PHD POSTERS

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Norwegian research school
on hydrogen and hydrogen-based fuels

TA1: SOCIETY & ENVIRONMENT

RCS – GOVERNANCE

TA2: PRODUCTION

RCS

TA3: STORAGE & DISTRIBUTION

RCS

TA4: APPLICATIONS

RCS

TA5: SAFETY

RCS

Topical Area 2: Production

Name (affiliation)	Title of PhD project
Amalie Bisgaard Møller (UiO)	Modeling and control of PEM water electrolyzer systems
Ashika Dilshani Wackwella Gamage (UiS)	Hydrogen purification by pressure swing adsorption (PSA)
Leif Hertwig (UiB)	Transition metal-catalyzed synthesis of ammonia from air and water
Luyang Wang (UiO)	Minority bulk and surface proton conduction in ceramic positrodes for proton ceramic electrochemical cells
Marius Fredriksen (NTNU)	Modeling, optimization, and control of PEM electrolysis systems
Patrick Ewerhardt (UiO)	Characterization and simulations of patterned electrodes in proton ceramic electrochemical cells
Tomasz Skrzydlo (UiS)	Methane cracking for hydrogen production on metal- and non-metal-based catalysts
Willow Dew (NTNU)	Pd-based membranes for hydrogen and ammonia

Topical Area 3: Storage and distribution

Name (affiliation)	Title of PhD project
Anna Piazzi (NTNU)	Tank and thermal insulation design for safe and efficient liquid hydrogen storage
Frank Viveros Acosta (UiB)	Biogeochemical interactions in multiphase system (bacteria-rock-gas-water): Implications for underground hydrogen storage
Ingrid Marie Stuen (UiB)	Supply chain losses and quality degradation for large-volume hydrogen transport chains
Johan Raftevold Espelund (NTNU)	Computational fluid dynamics simulations of cryogenic storage tanks
Josef Kosler (UiO)	Magnetocaloric metal-oxides for efficient hydrogen liquefaction
Melito Soares (UiB)	Numerical Modelling and Simulation of Underground Hydrogen Storage: Capturing Multiphase Flow Hysteresis and Operational Dynamics in Porous Media
Sadegh Ahmadpour (UiS)	Hydrogen storage in porous media
Samad Ali Taj (UiT)	Sustainable Nano-Enhanced Bio-Based PCMs for Thermally Regulated Hydrogen Storage Systems
Victoria Dimuro Duckwitz (NTNU)	Hydrogen Supply Chain Resilience and Optimization for Decarbonizing Energy-Intensive Industries

Topical Area 4: Applications

Name (affiliation)	Title of PhD project
David Zilles (NTNU)	Experimental study of low-carbon fuel injection and combustion in marine engines
Giulia Fede (NTNU)	Integrated production and maintenance planning in hydrogen supply systems for industrial decarbonization: from system design towards Digital Twin-based operations
Muhammad Uzair Azhar (UiT)	Development and Optimization of a Hybrid Fuel Cell based Combined Heat and Power System
Sahra Ahmed (UiO)	Design of MOF-based single-atom catalysts for CO_2 hydrogenation
Qingqing Shao (UiO)	Hydroxide-ion Conducting MOFs for Alkaline Fuel Cells

Topical Area 5: Safety

Name (affiliation)	Title of PhD project
Abhishek Subedi (NTNU)	Improved modeling of socio-technical systems for hydrogen value chain
Anne Marie Lande (USN)	Mitigation of hydrogen explosions
Dikshya Bhandari (UiS)	Identifying and Mitigating Risks in Hydrogen Energy for Safer Integration
Farhana Yasmine Tuhi (NTNU)	Reliability prediction for PEM water electrolyzer
Kangxue Zheng (UiB)	Mitigation hydrogen explosions by chemical inhibition – Experiments and simulations
Lucie Pratabuy Tran-Quang (UiB)	Hydrogen Explosions in Complex Geometries: Risk & Knowledge
Nicolas Dobler (NTNU)	Model Predictive Control for Safeguarding Water Electrolysis
Petar Bosnic (USN)	Deflagration-to-Detonation Transition in Hydrogen-Air Mixtures for Explosion Safety
Sudesh Rathnayake (UiB)	PhD project on hydrogen safety: modelling hydrogen explosions in complex geometries with an open-source PDR model

Topical Area 2: Production

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Amalie Bisgaard Møller (UiO)	Modeling and control of PEM water electrolyzer systems
Ashika Dilshani Wackwella Gamage (UiS)	Hydrogen purification by pressure swing adsorption (PSA)
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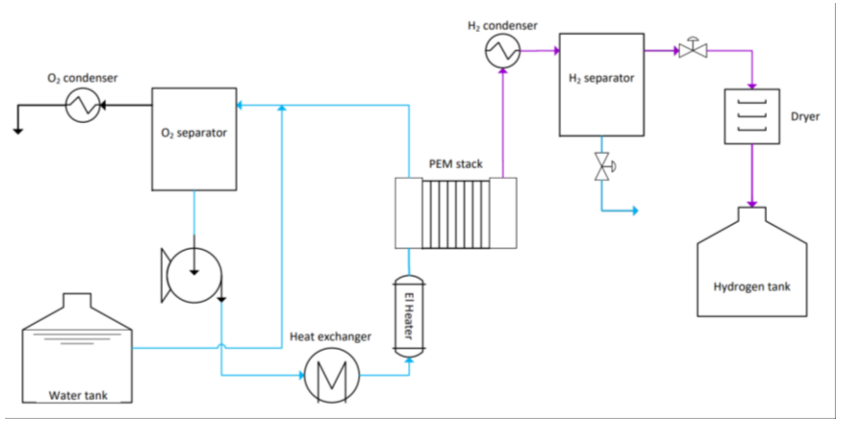
Willow Dew (NTNU)	Pd-based membranes for hydrogen and ammonia

Modeling and Control of PEM Water Electrolyzer Systems

Amalie Bisgaard Møller

Affiliation: Department of Technology Systems, University of Oslo & Hydrogen Department, Institute for Energy Technology

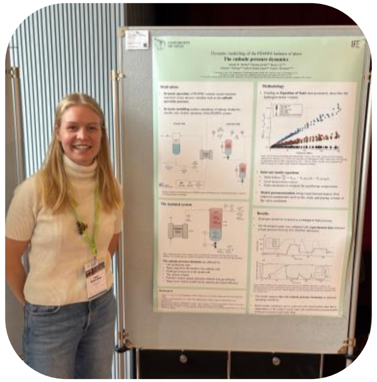
Related projects: REHSYS-project [REHSYS - IFE]



2019-2022: Bachelor's degree in Chemical Engineering, DTU

2022-2024: Master's degree in Renewable Energy Systems, UiO

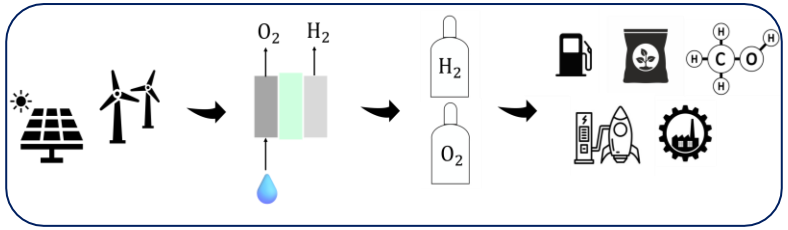
2024-2027: PhD Research Fellow, UiO & IFE



Introduction

Green hydrogen can be produced from water electrolysis powered by renewable energy. The variability of renewable energy is a challenge for electrolyzer plants, as it leads to fluctuating process conditions.

Dynamic process modeling can be used as a tool to analyze and optimize the operation of electrolyzer plants under such conditions. By using a dynamic process model, different control designs and operating strategies can be tested and evaluated.



Estimated progress of the PhD project:

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Primary objective

- Optimize operation of industrial scale PEM water electrolysis systems coupled with wind and solar power

Secondary objectives

- Develop a dynamic model of an industrial scale PEM water electrolyzer plant to describe the transient behavior of the process variables
- Develop different controllers and operating strategies that can improve system efficiency and safety

Publications

- A. B. Møller, T. Holm, B. Lie, Ø. Ulleberg, I. Llamas-Jansa, and G. Mirlekar, "Modeling the Dynamics of the Proton Exchange Membrane Water Electrolyzer Pressure," IFAC-PapersOnLine, vol. 59, no. 29, pp. 84–89, 2025, doi: 10.1016/j.ifacol.2025.12.186.

Hydrogen Purification by Pressure Swing Adsorption (PSA)

Ashika Dilshani Wackwella Gamage

Affiliation(s): University of Stavanger, PhD Candidate

Related projects: *HyValue*

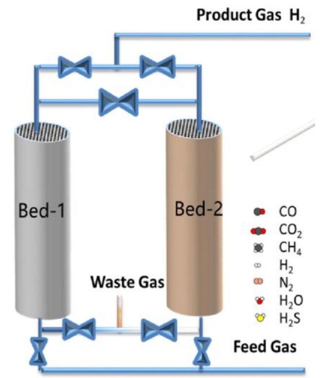
Supervisor: Assoc Prof Sachin Chavan

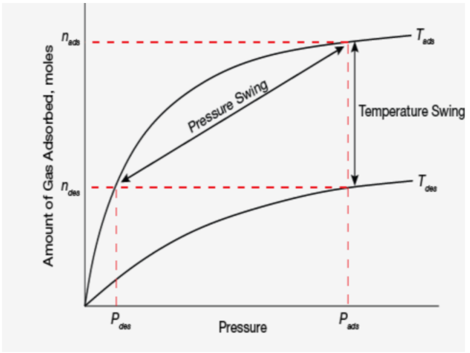
- Masters in Chemical NanoEngineering (Erasmus Mundus)
- B.Sc. in Chemical and Process Engineering.

Introduction

- Most of the global hydrogen demand is currently met through Steam Methane Reforming.
- Achieving high purity H_2, remains a significant challenge.
- **Aim** is to find the best adsorbent for H_2 purification to improve hydrogen purity, recovery, and optimize PSA process parameters.

PSA Operating Principle





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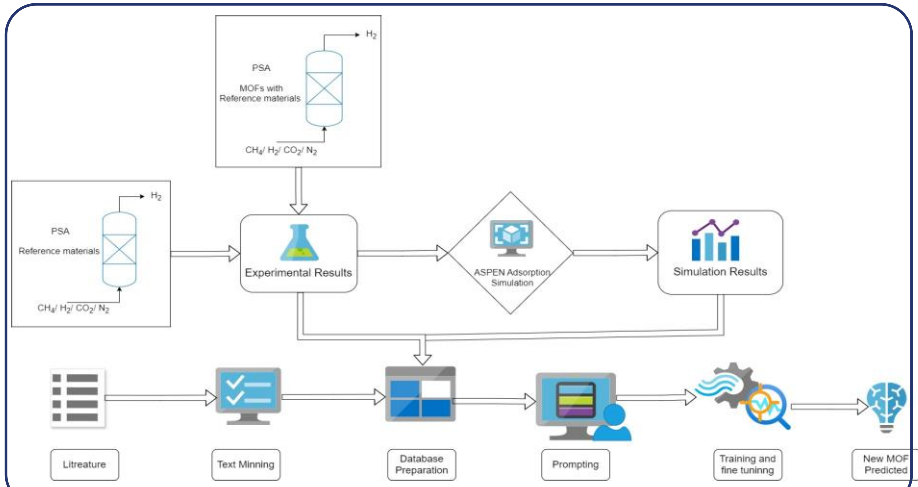
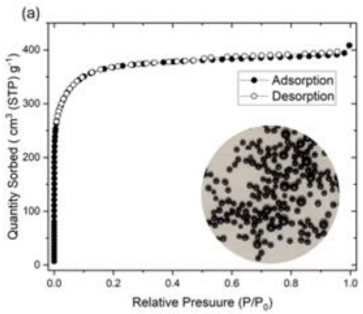
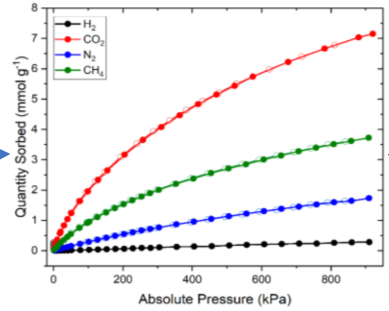
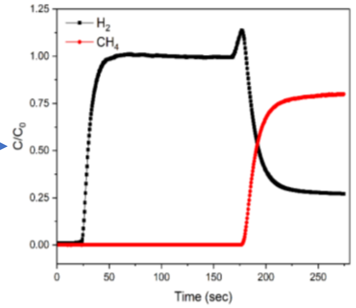




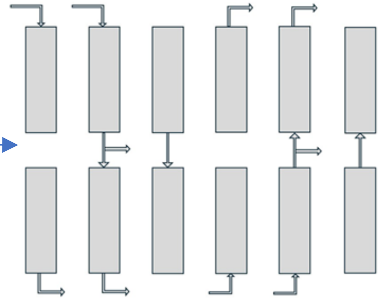
Adsorbent characterization



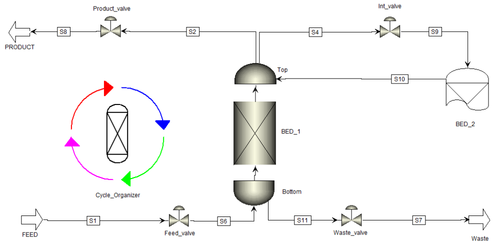
Adsorption Isotherms



Breakthrough Curves



PSA Cycles



Aspen Simulation

Publications (Planned)

- Activated carbon for hydrogen purification.
- $CALF-20$ for $CO2$ capture and hydrogen purification.

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Universitetet i Stavanger

HyValue

Transition metal-catalyzed synthesis of ammonia from air and water

Leif Hertwig

Affiliation = University of Bergen (UiB)

Related projects: *FME HyValue*

UiB ('23 - present)

PhD Candidate

University of Heidelberg ('19 - '22)

M.Sc. Chemistry

University of Heidelberg ('16 - '19)

B.Sc. Chemistry

Estimated progress of the PhD project:

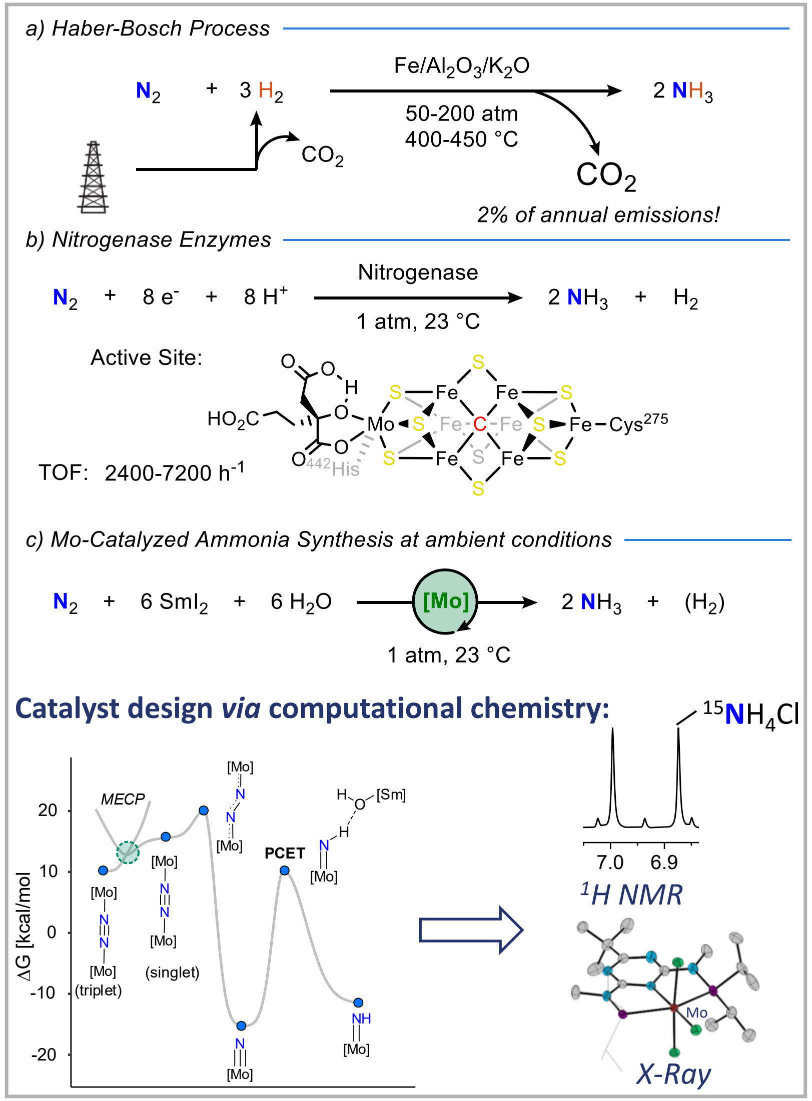
Just started ... **< 50 %** **> 50 %** **Almost done ☺**

Introduction

Ammonia is a promising carbon-neutral energy source, yet its current production via the Haber-Bosch process is highly energy-intensive, relying on hydrogen feedstock. In nature, nitrogenase enzymes reduce atmospheric dinitrogen to ammonia under ambient conditions. Inspired by this, ammonia formation at enzymatic rates and ambient conditions was shown to be facilitated by Mo-catalysts in conjunction with SmI_2 as reductant, and water as proton source. Despite this remarkable reactivity, the underlying mechanism and catalyst-reductant synergy remain poorly understood. Gaining such insight is essential to guide the design of robust catalyst and enable future direct electrocatalytic dinitrogen reduction.

Objectives

- Development of highly active and robust catalysts suitable for large scale synthesis of green ammonia
- Elucidate the reaction mechanism of the catalytic dinitrogen reduction using high-accuracy quantum chemical calculations
- Identify activity-determining factors



Publications

- Activity-Determining Factors and Interplay between the Molybdenum Catalyst, Water, and Samarium Diiodide in Dinitrogen Reduction to Ammonia, *submitted*
- Bis(silylene)pyridine Molybdenum Complexes for N_2 Reduction to NH_3, *manuscript in preparation*

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The Research Council of Norway

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Minority bulk and surface proton conduction in ceramic positrodes for proton ceramic electrochemical cells

Luyang Wang

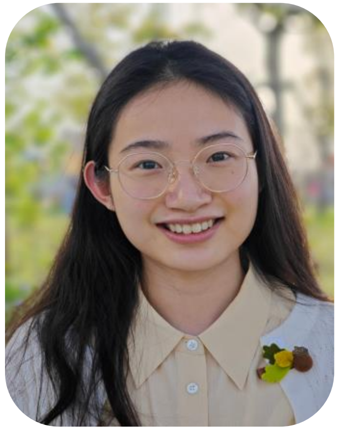
University of Oslo

Related projects: FME HYDROGENi

Electrochemistry, Truls Norby, Reidar Haugsrud, Einar Vøllestad.

Bachelor in Environmental Engineering - Huazhong University of Science and Technology, China.

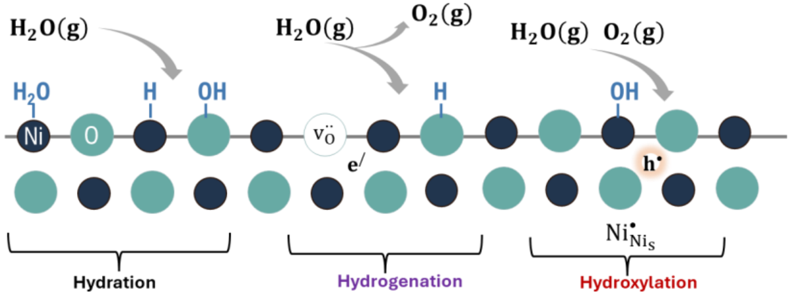
Master of Research in Green Chemistry: Energy and Environment - Imperial College London, UK.

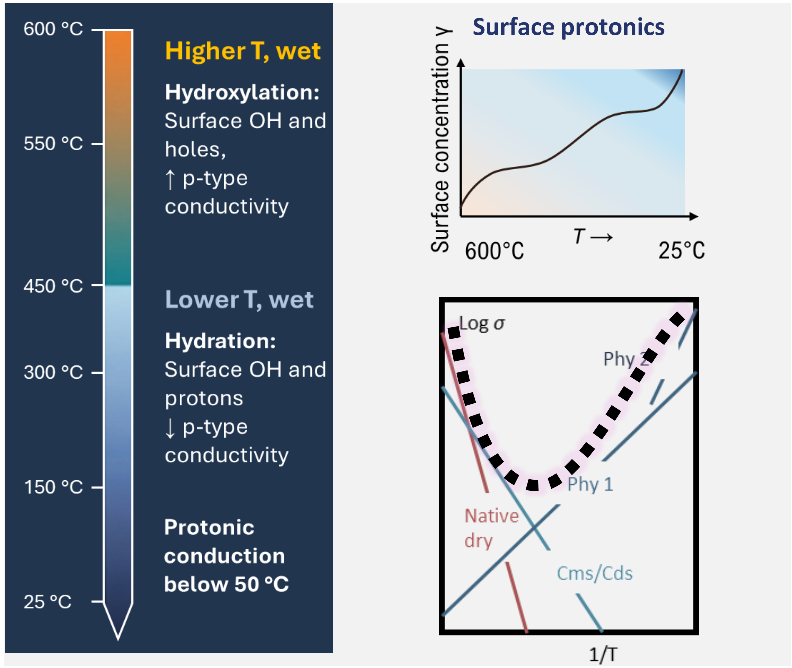


Introduction

The **positrode (*AMO_3*)** for proton ceramic electrochemical cells (PCECs) in **H_2** and NH_3 production, has a major contribution to the over-potentials and hence losses in the whole cell.

We want to establish theory and methodology for measuring **minority protonic** conductivities in ***electronic conductors.***





Primary objective

- Proton concentration and migration in the bulk and on surfaces of oxides.

Secondary objectives

- H_2O effects on oxides' p-type conduction.
- Theoretical model of water adsorption.

Estimated progress of the PhD project:

Just started ...	< 50 %	> 50 %	Almost done ☺

Manuscripts on

- Hydroxylation and p-type conduction on NiO
- NiO thin film on interdigitated electrode (IDE)
- Surface protonics with blocked electronic conduction by NiO/CeO_2.

Modeling, Optimization, and Control of PEM electrolysis systems

Marius Fredriksen

Norwegian University of Science and Technology (NTNU)

Related projects: FME HYDROGENi

I am a Ph.D. student in the Process Systems Engineering group at NTNU, where I obtained my master's degree in Chemical Engineering in 2023. My days are spent writing, wrestling with unruly models, and supervising students.

Introduction:

The successful shift towards a hydrogen-based energy economy depends heavily on the efficiency and sustainability of the available hydrogen production methods. Among the promising technologies, water electrolysis with proton exchange membrane (PEM) electrolyzers stands out for its high energy efficiency and flexibility. However, as renewable energy sources such as wind and solar are highly transient, proper control is crucial to improve stack performance, extend lifespan, and meet critical safety constraints.

Primary Objective:

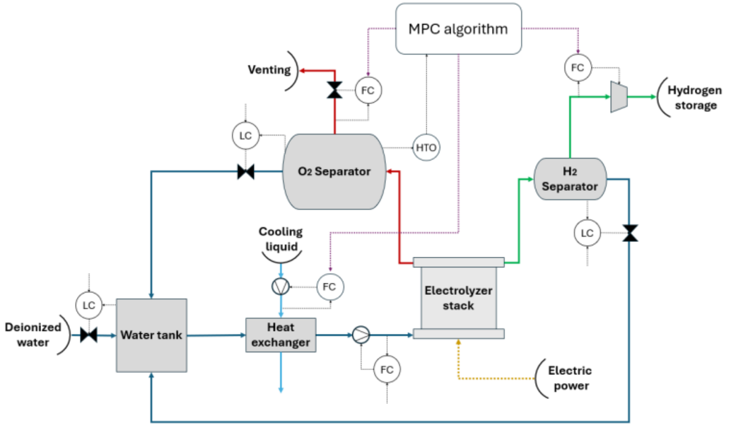
- Develop control strategies for PEM electrolyzer systems

Secondary Objectives:

- Develop a dynamic model for PEM stacks
- Study optimal operating conditions

Current activities:

- Investigating the optimal operating regime of **multi-stack** PEM systems and suitable control structures
- Developing **model predictive control (MPC)** for PEM single-stack systems. Using power forecasts to proactively mitigate safety risks, such as the HTO ratio



Estimated progress of the PhD project:

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Publications

- *Advanced Regulatory Control Structure for Proton Exchange Membrane Water Electrolysis Systems.* Systems and Control Transactions (SCT) (2025)
- *Model Predictive Control of bioreactors based on a reformulation of dynamic metabolic network models.* Computer-aided chemical engineering (2024)

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HYDROGENi

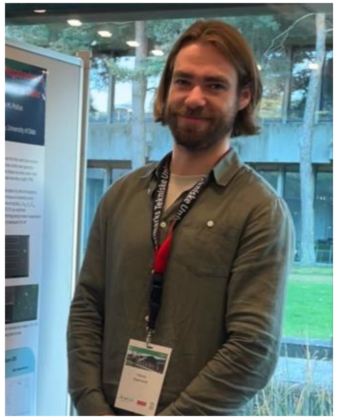
NTNU
Department of Chemical Engineering
Norwegian University of Science and Technology

Characterization and simulations of patterned electrodes in proton ceramic electrochemical cells

Patrick Ewerhardt

University of Oslo, Department of Chemistry, Centre for Material Science and Nanotechnology

Related projects: FME HYDROGENi



PhD research fellow in the Group for Electrochemistry under the supervision of Jonathan Polfus at UiO

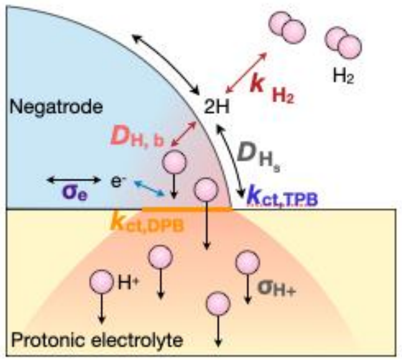
B.Sc. Nanoscience, University of Hamburg

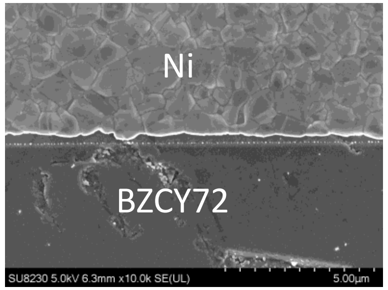
M.Sc. Nanoscience, University of Hamburg

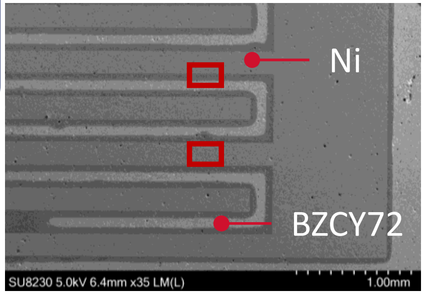
Introduction

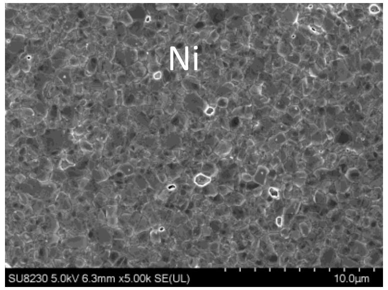
Proton Ceramic Electrochemical Cells (PCECs) are promising devices for converting and storing renewable energy via hydrogen. They can operate reversibly in electrolysis and fuel cell modes using solely hydrogen, oxygen and steam, but are capable of operating with other fuels as well.

However, current cells suffer from slow reaction kinetics – especially at the steam electrode (positrode) – and by poor durability. While most work focuses on improving existing and finding new materials, detailed studies of the underlying reaction pathways are rare. Therefore, we focus on fundamental mechanism and aim to identify limitations of operating cells using patterned electrodes with well-defined geometries.









Primary objective

- Fundamental understanding of the electrodes and their limitations

Secondary objectives

- Fabrication and characterization procedure for model electrodes
- Profound understanding of electrode materials through structural characterization

Results

- Electrochemical characterization (Impedance spectroscopy) of patterned electrodes indicates importance of bulk electrode pathway

Estimated progress of the PhD project:

Just started ... **< 50 %** **> 50 %** **Almost done ☺**

References

- Doppler, M. C., Fleig, J., Bram, M., & Opitz, A. K. (2019). Comparison of electrochemical hydrogen oxidation on different metal/ceramic model anodes and mechanistic implications. *Journal of Physics: Energy*, 1(3).
- Shin, Y., Kim, Y., Sanders, M., Harvey, S. P., Walker, M., & O'Hayre, R. (2022). Tuning the Co/Fe ratio in BaCoxFe0.8−xZr0.1Y0.1O3−δ, a promising triple ionic and electronic conducting oxide, to boost electrolysis and fuel cell performance. *Journal of Materials Chemistry A*, *10*(46), 24839–24853.

Methane cracking for hydrogen production on metal- and non-metal-based catalysts

Tomasz Skrzydlo

University of Stavanger

Introduction

This project aims to explore the activity of metal and non-metal (e.g., carbon) catalysts for hydrogen production from methane cracking. This investigation will also look into fine-tuning the solid carbon product type by judicious choice of catalyst compositions and the reaction conditions. The methodology consists of a series of experimental investigations, encompassing catalyst design and synthesis, catalyst characterization, catalyst performance evaluation on their effects on the final product and reaction process, mechanistic exploration, as well as carbon product characterization.

Primary objective
- Determine which type of the catalyst is most efficient for the catalytic cracking of methane

Secondary objectives
- Tuning metal- and carbon-based catalysts to produce carbon nanotubes as product with specific electrical properties
- Optimization of reaction conditions for scalability

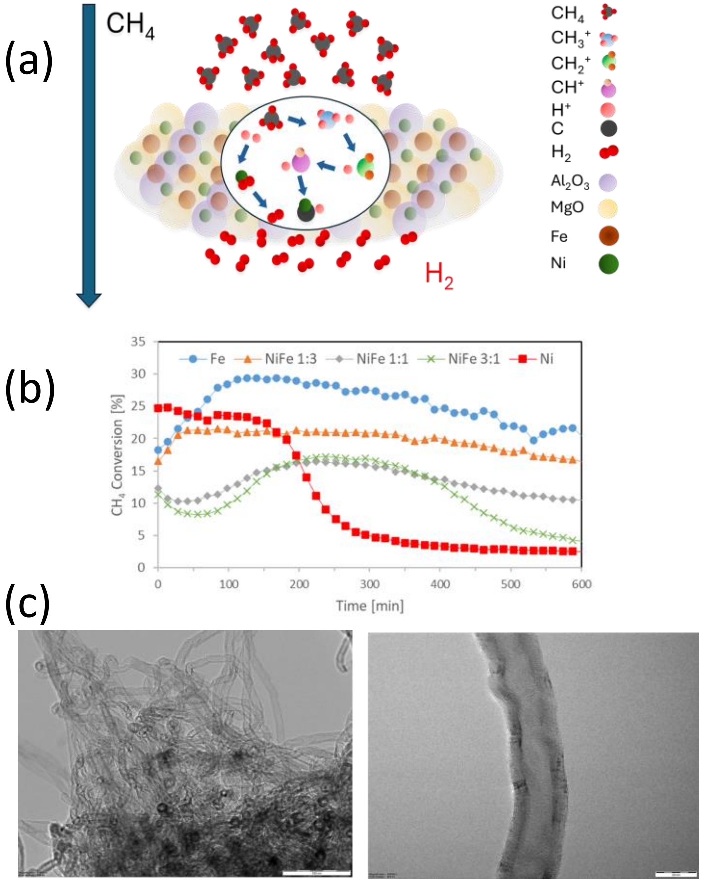
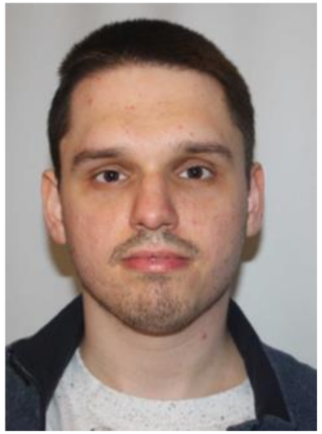


Figure 1. (a) general scheme of reaction, (b) CH4 Conversion of diffrent catalysts, (c) TEM images of produced carbon nanotubes

- Bachelor's degree (B. Tech) in Chemical engineering from Silesian University of Science and Technology, Poland
- Master's (Msc) degree in Chemical catalysis from Norwegian University of Science and Technology (NTNU), Norway
- Currently pursuing PhD in Hydrogen Production from University of Stavanger (UiS)



Estimated progress of the PhD project:

Just started ... **< 50 %** **> 50 %** **Almost done ☺**

References
- Muradov, N.: Hydrogen via methane decomposition: an application for decarbonization of fossil fuels. International Journal of Hydrogen Energy. 26, 1165–1175 (2001). https://doi.org/10.1016/S0360-3199(01)00073-8
- Ahmad, A., Hamdani, I.R., Srinivasakannan, C., Al Shoaibi, A., Hossain, M.M.: Catalytic cracking of methane to hydrogen and carbon: Scale-up perspective. International Journal of Hydrogen Energy. 54, 1212–1230 (2024). https://doi.org/10.1016/j.ijhydene.2023.12.042

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NORCE Norwegian Research Centre AS

The Research Council of Norway

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University of Stavanger

Pd-based membranes for hydrogen and ammonia

Willow Dew

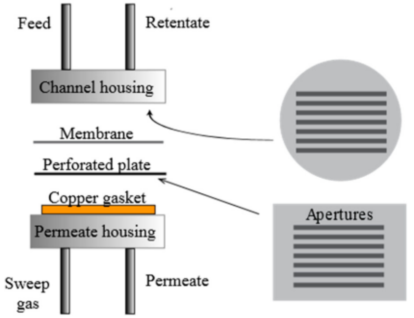
Affiliation(s) = Norwegian University of Science and Technology (NTNU)

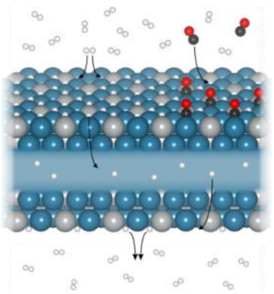
Related projects: *FME Hydrogeni*

PhD Candidate, Department of Chemical Engineering, NTNU, Norway

Education
- MSc. in Science Technology, Aalto University, Finland
- MSc. in Engineering, Taltech, Estonia
- MSc. Biology AgroSciences, URCA, France
- BSc. In Chemical Engineering, University of Alberta, Canada

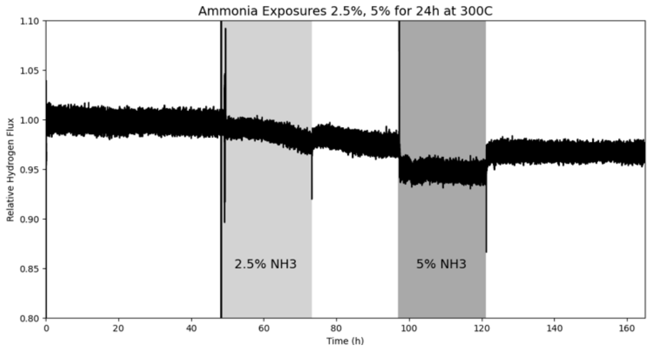
Introduction
- To address distribution challenges in the development of hydrogen systems, ammonia is regarded as a high-potential carrier.
- While this solution would improve economic and safety considerations of hydrogen transport, it requires efficient separation and purification of hydrogen prior to end use.
- Palladium-silver (Pd-Ag) membranes have been shown to separate H_2 from gas mixtures with high purity





Primary objective
- Investigate performance and stability of Pd-Ag membranes for hydrogen separation when exposed to ammonia

Secondary objective
- Improve understanding of Pd-Ag membrane surface changes (adsorption, segregation) in presence of impurities



Estimated progress of the PhD project:

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Publications

- Peters T, Caravella A. Pd-Based Membranes: Overview and Perspectives. Membranes (Basel). 2019 Feb 1;9(2):25. doi: 10.3390/membranes9020025. PMID: 30717272; PMCID: PMC6410063.
- Vicinanza, Nicla & Svenum, Ingeborg-Helene & Næss, Live & Peters, T.A. & Bredesen, Rune & Borg, Anne & Venvik, Hilde. (2015). Thickness dependent effects of solubility and surface phenomena on the hydrogen transport properties of sputtered Pd77%Ag23% thin film membranes. Journal of Membrane Science. 476. 602-608. 10.1016/j.memsci.2014.11.031.

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NTNU

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Topical Area 3: Storage and distribution

Name (affiliation)	Title of PhD project
Anna Piazzi (NTNU)	Tank and thermal insulation design for safe and efficient liquid hydrogen storage
Frank Viveros Acosta (UiB)	Biogeochemical interactions in multiphase system (bacteria-rock-gas-water): Implications for underground hydrogen storage
Ingrid Marie Stuen (UiB)	Supply chain losses and quality degradation for large-volume hydrogen transport chains
Johan Raftevold Espelund (NTNU)	Computational fluid dynamics simulations of cryogenic storage tanks
Josef Kosler (UiO)	Magnetocaloric metal-oxides for efficient hydrogen liquefaction
Melito Soares (UiB)	Numerical Modelling and Simulation of Underground Hydrogen Storage: Capturing Multiphase Flow Hysteresis and Operational Dynamics in Porous Media
Sadegh Ahmadpour (UiS)	Hydrogen storage in porous media
Samad Ali Taj (UiT)	Sustainable Nano-Enhanced Bio-Based PCMs for Thermally Regulated Hydrogen Storage Systems
Victoria Dimuro Duckwitz (NTNU)	Hydrogen Supply Chain Resilience and Optimization for Decarbonizing Energy-Intensive Industries

Tank and Thermal Insulation Design for Safe and Efficient Liquid Hydrogen Storage

Anna Piazzi

PhD Candidate at NTNU – Norwegian University of Science and Technology

Related project: *NICOLHy (Novel Insulation Concept for Liquefied Hydrogen Storage Tanks)*

- MSc in Energy Engineering – University of Bologna (2025)
- Master`s Thesis at NTNU "Thermo-mechanical Analysis of a Novel Insulation Concept for Liquid Hydrogen Tanks" (2024)

Introduction

The transition towards a climate-neutral energy system requires the development of **efficient and scalable liquid hydrogen (LH_2) storage** solutions. However, current large-scale stationary storage technologies rely on spherical double-walled vacuum-insulated vessels, with a maximum capacity of approximately 4,700 m^3.

The scalability of these systems is limited by **long construction times and low failure tolerance**. This highlights the need to increase storage capacities while introducing safer and more efficient insulation systems.

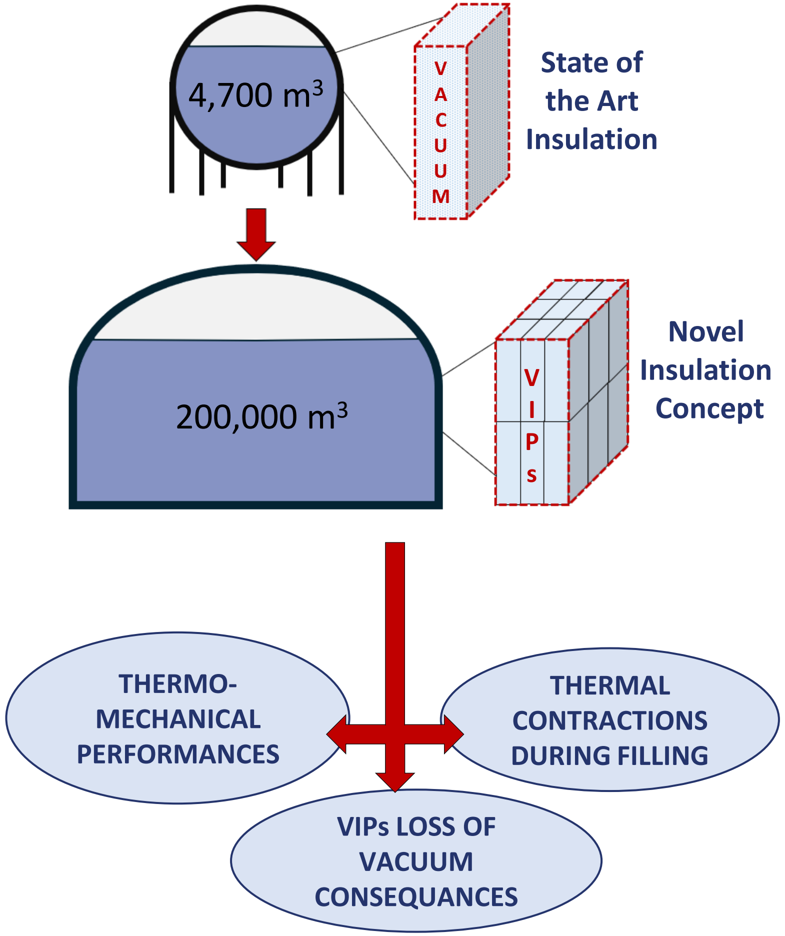
This PhD project is conducted within the European project NICOLHy, which investigates **novel insulation concepts based on Vacuum Insulation Panels** (VIPs) to enable large-scale LH_2 storage systems, targeting capacities up to 200,000 m^3 for stationary applications while limiting boil-off losses to 0.1% mass per day. The research focuses on the modelling and assessment of the thermo-mechanical performance of these novel insulation systems, while accounting for safety aspects related to insulation degradation and failure scenarios.

Primary objective

To model the **thermo-mechanical behavior** and investigate **safety-related aspects** of novel insulation systems for large-scale LH_2 storage tanks using numerical tools (FEA and CFD).

Secondary objectives

- Model the structural response and investigate the reliability of the insulation system during operation, including filling phases and thermal contraction effects.
- Analyse the insulation conditions and accidental scenarios (e.g., partial loss of vacuum within the insulation system).
- Support the benchmarking and comparison of alternative insulation concepts within the NICOLHy project.



Estimated progress of the PhD project:

Just started ...	< 50 %	> 50 %	Almost done ☺
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Publications

- A. Campari, A. Piazzi, E. Salzano, F. Ustolin - ***"Thermo-mechanical assessment of a novel insulation concept for liquid hydrogen tanks"*** (2025, International Conference on Cryogenics)
- A. Piazzi, I. De Fazio, F. Ustolin - ***"Benchmarking of Novel Insulation Concepts for Liquid Hydrogen Storage Tanks"*** (2026, Submitted for Esrel)

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NTNU
Kunnskap for en bedre verden

NICOLHy

Biogeochemical interactions in multiphase system (Bacteria-Rock-Gas-Water): Implications for underground hydrogen storage

Frank Viveros Acosta

UiB. University of Bergen.

HyDra - Diagnostic tools and risk protocols to accelerate underground hydrogen storage.

BSc. Petroleum Engineering

MSc. Chemical Engineering

Introduction

Hydrogen (**H_2**) has emerged as a promising **energy vector** and alternative fuel. Despite its high gravimetric energy density, its **low volumetric energy density** limits large-scale surface storage, making underground hydrogen storage (**UHS**) an attractive solution.

However, UHS promotes **biogeochemical** interactions. Indigenous **microorganisms** can use **H_2** as an **electron donor** and surrounding **minerals** as **electron acceptors**, activating their metabolic pathways. This process can result in the formation of **by-products** that reduce the **purity** of the H_2 and alter the **petrophysical** properties of the porous medium initially.

Publications.

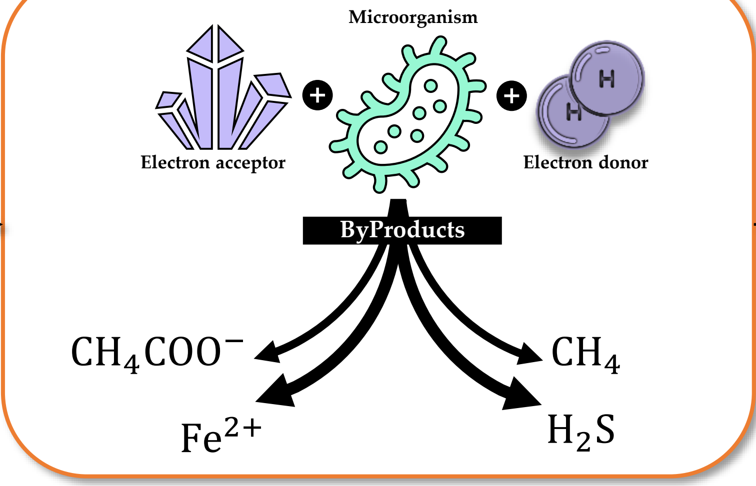
- **Viveros, F. E.**, Et al. (2024). *Hydrogen storage in depleted gas reservoirs using methane cushion gas: An interfacial tension and pore scale study.* Journal of Energy Storage, 98, 113110.
- **Viveros, F. E.**, Et al. (2025). *Biogeochemical Interactions and Their Role in European Underground Hydrogen Storage.* Minerals, 15(9), 929.
- Zapata, K., **Viveros, F. E.**, Et al. (2026). *Immobilized Nostoc sp. on biopolymers for enhanced CO_2 photoconversion.* Molecular Catalysis, 589, 115571.

HyDRA

WorkPackage

- WP1
- ⋮
- WP7 Microbial Impact
- WP8 BioGeoChemical
- ⋮
- WP12

Risk identification and management guidelines



Estimated progress of the PhD project:

< 50%

i. Evaluate the feasibility of UHS coupled biogeochemical in a multimineral system.
ii. Assess the influence of microbial activity, brine chemistry, rock type, and thermodynamic conditions.
iii. Investigate hydrogen behavior across pore, core, and meter scales.

Objectives

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CSSR

Supply Chain Losses and Quality Degradation for Large-Volume Hydrogen Transport Chains

Ingrid Marie Stuen

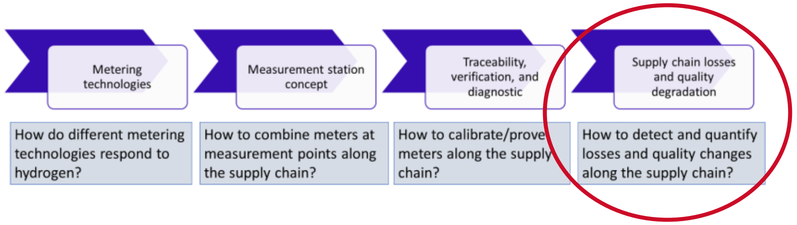
Affiliation: *University of Bergen*

Related projects: HyMe, HyValue

- PhD candidate in measurement science at the Department of Physics and Technology
- Background in physics

Introduction

My PhD project is part of the HyMe, "Reliable metering for the hydrogen supply chain", research project. Our focus is on metering in large-volume supply chains with transfer of hydrogen gas in pipelines. My work focuses on internal leak detection methods and quality changes for hydrogen gas grids.



Primary objective

- Develop methods to detect losses and quality changes along hydrogen supply chains

Secondary objectives

- Investigate effects of uncertainty correlation effects on detection limits for mass balance
- Simulate pressure drop from leaks in hydrogen gas grids

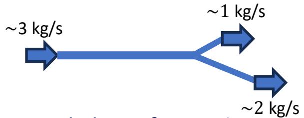
Mass balance

- Based on fiscal flow (and quality) measurements
- Simple calculation balancing input and output amounts of gas
- The detection limit of a potential leak is based on the uncertainty of the calculated mass balance
- Total uncertainty depends on correlations in time and between meters

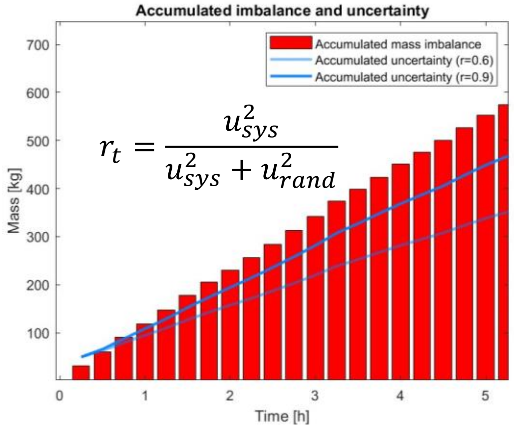
Pressure point analysis

- Monitor pressure at fiscal measurement points
- A pressure drop at one or several points may indicate a leak
- Detection limits based on pipeline simulations and measurement uncertainties

Case



- Imbalance from 1% metering error in source
- Detection limit dependent on time correlation factor, r_t
- r_t defined by systematic, u_{sys}, and random uncetainty, u_{rand}



Estimated progress of the PhD project:

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Conference contributions

- Measurement Uncertainty and Time Correlation Effects on Mass Balance Thresholds for Detecting Leaks in Hydrogen Networks, Mathmet 2025
- Monitoring of hydrogen gas networks: pressure and mass balance, EHEC 2026

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NORCE Justervesenet TotalEnergies Funded by The Research Council of Norway equinor GASSCO HyValue UNIVERSITETET I BERGEN

Computational Fluid Dynamics Simulations of Cryogenic Storage Tanks

Johan R. Espelund

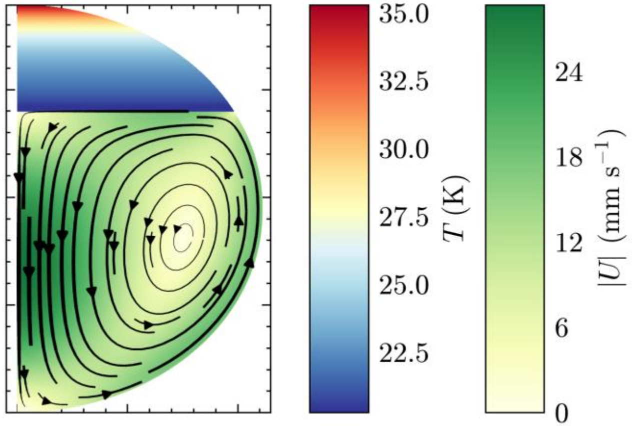
Norwegian University of Science and Technology,
Sintef Energy Research
Supervisor: Corinna Schulze-Netzer (NTNU)
Co-supervisors: Åsmund Ervik (Sintef), Svend Tollak Munkejord (Sintef), Luca Brandt (Politecnico di Torino)

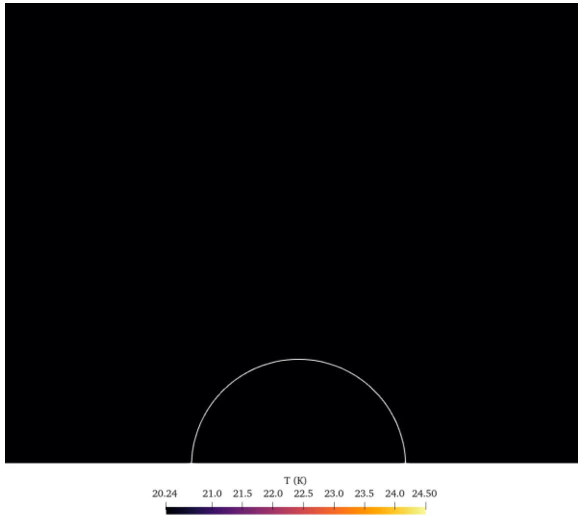
Introduction

To minimize boil-off losses during large-scale storage and transport of liquid hydrogen (LH_2), accurate prediction of evaporation rates and boil-off temperatures is essential.

In my PhD, I use Computational Fluid Dynamics (CFD) to simulate how natural convection influences evaporation and thermal stratification inside LH_2 tanks. Heat ingress through the tank insulation drives convective flow in the gas phase, enhancing heat transfer to the liquid surface and accelerating evaporation.

These flows are highly transient, can transition to turbulence, and span a wide range of spatial and temporal scales. Due to the cost and safety challenges of detailed LH_2 experiments, CFD can be a valuable tool to predict flow behaviour under various conditions.





- 2022: MSc Mechanical Engineering (NTNU) – CFD simulations of heat exchangers
- 2022-2023: Master of Science at Sintef Energy Research (CFD, heat exchanger modelling)

Estimated progress of the PhD project:

Just started ... | < 50 % | > 50 % | Almost done ☺

Primary objective

- Use CFD (OpenFOAM) to predict evaporation and thermal stratification in LH_2 storage tanks
- Use two-phase direct numerical simulations (DNS) to model phase change phenomena in LH_2 at smaller scales

Secondary objectives

- Use CFD to improve accuracy of heat transfer correlations in thermodynamic models of larger tanks

Publications

- Espelund, J., Gjennestad, M., Blakseth, S., & Netzer, C. (2024, November). Assessment of turbulence models for evaporation and stratification in cryogenic storage tanks. In *APS Division of Fluid Dynamics Meeting Abstracts* (pp. J32-001). **(conference presentation)**
- **Subittmed to IJHMT:** *Impact of buoyancy production and tank thermal modelling in RANS simulations of liquid hydrogen storage tanks*

Magnetocaloric Metal-oxides for Efficient H_2 Liquefaction

Josef Kosler

Affiliations: University of Oslo, Institute for Energy Technology

Related projects: HYDROGENi

Research interests: energy materials, structural characterization and optimization, hydrogen liquefaction, magnetocaloric materials

Background: Nanoscience and materials chemistry

Introduction

- Storage and transportation of H_2 are key challenges in the hydrogen value chain.
- Liquefaction by cooling down to 20 K (-253 °C) is a promising solution, but highly energy intensive with today's technology.
- Magnetocaloric cooling uses magnetic materials and strong magnetic fields to achieve an up to 50 % higher efficiency.

Primary objective:

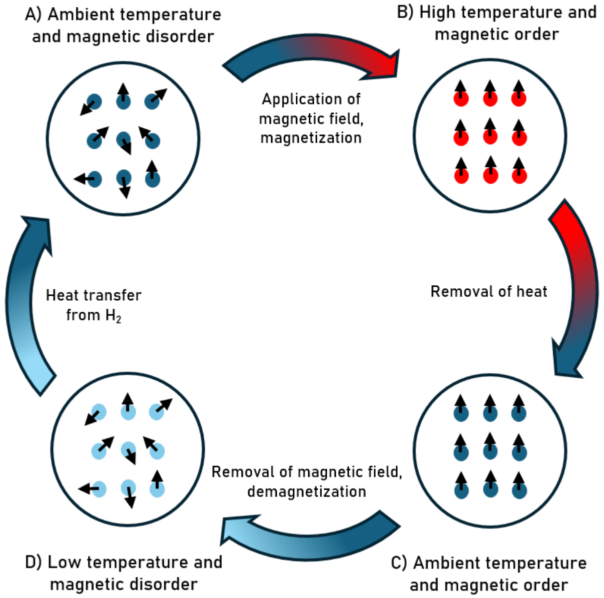
To identify and produce promising materials for magnetocaloric H_2 liquefaction

Secondary objectives:

- Identify design principles for magnetocaloric materials
- Optimize the $Ho_{1-x}Nd_xVO_3$ material class

Magnetocaloric cooling principles

- Transitions between ordered and disordered magnetic states are used to store and release thermal energy
- Application or removal of an external magnetic field is used to trigger these transitions, leading to cooling or heating of the material.



Estimated progress of the PhD project:

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Project future

- Investigating magnetocaloric properties in $Ho_{1-x}Nd_xVO_3$
  - Connect cooling properties with structure properties
  - Maximize cooling effect (J/kg) and working temperature range

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HYDROGENi

Numerical Modelling and Simulation of Underground Hydrogen Storage: Capturing Multiphase Flow Hysteresis and Operational Dynamics in Porous Media

Melito Soares

Affiliation(s): University of Bergen

Related projects: Centre for Sustainable Subsurface Resources (CSSR - NORCE)

- Master's degree in Mining & Geological Engineering from IST – University of Lisbon
- Currently a PhD student at the Department of Physics and Technology, University of Bergen

Ongoing Work:

- A Comparative Reservoir-Scale Evaluation of Relative Permeability Hysteresis Models for Underground Hydrogen Storage

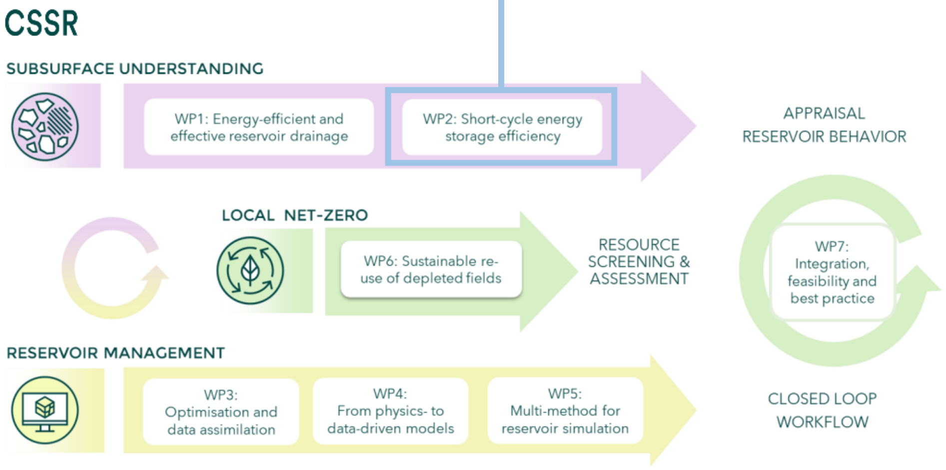
Estimated progress of the PhD project:

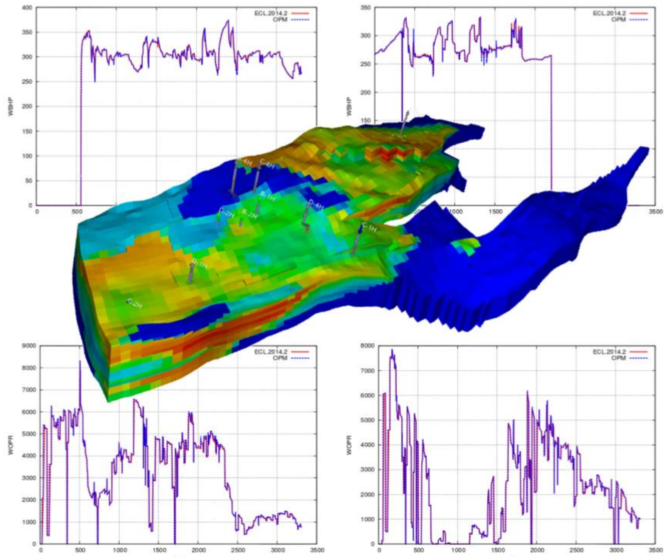
Just started ... < 50%

Introduction

Underground hydrogen storage (UHS) in geological reservoirs is a promising solution for balancing energy supply and demand. However, hydrogen's unique properties, along with its interactions with reservoir fluids, rocks and microbes, make its behaviour in porous media complex.

Key processes such as hysteresis, capillary trapping and multiphase flow significantly affect storage capacity and recovery, yet are often simplified or neglected in current models. As a result, reservoir-scale predictions remain uncertain, particularly under cyclic operations and in the presence of cushion gases (e.g., N_2, CH_4, CO_2).





Objectives

- Develop multi-scale models for hydrogen storage in porous reservoirs.
- Incorporate hysteresis and multiphase flow effects.
- Improve prediction and optimisation of UHS performance.

Hydrogen Storage in Porous Media

Sadegh Ahmadpour

Affiliation(s): PhD in University of Stavanger (UiS)

- Ph.D. Candidate in Underground Hydrogen Storage
- MSc. in Petroleum Engineering from UiS

Introduction

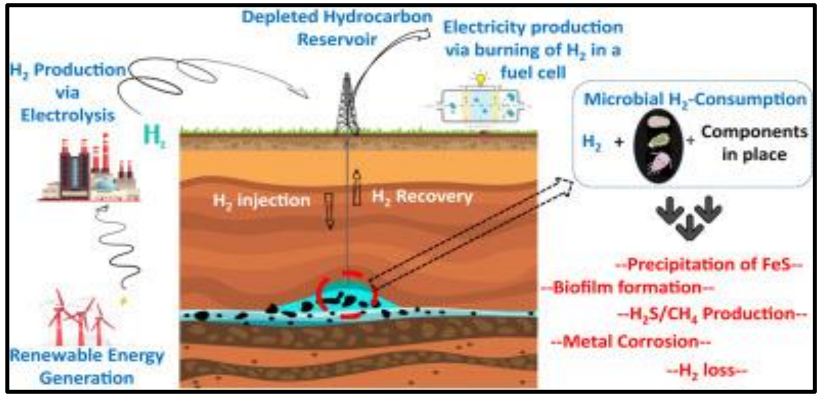
Storing hydrogen in depleted hydrocarbon reservoirs where the infrastructures are already built is a promising and safe solution to contribute to future hydrogen value chain. Porous geological settings can provide huge capacity for hydrogen storage. In order to store hydrogen in a safe and efficient way, the interaction of hydrogen with minerals, and residual fluids are necessary.

GUIDELINES

Existence of microorganisms without the need of light or oxygen in geological setting has created an opportunity for them to consume hydrogen by microbial activities. The products of these biochemical reactions, e.g., H_2S are undesirable and can be toxic and fatal. In addition, the reaction between pyrite (mineral) and dissolved hydrogen might occur at temperature above 100 °C leading to the production of H_2S in the storage site.

Size of hydrogen molecule is extremely small that might diffuse through caprocks, adjacent formations, or into the formation water. The diffusion of hydrogen in the formation water is the primarily mechanism for the geochemical and biochemical reactions. Diffusion of hydrogen in formation water combined with gravity force causes density driven convection mixing increasing hydrogen loss and the amount of dissolved hydrogen.

Coexistence of the hydrogen and cushion gases leads to the mixing and increase in hydrogen loss and impurity. This phenomenon is called mechanical dispersion which is intensified by the injection and production rate, and rick and fluid properties.



Primary objective

- Diffusion and Dispersion of Hydrogen
  - Evaluation of hydrogen loss through diffusion and dispersion
  - Evaluation of hydrogen loss through density driven convection mixing
- Geochemical Reactions
  - Investigation of the interaction between hydrogen and minerals

Publications

- Ahmadpour, Sadegh, Raoof Gholami, and Mojtaba Ghaedi. "Density driven flow in CO_2 storage sites: A new formulation for heterogeneous layered porous media." *Fuel* 381 (2025): 133721.
- Ahmadpour, Sadegh, and Raoof Gholami. "Hydrogen sulfide in underground hydrogen storage sites: Implication of thermochemical sulfate reduction." *Deep Underground Science and Engineering* (2025).
- Ahmadpour, S., Gholami, R., Ghaedi, M., & Blunt, M. J. (2025). An experimental study and mathematical formulation for hydrogen diffusion in water. Scientific Reports, 15(1), 44790.
- Ahmadpour, S., Gholami, R., & Ghaedi, M. (2026). A kinetic model for abiotic pyrite reduction in aqueous solutions under low temperature conditions. Gas Science and Engineering, 148, 205866.

Estimated progress of the PhD project:

Just started ...	< 50 %	> 50 %	Almost done ☺

University of Stavanger

University of Stavanger

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Sustainable Nano-Enhanced Bio-Based PCMs for Thermally Regulated Hydrogen Storage Systems

Samad Ali Taj

Affiliation(s):

PhD Candidate, IBEM

UiT The Arctic University of Norway

Research Interest:

Energy Storage Materials, Nanomaterials, Thermal Energy Storage,

Estimated Progress of the PhD Project:

Just Started	< 50 %	> 50 %	Almost Done ☺
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Primary Objective

To enhance heat transfer in metal hydride systems using nano-enhanced bio-based PCMs for efficient hydrogen absorption and desorption.

Secondary Objective:

-To synthesize and characterize waste-derived bio-based phase change materials.

-To incorporate nano-additives for improved thermal conductivity and heat transfer.

-To assess energy efficiency and reduction in external heating/cooling demand.

Key Features

-Biobased:

Waste derived, Low Cost, Biodegradable, Sustainable

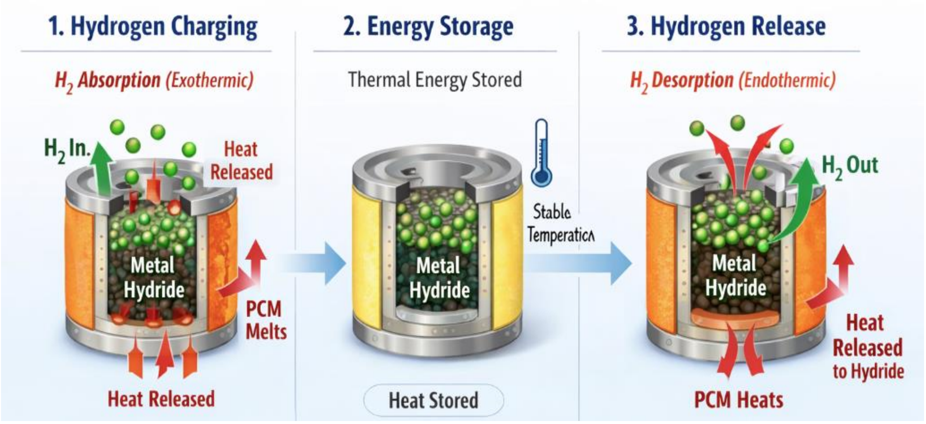
-Nano-Enhancement:

Improvement in Heat Transfer

-Hydrogen Synergy:

Reduce Energy Loss, Efficient Storage

Methodology



Deliverable Outcomes

-Improved hydrogen release kinetics in cold environments

-Reduced external energy requirement for storage and transport

-Sustainability assessment (biodegradability, cost, waste utilization)

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Norwegian Directorate for Higher Education and Skills

UiT The Arctic University of Norway

Hydrogen Supply Chain Resilience and Optimization for Decarbonizing Energy-Intensive Industries

Victoria Dimuro Duckwitz

Affiliation = *Norwegian University of Science and Technology (NTNU)*

Introduction

Energy-intensive industries (EIIs) face a structural imbalance in the energy transition:

- The mismatch: While variable renewable energy is intermittent, industrial demand is continuous and rigid.
- The solution: Low-carbon hydrogen could act as both a clean fuel and a feedstock, addressing production and demand mismatches.
- The problem: Current hydrogen infrastructure is in early development, and existing models often overlook system behavior under stress or disruption.
- The need: A holistic approach that integrates technical feasibility, economics, storage strategies, reliability, and safety.

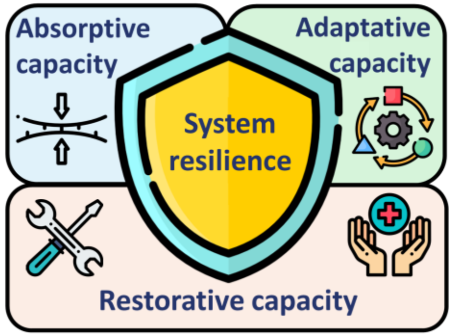
Research Objective

The primary goal is to develop an integrated decision-making framework for designing hydrogen supply and storage systems.

Featured Project:

HyTRIO

Tool for **R**esilience-**I**nformed **O**ptimization of **Hy**drogen Supply Chains

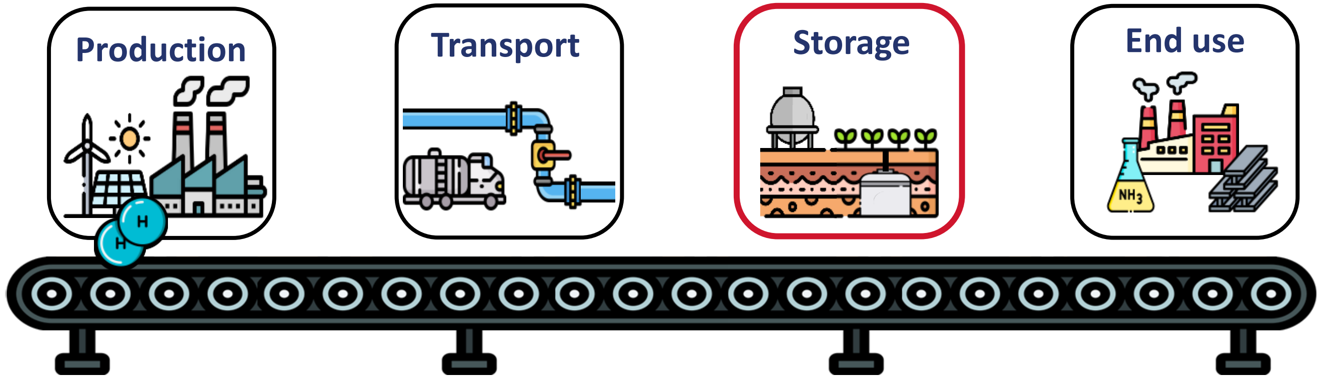


This project will bridge the gap between deterministic cost-minimization and real-world industrial risks.

Main objective

To develop and demonstrate a resilience-informed optimization methodology that embeds probabilistic failure behavior and epistemic uncertainty into the design of energy systems. This methodology will be validated using hydrogen supply chains for energy-intensive industries.

- ✓ Energy modelling
- ✓ Techno-economic assessment
- ✓ Stochastic optimizat.
- ✓ Reliability analysis
- ✓ LCA



PhD candidate at the Department of Mechanical and Industrial Engineering (NTNU) since June 2026.

Education:

- MSc. in Hydrogen Systems and Enabling Technologies, NTNU, Norway.
- MSc. in Energy Engineering, Politecnico di Milano, Italy.
- BSc. In Environmental Engineering, URJC, Spain.
- BSc. In Energy Engineering, URJC, Spain.

Estimated progress of the PhD project:

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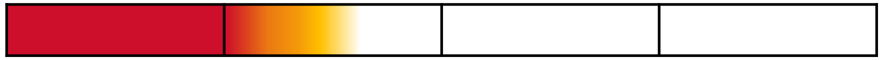


Publications

- Duckwitz, Victoria; Paltrinieri, Nicola; Kyaw, Khine. (2025) "Are Microbes Going to Eat My Investment?": an Economic Assessment of Microbial Activity in Underground Hydrogen Storage. *Chemical Engineering Transactions.* **DOI:** 10.3303/CET25119021
- Duckwitz, Victoria; Paltrinieri, Nicola; Kyaw, Khine. (2026). Strategic Risks in Underground Hydrogen Storage. *Journal of Physics: Conference Series.* **DOI** 10.1088/1742-6596/3195/1/012002

Ongoing work

- Duckwitz, Victoria; Sgarbossa, Fabio. (2026). Optimizing Hydrogen Supply Chains for Energy-Intensive Industries: A Cost–Efficient Framework. Submitted to *International Journal of Production Economics.*
- Duckwitz, Victoria; Paltrinieri, Nicola (2026). Integrating Resilience Metrics into Optimized Hydrogen Supply Chain Design. Accepted in the R.A.M.S. Europe Conference

Topical Area 4: Applications

Name (affiliation)	Title of PhD project
David Zilles (NTNU)	Experimental study of low-carbon fuel injection and combustion in marine engines
Giulia Fede (NTNU)	Integrated production and maintenance planning in hydrogen supply systems for industrial decarbonization: from system design towards Digital Twin-based operations
Muhammad Uzair Azhar (UiT)	Development and Optimization of a Hybrid Fuel Cell based Combined Heat and Power System
Sahra Ahmed (UiO)	Design of MOF-based single-atom catalysts for CO_2 hydrogenation
Qingqing Shao (UiO)	Hydroxide-ion Conducting MOFs for Alkaline Fuel Cells

Experimental study of low-carbon fuel injection and combustion in marine engines

David Zilles

Affiliation: NTNU, Institutt for marin teknikk (IMT)

Introduction

Ambitious goals of the International Maritime Organization envision a decarbonization of the international shipping industry until 2050. New synthetic fuels such as Ammonia (NH_3) and Methanol (CH_3OH) are promising options to reduce green-house-gas emissions from marine internal combustion engines. Their thermophysical properties deviate strong from conventional marine fuels resulting in strong cooling and slow reaction kinetics. These can be improved by dual fuel injection strategies, injecting small amounts of high reactive fuels as ignition and combustion promotion.

Primary objective

Determine dual fuel injection strategies supporting a retrofit of current marine engines with low-carbon NH_3 and CH_3OH (fuel-flexible).

Secondary objectives

- Identify injection parameters controlling combustion (main + pilot).
- Characterize various pilot fuels.
- Identify the maximum practical NH_3 and CH_3OH energy share for various pilot fuels to reduce ignition time and increase reliability of combustion.
- Develop a software tool predicting the ideal pilot and main spray interaction, validated with experimental data.

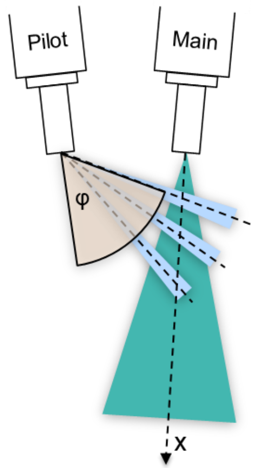


Fig.1: Spatial plume interaction controlled by pilot umbrella angle φ.

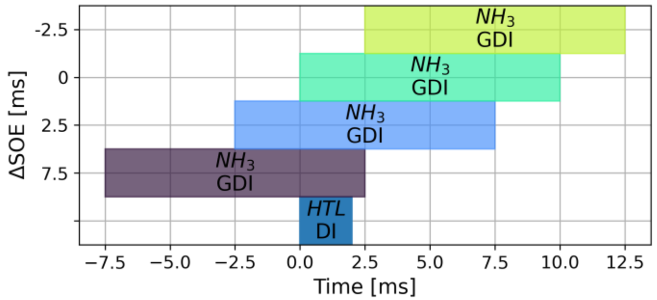
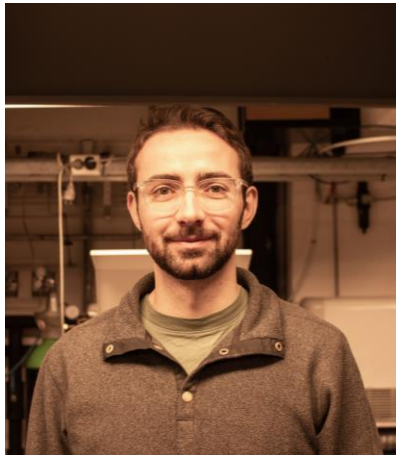


Fig.2: Temporal plume interaction ΔSOE – relative start of injection exemplary for HTL bio-fuel pilot and ammonia main.

Background in Automotive Engineering from TU Ilmenau, Germany. Specialization in internal combustion engines development and production.

Member of the ComKin work group at EPT, NTNU and HySchool.

Passion for green shift in industry, experimental design, Norwegian outdoors, road cycling and running.



Estimated progress of the PhD project:

Just started ... | **< 50 %** | **> 50 %** | **Almost done ☺**

Publications

Zilles, D., Emberson, D.R., 2026. Exploring Heat Release from Liquid Ammonia Injections Dual-Fueled with Heptane. Energy Fuels 40, 5346–5368. https://doi.org/10.1021/acs.energyfuels.5c06353

Zilles, D., Emberson, D.R., Castello, D., Achour, A., 2026. Heat release analysis of dual-fuel direct injected ammonia and HTL fuels. Fuel 419, 138870. https://doi.org/10.1016/j.fuel.2026.138870

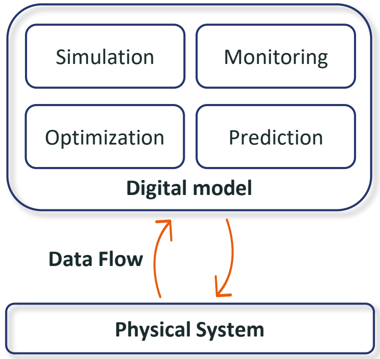
Integrated production and maintenance planning in hydrogen supply systems for industrial decarbonization: from system design towards Digital Twin-based operations

Giulia Fede

Norwegian University of Science and Technology (NTNU)

Introduction

Green hydrogen presents a promising solution for decarbonizing energy-intensive industries like glass, aluminium, and steel. The EU-funded initiative H2GLASS, which supports this research, aims primarily to demonstrate the feasibility of hydrogen adoption in the glass sector. However, transitioning to hydrogen comes with some challenges, including the lack of hydrogen-related infrastructure in manufacturing plants and the need to ensure a continuous and reliable hydrogen supply for industrial furnaces while maintaining safe operations. To facilitate this transition, Digital Twin (DT) technology has been identified as a valuable tool for supporting production and maintenance planning decisions. Given the strong interdependencies between these tasks, an integrated approach to decision-making can enhance overall performance. With its real-time synchronization capabilities and ability to provide a unified view of manufacturing processes, DT has the potential to improve collaborative and dynamic decision-making, ultimately enabling a more efficient transition to hydrogen-based manufacturing.



Digital Twin concept

Related projects: H2GLASS - advancing Hydrogen (H2) technologies and smart production systems TO decarbonise the GLass and Aluminium SectorS

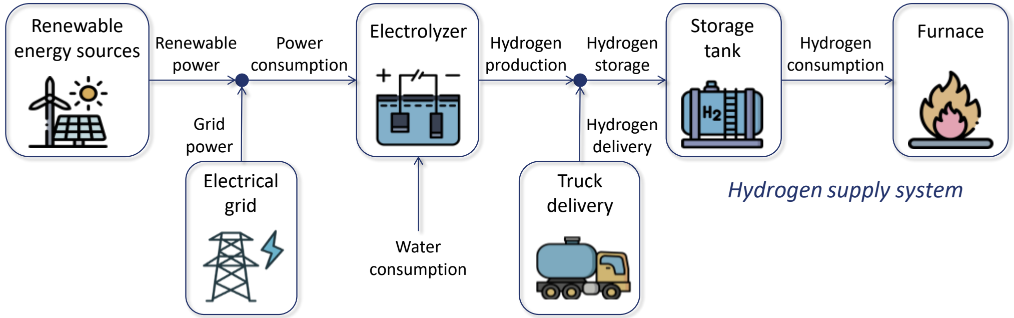
- *PhD candidate at the Department of Mechanical and Industrial Engineering (NTNU)*
- *MSc in Management Engineering - Analytics for Business at Politecnico of Milano (2021-2023)*
- *BSc in Management Engineering at Politecnico of Milano (2018-2021)*

Primary objective

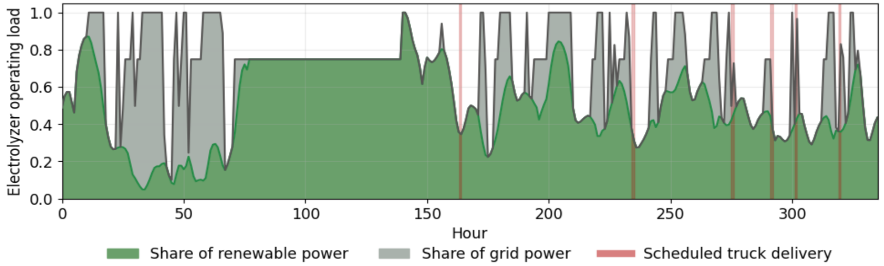
Investigate the benefits of using DT to support integrated planning of production and maintenance operations of hydrogen supply systems for industrial decarbonization

Secondary objectives

- Develop a multi-objective assessment framework guiding the design of hydrogen supply systems that considers production and maintenance performance indicators.
- Develop a simulation and an optimization model to support integrated planning and execution of production and maintenance operations in hydrogen supply systems.
- Develop a DT-based framework to support integrated planning of production and maintenance operations in hydrogen supply systems.



Hydrogen supply system



Optimal hydrogen supply system operations

Estimated progress of the PhD project:

Just started ... < 50 % > 50 % Almost done ☺

Relevant publications

- *G. Fede, F. Sgarbossa, N. Paltrinieri. (2024). Integrating production and maintenance planning in process industries using Digital Twin: A literature review. IFAC-PapersOnLine, 58 (19), 151-156. https://doi.org/10.1016/j.ifacol.2024.09.124*
- *G. Fede, F. Sgarbossa, D.F. Silva, G. Collina. (2025). A model-based approach to hydrogen supply scenarios for decarbonizing the glass melting process. IFAC-PapersOnLine, 59 (10), 178-183. https://doi.org/10.1016/j.ifacol.2025.09.032.*
- *G. Fede, G. Collina, A. Tugnoli, M. Bucelli, D.F. Silva, F. Sgarbossa. (2025). Hydrogen supply scenarios for the decarbonization of energy-intensive process industries considering costs, safety and environmental performance: A multi-objective model-based approach. International Journal of Hydrogen Energy, 175, 151373. https://doi.org/10.1016/j.ijhydene.2025.151373.*
- *G. Fede, F. Sgarbossa, D.F. Silva. (2026). Optimization of hydrogen supply operations for decarbonizing energy-intensive industries: A multi-timescale rolling horizon approach. Accepted for submission in Applied Energy.*
- *G. Fede, F. Sgarbossa, D.F. Silva (2026). Analyzing operational and maintenance strategies for electrolysis-based hydrogen production for industrial decarbonization. Submitted to the 40th ECMS International Conference on Modelling and Simulation.*

Development and Optimization of a Hybrid Fuel Cell based Combined Heat and Power System

Muhammad Uzair Azhar

Affiliation(s):
PhD Candidate, IBEM
UiT The Arctic University of Norway

Research Interest:
Energy Conversion Systems,
Fuel Cell Hybrid Power Plants

Estimated Progress of the PhD Project:

Just Started | < 50 % | > 50 % | Almost Done ☺

Primary Objectives:

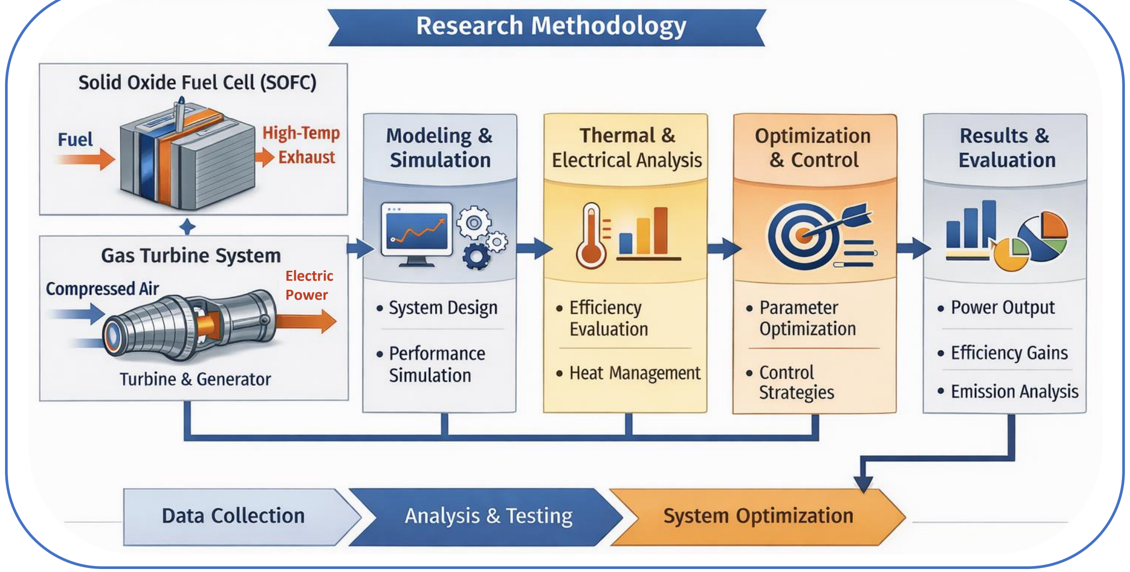
- Design a novel SOFC–GT design for power generation and perform thermodynamic and CFD-based parametric analysis under varying operating conditions.
- Optimize the system for efficiency, emissions, and application-specific performance.

Secondary Objectives:

- Evaluate environmental and economic feasibility through life cycle and cost-benefit analysis of the system.
- Validate results through experimental testing or prototype development.

Key Features

- High Efficiency Power Generation.
- Waste Heat Utilization.
- Improved Scalability, Modularity, Flexibility and System Reliability.
- *Low Emissions and Integrated Thermal Management*



Planned Outcomes

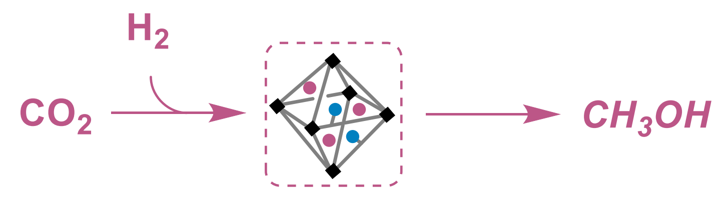
- Low emissions and high efficiency, fuel cell based robust power plant for transient and fluctuating loads.
- Comprehensive thermo-fluid and life cycle assessment of the system
- Application based evaluation for deployment in stationary and propulsion systems.

Design of MOF-based single-atom catalysts for CO_2 hydrogenation

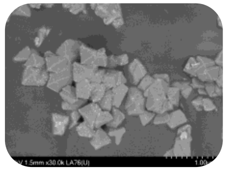
Sahra Ahmed

Affiliation(s) *Centre for Materials Science and Nanotechnology, Department of Chemistry, University of Oslo*

Introduction



Previous work: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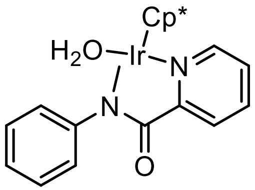
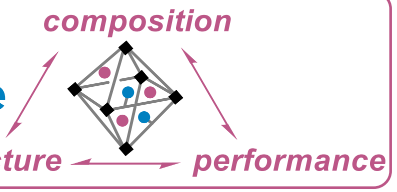


2

This work: Zr-UiO-66 MOFs serve as a suitable heterogeneous platform for immobilising single-site catalysts.



Methodology

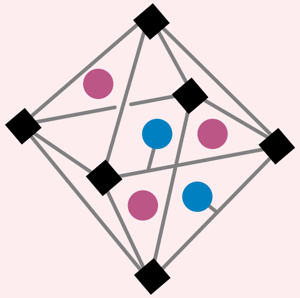
Project I:

- Pd single atoms and NPs immobilised in UiO-66.

Node

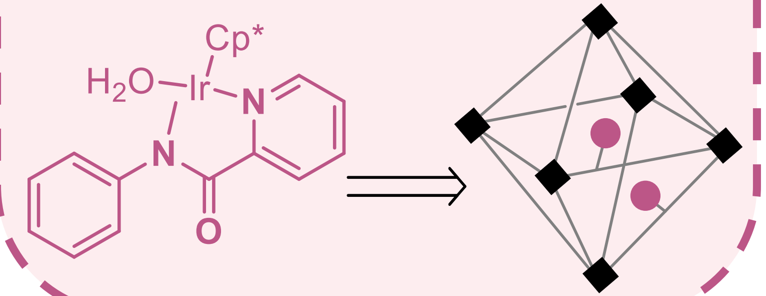
Functionalised linker

Pd single atom



Project II:

- Ir (III) molecular complexes anchored on UiO-66.



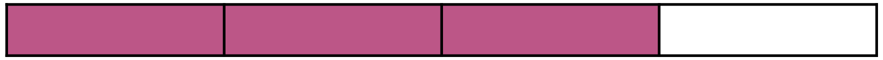
2023: BSc in Chemistry at UiO

2025: MSc in Organic Chemistry at UiO

2025 – now: PhD candidate in Material Chemistry at UiO

s.a.ahmed@kjemi.uio.no

Estimated progress of the PhD project:



Publications

- E. Tezel *et al.*, *J. Mater. Chem. A*, ***2026***, Manuscript accepted.
- R. Kanega *et al.*, *J. Am. Chem. Soc.*, **2021**, *143*, 1570-1576.

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UKRI Science and Technology Facilities Council

AIST

Hydroxide-ion Conducting MOFs for Alkaline Fuel Cells

Introduction

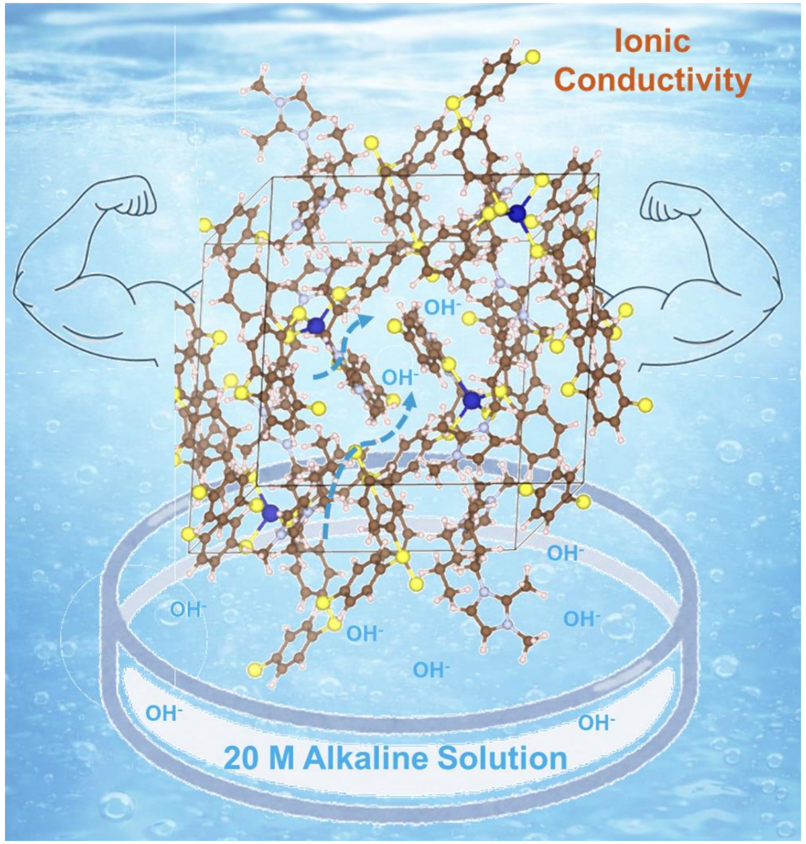
Hydrogen-based energy technologies are key to sustainable energy systems. Alkaline fuel cells are attractive due to low-cost catalysts, but are limited by the lack of efficient OH^- conducting membranes. Metal-organic frameworks (MOFs) are promising due to their tunable porous structures. This project develops alkali-resistant MOFs with intrinsic hydroxide-ion conductivity via ionic functionalisation. It also aims to understand ion transport mechanisms and guide material design.

Primary objective

- To develop alkali-resistant MOFs with intrinsic hydroxide-ion conductivity for alkaline membrane applications

Secondary objectives

- Synthesize MOFs stable in strongly alkaline conditions
- Measure ionic conductivity under controlled conditions
- Understand ion transport mechanisms



Qingqing Shao

University of Oslo

Supervisor: Petra Ágota Szilágyi

Co-supervisor: Truls Norby

I am a third-year PhD candidate in Materials Chemistry at the University of Oslo. My research focuses on hydroxide-ion conducting metal–organic frameworks for alkaline fuel cells, with an emphasis on stability and ion transport.

Estimated progress of the PhD project:

Just started ... **< 50 %** **> 50 %** **Almost done ☺**

Publications

- Qingqing Shao, Bo Jiang, Dipankar Saha, Truls Norby, and Petra Ágota Szilágyi*. Intrinsic Hydroxide-Ion Conductivity of the Highly Alkaline-Resistant CoTBT Metal-Organic Framework. Under revision of Communications Chemistry
- Zihan Zhong#, Qingqing Shao#, Baoxin Ni#, et al., and Tiesheng Wang*. HOF-Enabled Synthesis of Porous PEDOT as an Improved Electrode Material for Supercapacitor. ACS Applied Materials & Interfaces, 2025, 17(10), by core–15804–15812, DOI: 10.1021/acsami.4c19109
- Qingqing Shao and Hui Gu*. Transition layer rim structures for the martensitic β→α transition in sintered SiC ceramics. Journal of Materiomics, 2023, 9(2), 299–309. DOI: 10.1016/j.jmat.2022.10.004
- Alkali-resistant MOF-based membranes for alkaline fuel cells. Invention Disclosure submitted to Inven2 (Technology Transfer Office, University of Oslo), DOFI No. 25101 (First inventor)

Topical Area 5: Safety

Name (affiliation)	Title of PhD project
Abhishek Subedi (NTNU)	Improved modeling of socio-technical systems for hydrogen value chain
Anne Marie Lande (USN)	Mitigation of hydrogen explosions
Dikshya Bhandari (UiS)	Identifying and Mitigating Risks in Hydrogen Energy for Safer Integration
Farhana Yasmine Tuhi (NTNU)	Reliability prediction for PEM water electrolyzer
Kangxue Zheng (UiB)	Mitigation hydrogen explosions by chemical inhibition – Experiments and simulations
Lucie Pratabuy Tran-Quang (UiB)	Hydrogen Explosions in Complex Geometries: Risk & Knowledge
Nicolas Dobler (NTNU)	Model Predictive Control for Safeguarding Water Electrolysis
Petar Bosnic (USN)	Deflagration-to-Detonation Transition in Hydrogen-Air Mixtures for Explosion Safety
Sudesh Rathnayake (UiB)	PhD project on hydrogen safety: modelling hydrogen explosions in complex geometries with an open-source PDR model

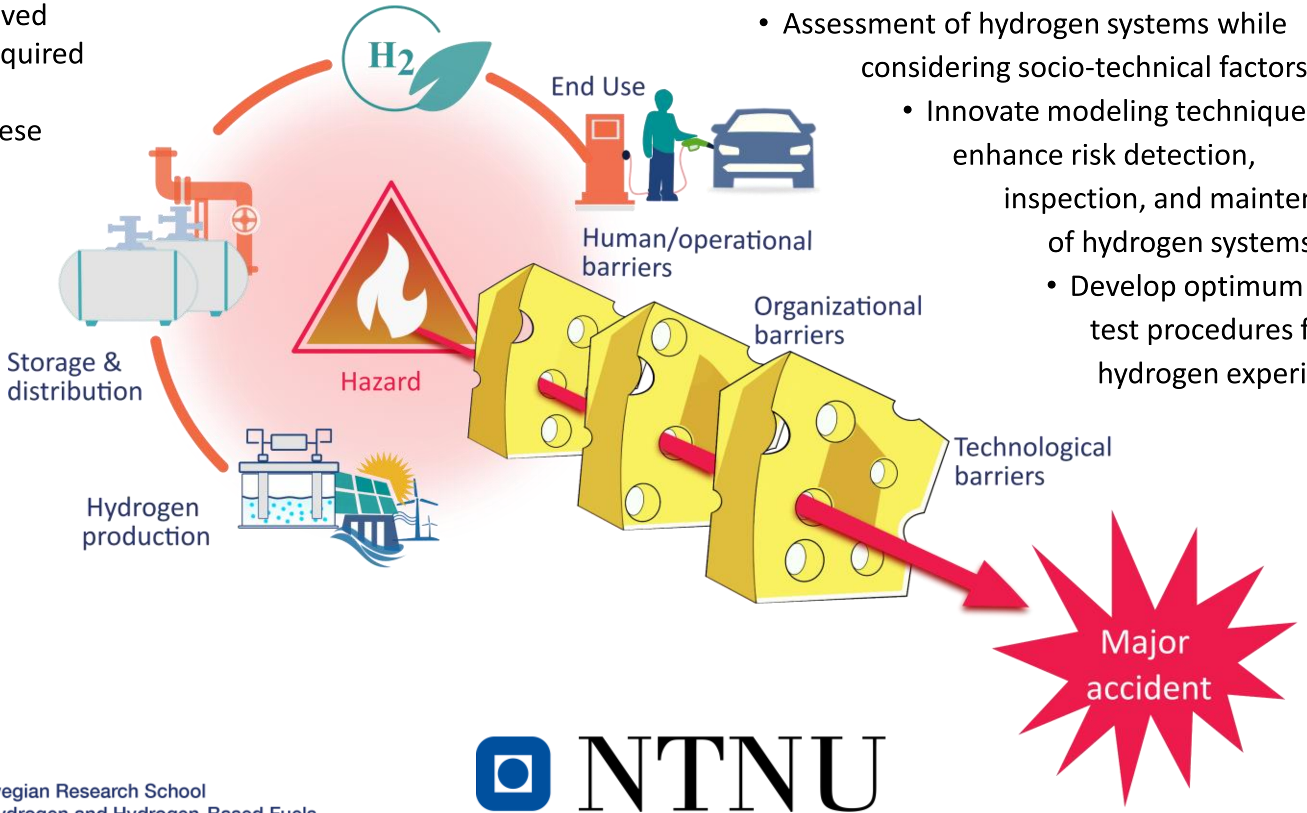
Improved modeling of socio-technical systems for hydrogen value chain

Abhishek Subedi

Norwegian University of Science and Technology (NTNU)
abhishek.subedi@ntnu.no

Introduction

Hydrogen technologies offers a sustainable solution to climate change problems, but its systems must be safe. Hydrogen systems are complex socio-technical systems. Human or operational, organizational along with technical aspects plays a crucial role in preventing catastrophic events as safety barriers. However, thorough study & improved modeling is required for properly quantifying these factors.



Research Gap and Objectives

Available knowledge	Gap	Expected knowledge
Safety barrier analysis methods are insufficient for complex hydrogen systems	Consideration of the safety barriers as socio-technical systems	Safety barriers to be assessed as socio-technical systems (STS).

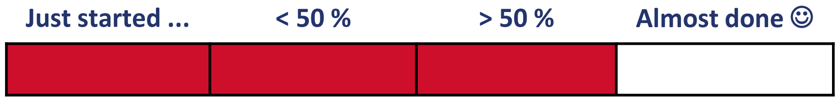
Objectives:

- Assessment of hydrogen systems while considering socio-technical factors.
- Innovate modeling techniques to enhance risk detection, inspection, and maintenance of hydrogen systems.
- Develop optimum & safe test procedures for hydrogen experiments

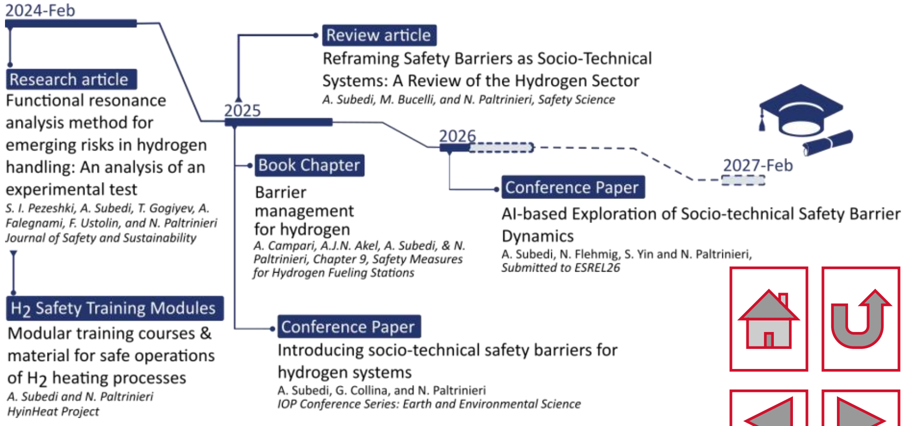
PhD candidate at Department of Mechanical and Industrial Engineering, NTNU

Master by Research (Hydrogen Safety) from Kathmandu University (2022/23)

Estimated progress of the PhD project:



Status and Publications



Mitigation of hydrogen explosions

Anne Marie Lande

PhD Research Fellow

Affiliation: University of South-Eastern Norway (USN)

Process Safety, Combustion and Explosions Research Group (USN)

Supervisor: Joachim Lundberg (USN)

Co-supervisors: Knut Vågsæther (USN)

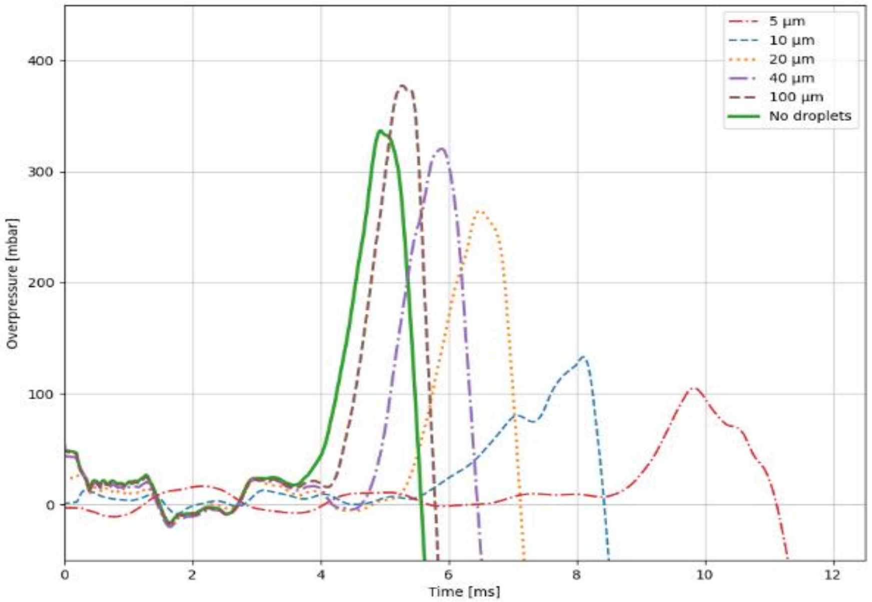
& Mathias Henriksen (USN)

- BSc in Mechanical Engineering from Høgskulen på Vestlandet (HVL)
- MSc in Process Technology from USN
- Experience with CFD on both Master's Thesis and Research Project

Introduction

Hydrogen is a highly explosive gas. Therefore, hydrogen safety is an important research topic.

Water spray systems are identified as a possible active fire protection method for mitigation of hydrogen explosions. If water spray is released when a leakage of hydrogen is detected, explosion pressure build-up might be prevented. However, such models of are generally not well validated, and more research should be conducted. Studies have shown divergent results because of the complex flow of gas explosion interacting with water droplets.



The aim of this PhD project is to analyze the mitigating effects of an actual water spray system on a hydrogen explosion.

Primary objective

- The main objective is to determine the effect of a distribution of water droplet sizes (polydisperse) on a hydrogen explosion compared to a monodisperse assumption in a computational fluid dynamics (CFD) simulation.

Secondary objectives

- The open-source CFD software OpenFOAM is used for the simulations.
- Water droplet injection in the post-flame region will also be investigated.

PhD workflow

- Develop a numerical model of a premixed hydrogen-air deflagration
- Validate the combustion model against experimental data
- Inject water droplets into the deflagration model
- Analyze the effect of droplet size on overpressure and flame propagation
- Compare polydisperse and monodisperse droplet size distributions

Estimated progress of the PhD project:

Just started ... | **< 50 %** | **> 50 %** | **Almost done ☺**

Publications

- A. M. Lande, J. Lundberg and M. Henriksen, "Modeling Monodispersed Water Droplets in Hydrogen Deflagration Using OpenFOAM ," The International Seminar on Fire and Explosion Hazards (ISFEH), Rome, Italy, 2025
- A. M. Lande and J. Lundberg, "Summary of mechanisms of water droplets in hydrogen deflagration," Nordic Flame Days 2023, Trondheim, Norway, 2023

Identifying and Mitigating Risks in Hydrogen Energy for Safer Integration

Dikshya Bhandari

University of Stavanger

Related projects: *HyValue* WP4: *Hyvalue Centre for Environment-friendly Energy Research (FME)*

PhD-candidate in Risk Management and Societal Safety

Education

- *Master (MSc) in Risk and Safety Management*
- *Bachelor of Science in Statistics*

Experience

- *Data analysis ● Modeling ● Financial management ● Risk analysis*

Estimated progress of the PhD project:

Just started … | < 50 % | > 50 % | Almost done

PhD Supervisors: Jon Tømmerås Selvik, Eirik Bjorheim Abrrahamsen, & Ove Njå

Introduction

As society moves toward using hydrogen as a major energy source, it opens up opportunities to rethink our approaches to safety, security, and risk management. Traditional safety studies on hydrogen have been limited, focusing on specific uses and conducting small-scale experiments, with the assumption that hydrogen's use will grow significantly. This aspect might not fully cover the complex challenges and uncertainties of switching to hydrogen energy.

The concept of Strength of Knowledge (SoK) is crucial in this shift. SoK emphasizes the importance of deeply understanding the risks involved, beyond simple predictions from past data or small tests. It's about exploring unknowns to make our risk assessments as accurate and trustworthy as possible.

To address these challenges effectively, we need to combine knowledge from different disciplines and apply a broader systems perspective—this helps evaluate how current frameworks perform and where improvements are needed.

Primary objective

- Evaluate how well existing risk assessment methods, principles, and frameworks handle uncertainty and knowledge gaps in large-scale hydrogen systems.

Secondary objectives

- Assess how well current risk assessment methods handle uncertainty and knowledge gaps in hydrogen systems.
- Explore approaches that better represent socio-technical factors and system interactions.
- Support safer decision-making when knowledge is limited and uncertainty is high.

Publications

I. Bhandari, D., & Selvik, J. T. (2025). On the Use of Fault Tree Analysis to Capture Dynamic and Multistate Aspects in the Analysis of Hydrogen Systems. Chemical Engineering Transactions, 116, 157-162.

II. Bhandari, D., Selvik, J. T., Glette-Iversen, I., & Abrahamsen, E. B. (2025). On the use of the precautionary principle in the context of the hydrogen systems.In the 35th European Safety and Reliability & the 33rd Society for Risk Analysis Europe Conference. Research Publishing Singapore.

III. Bhandari, D., Selvik, J. T., & Abrahamsen, E. B. (2025). A Systems Thinking Perspective on Hydrogen Safety: Reviewing Models and Applications Submitted for Possible Publication to the International Journal of System Assurance Engineering and Management.

IV. Bhandari, D., Selvik, J. T.(2026). Integrating Event Tree Analysis and System-Theoretic Process Analysis for Hydrogen Refueling Station Safety

Reliability prediction for PEM water electrolyzer

Farhana Yasmine Tuhi

Affiliation = *Department of mechanical & industrial engineering, NTNU*

Related projects: *HYDROGENi* - HYDROGENi will spearhead research and innovations needed to fulfil the 2030 and 2050 visions of the Norwegian hydrogen roadmap.

- PhD candidate (Started in April 2023)
- Master's degree in RAMS engineering from NTNU (2020 - 2022)
- Bachelor's degree in Mechanical engineering from Bangladesh (2015 -2019)

Introduction

Since operational experience of PEMWE remains limited, the lack of failure/ degradation data continues to be a major challenge for reliability prediction of PEMWE. It is noticed that PEMWE has similar hardware with the well-established PEM fuel cell (PEMFC) technology, even though its operating principles are essentially the reverse. It is natural to assume that experiences and knowledge obtained from PEMFC degradation and failure events can be used for electrolyzers.

Based on this, the present study aims to introduce a novel framework to predict PEMWE reliability by conducting degradation modeling. This study seeks to overcome the data limitations associated with PEMWE by utilizing existing data, thereby enabling further quantitative analysis based on the predicted reliability metrices.

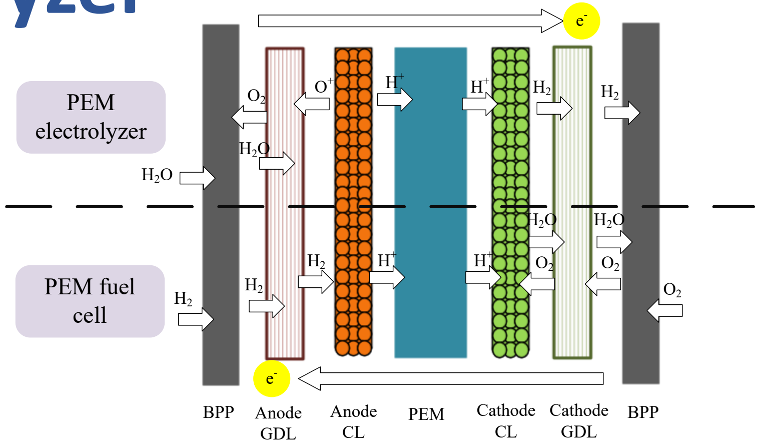


Fig 1: Structural layout of PEMWE (above) and PEMFC (Below)

Research objectives

- Proposing a novel framework for reliability prediction of PEM electrolyzer
- Conducting failure analysis to identify failure modes, causes & mechanisms
- Suggesting recommendations for reliability improvement of PEM electrolyzer

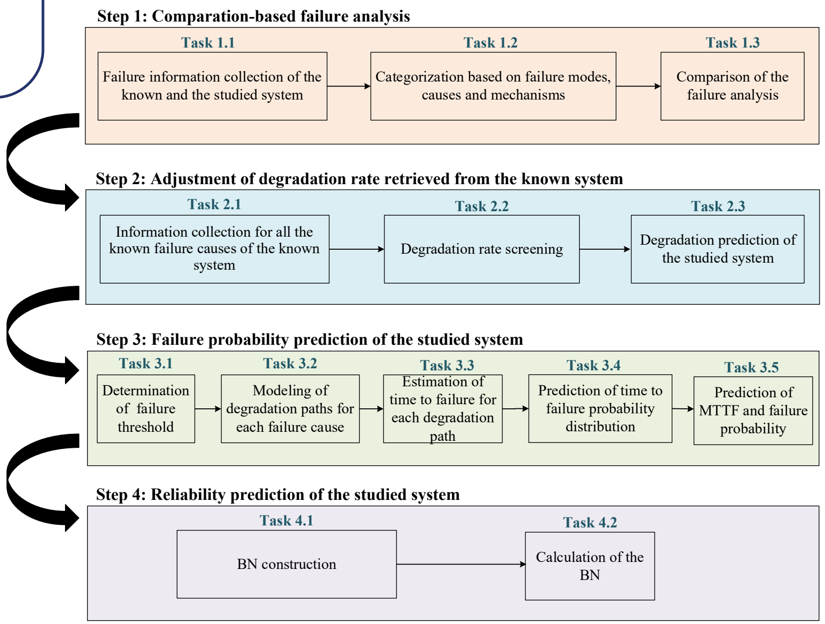


Fig 2: Proposed reliability prediction framework

Estimated progress of the PhD project:

Just started ... **< 50 %** **> 50 %** **Almost done ☺**

Publications

- Tuhi, F. Y., Bucelli, M., & Liu, Y. (2026). "Reliability prediction of PEM water electrolyzer using heterogeneous sources". (Submitted to Process Safety and Environment Protection)
- Tuhi, F. Y., Bucelli, M., & Liu, Y. (2025). "*A comparative assessment of failures between a PEM electrolyzer and a PEM fuel cell*". In ICHS conference, Seoul, South Korea.
- Tuhi, F. Y., Bucelli, M., & Liu, Y. (2024). "*Technical Failures in Green Hydrogen Production and Reliability Engineering Responses: Insights from Database Analysis and a Literature Review*." International Journal of Hydrogen Energy 94 (December):608–25.
- Tuhi, F. Y., Fredriksen, M., Jäschke, J., Bucelli, M. & Liu, Y. (2024). "*Accidents Review and Control Assessment for Reliable Operation of PEM Water Electrolyzer Stacks*". In ESREL conference, Krakow, Poland.

Mitigation hydrogen explosions by chemical inhibition – Experiments and simulations

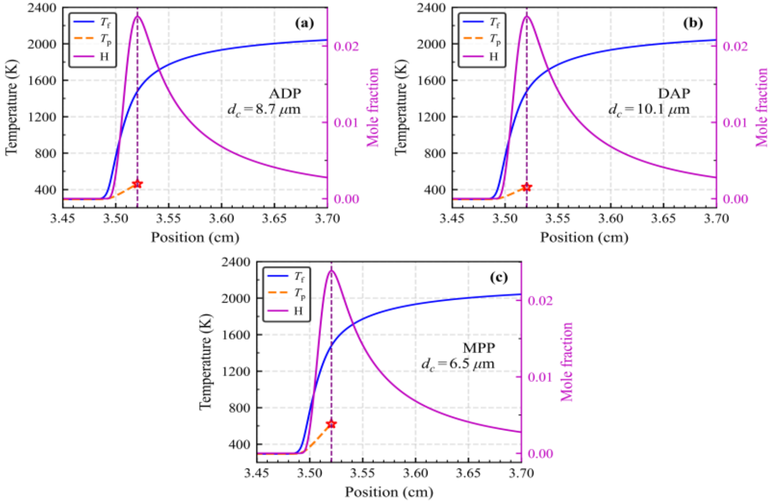
Kangxue Zheng

Affiliation: *University of Bergen*

Related projects: *SH2IPS*

Introduction

Hydrogen is a carbon-free fuel that can enable a transition of the energy systems towards increased use of renewable energy sources. However, it is not straightforward to achieve the same level of safety for hydrogen energy systems, compared to systems based on conventional hydrocarbon fuels. Therefore, research on chemical inhibition of premixed hydrogen-air flames is highly relevant for the safe implementation of hydrogen as an energy carrier in industry and society.
Recent studies have primarily focused on inert gases, solid inhibitors, water mist, and halogenated hydrocarbons. This PhD project will explore alternative substances, including phosphorus compounds.



Primary objective

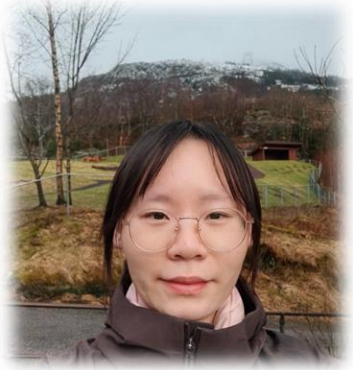
- To support the development of systems for explosion protection in congested and confined environments by chemical inhibition.

Secondary objectives

- To investigate the effects of various compounds on the inhibition of hydrogen-air explosions through a combination of experimental and theoretical methods.
- To contribute to the general development of hydrogen safety and the measures required to reduce the risk for hydrogen installations to an acceptable level.

Education

- Master of Safety Science and Engineering
- Bachelor of Safety Engineering



Estimated progress of the PhD project:

Just started ...	< 50 %	> 50 %	Almost done ☺

Publications

- Zheng, K., Skjold, T., Hisken, H., 2025. Numerical analysis of the inhibiting effect of phosphorus compounds on hydrogen-air explosions. Proceedings International Conference on Hydrogen Systems (ICHS11), 23-25 September 2025, Seoul: 507-518.

Hydrogen Explosions in Complex Geometries: Risk & Knowledge

Lucie Pratabuy Tran-Quang

***Affiliation**: University of Bergen*

Related projects: HyValue, PDR Alliance

Introduction

- Hydrogen is a clean energy carrier but highly reactive, with low ignition energy and a high risk of deflagration-to-detonation transition (DDT).
- Mitigation strategies for conventional fuels are often ineffective for hydrogen due to its unique explosion behaviour.
- A strong strength of knowledge requires reliable data, expert consensus, and accurate predictive models (Aven, 2013).
- State-of-the-art models can currently deviate from experimental results by 1-2 orders of magnitude.
- Uncertainties stem from both inherent model limitations and errors made by the modellers.

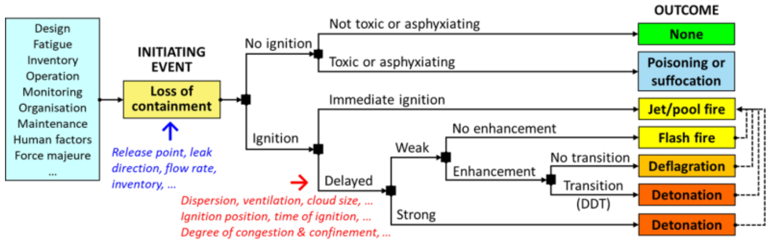


***Figure 1**: Typical event tree for accidental fuel-air explosions initiated by loss of containment (credit: Trygve Skjold)*

***Figure 2**: Experimental results of a vented hydrogen deflagration in a 20-foot ISO container (HySEA project, test 61). Comparison with blind-prediction study benchmarks (Skjold et al., 2019).*

- 2026: PhD Candidate, Department of Physics and Technology, UiB, Norway (Supervisor: Trygve Skjold)
- 2025: Experimental study of hydrogen flames in narrow channels, IRPHE, Marseille, France
- MSc. in Engineering: Energetic materials and combustion, ENSTA, Brest, France

Estimated progress of the PhD project:

Just started ...	< 50 %	> 50 %	Almost done ☺
■			

Objectives

- Review large-scale experimental investigations of hydrogen explosions in complex geometries.
- Coordinate the blind-prediction benchmark study in FME HyValue WP4.
- Design an experimental facility and perform laboratory-scale experiments.
- Validate predictive models by comparing numerical simulations with experimental result.

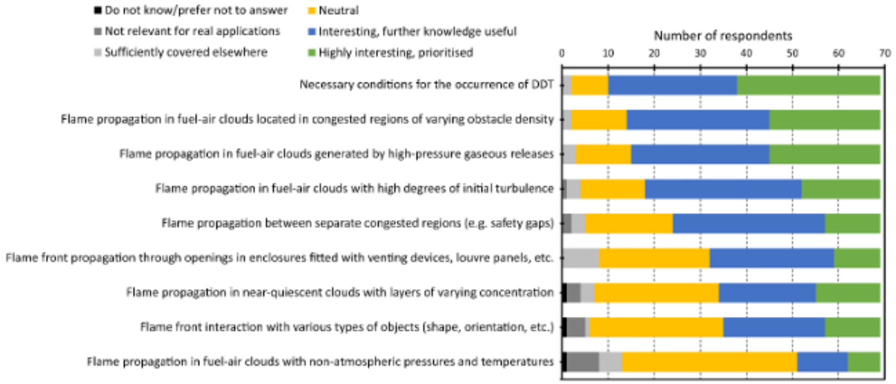


***Figure 3**:* Survey results: Priority physical phenomena for investigation in upcoming large-scale hydrogen experimental campaigns (HyValue 2027).

Publications

- Mejía-Botero, C. C., Pratabuy Tran-Quang, L., & Almarcha, C. (2026, July 21–26). *Cell size distributions of hydrogen-air flames during propagation in Hele-Shaw burners* [Paper presentation]. 41st International Symposium on Combustion, Kyoto, Japan.
- Mejía-Botero, C. C., Pratabuy Tran-Quang, L., Chen, Z., Boivin, P., & Almarcha, C. (2026, July 21–26). *Flame propagation limit and consumption speed of hydrogen-air flame in narrow channels* [Paper presentation]. 41st International Symposium on Combustion, Kyoto, Japan.

References

Aven, T. (2013). Practical implications of the new risk perspectives. Reliability Engineering & System Safety, 115: 136-145. DOI: https://doi.org/10.1016/j.ress.2013.02.020

Skjold, T., Hisken, H., Bernard, L., Mauri, L., Atanga, G., Lakshmipathy, S., Lucas, M., Carcassi, M., Schiavetti, M., Rao, V. C. M., Sinha, A., Wen, J. X., Tolias, I. C., Giannissi, S. G., Venetsanos, A. G., Stewart, J. R., Hansen, O. R., Kumar, C., Krumenacker, L., ... Huser, Å. (2019). Blind-prediction: Estimating the consequences of vented hydrogen deflagrations for inhomogeneous mixtures in 20-foot ISO containers. *Journal of Loss Prevention in the Process Industries*, *61*, 220–236. https://doi.org/10.1016/j.jlp.2019.06.013

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HyValue

PDR ALLIANCE

Hy School.no

Norwegian Research School on Hydrogen and Hydrogen-Based Fuels

Model Predictive Control for Safeguarding Water Electrolysis

Introduction

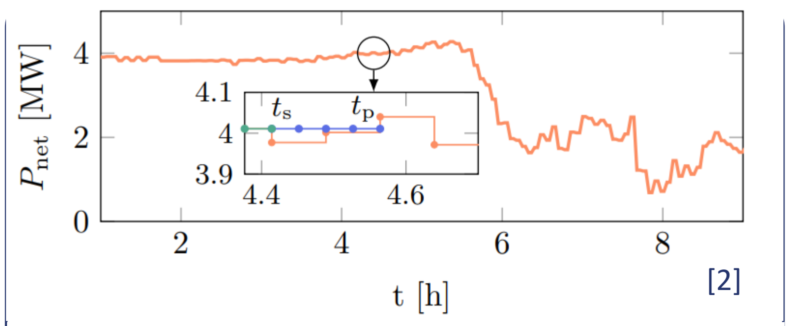
The project goal is to research and develop a novel method to control the hydrolysis of water with a special focus on safety. There has been a lot of research on how to run hydrogen production processes at the optimum and how to find these optimal working conditions. Often this research focuses on solving the academic optimization problem while neglecting the real-world challenges of chemical process industry. Many chemicals are toxic, flammable, explosive or in other forms dangerous, which is why the control of chemical processes also needs to include a safety aspect. This is where this project tries to inherently include safety aspects into modern control theory method. The main goal is to explore new safety monitoring processes and control strategies for optimal operation under safe circumstances.

Primary objective

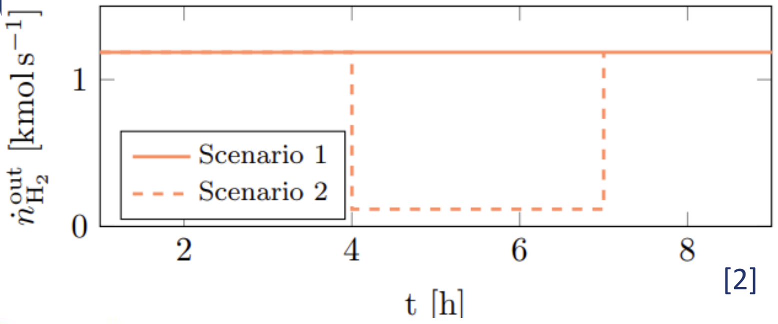
- Proposal of a robust, fault-tolerant, and safety-focused model-based control strategy that provides contingency plans for equipment and sensor failure.

Secondary objectives

- Validation of the approach on simulations
- Comprehensive robustness analysis



[2]



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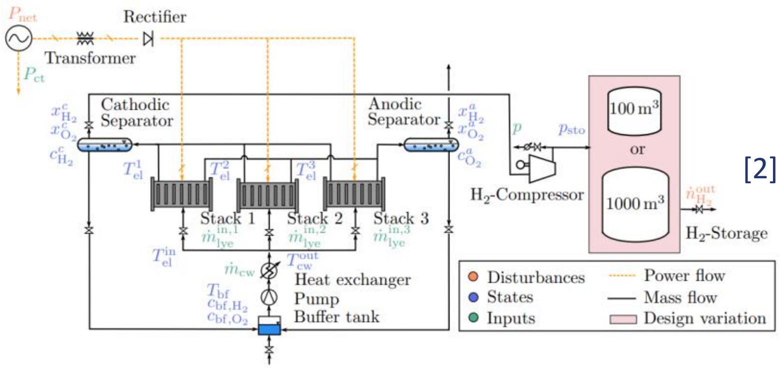


[2]

Nicolas Dobler

NTNU Trondheim - IKP

Related projects: *ProSafe*

- B.Sc. Chemical Engineering, ETH Zürich, 2018-2021
- M.Sc. Process Engineering, ETH Zürich, 2022-2024

Estimated progress of the PhD project:

Just started ...	< 50 %	> 50 %	Almost done ☺

Publications

[1] H.A. Krog, J. Jäschke, "A simple and fast robust nonlinear model predictive control heuristic using n-steps-ahead uncertainty predictions for back-off calculations", JoPC, vol. 141, 2024

[2] L. Camman, J.Jäschke, "Model predictive control of alkaline water electrolyzers with storage constraint", IFAC-PapersOnLine,vol. 59, no. 29, pp. 36-41, 2025.

Hy School.no 1

Norwegian Research School on Hydrogen and Hydrogen-Based Fuels

NTNU ProSafe

Deflagration-to-Detonation Transition in Hydrogen-Air Mixtures for Explosion Safety

Introduction

The global shift to ***low-carbon energy*** is vital for addressing ***climate change***, with ***hydrogen*** playing a key role in the deep ***decarbonization*** of sectors such as electricity production, industrial manufacturing, and transportation. However, ***accidental explosions*** remain a major ***safety*** concern in hydrogen systems, potentially causing severe damage or loss of life. Understanding the physics of such events is essential for implementing safety measures. Since large-scale testing is expensive and resource-intensive, ***Computational Fluid Dynamics*** (CFD) offers an effective alternative for ***assessing explosion consequences***.

Objectives and Methods

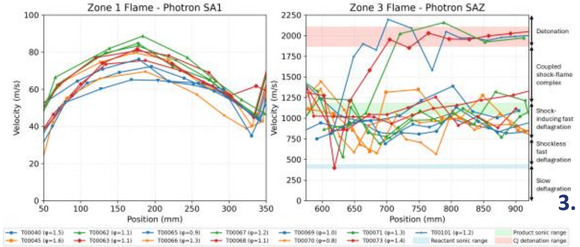
- ***Experimental***: Conduct ***systematic experiments*** on gas ***explosions*** using homogeneous ***hydrogen-air*** mixtures in a ***lab-scale*** explosion channel to study ***DDT.***
- ***Numerical***: ***Develop*** a ***numerical solver*** within the ***OpenFOAM*** framework that accurately ***simulates DDT*** on relatively ***coarse computational meshes***.

Results and Key Findings

1. Experimental Investigation of DDT in an Explosion Channel

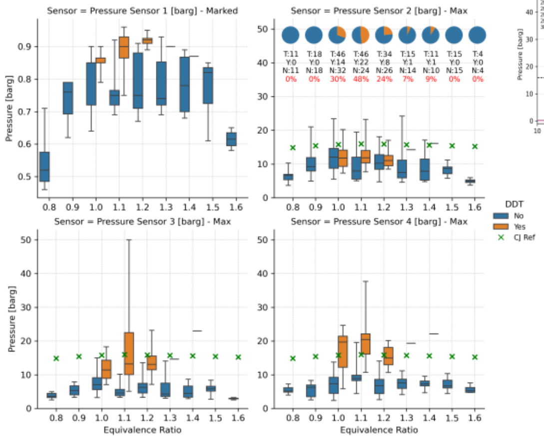
DEFLAGRATION

DEFLAGRATION-TO-DETONATION TRANSITION

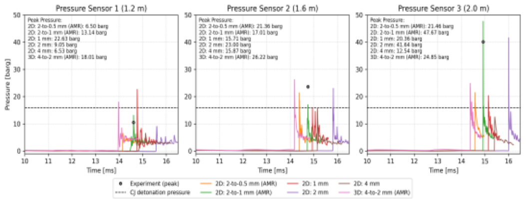


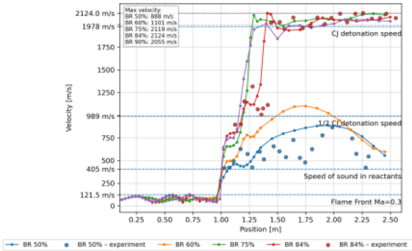
2. Development of a Multi-Mode Explosion Solver in OpenFOAM

Overview:
A simulation framework for solving the **compressible reactive Navier–Stokes equations** across both **subsonic (deflagration)** and **supersonic (detonation)** combustion regimes.



3. Prediction of DDT in Congested Hydrogen–Air Explosions





Petar Bosnic

Affiliation: **University of South-Eastern Norway** (USN)

Related projects: **FME HYDROGENi**

Supervisor: **Knut Vågsæther** (USN),

Co-supervisor: **Mathias Henriksen** (USN)

Mechanical Engineer with a Master's degree from the University of Split, Croatia, currently pursuing a PhD in **hydrogen safety** at the **University of South-Eastern Norway** (USN) within the Process Safety, Combustion and Explosion Research Group. My research focuses on the physics and dynamics of hydrogen **gas explosions**, combining experimental and numerical approaches. With expertise in combustion science, simulations, and experiments, I develop and implement **consequence analysis tools** to enhance hydrogen and process safety.

Estimated progress of the PhD project:

About to start	Just started	< 50 %	> 50 %	Almost done
	01.02.2023.			***SUBMITTED*** ☺ 09.02.2026.

Publications

Bosnic, P. et al. (2026) – Predictive numerical modelling of flame acceleration and DDT in confined hydrogen–air explosions *(under review, Journal of Loss Prevention in Process Industries)*

Bosnic, P. et al. (2026) – Multi-mode regress variable solver for modelling flame acceleration and DDT *(under review, Combustion Science and Technology)*

Bosnic, P. et al. (2025) – *Combustion Science and Technology*, 1–23

Bosnic, P. et al. (2025) – Dataset: DOI:10.6084/m9.figshare.29604935.v1

Bosnic, P. et al. (2025) – Modelling of flame acceleration and DDT in open-ended channels *(ICDERS, Ottawa)*

Bosnic, P. et al. (2024) – Flame acceleration and DDT in obstructed channels using OpenFOAM *(EPHyC, Ghent)*

Norwegian Centre for Environmentfriendly Energy Research

HYDROGENi SINTEF IFE

Universitetet i Sørøst-Norge

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Norwegian Research School on Hydrogen and Hydrogen-Based Fuels

PhD project on hydrogen safety: modelling hydrogen explosions in complex geometries with an open-source PDR model

Sudesh Rathnayake

Affiliation : University i Bergen

Related projects: ***HySEA***

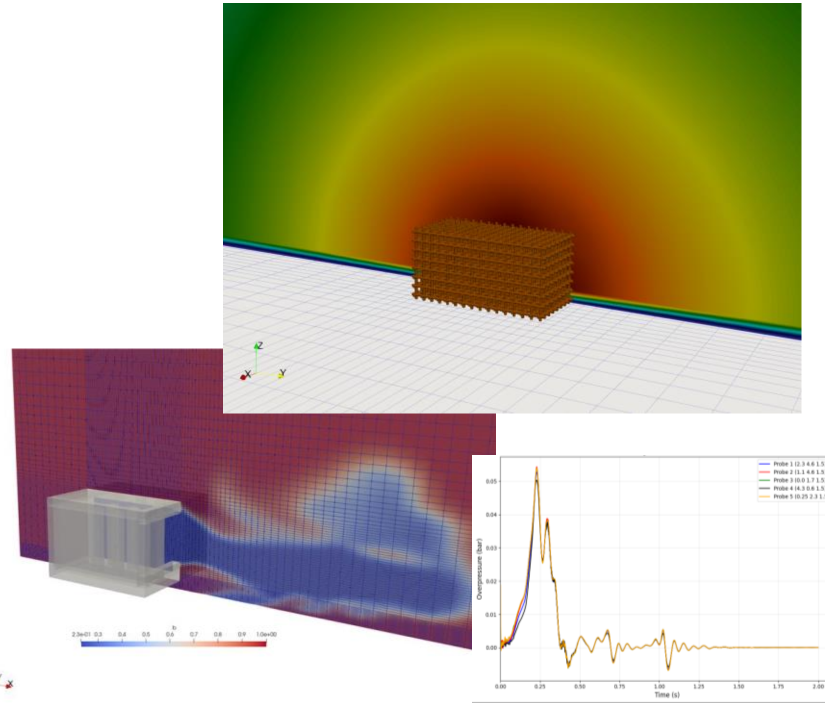
"I have completed a BSc in Mechanical Engineering and an MSc in Computational Engineering. I began my PhD project last September and am eager to apply my knowledge and experience to advance renewable energy technologies."

Introduction

The project will focus on physical phenomena relevant to hydrogen explosions in realistic scenarios, including flame-front interactions with various types and configurations of objects, concentration gradients, non-zero initial turbulence levels, and mean flow speeds.

The project's outcomes are expected to advance the most used tools for risk assessment of complex systems, thereby supporting the safe and efficient integration of hydrogen as an energy carrier in society.

Working Title: "Simulating hydrogen explosions in complex geometries"



"The figures are for illustrative purposes only. The solver requires additional validation, and it is in development.

Primary objective

- To enhance the open-source computational fluid dynamics (CFD) solver PDRFoam, improving its predictive capabilities for modelling turbulent premixed combustion in complex geometries

Secondary objectives

- The project activities will be part of the ***PDR Alliance*** initiative, which entails collaboration with relevant experts from both academia and industry

Estimated progress of the PhD project:

Just started ... **< 50 %** **> 50 %** **Almost done ☺**

Key literature:

- Puttock J, Walter F, Chakraborty D, Raghunath S, Sathiah P. Numerical simulations of gas explosion using Porosity Distributed Resistance approach Part −1: Validation against small scale experiments. Journal of Loss Prevention in the Process Industries. 2022 Feb;75:104659.
- Zambare A, Narasimhamurthy VD, Skjold T, Hisken H. Modelling of vented hydrogen deflagrations in an ISO container using PDRFoam. International Journal of Hydrogen Energy. 2024 Mar;59:251–62.
- Skjold, T., Hisken, H., Hjertager, B.H., Giljarhus, K.E.T, Henriksen, M., Vaagsaether, K., 356 Narasimhamurthy, V.D., Klein, T.S., Vianna, S.S.V, Johnson, D.M., Allason, D., Melguizo357 Gavilanes, J., Pekalski, A., Thompson, J., Rian, K.E., Coffey, C., & Siccama, D., 2025b. PDR 358 Alliance: Collaborative research on consequence modelling of accidental explosions in complex 359 geometries, Work-in-Progress poster, ICDERS30, 27 July – 1 August 2025, Ottawa.

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PDR ALLIANCE

OpenFOAM