HySchool Days 2024

Trondheim, 23-24 April 2024

Internal meetings Monday 22 April & Thursday 25 April

Norwegian Research School
on Hydrogen and Hydrogen-Based Fuels

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University of Bergen

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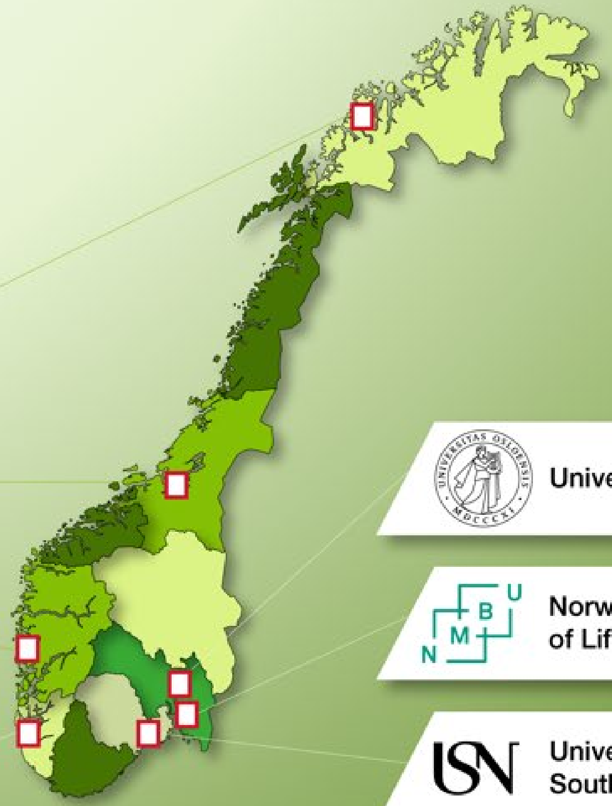

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HySchool Days 2024

Trondheim, 23-24 April 2024

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HySchool – Admitted PhD students (TA1)

TA1: Society and environment

Name	Org.	Project title	TA1	TA2	TA3	TA4	TA5
Brynhild Stavland	UiS	Safety regulation of hydrogen as an energy carrier in society	①	*	*	*	*
Claudia Cheng	UiT	Hydrogen: A new industry for the low-carbon energy transition in Arctic Norway	①				
Isabelle Viole	UiO	Energy storage systems for a sustainably-powered telescope	①		*	*	
Kine Høve Johnsen	NTNU	Public policy co-production, visions and strategies – Understanding the new hydrogen hype in Norway and the EU	①				
Martina Fantini	NTNU	Sustainable aviation futures in Norway: Visions and trajectories	①		*		
Moritz Langhorst	NTNU	Using dynamic and multi-layer material flow analysis for hydrogen usage in high-temperature processes of the aluminium and steel industries	①			*	
Teymur Gogiyev	NTNU	Environmental sustainability analysis of hydrogen production and use in Norway	①				
Vedant Ballal	NTNU	Environmental sustainability analysis of integrating the hydrogen economy with the bio-economy	①				

HySchool – Admitted PhD students (TA2)

TA2: Production

Name	Org.	Project title	TA1	TA2	TA3	TA4	TA5
Alicia San Martin Rueda	NTNU	In-situ characterization of perovskites using advanced techniques		②			
Anders Even Kvåle	UiB	Near field electrospinning for electrochemical electrodes	*	②			
John Senith Fernando	UiS	Carbon capture and gas separation technology		②			*
Jonas Himmelstrup	UiB	Design of novel catalysts for homogeneous ammonia synthesis		②			
Kristoffer Skjelanger	HVL	Development of mathematical and physical models for hydrogen production in rotating systems		②			
Leif Eric Hertwig	UiB	Design of novel catalysts for homogeneous ammonia synthesis		②			
Liina Sangolt	UiB	Utilization of offshore wind for hydrogen production		②	*		*
Lucas Cammann	NTNU	Plantwide control for flexible operation of electrolysis systems		②			*
Luyang Wang	UiO	Minority bulk and surface proton conduction in ceramic positrodes for proton ceramic electrochemical cells		②			
Marcello Costamagna	UiB	Towards sustainable ammonia production: development and implementation of evolutionary algorithms for catalyst design		②			
Marius Fredriksen	NTNU	Modelling, optimization and control of electrolyser systems	*	②			*
Megan Heath	NTNU	Towards reducing the anodic Ir loading in PEM water electrolysers		②			
Mengxin Wu	UiO	Performance and degradation of positrodes for proton ceramic electrolysers		②			
Minh Chi To	UiS	Green hydrogen production		②			
Mohamed Safy	UiO	Exploring the synergy of DFT and volcano plot analysis for the discovery of innovative catalysts in CO_2 hydrogenation		②			
Patrick Ewerhardt	UiO	Characterization and simulations of model electrodes in proton ceramic electrochemical cells		②			
Sivagowri Shanmugaratnam	UiB	Green hydrogen production through photocatalytic water splitting		②			
Stine Roen	UiO	Electrochemical characterization of mixed conducting ceramic positrodes for water splitting in electrolysis		②			
Thomas Benjamin Ferriday	UiA	Improving the membrane electrode assembly of an anion exchange membrane water electrolyser - A study of interfacial electrochemistry		②			
Tomasz Adam Skrzydlo	UiS	Catalytic cracking of methane over metal and carbon-based catalysts		②			
Torbjørn Egeland-Eriksen	UiO	Energy management for a novel hybrid energy storage system for the integration of renewable energy sources into the power grid		②	*	*	
Willow Dew	NTNU	Palladium-based membranes for hydrogen and ammonia		②			
Øyvind Lindgård	NTNU	Formulation and experimental validation of models for degradation and performance of catalytic layers for water electrolysis		②			

HySchool – Admitted PhD students (TA3)

TA3: Storage and distribution

Name	Org.	Project title	TA1	TA2	TA3	TA4	TA5
Abhishek Banerjee	UiS	Structure and dynamics in hydrogen-rich alloys for hydrogen storage			③		
Emil Høj Jensen	UiO	Energy storage systems for the integration of renewable energy sources into the power grid			③		
Ingrid Marie Stuen	UiB	Supply chain losses and quality degradation for large volume hydrogen transport chains			③	*	*
Mehmet Fazıl Kapçı	NTNU	Material integrity of titanium alloys for hydrogen energy applications			③		
Paula Endrös	NTNU	Designing hydrogen resistant Ti-6Al-4V parts manufactured by electron beam melting			③		
Raymond Mushabe	UiB	Experimental reservoir physics			③		*
Sadegh Ahmadpour	UiS	Hydrogen storage in porous media			③		
Sahra Louise Guldahl-Ibouder	NTNU	Development of novel materials for low-temperature ammonia cracking			③	*	
Sreeshyam Vadake Adat	UiO	High entropy alloys for hydrogen storage			③		
Vilde Gahr Sturtzel Lunde	UiO	Magnetocaloric materials for hydrogen liquefaction			③		
Wendpanga Jean Donald Minougou	UiS	PhD fellowship in geological storage of hydrogen			③		

HySchool – Admitted PhD students (TA4)

TA4: Applications

Name	Org.	Project title	TA1	TA2	TA3	TA4	TA5
Abinavnataraj Ramakrishnan	UiS	Metal organic frameworks and zeolites for catalytic CO_2 hydrogenation to methanol				④	
Asutosh Mallick	UiT	Electrical system integration of large maritime PEMFC				④	
David Zilles	NTNU	Experimental study of low-carbon fuel injection and combustion in marine engines				④	
Duc Duy Nguyen	NTNU	Combustion of ammonia and hydrogen fuel mixtures in marine engine				④	
Elena Baboi	NTNU	Safe operations in hydrogen-based industry	*			④	*
Giulia Collina	NTNU	Hydrogen technologies to decarbonise the glass and aluminium sectors				④	*
Giulia Fede	NTNU	H2GLASS: Hydrogen technologies and smart production systems to decarbonise the glass and aluminum sectors				④	
Jiyong Alex Shin	NTNU	Combustion dynamics				④	*
Keivan Afshar Ghasemi	NTNU	Study of zero-carbon fuels for internal combustion engines				④	
Kinza Huma	UiS	Synthesis, structure and dynamics of oxyhydrides				④	
Liya Jacob	NTNU	SiO reduction using hydrogen				④	
Muhammad Baqir Hashmi	UiS	Performance assessment of hydrogen fuelled gas turbines			*	④	*
Muhammad Salman	UiO	Green hydrogen from air (FAIR)	*	*		④	
Reyhaneh Banihabib	UiS	Development of real-time smart data analytic tools for monitoring and optimum operation of MGT systems				④	
Tristan van Kaam	NTNU	The use of hydrogen as a reducing agent in the production of rutile and ferro manganese alloys				④	

HySchool – Admitted PhD students (TA5)

TA5: Safety

Name	Org.	Project title	TA1	TA2	TA3	TA4	TA5
Abhishek Subedi	NTNU	Safety solutions for hydrogen storage and transport			*	*	⑤
Alessandro Campari	NTNU	Loss prevention and operational safety of hydrogen technologies			*	*	⑤
Alice Schiaroli	NTNU	Performance of hydrogen storage components exposed to fire with focus on cryogenic equipment			*		⑤
Anna Marie Lande	USN	Mitigation of hydrogen explosions					⑤
Dikshya Bhandari	UiS	Identifying and mitigating risks in hydrogen energy for safer integration		*			⑤
Efthymia Derempouka	UiB	Hydrogen as energy carrier in society: risk picture, risk awareness and public acceptance (HySociety)	*				⑤
Farhana Yasmine Tuhi	NTNU	Reliability and resilience of green hydrogen production systems		*			⑤
Federica Tamburini	NTNU	Liquid hydrogen transport and use			*		⑤
Leonardo Giannini	NTNU	Loss prevention and operational safety of hydrogen technologies			*		⑤
Lucas Claussner	NTNU	Modelling of loss of containment consequences of hydrogen technologies					⑤
Matthijs van Wingerden	UiB	Chemical inhibition of hydrogen explosions					⑤
Melodia Lucas	UiB	Improved modelling of hydrogen explosions					⑤
Petar Bosnic	USN	Development of a CFD methodology to reduce the hazards of hydrogen and ammonia systems in maritime and industrial sectors					⑤

HySchool in a Nutshell

Wednesday 24 April 2024

HySchool – Admitted PhD students (TA1)

TA1: Society and environment

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Vedant Ballal	NTNU	Environmental sustainability analysis of integrating the hydrogen economy with the bio-economy	①				

Safety Regulation of Hydrogen as an Energy Carrier

Brynhild Stavland

University of Stavanger

Related projects: *HySociety, Safe Hydrogen Fuel Handling and Use for Efficient Implementation 2 (SH2IFT-2)*

PhD-candidate in Risk Management and Societal Safety

Educational background – political science and societal safety

Introduction

A large-scale use of hydrogen as an energy carrier in society will result in significant changes in the production, distribution, use etc. of hydrogen compared to the current context. The PhD project is based on an assumption that these changes call for a review of the current hydrogen regulations and potentially development of a regulatory system that are aimed at safety and security-related concerns given a large-scale introduction of hydrogen as an energy carrier.

Objective

The primary objective of the PhD-project is to provide scientific knowledge about how safety and security can be regulated given a large-scale implementation of hydrogen as an energy carrier.

Finished activities

- Systems thinking as a basis for regulating hydrogen safety in society
- Strength of Knowledge and uncertainties in safety and security regulation of hydrogen as an energy carrier

Current activities

- Framework for assessing knowledge quality in hydrogen regulation (article in progress)
- Factors that enable the choice of regulatory strategies in the case of hydrogen as an energy carrier in society (article in progress)

Future activities

- Systems theoretical analysis of transport of liquid hydrogen (planned paper)

Estimated progress of the PhD project:

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

Publications

- Stavland, B. & Njå, O. (2022). Systems Thinking as a Basis for Regulating Hydrogen Safety in Society. *Proceedings of the 32nd European Safety and Reliability Conference (ESREL 2022)*. DOI: https://doi.org/10.3850/978-981-18-5183-4_R13-03-204-cd
- Stavland, B. & Njå, O. (2023). Strength of Knowledge and Uncertainties in Safety Regulation of Hydrogen as an Energy Carrier. I: Proceedings of the 10th International Conference on Hydrogen Safety (ICHS 2023). ISBN 9791221042740. s.1103-1114.

Hydrogen: A new industry for the low-carbon energy transition in Arctic Norway

UiT The Arctic University of Norway

Claudia Cheng

PhD Research Fellow
Department of Social Sciences
UiT Norway's Arctic University
Changing Arctic Research School
Arctic Centre for Sustainable Energy (ARC)

Research interests:

- Hydrogen
- Energy transition
- Energy justice
- Socio-technical perspective

Estimated progress of the PhD project:

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

Introduction

Cheap electricity prices and proximity to the majority of Norway's remaining natural gas resources makes Arctic Norway[1] an attractive region to build a new industry based on blue and green hydrogen. How can a just low-carbon energy transition towards a hydrogen economy come about in Arctic Norway?

Primary objective

Assess the prospects of a low-carbon hydrogen economy in Arctic Norway

Secondary objectives

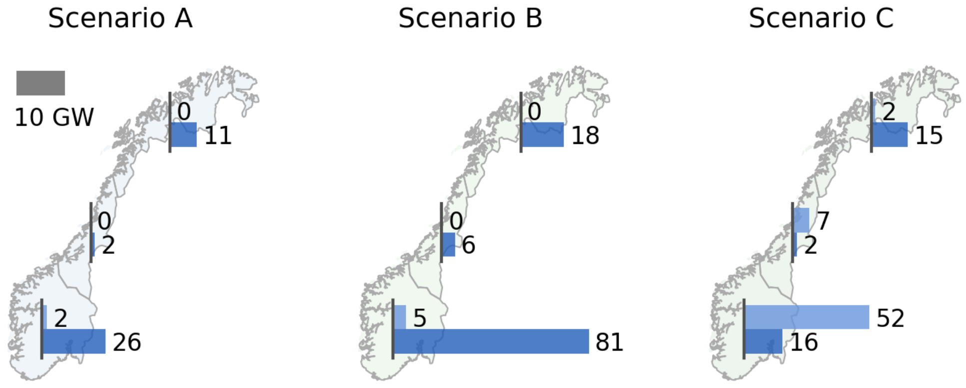
Examine the interactions between hydrogen and the various regimes (natural gas, power supply, maritime)

Assess Norway's competitiveness of hydrogen exports to the EU and the socio-environmental implications

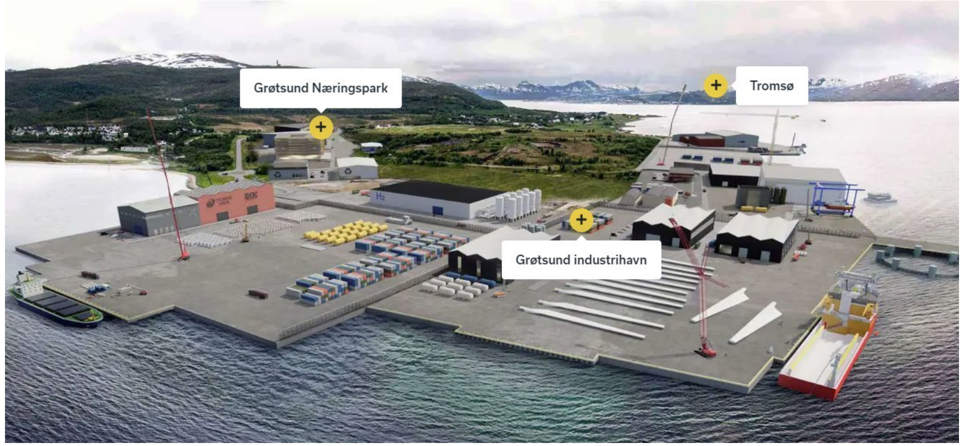
Study the potential for a green shipping corridor in the Arctic based on green ammonia

Identify key drivers and barriers for the development of a just and accelerated low-carbon hydrogen economy

[1] Nordland, Troms and Finnmark counties & Svalbard



Spatial distribution of onshore wind (dark blue) and offshore wind (light blue) capacities for blue and green hydrogen production in Norway (in GW)



Grøtsund Industry port. Source: Tromsø Havn

Publication(s):

Claudia Cheng (2023). Does time matter? A multi-level assessment of delayed energy transitions and hydrogen pathways in Norway. ERSS. 100, 103069, 11 pp.
DOI: https://doi.org/10.1016/j.erss.2023.103069

Claudia Cheng (*in revision*). A Green Shipping Corridor in the Arctic by 2030? Barriers and opportunities In *Handbook of Ocean Governance and Maritime Affairs.* De Gruyter.

C. Cheng, K. van Greevenbroek & I. Viole (*manuscript in progress*). Can Norway save the European Union's hydrogen ambition for 2030?

Public Policy Co-production, Visions & Strategies – Understanding the New Hydrogen Hype in Norway and the EU

Introduction

- Policymakers around Europe have released a wave of policy documents, advocating for different hydrogen visions
- Limited knowledge about what this new hydrogen hype in European energy politics and industry really entails from a transition perspective

Primary objective

Explore sociotechnical aspects of the new hydrogen hype in Norway and the EU

Secondary objectives

- Understand how roadmaps and strategy documents are produced (co-production)
- Explore various visions, strategies and dimensions embedded in the hype and how these intersect

Fields/perspectives applied

From Science and Technology Studies (STS) and Transition Studies

Kine Høve Johnsen

Affiliation:
Norwegian University of Science and Technology (NTNU)

Related projects:
FME HYDROGENi

Bachelor in International Environmental and Development Studies

Master in Innovation Studies

Estimated progress of the PhD project:

Just started ...	< 50 %	> 50 %	Almost done ☺
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Norwegian University of Science and Technology

Environmental Sustainability Analysis of H_2 Production and Use in Norway

Introduction

Reducing the carbon footprint of the energy, transportation, and industrial sectors is a major challenge in the fight against climate change that requires inventive solutions. This research aims to improve hydrogen-based value chains in Norway through advanced Life Cycle Assessment (LCA), promoting sustainability-driven innovation. It aims to quantify the climate change mitigation potential and identify environmental co-benefits and trade-offs of large-scale deployment of H_2-based technologies in Norway, particularly in hard-to-abate sectors

Primary objective

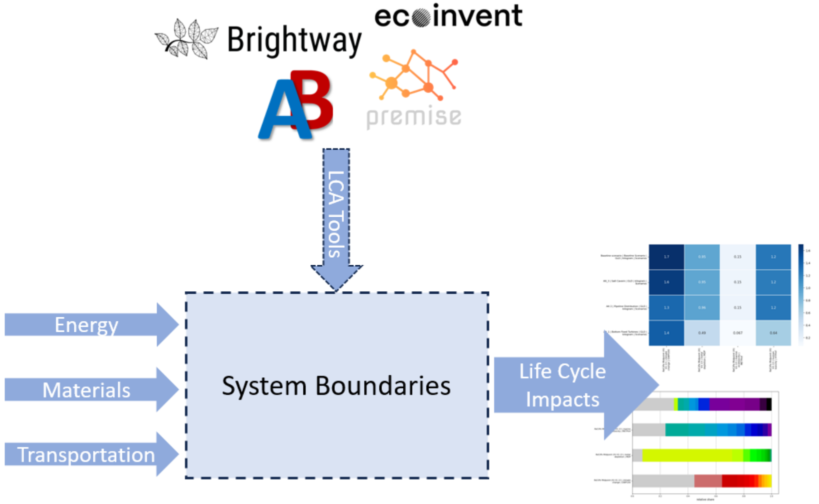
- Promote H_2 technologies to fulfill a green shift in Norway

Secondary objectives

- Identify environmental co-benefits and trade-offs
- Assessment of H_2 impact on the environment

Methods

The research focuses on two key areas. Method development involves refining integrated assessment tools that combine LCA with future scenario data for tailored prospective assessments in Norway. Applications include using these refined methods to assess specific value chains representing different combinations of hydrogen production and use.



Teymur Gogiyev

Affiliation(s): *NTNU*

Related projects: *FME HYDROGENi*

Educational Background:

- BSc Environmental Engineering (ADNSU)
- MSc Engineering (NTNU)
- MSc Industrial Ecology (NTNU)

Supervisor: Francesco Cherubini

Co-supervisors: Nicola Paltrinieri; Marcos Djun Barbosa Watanabe

Estimated progress of the PhD project:

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

Publications (WIP)

- Environmental aspects assessment of offshore H_2 production
- Environmental assessment of H_2 use as a reducing agent in the metallurgical industry

Climate impacts of advanced drop-in liquid biofuels for transport applications

Introduction

EU mitigation targets
55% reduction by 2030 *(EU Fit-for-55 package)*
90% reduction by 2050 *(EU net-zero Green deal)*

Difficult-to-abate transport applications
Aviation, Shipping, Road-freight transport need renewable drop-in fuels for mitigation

Advanced biofuels from forestry resources can offer more than 90% GHG reduction per MJ

Primary objective

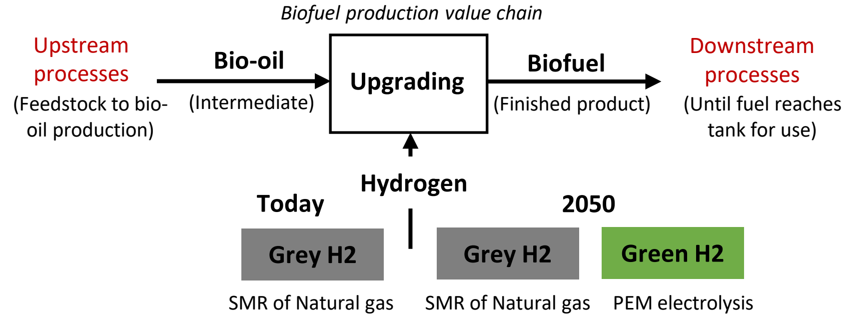
Identify emerging pathways for advanced biofuel production for climate mitigation in transport sector

Secondary objectives

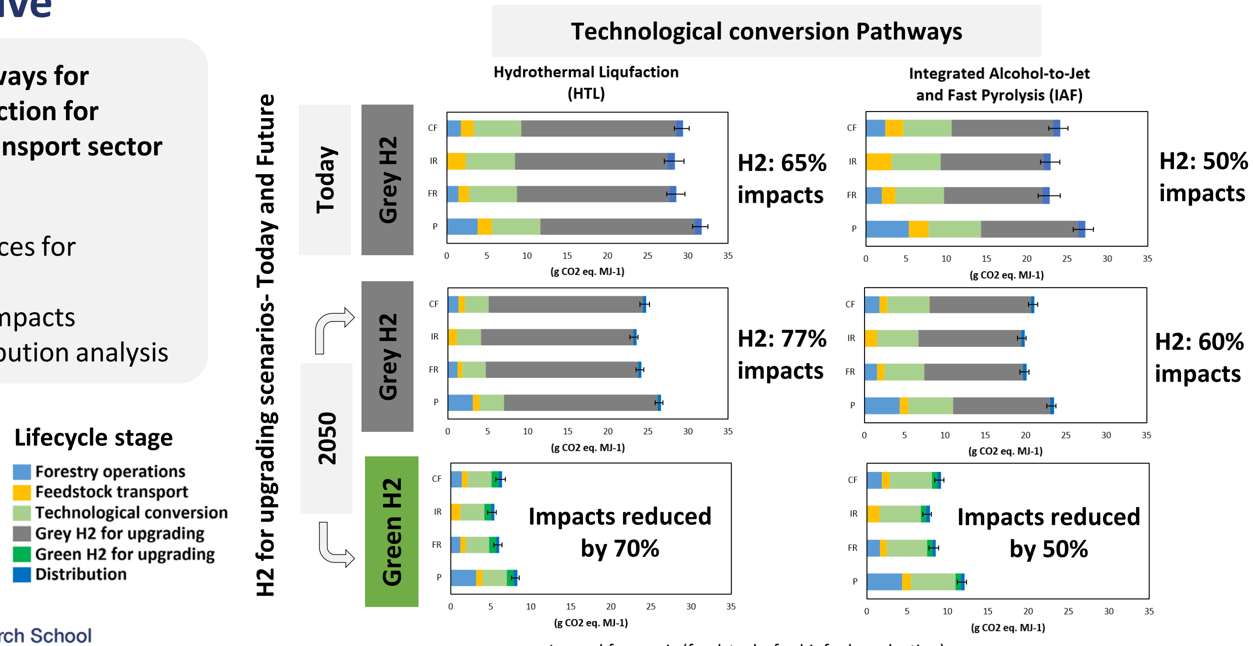
- Scenarios for H2 sources for upgrading
- Prospective climate impacts
- Lifecycle stage contribution analysis

Hydrogen for upgrading

Main driver for GWP100 life cycle climate impacts



GWP100 climate impacts of advanced biofuels



Legend for y-axis (feedstocks for biofuel production):
P- Pulpwood, FR- Forestry residues, IR- Industry residues, CF- Combined feedstocks

Vedant Ballal

Norwegian University of Science and Technology (NTNU), Trondheim

Project: FME Bio4Fuels- Norwegian Centre for Sustainable Bio-based Fuels and Energy

I am studying emerging technological pathways to produce **advanced biofuels** and **e-fuels** for difficult-to-abate **transport applications** of aviation, shipping and road-freight in Norway and in Europe. This involves conducting **techno-economic** and **lifecycle assessments** for sustainability.

Supervisor: Francesco Cherubini
Co-supervisor: Marcos Djun Barbosa Watanabe

Estimated progress of the PhD project:

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

Previous publication

***Climate change impacts** of **e-fuels** for **aviation** in Europe under present day conditions and future policy scenarios.*

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Norwegian University of Science and Technology

BIO4FUELS

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HySchool – Admitted PhD students (TA2)

TA2: Production

Name	Org.	Project title	TA1	TA2	TA3	TA4	TA5
Alicia San Martin Rueda	NTNU	In-situ characterization of perovskites using advanced techniques		②			
Anders Even Kvåle	UiB	Near field electrospinning for electrochemical electrodes	*	②			
John Senith Fernando	UiS	Carbon capture and gas separation technology		②			*
Jonas Himmelstrup	UiB	Design of novel catalysts for homogeneous ammonia synthesis		②			
Kristoffer Skjelanger	HVL	Development of mathematical and physical models for hydrogen production in rotating systems		②			
Leif Eric Hertwig	UiB	Design of novel catalysts for homogeneous ammonia synthesis		②			
Liina Sangolt	UiB	Utilization of offshore wind for hydrogen production		②	*		*
Lucas Cammann	NTNU	Plantwide control for flexible operation of electrolysis systems		②			*
Luyang Wang	UiO	Minority bulk and surface proton conduction in ceramic positrodes for proton ceramic electrochemical cells		②			
Marcello Costamagna	UiB	Towards sustainable ammonia production: development and implementation of evolutionary algorithms for catalyst design		②			
Marius Fredriksen	NTNU	Modelling, optimization and control of electrolyser systems	*	②			*
Megan Heath	NTNU	Towards reducing the anodic Ir loading in PEM water electrolysers		②			
Mengxin Wu	UiO	Performance and degradation of positrodes for proton ceramic electrolysers		②			
Minh Chi To	UiS	Green hydrogen production		②			
Mohamed Safy	UiO	Exploring the synergy of DFT and volcano plot analysis for the discovery of innovative catalysts in CO_2 hydrogenation		②			
Patrick Ewerhardt	UiO	Characterization and simulations of model electrodes in proton ceramic electrochemical cells		②			
Sivagowri Shanmugaratnam	UiB	Green hydrogen production through photocatalytic water splitting		②			
Stine Roen	UiO	Electrochemical characterization of mixed conducting ceramic positrodes for water splitting in electrolysis		②			
Thomas Benjamin Ferriday	UiA	Improving the membrane electrode assembly of an anion exchange membrane water electrolyser - A study of interfacial electrochemistry		②			
Tomasz Adam Skrzydlo	UiS	Catalytic cracking of methane over metal and carbon-based catalysts		②			
Torbjørn Egeland-Eriksen	UiO	Energy management for a novel hybrid energy storage system for the integration of renewable energy sources into the power grid		②	*	*	
Willow Dew	NTNU	Palladium-based membranes for hydrogen and ammonia		②			
Øyvind Lindgård	NTNU	Formulation and experimental validation of models for degradation and performance of catalytic layers for water electrolysis		②			

Near field electrospinning for electrochemical electrodes

Introduction

The PhD project is developing a novel near-field electrospinning method for preparing 3D structured nanofiber electrodes for electrochemical electrodes. The method can be used for production of several types of electrodes for electrolysis, fuel cells, battery, flow batteries or super capacitors. Advanced 3D structured electrodes can improve conductivity and increase the electrode surface area resulting in enhanced reaction activity. The development is an important measure to improve the capacity and performance of energy storage devices and reduce the need for critical raw materials. The project will focus on electrodes for electrolysis of water and the challenging oxygen evolution reaction, where today solutions require significant use of the critical raw material iridium as catalyst.

Primary objective

- Prepare 3D structured electrodes with nano fibers for improved electrochemical performance with a new novel near field electrospinning method.

Secondary objectives

- Fiber optimized for catalyst contact, pores for mass transfer and electron/ proton conductivity
- Reduce ohmic losses at the electrode
- Develop the method for preparing electrodes for batteries, super-capacitors, and other energy storage devices

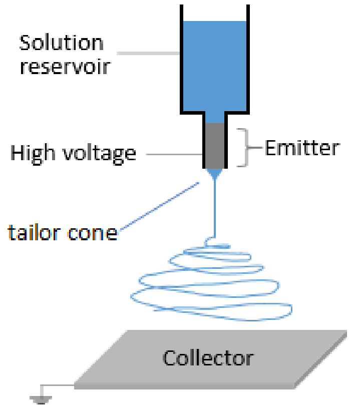


Figure 1 Traditional electrospinning method

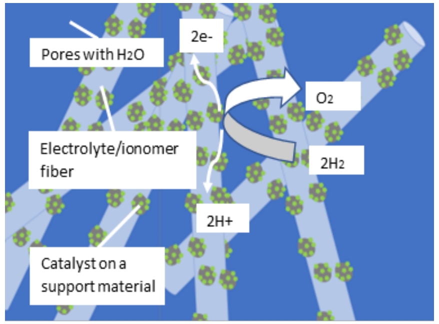


Figure 2: Electrospun fibers with electrochemical reaction

Anders E. Kvåle

University of Bergen & Element One Energy AS

I have a M.Sc. Degree in Engineering, Energy and Process from NTNU and worked for a couple of decades in the energy domain. The project is an industrial PhD for my start-up company Element One Energy AS where I am the founder

Estimated progress of the PhD project:

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

Publications

- Preparing a paper on "3d structured fiber with novel near-field electrospinning method" and publishing post patent on the near field method.

UNIVERSITETET I BERGEN

Norwegian Research School on Hydrogen and Hydrogen-Based Fuels

Decarbonizing H_2 Production in the Green Transition

Introduction

In 2022, 62 % of global hydrogen was produced from natural gas without carbon capture, utilization, and storage[1]. Steam Methane Reforming (SMR) with water gas shift which is the main process of H_2 production from natural gas, yields a product composition of 61% H_2, 19% CO_2, and 20% H_2O excluding the impurities [2]. It is essential to capture and store the produced CO_2 to produce blue hydrogen until the green transition takes over [3]. For H_2 to be utilized as a fuel with high energy density, the H_2 gas product mixture needs to be treated to produce high-purity H_2. The end-user applications such as different fuel cells, demand H_2 purities of 99.97% - 99.9995%. Therefore, the separation and purification unit should deliver H_2 at the highest recovery and highest purity with minimal energy input.

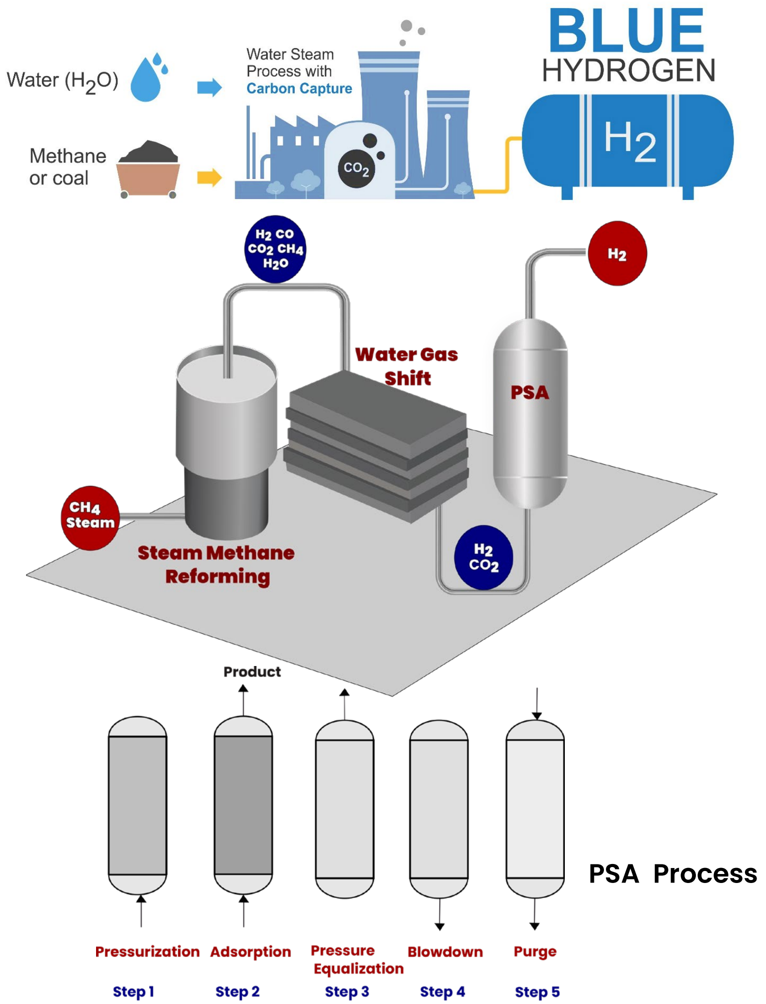
The future perspectives include enhancing the affinity of adsorbent materials for CO_2 to improve selectivity with better adsorption capacity and improving the material stability towards water and impurities. These could be achieved by modifying the surface area, pore sizes, and functionality of the materials.

Primary objective

- Investigating the potential of porous materials in gas separation.

Secondary objectives

- Developing PSA, TSA, and absorption-based systems using porous materials for carbon capture minimizing the drawbacks in current technologies.
- Purification and separation of gases such as hydrogen using the developed method.



John Senith Ravishan Fernando[1]

PhD Candidate, MSc. in Environmental Engineering - University of Stavanger, Norway, BSc. in Chemical & Process Engineering-University of Moratuwa, Sri Lanka.

Supervised by :

Dr. Sachin Maruti Chavan[1]

Prof. Bishnupada Mandal[2]

Affiliations:

[1]Functional materials and process chemistry (FUMAPRO) group Department of Chemistry, Bioscience and Environmental Engineering, University of Stavanger, 4036 Stavanger, Norway.

[2]Department of Chemical Engineering Indian Institute of Technology, Guwahati, India

Project: New Porous Liquids for Gas Separation and Carbon Capture.

Funded by Norwegian Research Council.

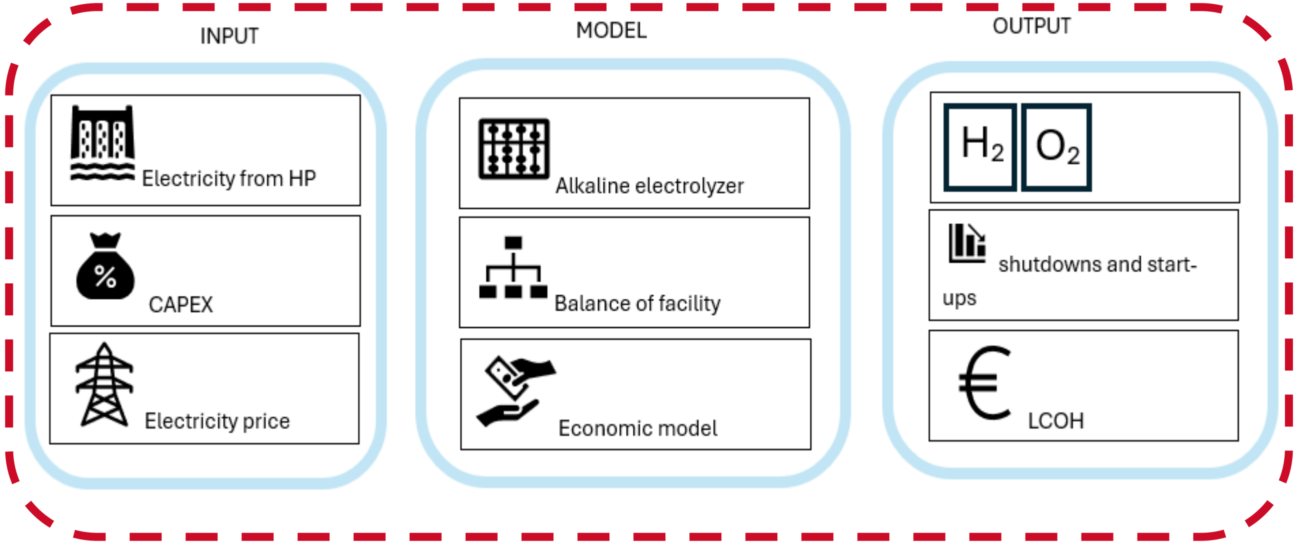
Estimated progress of the PhD project:

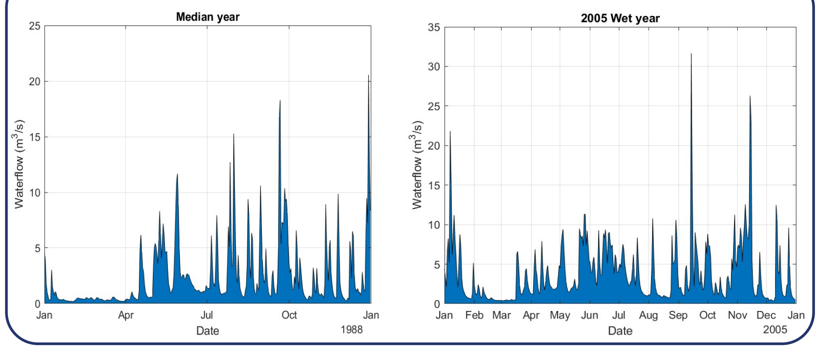
Just started ...	< 50 %	> 50 %	Almost done ☺
■	■		

Reference

1. IEA (2023), Global Hydrogen Review 2023, IEA, Paris https://www.iea.org/reports/global-hydrogen-review-2023, Licence: CC BY 4.0
2. Lei, L., Lindbråthen, A., Hillestad, M., & He, X. (2021). Carbon molecular sieve membranes for hydrogen purification from a steam methane reforming process. *Journal of Membrane Science, 627*. https://doi.org/10.1016/j.memsci.2021.119241
3. Noussan, M., Raimondi, P. P., Scita, R., & Hafner, M. (2020). The Role of Green and Blue Hydrogen in the Energy Transition—A Technological and Geopolitical Perspective. Sustainability, 13(1). https://doi.org/10.3390/su13010298

Hydrogen production from fluctuating power sources





Primary objective

- Analyze the different variable power sources that can be utilized for hydrogen production

Secondary objectives

- Analyze how to size the electrolyzers for the variable power input.
- Underwater storage safety aspects.

Liina Sangolt

Affiliations: = *UiB, HVL*

Related projects: *HyValue, Centre for safety at sea by HVL*

Master in Mechanical Engineering, 17 years of experience as a process engineer in the oil and gas industry, lecturing in Fluid Mechanics, Petroleum Production, and Technical safety in Process Industries

Estimated progress of the PhD project:

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

Publications:

- Sangolt L., Olivares A.F., Rognmo A.U., Quaysson E., Oltedal V.M., (2024-03-06-08) Modelling hydrogen production from small-scale hydropower, a case study, EHEC2024, Spain, Bilbao
- Sangolt L., (2024-03-21), Hydrogen production from run-off river power plant, EPHYC, Belgium, Ghent

Plantwide control for flexible operation of electrolysis systems

Lucas Cammann

Norwegian University of Science and Technology

TU Berlin (`15 - `18)

B.Sc. Chemical Engineering

TU Delft (`19 - `21)

M.Sc. Chemical Engineering

NTNU (`22 -)

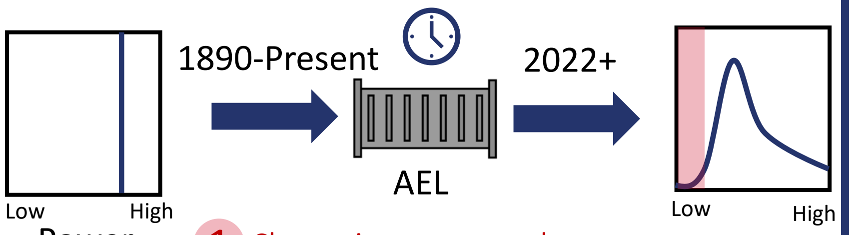
Ph.D. Candidate

Estimated progress of the PhD project:

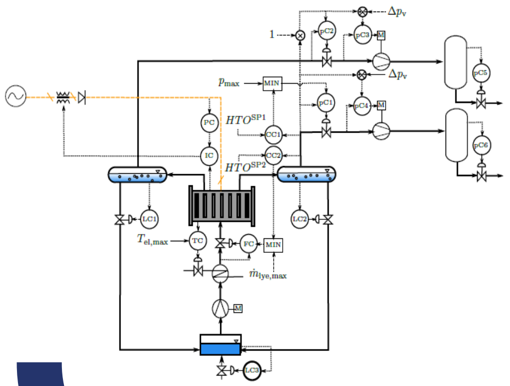
Just started ... **< 50 %** **> 50 %** **Almost done ☺**

Introduction

Coupling alkaline electrolysis processes with renewable energy sources requires rethinking electrolyser operating practices that today assume constant power supply. We are developing control methods to enable safe and efficient operation for renewably fuelled electrolysis systems, both on and off the electricity grid. The methodologies used are from the fields of process systems engineering, optimization and control.

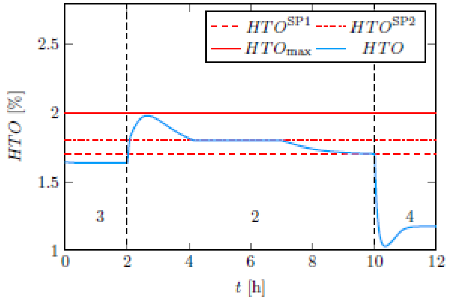


1 Change in power supply



2 Model and flowsheet development

3 *Simulation, optimization and control*



Primary objective

- Develop control strategies for the plantwide operation of electrolysis systems using renewable energies

Secondary objectives

- Elucidate bottlenecks in current operational practices
- Improve ways of handling the power input as a disturbance
- Analyse the control requirements for on-and off grid operation

Publications

- Cammann, L., Jäschke, J. (in press),A simple constraint-switching control structure for flexible operation of an alkaline water electrolyser, *IFAC-Papers Online*
- Cammann, L., Jäschke, J., Comparing operational strategies for alkaline electrolysis systems considering a probabilistic wind power distribution, *Computer Aided Chemical Engineering*

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Hy School.no 1

Norwegian Research School on Hydrogen and Hydrogen-Based Fuels

HYDROGENi *(Associated)

NTNU Department of Chemical Engineering

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

Introduction

The positrode is critical for proton ceramic electrochemical cells for **hydrogen** and ammonia, as a major contribution to the over-potentials and hence losses in the whole cell. It is challenging to characterise the proton transport in predominantly electronic conductors.

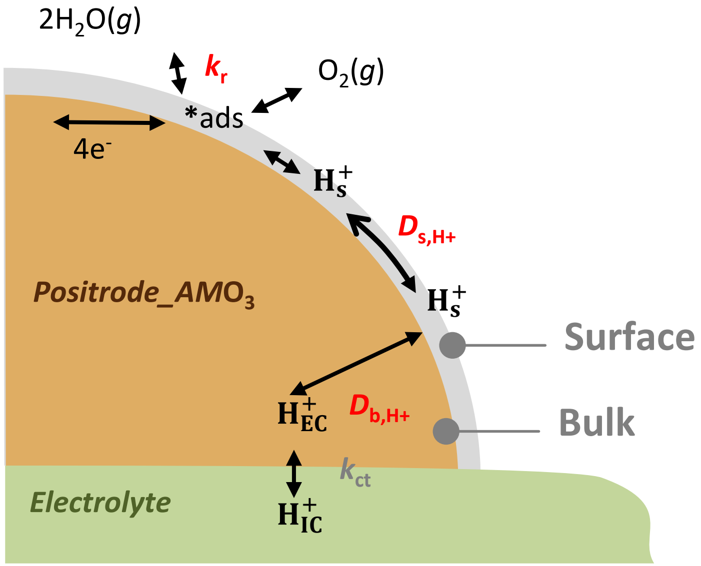
We want to establish theory and methodology for **measuring minority protonic** conductivities in electronic conductors. The results will be used as input to other project which perform computer simulations to seek strategies for optimization and effects on electrodes in scaled-up cells.

Primary objective

- Proton conduction in the bulk and on surfaces of positrode materials.

Secondary objectives

- Surface protonic conductance by proton flux.
- Proton conduction on conductive metal oxides.
- Brick layer model for mixed electronic and protonic conductive positrodes.



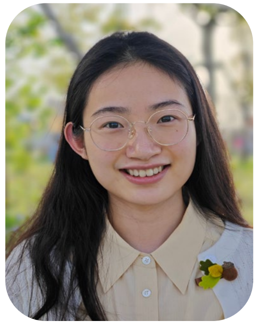
$$j_{H^+} = -D_{H_b^+}\frac{dc_{H_b^+}}{dx} = -D_{H_s^+}\frac{d\gamma_{H_s^+}}{dx}$$

$$G_{H_s^+} = F\gamma_{H^+}u_{H^+} = F\gamma_{H^+}\frac{FD_{H^+}}{RT}$$

Luyang Wang

University of Oslo

Related projects: FME HYDROGENi



I am doing PhD in Materials Chemistry at the Electrochemistry group with Truls Norby as my supervisor.

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

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

Estimated progress of the PhD project:

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

Publications

- Wang, L.; Gu, Y.; Wei, J.; Wu, X. Li-Ni-Co-Mn oxides powders recycled from spent lithium-ion batteries for OER electrodes in CO2 reduction. *Environ. Technol.* Innov. 2020, 18, 13, Article. *DOI: 10.1016/j.eti.2020.100732.*

Dissertation of MRes

- Using DFT to calculate the dual-atom catalysts for oxygen reduction reaction.

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HYDROGENi

UNIVERSITY OF OSLO : Centre for Materials Science and Nanotechnology

Towards reducing the anodic Ir loading in PEM water electrolysers

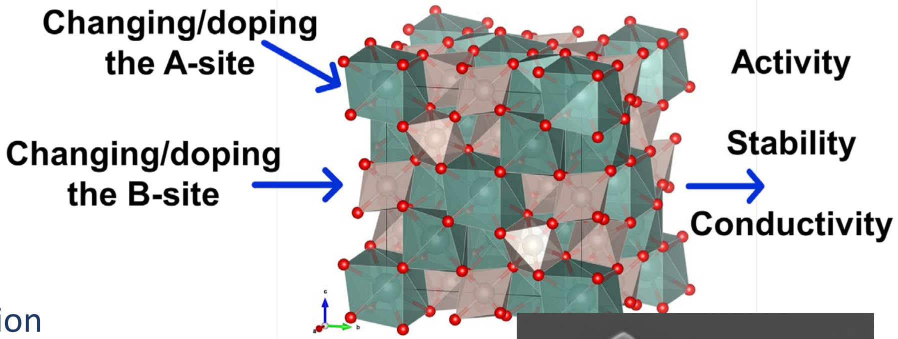
Introduction

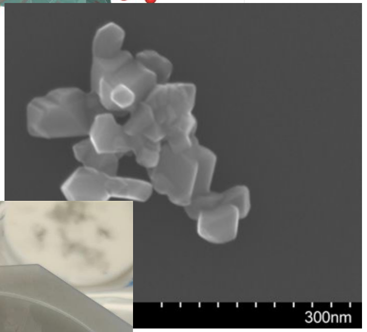
Hydrogen production through PEM water electrolysis (PEMWE) is:

- ✓ Flexible and compact
- ✓ Energy efficient
- ✓ Able to function with load changes

Expensive and scarce Ir used as oxygen evolution reaction (OER) electrocatalyst limits the large-scale implementation.
Ruthenium oxide is another excellent OER electrocatalyst, but has poor stability.

We investigate ruthenium pyrochlores ($Y_2Ru_2O_7$) to increase the stability of Ru and reduce the reliance on Ir. These pyrochlores are reported to have better OER activity than IrO_2[1,2]





References:

(1) Feng, Q.; Wang, Q.; Zhang, Z.; Xiong, Y.; Li, H.; Yao, Y.; Yuan, X.-Z.; Williams, M. C.; Gu, M.; Chen, H. Highly Active and Stable Ruthenate Pyrochlore for Enhanced Oxygen Evolution Reaction in Acidic Medium Electrolysis. Appl. Catal. B Environ. 2019, 244, 494–501.

(2) Kim, J.; Shih, P.-C.; Tsao, K.-C.; Pan, Y.-T.; Yin, X.; Sun, C.-J.; Yang, H. High-Performance Pyrochlore-Type Yttrium Ruthenate Electrocatalyst for Oxygen Evolution Reaction in Acidic Media. J. Am. Chem. Soc. 2017, 139 (34), 12076–12083.

Megan Heath

The Norwegian University of Science and Technology (NTNU)

HOPE project (Revolutionizing Green Hydrogen Production with Next Generation PEM Water Electrolyser Electrodes

I am passionate about conducting research pertaining to the green energy transition. I have a strong background in (electro)chemistry. I have conducted research on various OER electrocatalysts using electrochemical, physical and in-situ techniques (such as Raman spectroscopy).

Estimated progress of the PhD project:

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

Primary objective

Reduce the anodic Ir loading in PEMWE

Secondary objectives

- Optimise the synthesis method and doping strategy of the pyrochlores to obtain active and stable electrocatalysts.
- Develop standardised and rigorous methods to physically characterise the material and test activity and stability.

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NTNU
Norwegian University of Science and Technology

HOPE

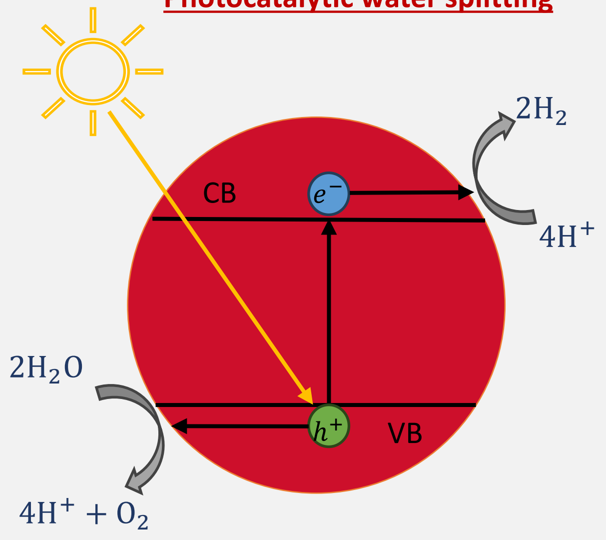
Noble-Metal-Free Core-Shell Plasmonic MOFs as Photocatalysts for Green Hydrogen Production

Introduction

Metal-Organic Frameworks (MOFs) are semiconductor-like materials composed of metal nodes and organic ligands. These materials have the potential to be good candidates for photocatalytic water splitting by themselves and through further enhancement [1].

The use of plasmonic enhancement for photocatalysts, focus largely on using conventional noble metals such as Ag or Au. This is due to their good optical response in the visible-near infrared region [2]. These metals, however, are scarce and have high cost, which is problematic for large scale production. The use of alternative plasmonic materials capable of surface resonance in the visible-near infrared region is therefore important to investigate [3].

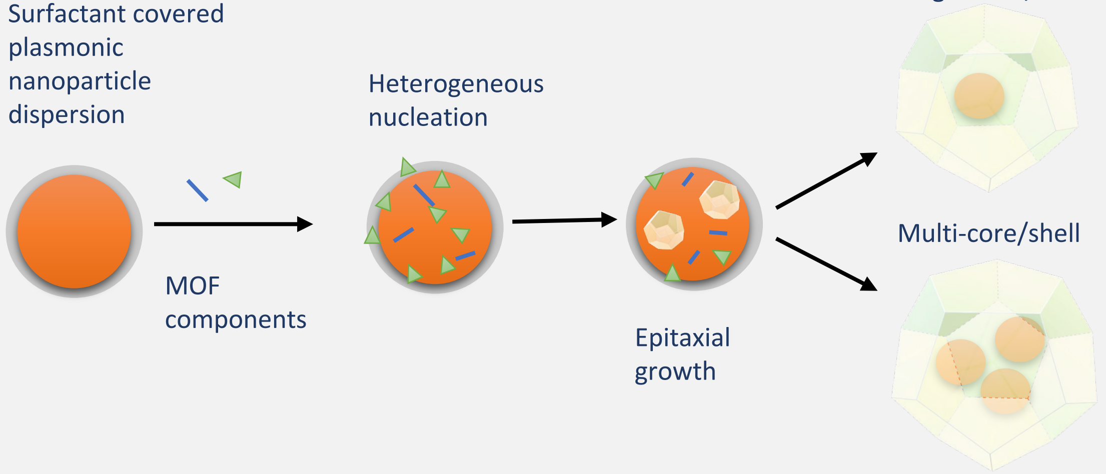
Photocatalytic water splitting



Primary objective

- Investigate and characterize plasmon enhanced MOFs based on alternative plasmonic materials
- Compare hydrogen production to plasmon enhanced MOFs based on conventional noble metal.

Synthesis of plasmon enhanced MOFs



Minh Chi To

University of Stavanger, Department of Mathematics and Physics

PhD-candidate in Material Physics

MSc in Physics from UiB

BSc in Physics from UiB

Estimated progress of the PhD project:

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

Reference

[1] Sergio Navalón, Amarajothi Dhakshinamoorthy, Mercedes Álvaro, Belén Ferrer, and Hermenegildo García. Metal–organic frameworks as photocatalysts for solar-driven over-all water splitting. Chemical Reviews, 123(1):445–490, 2023. PMID: 36503233

[2] Alberto Naldoni, Urcan Guler, Zhuoxian Wang, Marcello Marelli, Francesco Malara, Xiangeng Meng, Lucas V. Besteiro, Alexander O. Govorov, Alexander V. Kildishev, Alexandra Boltasseva, and Vladimir M. Shalaev. Broadband hot-electron collection for solar water splitting with plasmonic titanium nitride. Advanced Optical Materials, 5(15):1601031, 2017.

[3] Rou Li, Xianfeng Wang, and Ming Chen. Non-noble metal and nonmetallic plasmonic nanomaterials with located surface plasmon resonance effects: Photocatalytic performance and applications. Catalysts, 13(6), 2023.

University of Stavanger

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Green hydrogen as energy storage and energy carrier in combination with offshore wind power: Production, energy management and techno-economic analysis

Torbjørn Egeland-Eriksen

University of Oslo & NORCE

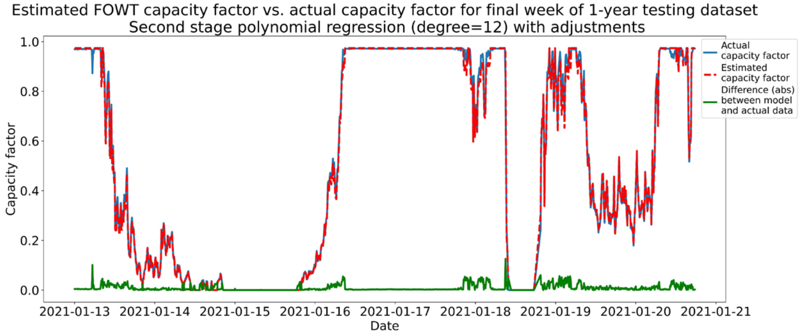
Introduction

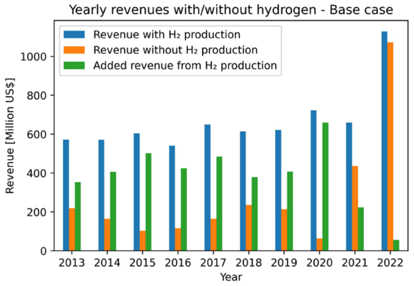
The global energy system is in a transition where the intent is to reduce anthropogenic emissions of greenhouse gases. The biggest cause of these emissions is the burning of fossil fuels, and one of the technologies that could potentially reduce fossil fuel usage is green hydrogen, i.e., hydrogen produced with renewable electricity. In my PhD project I have analysed technical and economic aspects of hydrogen as an energy storage medium and energy carrier in combination with renewable energy, with particular focus on the production of green hydrogen with electricity from offshore wind farms.

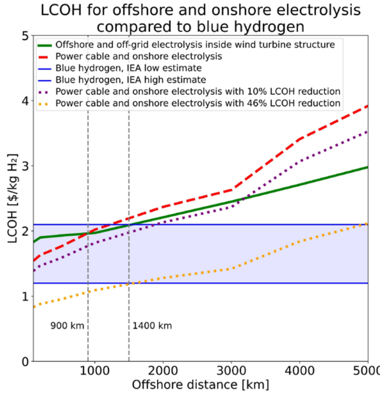
Primary objective

Perform research and analyses, collect data, develop computer models and perform simulations to answer the four research questions:

1. What are the main advantages and challenges with green hydrogen as energy storage in electricity systems?
2. What are the most important factors that influence the technical performance of green hydrogen production from offshore wind power?
3. What factors have the largest effect on the production cost of green hydrogen from offshore wind power?
4. Is it possible to improve the economic and technical viability of green hydrogen production from offshore wind power by developing a model that uses technical and economic factors to forecast and control the hydrogen production?







Top figure and bottom left figure is from the third publication. Bottom right figure is from the fourth publication.

I have worked on an industrial PhD in cooperation with the University of Oslo for the last five years (thesis submitted). I also work as a researcher with NORCE, where I am part of the Coastal and Ocean Systems group in Haugesund.

Estimated progress of the PhD project:

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

Publications

- T. Egeland-Eriksen, A. Hajizadeh, S. Sartori. Hydrogen-based systems for integration of renewable energy in power systems: Achievements and perspectives, *International Journal of Hydrogen Energy* (2021), vol. 46, pp. 31963-31983. DOI: https://doi.org/10.1016/j.ijhydene.2021.06.218
- T. Egeland-Eriksen, J. Flatgård Jensen, Ø. Ulleberg, S. Sartori. Simulating offshore hydrogen production via PEM electrolysis using real power production data from a 2.3 MW floating offshore wind turbine, *International Journal of Hydrogen Energy* (2023), vol. 48, pp. 28712-28732. DOI: https://doi.org/10.1016/j.ijhydene.2023.03.471
- T. Egeland-Eriksen, S. Sartori. Techno-economic analysis of the effect of a novel price-based control system on the hydrogen production for an offshore 1.5 GW wind-hydrogen system, *Energy Reports* (2024), vol. 11, pp. 2633-2655. DOI: https://doi.org/10.1016/j.egyr.2024.02.016
- T. Egeland-Eriksen, A. Oosterkamp. Electricity transport vs. hydrogen production from future offshore wind farms. Accepted for publication (March 2024) in the proceedings of *The 34th International Ocean and Polar Engineering Conference.*

Pd-based membranes for hydrogen and ammonia

Introduction

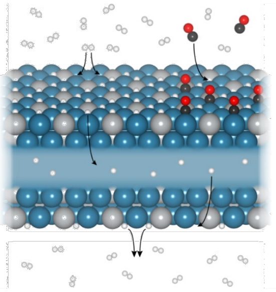
- To address distribution challenges in the development of hydrogen systems, ammonia is regarded as a high-potential carrier.
- While this solution would improve economic and safety considerations of hydrogen transport, it requires efficient separation and purification of hydrogen prior to end use.
-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

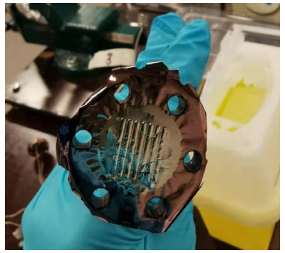
Primary objective

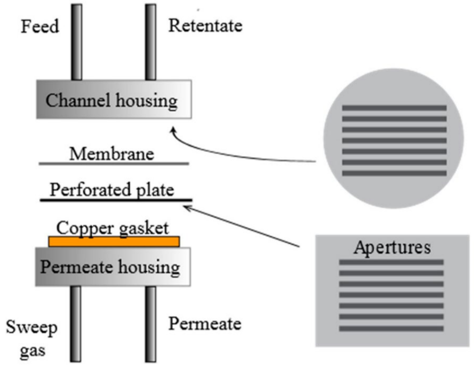
- Investigate performance and stability of PdAg membranes for hydrogen separation in the presence of ammonia

Secondary objective

- Improve understanding of PdAg membrane surface characteristics







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

Estimated progress of the PhD project:

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

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.

HySchool – Admitted PhD students (TA3)

TA3: Storage and distribution

Name	Org.	Project title	TA1	TA2	TA3	TA4	TA5
Abhishek Banerjee	UiS	Structure and dynamics in hydrogen-rich alloys for hydrogen storage			③		
Emil Høj Jensen	UiO	Energy storage systems for the integration of renewable energy sources into the power grid			③		
Ingrid Marie Stuen	UiB	Supply chain losses and quality degradation for large volume hydrogen transport chains			③	*	*
Mehmet Fazıl Kapçı	NTNU	Material integrity of titanium alloys for hydrogen energy applications			③		
Paula Endrös	NTNU	Designing hydrogen resistant Ti-6Al-4V parts manufactured by electron beam melting			③		
Raymond Mushabe	UiB	Experimental reservoir physics			③		*
Sadegh Ahmadpour	UiS	Hydrogen storage in porous media			③		
Sahra Louise Guldahl-Ibouder	NTNU	Development of novel materials for low-temperature ammonia cracking			③	*	
Sreeshyam Vadake Adat	UiO	High entropy alloys for hydrogen storage			③		
Vilde Gahr Sturtzel Lunde	UiO	Magnetocaloric materials for hydrogen liquefaction			③		
Wendpanga Jean Donald Minougou	UiS	PhD fellowship in geological storage of hydrogen			③		

Structure and Dynamics for Hydrogen Storage in Hydrogen-Rich Alloys

Abhishek Banerjee[1], Sato Toyoto[2], Stefano Deledda[3], Olena Zavorotynska[1]

[1] Department of Mathematics and Physics, University of Stavanger, 4021, Stavanger, Norway
[2] Department of Engineering Science and Mechanics, Shibaura Institute of Technology, Tokyo, Japan
[3] Department of Physics, Institute for Energy Technology, Kjeller NO-2027, Norway

equinor

Introduction

Background:

Titanium-iron (**TiFe**) is known for its hydrogen storage capabilities at room temperature, high volumetric capacities (**$0.096\ kg_{H2}/L$**). However, it is prone to **oxide** layer formation upon exposure to air, requiring energy-intensive activation processes.

Challenges and Solutions:

1. Elemental Doping: Incorporating different transition elements as **dopants** can potentially replace **Fe** and **Ti** in the crystal **lattice structure**, enhancing lattice **size** and creating new diffusion pathways.

2. Mechanical Processing: Post-mechanical processing offers further solutions to these challenges.

3. Research Gap: Limited studies exist showing **correlative**, **quantitative** understanding between **crystallographic** structures and H_2 **sorption** properties for TiFe metal-alloy systems doped with elements: **Nb**, **Ta**, **V** and in combinations.

Research Objectives and Methodologies

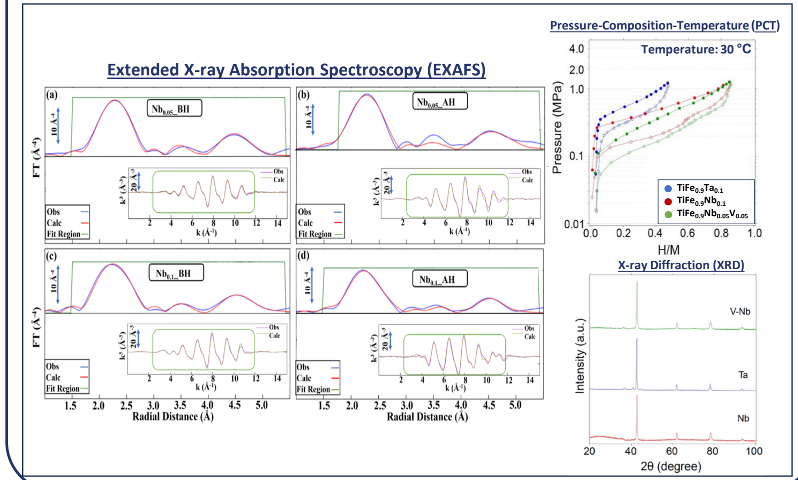
This project aims to address this gap by synthesizing TiFe samples with varied **Nb**/**Ta**/**V** stoichiometries using synthesis techniques: vacuum arc-melting (**VAM**) and mechano-chemical synthesis (for ex: **ball-milling**).

Utilizing state-of-art **characterization** techniques: Synchrotron powder X-ray diffraction (**S-PXRD**), X-ray Absorption Spectroscopy (**XAS**), Extended X-Ray Absorption Fine Structures (**EXAFS**) analysis to locate dopant **position** in TiFe crystal structure and understand its related effects on H_2 uptake/storage properties.

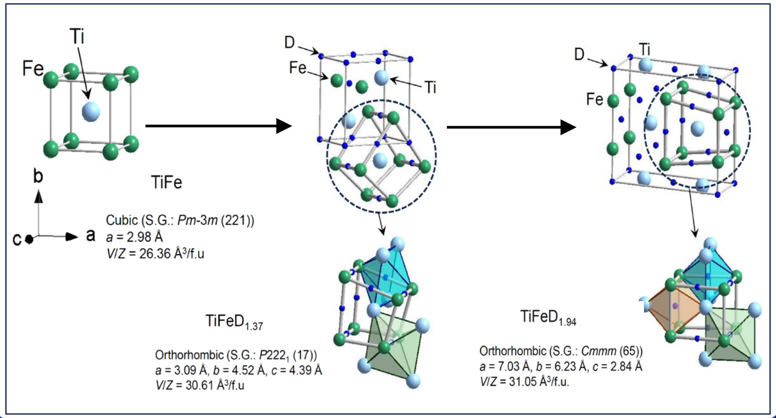
Acknowledgements

- Equinor ASA, Research Council of Norway, HyTack: Collaborative project between: UiS, USN, Savitribai Phule Pune University (SPPU), India, Tohoku University (TU), Japan, Shibaura Institute of Technology (SiT), Japan, IFE, NORCE, ISER, India.
- Staffs of ESRF (Grenoble, France) beamlines: BM01 (Swiss Norwegian Beamline (SNBL) in particular Dr. D. Chernysov) and BM31 (SNBL, in particular Dr. Stoian Dragos), respectively.

Characterization Techniques to Understand Fundamental Properties



Hydrogen Storage Methodologies



Abhishek Banerjee

Affiliation(s): ***University of Stavanger (UiS)***

Related projects: ***Hydrogen som Energibærer, Equinor***

Short Bio

- ***Masters (Ms) in Materials Physics from Norwegian University of Science and Technology (NTNU), Norway.***
- ***Currently pursuing PhD in Physics and Mathematics, from University of Stavanger (UiS).***

Estimated progress of the PhD project:

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

Publications/Conferences

- *Deciphering Atomic Structure and Hydrogen Sorption Kinetics and Uptake of TiFe-Nb doped Metal-Alloys utilizing Combined Techniques: Synchroton PXRD and EXAFS Techniques. **Banerjee, A.**, Deledda, S. and Zavorotynska, O. (2023) 'Research Exchange Program (REP)', Oral Talk. Tokyo: Shibaura Institute of Technology (SiT), 22nd Aug–3rd Nov, 2023.*
- *Deciphering Atomic Structure and Hydrogen Sorption Kinetics and Uptake of TiFe-Nb doped Metal-Alloys utilizing Combined Techniques: Synchroton PXRD and EXAFS Techniques. **Banerjee, A.**, Deledda, S. and Zavorotynska, O. (2023) 'Gordon Research Conference (GRC) - Hydrogen Metal System', Poster Presentation, Les Diablerets, 25th June-30th June, 2023.*
- *Sharma, A., Foppen, J. W., **Banerjee, A.**, Sawssen, S., Bachhar, N., Peddis, D., & Bandyopadhyay, S. (2021). Magnetic Nanoparticles to Unique DNA Tracers: Effect of Functionalization on Physico-chemical Properties. Nanoscale Research Letters, 16(1), 1-16. [24]. https://doi.org/10.1186/s11671-021-03483-5.*

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SIT SHIBAURA INSTITUTE OF TECHNOLOGY

IFE Institute for Energy Technology

Universitetet i Stavanger

RLABS

ESRF

PAUL SCHERRER INSTITUT PSI

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

Ingrid Marie Stuen

Affiliation: *University of Bergen*

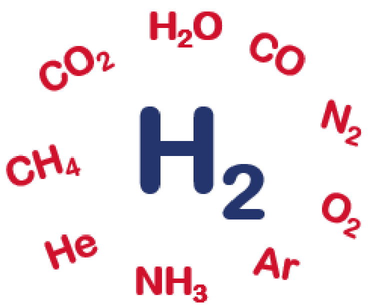
Related projects: HyMe, HyValue

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

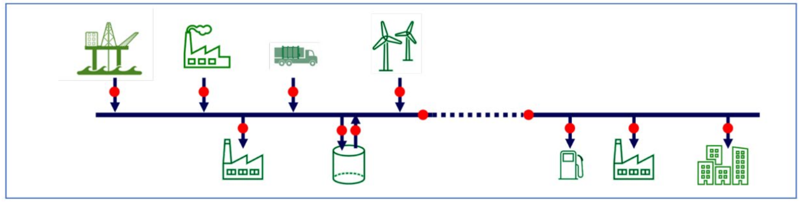
Introduction

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. For custody transfer of hydrogen, it is a prerequisite that the quantity and quality are measured accurately and can be traced to international standards.

A wide range of contaminants can enter the hydrogen stream along the supply chain. These must be measured to ensure that the hydrogen quality adheres to the relevant standards.



Example of hydrogen supply chain



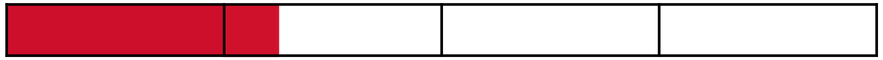
Primary objective

- How to detect and quantify losses and quality changes along the supply chain

Secondary objectives

- Identify high-risk nodes for loss and quality degradation
- Cost efficient quality determination
- Mass and energy balance

Estimated progress of the PhD project:



Publications (planned)

- State-of-the-art and challenges for quantity and quality measurements of large-volume hydrogen transportation
- High-Risk Nodes for Losses and Quality Degradation in Hydrogen Supply Chains

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

Experimental reservoir physics for underground hydrogen storage (UHS)

Introduction

I am conducting research in experimental reservoir physics relevant for underground hydrogen storage at core scale. The core of the research work is to understand short-cycle storage microbial effect on the hydrogen stored in the subsurface porous media. The research is being conducted at Centre for Sustainable Subsurface Resources (CSSR) in collaboration with University of Bergen.

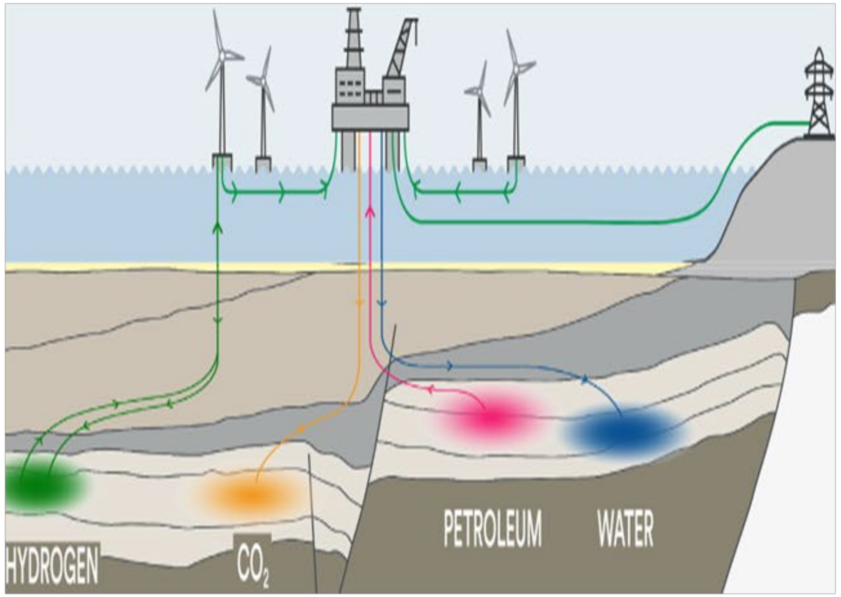
Primary objective:
Assess porous media hydrogen storage through multi-scale and multi-phase flow tests

Project goals:

1. To understand coupled transport processes such as hysteresis and bio-geochemical reactions as a result of exposure and history
2. Study at a core scale, microbial activity on stored hydrogen under anaerobic conditions
3. Utilise MRI-PET modalities to visualise bacteria growth and make in-situ saturation measurements in core samples
4. Correlate and upscale between core and pore scale experimental data
5. To provide quality laboratory data to validate a fully coupled numerical model

Why porous media:

- Offers enormous volumes
- Well distributed worldwide
- Established expertise from the petroleum industry
- Safety and environment
- *Microbial effect on UHS effeciency*



RAYMOND MUSHABE

Affiliation(s) = University of Bergen

Related projects: Centre for sustainable subsurface resources (CSSR-NORCE)

PhD fellow at UiB

MSc. Reservoir engineering from NTNU, Trondheim

BSc. Petroleum geoscience and production from MAK, Uganda

Estimated progress of the PhD project:

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

Publications (in the pipeline)

- In-situ visualization of microbial hydrogen consumption in a porous medium using high-resolution PET-MRI
- Predicting ultimate hydrogen production and residual volume during cyclic underground hydrogen storage in porous media using machine learning
- Quantifying microbial hydrogen consumption in porous media

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CSSR

NORCE

Underground Hydrogen Storage in Porous Media

Introduction

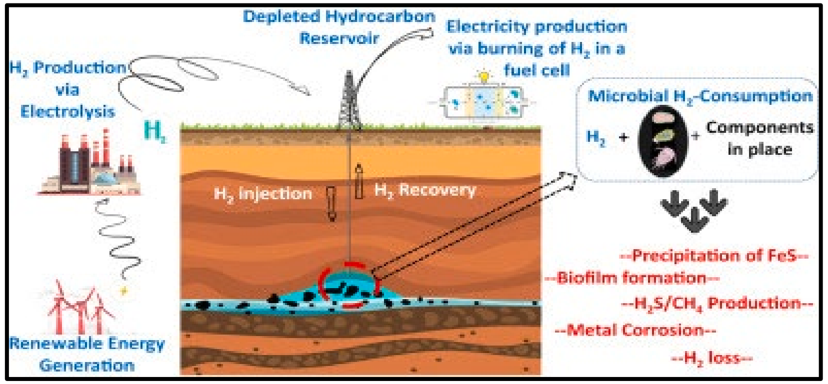
Storing hydrogen in depleted hydrocarbon reservoirs where the infrastructures are already built is a promising and safe solution to contribute to future hydrogen value chain. Porous geological settings can provide huge capacity for hydrogen storage. In order to store hydrogen in a safe and efficient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

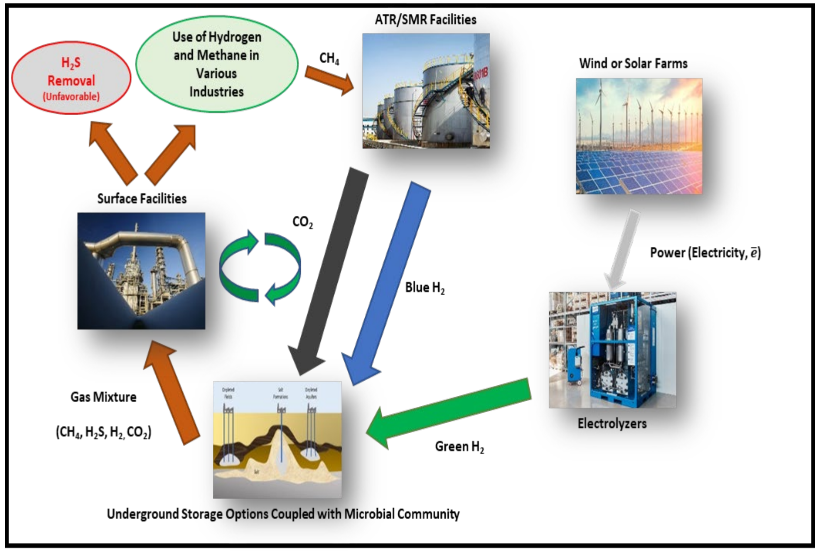
GUIDELINES

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 size of hydrogen molecule is extremely small that might diffuse through caprocks or adjacent formations.

Primary objective

- Biochemical reactions
  - Evaluation of microbial activities in contact with excess hydrogen
- Diffusion and Dispersion of Hydrogen
  - Evaluation of hydrogen loss through diffusion and dispersion
- Geochemical Reactions
  - Investigation of the interaction between hydrogen and minerals





Sadegh Ahmadpour

Affiliation(s): University of Stavanger (UiS)

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

Estimated progress of the PhD project:

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

Publications

- Ahmadpour, S., Gholami, R., *"Hydrogen Sulphide in Underground Hydrogen Storage Sites: Implication of Thermochemical Sulphate Reduction"*, Journal of Energy Storage (Under Review)

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Norwegian Research School on Hydrogen and Hydrogen-Based Fuels

University of Stavanger

University of Stavanger

High Entropy Alloys for Hydrogen Storage

Introduction:

- Hydrogen, a clean and versatile energy carrier, is pivotal for a sustainable energy future.
- Effective hydrogen storage is essential for promoting hydrogen-based energy sources.
- Many metal hydrides demonstrate an exothermic hydrogen absorption, offering compact and safer storage options with minimal risk of major hydrogen leaks.
- High entropy alloys (HEAs) offer promising solutions with unique properties for efficient hydrogen storage, while also enhancing safety and storage capabilities alongside metal hydrides.

Main Objective:

- To develop fundamental insight into HEAs with respect to their hydrogen storage performance.

Project Goals:

- Investigate why there is underutilization of hydrogen storage capacity in certain materials.
- Enhance hydrogen capacities and stabilities via alloy composition tuning.
- Explore hydrogen-to-metal ratios beyond standards in HEAs.
- Assess incorporating elements into HEAs while maintaining kinetics and reversibility.
- Examine the impact of non-hydride-forming elements in HEAs.

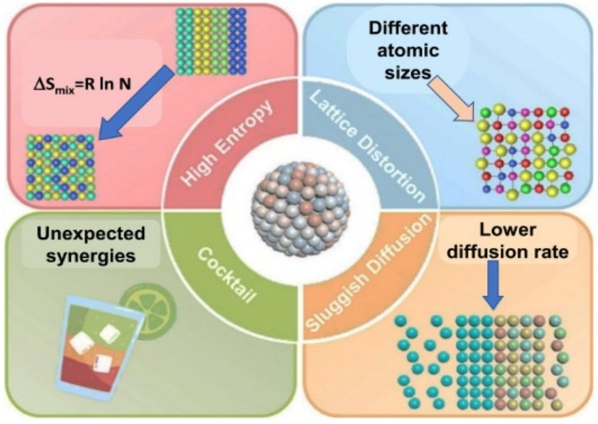


Fig.1 Schematic illustration of the four core effects affecting the properties of the HEAs [1]

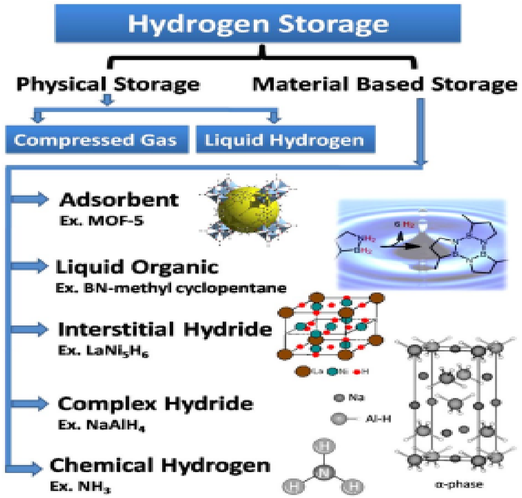


Fig.2 Different methods and phenomena of the various hydrogen storage systems [2]

Sreeshyam Vadake Adat

Affiliation(s) *= University of Oslo (UiO) & Institute for Energy Technology (IFE)*

Related projects: FME HYDROGENi

Supervisors: Professor Anja Olafsen Sjåstad (UiO) , Chief Scientist/Professor II Bjørn C. Hauback (IFE/UiO), Senior Scientist Stefano Deledda (IFE) and Professor Helmer Fjellvåg (UiO)

Education and Experiences:

PhD Research Fellow, Centre for Materials Science and Nanotechnology, Department of Chemistry, UiO (2024 onwards)

Research Assistant Intern, National Changhua Normal University, Taiwan (2023)

Master's Degree in Physics, Indian Institute of Technology Mandi, India (2020-22)

Estimated progress of the PhD project:

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

References:

1. Somo, T.R., Lototskyy, M.V., Yartys, V.A., Davids, M.W., & Nyamsi, S.N. **(2023)**. Hydrogen storage behaviours of high entropy alloys: A Review. Journal of Energy Storage, 73(Part B), 108969. ISSN 2352-152X. DOI: 10.1016/j.est.2023.108969.
2. Yadav, T.P., Kumar, A., Verma, S.K., et al. **(2022).** High-Entropy Alloys for Solid Hydrogen Storage: Potentials and Prospects. *Transactions of the Indian National Academy of Engineering*, 7, 147–156. DOI: 10.1007/s41403-021-00316-w.

- Sahlberg, M., Karlsson, D., Zlotea, C., et al. **(2016).** Superior hydrogen storage in high entropy alloys. *Scientific Reports*, 6, 36770. DOI: 10.1038/srep36770.

HySchool – Admitted PhD students (TA4)

TA4: Applications

Name	Org.	Project title	TA1	TA2	TA3	TA4	TA5
Abinavnataraj Ramakrishnan	UiS	Metal organic frameworks and zeolites for catalytic CO_2 hydrogenation to methanol				④	
Asutosh Mallick	UiT	Electrical system integration of large maritime PEMFC				④	
David Zilles	NTNU	Experimental study of low-carbon fuel injection and combustion in marine engines				④	
Duc Duy Nguyen	NTNU	Combustion of ammonia and hydrogen fuel mixtures in marine engine				④	
Elena Baboi	NTNU	Safe operations in hydrogen-based industry	*			④	*
Giulia Collina	NTNU	Hydrogen technologies to decarbonise the glass and aluminium sectors				④	*
Giulia Fede	NTNU	H2GLASS: Hydrogen technologies and smart production systems to decarbonise the glass and aluminum sectors				④	
Jiyong Alex Shin	NTNU	Combustion dynamics				④	*
Keivan Afshar Ghasemi	NTNU	Study of zero-carbon fuels for internal combustion engines				④	
Kinza Huma	UiS	Synthesis, structure and dynamics of oxyhydrides				④	
Liya Jacob	NTNU	SiO reduction using hydrogen				④	
Muhammad Baqir Hashmi	UiS	Performance assessment of hydrogen fuelled gas turbines			*	④	*
Muhammad Salman	UiO	Green hydrogen from air (FAIR)	*	*		④	
Reyhaneh Banihabib	UiS	Development of real-time smart data analytic tools for monitoring and optimum operation of MGT systems				④	
Tristan van Kaam	NTNU	The use of hydrogen as a reducing agent in the production of rutile and ferro manganese alloys				④	

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

Introduction

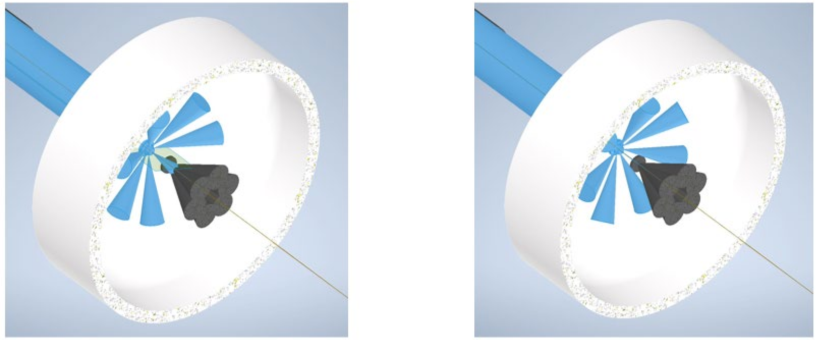
Ambitious goals of the International Maritime Organization envision a decarbonization of the international shipping industry until 2050. New synthetic fuels such as Ammonia (NH_3) and Methanol (CH_3OH) are promising options to reduce green-house-gas emissions from marine internal combustion engines. Their thermophysical properties deviate strong from conventional compression ignition fuels resulting in 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

Identify and determine injection parameters supporting a retrofit of current marine engines with low-carbon NH_3 and CH_3OH.

Secondary objectives

- Characterize experimentally the dual fuel combustion of NH_3/CH_3OH (main injection) and various ignition promoters (pilot injections) in a constant volume combustion chamber.
- Identify the maximum practical NH_3 and CH_3OH energy share for various pilot fuels to reduce ignition time and increase reliability of combustion.
- Determine the best injection timings and spray interaction between main and pilot injections.



blue – heptane injection
black – NH_3 injection

Fig.1: Spatial plume interaction of main and pilot

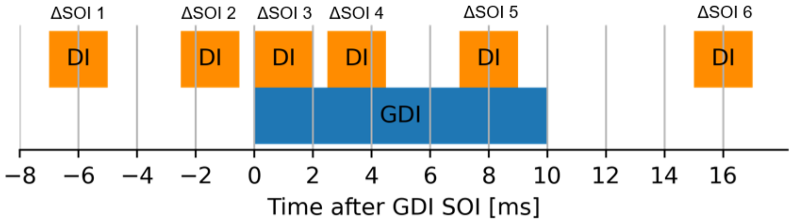


Fig.2: Temporal plume interaction of main and pilot

David Zilles

Affiliation: NTNU, Institutt for marin teknikk (IMT)

Master of Science degree 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 friluftsliv, road cycling and running.

Estimated progress of the PhD project:

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

Publications

Oftedahl, Live; Zilles David. (2023) Flytende ammoniakk og methanol kan bli fremtidens drivstoff. (Blog entry)

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NTNU
Department of Marine Technology

NTNU – Trondheim
Norwegian University of Science and Technology

Combustion Kinetics Group

Safe Operations in Hydrogen-based Industry

Introduction

As part of the HyInHeat project, through the creation of safety training material, the scholarship will assist with the integration of hydrogen in high temperature heating processes taking place within steel and aluminum manufacturing.
The HyInHeat project is one of the first EU funded projects that has a section in a Work package that is dedicated to the creation of safety training material.

Primary objective

- Creation of modular safety training material covering:
  - Normal operations
  - Maintenance operations
  - Critical events

Elena Baboi

Affiliation: Norwegian University of Science and Technology

Related projects: *Hydrogen technologies for decarbonization of industrial heating processes (HyInHeat)*

Master of Engineering of Chemical Processes

Bachelor in Engineering in Chemical Engineering

Experience in molecular dynamics for CO_2 capture, medical device manufacturing, food engineering, dyes, tensio-active agents

Estimated progress of the PhD project:

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

Publications:

- Hazards33 IChemE:
- ESREL2024
- CISAP11

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NTNU
HYINHEAT

Loss Prevention and Maintenance Modelling for Hydrogen-based Industry

Description

This Ph.D. is part of the H2GLASS project (*https://h2-glass.eu/*).

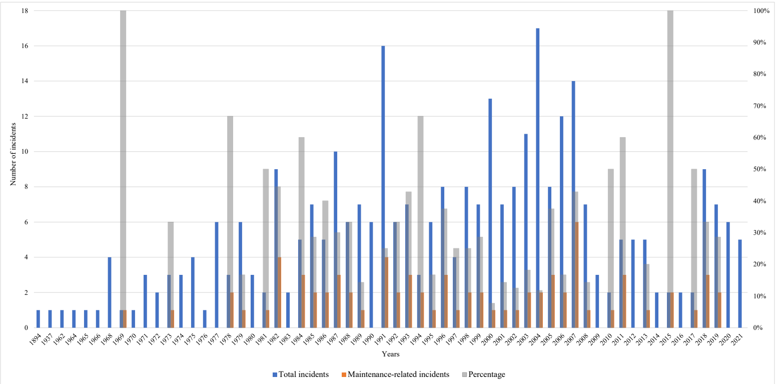
The glass industry will have to be completely decarbonised to reach net-zero emissions by 2050. This project aims to create the technology stack that glass manufacturers need to realise 100% H2 combustion in their production facilities, ensure the required product quality, and manage this safely.

Primary objective

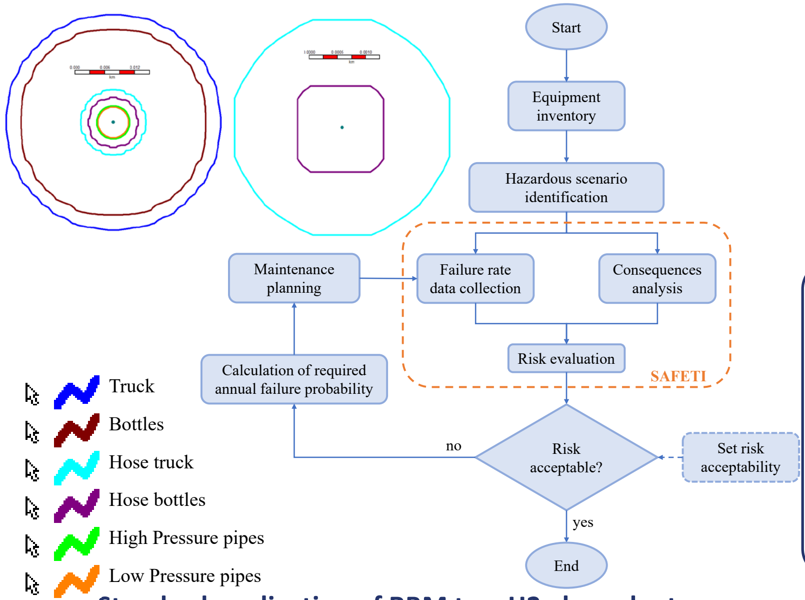
Guarantee safe operability of emerging hydrogen-based industry

Secondary objectives

- Loss of integrity analysis: models and sensors for H2 applications
- Risk-based inspection and maintenance model development



Criticality of maintenance operations



Standard application of RBM to a H2 glass plant

TA4 – Applications
TA5 – Safety

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H2GLASS DECARBONISING OUR FUTURE

NTNU | Norwegian University of Science and Technology

Giulia Collina

PhD candidate at NTNU – Norwegian University of Science and Technology

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

- Master's degree in Chemical and Process Engineering – University of Bologna (2020-2023)
- Bachelor's degree in Chemical and Biochemical Engineering – University of Bologna (2017-2020)

Estimated progress of the PhD project:

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

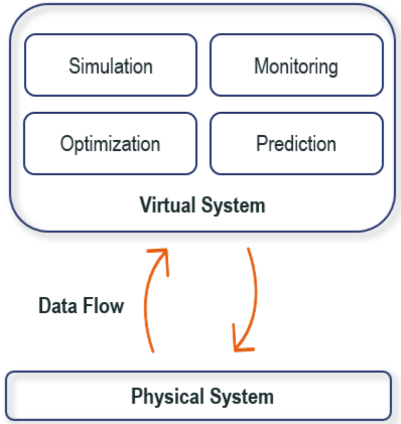
Publications

- Collina, G. et al., (2023). Fragments generated during liquid hydrogen tank explosions. *Chem. Eng. Trans.*
- Collina, G. et al. (2023). Risk-Based Maintenance models for hydrogen systems: a review for the glass and aluminium industry. Hazards33, IChemE.
- Collina, G. et al. (2023). Lesson learned from H2-related incidents: criticality of maintenance operations. Hazards33, IChemE.

Digital Twin for integrated production and maintenance planning in hydrogen-based process industries

Introduction

Green hydrogen offers a promising path to decarbonize energy-intensive process industries like glass, aluminium, and steel. H2GLASS, the EU initiative funding this research, is moving in this direction. The goal is to demonstrate the feasibility of integrating green hydrogen into glass production and prove its transferability to the aluminium sector. However, this transition may bring several challenges due to different combustion conditions, potentially affecting glass quality and furnace integrity. To remain competitive, process industries rely on maximizing production efficiency, leveraging effective maintenance to minimize costly downtime and ensure continuous production. Maintenance becomes even more critical when a hazardous substance is introduced in the process. To address the expected inefficiencies glass manufacturers may face, Digital Twin (DT) has been identified as relevant for optimizing production and managing maintenance. Furthermore, considering the interdependencies between these tasks, adopting an integrated perspective on their related decision-making processes can enhance overall business performance, as claimed by many researchers.



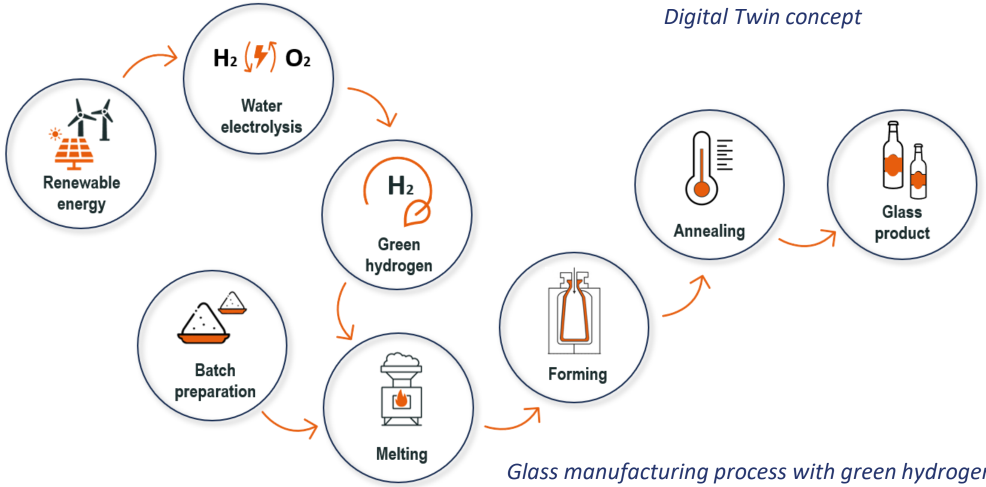
Digital Twin concept

Primary objective

Investigate the benefits of integrating production and maintenance planning using DT in hydrogen-based process industries

Secondary objectives

- Develop a decision support tool to assess the potential benefits of DT implementation based on manufacturing process characteristics
- Investigate the implications of integrating hydrogen into glass manufacturing from production and maintenance perspectives
- Develop a DT-based framework for the joint planning of production and maintenance in hydrogen-based process industries



Glass manufacturing process with green hydrogen

Giulia Fede

Norwegian University of Science and Technology (NTNU)

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)

Estimated progress of the PhD project:

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

Publications

- G. Fede, F. Sgarbossa, N. Paltrinieri (2024). Integrating production and maintenance decisions in process industries using Digital Twin: A literature review. 18th IFAC Symposium on Information Control Problems in Manufacturing – INCOM2024 **(submitted)**

Combustion instability in future hydrogen combustors for power generation applications

Introduction

My work is investigating the instability of hydrogen combustion inside the gas turbine systems. The 'FlameSheet' is a versatile gas turbine combustor that can accommodate various fuel types. Pressure and heat release fluctuations are the primary factors of combustion instability, which can potentially damage the combustor.

Primary objective

- Analyzing the dynamics of 'FlameSheet' combustor model system which is relevant to combustion instability

Secondary objectives

- Analyzing the resonance frequency and vortex shedding of the 'FlameSheet' combustor model system.

Recent Progress
Non-Reactive flow analysis

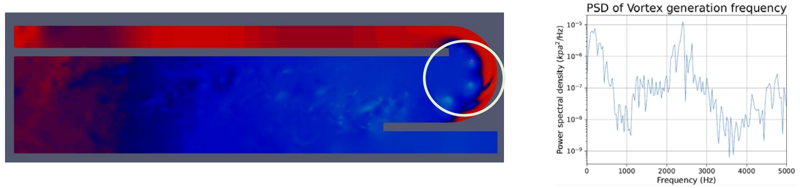


Fig 1. Vortex generation analysis; Left-Location of vortex generation, Right-Pressure Power Spectrum Density measured at vortex generation point

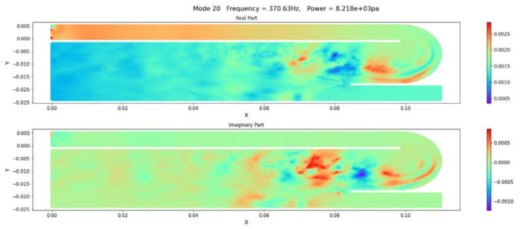


Fig 2. Dynamic Mode Decomposition (DMD) pressure eigenvectors (associated frequency: 370.63 Hz) expressed on the gas turbine system

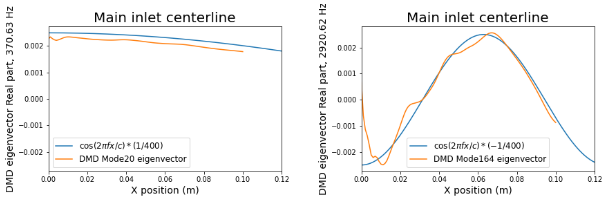


Fig 3. Acoustic wave observed at Main inlet centerline; Left-Mode 20 associated with 370.63 Hz, Right-Mode 164 associated with 2920.62 Hz

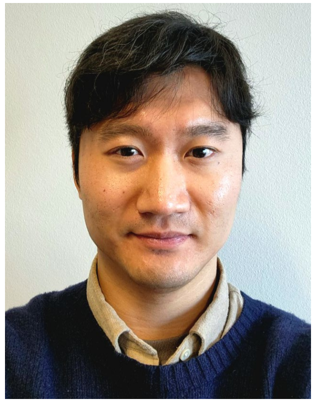
Jiyong Alex Shin

PhD candidate at NTNU

Related projects: LowEmission , Carbon-free firing of gas turbines

MSc. Energy and Environment Technology from University of South-eastern Norway

BSc. Mechanical Engineering from Kyushu University



Estimated progress of the PhD project:

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

Publications

- Shin J., Henriksen M., Bjerketvedt D., Hydrogen and Ammonia Combustion (Master's thesis)
- M.Ibrahim O.1, Shin J.1, Sikka R.1, Hansen P.M.1, Vågsæther K.1, Experimental study on hydrogen pipeline leakage: Negative pressure wave characteristics and inline detection method (Progress)

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NTNU
Norwegian University of Science and Technology

LOWEMISSION

Study of zero-carbon fuel for internal combustion engines (ICEs) – Ammonia Injection

Introduction

- Addressing climate change involves reducing greenhouse gas emissions. Hydrogen, a carbon-free energy carrier, is popular but its storage and use in ICEs are controversial due to its properties.
- Ammonia (NH_3), with its high hydrogen content, existing production infrastructure, and easy liquid storage, is a promising ICE fuel. However, its unique characteristics, such as high auto-ignition temperature and narrow flammability range, require further research.
- Direct injection (DI) of liquid NH_3 into ICEs can improve combustion and emissions control. And allow co-injection with other fuels like biodiesel. However, the rapid phase change phenomena of liquid NH_3, namely cavitation and flash boiling, which are more likely to happen in this approach, need more experimental data and precise numerical models.

Numerical Approach

- Most cavitation models, using volume of fluid, treat the phenomenon as isothermal, with mass transfer rates calculated based on pressure differences between phases, i.e. mechanical effect. However, if the superheated liquid nears its boiling temperature, this approach may fall short, necessitating the inclusion of thermal effects, which would be the case for thermal fluids like ammonia.
- The methodology for this project includes implementation of a new thermodynamic cavitation model and a non-isothermal cavitation solver in OpenFOAM, to simulate ammonia's cavitation and flash boiling inside the injector.

Experimental Approach

- There is a notable lack of comprehensive data pertaining to the characterization of ammonia injection and spray. To address this, it is crucial to conduct experimental characterizations alongside numerical simulations. This dual approach will facilitate subsequent validation and comparative analysis of the results.
- The methodology for this project incorporates the utilization of a well-established experimental technique known as momentum flux measurements. This is complemented by high-speed imaging to effectively characterize the injection and spray of ammonia.

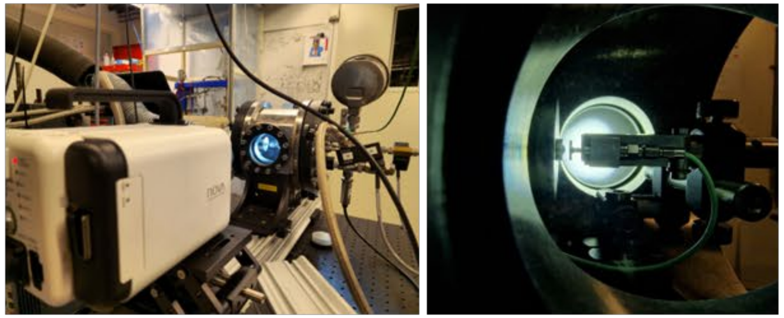

Fig. Experimental Setup

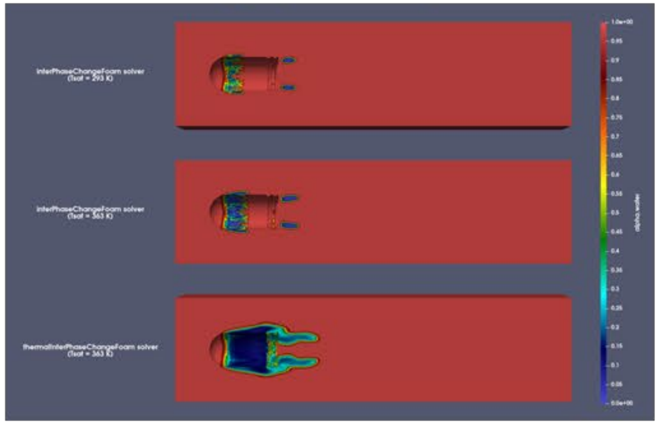

Fig. Initial numerical results, i.e. comparison between models

Keivan Afshar Ghasemi

Ph.D. candidate at NTNU – Norwegian University of Science and Technology

Starting with Aerospace Engineering, I found my passion in addressing energy and environmental issues. My bachelor's project simulated a new wind turbine design, and my thesis developed an innovative natural gas burner. In my master's in Norway, I delved into hydrogen research, focusing on safety aspects of compressed gaseous hydrogen, including auto-ignition of leakages and hydrogen-air mixing. My PhD research is on practical applications of zero-carbon fuels in ICEs, with a special focus on ammonia behavior.

Estimated progress of the PhD project:

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

Publications

- K. Afshar Ghasemi, "Implementing a non-isothermal interPhaseChangeFoam solver with a thermodynamic cavitation model," In Proceedings of CFD with OpenSource Software, 2023, Edited by Nilsson. H., doi: http://dx.doi.org/10.17196/OS_CFD#YEAR_2023.

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NTNU
Department of Marine Technology

HySchool – Admitted PhD students (TA5)

TA5: Safety

Name	Org.	Project title	TA1	TA2	TA3	TA4	TA5
Abhishek Subedi	NTNU	Safety solutions for hydrogen storage and transport			*	*	⑤
Alessandro Campari	NTNU	Loss prevention and operational safety of hydrogen technologies			*	*	⑤
Alice Schiaroli	NTNU	Performance of hydrogen storage components exposed to fire with focus on cryogenic equipment			*		⑤
Anna Marie Lande	USN	Mitigation of hydrogen explosions					⑤
Dikshya Bhandari	UiS	Identifying and mitigating risks in hydrogen energy for safer integration		*			⑤
Efthymia Derempouka	UiB	Hydrogen as energy carrier in society: risk picture, risk awareness and public acceptance (HySociety)	*				⑤
Farhana Yasmine Tuhi	NTNU	Reliability and resilience of green hydrogen production systems		*			⑤
Federica Tamburini	NTNU	Liquid hydrogen transport and use			*		⑤
Leonardo Giannini	NTNU	Loss prevention and operational safety of hydrogen technologies			*		⑤
Lucas Claussner	NTNU	Modelling of loss of containment consequences of hydrogen technologies					⑤
Matthijs van Wingerden	UiB	Chemical inhibition of hydrogen explosions					⑤
Melodia Lucas	UiB	Improved modelling of hydrogen explosions					⑤
Petar Bosnic	USN	Development of a CFD methodology to reduce the hazards of hydrogen and ammonia systems in maritime and industrial sectors					⑤

Improved modeling of socio-technical systems for hydrogen value chain

Introduction

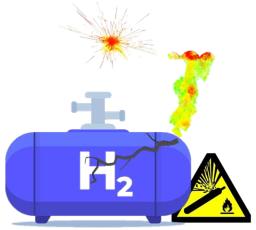
The need for a sustainable energy source is on the rise as fossil fuel reserves dwindle and the impacts of climate change become more evident. Hydrogen is emerging as a potentially clean and sustainable energy carrier. For viable integration of hydrogen into the energy value chain, the hydrogen systems should be safe. It is important to realize that hydrogen systems are complex socio-technical systems. Human and or operational aspects plays a crucial role in preventing catastrophic events. These aspects serve as safety barriers to prevent, control, and or mitigate undesired events. However, there is a challenge to correctly quantify these aspects. This requires an absolute study towards improved modeling and quantification of socio-technical systems for hydrogen value chain

Primary objectives

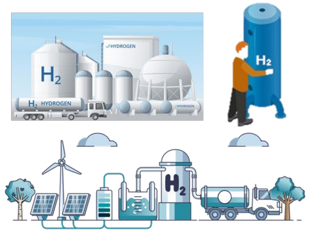
- Assessment of hydrogen systems while considering socio-technical factors.
- Innovate modeling techniques to enhance risk detection, inspection, and maintenance of hydrogen systems.
- Develop optimum and safe test procedures for hydrogen experiments.

Secondary objectives

- Develop ad-hoc models to identify critical points of failure in hydrogen systems.
- Study and analyze emerging risk to enhance hydrogen system reliability and resilience



Hydrogen Hazard



Secure Hydrogen value chain

Abhishek Subedi

Norwegian University of Science and Technology (NTNU)

PhD candidate at Department of Mechanical and Industrial Engineering, NTNU

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

Author of **Compendium of Fundamental of Hydrogen Technology**

Estimated progress of the PhD project:

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

Publications

- Subedi, A., & Thapa, B. S. (2023). Compendium of Fundamentals of Hydrogen Technology (I). Kathmandu University.
- Subedi, A., Campari, A., Singh Thapa, B., & Paltrinieri, N. (2023). Safety Evaluation of Hydrogen Pipeline Transport: an Approach Based on Machine Learning. Chemical Engineering Transactions
- Subedi, A., Campari, A., Alvaro, A., Thapa, B. S., & Paltrinieri, N. (2023). Evaluation of the Factors Determining Hydrogen Embrittlement in Pipeline Steels: An Artificial Intelligence Approach.
- Collina, G., Subedi, A., Campari, A., Singh Thapa, B., & Paltrinieri, N. (2023). Lesson learned from H2-related incidents: criticality of maintenance operations. In SYMPOSIUM SERIES.
- Ghimire, R., Niroula, S., Pandey, B., Subedi, A., & Thapa, B. S. (2024). Techno-economic assessment of fuel cell-based power backup system as an alternative to diesel generators in Nepal: A case study for hospital applications. I.J. of Hydrogen Energy
- Niroula, S., Chaudhary, C., Subedi, A., & Thapa, B. S. (2023). Parametric Modelling and Optimization of Alkaline Electrolyzer for the Production of Green Hydrogen. IOP Conference Series: Materials Science and Engineering
- Subedi, A., & Thapa, B. S. (2022). Parametric modeling of re-electrification by green hydrogen as an alternative to backup power. IOP Conference Series: Earth and Environmental Science

abhishek.subedi@ntnu.no

Loss Prevention and Operational Safety of Hydrogen Technologies

Towards Risk-Based Inspection of Hydrogen Transport and Storage Equipment

Introduction

Hydrogen could replace fossil fuels and mitigate the issue of global warming. However, equipment operating in H_2 environments is prone to hydrogen-induced damages, which manifest through a reduction of ductility, fracture toughness, and fatigue performance. They may cause component failures at stress levels significantly below the design level, therefore determining loss of containment.

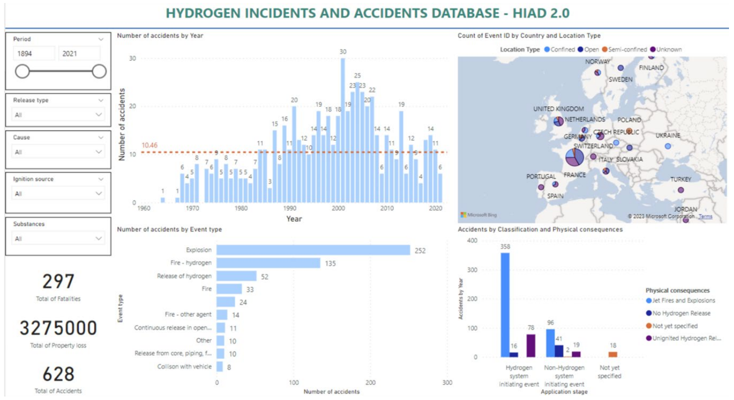
Inspection activities are necessary to preserve the physical integrity of the containment systems, and the risk-based (RBI) methodology is considered the most beneficial approach.

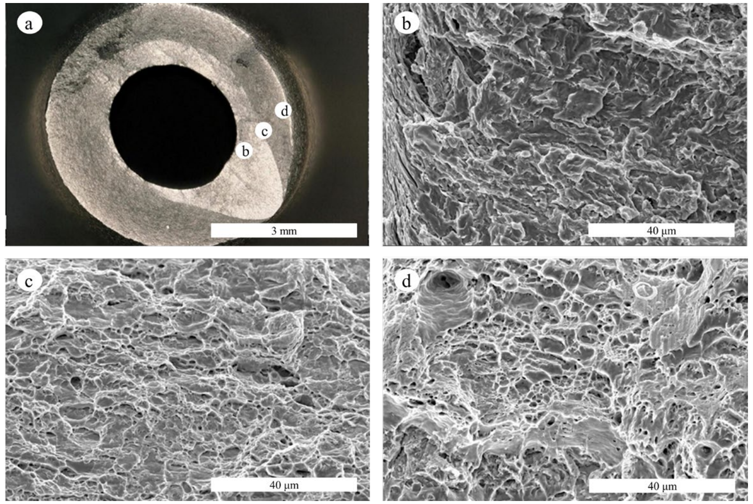
Primary objective

- Investigation of hydrogen embrittlement effects
- Development of machine learning models for inspection and maintenance planning of hydrogen technologies
- Application of the RBI methodology to equipment operating in gaseous hydrogen environments
- Experimental investigation of HE in pipeline steels

Secondary objectives

- Design of ad-hoc preventive safety barriers for hydrogen technologies
- Multi-objective optimization of inspection and maintenance of hydrogen transport pipelines





Alessandro Campari

Norwegian University of Science and Technology NTNU

Related projects: H_2 CoopStorage, SH_2IFT – 2, SUSHy, NICOLHy

PhD candidate at the Department of Mechanical and Industrial Engineering (NTNU).
Visiting researcher at the Federal Institute for Material Research and Testing (BAM).
Visiting researcher at the University College London (UCL).
My research is aimed at developing a methodology for inspection and maintenance planning of hydrogen technologies through the combination of experimental tests and machine learning tools.

Estimated progress of the PhD project:

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

Journal publications

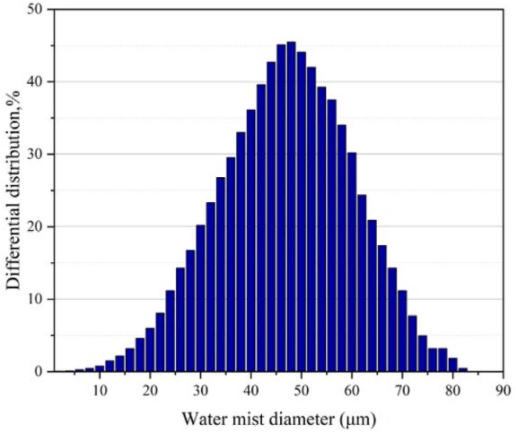
- Campari et al., 2023, Lessons Learned from HIAD 2.0: Inspection and Maintenance to Avoid Hydrogen-Induced Material Failures, *Computers and Chemical Engineering*
- Campari et al., 2023, A Review on Hydrogen Embrittlement and Risk-based Inspection of Hydrogen Technologies, *International Journal of Hydrogen Energy*
- Campari et al., 2024, Inspection of Hydrogen Transport Equipment: A Data-Driven Approach to Predict Fatigue Degradation, *Reliability Engineering and System Safety*
- Campari et al., 2024, Hollow specimen technique for in-situ hydrogen testing: a comparison of vintage and modern X65 pipeline steel, *Engineering Failure Analysis*
- Campari et al., 2024, Machine learning-aided risk-based inspection strategy for hydrogen technologies, *Process Safety and Environmental Protection*

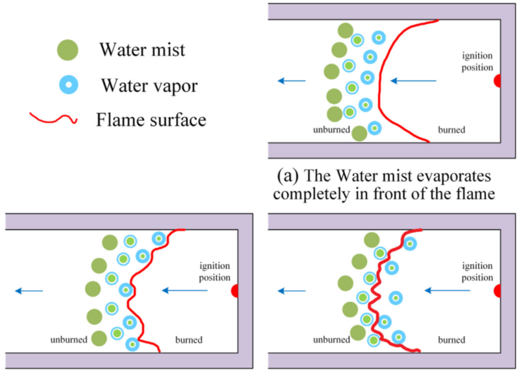
Mitigation of hydrogen explosions

Introduction

Hydrogen is considered to be an important part of the energy supply of the future and a major driver of the green shift. However, hydrogen is a highly explosive gas. Therefore, safe use of hydrogen is an important research topic.

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





(a) The Water mist evaporates completely in front of the flame
(b) The water mist touches the flame surface
(c) The water mist penetrates the flame surface

Y. Xia et al., "Experimental research on combined effect of obstacle and local spraying water fog on hydrogen/air premixed explosion," International Journal of Hydrogen Energy, vol. 47, no. 94, pp. 40099-40115

The nozzle of a regular water spray system produces a distribution of water droplet sizes, a *polydisperse* spray. The droplet size is one parameter that affects whether the spray will have a mitigating or increasing effect on a gas explosion.

Objectives and Methods

- The main objective is to determine the effect of a distribution of water droplet sizes (polydisperse) on a hydrogen explosion in a computational fluid dynamics (CFD) simulation compared to a monodisperse assumption.
- The Open-Source CFD software OpenFOAM and the chemical kinetics software Cantera will be used.

Anne Marie Lande

PhD Research Fellow, Ministry of Education and Research Position

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

Estimated progress of the PhD project:

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

Publications

- A. M. Lande and J. Lundberg, "Summary of mechanisms of water droplets in hydrogen deflagration," Nordic Flame Days 2023, Trondheim, Norway, 2023
- J. Lundberg, K. Vågsæther, R. Sikka, and D. Bjerketvedt, "Water Mist Characteristics for Explosion Mitigation," in Tenth International Seminar on Fire and Explosion Hazards, Oslo, Norway, 2022

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USN Universitetet i Sørøst-Norge

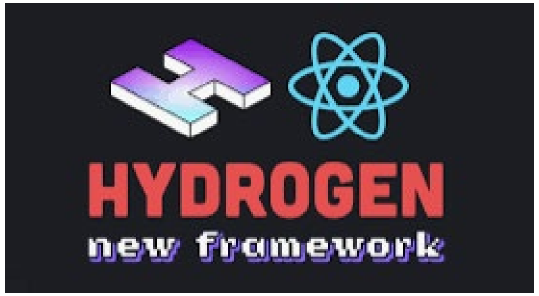
Identifying and Mitigating Risks in Hydrogen Energy for Safer Integration

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 fields and conduct larger experiments that better reflect real-world conditions. Also, developing and testing the SoK within a broader systems framework will help improve the precision of our safety, security, and risk evaluations as we adopt hydrogen energy.



Primary objective

- Develop novel frameworks for assessing and improving the SoK in risk assessments for hydrogen-based energy systems.

Secondary objectives

- Identifying gaps in understanding and assessing risks, and employing a reliable framework to address these issues
- To create a new model, methods, or structured approaches that are innovative and different from the current methods industries use to assess risk today

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

Master thesis: The Energy Hub in the North Sea- Reliability and Resilience Analysis of Different Topologies

Conference paper: Unavailability Calculation For North Sea Energy Hub Using Fault Tree Analysis and Monte Carlo Simulation (In Press)

Hy School.no Norwegian Research School on Hydrogen and Hydrogen-Based Fuels

University of Stavanger

WP4: Safety science and risk

HyValue NORCE

Hydrogen as energy carrier in society: risk picture, risk awareness and public acceptance

Efthymia Derempouka

University of Bergen, Department of Physics & Technology

With support from the projects:

- *Safe Hydrogen Implementation: Pre-normative research for Ships* (SH2IPS)
- *Safe Hydrogen Fuel Handling and Use for Efficient Implementation 2* (SH2IFT-2)

I have engineering background (within Transportation) and a Master's degree in Risk Management and Offshore Technology.

Experience with consequence modelling tools.

Background

Widespread use of hydrogen and hydrogen-based fuels as energy carriers in society may enable the gradual replacement of fossil fuels. To facilitate this development, the providers of hydrogen technologies must demonstrate that the risk for hydrogen systems will be equivalent, or even lower to this achieved by conventional fuels and energy carriers. This requirement is clearly stated in international regulations, codes and standards (RCS), such as the IGF Code from IMO (2016). To enable a comparison of the risk associated with hydrogen use versus to the risk of conventional fuels and energy carriers, it is vital to assess the strength of the knowledge in risk assessments of hydrogen-based systems, including the inherent uncertainties in the estimation of event frequencies and the calculation of consequences.

Furthermore, societal factors such as the awareness and perception of hydrogen risk amongst key stakeholders in the emerging hydrogen economy including the public, will influence the attitudes towards hydrogen technologies. Existing work (Thesen and Langhelle, 2008) indicates that the framing of hydrogen technologies in the media, and the messages communicated by key-stakeholders impact presumably the way people perceive the risk of hydrogen use.

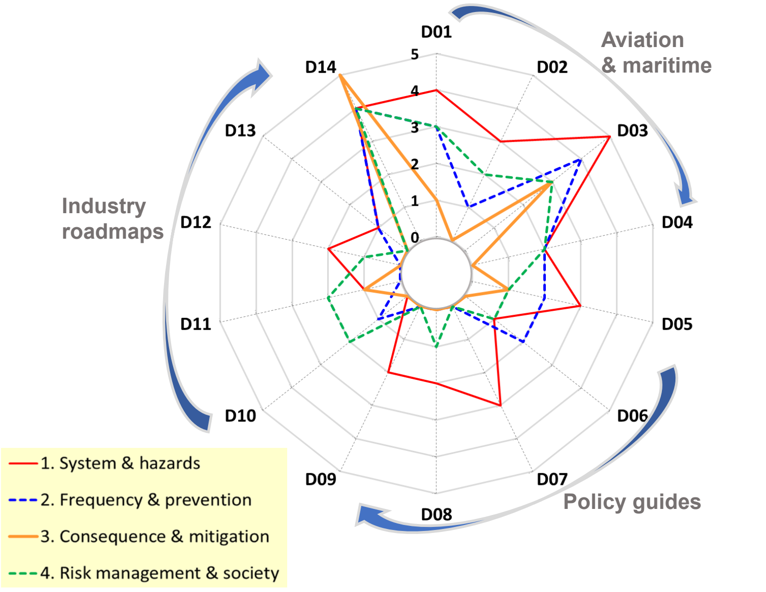


Fig 1. Results from the content analysis of the 14 documents. (Derempouka et al.,2022)

Primary objective

- To analyse barriers & drivers for the implementation of hydrogen as an energy carrier in society.

Secondary objectives

- To investigate the perception and awareness of hydrogen as an energy carrier among key stakeholders in the emerging hydrogen economy including the public.
- To contribute towards the development of a science-based tool for the assessment of the strength of the knowledge supporting the risk assessment in hydrogen-based systems.

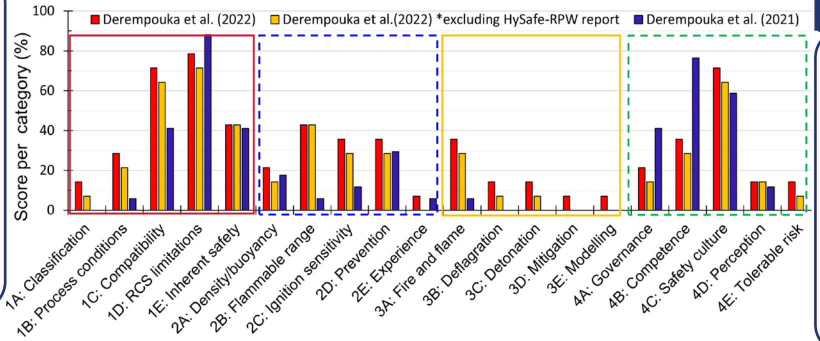


Fig 2. Score on safety per sub-category for all the documents addressed in the two studies (Derempouka et al., 2021; 2022)

Estimated progress of the PhD project:

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

Publications

- Derempouka, E.; Njå, O.; Skjold, T.; Haarstad, H.; Tvinnereim, E.M. (2023). Public perception of hydrogen: Response to an open-ended question. Proceedings tenth International Conference on Hydrogen Safety (ICHS2023)
- Bentsen, H. L.; Skiple, J. K; Gregersen, T. J.; Derempouka, E.; Skjold, T. (2023). In the green? Perceptions of hydrogen production methods among the Norwegian public. *Energy Research & Social Science*. 97: 102985 (11 pp.). DOI: https://doi.org/10.1016/j.erss.2023.102985
- Derempouka, E.; Skjold, T.; Njå, O.; Haarstad, H. (2022). The Role of Safety in the Framing of the Hydrogen Economy by Selected Groups of Stakeholders. *Chemical Engineering Transactions*. 90: 757-762. DOI: https://doi.org/10.3303/CET2290127
- Derempouka, E.; Skjold, T; Haarstad, H; Njå, O. (2021). Examining the role of safety in communication concerning emerging hydrogen technologies by selected groups of stakeholders. Proceedings Ninth International Conference on Hydrogen Safety (ICHS2021)

Reliability and resilience analysis of green hydrogen production process

Introduction

Hydrogen produced by water electrolysis using renewable energy sources is defined as green hydrogen. It's a carbon neutral way of producing H2 and it can assist in dealing with the variability of renewable energy. Reliability analysis of such production process can help to extend functioning time of the equipment and thus improve efficiency, reduce production cost etc. However, studies focusing on the reliability analysis of water electrolysis plant for producing green H2 is very limited to date.

This PhD work aims at performing reliability analysis for such system as well as identifying the challenges of applying the reliability analysis methods in the field of green hydrogen production technologies. In addition, this PhD work will also include studying the green H2 production process from a new perspective, resilience engineering to improve the reliability of the whole process.

Primary objective

- Provide an effective tool for analyzing the reliability of green H2 production process and how to make the system resilient.

Secondary objectives

- Identifying the challenges of applying reliability analysis methods for green hydrogen production process.
- Identifying research opportunities that can be explored in order to improve reliability and resilience of such system.

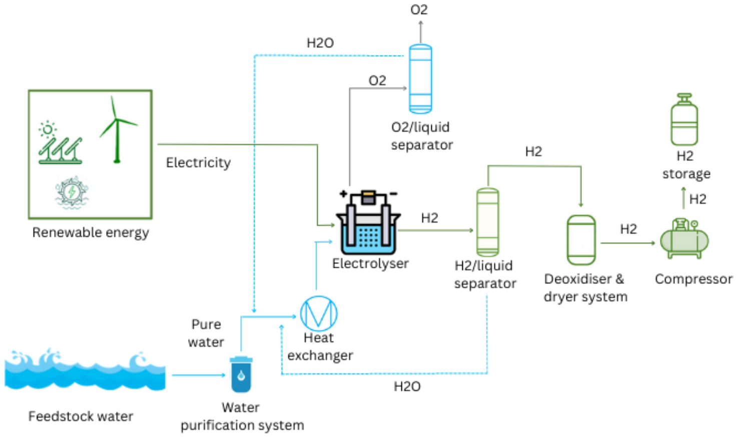


Fig: Green hydrogen production plant

Farhana Yasmine Tuhi

Affiliation: *Department of mechanical and 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)

Estimated progress of the PhD project:

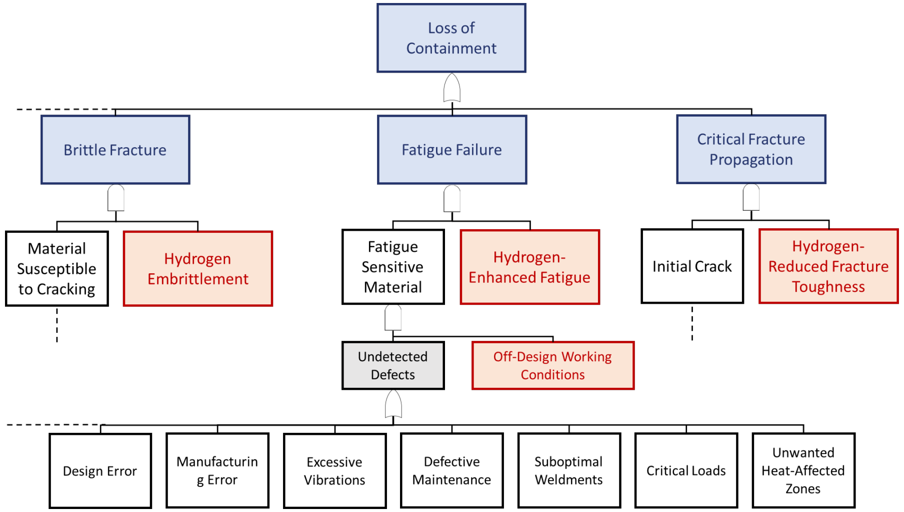
Just started ...	< 50 %	> 50 %	Almost done ☺
■	■		

Publications

- Tuhi, F. Y., Fredriksen, M., Jäschke, J., & Bucelli, M. (2024). Accidents Review And Control Assessment For Reliable Operation Of PEM Water Electrolyzer Stacks. (Submitted *in ESREL conference*, Krakow, Poland.)
- Tuhi, F. Y., Bucelli, M., Liu, Y., (2024). Hazop study of a water electrolysis plant used in green hydrogen production. (Abstract submitted in H2Science conference, 2024)
- Tuhi, F. Y., Bucelli, M., Liu, Y., (2024). Reliability analysis of green hydrogen production: literature review, challenges and opportunities. (Ongoing work)

Risk-Based Inspection and Maintenance for Safe Handling and Use of Hydrogen

Introduction: My project focuses on development and optimization of inspection procedures for hydrogen systems – Risk-Based Inspection (RBI) – with particular attention paid to metal-hydrogen interactions and the degradation of equipment working in high-pressure gaseous hydrogen environments.

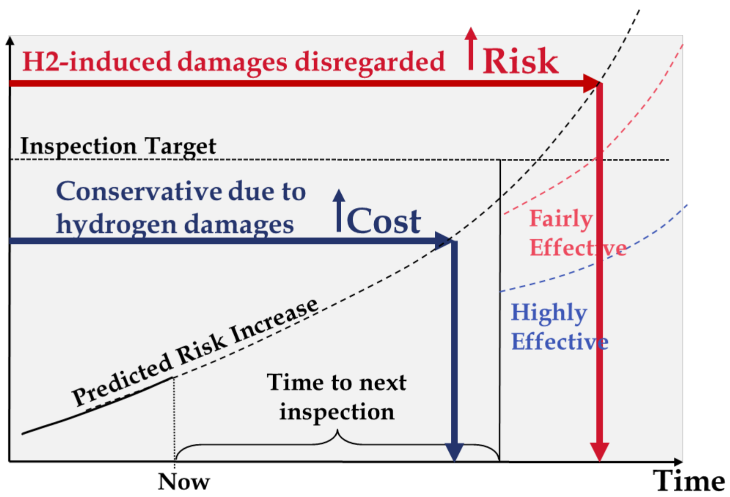


Primary objective:

- Provide insight to support optimal inspection planning for hydrogen systems considering material integrity.

Secondary objectives:

- Optimizing inspection programs through cost-effectiveness analysis.
- Investigating hydrogen-enhanced fatigue in pipeline steels.



Leonardo Giannini

Affiliation = NTNU

Related projects: *SH2IFT-2*

Leonardo Giannini holds a master's degree in Energy Engineering, obtained at the University of Bologna in March 2022. His background includes the design of energy systems, power plants and hydrogen technologies. Concerning the latter, he worked on a master's thesis focused on the consequence analysis of accidental hydrogen releases at NTNU, where he is now enrolled in this PhD program.

Estimated progress of the PhD project:

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

Publications:

- Embrittlement, Degradation and Loss Prevention of Hydrogen Pipelines, MRS Bulletin, 2024.
- Peer-Reviewed Conference Papers: see

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NTNU ENERGY Team Hydrogen

NTNU | Norwegian University of Science and Technology

SH2IFT II

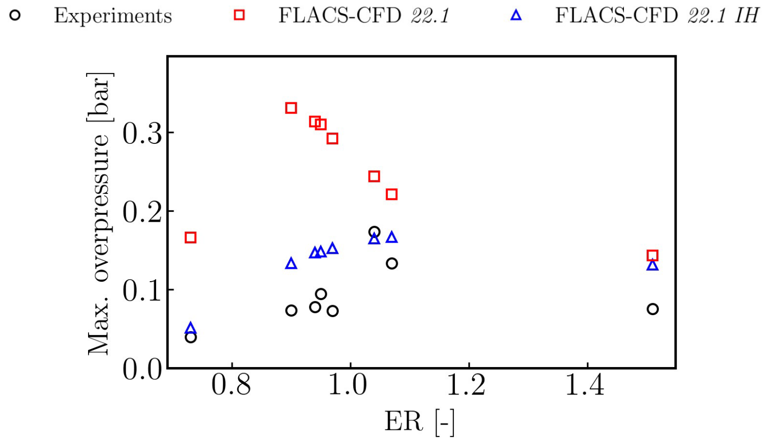
Improved modelling of hydrogen explosions

Melodía Lucas

Affiliations: University of Bergen, Gexcon

Introduction

The consequence model system FLACS, developed by Gexcon, is based on computational fluid dynamics. The capability of FLACS to represent the consequences of accident scenarios involving hydrogen has been developed as part of several research programs. However, several of these initiatives have also uncovered limitations in the predictive capabilities of the model. For example, the predicted reactivity for a range of concentrations of hydrogen-air mixtures has been found to be overly conservative. A combustion model that alleviates this problem exists in-house in Gexcon, however, this model requires further development to be sufficiently general. Furthermore, the present version of FLACS can only account for the mitigating effect by introducing additional nitrogen to the atmosphere, while it would be highly relevant to also represent the effect of water, CO_2, and various types of chemical inhibitors.



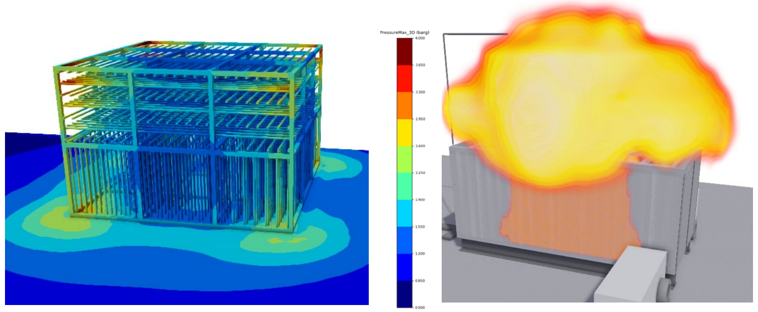
Simulation and experimental results for one experimental campaign testing different hydrogen concentrations. FLACS-CFD 22.1 IH is the version under development.

Primary objective

- To develop a general framework for modelling burning velocities of gas mixtures containing hydrogen in the CFD tool FLACS.

Secondary objectives

- Establish a validation database.
- Develop scripts and establish model evaluation criteria.
- Generate a library of the relevant properties of hydrogen mixtures.
- Demonstrate the practical effect of improved model capabilities for one hypothetical risk assessment study.



Pressure load on surfaces (right). Products fraction (left)

I have been working within gas explosions modelling development and validation for FLACS-CFD software since 2018.

Estimated progress of the PhD project:

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

Publications

- Lucas, M., Hisken, H., Skjold, T., Arntzen, B.J., van Wingerden, Kees, 2023, CFD modelling of hydrogen and hydrogen-methane explosions – Analysis of varying concentration and reduced oxygen atmospheres, Journal of Loss Prevention in the Process Industries, 83 : 105012.
- Lucas, M., Atanga, G., Hisken, H., Mauri, L., Skjold, T., 2021, Simulating vented hydrogen deflagrations: Improved modelling in the CFD tool FLACS-hydrogen, International Journal of Hydrogen Energy, 46(23) : 12464-12473
- Lucas, M., Skjold, T. & Hisken, H., 2020, Computational fluid dynamics simulations of hydrogen releases and vented deflagrations in large enclosures, Journal of Loss Prevention in the Process Industries, 63 : 103999.

HySchool Days 2024

Trondheim, 23-25 April 2024

Internal meetings on Monday 22 April

HySchool in a Nutshell

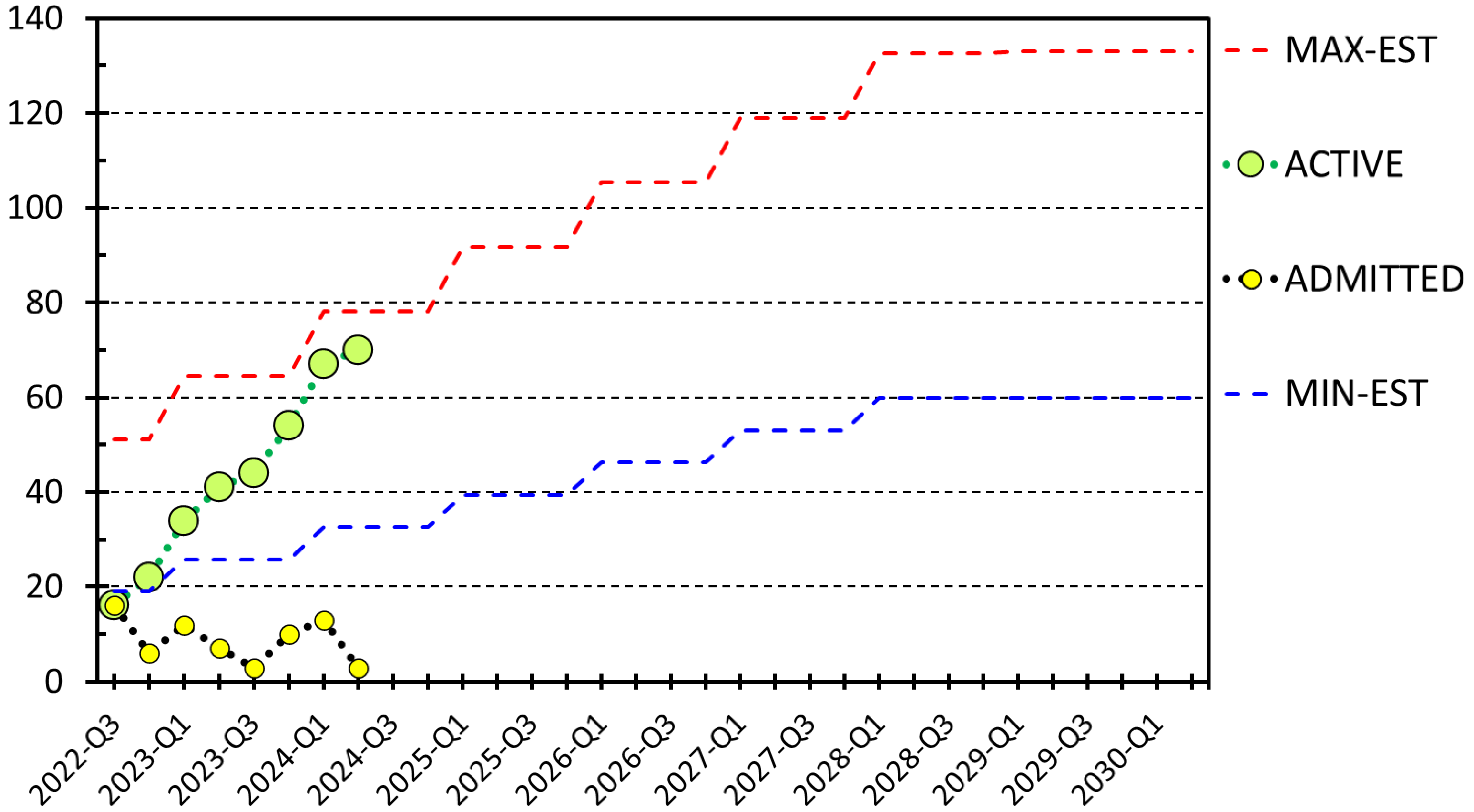
Objectives

The primary objective of HySchool is to contribute to the global energy transition by enhancing the quality of Norwegian doctoral training on the use of hydrogen and hydrogen-based fuel as energy carriers.

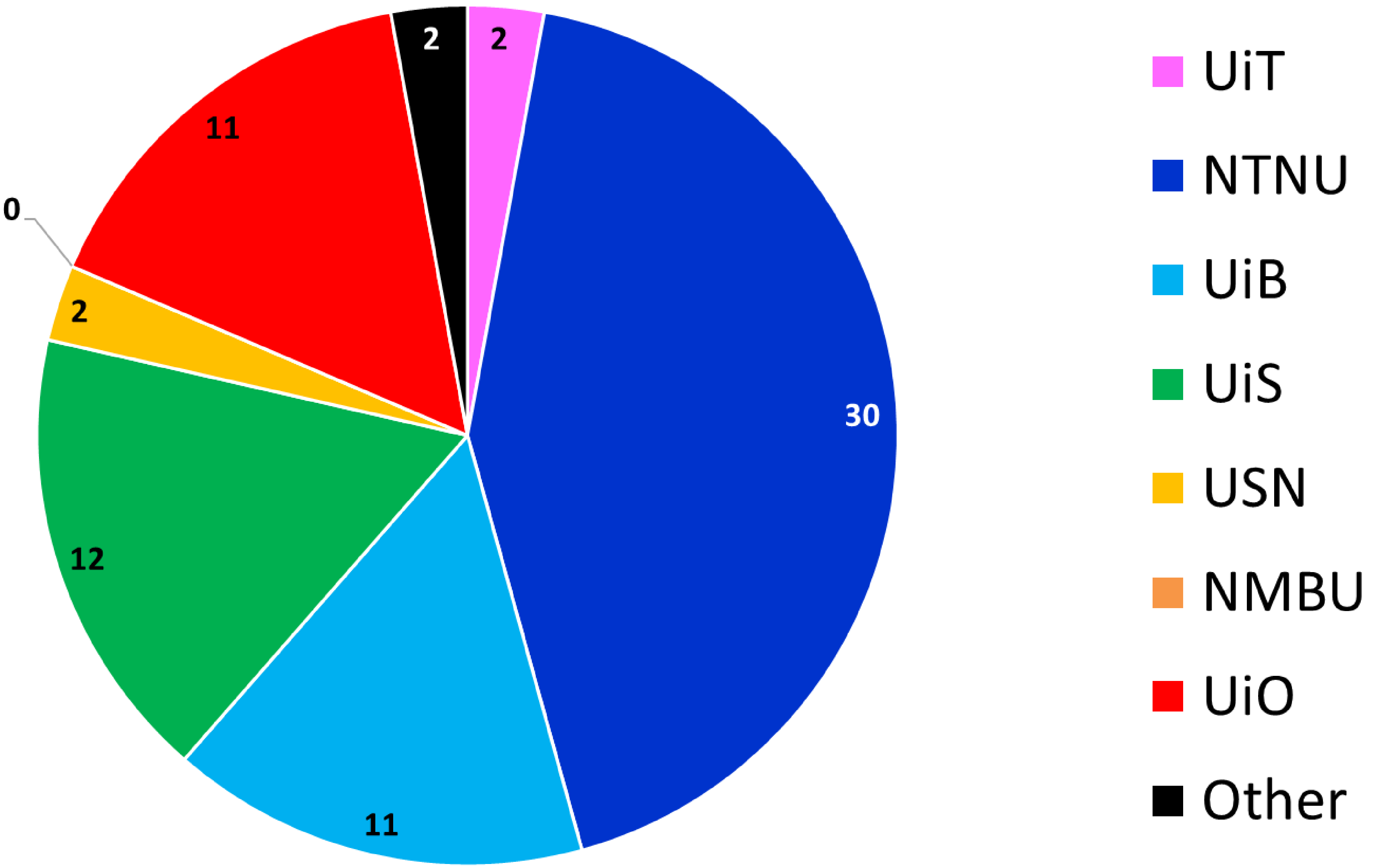
Secondary objectives that support this aim include:

- To create positive learning experiences for PhD candidates.
- To create a meeting place for PhD candidates and supervisors from different institutions and disciplines.
- To facilitate networking and mobility for PhD candidates.
- To offer arenas where PhD candidates can develop competence and skills.
- To expose PhD candidates to real-life challenges from industry and society.
- To develop courses and promote teaching practices and interdisciplinary research methods that prepare PhD candidates for solving complex problems.
- To promote best practices for open and responsible research.
- To secure high relevance of Norwegian doctoral education on hydrogen and hydrogen-based fuels for the labour market.

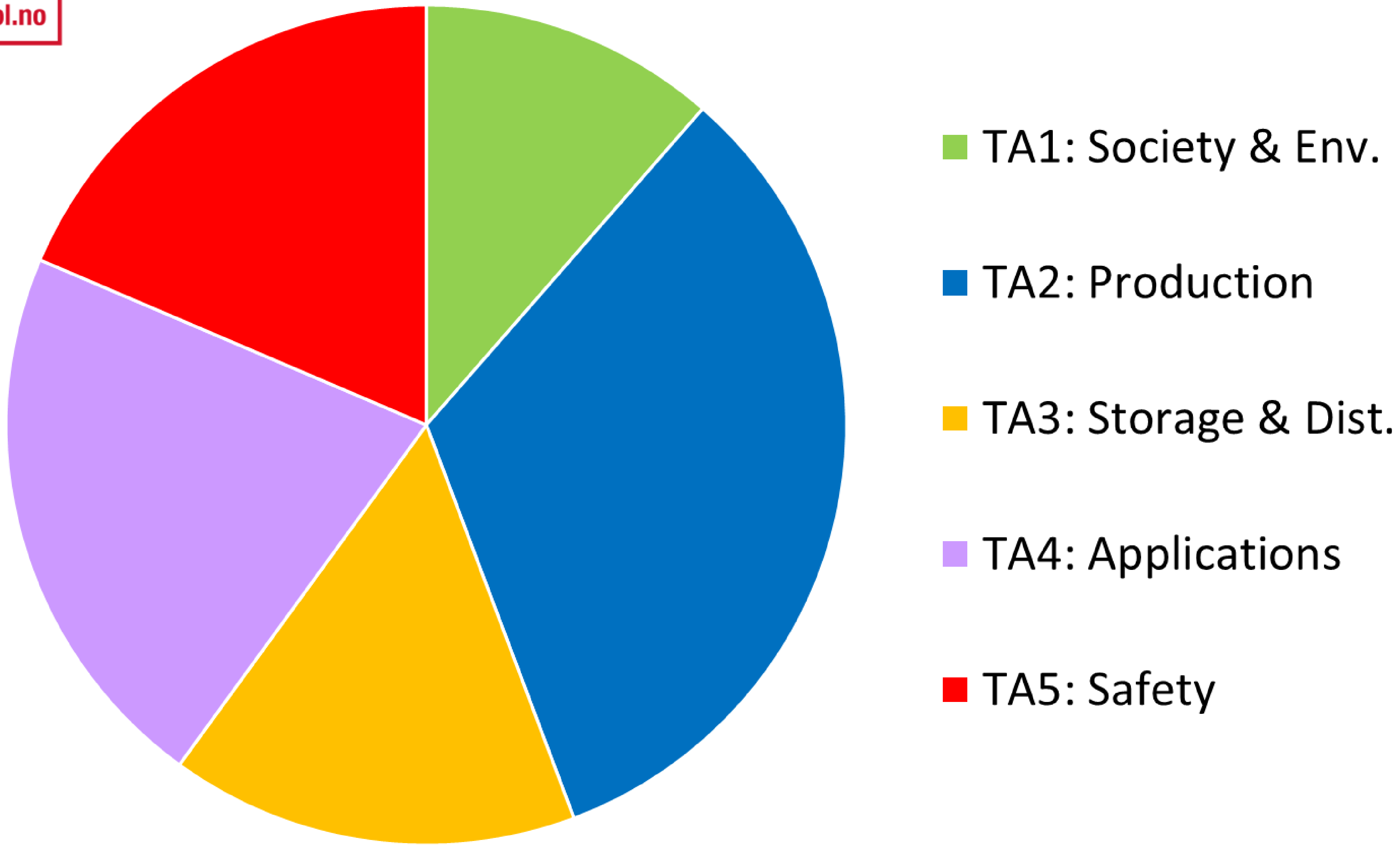
Active and admitted PhD candidates



Active PhD Candidates by University



Active PhD Candidates by Topical Area



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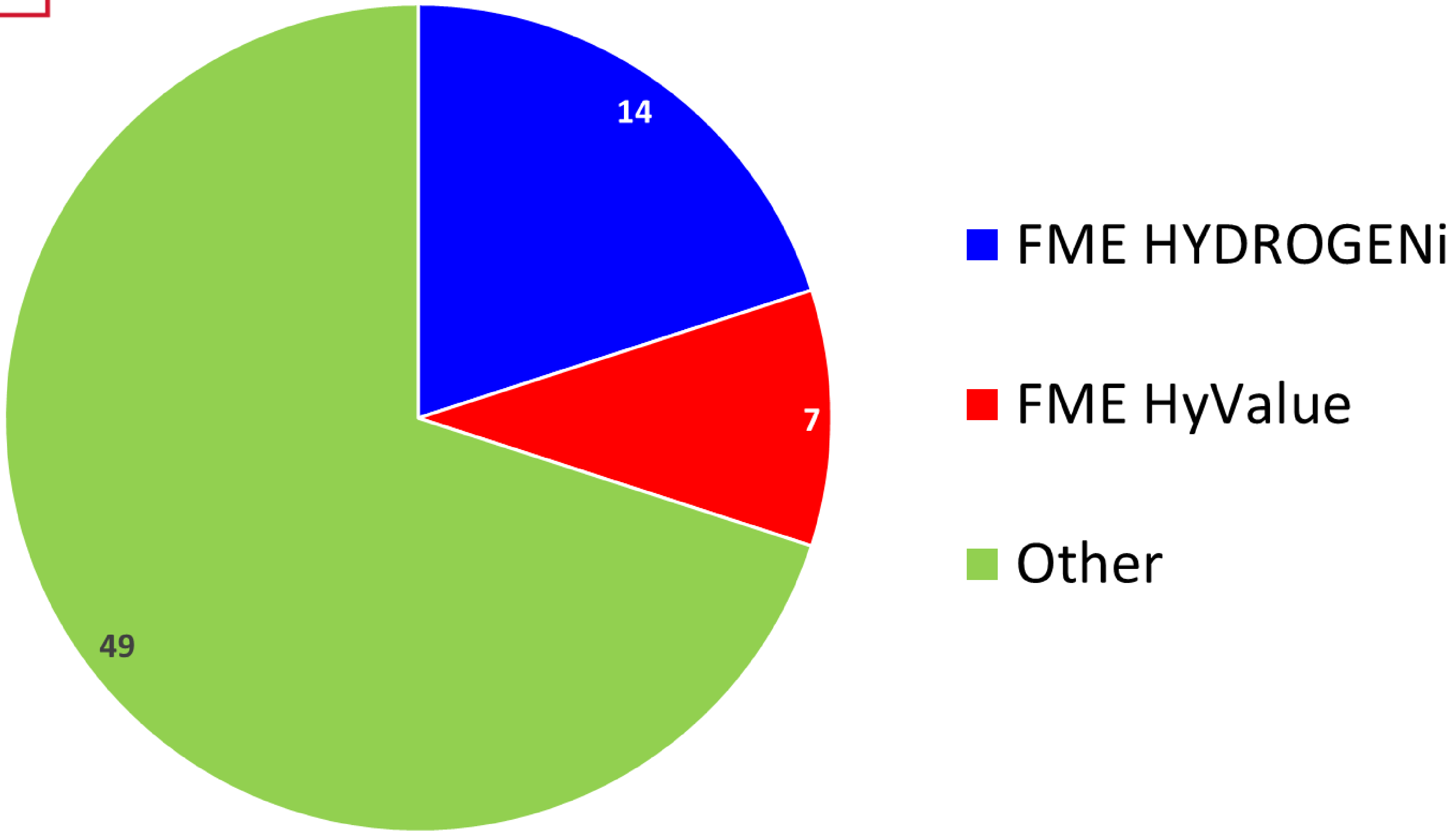
Active PhD Candidates by Project



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HySchool Days 2025

Porsgrunn, 1-2 April 2025

Internal meetings 31 March & 3 April

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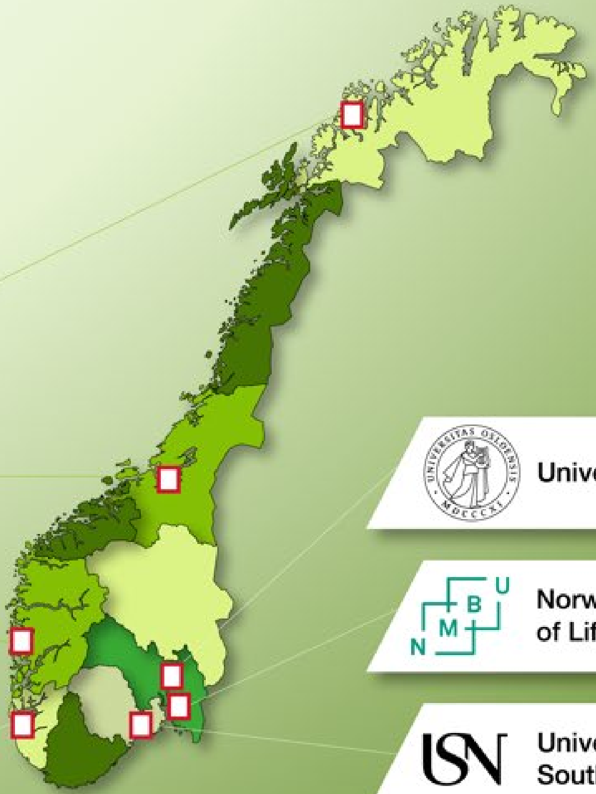
University of Tromsø

Norwegian University of Science and Technology

University of Bergen

University of Stavanger



University of Oslo

Norwegian University of Life Sciences

University of South-Eastern Norway

equinor

IFE Institute for Energy Technology

GEXCON CERTIFICATION