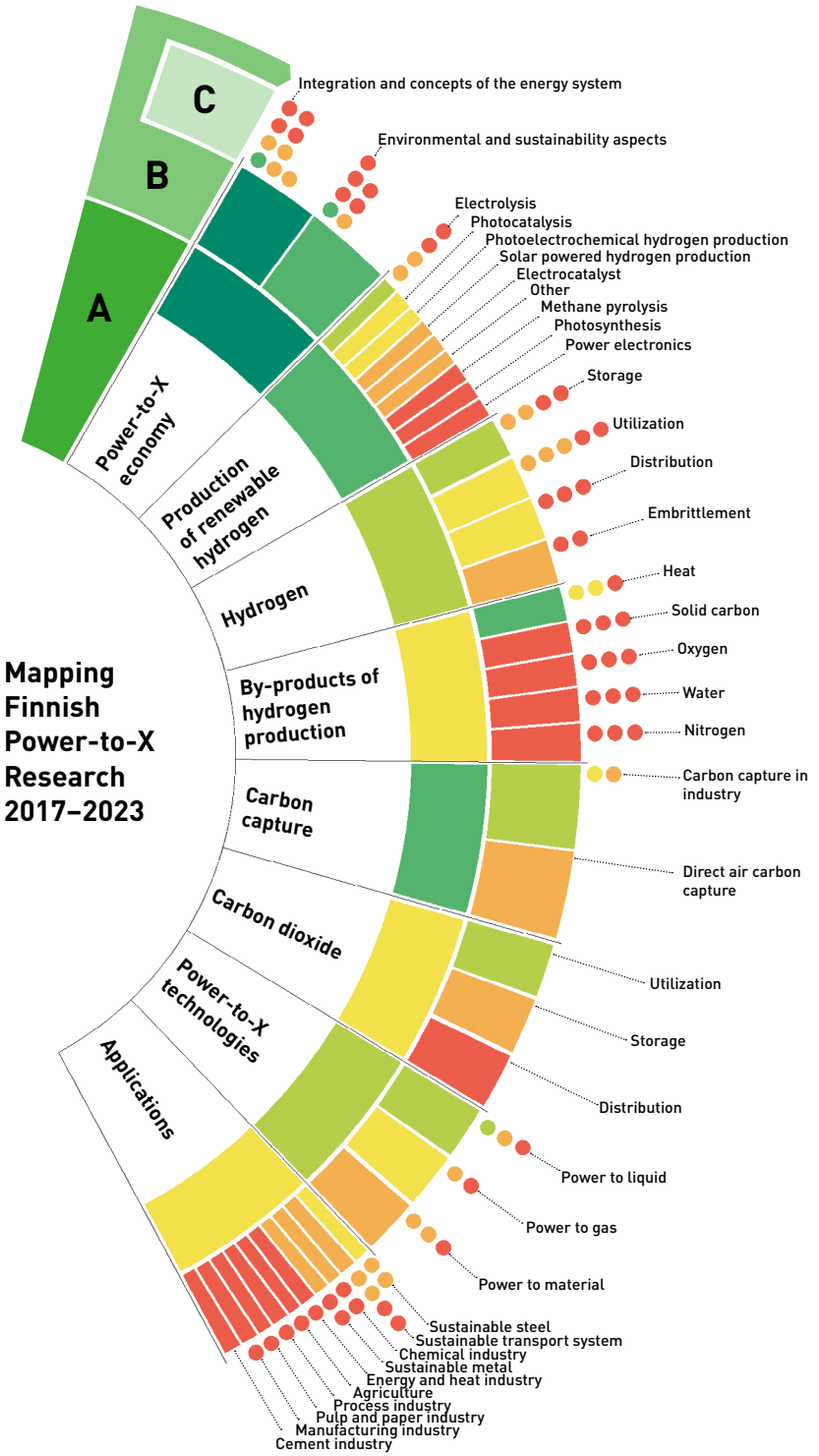
LUT University

THE STATE OF FINNISH HYDROGEN ECONOMY RESEARCH

Power-to-X (PtX) technologies are essential for combating climate change and increasing energy self-sufficiency. This summary provides an overview of Finnish PtX research in recent years. The study was based on a bibliometric analysis and interviews and survey conducted for Finnish research institutions.



Category A
Research areas and processes within the hydrogen value chain

Category B
Research topics on Products, technologies and methods within the hydrogen value chain

Category C
Sub-categories and components of hydrogen value chain technologies and methods

Research status

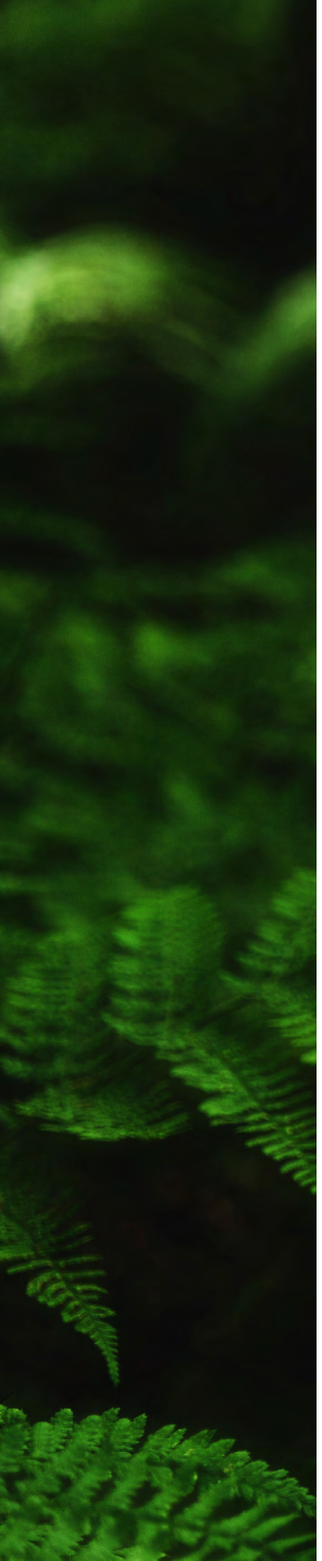
- Very strong
- Strong
- Established
- Somewhat
- Limited
- None

Legislative, material and safety perspectives

Legislation and politics
- Legislation and EU regulations
- Political actions and support
- Licensing
- Lock-in-effects of long-term agreements
- Soft law mechanisms

Raw materials and other materials
- Critical raw materials
- Raw material independence
- 3D printing
- Material characterization

Quality and safety
- Safety
- Quality



The state of Finnish hydrogen economy research

Power-to-X (PtX) technologies are essential for combating climate change and increasing energy self-sufficiency. This summary provides an overview of Finnish PtX research in recent years. The research is based on bibliometric analysis and interviews and survey conducted for Finnish research institutions.

The bibliometric analysis covered all Finnish articles about PtX technologies published between 2017–2023 as identified in the the Scopus database. Twelve Finnish universities and research institutes participated in the survey and interviews. These included Aalto University, University of Helsinki, University of Jyväskylä, Natural Resources Institute Finland, LUT University, University of Oulu, Tampere University, University of Turku, University of Eastern Finland, University of Vaasa, VTT Technical Research Centre of Finland and Åbo Akademi.

The study established a framework for delineating PtX economy-related research and created a structure for future research activities. The framework consists of three categories: main category A describes research areas and processes within the hydrogen value chain. Category B contains products, technologies and methods of the hydrogen value chain research. Finally, the more detailed category C contains the subclasses and components of the hydrogen value chain technologies and methods.

Key findings

The focus of Finnish PtX research lies in the PtX economy, particularly in the study of energy systems. Environmental and sustainability aspects, especially climate change, are key research topics, often studied together with energy system integration and concepts. Popular topics also include renewable hydrogen production through electrolysis, as well as carbon capture from industrial sources. Additionally, research on e-methanol within Power-to-Liquid (PtL) technologies is well established. Research into hydrogen storage, the utilization of carbon dioxide, and heat generated from hydrogen production side streams is also well developed. The results indicate that legislative and materials research are significant areas in Finnish PtX research. Legislative research focuses on the PtX economy at a general level, while materials research emphasizes renewable hydrogen production and electrolysis technologies.

Future trends and gaps in research

There are numerous research gaps in Finland's PtX research. In terms of PtX economy, there are deficiencies in the research of energy system integration and concepts, energy transitions, value chains, business models, life cycle assessments, security of supply, infrastructure, hydrogen valleys, machine learning, artificial intelligence, and information technology. There are also gaps in environmental and sustainability aspects related to wealth creation, circular economy, biodiversity, land use, sustainability, and general acceptability.

In the production of renewable hydrogen, there are shortcomings in the research of photosynthesis, solar hydrogen, PEM, AEM, and SOEC technologies, power electronics, and methane pyrolysis. There is little research on carbon dioxide capture, both from direct air and industrial sources, particularly from biogenic sources. Less studied topics concerning carbon dioxide include its storage and transportation.

There are many research gaps regarding hydrogen. Its utilization has mainly been studied in the context of heat production, where heat generated from hydrogen production is captured and utilized. However, there are still research gaps in areas such as electricity, fuel cells, gas turbines, and internal combustion engines. There is no research on hydrogen transportation regarding compression, pipelines, or maritime transport. In hydrogen storage, there is no research on the storage of gases, liquids, and metals, nor on compression. Research on hydrogen embrittlement is also limited. Regarding by-products of hydrogen production, research on solid carbon, oxygen, and nitrogen is lacking.

Research on PtX technologies is limited, particularly in PtL technology regarding e-fuels, PtG technology regarding e-ammonia and e-methane, and PtM technology regarding e-food and e-cement. There are deficiencies in application areas such as sustainable transportation systems, sustainable metals, chemical industry, agriculture, cement industry, manufacturing industry, process industry, paper and pulp industry, and electrical and thermal industries.

There are also significant research gaps in legislation, materials, and quality issues. Legislative and policy research has not addressed topics outside the PtX economy, which is a notable research gap. Additionally, quality and safety aspects are absent from Finland's PtX research. Material and raw material research could be expanded from renewable hydrogen production to carbon dioxide capture and hydrogen, including aspects like embrittlement, transportation, and storage

Summary

Finnish PtX research has developed greatly in recent years, although challenges remain to address. International cooperation plays an important part in improving the efficiency of research. Furthermore, collaboration between domestic research organizations and across different disciplines should be encouraged. Research results may also be used as a basis for national and international comparison, as well as to support the development of PtX technologies and PtX economy globally.

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