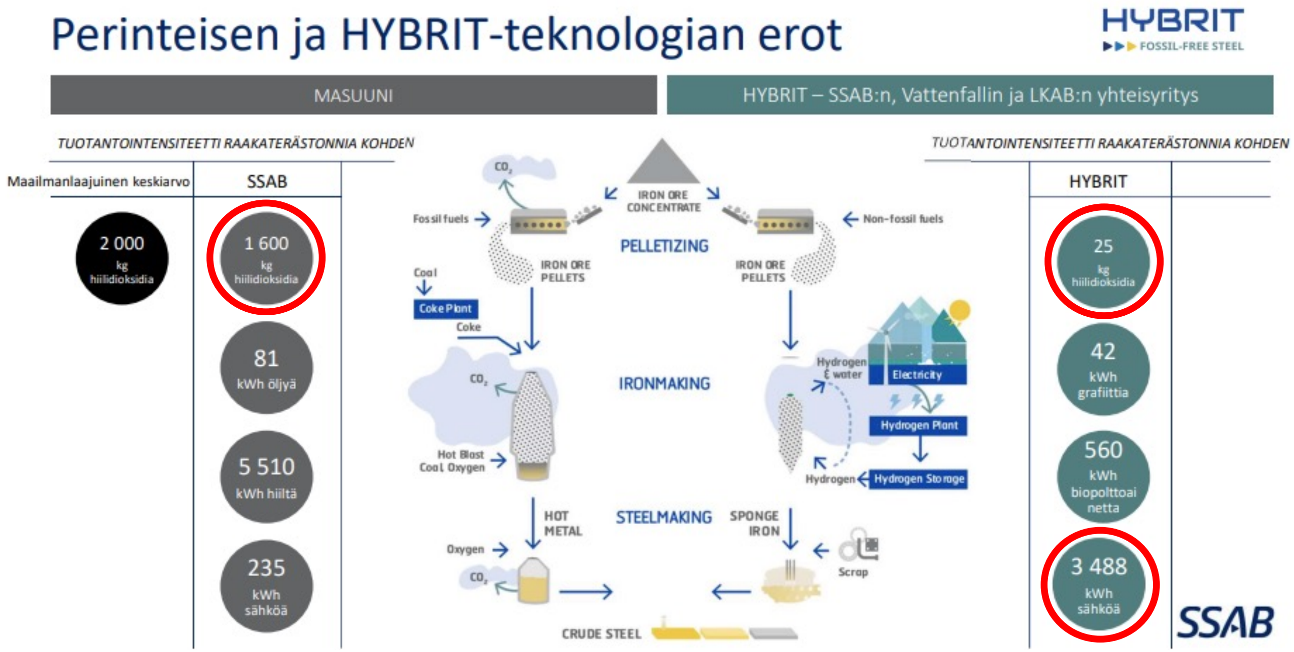




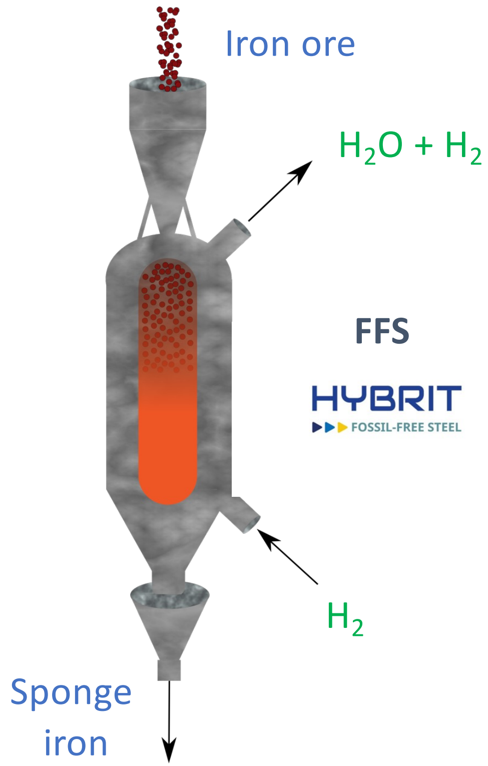


Vihreitä teräksiä vedyllä



– Carbon-containing reducing agents are replaced with hydrogen for reduction in solid state.

$$3\,Fe_2O_3 + \text{~~CO~~}\ H_2 \rightarrow 2\,Fe_3O_4 + \text{~~CO}_2\text{~~}\ H_2O$$
$$Fe_3O_4 + \text{~~CO~~}\ H_2 \rightarrow 3\,FeO + \text{~~CO}_2\text{~~}\ H_2O$$
$$FeO + \text{~~CO~~}\ H_2 \rightarrow Fe + \text{~~CO}_2\text{~~}\ H_2O$$



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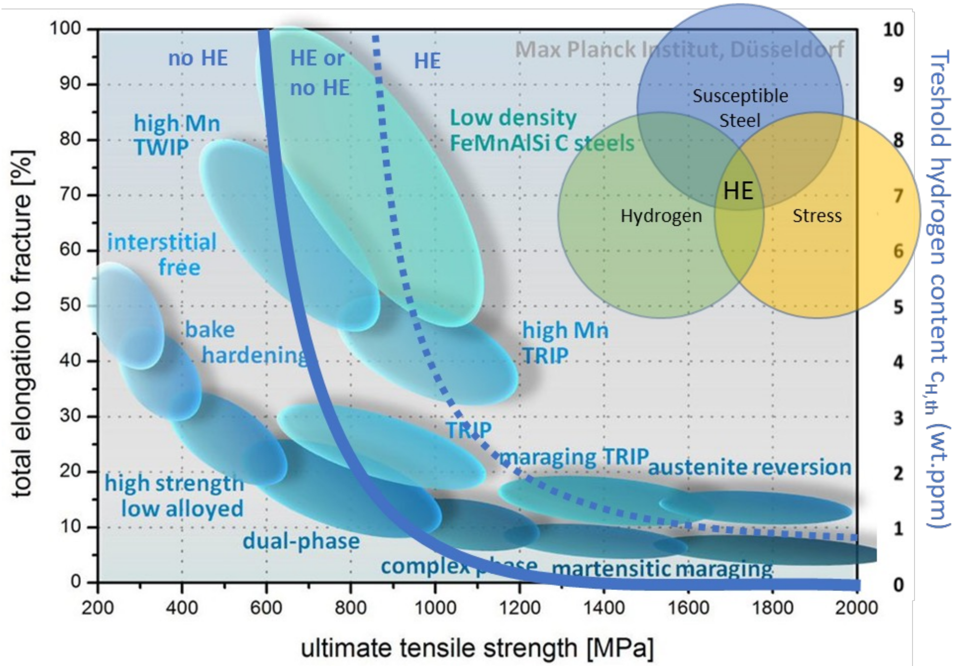
E-mail: timo.fabritius@oulu.fi

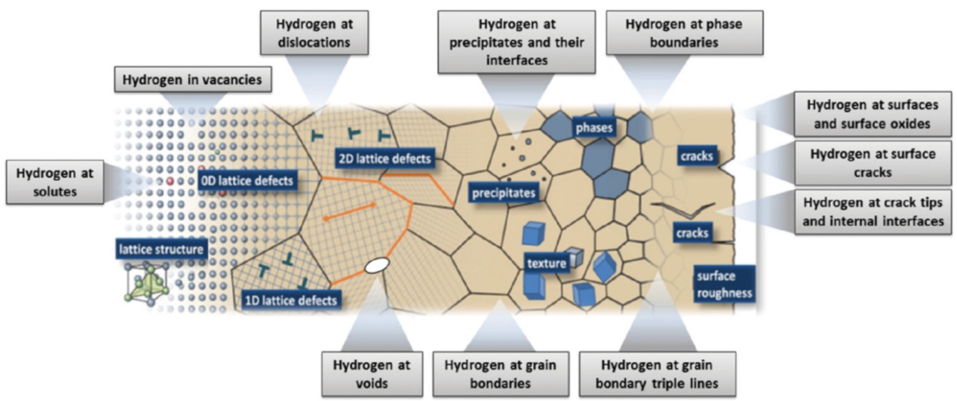
1 000 kg steel
~ 2 000 kg CO_2

Steel production equals CO_2
7-8% total CO_2 emissions

Metallurgiaa kehittyneiden hiilineutraalien terästen valmistukseen



- **Development of 4th generation ultrahigh-strength steels** with extremely good mechanical properties
- **Physical metallurgy enables** novel composition and process designs.
- Significant **reductions in the weights of steel structures** ensure substantial reductions in greenhouse gas emissions and raw material usage



Recent progress in microstructural hydrogen mapping in steels: quantification, kinetic analysis and multi-scale characterization. Source Kayama et al., 2017

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Contact:
Prof. Jukka Kömi
E-mail: jukka.komi@oulu.fi

Climate neutral, justified and sustainable H_2 transition

JustH$_2$Transit

Strategic Research Council (SRC)
2023-2029 Just Energy initiative

Consortium PI:
Prof. Marko Huttula
University of Oulu

Consortium Partners:

UNIVERSITY OF OULU · VTT · LUT University · Luke NATURAL RESOURCES INSTITUTE FINLAND · BotH$_2$nia

Interact, support, influence

Research

Academic research, education, knowledge transfer

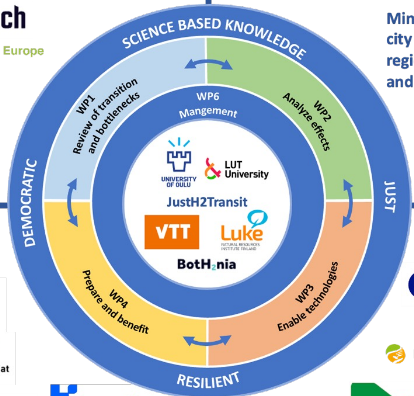
H2Forum Finland · FITech · CLIMATE UNIVERSITY · Hydrogen Europe Research · I4WORLD UNIVERSITY OF OULU · Co-funded by the European Union · CASR · National Doctoral School on H2 economy

Public sector

Financing policy, innovation support, regulation, land planning

Ministries (TEM, YM, MM), city planners, ELY and AVI officials, regional councils, and Tukes

KUNTALIITTO · Elinkeino-, liikenne- ja ympäristökeskus · Työ- ja elinkeinoministeriö · Ympäristöministeriö Ministry of the Environment · Maa- ja metsätalousministeriö



Business

AURELIA · H2cluster FINLAND · CASR Ecosystem · SUOMEN BIOKIERTO & BIOKAASU RY · Metallinjalostajat · Hydrogen Europe · BotH$_2$nia · hycamite

General Public

Societal involvement & engagement

CLIMATE UNIVERSITY · Students, land owners, citizen groups, associations, influencers · MAASEUTU.FI · LEADER · KANSALAISFOORUMI · Instagram

Mission of JustH$_2$Transit

- To facilitate the transition towards sustainable net-zero carbon society by promoting clean hydrogen (H_2) as an energy storage and means of powering industry and society.
- To support the EU's aim of switching to renewable H_2 by 2030 by developing innovative technologies and solutions for the production of renewable H_2 that are emissionles, cost-effective, energy efficient and scalable.
- To address the challenge of intermittent renewable energy sources by developing new approaches to hydrogen production that can operate effectively with fluctuating renewable energy inputs.
- To promote public awareness and understanding of the benefits of renewable H_2 as a key element of the energy transition
- To foster collaboration among industry, government, and academic stakeholders to accelerate the adoption of the vital technology

BotH$_2$nia

JustH2Transition

Hydrogen Impact Forum

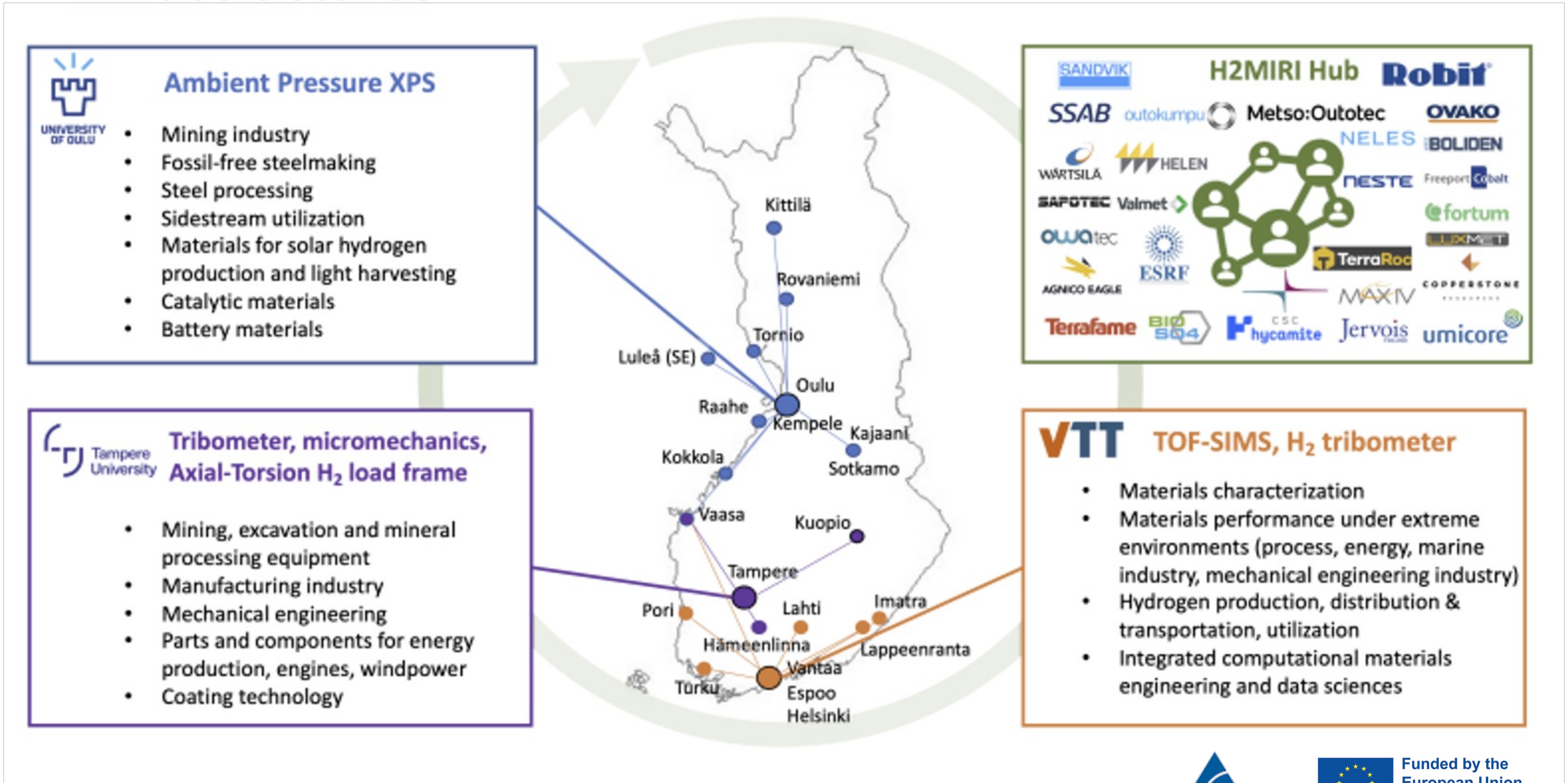
- 4 workshops / year for ongoing governance and society dialogue in Finland
  - Representatives for central stakeholder groups identified in local hydrogen valleys
  - Representatives for municipal, regional and national officials
  - 2 hour Teams meetings in workshop form, including small group discussions when needed
  - Focus in monitoring and management of impacts from hydrogen development projects

⇒producing a handbook for governance and society dialogue

⇒replicable in Sweden, Norway, Estonia, other Baltic States

www.both2nia.com

Hub for Hydrogen-Materials Interactions Research Infrastructures



SUOMEN AKATEMIA

Funded by the European Union
NextGenerationEU

Green Arctic Hydrogen Valley Initiative