www.hytep.cz
www.hydrogendays.cz

HydrogenDays 2026

16th International Conference
on Hydrogen Technologies

March 11th – 13th 2026
Prague, Czech Republic

Programme & Abstracts

Organised by
HYTEP
CZECH HYDROGEN
TECHNOLOGY PLATFORM
SINCE 2007

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ORGANIZED BY

HYTEP
CZECH HYDROGEN
TECHNOLOGY PLATFORM
SINCE 2007

UNDER THE AUSPICES OF

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OF REGIONAL
DEVELOPMENT CZ

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ENERGETIKA

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PRO-ENERGY
MAGAZÍN

THE ENERGY DATA

Content

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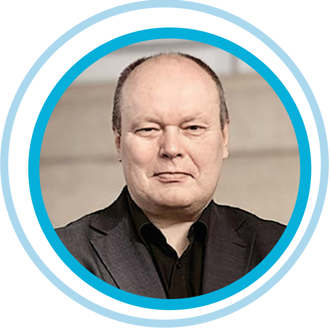
“Hydrogen at the Crossroads: Courage to Continue”



Dear Colleagues,

It is my pleasure to invite you to **Hydrogen Days 2026**, now in its 16th edition. Over the years, this conference has grown into a respected melting pot—a place where professionals from across Europe who are shaping the hydrogen landscape through research, policy, and project implementation meet and discuss the latest development with specialists from the commercial sector. One of our key goals is to provide commercial partners with both a qualified introduction to the field and an update on current regulations. In 2026, we will once again gather to reflect, connect, and look ahead—together.

Although we have recently seen several important hydrogen projects cancelled, the sector as a whole continues to grow steadily, and the infrastructure development is ongoing. Electrolyzer capacities are increasing, more pilot and demonstration projects are coming online, and key policies are taking shape at both national and European levels. These achievements are the result of tireless efforts, strong collaboration, and a shared belief in hydrogen’s critical role in diversifying energy sources, reducing dependence on fossil resources and enabling more environmentally friendly technologies.

Yet, as the title of this year’s conference suggests—***Hydrogen at the Crossroads: Courage to Continue***—the path forward is anything but simple. The momentum built over the past years now faces headwinds: regulatory complexity, high costs, and frustration caused by slower-than-expected progress. But these are not reasons to retreat. On the contrary—they are challenges to overcome. They are opportunities to improve current technologies, to gather more experience, and to continue building trust among the public and decision-makers alike.

This year’s program will highlight both the milestones achieved and the challenges that lie ahead. In addition to exploring the latest developments in research and innovation, we will examine the evolving hydrogen value chain—from materials research to market deployment—and address key questions on financing, integration with renewables, and regulatory frameworks. Particular attention will be paid to real-world implementation: which approaches have proven feasible, and which must change to accelerate progress.

Hydrogen Days 2026 will take place in Prague in March. We warmly welcome you to join us as we explore where the hydrogen journey stands today—and how, together, we can shape its next chapter.

With courage, clarity, and collaboration—let us continue.

Sincerely

Karel Bouzek

Chairman of the Scientific Committee

General Information

Scientific conference

OREA Hotel Pyramida
Bělohorská 24
169 00 Prague 6
Czech Republic

Conference language

The conference is being held in English.
No simultaneous translation will be available.

Student award

To encourage high-quality work among young researchers, on the occasion of Hydrogen Days 2026, Student Awards will be delivered in recognition of the best student contributions. The Student Awards Committee will award 2 attendees, one for the best presentation and the other for the best poster. The student awards are sponsored by the International Society of Electrochemistry (ISE). Each winner will receive a cash prize of 200 EUR.

All student contributions will be automatically included in the contest for Student Awards, if not stated otherwise.

The student award committee will evaluate student contributions according to the following criteria:
- Quality of research
- Compliance with ethical standards for publication
- Clear structure and explanation of content
- Poster resp. presentation design
- The ability of the student presenter to answer questions

Student Awards will be announced during the closing ceremony on Friday, 13 March 2026.

Social programme

Conference Dinner

Conclude the first day of Hydrogen Days 2026 in style with a **Reception & Conference Dinner**. Set in an elegant and relaxed atmosphere, this event invites participants to connect with peers, exchange ideas, and forge valuable collaborations while enjoying delicious cuisine. Join us for an evening of networking and inspiration as we celebrate the progress and potential of the hydrogen economy.
Date: Wednesday, 11 March, 2026
Time: start at 17:45
Venue: OREA Hotel Pyramida Prague

Evening Event

Connecting good energies—Networking reception hosted by HZwo and the Liaison Office of the Free State of Saxony in Prague

In the spirit of cross-border cooperation between the Czech Republic and the Free State of Saxony, as well as between the Czech Hydrogen Technology Platform (HYTEP) and the European hydrogen technology cluster HZwo, we warmly invite all conference participants to join an evening reception. Continue the conversations sparked during the day's sessions, exchange ideas, and connect with fellow participants in a relaxed and welcoming atmosphere.
Please have your conference badge ready for admission.

Date: Thursday 12 March 2026
Time: 18:00
Venue: Liaison Office of the Free State of Saxony in Prague
Address: U Lužického semináře 13, 118 00 Malá Strana

Publication policy

Participants will receive the Book of Abstracts with summaries of lectures and posters presented during the conference only in the online form. Authors are free to publish their papers at will after the conference. Based on the author's permission, the presentation will be available at the Hydrogen Days website after the conference.

Contact

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E-mail: hydrogendays2026@guarant.cz
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KOREA HYDRO & NUCLEAR POWER CO., LTD

Hydrogen Business

Korea Hydro & Nuclear Power, Korea's largest power generation company, is recognized as a trusted global clean energy company based on solid financial status and excellent operational performance.

Overview

Company Name	Korea Hydro & Nuclear Power Co., Ltd.(KHNP)
Established	April 2, 2001
Head Office Location	1655, Bulguk-ro, Munmudaewang-myeon, Gyeongju-si, Gyeongsangbuk-do
Main Business	Power generation business / Hydrogen business / Development of power resources / R&D and subsidiary business / Overseas business
Mission	Enrich Life through Eco-Friendly Energy
Vision	Carbon-Free Clean Energy Leader

Producing about 30% of Korea's electricity

Nuclear power, hydropower, pumped-storage power generation, renewable energy sources

Approximately 31,471 MW(2025. 5.) in Installed Capacity

Operating 26 Units of Nuclear Power Plants, 37 Hydropower plants, 16 pumped-storage power plants, etc.

Approximately KRW 77 Trillion Assets (2025. 9.)

Achieved approximately KRW 13.6 trillion(EUR 8billion) in sales in 2024.
※ Moody`s : Aa2 / S&P : AA

"**KHNP** is actively carrying out clean energy projects both domestically and internationally."

Business Overview - Korea

Business Overview - Overseas

Nuclear Power - 4 countries
Czech Republic UAE Egypt
Romania

Wind Power - 1 country
U.S.A.

Hydropower - 2 countries
Pakistan Nepal

Solar Power - 3 countries
Chile Columbia(ODA)
Tajikistan(ODA)

KHNP is also leading the way in the field of nuclear hydrogen at a world-class level

Nuclear Hydrogen Demonstration (2024-2028)

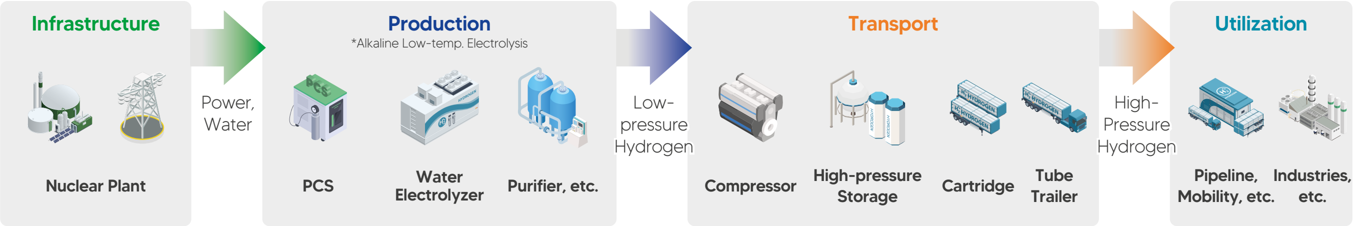
Organizer
KHNP

Integrated Management (Licensing, Hydrogen Plant EPC Project Management)
Plant Demonstration Operation & Optimization Planning
Foundation for Commercialization (Legal/System Improvement)

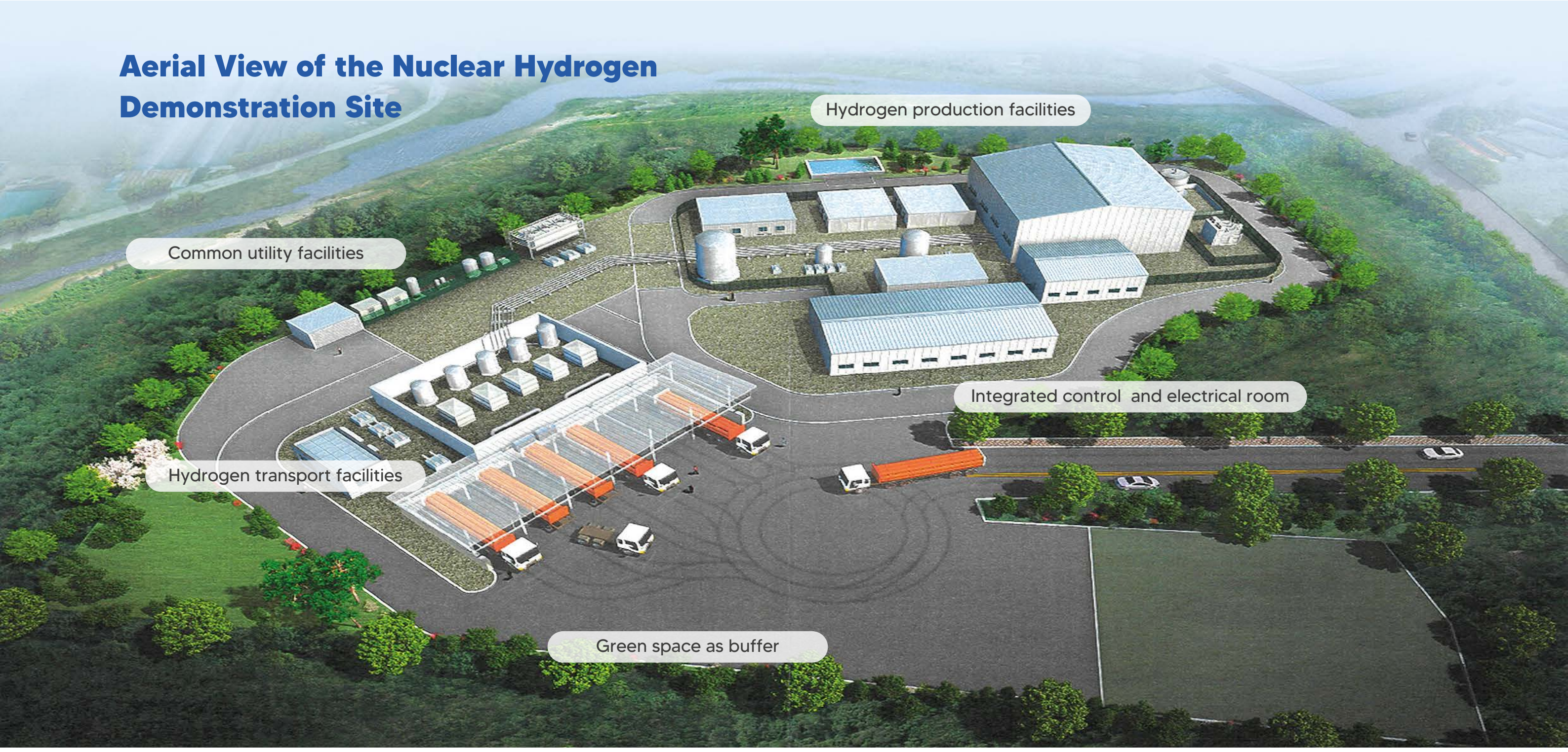
Safety / Regulation / Licensing
- **Nuclear Power**
  - KEPCO E&C
  - KAERI Korea Atomic Energy Research Institute
- **Hydrogen**
  - KOREA GAS SAFE CORPORATION
  - MERI

Overall Management
- **Plant Construction (EPC)**
  - Production: SAMSUNG C&T
  - Transport: DOOSAN Enerbility
  - Common: HYUNDAI ENGINEERING & CONSTRUCTION

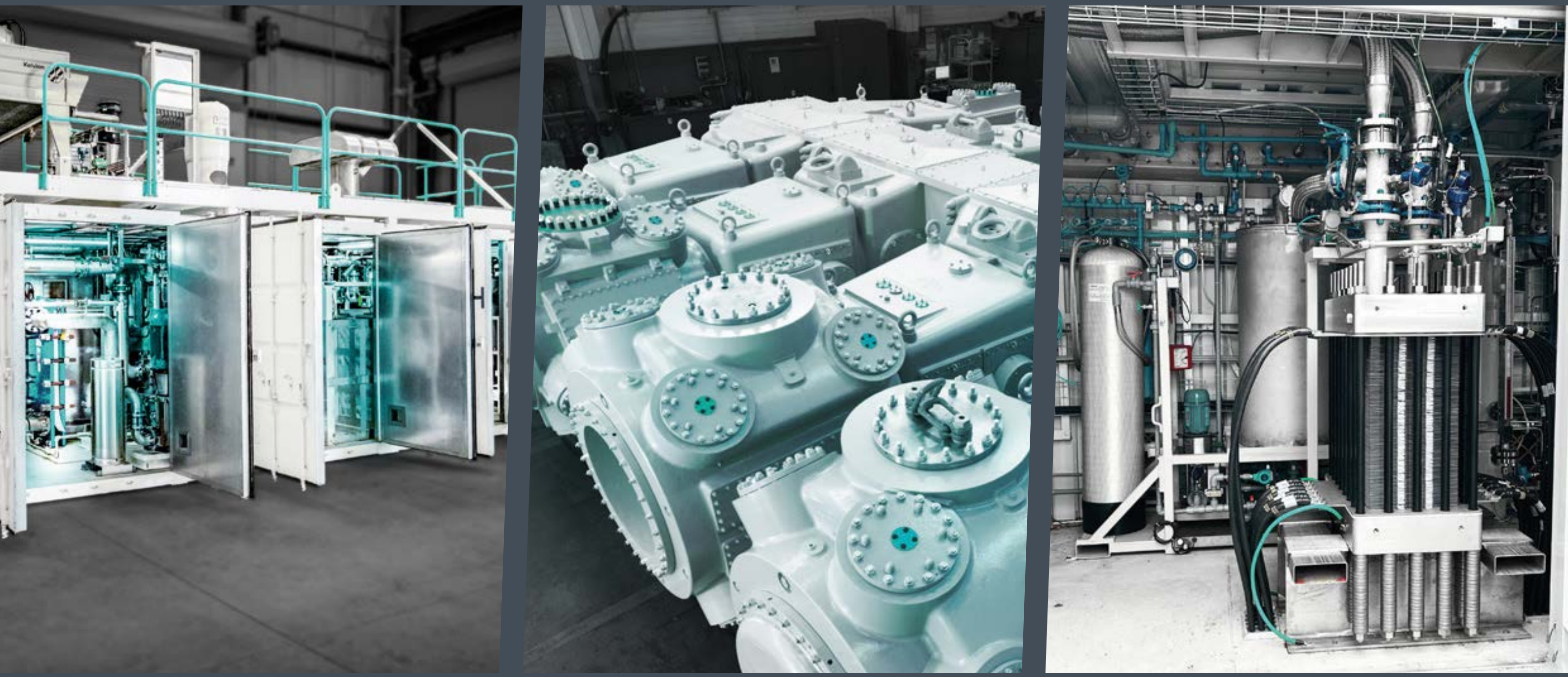
Demo Operation / Commercialization
- **Plant Operation Technology**
  - KOGAS
  - KIER
  - KOREA NATIONAL UNIVERSITY OF TRANSPORTATION
- **Legal/System Improvement**
  - smart KPX
  - KTR KOREA TESTING & RESEARCH INSTITUTE



Aerial View of the Nuclear Hydrogen Demonstration Site




APPLICATION
TRANSPORT
STORAGE
GENERATION



NL Netherlands

The Future of Hydrogen in the Netherlands: A Key to Sustainable Growth

As the world continues to look for cleaner energy solutions, hydrogen has emerged as a promising alternative. In the Netherlands, the government has already made significant strides in establishing hydrogen as a cornerstone of its energy transition strategy.

The Dutch Hydrogen Strategy:

The Dutch government recognizes hydrogen as a vital component for decarbonizing sectors such as industry and transport. By 2030, the Netherlands plans to produce 3-4 gigawatts (GW) of green hydrogen. In addition, the Netherlands aims to be the leading European hub for hydrogen, with major investments and strategic partnerships to boost both domestic production and cross-border connections.

Key Investments: Several initiatives are already underway, including:

- **Green hydrogen production**: The government is focusing on renewable energy sources such as wind and solar to power electrolysis, ensuring the production of green hydrogen with a minimal carbon footprint
- **Infrastructure:** Investment in pipelines, refueling stations, and storage facilities to enable hydrogen's widespread use.
- **Research & Innovation:** Strong support for research to improve the efficiency of hydrogen technologies and scaling up production methods.

Hydrogen in Industry & Transport:

With hydrogen's potential in heavy industry and long-haul transport, the Netherlands is well-positioned to lead Europe in developing hydrogen-powered freight logistics, aviation, and shipping.

Why It Matters:

The Netherlands' strategy aligns with the EU's broader green transition goals and positions the country as a key player in global hydrogen markets. Not only does this reduce carbon emissions, but it also promotes energy security and economic growth. As we move towards a more sustainable future, the importance of continued innovation and investment in hydrogen cannot be overstated. The Netherlands is paving the way—let's continue to support and invest in these game-changing technologies.

VSB TECHNICAL UNIVERSITY OF OSTRAVA | CENTRE FOR ENERGY AND ENVIRONMENTAL TECHNOLOGIES | ENERGY RESEARCH CENTRE

ENERGY SERVICES FOCUSED ON HYDROGEN TECHNOLOGIES

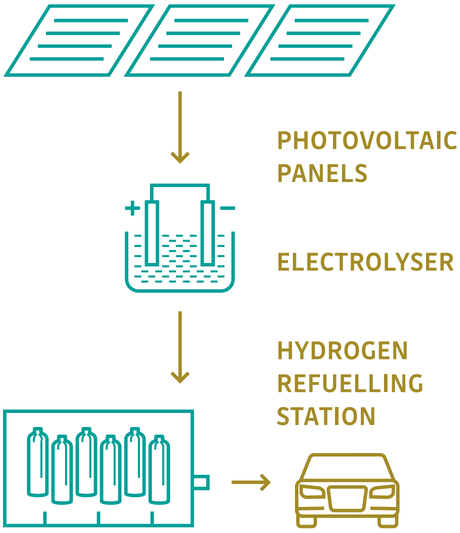
RESEARCH

IMPLEMENTATION

Comprehensive **safety risk assessment** of hydrogen technologies

Research and development for sustainable hydrogen **production, separation and storage**

H2 sampling for **purity analysis**



Preparation of **techno-economic studies** focusing on hydrogen technologies

Comprehensive **design and engineering activities** in the field of hydrogen technologies

Energy balance **monitoring and optimisation** of hydrogen systems

ENERGY
RESEARCH
CENTRE

ceet.vsb.cz/vec

Programme

Short Programme

11 March 2026

(Wednesday)

BUSINESS & POLICY PART (SUN I + II HALL)

OPENING & WELCOME SESSION
10:00–10:20

I. BLOC
Hydrogen reality check: Where do we stand?
10:20–10:50

II. BLOC
Does regulation enhance or hamper investments?
10:50–12:20

LUNCH
12:20–13:50

III. BLOC
Building European hydrogen backbone: regulation, networks and market integration
13:50–15:20

COFFEE BREAK
15:20–15:30

IV. BLOC
What works? Implementation stories from the field
15:50–17:00

V. BLOC
The Role and Importance of Nuclear Hydrogen in a Low-Carbon Industrial Transition in the Czech Republic: Challenges and Strategic Opportunities
17:00–17:30

HYTEP AWARD
17:30–17:45

POSTER SESSION
17:45–19:00

RECEPTION & CONFERENCE DINNER
Networking in Motion
17:45–21:00

12 March 2026

(Thursday)

BUSINESS & POLICY PART (SUN II HALL)

I. BLOC

Hydrogen Technologies: Technical Aspects of Large-Scale Hydrogen
09:00–10:20

COFFEE BREAK
10:20–10:50

II. BLOC

Preliminary results of the project ELVRIS— Could hydrogen electrolysers also provide grid ballancing services?
10:50–12:30

LUNCH
12:30–13:30

III. BLOC

Hydrogen on the move: The power of regional cooperation
13:30–14:50

COFFEE BREAK
14:50–15:20

Industry session powered by HYTEP and HZwo
15:20–16:40

Networking event by HZwo
18:00

SCIENTIFIC PART (SUN I HALL)

PARALLEL BLOC I

Hydrogen education & research projects
09:00–10:20

COFFEE BREAK
10:20–10:50

PARALLEL BLOC II

H2 production methods
10:50–12:30

LUNCH
12:30–13:30

PARALLEL BLOC III

H2 in applications
13:30–14:50

COFFEE BREAK
14:50–15:20

PARALLEL BLOC IV

Project PEACE (AWE)
15:20–17:20

13 March 2026

(Friday)

SCIENTIFIC PART (SUN II HALL)

I. BLOC

H2 Mobility

09:00–10:40

COFFEE BREAK

10:40–11:00

II. BLOC

Project PaC-NG (PEM FC)

11:00–12:40

CLOSING CEREMONY

12:40–13:00

SCIENTIFIC PART (SUN I HALL)

PARALLEL BLOC I

AWE and PEM WE

09:00–10:40

COFFEE BREAK

10:40–11:00

PARALLEL BLOC II

PEM WE

11:00–12:40

CLOSING CEREMONY (SUN II HALL)

12:40–13:00

Detailed Programme

11 March 2026

(Wednesday)

BUSINESS & POLICY PART (SUN I + II HALL)

OPENING & WELCOME SESSION

10:00–10:20

Hydrogen Days 2026 begins with an **Opening and Welcome Session** led by the Chairman of the Scientific Committee and the Chairman of the Board of HYTEP. Together, they will officially launch the conference, outline its key themes, and set the tone for the days ahead. Join us as we open this year's edition, celebrating collaboration, innovation, and the shared vision driving the hydrogen sector forward.

- **Karel Bouzek** (UCT Prague)
- **Aleš Doucek** (HYTEP)
- **Petr Mervart** (Ministry of Industry and Trade)
- **Christopher von dem Bussche** (Gascade)

I. BLOC

Hydrogen reality check: Where do we stand?

10:20–10:50

The hydrogen sector is at a turning point. After years of strategies and promises, how much real progress has been made? This keynote will provide a clear-eyed assessment of achievements, setbacks, and current dynamics in Europe's hydrogen landscape — setting the stage for the discussions to follow.

- **Martin Tengler** (Bloomberg NEF)

II. BLOC

Does regulation enhance or hamper investments?

10:50–12:20

Clear and simple rules and regulatory certainty are essential to unlock large-scale hydrogen deployment. Yet many stakeholders argue that regulation sometimes slows innovation and raises costs. This session will debate whether Europe's evolving framework acts as a driver or a barrier for investments — and what adjustments are needed to strike the right balance.

- **Martin Tengler** (Bloomberg NEF)
- **Gunther Grathwohl** (BMWE)
- **Jakub Iwanowski** (Orlen Unipetrol)
- **Areti Kostaraki** (ENGIE)
- **Petr Mervart** (Ministry of Industry and Trade)
- **Dimitrios Apostolos Triantafyllopoulos** (Hellenic Hydrogen)
- **Jan Šícha** (ČEZ)

LUNCH
12:20–13:50

III. BLOC

Building European hydrogen backbone: regulation, networks and market integration

13:50–15:20

Europe's vision for a hydrogen backbone requires cross-border cooperation, infrastructure repurposing, and coordinated markets. This session brings together different stakeholders to discuss the path forward: how to ensure infrastructure readiness, market integration, and a framework that enables hydrogen to flow freely across Europe.

- **Mario Ragwitz** (Fraunhofer IEG)
- **Abel Enríquez** (ENNOH)
- **Tobias Bühnen** (GIE)
- **Lenka Krausová** (NET4GAS)
- **Helmie Botter** (Gasunie)
- **Tomáš Diósi** (Gas Storage CZ)

COFFEE BREAK
15:20–15:50

IV. BLOC

What works? Implementation stories from the field

15:50–17:00

Beyond visions and strategies, what is actually happening on the ground? This session showcases real-world hydrogen projects that are delivering results. Industry leaders will share lessons learned, highlight best practices, and demonstrate how barriers can be overcome in practice.

- **Marcus Pichler** (RAG Austria AG)
- **Mark Freymüller** (Hyundai Motor Group)
- **Claudia Černohuby-Wallner** (Wien Energy)
- **Konstantinos Chatzifotis** (Motor Oil Hellas)

V. BLOC

The Role and Importance of Nuclear Hydrogen in a Low-Carbon Industrial Transition in the Czech Republic: Challenges and Strategic Opportunities

17:00–17:30

Presenting a comprehensive analytical framework for nuclear hydrogen production in the Czech Republic, this work evaluates its economic viability within the context of the European Union's "Fit for 55" legislative package as of 2026. Utilizing a multidisciplinary methodology – encompassing LCOH modelling, LCA (Life Cycle Assessment) of carbon footprints, and a comparative analysis of certification schemes (RFNBO vs. LCH) — the research identifies nuclear energy as a critical baseload energy source essential for meeting the decarbonization quotas of the Czech industrial sector.

- **Martin Křemenák** (HYTEP)

HYTEP AWARD

17:30–17:45

POSTER SESSION

17:45–19:00

Discover the cutting-edge research driving innovation in the hydrogen sector at the **Poster Session**. Explore a wide array of scientific posters presented by researchers, academics, and industry experts, showcasing breakthroughs in hydrogen technologies, advancements in production and storage, and novel approaches to decarbonization. This interactive session provides a unique opportunity to engage with the latest research and network with experts in the field.

RECEPTION & CONFERENCE DINNER

Networking in Motion

17:45–21:00

Conclude the first day of Hydrogen Days 2026 in style with a **Reception & Conference Dinner**. Set in an elegant and relaxed atmosphere, this event invites participants to connect with peers, exchange ideas, and forge valuable collaborations while enjoying delicious cuisine. Join us for an evening of networking and inspiration as we celebrate the progress and potential of the hydrogen economy.

12 March 2025

(Thursday)

BUSINESS & POLICY PART (SUN II HALL)

I. BLOC

Hydrogen Technologies: Technical Aspects of Large-Scale Hydrogen

09:00–10:20

Moderator: *Martin Paidar (HYTEP)*

As hydrogen moves from vision to large-scale reality, the focus shifts from innovation to implementation. This session examines the technical challenges and practical lessons of installing, integrating, and operating hydrogen technologies at scale. Experts from leading electrolyser manufacturers and hydrogen refuelling station operators will share insights from the field — from system design and grid integration to operational reliability, safety, and cost efficiency. Join us to explore what it truly takes to turn hydrogen infrastructure into a functioning, high-performing reality.

- **Roy van Son** (Resato)
- **Andre Klinger** (Siemens Energy Global GmbH)
- **Vitaly Ivanov** (Bosch)
- **Anasztázia Vigh-Kis** (MOL)

COFFEE BREAK

10:20–10:50

II. BLOC

Preliminary results of the project ELVRIS – Could hydrogen electrolysers also povide grid ballancing services?

10:50–12:30

This section presents the scope and initial findings of the ELVRIS project, which examines the role of electrolyzers in the Czech energy system as providers of power grid balancing services. The project analyses hydrogen production scenarios in Czechia, including grid-based electrolysis and renewable hydrogen production in line with EU Renewable Energy Directive requirements. It assesses the operation of electrolyzers in combination with balancing services and explores the use of hydrogen, waste heat, and oxygen within sector coupling. The project will deliver a study and policy recommendations to support national energy strategies and conceptual frameworks.

Moderator: *Jan Sochor (HYTEP)*

- **Jiří Štefanica** (ÚJV Řež, a. s.)
- **Martin Paidar** (UCT Prague)
- **Ondřej Mamula** (CVUT CIIRC) and Petr Stejskal (CVUT CIIRC)

LUNCH

12:30–13:30

III. BLOC

Hydrogen on the move: The power of regional cooperation

13:30–14:50

No country can succeed in the hydrogen transition alone. Regional cooperation is essential for building infrastructure, sharing resources, and creating viable markets. This session will examine successful models of collaboration and ask: how can neighboring countries in Europe accelerate hydrogen deployment together?

Moderator: *Martin Křemenák (HYTEP)*

- **Julie Obivalněva** (HYTEP)
- **Katarzyna Faruga** (HzWO)
- **Ján Weiterschütz** (NVAS)
- **Karel Tichý** (Ústí region)
- **Jan Mašek** (DEVINN)

COFFEE BREAK

14:50–15:20

Industry session powered by HYTEP and HZwo

15:20–16:40

Powered by HYTEP and HZwo, this interactive industry session brings Czech and German companies together to explore three concrete dimensions of hydrogen value creation.

1. Bridging the Valley of Death—startup reality in PEM electrolysis: high-risk funding models in Germany and Czechia, IP transfer, regulatory hurdles, and scaling from lab prototypes to industry.
2. Beyond the Highway—engineering integration of hydrogen in heavy-duty applications: lessons from a hydrogen tractor and a TATRA truck covering packaging, safety design, and the transition from prototype to field deployment.
3. The Decentralized Frontier—small-scale electrolysis and Czech-German implementation: deploying modular electrolyzers, permitting, site integration, cross-border supply chains, and partnership models that make small projects bankable today.

Moderators: *Jan Sochor (HYTEP) & Frederik Wewetzer (HZwo)—dialogue-oriented format for candid, practical exchange.*

- **Zahra Nasri** (elementarHy)
- **Pavel Srbecký** (NANO Advanced)
- **Manuel Mehrkens** (Hörmann Vehicle Engineering GmbH)
- **Jiří Vršínský** (DEVINN s.r.o.)
- **Jan Valha** (Valcon International)
- **Björn Ahrendt** (H2greenPlanet)

Networking event by HZwo

18:00

Connecting good energies – Networking reception hosted by HZwo and the Liaison Office of the Free State of Saxony in Prague

12 March 2026

(Thursday)

SCIENTIFIC PART
(SUN I HALL)

PARALLEL BLOC I

Hydrogen education & research projects

09:00–10:20

Chair: *Thomas von Unwerth (TU Chemnitz)*

09:00–09:20

Providing Access to Hydrogen Education Across Europe

Robert Steinberger-Wilckens (University of Chemistry and Technology Prague)

09:20–09:40

CEETe H2: Integrated research infrastructure for hydrogen technologies

Ján Vereš (Technical University of Ostrava)

09:40–10:00

Life Cycle Assessment of an Integrated Power-to-Methanol/SOFC Plant Fed by Green Hydrogen

Vittorio Tola (University of Cagliari)

10:00–10:20

Experimental Optimization of Operating Parameters in a Fuel Cell System for Off-Road Applications

Martin Rabensteiner (HyCentA Research GmbH)

COFFEE BREAK

10:20–10:50

PARALLEL BLOC II

H2 production methods

10:50–12:30

Chair: *Lars Röntzsch (Brandenburg University of Technology Cottbus-Senftenberg)*

10:50–11:10

Status of Nuclear-based Clean Hydrogen Production Demonstration

WonGyu Kim (Korea Hydro & Nuclear Power Co., Ltd)

11:10–11:30

Water electrolysis under sustained pH-gradient in a salt-based electrolyte for the co-production of hydrogen and lime as a cement precursor

Rémy Rouxhet (UC Louvain)

11:30–11:50

CH4 cracking for hydrogen production via electrical heating

Federico Rossi (University of Perugia)

11:50–12:10

Utilization of Waste Biomass in the Design of Catalysts for Hydrogen Generation via Methanol Reforming

Natalia Łukasik (Gdańsk University of Technology)

12:10–12:30

Thermal plasma gasification for hydrogen-rich syngas production from heterogeneous waste feedstocks

Jakub Pilař (Czech Academy of Science)

LUNCH

12:30–13:30

PARALLEL BLOC III

H2 in applications

13:40–14:50

***Chair:** Robert Steinberger-Wilckens (University of Chemistry and Technology Prague)*

13:30–13:50

Hydrogen based poly-generation for energy communities: a case study

Giulia Crescente (Institute of Advanced Technologies for Energy "Nicola Giordano")

13:50–14:10

A new interconnect design for improving thermal uniformity in planar solid oxide fuel cell

Jeongin Choi (Pusan National University)

14:10–14:30

Characterisation of hydrocarbon-based proton-exchange membranes for electrochemical hydrogen compression

Tomáš Jedlička (University of Chemistry and Technology Prague)

14:30–14:50

Hydrogen Embrittlement of Steel in Repurposed Natural Gas Infrastructure: Experimental Insight and Safety Assessment

Klára Kuchťáková (University of Chemistry and Technology Prague)

COFFEE BREAK

14:50–15:20

PARALLEL BLOC IV

Project PEACE (AWE)

15:20–17:20

Chair: *Peter Kúš (Charles University)*

15:20–15:40

Pressurised Efficient Alkaline Electrolyser

Fatemeh Razmjooei (German Aerospace Center)

15:40–16:00

Qualification of alkaline water electrolyser under atmospheric and pressurised conditions

Dirk Ullmer (German Aerospace Center)

16:00–16:20

Mechanical challenges in developing a pressurized efficient alkaline electrolyser cell

Paolo Lupotto (Materials Mates Italia srl)

16:20–16:40

Bubble-ohm-lysis: The story of bubbles in alkaline water electrolysis

Saksham Pandey (Eindhoven University of Technology)

16:40–17:00

Operating Strategies for High-Pressure Alkaline Electrolysers: A Transient Modelling Approach

Hans Julian Wiggenhauser (German Aerospace Center)

17:00–17:20

Proof of concept adaptation, operation and validation of a dual-stage high pressure aklaline electrolyser

Lars Röntzsch (Brandenburg University of Technology Cottbus-Senftenberg)

13 March 2026

(Friday)

SCIENTIFIC PART
(SUN II HALL)

I. BLOC

H2 Mobility

09:00–10:40

Chair: *Jiří Vávra (HYTEP)*

09:00–09:20

A modular simulation framework for hydrogen storage system design in mobile applications

Daniel Valentin (HyCentA Research GmbH)

09:20–09:40

The Challenge of Developing an Automotive Hydrogen Storage Container according to R134-02

Martin Herrenbrück (BMW)

09:40–10:00

Transport and Economic Modelling of Fleet Service Operations in a Hydrogen Valley

Václav Koleník (Czech Technical University)

10:00–10:20

Challenges in scaling electrode production for hydrogen economy

Rameshwori Loukrakpam Jalan (Dinex Deutschland GmbH)

10:20–10:40

The Hydrogen Prism for Maritime: Angles for Regulating Hydrogen Fuels in the EU Maritime Sector

Kelsey Pailman (University of Groningen)

COFFEE BREAK

10:40–11:00

II. BLOC

PEM WE

11:30–12:40

Chair: *Martin Paidar (University of Chemistry and Technology Prague)*

11:00–11:20

Designing active and stable ORR catalyst with reduced Pt loading

Ivan Khalakhan (Charles University)

11:20–11:40

Real-time SAXS/Xa Studies of PEM FuelCell Catalyst Degradation under Operating Conditions

Yurii Yakovlev (Charles University)

11:40–12:00

Stable low-platinum carbon-supported catalysts for oxygen reduction reaction in PEM fuel cells

Eugenia Lobko (Charles University)

12:00–12:20

Model-Based design of in-plane and through-plane gradients in PEM fuel cell catalyst layers

Miroslav Hala (University of Chemistry and Technology Prague)

12:20–12:40

Mathematical modelling and experimental investigation of Pt catalyst degradation in high-temperature polymer electrolyte membrane fuel cells

Vojtěch Domín (University of Chemistry and Technology Prague)

CLOSING CEREMONY

12:40–13:00

13 March 2026

(Friday)

SCIENTIFIC PART (SUN I HALL)

PARALLEL BLOC I

AWE & PEM WE

09:00–10:40

Chair: *Fatemeh Razmjooei (German Aerospace Center)*

09:00–09:20

Recent development in AEM Hydrogen Technology Projects

Jan Valha (Valcon International s. r. o.)

09:20–09:40

Numerical assessment of electrolyte flow distribution through flow-engineered 3-D printed bi-layer electrodes for alkaline water electrolysis

Kevin Van Droogenbroek (UC Louvain)

09:40–10:00

Performance enhancement of proton exchange membrane water electrolyzers through intermittent operation

Peter Kúš (Charles University)

10:00–10:20

Relation between mass transfer limitations in PEM water electrolyser and anode porous transport layer structure

Martin Prokop (University of Chemistry and Technology Prague)

10:20–10:40

Experimental investigation of proton exchange membrane water electrolyzer activation

Ivan Pivac (University of Split)

COFFEE BREAK

10:40–11:00

PARALLEL BLOC II

PEM WE

11:00–12:40

Chair: *Martin Prokop (University of Chemistry and Technology Prague)*

11:00–11:20

Performance and degradation analysis of magnetron sputtered thin-film catalysts for the hydrogen evolution reaction in a proton-exchange membrane water electrolyzer

Jaroslav Herman (Charles University)

11:20–11:40

Heat Transfer and Flow Analysis of a Dryer with Flow Splitter and Induction Heating for PEM Electrolysis

Davaanyam Dorj (Pusan National University)

11:40–12:00

Strain-Engineered Magnetron-Sputtered Ir–Co Thin Films as Low-Iridium Catalysts for PEM Water Electrolysis

Tomáš Hrbek (Charles University)

12:00–12:20

Unraveling the Dynamic Active Phase of Low-Loading Iridium OER Catalysts, Its Impact on Stability and Mitigation Strategies

Jakub Drnec (Nano Advanced s. r. o.)

12:20–12:40

Tungsten carbide-based catalysts for Hydrogen Evolution Reaction

Elisa Galli (University of Brescia)

CLOSING CEREMONY (SUN II HALL)

12:40–13:00

Posters Programme

H2 production

ID 24 **Analysis of preheating strategy and heat transfer mechanism of the MS-SOEC system**
Jenn-Kun Kuo (National Sun Yat-sen University)

ID 79 **PVD-coated interconnects for solid oxide electrolysers**
Kun Zhang (University of Birmingham)

ID 20 **Dual-driven Activation of High-valence States in Prussian Blue Analogues via Graphene-quantum dots and Ozone Induced Surface Restructuring for Hydrogen Evolution**
Min-Hsin Yeh (National Taiwan University of Science and Technology)

ID 19 **Interlayer-Modulated NiFe-LDH Electrodes with Tunable Interlayer Spacing for Robust and Efficient OER in Water Splitting**
Ling-Yu Chang (National Taipei University of Technology)

ID 25 **Asymmetric Co-Flow Membraneless Electrolysis for High-Purity Hydrogen Production via Hydrodynamic Bubble Control**
Mohammad Torkian (Universite Libre de Bruxelles)

ID 48 **Rapid and Facile Fabrication of Electrocatalyst Using Photo-derived Procedure for Hydrogen Evolution**
Jung Woo Lee (Pusan National University)

ID 37 **Life Cycle Assessment and Environmental Life Cycle Cost of a Photoelectrolysis Cell for Hydrogen Production**
Mauro Giorgianni (Institute of Advanced Technologies for Energy “Nicola Giordano”)

ID 31 **Accelerating Start-Up and Boosting Hydrogen Output through Applied Potential Control in Bench-Scale Membraneless Single-Chamber MECs**
Minsoo Kim (Pusan National University)

ID 75 **Hydrogen production from aluminum reaction with NaOH/H2O solution: experiments and insights into reaction kinetics**
Martina Iaia (University of Modena and Reggio Emilia)

ID 52 **On-demand hydrogen production by ammonia decomposition at low temperatures**
Yasushi Sekine (Waseda University)

H2 embrittlement

ID 28 **Hydrogen embrittlement: Phase-selective lattice swelling and stress evolution**
Antonin Dlouhy (Czech Academy of Sciences)

ID 54 **Influence of microstructure evolution and precipitation on hydrogen embrittlement in Al0.35CoCrFeNi complex concentrated alloy**
Selim Burak Canturk (Slovak Academy of Science)

ID 57 Hydrogen Embrittlement of Cast and Forged Steels for Hydrogen Gas Infrastructure Applications

Hana Jirková (Research and Testing Institute Pilsen)

ID 59 Advanced microscopic techniques for studying hydrogen embrittlement in electrolytically hydrogen-saturated steels

Josef Kasl (Research and Testing Institute Pilsen)

H2 compression & storage

ID 40 Potential of the Underground Hydrogen Storage in the Czech Republic: the preliminary study

Katerina Musilova (Czech Geological Survey)

ID 9 Adhesives and sealants for electrolysers, fuel cells and energy storage devices

Andreas Arlt (WEVO-CHEMIE GmbH)

ID 22 Efficient component development of Mg-based solid-state H2 storage alloys for enhanced hydrogen des-/absorption dynamics driven by machine learning

Wei Xue (EPFL)

H2 mobility

ID 56 Mobile hydrogen filling stations

Vít Doleček (Czech Technical University)

ID 44 Ecosystem for hydrogen dispensing at rates above 60 g H_2/s

Bronislav Vahalík (Transport Research Centre)

ID 42 Sampling device for high-pressure hydrogen

Aleš Dynda (APT spol. s r. o.)

ID 34 Didactic Aid – Hydrogen Refueling Station (HRS) Simulator

Aleš Dynda (APT, spol. s r. o.)

ID 53 The Hydrogen Prism for Maritime: Angles for Regulating Hydrogen Fuels in the EU Maritime Sector

Kelsey Pailman (University of Groningen)

H2 applications

ID 47 Ammonia-cracking-integrated gas turbine system utilizing turbine waste heat: a thermodynamic performance analysis

Gyungmin Choi (Pusan National University)

ID 73 Modeling and Analysis of the Cost Breakdown in the Mass Production of a 10 kW Fuel Cell Stack

Miroslav Kludský (ÚJV Řež a. s.)

ID 43 Modulating the surface properties of Pd/C catalysts by liquid-phase reductants for enhanced selectivity in benzaldehyde hydrogenation

Anna Hwang (Korea Institute of Industrial Technology)

ID 23 Hybrid NiMo@CC-GF biocathode enhances hydrogen-mediated microbial electrosynthesis for acetate production from CO2

Jung Rae Kim (Pusan National University)

ID 80 Using Molten Carbonate Electrolyser as a CO2 concentrator from air: conceptual and experimental study

Aliaksandr Martsinchyk (Warsaw University of Technology)

Ion exchange membranes production

ID 81 Continual casting production process of homogeneous tailormem ion exchange membranes Hollex

Jan Žítka (TailorMem)

Abstract Orals

ID 38

Providing Access to Hydrogen Education Across Europe

Hana Bartkova Dr, Prof Karel Bouzek Dr, Martin Paidar Dr, Robert Steinberger-Wilckens Dr

Vysoká škola chemicko-technologická v Praze (VSCHT), Praha 6, Czech Republic

Keywords: Education; universities; schools; Formal Education; Hydrogen Academy

The European Hydrogen Academy (short: HyAcademy.eu) has built a network of over 100 universities (Network 100+) and a network of over 500 schools (Network 500+) that have integrated hydrogen topics into their lectures, modules, science teaching, and educational and training work.

Several databases hosted by HyAcademy.eu offer students access to information on programmes of study in Europe, teachers insight into collegues active in the hydrogen area, and the general public information on university, school, and industry activities in training and upskilling, as well as offering a broad range of information useful in teaching and education.

The project is currently working on a series of 12 textbooks covering various topics from the hydrogen, electrolyser, and fuel cell field. These are intended as open access core educational material that can be used in teaching and training. School workbooks are in preparation, as well as a children's book on hydrogen.

A series of hands-on hydrogen courses has begun in cooperation with the Green SKHy Interreg NWE proojest, whilst a staff and student exchange programme is being conducted together with the GreenSkills4H2 ERASMUS+ project.

A new project on training staff involved in permitting processes will start on 01 Jan. 2026 and join the efforts of HyAcademy.eu in delivering recognised qualifications and meaningful training programmes endorsed by industry, trade associations, and EU Member States.

HyAcademy.EU considerably contributes to the EU goals of offering access to high-quality education, supporting the creation of a highly-skilled workforce and more and better jobs in the European hydrogen industry. Via the school activities it will foster public awareness and acceptance of hydrogen technologies.

The partners of the European Hydrogen Academy are: Vysoká škola chemickotechnologická v Praze (VSCHT or UCTP, coordinator), Rijksuniversiteit Groningen (RUG), Politecnico di Torino (POLITO), Université Libre de Bruxelles (ULB), Universitatea Nationala de Stiinta si Tehnologie Politehnica Bucuresti (NUSTPB), Universita Degli Studi Di Modena E Reggio Emilia (UNIMORE), Trakiyski Univesitet (TrU), Université de Technologie de Belfort-Montbéliard (UTBM), Fundacion Para El Desarrollo De Las Nuevas Tecnologias Del Hidrogeno En Aragon (FHa), DVGW Deutscher Verein des Gas- und Wasserfaches Technischwissenschaftlicher Verein e.V., KIC innoenergy SE, EUREC, Technokrati Ltd., Future.Soloutions Sárl, University of Ulster (UU), Bertz Associates Ltd., and the University of Birmingham (UoB).

ID 51

CEETe H_2: Integrated research infrastructure for hydrogen technologies

Ján Vereš

VŠB TU Ostrava, CEET, Ostrava, Czech Republic

Keywords: hydrogen, conversion, digital twin, safety, monitoring

The CEETe H_2 (Centre for Energy and Environmental Technologies – Hydrogen) project aims to establish a comprehensive, large-scale research and testing infrastructure dedicated to the development, validation and optimization of hydrogen technologies across the entire value chain, from production and storage to distribution and end-use. The CEETe H_2 hydrogen research polygon will serve as a national pilot platform enabling systematic experimentation, digital modelling, and integration of hydrogen energy systems into industrial and transport applications.

The project will create a unique experimental environment combining real-world hydrogen production through electrolysis, high-pressure storage, and distribution with the end-use of hydrogen in mobility, power generation, and hybrid microgrids. CEETe H_2 will provide the capability to investigate key aspects of efficiency, stability, durability, and operational reliability of electrolyzers under dynamic loads, as well as to study storage and compression technologies operating under high-pressure and extreme environmental conditions. The infrastructure will further include facilities for rapid refueling of hydrogen tanks, validation of refueling protocols, and evaluation of safety parameters during filling operations.

An integral part of the polygon is the **Functional module of Safety and Monitoring**, which forms the backbone of the entire research infrastructure. This laboratory will ensure the safe and reliable operation of all experimental units by integrating real-time sensor networks, advanced data analytics, and digital twins. The system will continuously monitor key operational variables—pressure, temperature, flow rate, hydrogen concentration, and electrical parameters—while employing predictive algorithms to detect anomalies and prevent potential failures. Research will focus on developing models for risk assessment, predictive maintenance, and dynamic safety management, enabling continuous optimization of hydrogen processes and infrastructure resilience.

CEETe H_2 is structured into three interconnected laboratories:

Laboratory of Conversion and Synthesis of Low-Carbon Fuels – focusing on the production of green hydrogen via water electrolysis and subsequent conversion into synthetic fuels.

Laboratory of Energy Storage and Accumulation – dedicated to studying high-pressure and solid-state storage systems, energy buffering, and hybridization with battery storage.

Laboratory of Distribution and Utilization of Low-Carbon Technologies – enabling experimental research on hydrogen use in transport, stationary energy systems, and industrial processes.

The core research ambition of CEETe H_2 is to generate high-quality experimental data for the creation of digital twins and advanced simulation models that can predict system behaviour, optimize control strategies, and support the deployment of hydrogen technologies in real applications. The combination of physical experimentation and digital modelling will provide a scientific basis for evaluating the safety, efficiency, and economic feasibility of hydrogen energy systems under realistic operational conditions.

ID 64

LIFE CYCLE ASSESSMENT OF AN INTEGRATED POWER-TO-METHANOL/SOFC PLANT FED BY GREEN HYDROGEN

Prof Vittorio Tola PhD, Dr Mario Cascetta Eng.

University of Cagliari, Cagliari, Italy

Keywords: Green hydrogen, Power-to-methanol, Life Cycle Assessment

Objectives

This paper aims to evaluate the environmental impact along the overall life cycle of a small-scale and decentralised integrated power-to-methanol system designed to store the energy surplus produced by renewable energy sources (RES). The production of hydrogen from RES and its conversion to methanol via recycled CO_2 allows to mitigate the negative effect of CO_2 emissions and to compensate for RES intermittency.

Methods

Two different water electrolysis technologies were considered and compared: a low-temperature alkaline electrolyzer (AEL) and a high-temperature solid-oxide one (SOEC). The conversion of hydrogen and CO_2 occurs in a catalytic reactor where methanol is synthesized through the hydrogenation process. The produced methanol is stored for feeding a high-temperature solid-oxide fuel cell (SOFC). Two configurations based on electrolysis technology, namely A and B, were studied. The overall system during the charging phase stores the electricity excess produced from RES as chemical power, and during the discharging phase uses the stored methanol to produce electricity by the SOFC (and a ORC in configuration A) [1].

To predict the performance of the main components and of the overall system, detailed numerical simulation models were developed using the Aspen Plus software. A comprehensive analysis through mass and energy balances was carried out to evaluate performance indices of each section and of the overall plant. To evaluate the environmental impact, a Life Cycle Assessment (LCA) of the power-to-methanol system has been carried out, to assess the potential impact on human health, ecosystem, climate change, and resource consumption of the two plant configurations [2].

Results

From an energetic point of view, a global efficiency of the overall system slightly lower than 0.35 was obtained for both configurations. Regarding the LCA, the most critical component in configuration A is the AEL, which alone contributes more than 60% in each category, mainly due to the nickel of the electrodes, the tetrafluoroethylene of the Teflon seals and the large amount of steel used in the production of the stack and the auxiliary systems. In configuration B, instead, the greatest contribution comes from the Reversible Solid Oxide Cell (RSOC) and in particular from the nickel-chrome alloy used in the production of interconnections between cells.

Conclusions

The results of the LCA study demonstrated that the most critical component is the electrolyzer. Configuration B shows a lower impact, thanks to the use of a single reversible component rather than a separate electrolyser and fuel cell. The LCA was carried out on systems in the design phase, using average data from scientific literature, due to the relatively scarce availability of information for the Inventory analysis phase. However, it can be stated that the results obtained are in line with those found in the literature.

Reference

[1] Lonis F, Tola V, Cau G. Assessment of integrated energy systems for the production and use of renewable methanol by water electrolysis and CO2 hydrogenation. Fuel 2021;285.

[2] Douglas CM, Lai H, Ostadi M, Shin W, Bromberg L, Zang G. Techno-economic analysis and life-cycle assessment of methanol synthesis plants using renewable hydrogen and carbon dioxide feedstocks Energy Conversion and Management 347 (2026) 120374.

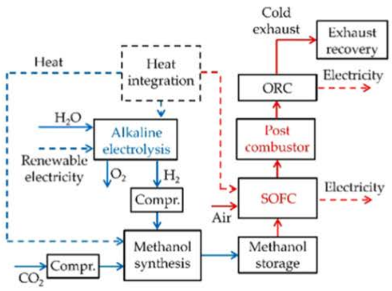


Figure 1a - Functional scheme of Configuration A

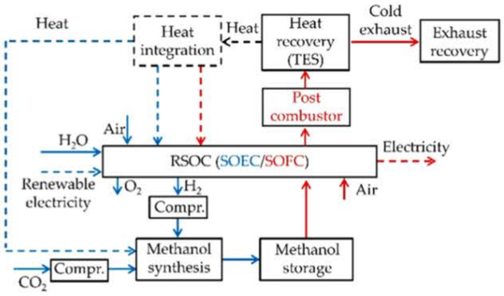


Figure 1b - Functional scheme of Configuration B

ID 27

Experimental Optimization of Operating Parameters in a Fuel Cell System for Off-Road Applications

Dipl. Ing. Martin Rabensteiner, Dipl. Ing. Martin Aggarwal, Dipl.-Ing. Dr. Patrick Pertl,
Ass.Prof. Dipl.-Ing. Dr. Alexander Trattner

HyCentA Research GmbH, Graz, Austria

Keywords: Fuel Cell System Development; Experimental Testing; System Optimisation; Parameter Variation; System Load Dynamics

Within the framework of the Austrian-funded HyFleet project, a fuel cell system was developed for integration into a side-by-side off-road vehicle. The goal was to design, assemble, and calibrate a compact, dynamic system capable of meeting the demanding performance requirements of mobile off-road applications.

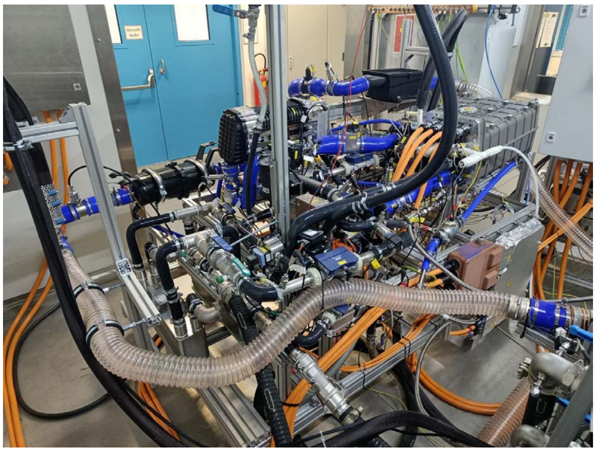
To investigate and optimise system behaviour, a comprehensive parameter variation study was performed on a dedicated test bench. The influence of key operating parameters — coolant temperature, purge interval, and cathode lambda — was analysed with respect to stack performance, efficiency, and voltage stability. Variations in coolant temperature enabled the assessment of thermal management and humidification effects, while adjustments to purge intervals provided insights into hydrogen concentration and recirculation dynamics. The impact of oxygen supply on electrochemical performance was evaluated by varying the cathode lambda. Additionally, freeze-start experiments were performed to develop strategies for reliable shut-down and start-up procedures under sub-zero ambient conditions.

The results revealed clear interdependencies between thermal management, gas supply, and electrochemical efficiency. Optimal operating windows were identified that maximise power output while maintaining voltage uniformity across cells. The system demonstrated excellent dynamic response, handling load gradients of up to +300 A/s and −2000 A/s, confirming its ability to manage transient load profiles typical for off-road vehicles.

These findings highlight the importance of precise control strategies for temperature, purge, and air supply in achieving robust and efficient operation in harsh environments. The results contribute to advancing fuel cell technology for reliable, high-performance propulsion systems in mobile applications.

Acknowledgement

The COMET Centre HyCentA is funded within COMET — Competence Centers for Excellent Technologies by the Federal Ministries of Innovation, Mobility and Infrastructure (BMIMI) and of Economy, Energy and Tourism (BMWET), as well as the provinces of Styria, Upper Austria, Vienna and Tyrol. The COMET programme is managed by FFG.



ID 77

Status of Nuclear-based Clean Hydrogen Production Demonstration

Senior Manager Won-Gyu Kim Ph.D.

Korea Hydro & Nuclear Power Co., Ltd, Gyeongju-Si, Republic of Korea

Keywords: Nuclear Power Plant, Clean Hydrogen, Hydrogen Risk Assessment, Electrolysis, Power system

1. Objectives

- This presentation provides an overview of the current progress in developing a nuclear clean hydrogen plant. In particular, it focuses on key aspects such as the demonstration site, facility layout, power system integration between Nuclear Power Plant(NPP) and hydrogen plant, and hydrogen hazard assessment.

2. Methods

- This study explains the current status and future plans for power grid operation in accordance with Korea's Basic Plan for Electricity Supply and Demand, and describes the role of water electrolysis as a power grid flexibility resource.
- It also describes the current status and plans for the construction of a 10 MW low-temperature water electrolysis demonstration plant integrated with nuclear power.
- In addition, this study explains the methodology for hydrogen hazard assessment of hydrogen production facilities located near nuclear power plants.

3. Results

- In a situation where renewable energy generation continues to increase while power grid capacity remains constrained, water electrolysis serves as a key solution for securing transmission margins, ensuring stable grid operation, and promoting carbon neutrality as well as the hydrogen economy.
- Based on the distance between the NPP and the hydrogen production facility as well as simulation results assuming an explosion at the hydrogen production facility, the impact on the nuclear power plants is found to be negligible.
- Accordingly, the timely development of nuclear-based clean hydrogen production facilities is essential.

4. Conclusions

- Korea Hydro & Nuclear Power(KHNP) has been promoting a 10 MW low-temperature water electrolysis hydrogen production demonstration project utilizing surplus electricity from nuclear power plants from 2024 to 2028. Construction is scheduled to begin this year, and be completed in 2027, the facility is expected to produce approximately 4 tonnes of clean hydrogen per day. The results of this demonstration clearly indicate that nuclear energy has the potential to extend beyond conventional electricity generation and play a key role in enabling a sustainable hydrogen economy.

ID 29

Water electrolysis under sustained pH-gradient in a salt-based electrolyte for the co-production of hydrogen and lime as a cement precursor

Rémy Rouxhet, Pr. Joris Proost, Raphaël Defroyennes, Ronny Santoro

Université catholique de Louvain (UCLouvain), Div. of Materials and Process Engineering, Louvain-La-Neuve, Belgium

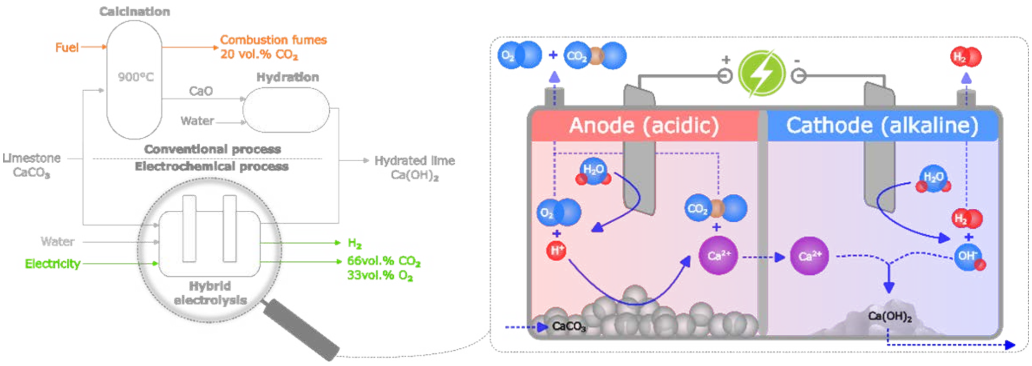
Keywords: Lime; electrification; decarbonation; electrolysis;hydrogen

A new water electrolysis approach has recently emerged thanks to the seminal work of Ellis & al [1]. His innovative method considers a neutral salt-based electrolyte to naturally generate a pH gradient during water electrolysis. While this method leads to a higher energy consumption than acidic or alkaline water electrolysis, it offers a distinct benefit: the generation of additional valuable solids driven by the pH gradient created. This novel approach has drawn significant attention in recent years, as reflected by the growing number of publications and patents, due to its potential to electrify the production of key chemical components. The most promising application is the electrification of lime and cement production, an industry responsible for 8% of global CO_2 emissions and often labeled as "hard-to-abate". The production by electrolysis offers the opportunity to drastically shift this industry towards a more sustainable process but still requires major improvements for industrial-scale deployment.

A comparison between thermal and electrochemical lime production, along with a simplified reaction scheme of the hybrid electrolyzer utilized in this study, is presented in Figure 1. The acidity generated by water oxidation at the anode dissolves the calcium carbonate inserted. Calcium cations then migrate through the cationic membrane towards the cathodic compartment to react with hydroxide ions generated by water reduction at the cathode. Calcium hydroxide is finally collected after precipitation.

In this presentation, the challenges associated with this new approach and differences with conventional water electrolysis will be discussed. A two-compartment electrolysis cell capable of producing $Ca(OH)_2$ has been tested at different current densities. Precise pH and Ca_2+ concentration measurements demonstrate that the electrolysis setup is able to dissolve $CaCO_3$ and precipitate $Ca(OH)_2$ while ensuring perfect faradic efficiencies. Key guidelines are proposed to achieve a perfect reaction stoichiometry. The research also highlighted a major issue: membrane precipitation, which poses significant risks to long-term stability and energy efficiency. This stability will be further investigated on a zero-gap cell, and strategies to overcome membrane stability will be discussed. In particular, the CO_2 recovery, necessary to perform ex-situ precipitation, will be examined. These findings are believed to pave the way for a more sustainable and environmentally friendly approach to lime and cement production.

[1] L.D. Ellis et al, "Toward electrochemical synthesis of cement-An electrolyzer-based process for decarbonating $CaCO_3$ while producing useful gas streams", Proc Natl Acad Sci USA, 2020;117:12584-12591.



ID 76

CH4 cracking for hydrogen production via electrical heating

Phd Luca Brunelli, PhD Alberto Maria Gambelli, Dr. Laura Carbini, PhD Valentina Coccia,
Professor Federico Rossi

University of Perugia, Perugia, Italy

Keywords: CH4, carbon black, hydrogen, carbon-neutral efficiency, fuel-cell

The aim of this study is to compare methane cracking, including its associated potential for carbon sequestration, with alternative pathways for converting methane into useful energy. In particular, we propose an innovative reactor concept in which a fraction of the hydrogen produced is used to feed a PEM fuel cell, which in turn supplies electricity to resistance heaters integrated within the reactor.Preliminary energy-balance calculations, carried out under conservative assumptions, suggest that the proposed configuration merits further theoretical analysis and, potentially, experimental validation. In this framework, several aspects require deeper investigation: (i) overall process design, with particular emphasis on the layout of resistance heaters and heat-recovery systems; (ii) the thermodynamic and kinetic behavior of methane cracking; and (iii) the design and performance of the carbon black recovery system. These issues will be addressed in future work in order to evaluate the potential economic advantages associated with the valorization of the recovered carbon black in complementary applications. Additional benefits stem from the fact that methane cracking in the proposed system does not rely on catalysts or plasma torches, thereby improving technological simplicity, robustness, and modularity.

CH_4 cracking for hydrogen production via electrical heating

Luca Brunelli, Alberto Maria Gambelli, Laura Carbini, Valentina Coccia, Federico Rossi

Objectives

The objective of the study is comparing a novel methane cracking concept, which involves carbon sequestration, to conventional gas-to-power plants. It will be demonstrated the potentiality of the innovative reactor design based on a PEM fuel cell to power reactor electrical heating.

Methodology

Preliminary energy-balance was conducted under conservative assumptions to assess the performance of the novel reactor. CH4 cracking is ruled by the reaction: $CH_4 \rightarrow C + 2\,H_2$. At1200°C such a reaction occurs spontaneously. Thermodynamical calculation results are shown in Fig.2 which do not tale into account energy saving attained by the preheating heat exchangers R1 and R2 (see Fig.1)

Results

The schematic in Figure 1 illustrates the proposed methane-cracking system and the associated mass and energy balances. One mole of methane (16 g) is fed to a high-temperature reactor operating at 1200 °C, where it decomposes into one mole of solid carbon (12 g) and two moles of hydrogen (4 g). The endothermic heat demand of the cracking reaction ($\Delta H \approx 90$ kJ/mol) is supplied by electric resistors powered by a PEM fuel cell with an assumed efficiency of 50%. Part of the produced hydrogen is diverted to the fuel cell, delivering electrical energy (≈180 kJ/mol H_2), while the remaining hydrogen is available as an energy carrier (≈300 kJ/mol H_2).

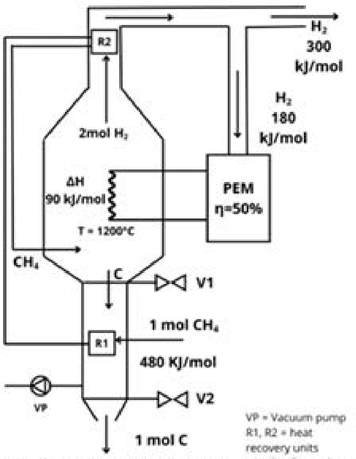


Figure 1: CH4 cracking reactor

Technology	Energy efficiency	Source
CH4 cracking reactor	43%	
NGCC	48,88-50%	Liang et al. [2]
NGCC	45-48%	Marques et al.[3]
NGCC	48.88 - 51.40 %	Lei et al.[4]

Table 1: comparison with conventional gas-to-power plants with carbon capture

Conclusion

The proposed methane-cracking system shows promise mainly for theoretical, efficiency carbon-sequestration capabilities without catalysts and plasma torches. Efficiency of the novel reactor is around conventional gas-to-power (NGCC) plants with carbon capture. Future studies will focus on evaluating the efficiency improve given by heat recovery. Further research are required to refine the scheme and getting economical numbers.

Litterature

[1] E. Zeza, E. Pachatouridou, A. A. Lappas, and E. F. Iliopoulou, *Catalysts*, vol. 15, no. 2, p. 145, 2025. https://doi.org/10.3390/catal15020145

[2] Y. Liang, T. Lei, Y. Zhu, K. Ye, and J. Wang, *Appl. Therm. Eng.*, vol. 255, p. 124019, 2024. https://doi.org/10.1016/j.applthermaleng.2024.124019

[3] L. Marques, M. Monteiro, C. Cenci, M. Mateus, and J. Condeço, *Energies*, vol. 18, no. 13, p. 3539, 2025. https://doi.org/10.3390/en18133539

[4] T. Lei, Y. Liang, Y. Zhu, K. Ye, and J. Wang, *Energy*, vol. 316, p. 134491, 2025. https://doi.org/10.1016/j.energy.2025.134491

ID 7

Utilization of Waste Biomass in the Design of Catalysts for Hydrogen Generation via Methanol Reforming

Doctor Natalia Lukasik PhD Eng. Doctor Izabela Frackiewicz PhD Eng.,
Doctor Andrzej Rogala PhD Eng., Professor Jacek Gebicki PhD DSc. Eng

Gdańsk University of Technology, Gdańsk, Poland

Keywords: chemical hydrogen storage; methanol steam reforming; biomass

Objectives

Lignocellulosic biomass is an abundant, renewable, and low-cost feedstock that can serve as an alternative to fossil resources for the production of energy carriers and advanced materials [1]. Owing to its porous structure and the presence of oxygen-containing functional groups, it can be effectively transformed into catalytic materials with high surface reactivity [2]. In the context of sustainable hydrogen technologies, methanol is considered a promising chemical hydrogen carrier due to its high hydrogen content and ease of handling [3]. The main objective of this work is to develop and characterize catalysts derived from waste biomass for hydrogen generation via methanol steam reforming, using lignocellulosic precursors as renewable catalyst supports.

Methods

Banana peel waste was employed as a lignocellulosic precursor for the preparation of $Cu/ZnO/Al_2O_3$ (CZA) catalysts. Metallic species were deposited on the carbonized biomass support by impregnation and co-precipitation, followed by thermal treatment. The obtained catalysts were characterized using X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy with energy-dispersive spectroscopy (SEM-EDS), CHNS elemental analysis, thermogravimetric analysis (TGA), and X-ray photoelectron spectroscopy (XPS). These techniques allowed the determination of crystalline structure, surface composition, porosity, and metal–support interactions.

Results

The physicochemical characterization confirmed the formation of well-dispersed Cu, ZnO, and Al_2O_3 nanoparticles on the porous carbon matrix derived from banana peel. The morphology and surface chemistry were strongly influenced by the synthesis method and the ratio of metal precursors. The catalysts exhibited favorable textural properties, which are expected to enhance catalytic performance in methanol steam reforming. Correlations between composition, surface properties, and catalytic activity were established, indicating that biomass-derived supports can effectively promote hydrogen production reactions.

Conclusions

This study demonstrates the potential of waste lignocellulosic biomass as a sustainable raw material for catalyst synthesis. The obtained CZA catalysts from banana peel waste combine renewable origin, structural robustness, and promising surface functionality. Their physicochemical characteristics make them suitable candidates for hydrogen generation through methanol steam reforming. The approach contributes to waste valorization, circular economy practices, and low-carbon hydrogen technologies, supporting the global transition toward sustainable energy systems.

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Acknowledgements

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ID 60

Thermal plasma gasification for hydrogen-rich syngas production from heterogeneous waste feedstocks

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Keywords: Thermal plasma; Hydrogen production; Syngas; Waste-to-hydrogen; Plasma gasification

Thermal plasma technology provides an efficient and highly flexible route for producing hydrogen-rich synthesis gas (syngas) from complex and heterogeneous hydrocarbon-based materials. At the Institute of Plasma Physics of the Czech Academy of Sciences, several high-power plasma torches are employed for thermochemical treatment, including a self-developed H_2O–Ar DC arc torch (~150 kW) and a microwave plasma torch (~100 kW). These torches enable processing of diverse feedstocks under extreme thermochemical conditions, such as refuse-derived fuel (RDF), simulated medical waste (SMW) and other challenging real-waste feedstocks. Under plasma gasification or pyrolysis, the organic feedstock is rapidly converted into a clean syngas stream with lower heating values reaching up to ~20 MJ/kg. The syngas, dominated by hydrogen (H_2) and carbon monoxide (CO), can be compositionally controlled by addition of oxidizing agents such as steam or CO_2, allowing optimisation of reforming pathways, suppression of soot formation and improvement of overall conversion efficiency. In addition to gaseous products, valuable carbonaceous and inorganic solid materials are generated, providing further potential for material valorisation. Combining rapid reaction kinetics, broad feedstock tolerance and compatibility with renewable or surplus energy inputs, thermal plasma offers a promising foundation for future waste-to-hydrogen systems. The results indicate that plasma-assisted conversion can provide a viable pathway for hydrogen production from waste streams that are typically considered difficult to process.

ID 21

Hydrogen based poly-generation for energy communities: a case study

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Keywords: Renewable energy; Energy storage; Hydrogen; Polygeneration; Energy communities

Renewable energy communities and green hydrogen are increasingly recognized as key enablers of the energy transition toward a decarbonized energy system. Within this context, photovoltaic (PV) technology currently represents the most mature and cost-effective solution for renewable electricity generation in the residential sector, whereas solar water heating (SWH) systems remain the predominant technology for renewable domestic hot water. Nevertheless, renewable energy generation is inherently variable due to meteorological and seasonal fluctuations, emphasizing the necessity of efficient and flexible energy storage technologies capable of ensuring a stable and reliable energy supply.

Among available electrical energy storage options, batteries are the most widespread due to their high round-trip efficiency, easy installation, and low maintenance requirements. However, in recent years, hydrogen-based energy storage systems have gained increasing attention as a promising long-term storage solution for residential and community-scale applications.

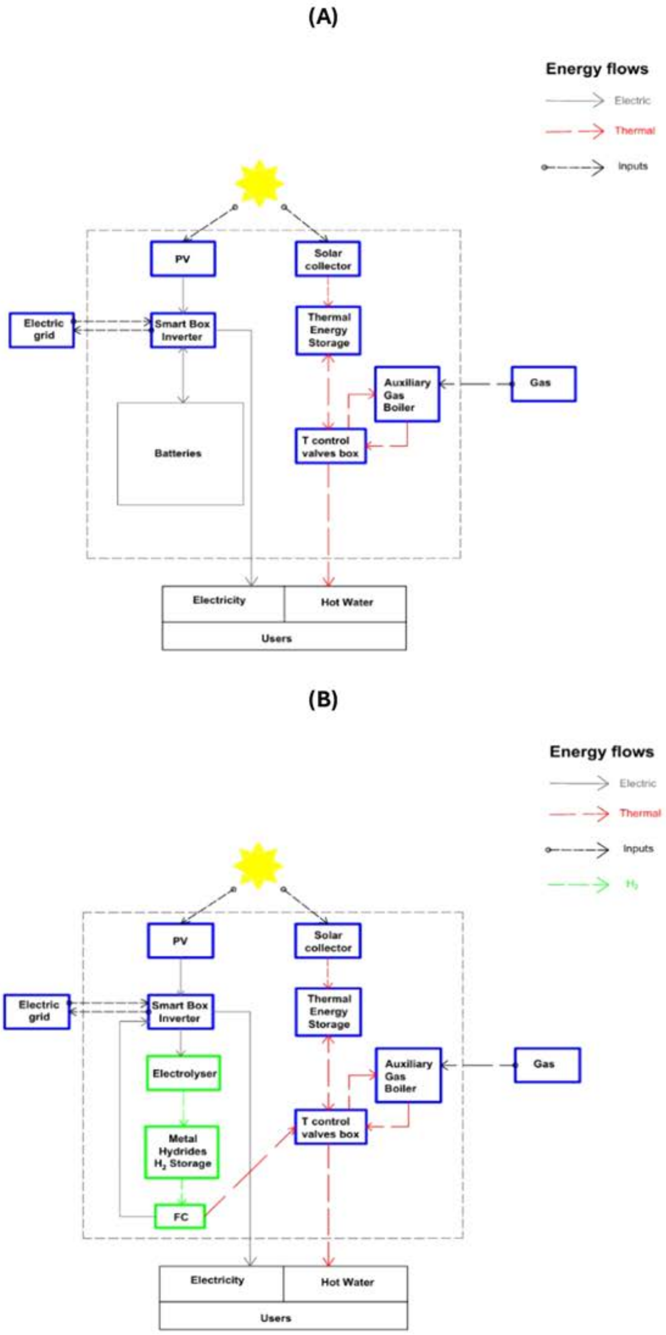
A hydrogen energy storage system typically consists of an electrolyser, hydrogen storage unit, and fuel cell, enabling an energy-to-hydrogen-to-energy conversion cycle. Although this system exhibits a lower electrical round-trip efficiency compared to batteries, it offers unique advantages such as seasonal storage capability and the possibility of polygeneration through the recovery and utilization of thermal energy produced during the electrolyser and fuel cell operation. This feature substantially increases the overall system efficiency.

In this work, a technical analysis was performed to assess the competitiveness of hydrogen storage systems compared to conventional battery-based systems, which serve as a benchmark. The study considers a renewable energy community composed of ten residential units located in Italy. Family size and electricity consumption were derived from national statistical data, while domestic hot water consumption was estimated according to standard residential profiles.

The analyzed configurations include a PV system (20–40 kWp) combined with an SWH system featuring 20 m² of solar collectors and a 1,000-liter hot water storage tank, supported by a 15 kW auxiliary boiler. Two storage strategies were evaluated: (i) a battery-based system, and (ii) a hydrogen-based system including an electrolyser, metal-hydride hydrogen storage tanks, and a hydrogen fuel cell equipped with heat recovery. For the battery system, two sizing strategies were adopted: (i) designing the battery to store all excess PV energy generated during sunlight hours, and (ii) designing the battery to meet electrical demand during non-sunlight hours. For the hydrogen system, the electrolyser size was defined to consume an amount of energy comparable to the battery system, while the metal-hydride tank was designed to store the average daily hydrogen production, and the fuel cell size was calculated to utilize all the daily produced hydrogen.

The annual energy balance results indicate that, in the battery-based configuration, full electrical independence from the grid can be achieved even for the smallest PV system size. In contrast, the hydrogen-based configuration attains grid independence only at the largest PV capacity. Nevertheless, the hydrogen system compensates for this lower electrical efficiency with superior thermal performance: thanks to heat recovery from the electrolyser and fuel cell, the auxiliary boiler is no longer required, leading to a reduction in natural gas consumption and greenhouse gas emissions.

Thus, the technical feasibility of hydrogen-based energy communities has been demonstrated. Future developments will include simulations under different climatic and lifestyle conditions across Italian cities, as well as a techno-economic assessment to evaluate the long-term competitiveness and scalability of hydrogen storage systems within decentralized renewable energy networks.



Analysed configurations: (A) conventional plant with PV+Batteries and Solar Boiler assisted by an auxiliary gas boiler, (B) the proposed hydrogen-based system.

ID 26

A new interconnect design for improving thermal uniformity in planar solid oxide fuel cell

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Keywords: Solid oxide fuel cell, Thermal management, Uniform temperature, Interconnect design, Electrochemistry simulation

Solid oxide fuel cells (SOFCs) operate at high temperatures ranging from 600 to 1000 °C, which can lead to severe degradation and delamination due to thermal stress. Therefore, achieving a uniform temperature distribution is essential to prevent these issues and improve the long-term durability and power performance of SOFC systems. In this study, a new interconnect design for efficient thermal management was proposed, and its influence on the internal temperature distribution of a planar SOFC cell was analyzed. Three-dimensional electrochemistry simulations were performed to compare the thermal and flow characteristics of the proposed design with those of the conventional cross-type flow configuration, which is most widely used in SOFC research. The new design aims to achieve a more uniform in-plane (horizontal) temperature distribution by adjusting the positions and number of gas inlets and outlets, thereby optimizing the flow path and reducing local hot spots. In the cross configuration, the maximum temperature occurs near the intersection of the air and fuel outlets, resulting in a long and asymmetric distance between the inlet and the hot region, which causes excessive in-plane temperature differences. In contrast, the proposed design rearranges the flow paths to produce a symmetric temperature distribution, with the maximum temperature appearing near the center of the cell, contributing to the reduction of in-plane temperature deviation. The simulation results showed that the maximum temperature of the new cell decreased by approximately 12 °C, while the minimum temperature increased by about 40 °C, indicating a significant reduction in temperature deviation compared to the cross configuration. Furthermore, improved gas mixing near the anode region led to a more uniform temperature field across the entire cell surface. These results demonstrate that the proposed interconnect design can serve as an effective solution for improving the temperature distribution and thermal stability of SOFCs. By minimizing horizontal temperature gradients, the new design not only mitigates thermal imbalance compared to the conventional cross configuration but also enhances structural stability and reduces thermal stress, thereby extending the operational lifetime of SOFC stacks.

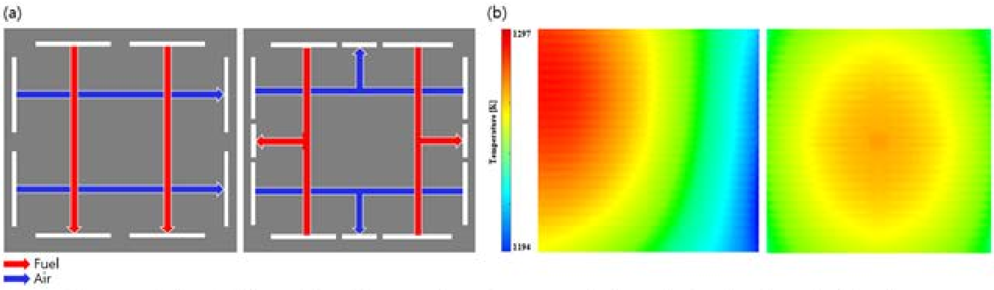

Figure 1. (a) Channel designs of the reference and new interconnect for improving in-plane thermal uniformity;
(b) Temperature distribution for reference and new interconnects

ID 68

Characterisation of hydrocarbon-based proton-exchange membranes for electrochemical hydrogen compression

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Keywords: Hydrocarbon; membranes; characterisation; hydrogen; compression

In electrochemical hydrogen compression (EHC), proton-exchange membranes are a key component, acting as both the separator and solid electrolyte. This enables ionic contact and operation under differential pressure. The performance and efficiency of an EHC cell are largely determined by the membrane's ohmic resistance, which depends on its structure, thickness, and water content. Perfluorosulfonic acid-based polymers are currently the dominant membrane materials in EHC due to their superior ionic conductivity, chemical stability, and water retention. However, because the use of per- and polyfluoroalkyl compounds, they are costly and are also a subject of a possible market ban 1]. In EHC, hydrocarbon-based (HC) membranes can provide adequate performance and durability given the non-oxidising electrode environment, making them a viable alternative to fluorinated membranes.

In this work, properties (swelling ratios and ionic conductivities) of recently developed HC membranes of different nominal thicknesses (120, 90 and 60 µm) are compared against commercial membranes of Nafion® series (N117, N115, N212). The ionic conductivity was measured in a heated cell with 4-electrode setup at different relative humidities and constant gas flow. Furthermore, performance of individual membranes was evaluated in EHC cell. For that, gas-diffusion electrodes were prepared by ultrasonic spray coating of the catalyst layer onto Sigracet 28 BC carbon paper with Pt loading of 0.2 mg cm^{-2}. Each membrane was characterized at 40 °C, 100 % relative humidity and voltages from 0.1 to 0.5 V using constant voltage curves and electrochemical impedance spectroscopy. The inlet pressure was 2 bar while the outlet was 31 bar. The effective permeability of each membrane was calculated based on the pressure decay data.

The results showed that the Nafion® membranes have higher ionic conductivity than HC ones. The swelling results show that the HC membranes absorb more than 2× the water than Nafion® membranes. This suggests that the ionic conductivity differences are likely due to different membrane structure caused by the material of HC membrane. For both series of membranes, the performance in EHC cell was improved as the membrane thickness decreased. The best performing Nafion® membrane was the thinnest (50 µm) N212, achieving current density 1.7 A cm^{-2} at 0.5 V. In comparison, the best HC membrane (60 µm) only achieved 0.7 A cm^{-2} at the same voltage. The performance difference was ascribed to the higher ohmic resistance of the HC membrane and its decreasing water content during the operation, which corelates with conductivity measurements. This also results in higher polarization resistance, i.e. slower reaction rates in the catalyst layers. Moreover, the effective H_2 permeability of the HC membranes was almost twice compared to the Nafion® ones. These results indicate that the tested HC membranes should be further optimized to enhance the ionic conductivity and reduce H_2 permeability.

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ID 15

Hydrogen Embrittlement of Steel in Repurposed Natural Gas Infrastructure: Experimental Insight and Safety Assessment

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Keywords: hydrogen; gas grid; hydrogen embrittlement; repurposed pipelines; underground gas storage

Repurposing and retrofitting the existing natural gas infrastructure for gaseous hydrogen is connected with technical challenges including the risk of hydrogen embrittlement (HE) of steel components. To ensure the safety and minimize financial investments, it is necessary to understand the critical operation conditions that may lead to HE.

This study focused on underground gas storage (UGS) facilities where the conditions are specific due to presence of water and other liquids in gas. Long-term exposures of pipeline steels to high-pressure hydrogen, hydrogen quantification by thermal desorption analysis and electrochemical permeation test, and mechanical tests such as slow strain rate test, fracture toughness and fatigue tests were combined to quantify hydrogen entry to steel and the risk of HE. The studied parameters included hydrogen pressure and temperature, gas composition and operational contaminants, surface conditions, material properties, and weld characteristics.

The comprehensive experimental approach allowed for identification of the critical factors controlling the steel-hydrogen interactions in gas grid environments. An assessment tool for determination of the safe limit of hydrogen concentration in natural gas for UGS technologies was developed, providing a practical instrument for industry application.

ID 62

Pressurised Efficient Alkaline Electrolyser

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Keywords: Hydrogen, Pressurised AEL, Transient Simulation, TEMPEST

Objectives

The EU-funded PEACE project aims to develop an advanced high-pressure alkaline electrolyser (AEL) capable of significantly reducing the cost of pressurised hydrogen production. The objective is to demonstrate that the integration of a dual-stage pressurisation concept, combined with enhanced stack components and optimised operational strategies, enabling the pressurised AEL system to achieve a high efficiency at a current density along with long-term durability.

Methods

To achieve the objectives of the PEACE, the methodology consists of qualification of components, engineering, construction and assembling of stacks, pressure vessel and a demonstrator test rig as well as optimization through modelling. This methodology not only involves qualifying the cells under pressurized conditions, but also includes the development of concepts and designs for a high-pressure AEL system capable of operating under transient conditions. The methodology also covers the integration of experimental work with modelling and simulation of the AEL. Moreover, a dispatch model supports the integration of PEACE technology into chemical plants by simulating plant operation under varying energy availability and process demands. This is complemented by a circularity and sustainability approach, in which an LCA methodology will be used to assess the potential environmental impacts and benefits of the technology in comparison with the state of the art.

Results

To investigate the AEL cell behaviour under pressurisation, experiments were conducted under both atmospheric and pressurised conditions and the similar high efficiency was achieved under both conditions. Accordingly, the short stack is designed and assembled for testing inside the pressure vessel prior to the full demonstrator evaluation. The simulation framework “Transient Electrochemical Model for Process and Energy SysTems” (TEMPEST) is used to simulate the transient behaviour of the system. The modelling allows an assessment of the influence of different operating modes beyond experimental limitations. Process simulations are utilised to identify industrial processes which are well suited for integration with high-pressure AEL. Process coupling concepts are developed with the aim of improving integration and maximising the benefits of high operating pressure, focussing on methanol and ammonia synthesis at realistic plant scales. The dispatch model defines feasible operational scenarios by combining renewable energy availability with the PEACE concept performance data. A life cycle analysis is being conducted to assess the potential environmental impacts and benefits of the technology compared to the state of the art.

Conclusions

The same high efficiency achieved under atmospheric and pressurised conditions for AEL cell indicates the suitability of AEL used in the PEACE for pressurised conditions. This successful qualification allows us to enter the final phase of the project, testing in the short stack and later the full large PEACE stack inside the pressure vessel. The transient simulation shows that maintaining stable gas purity and a uniform temperature distribution under varying operational conditions and pressurisation needs controlled measures such as flow control. The transient simulation model was found to be a suitable means for comparing operating strategies and supporting the development of robust control concepts for high-pressure AELs. The process and dispatch modelling will allow to identify optimised operating windows for integration with downstream processes.

Acknowledgements

This work was supported by the project ‘Pressurized Efficient Alkaline Electrolyser (PEACE)’, funded under the Horizon Europe programme (Grant Agreement No. 101101343) by the Clean Hydrogen Partnership and its members.

ID 63

Qualification of alkaline water electrolyser under atmospheric and pressurised conditions

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Keywords: Electrolyser; Alkaline; Pressurised

Objectives

PEACE is a research and innovation action project financed by the Clean Hydrogen Partnership under the Horizon Europe program. Its main objective is to reduce the levelised cost of hydrogen via development of an innovative high-pressure alkaline electrolysis (AEL) technology for hydrogen production. The potential for obtaining excellent performance of the pressurised PEACE AEL electrolyser lies in the stack and system design and modification. However, under pressurised operating conditions, multiple questions remain regarding how the cell/stack responds in terms of performance, efficiency and gas purity. Herein, the electrochemical behaviour and response of AEL were investigated under atmospheric and pressurised conditions to evaluate the effect of operational parameters such as pressurisation, temperature and cell design on the overall performance and gas purity.

Methods

To investigate the AEL's performance when operated under pressurised conditions, extensive experimental investigations were conducted under both atmospheric and pressurised conditions. The PEACE project focuses on the development of AEL at high pressure, where crossover is expected to be considerably higher, as pressure is the main driver for hydrogen crossover. Therefore, an approach was investigated to overcome the issue of crossover. One potential method is the use of a gap between the electrode and separator that can reduce local supersaturation at the separator-electrolyte interface. Therefore, the influence of gap size on gas crossover and electrochemical performance was investigated.

Results

To investigate the AEL behaviour under pressurisation, AEL was examined under both atmospheric and pressurised conditions, and the same high efficiency was achieved under both operating conditions, indicating the suitability of AEL used in the PEACE project for pressurised operation. As expected, the temperature trends show that performance will improve under both atmospheric and pressurised conditions. The gas purity was evaluated and controlled by optimised cell design with optimised gaps between electrode and separator. The gas crossover significantly decreased when the gap size between electrode and separator was optimised, resulting in a hydrogen-to-oxygen (HTO) level four times lower than in the zero-gap configuration under optimal conditions. This approach can be implemented in pressurised systems to improve gas purity.

Conclusions

The investigations show that the results obtained under pressurised conditions in terms of performance are largely in line with tests carried out under atmospheric conditions, which shows that pressurised operation has no major influence on the electrochemical performance and that efficient AEL operation at higher current densities is possible. As gas crossover is expected to be a major challenge for high pressure operation, it was also worth considering introducing a gap between the separator and the electrode to reduce gas crossover and in this way ensure safe HTO levels when the electrolyser is operated at low load. This approach could be later investigated under pressurised conditions to improve gas quality.

Acknowledgements

This work was supported by the project 'Pressurized Efficient Alkaline Electrolyser (PEACE)', funded under the Horizon Europe programme (Grant Agreement No. 101101343) by the Clean Hydrogen Partnership and its members.

ID 69

Mechanical challenges in developing a pressurized efficient alkaline electrolyser cell

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Keywords: Pressurized; stack; mechanical; PEACE; cost lowering

Objectives

The EU-funded PEACE project aims to develop an advanced high-pressure alkaline electrolyser (AEL) capable of significantly reducing the cost of pressurised hydrogen production. The CAPEX of the plant is strongly affected by the cost of the stack, especially if a high pressure H_2 output is required. The objective of the WP 3 in the PEACE project is to provide a stack design to be used in the dual-pressurization implementation that minimizes the materials and processes costs once brought to production level. The task include the realization of a short stack to verify the choices followed by a full PoC (Proof of Concept), about 50 kW applied power, able to reach the performance levels declared and ready to be scaled-up.

Methods

To achieve the project PEACE objectives the stack production is explored in each step, from the materials' choice to the production processes of each component, supported by tests that ensure the performance level of the parts in their specific functions. To obtain this, small test cells were developed for testing the plastic and the cell materials behaviour, while the full production set-up plant was created on small scale and used to produce the parts. The sizing of the stack's dimensions, affected by the mechanical part of the pressure vessel present in the test rig of BTU, chosen for the performance tests, can identify the weak points of the design when applied to larger scale units. The design method, fully supported by FEA(Finite Elements Analysis) and CFD (Computational Fluid Dynamic) simulation, was driven to a deep modularity that allows the comparison of different choices and solutions not only in the simulation phase but also on the short stack and at the PoC level.

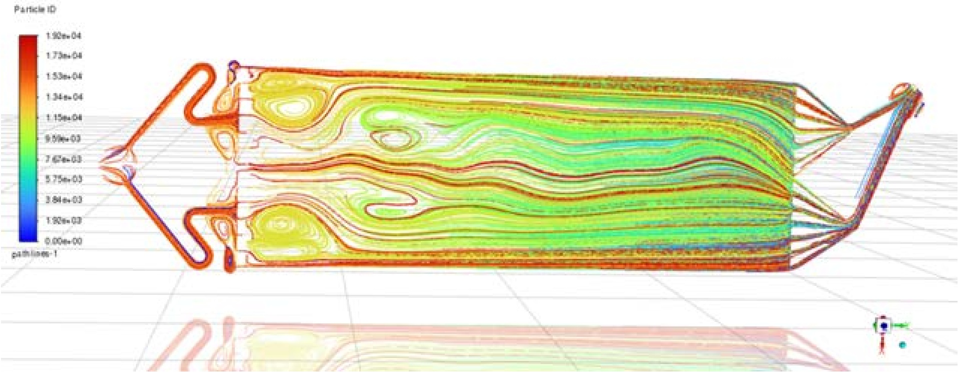
Results

The activity reached the required production of the test units and collected all the information on the materials and design necessary for further implementation on larger scale. The experimental part spotted the weak points of the original choices and allowed a second-generation design used on the final PoC. The life test of the units under performance and stress conditions run at BTU confirmed the choices and completed the project's task.

Conclusions

The WP3 of the PEACE project was able to show viable paths for the cost reduction of pressurized stack with accurate production and design choices: lighter metal parts and the use of non-fluorinated plastics are able to reduce the environmental impact of this technology while driving to a lower Hydrogen production cost.

This work was supported by the project 'Pressurized Efficient Alkaline Electrolyser (PEACE)', funded under the Horizon Europe programme (Grant Agreement No. 101101343) by the Clean Hydrogen Partnership and its members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ID 8

Bubble-ohm-lysis: The story of bubbles in alkaline water electrolysis

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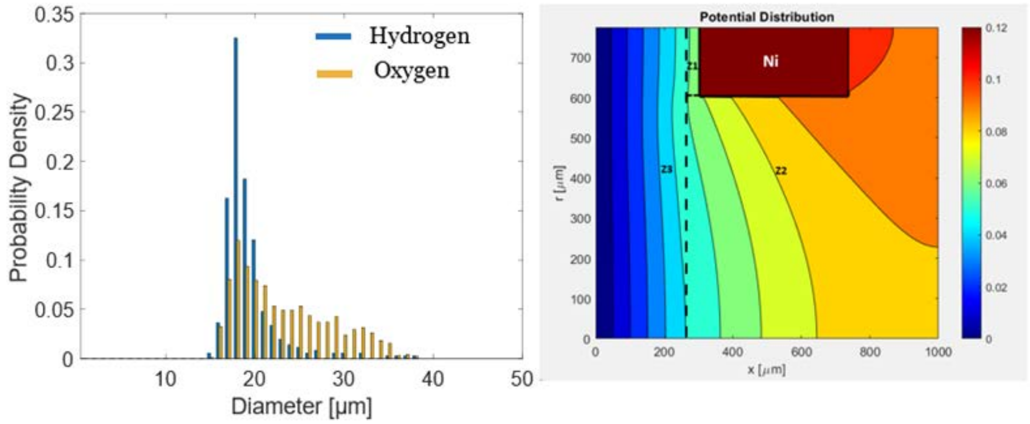
Keywords: AWE, Bubbles, Ohmic, Efficiency

Among various hydrogen production techniques, alkaline water electrolysis stands out due to its reduced reliance on noble and rare earth metals and its advanced technology readiness level (TRL). However, high current density operation still faces challenges due to ohmic resistance limitations. The bubbles remain the most mysterious contributor to ohmic resistance, highlighting the need to explore their dynamics and impact on electrolyser performance.

Hence, in this study measurement and modelling of ohmic resistances along with investigation of bubble behaviour was undertaken. Ohmic resistances were measured using impedance spectroscopy and modelled using an axisymmetric model of a half cell with a perforated plate electrode and half diaphragm, as done earlier by De Groot et al1. Bubble dynamics were investigated in situ using a high speed camera and analysed using a MATLAB script, enabling determination of the bubble diameter and role of coalescence in a customised transparent flow cell.

The measured ohmic resistance was 0.16 Ω·cm² under conditions of 70 °C, 6 M KOH, and 0.8 A/cm². These findings align with voltage contours (see Figure 1) generated by the model, suggesting 60% and 30% gas fractions in the gap between the electrode and diaphragm and in the bulk electrolyte, respectively. Furthermore, the mean bubble diameter for oxygen was confirmed to be larger than that for hydrogen, with an average bubble size of approximately 20 μm (see Figure 1). The findings shed light on bubble behavior and its impact on the ohmic resistance of industrial alkaline electrolysers, paving the way for enhanced efficiency.



ID 61

Operating Strategies for High-Pressure Alkaline Electrolysers: A Transient Modelling Approach

Hans Wiggenhauser[1], Dirk Ullmer[1], Fatemeh Razmjooei[1], Syed Asif Ansar[1], Kamal Ghotia[1], Yoga Rahmat[1], Hesham Mahfouz[2], Sai Ram Vissavajhala[2], Lars Röntzsch[2]

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Keywords: transient simulation; TEMPEST;

Objectives

The EU-funded PEACE project aims to develop an advanced high-pressure alkaline electrolyser (AEL) capable of significantly reducing the cost of hydrogen production. A central objective is the implementation of a two-stage pressurisation concept. High-pressure operation offers benefits in system efficiency and reduces downstream compression needs. However, it also introduces challenges related to increased gas solubility and the resulting risk of gas cross-permeation, making gas purity control a core operational concern, which is becoming more demanding under dynamic operation. This work focuses on analysing dynamic operating strategies that ensure high gas purity and stable temperature conditions in the electrolyser specifically under pressurization.

Methods

To investigate dynamic and steady-state behaviour under high-pressure conditions, the simulation framework Transient Electrochemical Model for Process and Energy SysTems (TEMPEST) [1, 2] was extended and parameterised for this specific configuration. TEMPEST is designed for modelling process engineering systems containing electrochemical reactors. It allows to model temperature, current density, electrolyte flow, and gas composition within the electrolysis cell with a spatial discretization along the direction of flow. Various operating conditions and load profiles were simulated, with emphasis on evaluating pressure-dependent gas crossover, transient responses during load shifts, and strategies to mitigate thermal inhomogeneities and excessive gas impurity.

Results

The simulation results provide improved control strategies for pressurized operation of AEL via regulating the operational parameters such as electrolyte flow rate. A PID controller was designed for the lye flow, with parameters defined for both partial and full load operating points, as well as for transitions between them. Key outcomes include a detailed temperature distribution along the cell and improved gas purity.

Conclusions

The investigations show that stable gas purity and uniform temperature distribution under varying operating conditions at pressurization requires coordinated measures such as flow adjustment. The transient simulation model is a suitable tool for comparing operating strategies and supporting the development of robust control concepts for high-pressure AELs.

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Acknowledgements

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ID 65

Proof of concept adaptation, operation and validation of a dual-stage high pressure aklaine elektrolyser

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Keywords: PEACE project; High pressure alkaline electrolysis; Dual-Stage pressurization; AEL

Objective

One of the objectives of PEACE project is to demonstrate, test, and validate an alkaline electrolysis system capable of achieving 60 (90) bar total operating pressure through a dual-stage pressurization concept. The system combines a stack developed in project designed to reach 1 A/cm² at <1.8 V with a sealing architecture compatible with pressurization up to 30 bar differential pressure of the stack versus its ambient. Herein, the experimental data will be generated for validating the project's simulation framework.

Methods

Several stages were taken to reach the goal of demonstrating dual-stage pressurization. First, the balance-of-plant (BoP) is redesigned to adapt to a dual-stage pressurization system, including selection of suitable piping, sensors, valves, and auxiliary components. The atmospheric stack is disassembled and replaced with a short stack supplied and assembled in the project, designed for installation inside the pressurized vessel. The short stack is tested after being mounted to the pressure vessel, then any adjustments to the stack design are made before the proof of concept (PoC) of the full stack is produced. System safety is ensured through HAZOP and FMEA analyses. Standardized test procedures are defined based on international electrolysis testing practices. After the PoC stack is assembled, it is integrated into the vessel, then pressure-tightness is verified, and static checks of electrolyte, gas, and monitoring connections are performed. TÜV approval is required before commissioning. Following commissioning, the demonstrator undergoes performance and dynamic testing, with data collected, evaluated and managed according to FAIR principles.

Results

Preliminary pressure-tightness tests for the short stack are underway to define safety of performing dynamic tests with it. Performance of the short stack should reach 1 A/cm² at <1.8 V and the results will validate the modelling conducted in the project. The PoC will be produced, assembled and mounted to the pressure vessel with pressure-tightness verified, and static checks of electrolyte, gas, and monitoring connections performed.

Conclusions

The findings are expected to demonstrate the feasibility of dual-stage pressurization in alkaline electrolysis for producing high-pressure hydrogen suitable for downstream processes such as methane or methanol synthesis. These processes require hydrogen at elevated pressures, and generating highly pressurized hydrogen directly through electrolysis would eliminate the costs associated with using compressors to achieve the required final pressure.

Acknowledgements

This work is supported by the project 'Pressurized Efficient Alkaline Electrolyser (PEACE)', funded under the Horizon Europe program (Grant Agreement No. 101101343) by the Clean Hydrogen Partnership and its members.

ID 14

A modular simulation framework for hydrogen storage system design in mobile applications

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Keywords: hydrogen storage systems, hydrogen storage technologies, hydrogen for mobile applications, refueling simulation tool

Hydrogen plays a key role in the decarbonization of the mobility sector. The development of efficient hydrogen storage systems (HSS) for mobile applications remains a crucial challenge, as these systems must meet demanding technical, spatial, and infrastructure requirements. To accelerate innovation and facilitate system integration, a flexible and user-friendly simulation tool is needed that supports the design and evaluation of different hydrogen storage concepts.

This study builds upon the H2VPATT simulation library, a validated tool developed by HyCentA Research GmbH. H2VPATT is a modular MATLAB/Simulink-based framework designed for the modeling and simulation of hydrogen refueling and storage systems. It allows rapid evaluation of different system layouts and refueling strategies and includes detailed component models such as hydrogen tanks, piping, and valves. The tool has been experimentally validated using a 320-liter Type III pressure vessel, confirming its suitability for system design and infrastructure analysis. [1]

Within the scope of this work, H2VPATT has been significantly extended to include models for liquid hydrogen and metal hydride storage technologies. Furthermore, the library was enhanced with specific automotive and mobile machinery use cases to broaden its applicability in the mobility sector. Experimental validation of these new storage technologies is currently ongoing.

Using H2VPATT's graphical drag-and-drop interface, users can easily configure various system architectures. When combined with a Design of Experiments (DoE) approach, this enables systematic analysis and optimization of hydrogen storage systems for defined application requirements.

The presented study applies this extended simulation framework to a mobile construction machinery use case, comparing three hydrogen storage technologies: gaseous, liquid, and metal hydride storage. The results illustrate how system behavior and performance vary with different storage technologies and piping configurations. The methodology, implementation, and results are discussed in detail, providing valuable insights for the design and optimization of hydrogen storage systems in mobile applications.

Acknowledgement

The COMET Centre HyCentA is funded within COMET — Competence Centers for Excellent Technologies by the Federal Ministries of Innovation, Mobility and Infrastructure (BMIMI) and of Economy, Energy and Tourism (BMWET), as well as the provinces of Styria, Upper Austria, Vienna and Tyrol. The COMET programme is managed by FFG.

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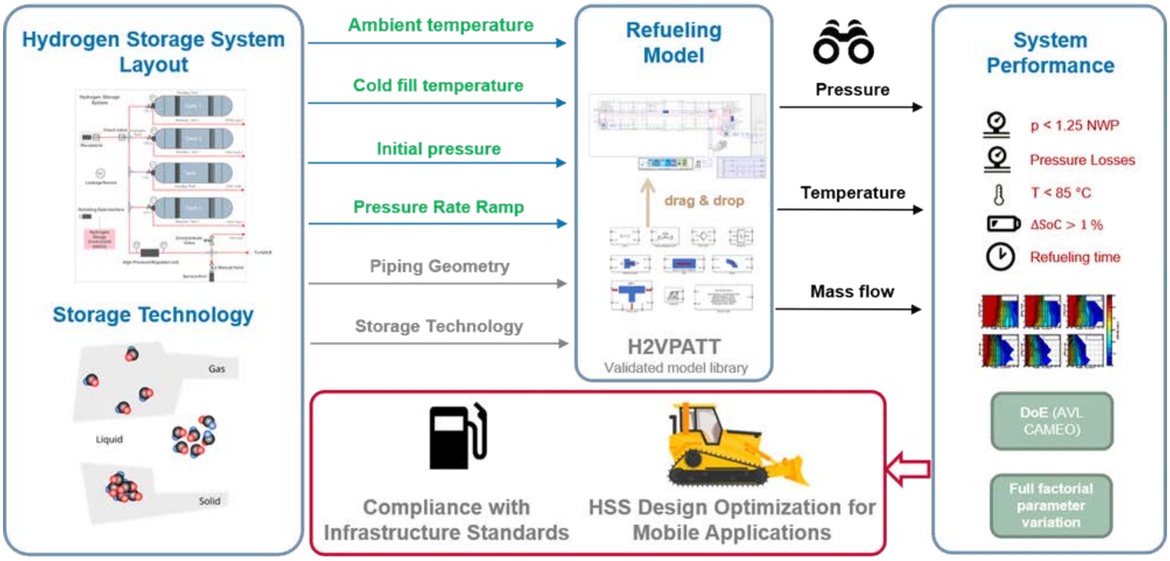
Hydrogen Storage System Layout
Storage Technology
Gas
Liquid
Solid
Ambient temperature
Cold fill temperature
Initial pressure
Pressure Rate Ramp
Piping Geometry
Storage Technology
Refueling Model
drag & drop
H2VPATT
Validated model library
Pressure
Temperature
Mass flow
System Performance
p < 1.25 NWP
Pressure Losses
T < 85 °C
ΔSoC > 1 %
Refueling time
DoE (AVL CAMEO)
Full factorial parameter variation
Compliance with Infrastructure Standards
HSS Design Optimization for Mobile Applications

ID 16

The Challenge of Developing an Automotive Hydrogen Storage Container according to R134-02

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BMW AG, Munich, Germany

Keywords: Hydrogen Storage Container R134-02

The technology openness of the BMW Group offers each customer a convenient powertrain, according to his driving use case, the availabilty of electric charging infrastructure and the environmental conditions he is in. The powertrain portfolio should be well balanced and offer a variety of options, like the efficient combustion engine, the plug-in hybrid electric vehicle, the battery electric vehicle and the fuel cell electric vehicle.

The number of FCEVs produced will not equal the number of BEVs right from the beginning, which from an economical point of view requires a common vehicle architecture for both BEV and FCEV. The technical challenge is mainly on the hydrogen storage side and leads to developping a hydrogen storage system with the external shape of a high voltage battery. However, the legal framework for homologating a mobile hydrogen storage in the EU did not allow an efficient design of such a system until the year 2024 when the updated regulation UN ECE R134-02 entered into force [1].

The installation of a 70 MPa hydrogen storage system with type 4 storage cylinders leads to an assembly of parallel cylinders with small diameter. Before the regulatory update a single valve per cylinder was required. A cost and space efficient system with many cylinders is difficult to realize this way.

The updated regulation includes the definition of a storage container, as in paragraph 2.4: “Container” (for hydrogen storage) means the pressure-bearing component on the vehicle that stores the primary volume of hydrogen fuel in a single chamber or in multiple permanently interconnected chambers.“ It also includes a definitions of container attachments in paragraph 2.5: “Container Attachments” mean non-pressure bearing parts attached to the container that provide additional support and/or protection to the container and that may be only temporarily removed for maintenance and/or inspection only with the use of tools.“ [1]

This amendment allows to interconnect pressure cylinders to be regarded as one storage volume, which can be tested and certified in a similar way as the former single tank and only needs one primary closure device..

The advantages are a less complex layout and only one tank valve, less weight, more storage volume, reduced wire harness and cost. But some challenges have to be solved:

The method of interconnecting the cylinders, for example a rigid or a more flexible pipe based rail. An interpretation of the permant connection is necessary to homologate the system.

The rail and valve technology for this hydrogen storage concept is not available and has to be developped.

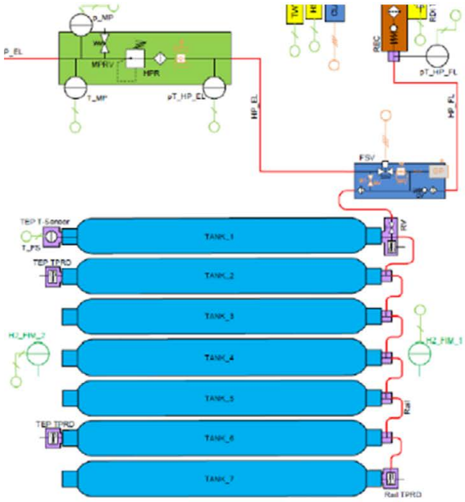
As the assembly has to be tested instead of a single vessel, a structural component is needed for supporting the pressure bearing components. Suitable bearings for the pressure chambers have to be designed which are capable of withstanding all test requirements.

The exterior shape of the module being the same as a traction battery, it is exposed to side impact in a vehicle crash and must contribute to the structural integrity of the car.

Figure 2 shows how a system designed that way could be realized, which system architecture it could have and how it will be integrated into the vehicle body.

The presentation will detail the mentioned challenges and how they can be resolved during the development process.

[1] Addendum 133 — UN Regulation No. 134 Revision 1 — Amendment 3.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TEP TPRD
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TANK_3
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H2_FIM_1
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Rail
TEP TPRD
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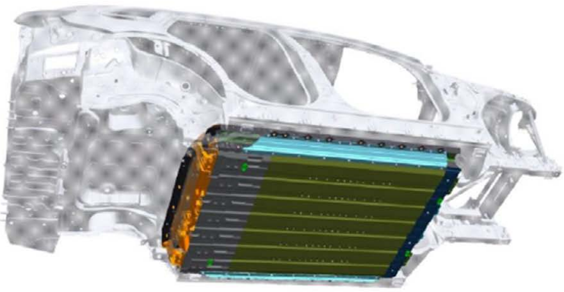
Rail TPRD



ID 32

Transport and Economic Modelling of Fleet Service Operations in a Hydrogen Valley

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Keywords: transport modelling, hydrogen mobility, fleet operations

The paper presents a digital modelling framework for analysing transport and economic aspects of fleet service operations within a hydrogen valley. The core of the approach is a transport microgrid model that represents a geographically and functionally defined area with its own mobility demand and service structure, while maintaining interactions with the surrounding region. The model integrates detailed parametrisation of individual services (public transport, waste collection, technical and cleaning services, logistics and retail distribution, taxi, emergency services, corporate transport and individual mobility) with vehicle fleet characteristics, route definitions and operational regimes. On this basis, traffic performance, energy balances and overall efficiency of the hydrogen value chain are evaluated. The economic module links operational and infrastructure parameters to cost indicators, allowing comparison of different deployment scenarios of hydrogen-powered fleets against conventional technologies. The modelling environment supports scenario analysis of current and future mobility patterns, including the introduction of new modes such as micromobility, and quantifies environmental and financial impacts at the level of a hydrogen valley. The results provide a decision-support tool for optimising fleet operations, planning refuelling infrastructure and guiding strategic investments into hydrogen-based, low-emission transport systems.

ID 35

Challenges in scaling electrode production for hydrogen economy

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Keywords: Catalyst coated membranes, heavy duty applications, slot-die coating, non-PFAS membranes

A critical bottleneck in clean-mobility and green-hydrogen value chains is the limited availability, high-costs and supply of durable catalyst-coated membranes (CCMs) for proton-exchange membrane fuel cells (PEMFC) and electrolysers (PEMWE). High production costs, mainly due to the use of expensive precious metals and PFAS membranes, have hindered widespread adoption of carbon-free powertrains in commercial sector and heavy-duty vehicles[1,2]. To address these challenges, several approaches have been explored to optimize catalyst composition, ink formulation, and coating techniques, aiming to enhance mass transport and overall efficiency[3]. However, scaling these methods for industrial application remains challenging, requiring further collaboration between academic and industrial researchers.

Under the Bayern Innovative CCMplus project funded by the Bavarian Ministry of economic affairs, regional development and energy, Dinex and University of Bayreuth is working to optimize CCMs for heavy duty applications. We aim to scale up from sheet-to-sheet to an industrial roll-to-roll (R2R) manufacturing route for serial-grade CCMs, combining precision slot-die coating, decal transfer and in-line/external quality control to deliver uniform layers, controlled thickness and catalyst loadings, and reproducible performance at scale. Optimization of ink rheology and coating parameters were performed aimed at homogenous and precise slot-die coating. Challenges of direct membrane coating for non-PFAS membranes will also be discussed.

Future research is focused on optimizing the 3-phase boundary and benchmark the CCMs for heavy-duty applications, with a focus on improving performance and durability under targeted operational conditions. Integration of circularity concepts from the outset through platinum-group metal (PGM) scrap capture and certified recycling will facilitate circular-economy and environmental outcomes promoting the deployment of fuel-cell trucks and renewable-hydrogen production. These advancements will contribute to the development of high-performance CCMs with enhanced durability and scalability which can then be validated in small stacks and full balance of plant.

ID 53

The Hydrogen Prism for Maritime: Angles for Regulating Hydrogen Fuels in the EU Maritime Sector

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EU Marie Skłodowska-Curie Actions: Training for a Hydrogen Economy based Renewable Energy Society in the Anthropocene (THERESA) Project, Groningen, Netherlands

Keywords: EU Maritime Regulation, Sustainable Maritime Fuels, EU Energy Law

1. Objectives

The maritime sector in the EU is navigating new waves of fuel transitions away from fossil fuels, towards sustainable mobility. It is anticipated that renewable and low-carbon hydrogen as well as derivative fuels such as ammonia and methanol, will play an important role in decarbonising both inland waterways and deep-sea shipping. This paper seeks to evaluate to what extent the legal framework in the EU governing the adoption of renewable and low-carbon hydrogen fuels be enhanced, so as to promote sustainable mobility in the maritime sector.

2. Methods

This paper utilises the Hydrogen Prism normative framework, concerning the use of renewable and low-carbon hydrogen fuels in the heavy-duty transportation sector. The Hydrogen Prism comprises three key angles of analysis namely: 1) cohesiveness in policy and legal frameworks; 2) risk mitigation concerning safety standards; and 3) substantive and procedural compliance. Primarily, this article will analyse the angles of the Hydrogen Prism through the lens of the current EU and policy legal framework. In addition, the article will also discuss the IMO policy and legal frameworks relevant to the EU Maritime Sector. The Hydrogen Prism will be analysed in the context of: decarbonisation targets in the maritime sector; vessel approval for alternative fuels, and 3) bunkering (refueling) infrastructure.

3. Results

This paper finds that greater coherence is required between the FuelEU Maritime Regulation and RED III to align demand- and supply-side targets for renewable hydrogen-based maritime fuels. While FuelEU places GHG-intensity obligations on shipowners and RED III requires higher reductions from fuel suppliers, discrepancies in target size and responsible actors risk undermining effectiveness. On risk mitigation, the alternative design process for low-flashpoint fuels offers flexibility, yet clearer guidance is needed to ensure vessels can demonstrate equivalent safety to conventional ships. Regarding compliance, the absence of harmonised EU and IMO standards, particularly for hydrogen bunkering, creates legal uncertainty and uneven procedures across ports. Developing coordinated guidelines and standards, while preserving flexibility through soft-law instruments, will be essential to support consistent, safe and efficient deployment of hydrogen-based fuels in the maritime sector.

4. Conclusions

The fuel transition towards renewable and low-carbon hydrogen-based fuels in the EU's maritime sector has presented both significant challenges and opportunities viewed through the lens of the Hydrogen Prism. The angles of cohesiveness, risk mitigation and compliance have highlighted that the success of this transition depends not only on technological readiness or market uptake, but on the legal and policy frameworks that facilitate its implementation. The early adoption of these fuels requires legal and policy frameworks which are both clear and agile. Global approaches catered to regional objectives, clear risk-based safety standards supporting innovation, and practical compliance solutions will be required going forward.

5. Literature

This paper utilises the normative framework in K Pailman, The Hydrogen Prism: Angles of EU Hydrogen Regulation for Sustainable Mobility. Journal for European Environmental and Planning Law, 21(3-4), 274-296. The Paper also draws from Fleming, R. (2022). The Hydrogen Revolution and Natural Gas: A New Dawn in the European Union? In D. Olawuyi, & E. Pereira (Eds.), The Palgrave Handbook of Natural Gas and Global Energy Transitions (pp. 123-140). In the maritime sector the paper draws from export reports including Interreg North-West Europe H2Ships, 'Final report & policy paper on upgraded regulatory framework for the uptake of H2 propulsion & bunkering' (2022).

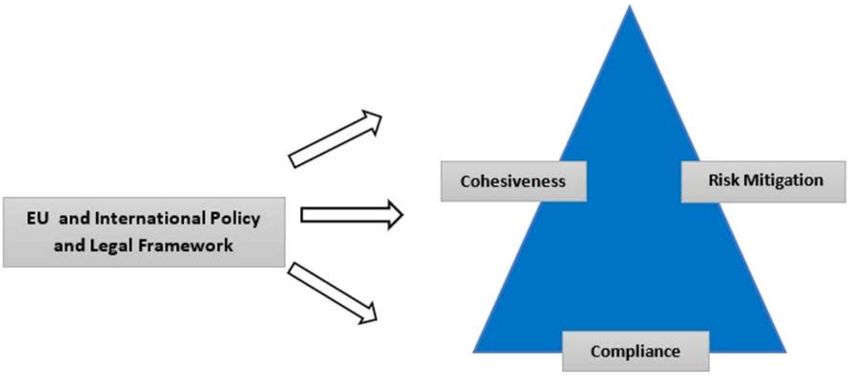

Figure 1: The Hydrogen Prism

ID 17

Designing active and stable ORR catalyst with reduced Pt loading

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Keywords: PEMFC; ORR; Pt-based catalyst; Activity; Stability

Achieving a balance between catalytic performance, durability and material cost remains a major objective in the development of oxygen reduction reaction (ORR) catalysts for proton-exchange membrane fuel cells (PEMFCs).

In this work, we explore a rational design approach that integrates alloying of platinum with nickel and gold to enhance its activity and stability while reducing the overall Pt content. Compositionally controlled PtNiAu catalyst layers were deposited by magnetron co-sputtering. The samples were systematically examined using a diverse range of complementary characterization techniques and electrochemistry, including Synchrotron Radiation Photoelectron Spectroscopy (SRPES), X-ray Diffraction (XRD), Rotating Disk Electrode (RDE) measurements, and Scanning Flow Cell coupled with Inductively Coupled Plasma Mass Spectrometry (SFC-ICP-MS) to understand the correlation between composition, activity and stability.

Our study demonstrates how controlled compositional modifications can be employed to design stable and active ORR catalysts with reduced Pt loading, offering a practical pathway toward durable and economically viable PEMFC cathodes.

ID 78

Real-Time SAXS/XAS Studies of PEM Fuel Cell Catalyst Degradation under Operating Conditions

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Keywords: Fuel cell; operando SAXS; catalyst morphology; AST

To increase the adoption of hydrogen fuel cell technology, several technological challenges must be addressed — one of the most critical being the improvement of catalyst stability. Despite significant progress, a deeper mechanistic understanding of degradation processes remains necessary.

Objectives

This study aims to bridge electrochemical performance data from operating fuel cells with the morphological and chemical evolution of catalyst nanostructures. A home-built operando cell enabled accelerated stress tests (ASTs) on Pt@Vulcan and Pt_3Co@Vulcan catalysts while simultaneously recording **SAXS** and XAS data, providing direct insight into degradation mechanisms.

Methods

Operando measurements were performed in a PEM fuel cell using a titanium cell equipped with a single serpentine flow field and an X-ray transparent window for data acquisition. Synchrotron radiation was employed with a beam energy of 8 keV for SAXS and adjusted near (300eV range) the Pt L_3-edge (11,564 eV) and **Co K-edge (7,709 eV)** for XAS. The cell operated at 70 °C with humidified H_2/O_2 feeds. TEM was used ex situ to confirm morphological changes.

Results

Operando SAXS and XAS revealed distinct degradation pathways for Pt and Pt_3Co catalysts. For Pt, nanoparticle coarsening dominated, with the mean size increasing from 2.28 nm to 6.21 nm within the first **3,000 AST cycles**, accompanied by a ~50% ECSA loss and minimal oxidation-state variation. In contrast, Pt_3Co exhibited an initial particle size decrease during break-in due to Co leaching, confirmed by Co K-edge XAS and ICP-MS. This process formed a Pt-rich skin, mitigating further growth. Application of different AST protocols showed that ECSA reduction correlated with particle growth; however, support-degradation-oriented tests led to pronounced active area loss with only minor morphological change.

Conclusions

Operando SAXS/XAS proved invaluable for correlating nanoscale structural and chemical evolution with electrochemical performance, offering mechanistic insights to guide the design of next-generation fuel cell and electrolyzer catalysts with enhanced durability.

Acknowledgements

This research was supported by the OP JAK project "Energy Conversion and Storage" (CZ.02.01.01/00/22_008/0004617).

ID 12

Stable low-platinum carbon-supported catalysts for oxygen reduction reaction in PEM fuel cells

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Prof. Vladimír Matolín, Prof. Iva Matolínová

Charles University, Prague, Czech Republic

Keywords: Platinum, carbon supports, ORR, durability, fuel cells

Platinum remains the most active catalyst for the oxygen reduction reaction (ORR) in PEM fuel cells. The development of durable supports and efficient platinum utilization is crucial for reducing platinum content while maintaining high catalytic activity and long-term stability.

Objectives

This study aims to analyze the influence of carbon supports on metal–support interactions, ORR activity, and the stability of platinum catalysts. Specifically, it focuses on comparing the structure, activity, and durability of low-platinum catalysts supported on various carbon materials, including polypyrrole nanotubes (PPyNTs), carbon nanotubes, and Vulcan XC-72. The objective is to elucidate how the morphology and composition of these supports affect the degradation behavior of the catalysts during the ORR.

Methods

Catalysts were prepared by solvothermal synthesis and characterized by TEM, BET, and XPS. ORR performance was evaluated by RRDE in 0.1 M $HClO_4$, and durability by accelerated stress tests (0.6–1.0 V, 5,000–30,000 cycles). Structural and chemical changes after degradation were analyzed using photoelectron spectroscopy.

Results

The size of Pt nanoparticles depended on the type of carbon support and ranged from 3 to 6 nm. After 5,000 potential cycles, a decrease in the H_2 adsorption peaks and a broadening of the double-layer region were observed for some catalysts, indicating partial degradation of the Pt catalysts due to carbon support corrosion and partial detachment of Pt nanoparticles. Among the tested materials, Pt/PPyNTs exhibited the highest activity and durability even after 30,000 cycles, along with a slight increase in electrochemically active surface area, which was attributed to the electrochemical oxidation of surface impurities. ORR proceeded predominantly via a four-electron pathway leading to H_2O formation, with only a negligible amount of H_2O_2 detected between 0.15–0.65 V vs. RHE. After the accelerated stress test, a negative shift of the half-wave potential was observed, consistent with partial catalyst degradation. A minor increase in limiting current for certain samples suggested detachment and redistribution of Pt nanoparticles from the electrode surface. Catalyst-coated membranes prepared with Pt/PPyNTs catalysts were fabricated, and their fuel cell performance and cathode electrochemical surface area were measured.

Conclusions

Nitrogen-containing PPy nanotubes effectively stabilize Pt nanoparticles, providing high activity, stability, and power output. Their unique nanostructure enhances Pt utilization, confirming PPyNTs as promising supports for durable, low-Pt cathode catalysts in PEM FCs.

Acknowledgements

This research was supported by the OP JAK project “*Energy Conversion and Storage*“ (CZ.02.01.01/00/22_008/0004617).

ID 10

Model-Based design of in-plane and through-plane gradients in PEM fuel cell catalyst layers

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University of Chemistry and Technology Prague, Prague, Czech Republic

Keywords: PEM; Fuel Cells; Catalyst Layers; Agglomerate Model; Gradient

Spatial gradients in catalyst layers (CLs) help address the non-uniform conditions in PEM fuel cells (PEMFCs), where activities of oxygen, water, and local current density vary significantly across the cathode. By optimising Pt loading, ionomer content, and porosity across the CL, transport and reaction zones can be better aligned with respect to local reaction intensity. Such grading enables improved Pt utilization and extends durability while maintaining high performance at reduced Pt loadings.

A 3D, two-phase, stationary agglomerate CL model with macrohomogeneous flow field and gas diffusion layers was developed to analyse the effect of through-plane (TP) and in-plane (IP) gradients in CL composition and structure on performance. The model incorporated composition-dependent properties while keeping the mean Pt loading constant. Linear gradients of varying magnitude and orientation were applied, and polarization curves, local current distributions, and reaction source profiles were evaluated. Model validation was performed against experimental data obtained from a FC with homogeneous CLs.

Outlet-oriented IP gradients improved both mid- and high-current performance by improving homogeneity of local oxygen activity and reducing local current density extremes. Optimal gradient of CL provided the highest reaction uniformity, while stronger gradients led to underutilization of CL near the inlet. Among TP designs, porosity variation dominated. CLs more porous toward the gas diffusion layer (GDL) side enhanced oxygen mass transport and overall performance of the cell, whereas Pt relocation alone had limited effect. Membrane-side Pt enrichment was beneficial at moderate loads (below 2 A cm^{-2}) due to shorter protonic paths in CL, but neutral or mild GDL-side bias performed better at high loads (above 3 A cm^{-2}) where diffusion limitation prevails. Similarly, combining IP and TP gradients led to improved cell performance at medium loads, but inferior at high current densities above, highlighting their load-dependent performance.

The results demonstrate that graded CLs can mitigate transport and kinetic limitations simultaneously. IP gradients homogenise reactant supply, while TP porosity grading governs diffusion–reaction coupling across the CL thickness. The modelling provides quantitative guidelines linking gradient magnitude and direction to the operating regime of PEMFC and offers a framework for design of graded electrodes and lays foundation for further experimental work.

This work was supported by the project "The Energy Conversion and Storage", funded as project No. CZ.02.01.01/00/22_008/0004617 by Programme Johannes Amos Comenius, call Excellent Research.

ID 67

Mathematical modelling and experimental investigation of Pt catalyst degradation in high-temperature polymer electrolyte membrane fuel cells

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University of Chemistry and Technology, Prague, Czech Republic

Keywords: Pt catalyst; degradation; high-temperature PEM fuel cell; mathematical modelling

High-temperature polymer electrolyte membrane fuel cells (HT-PEMFCs) operate at temperatures between 120 and 180 °C and utilise polymer membranes doped with concentrated H_3PO_4. Such high temperatures improve the resistance of Pt catalysts against CO poisoning, enabling the use of reformate gas as a fuel, and heat cogeneration. On the other hand, P oxoacid anions and H_3PO_3 poison the catalyst nanoparticles and slow down the already sluggish kinetics of the oxygen reduction reaction. Furthermore, high operating temperature and acidic environment promote Pt catalyst degradation, mostly in the form of Ostwald ripening.

To gain theoretical insight into the dissolution of Pt/C catalysts, a 1D transient mathematical model (based on field-continuum theory) was developed and validated based on our previously published experimental data measured with a single cell. The model domains comprise the cathode gas diffusion layer, cathode catalyst layer (CL) and the membrane. Pt degradation in anode CL is considered negligible. The cathode CL is comprised of spherical nanoparticles of diameters ranging from 2 to 3 nm – accordingly to the Pt dimension distribution obtained from pristine samples – to consider the variations in behaviour depending on the nanoparticle diameter. Regarding the Pt degradation reactions, the model includes Pt oxidation to PtO, its subsequent dissolution, transport in the catalyst layer and membrane, and redeposition. As for the results, the model displays gradual dissolution of smaller nanoparticles and redeposition of Pt on the bigger ones with consequent loss of the total active surface area. These results improve our understanding of Pt ion dissolution and transport in the MEA in relation to applied voltage and other operating conditions. Furthermore, thanks to this study, performance and rate and extent of catalyst degradation of a single cell can be evaluated for various operation times, well beyond 500 h. Finally, this model serves as the foundation for future mathematical modelling of dissolution of Pt-based alloy catalysts.

We acknowledge the Czech Science Foundation (GAČR) for its support through the project No. 22-23668K. The work was also supported from the grant of Specific university research — grant No. A2_FCHT_2025_088 of University of Chemistry and Technology, Prague, and by the project "The Energy Conversion and Storage", funded as project No. CZ.02.01.01/00/22_008/0004617 by Programme Johannes Amos Comenius, call Excellent Research.

ID 18

Recent development in AEM Hydrogen Technology Projects

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Valcon International s. r. o., Prague, Czech Republic

Keywords: HYTEP; AEM Electrolysers;Hydrogen Days;Hydrogen production

This presentation outlines recent advances in the application of (AEM) ion-exchange membrane electrolysers. Emphasis of the presentation will be placed on the development and optimization of configurations across the full hydrogen production cycle, including water treatment, electrolysis, hydrogen purification, storage, compression, and end-use. Several case studies of small-scale systems with capacities up to 1 MW will be discussed, highlighting practical implementation challenges and performance outcomes.

VALCON

ID 6

Numerical assessment of electrolyte flow distribution through flow-engineered 3-D printed bi-layer electrodes for alkaline water electrolysis

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Keywords: Alkaline water electrolysis; TPMS electrodes; Bi-layer configuration; Computational Fluid Dynamics

The use of porous electrodes within zero-gap cell configurations for alkaline water electrolysis has gained popularity over the past years. Even though these 3-D electrodes present an increased hydrogen production rate thanks to their high available surface area, bubble evacuation remains a challenge, as bubbles are trapped within the intricate porous structure of the electrodes. Recent studies in our group have shown that current densities of 2 $A \cdot cm^{-2}$ can be reached at cell voltages lower than 2 V when using flow-engineered laterally-graded bi-layer foam electrodes with forced electrolyte flow [1]. This performance improvement arises from the electrode design, which promotes efficient bubble removal and thereby reduces the Ohmic resistance. In this work, the bi-layer foams are compared to 3-D printed bi-layer geometries with so-called triply periodic minimal surfaces (TPMS) [2]. The latter are defined based on a mathematical expression involving void fraction and a lattice parameter. In a first approach, two so-called Schwarz CLP structures are combined with lattice parameters matching the pore sizes of the previously used 450 µm foam (catalytic layer) and 3000 µm foam (porous transport layer — PTL).

Computational fluid dynamics (CFD) simulations are combined with experimental data to correlate the electrolyte flow characteristics of various bi-layer structures with their electrochemical performance. In particular, single-phase electrolyte flow (30 wt% KOH solution at 80 °C) through explicitly defined 3-D electrode geometries has been simulated using OpenFOAM. Postprocessing allows extraction of specific velocity components, in particular the lateral y-velocity, which describes electrolyte transfer away from the diaphragm, i.e. from the catalytic layer to the PTL.

As illustrated in Figure 1 below, the lateral velocity profiles differ markedly between the bi-layer foam and the bi-layer TPMS. The bi-layer foam exhibits a pronounced inlet effect, whereas the bi-layer TPMS provides a steadier and more uniform transfer towards the PTL as the electrolyte penetrates upwards through the electrode. This first 3-D printed bi-layer TPMS already achieves a performance comparable to that of the optimised bi-layer foam electrode. Importantly, TPMS structures offer far greater design flexibility. Indeed, by tuning parameters such as channel orientation, lattice size and porosity through 3-D printing, the velocity fields — and consequently bubble removal and overall cell efficiency — can be precisely tailored. We then believe that TPMS structures can overcome the current bi-layer foam in terms of performance.

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[2] F. Rocha, R. Delmelle, C. Georgiadis and J. Proost, “Electrochemical Performance Enhancement of 3D Printed Electrodes Tailored for Enhanced Gas Evacuation during Alkaline Water Electrolysis”, Advanced Energy Materials, vol. 13, no. 1, p. 2203087, 2023.

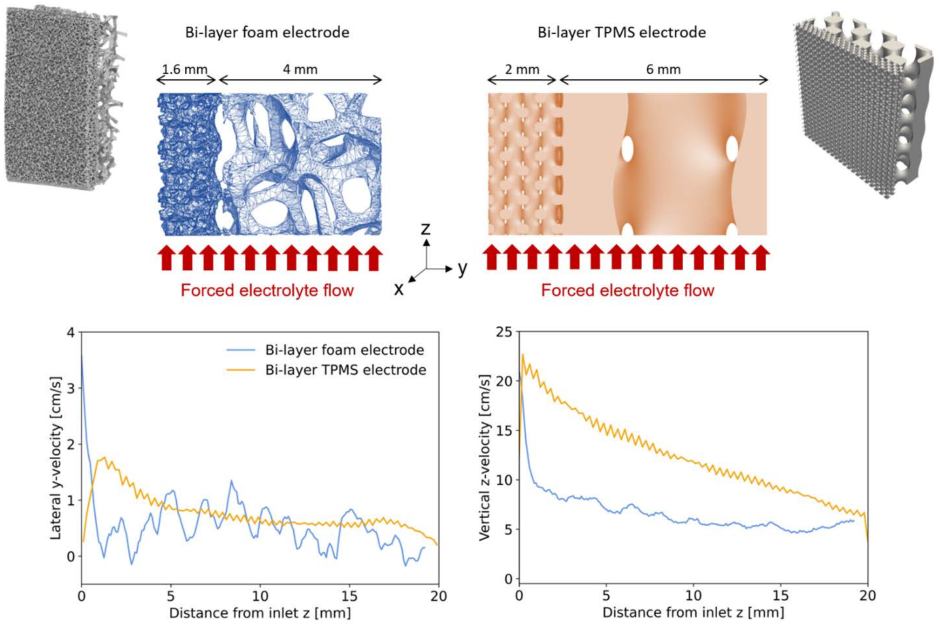

Figure 1: Lateral y-velocity profile (left) and vertical z-velocity profile (right) averaged over x-y planes within the catalytic layer.

ID 71

Performance enhancement of proton exchange membrane water electrolyzers through intermittent operation

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Keywords: PEM water electrolysis, iridium, intermittent operation, operando XPS, operando WAXS

With the global shift toward renewable energy, proton exchange membrane water electrolyzers (PEM-WEs) are gaining increasing attention as efficient technologies for converting and storing electrical energy in the form of hydrogen. To enable deployment at multi-gigawatt scale, it is crucial to enhance both their electrochemical performance and operational lifetime. Although a significant part of current research focuses on reducing noble-metal content, performance and durability can also be improved through optimized catalyst deposition and by tuning the operational regime.

In this work, we demonstrate that periodically interrupting PEM-WE operation by switching to open-circuit voltage (OCV) has a beneficial effect on performance. When operated in a dynamic regime—i.e., with regular OCV interruptions inserted between potentiostatic segments—the average current density increases compared with continuous potentiostatic operation. Integration of the transferred charge over a fixed time further shows that, provided the OCV periods are kept sufficiently short, the dynamically operated PEM-WE produces more hydrogen than its purely static counterpart. This trend is consistent and independent of membrane-electrode-assembly design or catalyst loading.

To elucidate the origin of this phenomenon, we performed comprehensive single-cell electrochemical impedance spectroscopy (EIS) experiments, alongside operando X-ray photoelectron spectroscopy (XPS) and operando wide-angle X-ray scattering (WAXS).

ID 66

Relation between mass transfer limitations in PEM water electrolyser and anode porous transport layer structure

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Keywords: PEM water electrolysis; titanium; porous transport layer; anode; mass transport

Water electrolysis with proton-exchange membrane (PEM WE) represents one of the key technologies for green hydrogen production. In comparison with other water electrolysis technologies, PEM WE operates with deionised water at ambient temperature, has possibility of pressurised hydrogen production and flexible start-up/shut-down regime. This makes PEM WE suitable for storage of electric energy produced by renewables.

The electrochemically active part of PEM WE consists of membrane, made of perfluorinated-sulfonated polymer, and electrodes. The cathode comprises Pt-based catalysts on carbon support and ionomer, contacted by carbon-based porous transport layer (PTL). On the anode, catalyst is based on IrO2, which is unsupported or immobilised on non-conductive ceramic supports. The catalyst layer on the anode is in direct electron contact with PTL made of Ti, which acts as a current collector and mechanical support of the anode in case of asymmetric pressure operation. Simultaneous production of oxygen and counterflow of water on the anode require highly porous PTLs with low tortuosity for minimisation of mass transfer limitations in the cell. Near catalyst layer, however, microporous structure is preferable to minimise contact resistance with catalyst layer. Majority of commercially available porous Ti materials do not fulfil these requirements or are not sufficiently mechanically stable.

The goal of his study is to compare performance of PEM WE single cell with various anode PTLs based on porous Ti. These included sintered fibres and sintered particles of various size. A single cell was based on catalyst-coated Nafion 117 membrane with Pt/C catalyst on the cathode (contacted by carbon paper PTL) and Ir black on the anode (contacted by Ti PTL). High catalyst loadings were used for minimisation of activation and contact resistances in cell, to evaluate mass transfer losses of PTL on anode. Single cells were characterised at atmospheric pressure and temperature of 80 °C using voltammetric and electrochemical impedance spectroscopy methods. Anode PTLs were characterised by mercury intrusion porosimetry, optical and scanning electron microscopies.

PEM WE cell with highly porous Ti felt on the anode exhibited very good performance. However, sintered Ti PTL performance varied greatly, depending on sample porosity and average pore radius. The general trend was significant improvement of performance with increasing average pore radius, while the porosity was not detrimental for performance increase. These results suggest high impact of PTL pore structure on the two-phase flow of water and oxygen through PTL, especially at current densities above 1 A cm−2. By further modifying the PTL thickness and tortuosity of pores, further improvements in single cell performance can be achieved.

This project is co-financed from the state budget by the Technology agency of the Czech Republic under the M-ERA.Net Programme, project No. TH82020001. This work was supported by the project “The Energy Conversion and Storage”, funded as project No. CZ.02.01.01/00/22_008/0004617 by Programme Johannes Amos Comenius, call Excellent Research.

ID 50

Experimental investigation of proton exchange membrane water electrolyzer activation

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Prof. Emer. Frano Barbir Ph.D.

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Keywords: Proton Exchange Membrane Water Electrolyzers; Activation; Break-In; Diagnostics; Power Supply Profile

Despite the technical capability of proton exchange membrane water electrolyzers (PEMWEs) to operate under the dynamic conditions typical of renewable energy sources, their long-term efficiency still strongly depends on the initial break-in period, i.e. the appropriate selection and execution of the membrane electrode assembly (MEA) activation procedure at the beginning of their operating life. Complete activation of the MEA is essential to promote the formation of as many ion channels as possible within the ionomer, increasing the electrochemically active surface area, and removing residues remaining from the manufacturing process, all of which are prerequisites for stable and efficient device operation. However, a universally accepted and standardized PEMWE activation protocol has not yet been established. Existing approaches vary significantly in duration, temperature conditions, and power supply profiles, making it difficult to compare results and ensure the reproducibility of research. To address this gap, a series of demanding experiments were conducted applying several distinct 24-hour power supply profile forms and evaluating their effects on activation efficiency and long-term performance stability in a single PEMWE cell with a commercial 45 cm^2 MEA. Throughout each activation procedure, a range of electrochemical diagnostic techniques, including polarization curves, electrochemical impedance spectroscopy, and cyclic voltammetry, were periodically recorded and analyzed in order to characterize and monitor device performance. The data and findings obtained from these experiments will serve as the foundation for a systematic approach to developing a novel methodology for identifying the most effective activation protocol for a specific PEMWE, a process that is still largely guided by heuristics and empirical practice. In this context, applying data-driven tools, particularly machine learning approach, to model, predict, and optimize PEMWE activation procedures offers significant potential to overcome existing limitations and enhance the repeatability and comparability of results, which will be explored in future research.

ID 72

Performance and degradation analysis of magnetron sputtered thin-film catalysts for the hydrogen evolution reaction in a proton-exchange membrane water electrolyzer

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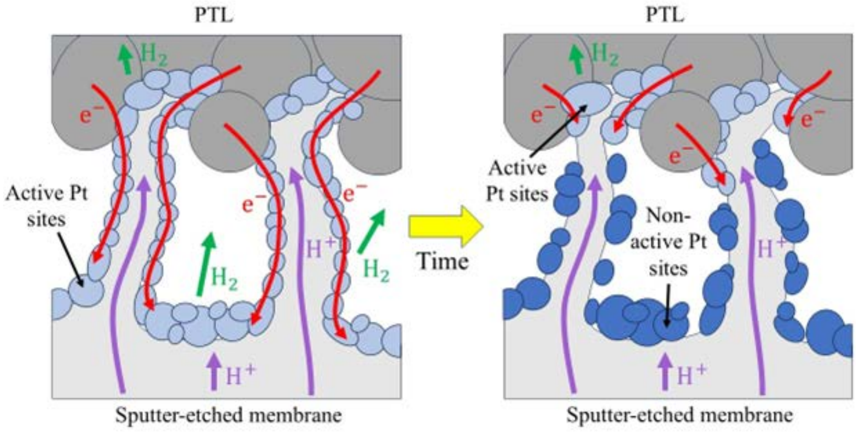
Keywords: proton exchange membrane water electrolyzer; hydrogen evolution reaction; ultra-low-loading platinum catalyst; magnetron sputtering; electrochemical impedance spectroscopy

Proton exchange membrane water electrolyzers are a promising technology for hydrogen production within the emerging hydrogen economy. Their large-scale deployment, however, is limited by the high cost of the noble metal catalysts required for the electrochemical reactions. The main aim of this thesis is therefore to develop an efficient cathode catalyst layer for the hydrogen evolution reaction with an ultra-low platinum loading (~20 µg·cm^{-2}), prepared by magnetron sputtering.

Although sputtered layers with this platinum loading deposited onto modified, sputter-etched membranes initially deliver high performance, they do not remain stable during prolonged operation. Detailed electrochemical impedance spectroscopy, supported by complementary characterization methods, revealed that degradation arises from particle growth and, most critically, from the loss of electrical connectivity between platinum sites.

To overcome this issue, the study shows that the sputtered platinum layers can be effectively stabilized by adding a thin, electrically conductive overlayer. Carbon was used as the stabilization material, leading to significant improvements in both performance and durability. Several variations of the catalyst layer architecture were evaluated, ultimately achieving 30-day stable operation reaching 4,500 mA·cm^{-2} at 2.0 V with only 18 µg·cm^{-2} of platinum—surpassing the performance of many state-of-the-art Pt-based catalysts.



ID 46

Heat Transfer and Flow Analysis of a Dryer with Flow Splitter and Induction Heating for PEM Electrolysis

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Keywords: Hydrogen, PEM electrolysis, Water Adsorption, Flow splitter, Induction heating, Computational Fluid Dynamics

The production of high-purity green hydrogen from renewable energy-based PEM (Proton Exchange Membrane) electrolysis systems necessitates an efficient drying process. Conventional fixed-bed adsorption towers often show flow maldistribution and channeling, which waste adsorbent, and they depend on external heat jackets for desorption, resulting in slow heat transfer and high energy use.

We study a dryer-tower design that adds an internal flow splitter to improve bed-scale flow uniformity and replaces jacket heating with induction-based regeneration for faster, more efficient heating. A 3-D model (overall height 450 mm; packed section 400 mm) was built in two configurations—with and without a perforated splitter plate. The splitter sits 10 mm from both the inlet and outlet and contains 24 holes with diameters that increase from center to edge to spread the flow.

Multiphysics simulations couple ANSYS Fluent (gas flow and species transport in the packed bed) with ANSYS Maxwell 3D (induction heating of metallic components). We quantify (a) a flow-maldistribution index across the bed, (b) pressure drop (ΔP), (c) moisture breakthrough during adsorption, and (d) temperature uniformity and regeneration time during desorption under induction heating. Comparing the two configurations will clarify trade-offs among flow uniformity, ΔP, and thermal-regeneration metrics and provide practical guidelines for improving efficiency, adsorbent utilization, and reliability in large-scale systems.

ID 70

Strain-Engineered Magnetron-Sputtered Ir–Co Thin Films as Low-Iridium Catalysts for PEM Water Electrolysis

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Keywords: PEM-WE, OER, magnetron-sputtering, Ir-Co, strain

The development of highly active and stable low-Iridium anode catalysts remains a decisive challenge for large-scale Proton Exchange Membrane Water Electrolysis (PEM-WE). While alloying Ir with other transition metals is a proven route to enhance intrinsic activity, the role of *microstrain*—a parameter that can be efficiently tuned in physical-vapour-deposited catalysts—has been largely overlooked. In this work, we introduce **strain-engineered Ir–Co thin-film catalysts** prepared by magnetron co-sputtering as a promising pathway towards reduced Ir loading without compromising performance.

By systematically varying the sputtering power densities, we induce controlled changes in deposition rate, adatom energy and local atomic mobility, giving rise to distinct levels of lattice strain and defect-driven microstructural disorder. These films are investigated using a multi-technique approach combining **PEM-WE single-cell testing**, **X-ray photoelectron spectroscopy (XPS)**, **wide-angle X-ray diffraction**, and **scanning photoelectron microscopy (SPRES)**. The results reveal a direct correlation between strain state, Co incorporation, and the formation of active Ir-Co@IrOx core-shell under OER conditions. Highly strained films show accelerated Co surface restructuring and enhanced intrinsic OER activity, while maintaining favourable stability.

Our study demonstrates that microstrain introduced during magnetron sputtering is an effective and tunable descriptor for catalytic performance. Strain engineering therefore represents a viable strategy for designing next-generation low-Iridium PEM-WE catalysts using industrially scalable thin-film deposition methods.

ID 55

Unraveling the Dynamic Active Phase of Low-Loading Iridium OER Catalysts, Its Impact on Stability and Mitigation Strategies

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Keywords: OER, Water electrolysis, X-rays, synchrotron, stability

Proton Exchange Membrane Water Electrolyzers (PEM-WE) represent a cornerstone technology for green hydrogen production. However, the economic viability and scalability of this technology are, beside other factors, hindered by the scarcity of Iridium (Ir) and the trade-off between catalyst activity and long-term stability. To bridge the gap between fundamental research and economic reality, it is imperative to understand the structural evolution of Ir-based catalysts under realistic operating conditions and translate these insights into robust industrial designs.

This contribution presents a multi-scale investigation utilizing high-energy operando X-ray scattering techniques at the ESRF ID31 beamline. By combining Wide-Angle X-ray Scattering (WAXS), Pair Distribution Function (PDF) analysis, and Small-Angle X-ray Scattering (SAXS), we monitor the dynamic structural transformations of Ir-based anodes from the atomic to the nanoscale.

First, we elucidate the intrinsic structural dynamics of ultrasmall (<3 nm) Ir nanoparticles during the Oxygen Evolution Reaction (OER) [1]. Operando PDF and SAXS analysis reveal that while metallic Ir nanoparticles exhibit a decahedral structure, the electrochemically formed active phase consists of highly disordered rutile-like oxide domains (<1 nm). These domains lack long-range order and exhibit significant structural flexibility, which is intrinsic to their high catalytic activity.

Building on this fundamental understanding, we explore strategies to reduce Ir loading while enhancing stability through magnetron-sputtered Ir-Ru bimetallic thin films [2]. Operando WAXS reveals that Ru leaching from the surface leads to the dynamic formation of a strain-engineered Ir–Ru@IrOx core-shell structure. The Ru-rich core imposes a compressive strain on the Ir shell, which stabilizes Ir in a higher oxidation state. This strain-engineering mechanism significantly enhances both activity and stability compared to pure Ir catalysts, even at ultra-low loadings (~150µg/cm^{-2}).

Finally, we discuss how these fundamental insights are critical for developing “immortal” catalyst layers and how they inform system-level engineering strategies—such as decentralized stack architectures—to mitigate degradation and meet the economic demands of large-scale hydrogen deployment [3].

[1] R. Pittkowski et al., *J. Am. Chem. Soc*. 2024, 146, 27517–27527
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ID 33

Tungsten carbide-based catalysts for Hydrogen Evolution Reaction

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Keywords: Hydrogen Evolution Reaction; Tungsten Carbides; Electro-Catalysis; PGM-free; Electrolysis

Objectives

Green hydrogen production through water electrolysis is a promising strategy for clean energy production. However, two main challenges still limit its large-scale implementation: the high overpotential required to drive the oxygen evolution reaction (OER), and the reliance on platinum (Pt) for the development of electrocatalysts for the Hydrogen Evolution Reaction (HER). Although Pt exhibits outstanding activity and stability, its rarity in the Earth's crust results in high costs, significant environmental impact and serious supply risks. In the last years, extensive research has been carried out to developing alternative, cost-effective and earth-abundant catalysts for HER. Different types of materials have been investigated, and tungsten carbides (WC, W_2C and W_xC) have attracted attention thanks to their high chemical and thermal stability, excellent corrosion resistance, mechanical robustness, good electronic conductivity and Pt-like catalytic behavior. The main objective of this work is to develop a catalyst capable of performances similar to conventional Pt/C, with the additional advantages of reduced cost and higher availability.

Methods

The synthesis of tungsten carbide nanostructures was performed in close relation to the work of Han et al. [1] Initially, WO_3 precursor was synthesized directly on a C-based substrate through a hydrothermal process, and subsequently converted into tungsten carbides via chemical vapor deposition (CVD). In this study, we investigated the influence of various carbon sources (sucrose, dopamine, waste rice husk, melamine, ABS, or urea,) and varying its amount (500 mg-2 g) on the morphology, chemical composition and catalytic activity of the resulting material. In particular, the prepared electrodes were characterized through X-Ray Diffraction, Raman Spectroscopy and Scanning Electron Microscopy and they were tested for the HER inside a three-electrode electrochemical cell, using H_2SO_4 0.5 M as electrolyte.

Results

All the prepared samples exhibited an increase of current density associated to the HER after the conversion of WO_3 into tungsten carbides. Among the tested samples, the one synthesized using 2 g of dopamine as the carbon source resulted in a mixture of different tungsten carbides, tungsten oxides and tungsten nitride and showed particularly promising results in terms of overpotential and current density.

Conclusions

This study highlights the potential of tungsten carbide–based nanomaterials as efficient, durable, and sustainable catalysts for hydrogen evolution reaction. The combination of chemical stability, cost-effectiveness, and Pt-like catalytic activity makes them promising candidates for applications in green hydrogen production.

Literature

[1] Han et al., *Nature Communications*, **2018**, DOI: [10.1038/s41467-018-03429-z]

Acknowledgements

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ID 53

The Hydrogen Prism for Maritime: Angles for Regulating Hydrogen Fuels in the EU Maritime Sector

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EU Marie Skłodowska-Curie Actions: Training for a Hydrogen Economy based Renewable Energy Society in the Anthropocene (THERESA) Project, Groningen, Netherlands

Keywords: EU Maritime Regulation, Sustainable Maritime Fuels, EU Energy Law

Objectives

The maritime sector in the EU is navigating new waves of fuel transitions away from fossil fuels, towards sustainable mobility. It is anticipated that renewable and low-carbon hydrogen as well as derivative fuels such as ammonia and methanol, will play an important role in decarbonising both inland waterways and deep-sea shipping. This paper seeks to evaluate to what extent the legal framework in the EU governing the adoption of renewable and low-carbon hydrogen fuels be enhanced, so as to promote sustainable mobility in the maritime sector.

Methods

This paper utilises the Hydrogen Prism normative framework, concerning the use of renewable and low-carbon hydrogen fuels in the heavy-duty transportation sector. The Hydrogen Prism comprises three key angles of analysis namely: 1) cohesiveness in policy and legal frameworks; 2) risk mitigation concerning safety standards; and 3) substantive and procedural compliance. Primarily, this article will analyse the angles of the Hydrogen Prism through the lens of the current EU and policy legal framework. In addition, the article will also discuss the IMO policy and legal frameworks relevant to the EU Maritime Sector. The Hydrogen Prism will be analysed in the context of: decarbonisation targets in the maritime sector; vessel approval for alternative fuels, and 3) bunkering (refueling) infrastructure.

Results

This paper finds that greater coherence is required between the FuelEU Maritime Regulation and RED III to align demand- and supply-side targets for renewable hydrogen-based maritime fuels. While FuelEU places GHG-intensity obligations on shipowners and RED III requires higher reductions from fuel suppliers, discrepancies in target size and responsible actors risk undermining effectiveness. On risk mitigation, the alternative design process for low-flashpoint fuels offers flexibility, yet clearer guidance is needed to ensure vessels can demonstrate equivalent safety to conventional ships. Regarding compliance, the absence of harmonised EU and IMO standards, particularly for hydrogen bunkering, creates legal uncertainty and uneven procedures across ports. Developing coordinated guidelines and standards, while preserving flexibility through soft-law instruments, will be essential to support consistent, safe and efficient deployment of hydrogen-based fuels in the maritime sector.

Conclusions

The fuel transition towards renewable and low-carbon hydrogen-based fuels in the EU's maritime sector has presented both significant challenges and opportunities viewed through the lens of the Hydrogen Prism. The angles of cohesiveness, risk mitigation and compliance have highlighted that the success of this transition depends not only on technological readiness or market uptake, but on the legal and policy frameworks that facilitate its implementation. The early adoption of these fuels requires legal and policy frameworks which are both clear and agile. Global approaches catered to regional objectives, clear risk-based safety standards supporting innovation, and practical compliance solutions will be required going forward.

Literature

This paper utilises the normative framework in K Pailman, The Hydrogen Prism: Angles of EU Hydrogen Regulation for Sustainable Mobility. Journal for European Environmental and Planning Law, 21(3-4), 274-296. The Paper also draws from Fleming, R. (2022). The Hydrogen Revolution and Natural Gas: A New Dawn in the European Union? In D. Olawuyi, & E. Pereira (Eds.), The Palgrave Handbook of Natural Gas and Global Energy Transitions (pp. 123-140). In the maritime sector the paper draws from export reports including Interreg North-West Europe H2Ships, ‘Final report & policy paper on upgraded regulatory framework for the uptake of H2 propulsion & bunkering’ (2022).

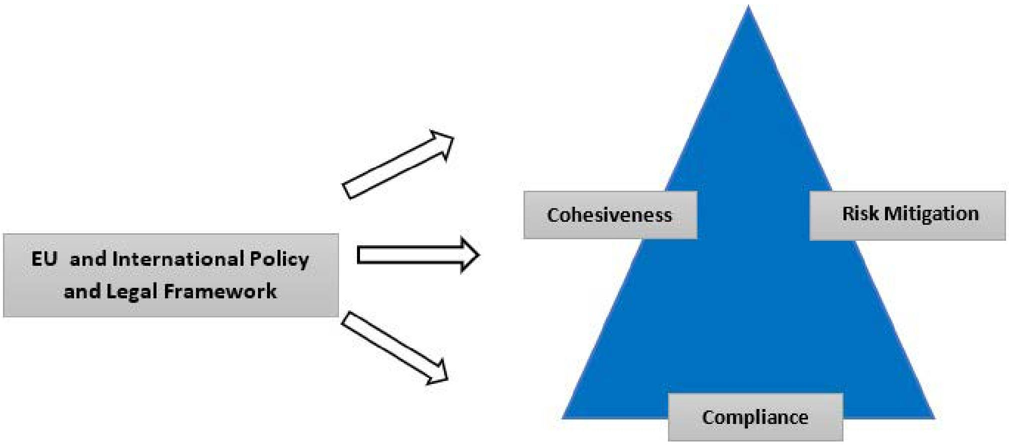

Figure 1: The Hydrogen Prism

Abstract Posters

H_2 production

ID 24

Analysis of preheating strategy and heat transfer mechanism of the MS-SOEC system

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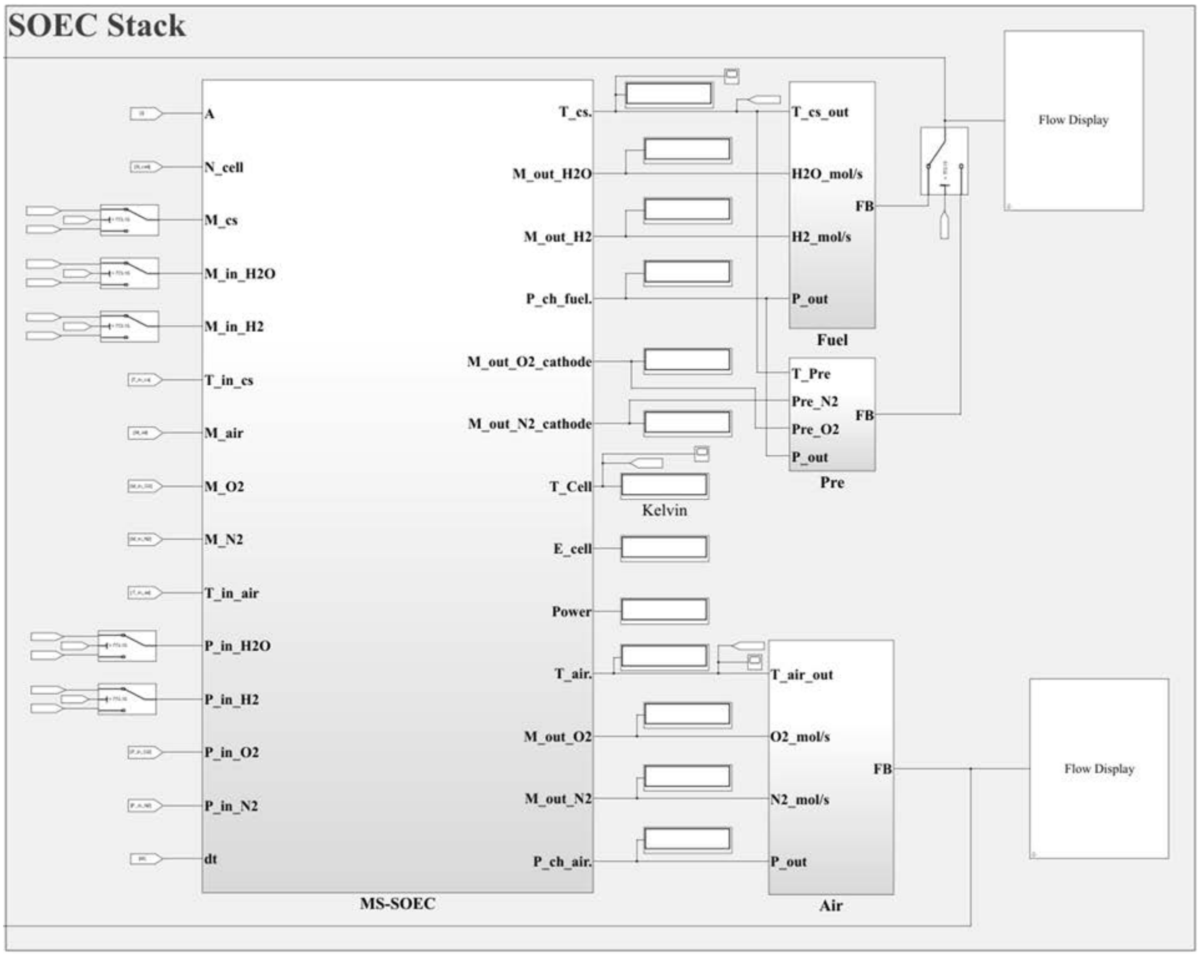
Keywords: Metal-Supported Solid Oxide Electrolysis Cell, thermal management system, novel three-stage cold-start preheating strategy, electrolysis-generated heat, dual-side PID coordinated control strategy

The Metal-Supported Solid Oxide Electrolysis Cell (MS-SOEC) system comprises a metal-supported stack, evaporator, mixing valve, heat exchanger, electric heaters, and blowers, forming a complete electrolysis and thermal management system. A novel three-stage cold-start preheating strategy enables safe ramp-up from room temperature to the operating temperature (873.15 K). By leveraging electrolysis-generated heat during the second stage, the preheating time is reduced by approximately 46 minutes compared to relying solely on external heaters, improving startup efficiency by 27.7%. The thermal management system employs a fixed heating rate of 2 K/s and a dual-sided PID coordinated control strategy. Among the three main heat transfer modes, conduction is the most temperature-sensitive and exhibits the strongest response (peak ~7000 W).



ID 79

PVD-coated interconnects for solid oxide electrolysers

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Keywords: Solid oxide electrolysers, Interconnects, Corrosion, Chromium evaporation, PVD coating

Background and objectives

Solid oxide electrolysers are currently the most energy-efficient electrolyser technology for producing green hydrogen using renewable energy sources like solar, or wind. However, there are challenges related to their performance, lifetime, durability and cost, along with the scale-up from kW to MW level. The interconnect plays an important role as a current collector and a physical barrier that separates the electrodes between cells. It has to meet technical requirements such as matching thermal expansion coefficient to other (ceramic) layers, high thermal and electrical conductivities, formation of a dense low-resistive oxide layer in redox atmospheres, and high thermomechanical strength at elevated temperatures (600 to 900 °C). The metallic interconnects employed in the SOC stack usually suffer high temperature corrosion and Cr-evaporation in the steam-rich environment, leading to material failure and overall degradation of electrolysis stack performance. There is a need to control the chromium (VI) diffusion from the metallic interconnects and its poisoning of the air electrode to achieve increased electrolyser durability and performance.

Methods

This work presents conducting, protective spinel oxide coatings deposited by PVD method to reduce chromium evaporation from the interconnects. The effect of coating thickness and composition on high temperature stability and chromium evaporation rate from ferritic stainless steel has been investigated. Chemical analysis of the coatings was subsequently studied by XRD and SEM/EDX before and after the Cr evaporation tests.

For this research, we investigated the protective effect of (Cu, Mn)-spinel coatings on stainless steel 441 and stainless steel 430, and the effect of metal doping on (Cu, Mn)-spinel coatings. The coatings were deposited with a Closed-Field Unbalanced Magnetron Sputtering system (Teer Coating Ltd, Droitwich, UK). The Cr evaporation tests were conducted by isothermally exposing one type of uncoated or coated stainless steel coupons (triplicate) in a denuder set-up installed within a tubular furnace (Vecstar HZ ST 1100) for 168 h 750 °C in air humidified with 3 vol% H_2O with a total flow rate of 1.0 L/min. The crystalline structure of the oxide scales formed on the steel surfaces was analysed by X-ray diffraction (XRD) (D2 PHASER 2nd generation, Bruker) with Co-K_α radiation (λ=0.179026). The surface microstructure of non-exposed and exposed samples was studied by imaging the samples using a Zeiss EVO 15 (Carl Zeiss Microscopy Gmbh, Jena, Germany) SEM and EDX.

Results

All the coated SS441 samples showed a high Cr retention capability compared the coated SS430 samples. The samples coated CuMn+Ti interlayer showed the lowest amount of Cr evaporation compared to samples with CuMn and CuMn+Cr coatings. Chemical analysis of the coatings was subsequently studied by XRD and SEM/EDX before and after the Cr evaporation tests. XRD confirmed the formation of (Cu,Mn)-spinel as top scales for all samples after the high temperature Cr evaporation tests. SEM revealed that there was no cracking or delamination of the coatings occurred after 168 hours exposure at 750 °C.

Conclusions

CuMn coatings could hinder Cr evaporation from the steel substrate at high temperatures. The CoNi coatings were better Cr barriers than CuMn coatings, despite being thinner. The thin Ti interlayer showed potential to future reduce the Cr evaporation rates for NiCo and CuMn spinel coatings. In addition, using a Ti interlayer helped to avoid segregation of Mn and Cu and reduced the Cr evaporation rate.

ID 20

Dual-driven Activation of High-valence States in Prussian Blue Analogues via Graphene-quantum dots and Ozone Induced Surface Restructuring for Hydrogen Evolution

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National Taiwan University of Science and Technology

Keywords: hydrogen evolution reaction; UV/ozone treatment; graphene quantum dots; Prussian blue analogues; X-ray absorption spectroscopy

Electrochemical water splitting is a pivotal process for sustainable hydrogen energy production, relying on efficient hydrogen evolution reaction (HER) catalysts, particularly in acidic environments, where both high activity and durability are crucial. Despite the favorable kinetics of Pt-based materials, their performance is hindered under harsh conditions, driving the search for alternative catalysts. Due to their unique structural characteristic, Prussian blue analogues (PBAs) emerge as attractive candidates for designing efficient HER electrocatalysts. However, modulating their properties and functionalities is crucial to overcome their conductivity issue. Herein, we proposed a reconfiguration strategy for the dual-driven surface restructuring of the CoFe PBA involving the integration of graphene quantum dots (GQD) and UV/ozone activation. Employing X-ray absorption spectroscopy (XAS), we successfully elucidated that dual-driven reconstruction plays a pivotal role in promoting the high-valence metal ions, effectively reducing charge transfer resistance—a key limitation in HER. The optimized CoFe PBA/GQD-UV exhibits remarkable electrocatalytic performance toward HER, with a low overpotential of 77 mV to reach a current density of 10 mA cm^{-2} with excellent durability for 12 h under an extremely high current density of 500 mA cm^{-2} in an acidic solution. This dual-combination strategy provides a critical approach to the PBA reconfiguration to construct highly active electrocatalysts.

ID 19

Interlayer-Modulated NiFe-LDH Electrodes with Tunable Interlayer Spacing for Robust and Efficient OER in Water Splitting

Ling-Yu Chang

National Taipei University of Technology

Keywords: water splitting; oxygen evolution reaction; poly(3,4-ethylenedioxythiophene); layered double hydroxides

Electrolytic water splitting for hydrogen production has rapidly advanced with the growing demand for clean energy resources. However, the oxygen evolution reaction (OER), governed by a sluggish four-electron transfer process, remains a major bottleneck, necessitating the development of efficient, stable, and earth-abundant electrocatalysts. Among the potential candidates, layered double hydroxides (LDHs) possess a tunable structure with modifiable interlayer anions and metal compositions; nevertheless, their intrinsic OER activity remains limited. The synthesis of NiFe-LDH intercalated with the conductive polymer poly(3,4-ethylenedioxythiophene) [(PEDOT-X^-)_n], designed to expand the basal spacing and enhance the electrochemical performance. The interlayer distance was systematically tuned by varying the molecular weight of (PEDOT-X^-)_n, enabling an investigation of its effect on OER activity while maintaining the overall morphology and dimensional characteristics of the LDHs. Comprehensive characterization techniques, including FT-IR, SEM, TEM, XPS, and XRD, confirmed successful polymer intercalation and the structural integrity of the resulting composites. Electrochemical measurements revealed that increased interlayer spacing significantly reduced the Tafel slope, increased the electrochemical surface area, and decreased the resistance associated with oxygen chemisorption. Furthermore, the optimized samples exhibited enhanced long-term operational stability under OER conditions. This work highlights the potential of molecular-level engineering through polymer intercalation in modulating the electrochemical environment of LDHs, offering a viable strategy for developing high-performance electrocatalysts for seawater electrolysis and other sustainable energy applications.

ID 25

Asymmetric Co-Flow Membraneless Electrolysis for High-Purity Hydrogen Production via Hydrodynamic Bubble Control

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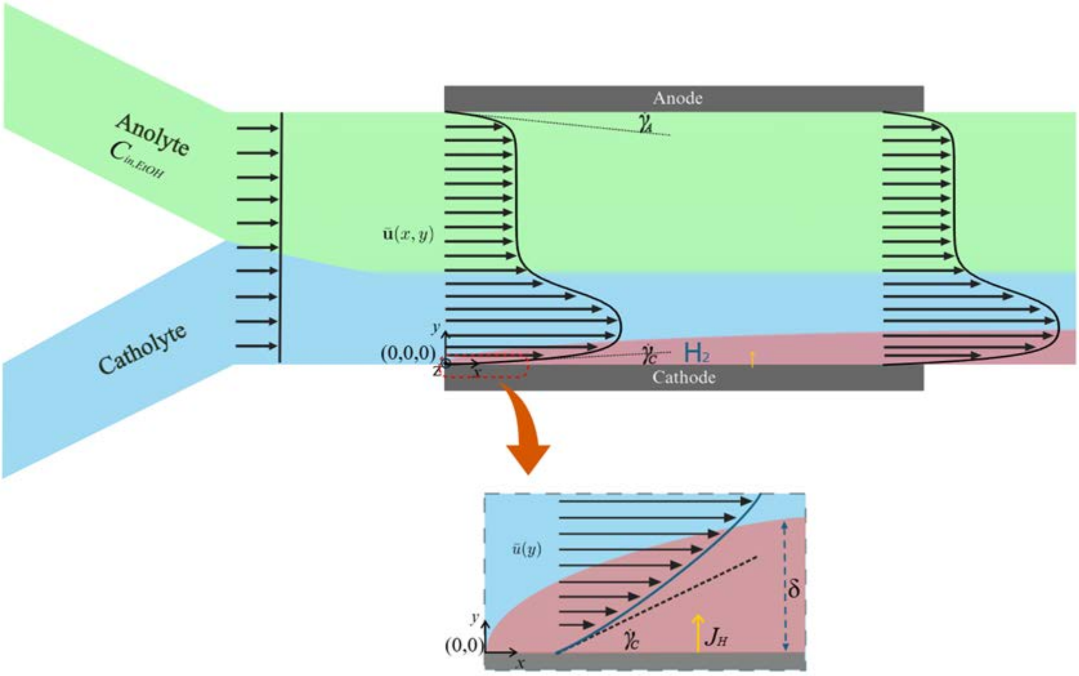
Keywords: Electrolysis; Hydrogen Production; Membraneless Electrolyzer

Membraneless electrolyzers offer a compact, low-cost route to hydrogen production, but their performance is often limited by gas crossover, bubble-induced resistance, and reduced conductivity when organic fuels are used. We present an asymmetric co-flow microfluidic electrolyzer that couples ethanol electro-oxidation at the anode with water reduction at the cathode to address these challenges. Ethanol is supplied only to the anode, preserving high ionic conductivity in the catholyte while suppressing unwanted ethanol reduction. The asymmetric velocity field generated by the dual-stream co-flow produces strong shear at the cathode, enhancing hydrogen bubble detachment by increasing hydrodynamic drag and lift relative to capillary adhesion forces. Simulations show that shear reverses across the channel, creating a hydrodynamic separator that passively confines bubbles to the cathodic half of the channel and prevents gas crossover without a membrane. Electrochemical measurements reveal a non-monotonic dependence of performance on ethanol concentration, with an optimum around 15% v/v, where ethanol oxidation kinetics are maximized while viscosity-induced transport penalties remain modest. This combined kinetic–hydrodynamic strategy demonstrates that tailored co-flow enables efficient, membrane-free hydrogen production with high gas purity and reduced overpotential, providing a scalable pathway for next-generation co-electrolysis technologies.



ID 48

Rapid and Facile Fabrication of Electrocatalyst Using Photo-derived Procedure for Hydrogen Evolution

Mr. Seung Geun Jo[1], Dr. Dong-Ha Lim[2], Dr. Hee Soo Kim[2], Prof. Jung Woo Lee[1]

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Keywords: electrocatalyst; hydrogen; photo-thermal reduction; graphene; laser

Water electrolysis is one of the most intriguing technologies for hydrogen production because of its carbon-neutral nature, however the development of efficient electrocatalysts is required to improve the energy conversion efficiency of water splitting. In this study, we suggest a facile route for the fabrication of $Pt_{1.6}Ni$ nanoalloys on laser-induced graphene ($Pt_{1.6}Ni$ NAs/LIG) by the photothermal reduction using commercial CO_2 laser which is irradiated on the surface of the LIG. The laser ablation process on the polyimide (PI) film resulted in porous and interconnected graphene sheets, while uniform nanoparticles with an average size of around 4.5 nm were decorated on their surface by the photothermal reduction effect. The overall process took only 60 seconds. Bonding structure investigation confirmed that PI film was successfully transformed into a graphene structure and the metal precursors were converted into bimetallic nanoalloy by using Raman spectroscopy and XPS, respectively. Electrochemical measurements for hydrogen evolution reaction discovered that the $Pt_{1.6}Ni$ NAs/LIG showed superior catalytic performance which required an overpotential of only 96 mV to achieve a current density of 10 mA cm^{-2}. It exhibited superior catalytic activity compared to LIG (740 mV), Pt NPs/LIG (204 mV), and $PtNi_{1.6}$ NAs/LIG (205 mV), as well as other previously reported catalysts at the same current density. Based on these results, the $Pt_{1.6}Ni$ NAs/LIG was employed for hydrogen gas collection and detection. The generated bubbles were collected separately from both electrodes, and their compositions with evolution rate were confirmed to be hydrogen using a commercial H_2 sensor.

ID 37

Life Cycle Assessment and Environmental Life Cycle Cost of a Photoelectrolysis Cell for Hydrogen Production

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Keywords: Hydrogen, photoelectrolysis cell, LCA, eLCC

Objectives

This work includes the results of research carried out within the framework of the “Piano Triennale di realizzazione 2022–2024 della Ricerca di Sistema Elettrico Nazionale”. It consists of a Life Cycle Assessment (LCA), performed according to ISO 14040/44 standards [1-2] and an Environmental LCC (eLCC) [3] analysis of a novel photoelectrolysis cell, using a cradle-to-gate approach to help designers make environmentally sustainable and economically viable choices.

Calculations were performed on a laboratory prototype cell of 10 cm^2 and scaled up to a commercial cell of 80 cm^2.

Methods

The LCA was conducted using SimaPro 9.6 [4] with Ecoinvent 3 data [5] and the ReCiPe 2016 Midpoint (H) method [6]. The functional unit was one assembled cell including the anode on FTO glass, cathode, polymer membrane and PVDF casing.

The LCC analysis included the calculation of capital expenditures (CAPEX) and operating expenditures (OPEX). In particular, the Net Present Value (NPV) was calculated to assess the economic viability of the investment.

The eLCC was based on the “Environmental Price” (EP) approach, which expresses the willingness to pay for less pollution in euros per kilogram of pollutant [7] considering Climate change category.

Results

The results highlight climate change, human toxicity and terrestrial ecotoxicity as the most relevant impact categories. The main hot spots are related to the anode process and fluoropolymer materials, due to high energy consumption and the production of fluorinated compounds. Membrane, casing and assembly stages contribute less significantly. Reducing energy use during thermal treatments and adopting low-impact materials could substantially improve the environmental performance of the cell.

Despite the low level of technology readiness, the study simulated a realistic production and commercialisation process.

The analysis assumed a semi-artisanal production, with production volumes not exceeding 4,000 units per year. The target market includes not only industry, but also research institutions commissioning cells for experiments. The NPV calculation showed that the break-even point is reached within 8 years.

Considering externalities as additional costs affecting the production value of the photoelectrolysis cell, their incidence is:

- Capex 91.98%
- Opex 7.94%
- Climate change (EP) 0.08%.

Conclusions

The study highlights the need to reduce the energy intensity of anode fabrication and to replace fluoropolymers with lower-impact materials, steering the development of photoelectrolytic cells toward more sustainable and scalable technologies.

The product and production process under investigation can be defined as virtuous and sustainable in terms of environmental impact, representing an investment with a good potential return in purely economic terms.

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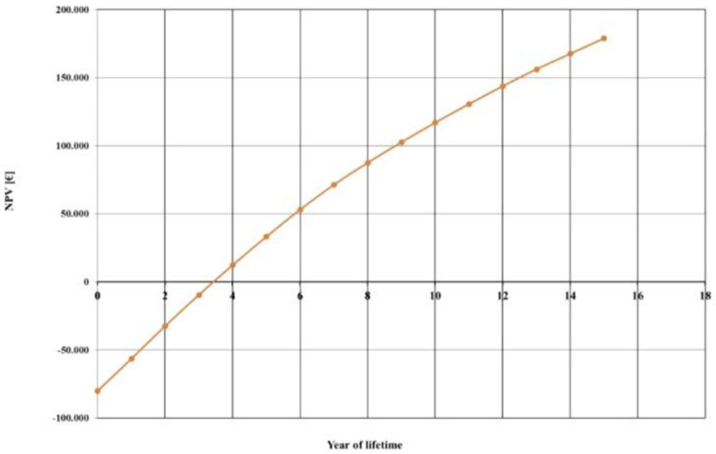

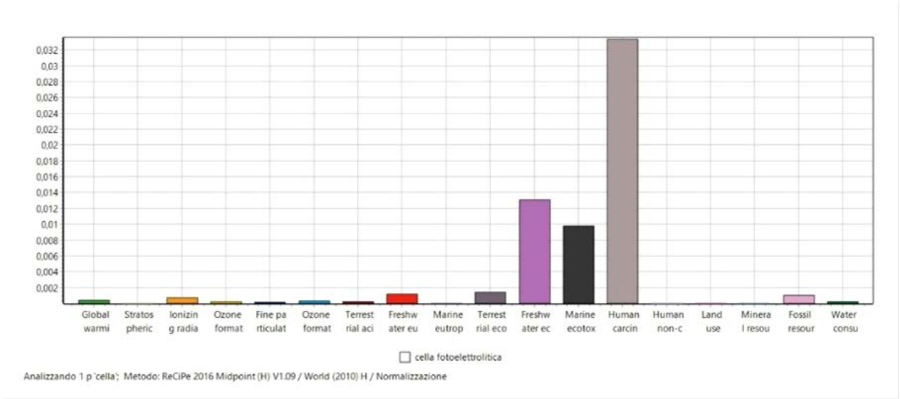

ID 31

Accelerating Start-Up and Boosting Hydrogen Output through Applied Potential Control in Bench-Scale Membraneless Single-Chamber MECs

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Keywords: Single-chamber Microbial Electrolysis Cell; Green Hydrogen; Waste valorization; Scaled-up

Green hydrogen production via single-chamber microbial electrolysis cells (S-MEC) offers several advantages over two-chamber MECs, including reduced internal resistance, a smaller pH gradient, and enhanced current density. However, achieving high-purity hydrogen necessitates suppressing side reactions, such as methane and acetate formation. One of the primary obstacles to scaling up is the extended stabilization period, often requiring months for exoelectrogens to establish and degrade organic matter efficiently. This study significantly reduced hydrogen production startup time by cultivating electrochemically active microbial communities under biogas-producing conditions without applying voltage. Selective enrichment of electroactive microorganisms on the anode was induced by applying voltage, enabling hydrogen production within five days, substantially faster than conventional approaches. To further improve hydrogen yield, homoacetogenesis, a major competing pathway, was inhibited by minimizing hydrogen retention time through rapid extraction, effectively preventing acetate formation and achieving 95% substrate utilization. This strategy was validated in lab-scale (250 mL) and bench-scale (4 L) reactors, achieving maximum hydrogen production rates of 0.77 ± 0.05 L/L/d and 0.22 ± 0.01 L/L/d, respectively. This demonstrates successful scalability. By addressing key limitations in S-MEC startup and mitigating competition from side reactions, this study presents a practical approach for advancing bioelectrochemical hydrogen production.

Hydrogen production from aluminum reaction with NaOH/H2O solution: experiments and insights into reaction kinetics

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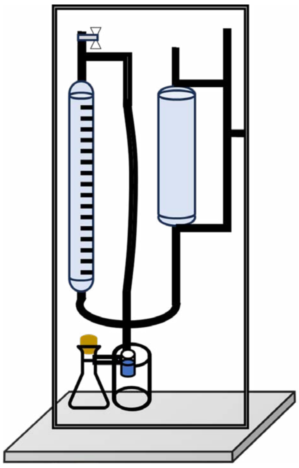
Keywords: Exothermic reaction, Dietrich-frühling method, Subzero experiments, Concentration, Reaction rate

Hydrogen is a promising candidate for an energy and economic transition away from fossil fuels due to its low environmental impact and potential to revolutionize energy production, storage, and utilization. While fossil fuels contribute significantly to greenhouse gas emissions and resource depletion, hydrogen can serve as a clean energy carrier. In recent years, its industrial applications, such as fuel cells for electricity generation, have expanded. Hydrogen, despite being Earth's most abundant element, is typically found bonded to other elements like water and hydrocarbons, but various processes, including the reaction with aluminum and alkaline solutions, offer a promising route for hydrogen production. The potential and kinetics of the reaction between aluminum and NaOH for hydrogen production were investigated both theoretically and experimentally. Several experiments were conducted using two types of aluminum (sheets and powder) and two NaOH concentrations (1M and 5M) under three different temperature conditions. The results indicate that the production process is consistent with the theoretical calculations derived from the reaction stoichiometry. Moreover, it was demonstrated that the kinetics are closely linked to key parameters such as temperature, molar concentration of the solution, and the specific surface area of the aluminum. In particular, an increase in temperature significantly accelerates the reaction, as does a higher concentration of NaOH. It was also observed that the use of aluminum powder, as opposed to sheets, enhances the reaction rate.



ID 52

On-demand hydrogen production by ammonia decomposition at low temperatures

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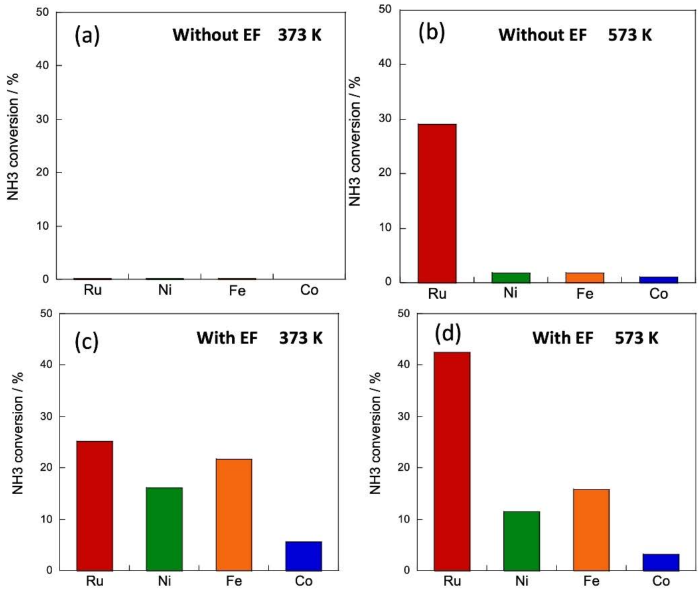
Keywords: Ammonia decomposition, Low temperature, Catalysis

Ammonia is considered a promising hydrogen carrier due to its high hydrogen density, readily available nature, and ease of transport, as it can be decomposed on-site to produce CO_2-free hydrogen. Unfortunately, ammonia decomposition requires high temperatures (above 773 K) to achieve complete conversion, hindering its practicality. We have found that a highly active Ru catalyst supported on CeO_2 works at low temperatures (473 K or less) in an DC electric field.

The applied electric field reduces the apparent activation energy, promoting conversion at low temperatures and even exceeding the equilibrium conversion rate at 398 K. With extended contact time, a conversion of nearly 100% can be achieved even at 398 K. Transient mass spectrometry results indicate that hydrogen and nitrogen are generated on the catalyst when ammonia is supplied. However, in the absence of an electric field, nitrogen desorption is slow, leading to a halt in the reaction. Conversely, applying an electric field promotes surface protonation of hydrogen. It is thought that a reaction promoting surface protonation via the N_2H_2 intermediate proceeds. Consequently, on-demand synthesis of CO_2-free hydrogen via ammonia decomposition can achieve high conversion rates and reaction speeds at low temperatures via an irreversible pathway. This demonstrates a feasible pathway towards economically attractive hydrogen production.



● **Experimental conditions**
・$5\%NH_3/Ar$ = 50 SCCM
(GHSV = 30000mL/g_{cat}h)
・catalyst :
5wt%Ru/CeO_2(JRC-CEO-01)
・catalyst weight : 100 mg
・ 0.1 MPa
・Current : 0 or 6.0 mA
・Response voltage : 0.1 kV

Fig. Temperature dependence of NH_3 decomposition rate with or without electric field.

ID 28

Hydrogen embrittlement: Phase-selective lattice swelling and stress evolution

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Keywords: hydrogen charging; in-situ synchrotron XRD; duplex steel; lattice swelling; FEM

Understanding of the temporal and spatial interactions between hydrogen and metals is crucial from both materials science and industrial perspectives. In the literature, hydrogen-induced cracking, or stress corrosion cracking, is often associated with time-resolved changes in the relative lattice parameter, commonly referred to as *strains*. However, in the case of duplex steels, no clear distinction has yet been made between hydrostatic strains, caused by isotropic swelling of the cubic α and γ lattices, and deviatoric elastic strains and stresses resulting from anisotropic material deformation induced by hydrogen absorption.

In this study, a Cr-Ni-Mn duplex steel of type A903 with approximately similar ferritic–austenitic phase fractions was examined in three different microstructural states: (i) the initial coarse-grained condition, (ii) the high-pressure torsion (HPT) as-processed state, and (iii) the heat-treated HPT state. Samples of suitable dimensions were fabricated by electro-discharge machining, and the final surfaces were polished electrolytically to minimize surface damage. Microstructural characterization before and after hydrogen charging was conducted using a combination of SEM techniques including EBSD, SE, and BSE imaging and TEM/STEM methods based on SAED, BF, HAADF, and TKD. In-situ CSmicroXRD experiments were performed at the High Energy Materials Science beamline P07B of the PETRA III synchrotron in Germany (for further details, see [1-3]). This state-of-the-art characterization technique, combined with simultaneous electrochemical hydrogen charging, enabled differentiation of hydrogen diffusion and absorption behavior in duplex steel across the three microstructural conditions. The results revealed that, after four hours of charging, the hydrogen-affected zone was comparable among all three samples.

In-situ synchrotron cross-section XRD reveals that, in the nanocrystalline HPT as-processed sample, austenite and ferrite exhibit lattice parameter expansions of 0.015 and 0.003 Å, respectively. In contrast, the initial (coarse-grained) sample shows a 0.005 Å increase in austenite, while no detected change is observed in ferrite. Furthermore, thermal desorption spectroscopy indicates a hydrogen uptake of 16 ppm. Subsequent heat treatment reduces hydrogen uptake to 4 ppm, yielding a fivefold decrease in the variation of the austenite lattice parameter while preserving the ferrite response observed in the as-processed HPT sample. This lattice swelling is accompanied by an increase in compressive in-plane stresses of 200 MPa in austenite and 850 MPa in ferrite. Using a final element model of grain interaction, this difference is qualitatively interpreted by mutual mechanical constraints between ferrite and austenite, as well as between the hydrogen-charged surface layer and the underlying material.

In summary

(1) *In-situ* CSmicroXRD analysis combined with electrolytic hydrogen charging allows decoupling of isotropic lattice swelling from anisotropic stresses induced by elastic deformation within the phases.

(2) The magnitude of lattice parameter changes in the two phases, as well as the in-plane residual stresses, strongly depends on the microstructural state.

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Acknowledgement

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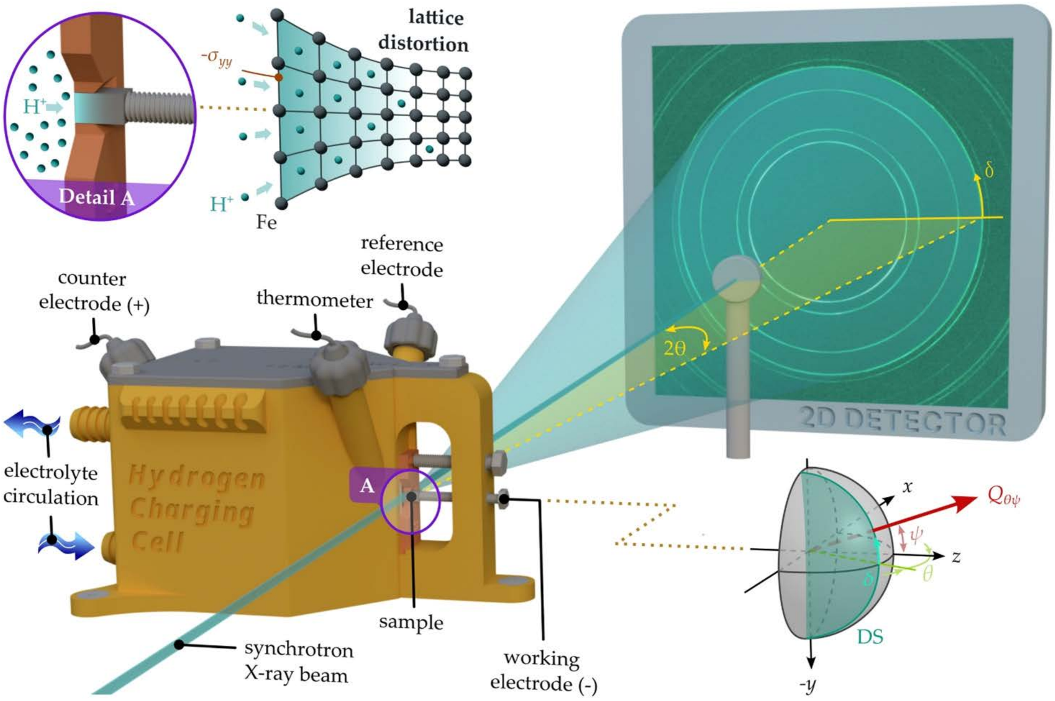

ID 54

Influence of microstructure evolution and precipitation on hydrogen embrittlement in Al0.35CoCrFeNi complex concentrated alloy

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Keywords: Complex concentrated alloys, High entropy alloys, Hydrogen embrittlement, mitigation strategies

Objectives

High-entropy alloys (HEAs) and complex concentrated alloys (CCAs) are promising candidates for hydrogen storage and structural applications due to their tunable properties. This study aims to evaluate the hydrogen embrittlement (HE) susceptibility of the Al0.35CoCrFeNi alloy, specifically investigating how the transition from a single-phase face-centered cubic (FCC) structure to multiphase precipitation-hardened microstructures influences mechanical degradation and fracture mechanisms under hydrogen-charged conditions.

Methods

The Al0.35CoCrFeNi alloy was prepared by vacuum induction melting and casting, followed by three-step hot forging at 1250 °C. To establish a baseline, samples were solution annealed at 1330 °C to achieve a homogenized single-phase FCC structure. Subsequently, precipitation annealing was performed at 700 °C (PA700) and 900 °C (PA900) for 50 hours to induce secondary phase formation. The phase compositions were analyzed using SEM, EBSD, and TEM. Hydrogen was introduced via electrochemical charging at 70C for 72 hours (6 mA/mm). Slow strain rate tensile tests ($2.5X10^{-4}$ s^{-1}) were conducted on uncharged and charged samples to determine the embrittlement factor (EF).

Results

The single-phase FCC samples absorbed ~126 wt. ppm hydrogen and exhibited moderate immunity to HE with an EF of 9.8%. While hydrogen caused surface embrittlement via the hydrogen-enhanced decohesion (HEDE) mechanism, the bulk material retained high ductility due to hydrogen-enhanced localized plasticity (HELP).

Heat treatment significantly altered the HE response. The PA700 condition (FCC + $L1_2$ + B2) absorbed the highest hydrogen content (~167 wt. ppm) yet maintained a low EF of 15%. In contrast, the PA900 condition (FCC + coarse B2 + Cr-rich phases) absorbed the least hydrogen (~43 wt. ppm) but suffered severe degradation with an EF of 51%. Fractography revealed that in PA900, cracks initiated at the interfaces of coarse B2 and Cr-rich particles. Conversely, in PA700, fine coherent $L1_2$nano-precipitates acted as beneficial irreversible traps, dispersing hydrogen and preventing critical accumulation at grain boundaries.

Conclusions

The Al0.35CoCrFeNi alloy demonstrates that HE resistance is strongly microstructure-dependent. While the single-phase FCC structure shows intrinsic resistance, precipitation hardening can either mitigate or exacerbate HE. Coarse B2 precipitates (PA900) serve as crack initiation sites, leading to significant ductility loss. However, the formation of fine $L1_2$ precipitates (PA700) provides an optimal balance of strength and HE resistance by effectively trapping hydrogen. These findings suggest that microstructure engineering via controlled precipitation of $L1_2$ phases is a viable strategy for designing hydrogen-tolerant CCAs.

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Acknowledgements

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ID 57

Hydrogen Embrittlement of Cast and Forged Steels for Hydrogen Gas Infrastructure Applications

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Keywords: hydrogen embrittlement; pipelines; microstructure; forming

The requirements for future hydrogen transport are placing increasing emphasis on the behaviour of structural steels exposed to hydrogen, particularly their resistance to hydrogen-induced degradation, which is determined by their microstructural condition and mechanical properties. While standard pipeline steels such as API 5L X52 exhibit a fine, homogeneous ferritic–pearlitic microstructure formed by hot working, many components of the gas infrastructure are produced from cast steel with a coarser dendritic structure and a higher incidence of internal defects. These include, for example, gate valve bodies and other components.

The study evaluated the influence of the initial microstructure on the degradation of mechanical properties caused by hydrogen exposure. In addition to API 5L X52 steel in the formed condition, steel 1.0619 was examined in two different states: the cast condition after heat treatment and the forged condition produced on a hydraulic press with different cooling procedures (water quenching and air cooling).

The samples were electrolytically saturated with hydrogen using a 0.5N H_2SO_4 solution with thiourea. Hydrogen charging was carried out for 1 to 24 hours. Mechanical properties were evaluated using Charpy V-notch impact testing. Microstructures were analysed by light and scanning electron microscopy, and fractographic analysis of fracture surfaces was also performed. The hydrogen content was measured in the initial state and after individual charging times. Additionally, hydrogen permeation through the material in its different conditions was determined using a Devanathan–Stachurski permeation test in accordance with ASTM G148.

During electrolytic hydrogen charging, steel X52 exhibited a decrease in impact energy after a short exposure time. In contrast, steel 1.0619 showed a more gradual decrease accompanied by a significantly higher increase in hydrogen content. Permeation tests demonstrated substantially higher effective hydrogen diffusivity in the formed steel X52, while the cast steel accumulated hydrogen in its microstructure and released it with a delay, reflecting the presence of numerous irreversible traps. Microscopic and fractographic analyses confirmed that defects typical of the cast state (segregations, inclusions, micropores) promote blistering and increase the risk of delayed hydrogen degradation.

Overall, it can be concluded that the formed pipeline steel shows higher mechanical reliability under hydrogen exposure, although it is sensitive to a rapid decrease in toughness. Cast steel exhibits slower hydrogen permeation, but its pronounced ability to accumulate hydrogen represents a higher risk of hydrogen-induced cracking during long-term service. The results, therefore, highlight the need to separately evaluate the pipeline and cast components of gas infrastructure, as their resistance to hydrogen embrittlement is primarily determined by their metallurgical state rather than by chemical composition alone.

Acknowledgements

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ID 59

Advanced microscopic techniques for studying hydrogen embrittlement in electrolytically hydrogen-saturated steels

Josef Duliskovic[1], Dr. Hana Jirkova PhD[1], Dr. Josef Kasl PhD[1], Lorenzo Miconi[2], Filip Votava[3]

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[3] Regional Technological Institute, Pilsen, Czech Republic

Keywords: EBSD, Hydrogen embrittlement, Structural steels

Hydrogen embrittlement represents a major obstacle to the safe deployment of steels in energy and hydrogen-related applications, and even after decades of intensive research the relationship between local microstructure and macroscopic fracture behaviour is still not fully understood. In this work, we focus on the structural steel S355 J2+M in two deliberately tailored microstructural conditions, namely a martensitic condition (forging at 850 °C, water quenching) and a ferrite–pearlite condition (750 °C, air cooling), and investigate their susceptibility to hydrogen embrittlement after electrochemical hydrogen charging. The samples were charged for 48 h in a 0.5 N H_2SO_4 + 5 $g \cdot l^{-1}$ CH_4N_2S solution, which led to an increase in hydrogen content from approximately 1 ppm to about 6 ppm, accompanied by a pronounced decrease in Charpy V-notch impact toughness KV2; from 45 to 25 J in the martensitic state and from 111 to 68 J in the ferrite–pearlite state.

The microstructural response to hydrogen loading is quantified by EBSD analysis in the vicinity of the notch region, with emphasis on Kernel Average Misorientation (KAM), the fraction of low- and high-angle grain boundaries (LAGB/HAGB), texture and indexing quality. For the ferrite–pearlite condition after electrochemical charging, we observe a significant increase in the LAGB fraction from 32.7 % to 45.4 %, accompanied by the formation of local regions with elevated KAM values, while the average KAM remains comparable, and the Confidence Index remains high. This combination of an increased density of low-angle boundaries and localized deformation, without degradation of EBSD pattern quality, points to enhanced dislocation activity and substructure formation rather than massive lattice damage. At the same time, the pole figures reveal a weakening of the original texture after charging, indicating grain reorientation driven by locally increased plastic deformation.

These EBSD signatures are consistent with the hydrogen-enhanced localized plasticity (HELP) mechanism, in which hydrogen facilitates dislocation motion, promotes subgrain formation and localized deformation, while at the same time reducing the ability of the microstructure to accommodate plastic strain homogeneously. In combination with fractographic analysis of Charpy fracture surfaces, which enables differentiation between ductile and brittle fracture regions and their relation to local microstructural states, EBSD thus provides a sensitive tool for mapping hydrogen-induced degradation even in cases where conventional mechanical testing reveals only limited changes.

The aim of this work is to demonstrate, on this representative low-alloy steel system, that the combination of electrochemical hydrogen charging, Charpy impact testing, EBSD and fractography not only allows the degree of hydrogen embrittlement to be quantified, but also enables the influence of microstructure (martensite vs. ferrite–pearlite) to be separated and brings us closer to identifying the dominant mechanisms of hydrogen-assisted damage. The results will be discussed in terms of the applicability of EBSD metrics as a practical “diagnostic toolkit” for hydrogen embrittlement in structural steels.

ID 40

Potential of the Underground Hydrogen Storage in the Czech Republic: the preliminary study

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Keywords: Hydrogen storage; energy storage; depleted gas reservoirs; underground gas storage; porous reservoirs

Introduction and objectives

Underground Hydrogen Storage (UHS) is critical for enabling large-scale seasonal energy storage within the developing hydrogen economy. Geological storage offers the unique advantage of vast capacity, essential for the seasonal balancing of intermittent renewable energy sources.

Nowadays, the most advanced large-scale UHS projects focus on storing hydrogen in salt caverns due to their mechanical and petrophysical properties. Nevertheless, Central Europe shifts the focus to the conversion of Depleted Gas Reservoirs (DGR) for UHS due to absence of salt caverns.

This strategy is supported by the current leading pilot project Underground Sun Storage 2030 in Austria, which has already achieved two seasonal cycles of pure H_2 storage. A historical example from Czechia that provides valuable local data for DGR implementation is the Lobodice underground storage facility, which stored city gas (up to 52% H2) between 1965 and 1990. However, multiphase flow, geochemistry, and microbial activity still present significant operational challenges in similar projects.

In recent years, approximately 125,000 tons of hydrogen have been produced annually in Czechia. According to the Czech Republic's Hydrogen Strategy, the national goal for 2030 is to produce approximately 20,000 tons of renewable hydrogen (RFNBO) annually. Furthermore, in 2040, it is expected that the required amount of renewable and low-carbon hydrogen will reach 1,000,000 tons (≈ 33.3 TWh) per year. Both 2030 and 2040 national goals are considered very ambitious but are still valid.

HyPoteS-CZ project aims to establish the foundational knowledge and screening criteria for UHS within the Czech Republic. The key objectives are:

- Synthesize international and local best practices and current knowledge regarding UHS technologies.
- Pre-select the most promising geological structures, specifically DGRs and UGSes, based on methodological criteria, including a description of major associated risks.
- To compile a comprehensive set of maps and a database detailing the storage potential and key parameters of the selected geological structures.
- Identify suitable localities for a future UHS pilot project and estimate the preliminary Capital Expenditure (CAPEX).

Methods

Existing data from selected DGRs including currently active UGSes were analysed based on international practice and utilizing exclusion criteria addressing H_2-related risks (such as geological setting, caprock integrity, mineralogy, water chemistry, and potential biotic/abiotic reactions).

Hydrogen capacity calculation is focused only on Working Gas Volume (WGV) for both DGRs and UGSes. The technical feasibility of replacing cushion gas and associated gas purification technology will be addressed in subsequent case studies on the most promising sites.

Results

- A total of 32 DGRs and 8 active UGSes were selected for subsequent analysis, screened from approximately 150 hydrocarbon fields based on exclusion criteria.
- The database and maps are being processed for all selected DGRs including suitable UGSes. Geological and basic geochemical risks estimation are part of the goal.
- A methodology for hydrogen WGV estimation was developed and the approximate hydrogen capacity of selected sites was calculated.

Conclusions

- HyPoteS-CZ is the first screening project focused on UHS in DGR in the Czech Republic.
- Existing operational data were used for hydrogen storage potential estimation and the first knowledge gaps were identified.
- Based on the project's results, several selected objects appear suitable for a UHS pilot project. However, further close screening and research of these DGRs are required.

Acknowledgements

HyPoteS-CZ project is funded by Technology Agency of the Czech Republic, programme THÉTA 2 in cooperation of Czech Geological Survey and Gas Storage CZ.

ID 9

Adhesives and sealants for electrolysers, fuel cells and energy storage devices

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WEVO-CHEMIE GmbH, Ostfildern, Germany

Keywords: Sealants; adhesives; automization; H2-Permeability; PFAS-free

Objectives

For the implementation of the energy transition, technologies for storing (renewable) energy need to be developed further. One solution are redox flow batteries and on the other hand (green) hydrogen as an energy storage material. Redox flow batteries as well as electrolyser stacks for producing green hydrogen are elaborately constructed electro-chemical devices. In redox flow batteries electrolytes, often based on vanadium, are circulated by means of pumps. In electrolysers electrical energy is used to split water or other electrolytes into hydrogen and oxygen. These technologies have great potential as storage systems for renewable energy from solar photovoltaic and wind farms or rooftop systems. However, the design of the battery stacks and electrolysers has been a real challenge so far as the aggressive electrolytes may deteriorate the materials and production processes are hard to scale due to difficult automisation of production-processes.

Methods

Adhesives and sealants from Wevo can withstand these conditions and on the same time allow automised stack production and allow greater design freedom.

New production technologies for the stack assembly are playing a key role in the industrialization and scaling-up of redox flow batteries. Instead of using preformed gaskets and manual assembly of the stack with threaded rods or clamping rings, the use of adhesive joining techniques and liquid formed-in-place gaskets (FIPG) offer new possibilities, design freedom as well as simplified and faster automized production technologies.

Furthermore, the sealing of electrolyser and flow battery stacks is still challenging due to the lack of chemically resistant sealant materials. In our search for a solution to these problems, liquid sealants and adhesives have been developed

Results

In this presentation Wevo will present:

An overview of Wevo’s resin solutions for the Hydrogen Economy:

The presentation will highlight new PFAS free developments for sealing and adhesive solutions for electrolyser and fuel cell stacks with a focus on newly developed materials with a low Hydrogen permeation coefficient. The presentation will present Wevo's chemical resistant materials for PEM- and AEL-electrolysers and for the fast growing field of AEM-electrolysers.

- **Engineered resin solutions for redox flow batteries**

The presentation will highlight WEVO’s tailormade and specially developed solutions for sealing and assembling redox flow battery stacks with a focus an All-Vanadium-RFB.

Conclusions

The use of liquid cured in place gaskets and adhesives hasbeen identified as alternative to preformed gaskets and other technologies used in sealing of bipolar-plates. It allows fast and scalabel production of electgrolyser-, fuel cell- and flow battery stacks.

ID 22

Efficient component development of Mg-based solid-state H2 storage alloys for enhanced hydrogen des-/absorption dynamics driven by machine learning

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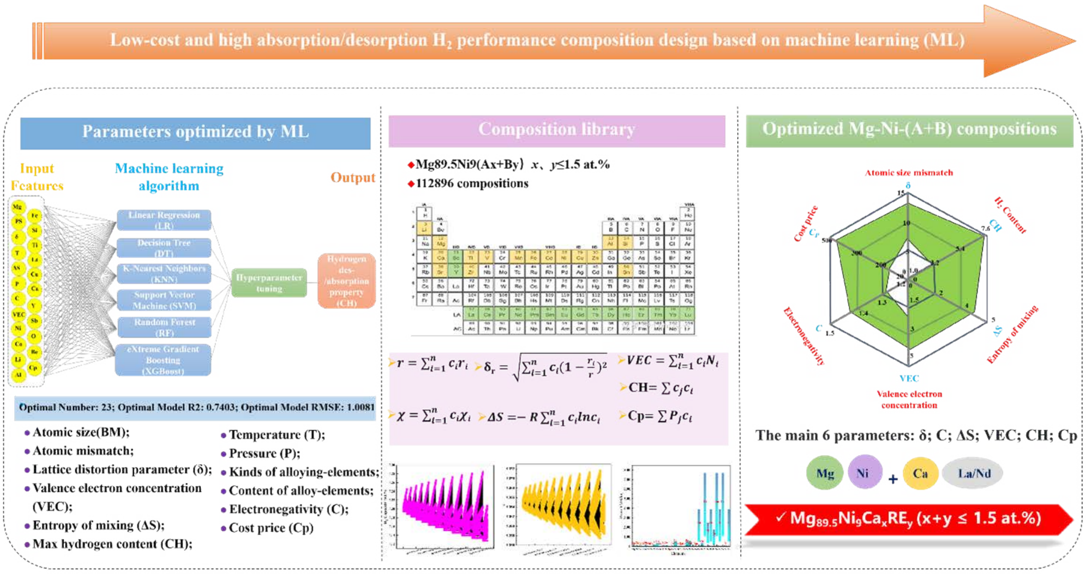
[2] North China Electric Power University, Beijing, China

Keywords: Mg-based alloys; Solid-state hydrogen storage; Machine learning; Dynamics behavior; Minor addition

Mg-based solid-state hydrogen storage faces a fundamental materials design paradox: reconciling near theoretical hydrogen capacity with rapid sorption kinetics while maintaining economically viable material costs-a triad wherein enhancing any two properties has traditionally necessitated compromising the third [1-3]. In this study, the quantitative relationship between absorption property with chemical compositions basing machine learning (ML) strategy through SHAP-based feature ranking with six algorithms: Linear Regression (LR), Decision Tree (DT), K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Random Forest (RF), and Xtreme Gradient Boosting (XGBoost), and then identifying six critical descriptors (Mg/Ni content, atomic size mismatch δ, mixing entropy change ΔS, valence electron concentration VEC and electronegativity C). Their contributions are mathematically fused into a composite parameter Z, which showed a sigmoidal logistic relationship with H_2 storage capacity. Crucially, Z enables rational binary doping synergistically pairing lattice-distorting and interface-catalyzing elements- to transcend performance-cost trade-offs. Guided by optimized boundaries (Mg≥90 at.%, Ni≤10 at.%, δ: 6.4-6.99%, ΔS: 2.81-3.35 J/mol·K, VEC:2.7-2.72 e/a, C: 1.356-1.368), the designed $Mg_{89.5}Ni_9(CaNd)_{1.5}$ is experimentally realized, achieving 6.27 wt.% H_2 absorption capacity, as well as lower 200°C desorption temperature. This series alloys showed 1.114 wt.%/min desorption kinetics behavior (with 6.3 times faster than that of Mg-Ni alloys with high Ni content), confirming 93% and 46% absorption/desorption time reduction, basing JMAK model analysis. These promotions are mechanistically attributed to binary-doping-induced α-Mg/Mg_2Ni lattice distortion and interfacial nano-structuring, thereby resolving the capacity-kinetics-cost triad through atomistically informed design.



ID 56

Mobile hydrogen filling stations

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Keywords: hydrogen filling station; mobile filling station; storage sections

Mobile hydrogen filling stations typically do not have a compressor to fill high-pressure vehicle tanks. The only source of compressed hydrogen is the initial pressure in the storage tank. Hydrogen cooling is also unavailable. This presentation describes and analyses all the weaknesses and problems of this simplified solution. The analysis begins with an examination of the physical properties of hydrogen and how it behaves when transferred between two tanks. The presentation is supplemented with the results of model case simulations. It also analyses the effect of dividing the tank into sections to maximize the capacity of the mobile tank.

ID 44

Ecosystem for hydrogen dispensing at rates above 60 g H_2/s

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Milan Bureš[1], Ing. Bronislav Vahalík[2], Ing. Vojtěch Přikryl[2]

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[2] Transport Research Centre, Brno, Czech Republic

Keywords: Hydrogen refuelling, high-rate refuelling, SAE J2601-5, mobile refuelling platform

Objectives

The goal of this poster is to present a project that aims to construct a mobile refuelling platform that allows high-rate refuelling of hydrogen vehicles (>60 g H_2/s). The platform will serve stakeholders for development and testing of technologies and components related to high-speed refuelling. The current state of the project will be presented, along with the planned results of the project.

Methods

The hydrogen fuelling protocol SAE J2601-5 was developed to allow medium and heavy-duty vehicles to be refuelled at speeds exceeding 60 g H_2/s. So far there is only limited experience with this protocol due to the absence of refuelling stations and vehicles compatible with the protocol. The goal of the project TN02000007-008 “Ecosystem for hydrogen dispensing at rates above 60 g H_2/s“ is to create a mobile platform that allows to test the protocol in operation at sites in the Czech Republic and to create a test appliance capable of receiving hydrogen at high speed.

Results

The project duration will be 2025–2028. During the first phase of the project the project will produce results directed at broadening the understanding of issues related to high-rate hydrogen refuelling. These include digital models mapping energy and thermodynamic phenomena during high-rate refuelling, mapping of relevant legislature and educational materials.

The second phase of the project will focus on producing a prototype device for fast refuelling. The device will consist of three standard road containers that when combined form the refuelling platform capable of filling vehicles with 350 bar hydrogen at rates higher than 60 g H_2/s. The prototype will be thoroughly tested with emphasis on safe refuelling, data collection and optimized operation. A prototype of a test appliance capable of receiving hydrogen at high-rates will be developer concurrently with the prototype.

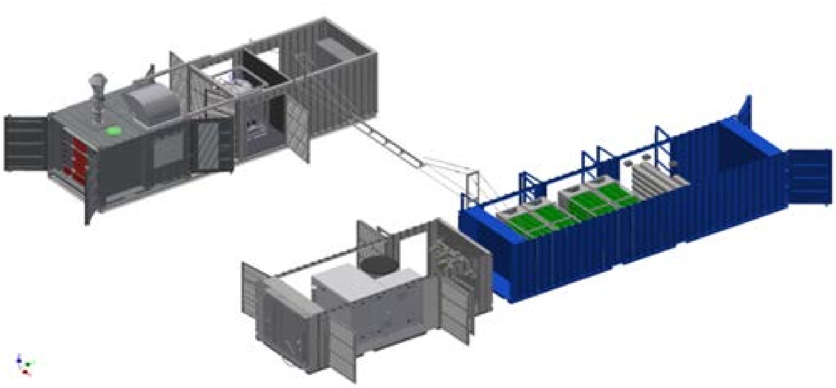
In the last phase of the project both the prototype and the test appliance will be finalised into a device that can be freely used in real-life condition in the Czech Republic. Utility models for the key components of the two devices will be produced and recommendations for legislation and strategic documents dealing with hydrogen refuelling will be issued based on the know-how gained in the project.

Conclusions

The poster will introduce the project “Ecosystem for hydrogen dispensing at rates above 60 g H_2/s“, familiarize the readers with the project’s goals, planned results and progress to date. The reader will gain a deeper understanding of the challenges of high-rate hydrogen refuelling and will be familiarized with an innovative project with potential international impact.

Acknowledgements

”This project is co-financed from the state budget by the Technology agency of the Czech Republic under the Národní centra kompetence Programme.“ “This work utilized outputs from Ekosystém plnění vodíku rychlostí přesahující 60 g H2/s (TN02000007-008) project.“



ID 42

Sampling device for high-pressure hydrogen

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Keywords: Hydrogen sampling, high-pressure hydrogen, quality control, hydrogen mobility, prototype development

Objectives

The goal of the poster is to introduce the project Sampling device for high-pressure hydrogen, which focuses on the development and verification of a functional system for safe and reliable sampling of hydrogen fuel at high pressure. The project aims to provide a comprehensive technical solution for hydrogen quality control in accordance with international standards and requirements for hydrogen mobility infrastructure.

Methods

The project TN02000007-007 combines research, design, and experimental validation of hydrogen sampling technologies. The work includes a detailed technology survey, optimisation of the sampling panel design to minimise dead volumes and potential contamination points, and the substitution of mechanical gauges with electronic or membrane-based sensors. Laboratory verification is performed on both the sampling system and the device for sample container preparation, using controlled conditions and automated measurement processes.

Results

The project runs from 2023 to 2026 and is expected to deliver the following outputs:

- Functional prototype of the high-pressure hydrogen sampling device;
- Utility model of the device assembly;
- Laboratory-verified device for the preparation of hydrogen sample containers.

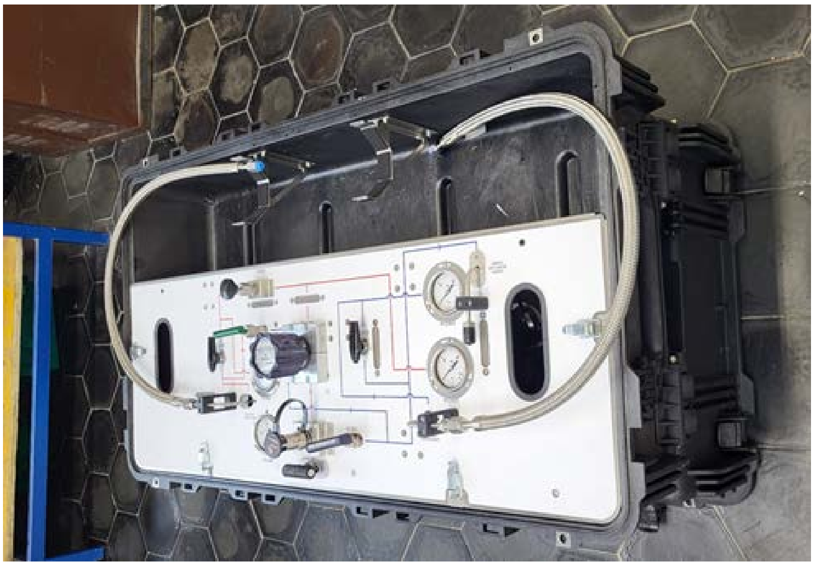
The developed system introduces a compact and safe design suitable for laboratory and field use. The device for preparing sample containers includes, among other things, a heating chamber for heating sample containers to approx. 50 °C, working positions for 2 sample containers, fully automatic operation of fittings, and functional connections designed for UHP (Ultra High Purity) — Face seal VCR. The cleanliness class of the workplace for final assembly and testing is expected to be in accordance with ČSN EN ISO 14644 (class 8). The solution enables accurate, repeatable hydrogen sampling that supports both quality assessment and certification processes for hydrogen refuelling stations.

Conclusions

The poster will present the *DP007 – Sampling device for high-pressure hydrogen* project, its objectives, technical concept, and achieved results. Visitors will gain insight into the development of precise and safe hydrogen sampling technologies, which are crucial for ensuring fuel quality and operational safety at hydrogen refuelling stations. If of interest, the device can also be presented on site to illustrate the developed solution in practice.

Acknowledgements

This project is co-financed from the state budget by the Technology Agency of the Czech Republic under the Národní centra kompetence Programme. This work utilized outputs from Odběrové zařízení vysokotlakého vodíku (TN02000007-007) project.



ID 34

Didactic Aid – Hydrogen Refueling Station (HRS) Simulator

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APT, spol. s r. o., Prague, Czech Republic

Keywords: didactic aid, simulator, hydrogen refueling station, technological process visualization, realistic operation training, safety

Objectives

The aim of this poster is to introduce to the professional public a device that facilitates the training of new specialists among young people, as well as the instruction of operators for newly built hydrogen refueling stations.

The goal of the project itself is to design and verify through practice an accessible educational tool that provides comprehensive training for specialists — both in terms of operational skills required for handling hydrogen refueling stations and in understanding the principles of their function and operational safety.

Methods

The development method of the didactic aid is primarily based on practical and operational experience gained from the design, construction, and operation of real hydrogen refueling stations. Verified knowledge from existing stations was applied — including thermodynamics of technical gases (specifically hydrogen), typical parameters of real pressure vessels for compressed gases, flow rates, technological operating temperatures, and ambient temperatures.

In addition to physical parameters, operational experience in the form of common technical and operator errors was also incorporated into the design. The control system can simulate such errors, thereby creating realistic situations that allow students to gain practical experience.

Results

The project was carried out from November 2024 to December 2025. The result is a prototype of a didactic aid in the form of a simulator installed at the Secondary Technical School in Chomutov. The project duration was shortened compared to the original plan in order to make the results available for teaching as soon as possible.

Conclusions

General description:

- The simulator is installed in a dedicated classroom
- It simulates refueling at both 350 and 700 bar
- The control system corresponds to that of a real refueling station
- The equipment adheres to the safety standards of actual stations
- Customer interaction is simulated via a standard display interface
- The simulator also includes a simulation of payment terminal

Visualization of the technological process includes:

- Hydrogen supply process to the station
- Compressor unit performance
- Logic of high-pressure storage filling
- Function of the valve block
- Hydrogen refueling process for vehicles
- Safety functions
- Simulation of error states
- Voice announcements and realistic operational sounds

The realistic simulator enables, among other things:

- Familiarization with real components used in hydrogen refueling technology
- Understanding of their construction principles
- Training in occupational safety and technical equipment handling
- Knowledge of pressure joint designs and methods of quality evaluation
- Development of practical skills during model assembly and disassembly of selected dispensing system components

The simulator is primarily intended for:

- Specialized training at secondary technical schools
- Future employees operating hydrogen refueling stations
- Preparation of experts for working with designated gas and pressure equipment in accordance with Government Decrees No. 191 and 192/2022 Coll.

Acknowledgment

The project is funded under the **Operational Programme Just Transition**, project title *“Specialized Classrooms and Polygons ESOZ Chomutov”*, project registration number **CZ.10.02.01/00/23_006/0000277**, and public procurement titled *“Supply of a Didactic Aid/Simulator — Refueling Station.”*

ID 47

Ammonia-cracking-integrated gas turbine system utilizing turbine waste heat: a thermodynamic performance analysis

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Professor Gyungmin Choi Ph.D Eng[1]

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Keywords: Ammonia cracking; Gas turbine; Hydrogen; Integration; Performance

Hydrogen has become a leading contender for clean fuel applications as the global energy industry speeds up its shift to carbon neutrality. However, issues with safety and storage of hydrogen hinder its widespread use. Ammonia, a carbon-free hydrogen carrier with high volumetric energy density and easy storage, is a viable option. This study analyses an innovative energy system integrating a gas turbine with an on-site ammonia cracking unit to provide a hydrogen-rich, carbon-free fuel for high-efficiency power generation. The research begins with a base simulation of a J-series methane-fired gas turbine, at both design and off-design conditions while maintaining constant Turbine Inlet Temperature (TIT) using ASPEN Plus software. Subsequently, hydrogen and ammonia fuels off design simulation is carried out to investigate influence on thermodynamic performance. It is assumed that a new combustor is designed for Wobbe Index (WI) greater than ±5% to consider combustion stability. For sustainable hydrogen supply, a novel on-site ammonia cracking subsystem is set up by recycling exhaust heat from turbine through recuperation to carry out thermal decomposition. The ammonia cracking integrated system performance was evaluated, with the degree of cracking controlled by the Ammonia Split Ratio (ASR) ranging from 0 to 1 and three ammonia cracking conversion rates (90%, 95%, and 99%). The results revealed strong interdependence between ASR, conversion rate and gas turbine performance. Increasing ASR reduced fuel mass flow rate due to higher H_2 fractions and fuel LHV, while 90% ammonia conversion at ASR=1 increased fuel mass flow by ~77% compared to near complete conversion, owing to residual NH_3. Surge margin improved substantially, rising from 0.43 for pure ammonia to higher values with increasing ASR and conversion rates, enhancing compressor stability. Higher conversion rate showed higher energy requirement for dissociation of ammonia in ammonia cracking. For instance, At ASR=1, the exhaust energy decrease relative to turbine exhaust energy was ~68%, ~56% and ~50% for 99%, 95% and 90% conversion rates, respectively. Net power output also decreased with higher ASR because of the reduced fuel mass flow. Similarly, system efficiency gradually declined with ASR, while 90% conversion achieved higher efficiency than 99% but at the cost of higher fuel consumption. The exhaust temperature decreased with increasing ASR but rises by up to ~7 % at 90% conversion relative to 99% conversion rate, potentially beneficial for bottoming cycle. To further improve system sustainability and efficiency, future research will concentrate on adding cracking catalysts for lower-temperature and analyzing combustion kinematics for hydrogen and ammonia blended fuels for different ASR and conversion rates.

ID 73

Modeling and Analysis of the Cost Breakdown in the Mass Production of a 10 kW Fuel Cell Stack

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Keywords: Hydrogen, Fuel cell, Economy, Cost breakdown, Mass production

This study deals in detail with complex modeling of the cost reduction process for 10 kW fuel cells during the transition from the development phase to fully established serial production. This transition is critical from both a technological and an economic point of view, as individual production steps, material purchases, personnel requirements, and logistics costs often change in a nonlinear manner during scaling. The objective of the work is not only to quantify these changes, but also to identify key cost components that most significantly influence the final price of a fuel cell as a function of production volume.

Modeling was conducted for two realistic production scenarios corresponding to the current and future demand of the emerging hydrogen technology market. The first scenario assumes the production of 10,000 fuel cells, which represents a smaller yet commercially relevant production line. The second scenario considers a volume of 100,000 units, corresponding to large-scale industrial production. Comparing the two scenarios allows for an accurate assessment of the scaling effect, in particular, the impact of economies of scale on unit costs.

Detailed technological data based on an innovative method of manufacturing a membrane-electrode assembly (MEA), namely the method of applying a catalytic layer by inkjet printing, were implemented within the cost model.

Based on the modeling results, a comprehensive business model was developed, the output of which is the calculated final retail price of the fuel cell. The model includes not only the direct production costs, but also an appropriate business margin, fixed operating costs, and the expected economic life of the production equipment. This approach allows for a realistic assessment of the expected price of the product on the market.

To validate the accuracy and reliability of the model, the final price was compared with available market data. This validation, based on market analysis, serves as a key criterion for assessing whether the modeling aligns with current trends and price levels in the industry. The comparison showed that the calculated values are within a realistic range, which confirms the functionality and applicability of the model as a support tool for strategic decision-making on investments, technological development, and the future direction of fuel cell production.

Acknowledgement

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ID 43

Modulating the surface properties of Pd/C catalysts by liquid-phase reductants for enhanced selectivity in benzaldehyde hydrogenation

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Keywords: Benzaldehyde, Hydrogenation, Pd/C, Reducing agent, Surface properties

Pd/C catalysts are widely used in fine chemicals and petrochemical processes, offering high conversion rates and activity. However, they frequently suffer from the intrinsic difficulty of controlling selectivity towards the desired products. Catalytic conversion and selectivity are known to be affected by various parameters such as the metal type, support type, and surface properties. Among these factors, surface properties can be adjusted by the choice of reducing agent. Herein, this work investigates the correlation between surface properties and catalytic performance of Pd/C. Pd species were deposited on carbon support via the electrostatic adsorption method and then reduced by four kinds of the liquid-phase reducing agents including formic acid, formalin, glucose, and L-ascorbic acid. The mole ratio of reducing agent to Pd was kept constant to determine the effect of the type of reducing agent on the surface properties. The prepared catalysts were characterized by XPS, TEM, XRD, N_2 adsorption-desorption, and NH_3-TPD. Comprehensive characterization confirmed that the type of reductant significantly modulated the Pd surface electronic state and modified the catalyst surface acidity. The catalytic performance was tested via benzaldehyde hydrogenation to benzyl alcohol. Pd/C reduced by formic acid exhibited the highest benzyl alcohol yield. Subsequently, the amount of formic acid was varied. Yield increased up to certain level, but remained constant beyond that point. This indicates that the amount of reducing agent influences the catalytic activity, but the effect decreases beyond an optimal amount.

ID 23

Hybrid NiMo@CC-GF biocathode enhances hydrogen-mediated microbial electrosynthesis for acetate production from CO_2

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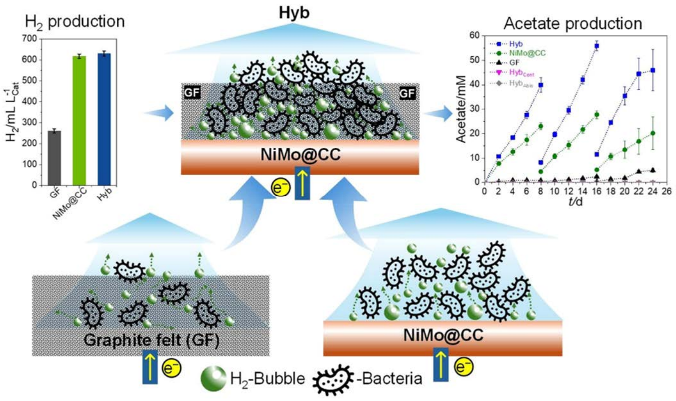
Keywords: NiMo@CC-GF, Hybrid electrode, Microbial Electrosynthesis, CO_2 upcycling, microbial electron transfer

Advancing microbial electrosynthesis (MES) requires efficient electron transfer at the biocathode to convert CO_2 into value-added products. Although the hydrogen molecule is an effective indirect mediator for electron delivery, its inherently low solubility in electrolyte restricts microbial uptake and lowers the faradaic efficiency. This study developed a hybrid electrode (NiMo@CC-GF) to overcome the limitation by embedding a NiMo catalyst-coated carbon cloth (NiMo@CC) within a porous graphite felt (GF). The suggested architecture promotes localized, in situ H_2 generation and entraps gas bubbles within the carbon matrix, enhancing microbial access and H_2-mediated CO_2 reduction. Electrochemical tests in phosphate buffer at −1.2 V (vs. Ag/AgCl) showed a maximum abiotic H_2 evolution (630 mL L^{-1}), more than NiMo@CC (618 mL L^{-1}) and GF (262 mL L^{-1}). When applied to MES, the hybrid biocathode achieved an acetate titer of 55.92 mM L^{-1}, almost double that of NiMo@CC (27.80 mM L^{-1}) and more than 12 times higher than GF (2.41 mM L^{-1}). These findings highlight the potential of NiMo@CC-GF biocathodes to enhance H_2 availability, accelerate microbial CO_2 uptake, and substantially improve the acetate yield in MES. The proposed hybrid electrode design revealed a scalable strategy for integrating a wide range of hydrogen evolution catalysts, including those with limited biocompatibility, into carbon matrix of MES biocathode systems.



ID 80

Using Molten Carbonate Electrolyser as a CO_2 concentrator from air: conceptual and experimental study

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Warsaw University of Technology, Warsaw, Poland

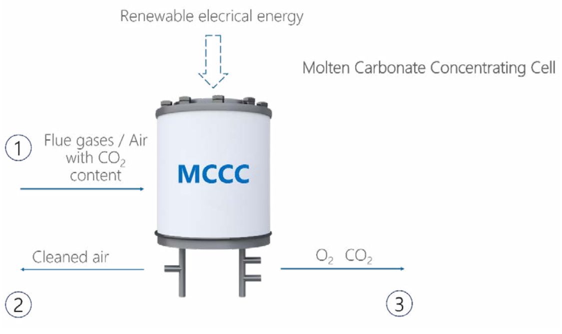
Keywords: molten carbonate electrolysis; CO_2 concentration; hydrogen economy; Power-to-X; electrochemical separation; high-temperature electrochemistry

Direct air capture (DAC) and low-partial-pressure CO_2 separation are increasingly relevant for the emerging hydrogen economy, enabling negative emissions and supplying purified CO_2 for Power-to-X routes (e-methane, e-methanol, e-kerosene) when coupled with renewable hydrogen. However, many DAC solutions rely on cyclic sorbents with significant thermal regeneration demand and complex gas–solid contacting. High-temperature electrochemical systems based on molten carbonates offer an alternative: rather than regenerating a sorbent, CO_2 is continuously "pumped" across an ion-conducting molten electrolyte using electrical work, with straightforward coupling to high-grade heat and potential integration with hydrogen production and utilization chains.

This study investigates the concept of using a Molten Carbonate Electrolyser (MCE) as a CO_2 concentrator from air, combining a conceptual/thermodynamic framework with proof-of-concept experiments. The MCE operates at 600–650 °C with a molten carbonate electrolyte, where CO_2 is captured at the cathode by forming carbonate ions and released at the anode as a concentrated CO_2 stream. In this role, the device functions as an electrochemical separation unit: the enrichment is governed by the Nernst relation via the ratio of CO_2 activities (or partial pressures) at the two electrodes, while practical performance under ppm-level inlet CO_2 is constrained by cathode mass transfer, electrode kinetics, ionic resistance, and gas management (sweep/recirculation strategies).

We first outline operating envelopes for air-to-concentrate operation relevant to hydrogen-driven synthesis: (i) the trade-off between enrichment and cell voltage (electricity demand), (ii) the impact of cathode boundary layers under ambient CO_2, and (iii) process configurations that can reduce specific energy per unit CO_2 concentrated by combining electrical work with available high-temperature heat. Design implications are discussed with emphasis on scalable integration: electrode microstructures that enhance gas diffusion and three-phase boundary activity, controlled air humidification to support transport, staged modules to avoid cathode starvation, and anode sweep optimization to deliver a CO_2-rich stream compatible with downstream catalytic reactors.

Experimentally, we test a lab-scale MCE cell under air-like cathode feeds (low CO_2 partial pressure) and quantify separation performance via outlet gas analysis and electrochemical diagnostics. The results confirm stable carbonate-ion transport under dilute-CO_2 conditions and demonstrate clear CO_2 enrichment at the anode (from ppm-level inlet toward percent-level outlet concentrations depending on operating current and sweep conditions). Observed trends are consistent with the conceptual model: higher current increases CO_2 flux but raises polarization losses, while gas-phase management strongly governs effective capture at the cathode.



Ion exchange membranes production

ID 81

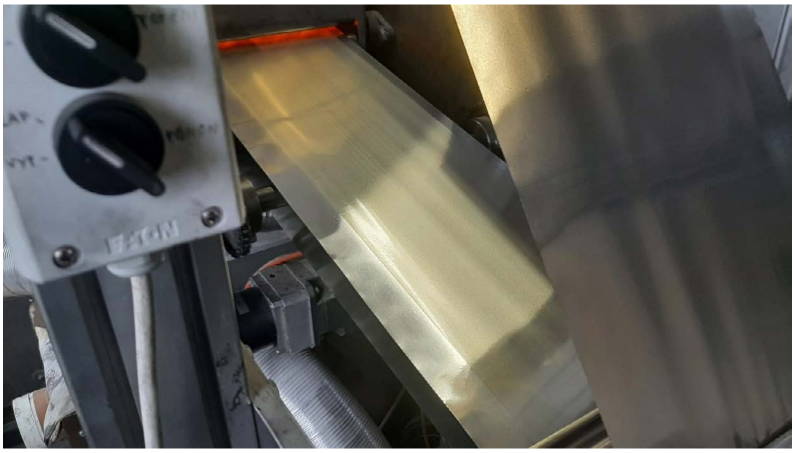
Continual casting production process of homogeneous tailormem ion exchange membranes Hollex

Jan Žitka PhD., Václav Nedvídek Mgr.

TailorMem, Prague, Czech Republic

Keywords: TailorMem, Hydrocarbon ion exchange membranes,

TailorMem is Czech small and medium-sized company that develops ion exchange membranes. Its membrane portfolio includes both anion exchange membranes (AEM) and cation exchnge membranes (PEM, CEM). The Hollex membranes are homogeneous hydrocarbon based polymer based, fluorine free (PFAS free) membranes. The membranes are manufactured using the new continual roll2roll process in widths up to 300 mm and in thicknesses of 30- 120 micrometers. The membranes are designed for PEM and AEM water electrolysis and for fuel cell applications. Research is being conducted for use as a single ion conductor solid state electrolyte for lithium ion batteries and other electrochemical devices. A binder for catalyst coated membranes (CCM) and catalyst coated substrate (CCS) is also supplied based on the same chemistry as Hollex membranes.



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