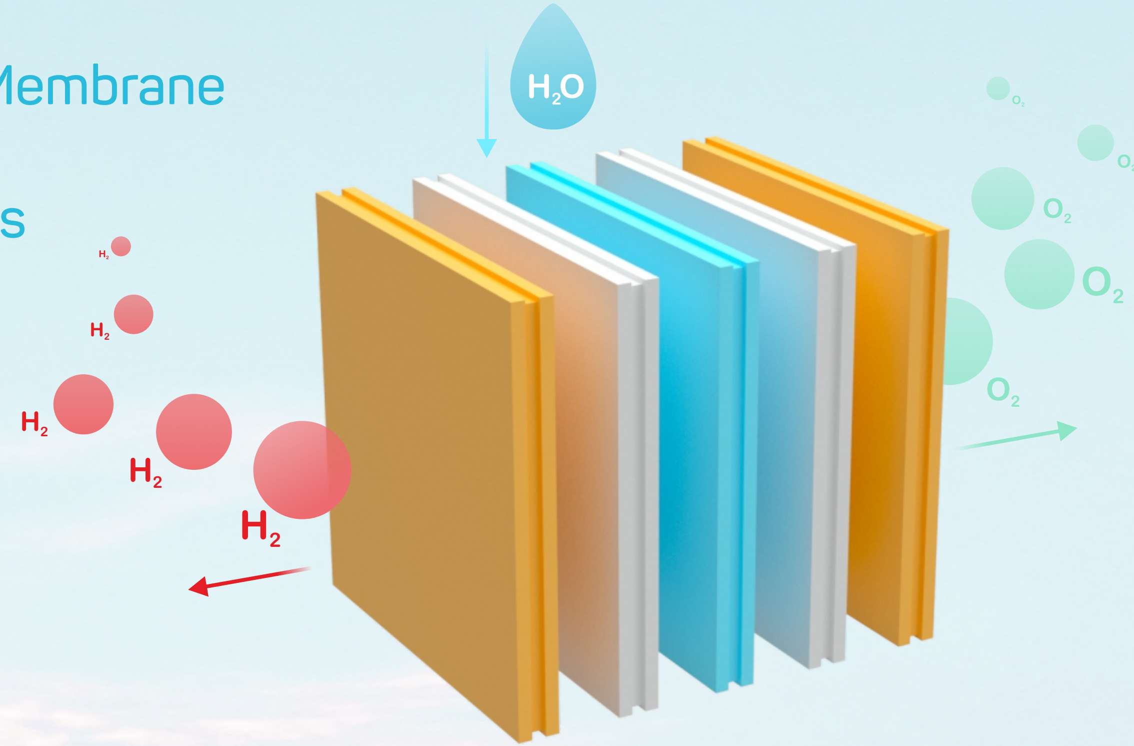
NEWELY

Next Generation Water Electrolyser

Next Generation Alkaline Membrane Water Electrolysers with Improved Components and Materials



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Clean Hydrogen Partnership

NRF National Research Foundation of Korea

This project has received funding from National Research Foundation of Korea (NRF, Grant No. 2019K1A3A1A78110399)

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PROJECT COORDINATOR

Deutsches Zentrum für Luft- und Raumfahrt - DLR
Germany

LARGE COMPANY

Air Liquide Paris Innovation Campus (Air Liquide)
France - Germany

SMEs

Membrasenz SARL
Switzerland

ProPuls GmbH
Germany

Cutting-Edge Nanomaterials UG - (CENmat)
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Germany

CEA French Alternative Energies and Atomic Energy Commission
France

Ústav Makromolekulární Chemie AV ČR (IMC-CAS)

Project Overview and Mission

Situation

The global energy transition is underway, with photovoltaic and wind power leading the way to make electricity the primary decarbonized energy source. However, the intermittent nature of these sources will result in a significant surplus of electricity. Green Hydrogen, renowned for its versatility, is poised to emerge as one of the most promising solutions for storing and supplying green hydrogen to hard-to-decarbonize sectors. To produce green hydrogen efficiently and affordably, the development of advanced water electrolysers is imperative. Anion Exchange Membrane Water Electrolysis (AEMWE) stands out among existing water electrolysis technologies due to its numerous advantages, albeit still at a relatively low Technology Readiness Level (TRL). The aim of the NEWELY project is to propel AEMWE to higher TRL, driving progress in this field.

Project

NEWELY is a European project funded by the Clean Hydrogen Partnership that develops and tests components for the next generation of Anion Exchange Membrane Water Electrolysers (AEMWE). The project develops a prototypic 5-cell stack with elevated hydrogen output pressure which reaches twice the performance of the state of the art of AEMWE operating with pure water or very low concentration KOH feed only.

Prototype

The prototype incorporates highly conductive and stable anion conducting membranes, alongside efficient and durable low-cost electrodes. The advancements in membrane, electrode, and stack design validate the project's achievement of developing the most efficient and economically viable AEMWE technology. This breakthrough paves the way for widespread adoption of green hydrogen energy storage solutions, not only in Europe but also globally, thereby facilitating the transition towards more sustainable energy systems.

CREATE AN ALTERNATIVE

Beyond the existing electrolyser technologies AEMWE gathers the advantages of the two existing types of electrolysers: compactness and non-critical raw materials usage.

COST REDUCTION

The market for water electrolysis is huge. Thousands of GigaWatts capacity must be installed in the coming decades to move from hydrogen production by steam methane reforming to water electrolysis.
To be competitive, low-cost technologies are needed.

DURABILITY

Lifetime of the water electrolysis stacks is of great importance for the economics of water electrolysis. AEMWE components (membrane, catalysts) must, at least, reach the same performances as PEMWE (Proton Exchange Membrane Water Electrolysis) and AWE (Alkaline Water Electrolyser) ones.

Project Objectives

Technical

- Development of 2 kW 5-cell AEMWE stack based on hydraulic single cell compression technology that can produce hydrogen at up to 40 bar.
- Cell voltage of 2 V at 1 A cm^{-2} with 0.1 M KOH feed at a temperature of at least 50 °C.
- Performance for 2,000 h endurance test.
- Membrane ionic conductivity of at least 50 mS cm^{-1} at 50 °C.
- AEMWE stack with 200 cm^2 active area cells.
- Non-critical raw materials (CRM) catalysts for Oxygen Evolution Reaction (OER) and Hydrogen Evolution Reaction (HER) with added overpotentials of less than 415 mV @ 1 mA cm^{-2}.

Socio-environmental

- Development of novel components with no CRM.
- Contribution to a sustainable European society by developing an advanced electrolyser technology based on alkaline anion exchange membranes.
- Develop environmentally friendly and energy efficient synthesis methods.
- Accelerate the implementation of zero CO_2 emission electrolysers for large-scale production of hydrogen from renewable energies.
- Fasten the market penetration of hydrogen produced by electrolysis compared to natural gas that emits much more CO_2 per ton of H_2.

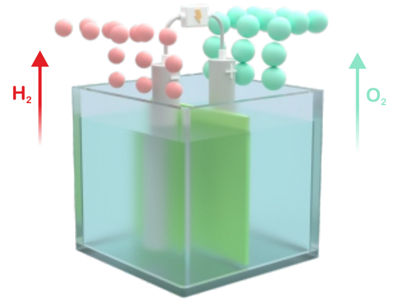
Economical

- Provide a full cost analysis based on techno-economic assessment (TEA) and life cycle assessment (LCA) demonstrating the reduction of capital and operative costs for AEMWE technology with respect to PEMWE and AWE.
- Support the technological leadership of Europe world-wide.
- Reduce drastically the total cost of ownership (TCO) compared to all the existing electrolysis technologies.
- Demonstrate the long-term durability of the newly developed materials and components.

Context, concept and value proposition

Context and challenges before the NEWELY project

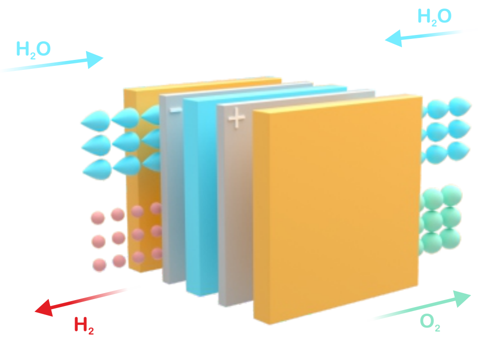
- **Alkaline Water Electrolysers (AWE)**



\+ Mature
\+ High durability
\+ Low costs for H_2 production

\- Low current densities
\- Highly concentrated alkaline solution
\- Slow response to demands for renewables

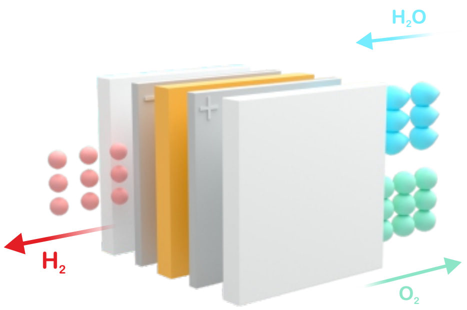
- **Proton Exchange Membrane Water Electrolysis (PEMWE)**



\+ High current densities /compactness
\+ Fast response to demands for renewables
\+ Fed with pure water

\- Expensive
\- Dependence on critical raw materials

- **Anion Exchange Membrane Water Electrolysers (AEMWE)**



\+ Dynamic response to renewables and lower concentration liquid
\+ High current density and compact design

\- Low performance
\- Lack of competitiveness: high costs, limited stability and industrial experience

The main challenge in AEMWE is to produce components and materials reaching a performance close to the ones of PEMWE. For that it is necessary to fabricate or adapt membranes and ionomers for the catalyst layer with higher OH^- conductivity and superior stability in operation with low concentration KOH solution. NEWELY addresses the three main challenges in AEMWE:

1. Chemically, thermally, and mechanically stable AEMs with improved ionic conductivity
2. Highly active and stable electrodes with reduced Ohmic resistance at the contact interfaces with the AEM
3. Stack based on the novel hydraulic single cell compression technology that will allow high pressure AEMWE without subsequent mechanical hydrogen compression.

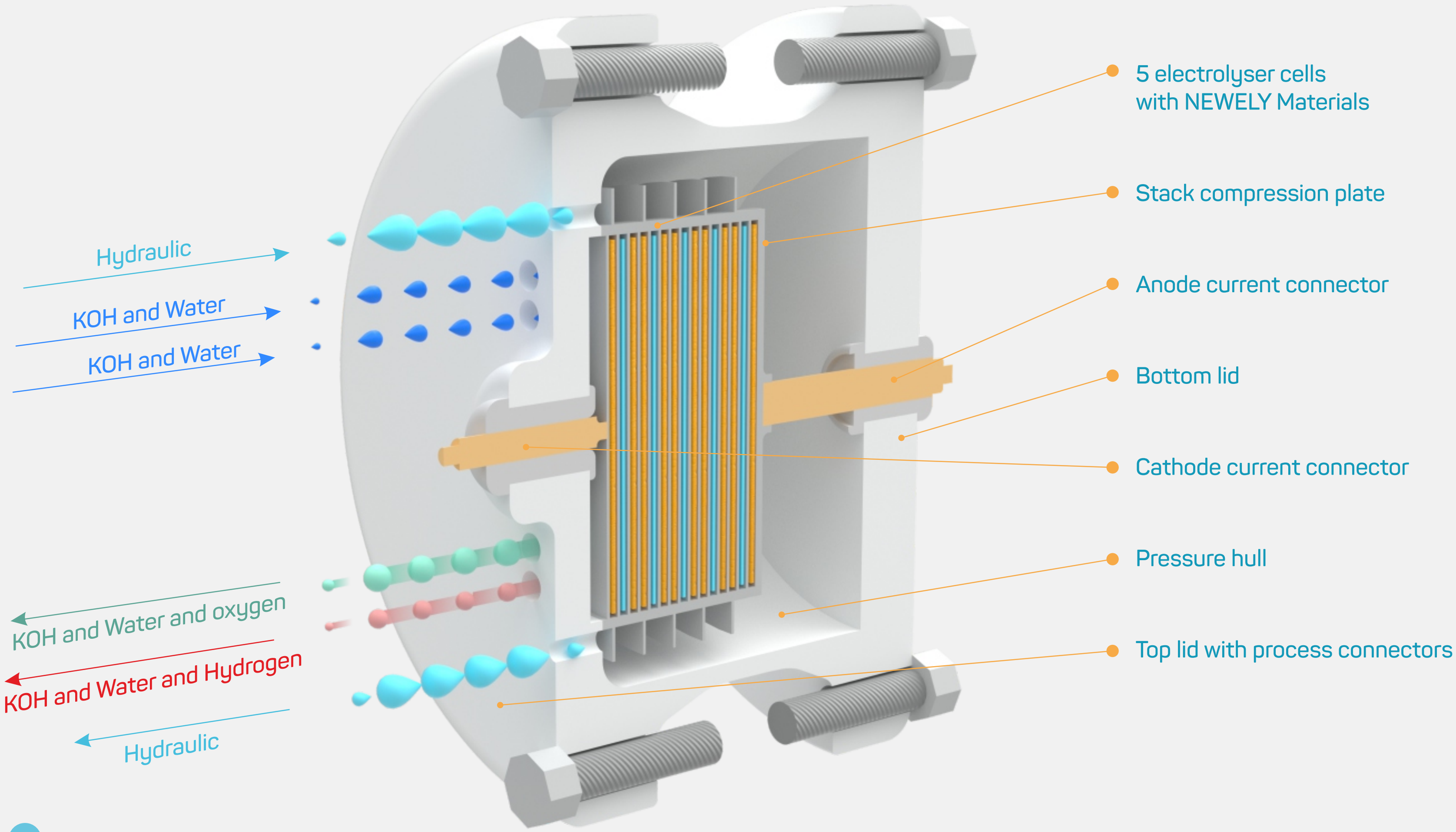
Concept and value proposition

The AEMWE technology can potentially combine the beneficial features of the PEMWE and AWE technologies. However, as of today, AEMWE is limited by AEMs exhibiting an insufficient ionic conductivity as well as a poor chemical and thermal stability. Furthermore, catalysts and electrodes that perform relatively well in high concentrated KOH environment are not suitable for operation in very low concentration KOH because the ionomers are still not able to bring the necessary degree of basicity into the catalyst layer.

Automated electrode spray-coating

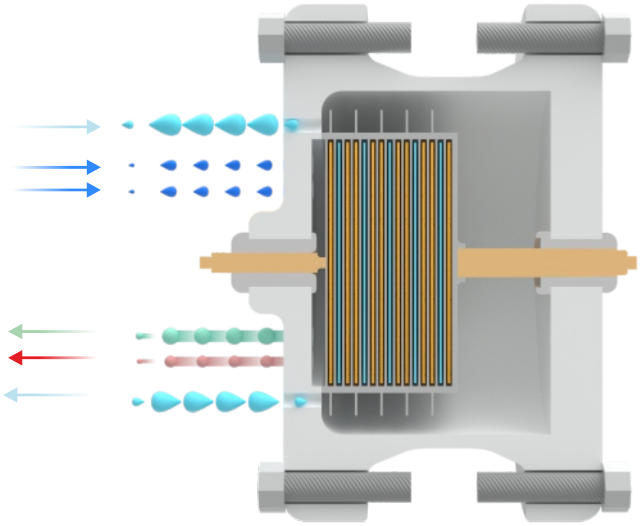
DLR Deutsches Zentrum für Luft- und Raumfahrt

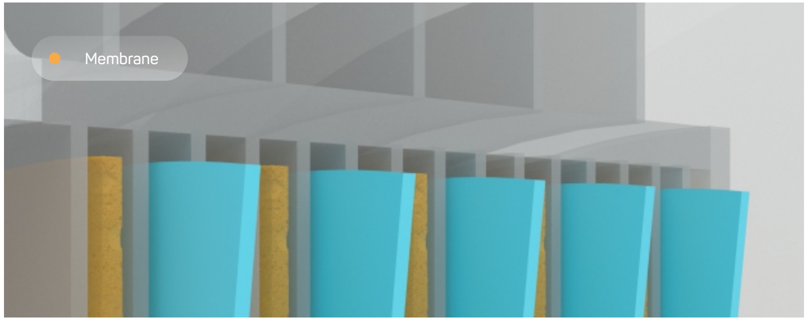
NEWELY

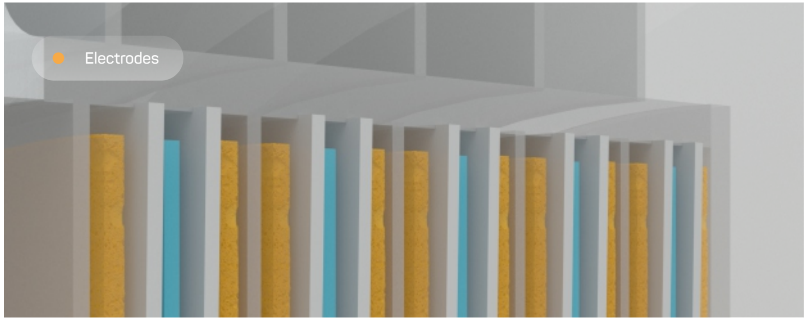

5 electrolyser cells
with NEWELY Materials
Stack compression plate
Anode current connector
Bottom lid
Cathode current connector
Pressure hull
Top lid with process connectors
Hydraulic
KOH and Water
KOH and Water
KOH and Water and oxygen
KOH and Water and Hydrogen
Hydraulic

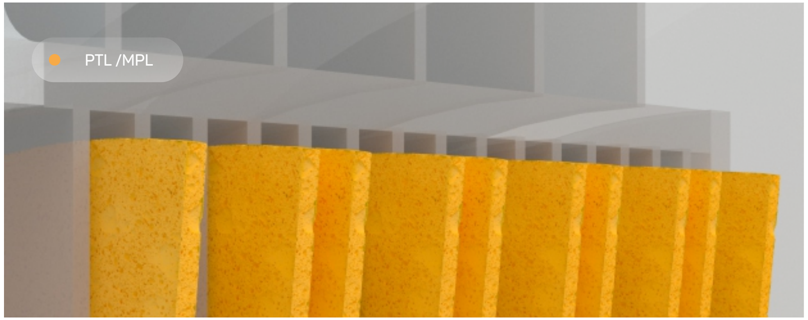
Technology / Prototype description

Water Electrolyser with high-performance









- 2kW 5-cell stack based on hydraulic cell compression technology.
- Membrane and ionomer binder, to have a stable AEM with high ionic conductivity.
- Catalysts and efficient electrode packages
- Optimized porous transport layers (PTL) with MPL

Results and Impact

1 – Membrane development and characterization

Membranes exceeding the project targets of conductivity, area specific resistance and dimensional stability were developed and produced in sufficient amount and size for the stack and cell tests. PSEBS Gen 1 membranes achieved a conductivity of 60 mS cm^{-1} and area specific resistance of 0.065 $\Omega\ cm^2$.
Fibre-mat reinforced membranes achieved good dimensional stability and high conductivity. A pre-swelling method for the membrane, mitigating excessive swelling in the cell when dry assembled, was developed and investigated.

PSEBS Gen 1 membrane 30 x 30 cm, made by IMC-CAS

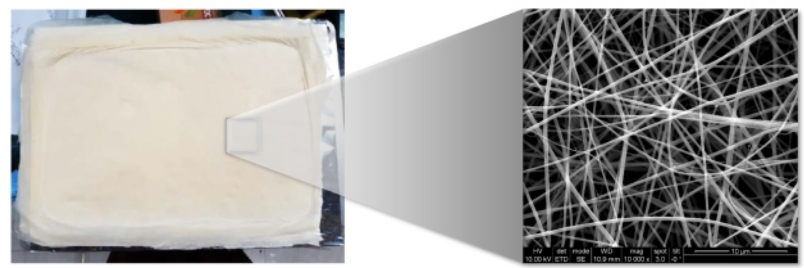
2 – Ionomer

During the project, an ionomer/binder for catalyst, based on the same polymer and chemistry as PSEBS Gen 1 membrane, was developed and used for MEA preparation.
Thus, electrochemical properties of the ionomer and the PSEBS Gen 1 membrane are similar.
Developed ionomers, surpassing the conductivity target of 20 mS cm^{-1}, were used in the electrode development of the project.

3 – Membrane reinforcement and upscale

PSEBS Gen 1 membranes were produced with dimensions 30x30 cm and 60 μm thickness by IMC-CAS for further testing and to be used in ProPuls stack. Polybenzimidazole nanofiber mats were produced by electrospinning and used to increase the mechanical strength and reduce swelling of membranes.

Membrane on a support indicating dimensions thereof



Polybenzimidazole nanofiber mats to increase the mechanical strength and reduce swelling of membranes.

4 - Electrode packages: catalyst materials, porous transport layers and CCSs

Catalysts

The CRM-free catalysts H2GEN-M and OXYGN-N were developed by CENmat, depicting sophisticated nanostructures and excellent performance in AEM technology, whilst being accessible via sustainable and economical production processes in batch sizes of 50g. The Overpotentials of 116 mV @ 10 mA cm^{-2} for HER and 215 mV @ 10 mA cm^{-2} for OER highlight the suitability of these catalysts for the AEM technology.

PTLs made of stainless steel or graphite.

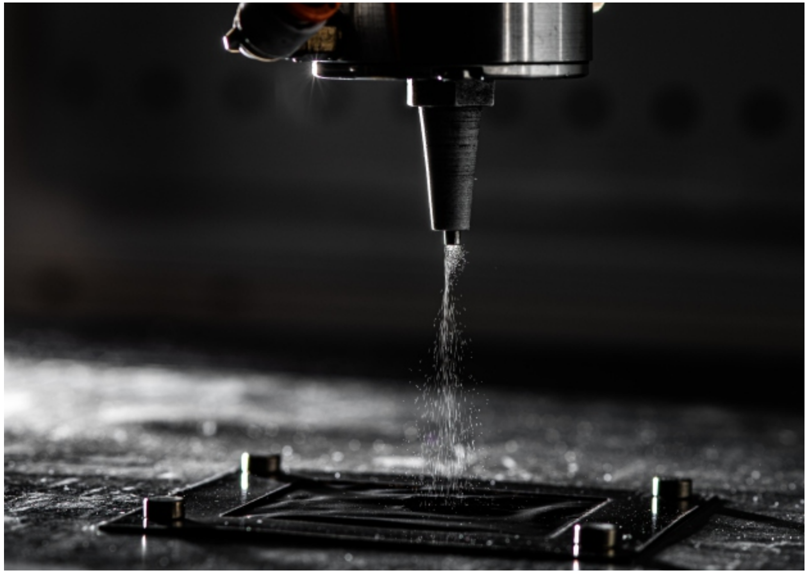
The porous transport layer (PTL) has several purposes in electrolyzers, including thermal and electrical conduction, mechanical support, pathways for delivering reactant liquid water to the catalyst layer, and removal of gases from the reaction sites to the outlet. Improved transport processes and reduced contact resistances can achieve a lower cell overpotential. At the same time material costs for the PTL could be reduced. For the final stack all PTL and electrode support material are of stainless steel or graphite contributing to cost reduction with nickel porous material being in contact with the active electrodes.

Macroporous layer (MPL) at contact interface

On the contact side to the electrode a layer with small pore sizes, a microporous layer (MPL) is able to further decrease contact resistances and improve the performance. PTLs plasma-coated with Nickel demonstrated a clear decrease in overpotential in AEMWE with pure water operation and some decrease in overpotential with low concentration KOH. PTLs made of stainless steel (SS) with a plasma-sprayed nickel MPL on top are produced and tested reducing the amount of more costly Nickel to a minimum.

CCS approach

Other than in PEM, coating of the catalyst to the substrates (CCS) rather than the membrane is possible in AEM, as with the use of higher loadings of catalysts and the addition of electrolyte contact resistances are causing less problems here. The CCS approach is preferable also in terms of an improved handling and easy manufacturing process also regarding the higher tendency of swelling of AEMs. Inks with improved stability using PSEBS-Ionomers and CENmat's nanocatalysts were developed. With an ultrasonicated spray coating method high performance electrodes of CCS type are produced in 25 cm^2 size for single cell tests and in 200 cm^2 size for stack tests.



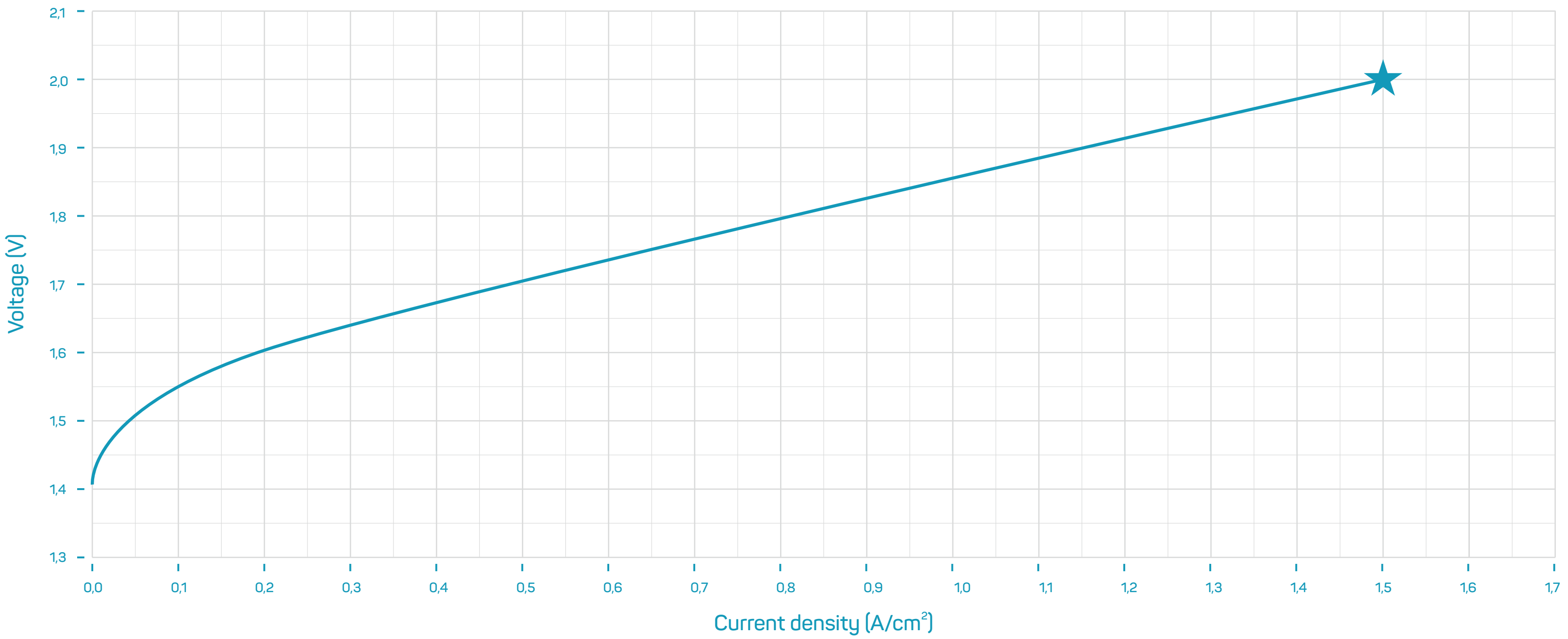
Spraying head of the electrode coating machine

DLR Deutsches Zentrum für Luft- und Raumfahrt

Single cell testing

All the components from NEWELY project (CENmat catalysts, PSEBS membrane from IMC-CAS and the single cell for testing from Propuls cell) were assembled and tested.

The milestone of NEWELY project (2V@ 1A/cm²) was outperformed with (1.5 A/cm² @2V) in 0.1 M KOH at 50°C with dry cathode with only 3 mg/cm² of OXYGN-N and H2GEN-M on the anode and the cathode side, respectively, assembled in a CCS-like MEA with a 60 µm thick membrane.



V-I graph used for analysing the cell performance.

5 - 5-cell 2kW Stack

The test bench is ready for proceeding to test. Stack and cell components are presently being optimized by tests in the similarly constructed 25 cm² single cell test system. A new construction of stack using hydraulic compression realized with 200 cm² cell area was developed and most parts are available to build the stack.
For testing the NEWELY materials a test bench was constructed and designed by FBK and ProPuls comprising a 25 cm² test cell of ProPuls. The test bench in connection with the test system based on hydraulic single cell compression provides the possibility to test new electrolyser components under reproducible homogenous operation conditions.
The working principle of the test environment guarantees for the obtained results being valid also in large-scale cells. Developed materials can directly be transferred to industrial scale stacks creating advantages in the overall development process. The final NEWELY component selection is validated in a demonstrator stack comprising 5 cells with an active area of 200 cm² and an overall power consumption of 2 kW, which is being characterised also utilizing the test bench at FBK.

Test bench designed and constructed by FBK to test NEWELY materials.

Single cell AEMWE testing device based on hydraulic cell compression

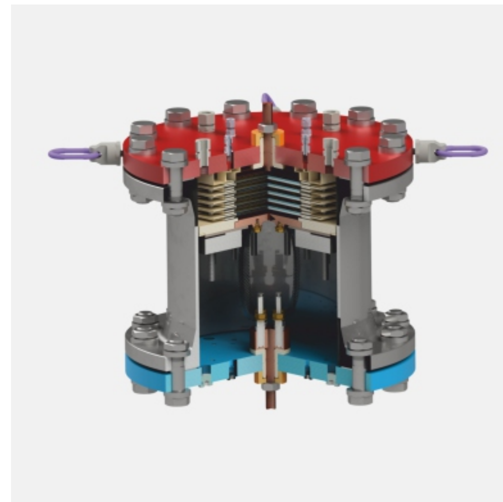


Image of the stack installed in FBK by WHS.

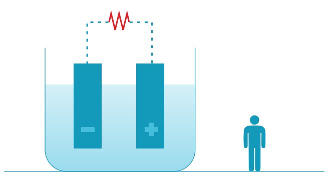
Exploitation

Why is NEWELY relevant for policy makers and industries?

- Raise awareness of AEMWE technology, its potential impact on reaching a hydrogen-supported fossil fuel–free society, the current status of the technology and further research needs to accelerate its implementation.
- EU competitiveness in production of green hydrogen from renewable sources at large scale.
- CAPEX for 2 kW determined: sizes of industrial relevance of 100 kW, 1 MW and 5 MW calculated by extrapolation based on the project results and known learning curves
- Electricity consumption and sourcing are confirmed to be the first optimization parameters to reduce the environmental impact of electrolytic hydrogen. This conclusion is independent from the water electrolysis technology (NEWELY AEMWE, PEMWE or AWE). Moreover, this conclusion remains valid also if the electrolyser is powered by the renewable electricity of the lowest environmental impact.
- In the NEWELY AEMWE stack, the innovative CRM-free catalysts are much more environmentally friendly than the conventional catalysts
- A modular, scalable and affordable system approach meets the specific needs and demands of different kinds of green hydrogen production infrastructures in the EU and all around the world from decentralised facilities to large-scale plants.
- Possibility for high-pressure hydrogen production with no additional compression using CRM-free alkaline technology
- Increased current density at high efficiency compared to alkaline water electrolyser reduces the footprint of the electrolyser installation

CRM-free alkaline technology

NO additional compression required.



Small footprint

Consortium

NEWELY has an international consortium which consists of 1 large hydrogen company, 3 small-medium-enterprises (SME) with market experience in the production and commercialization of membrane, electrodes and stack. They are supported by a group of 7 renowned R&D centers with high expertise in polymer chemistry and low temperature electrolysis.

PROJECT COORDINATOR

Deutsches Zentrum für Luft- und Raumfahrt - DLR
Germany

Deutsches Zentrum für Luft- und Raumfahrt eV., Institute for Engineering Thermodynamics (DLR) is coordinator of the project. It is developing porous transport layers and electrode coating procedures and performs tests in single cell.

LARGE COMPANY

Air Liquide Paris Innovation Campus (Air Liquide)
France - Germany

Air Liquide was responsible for the technoeconomical evaluation of AEMWE versus PEMWE and AWE and the Life Cycle Assessment (LCA) of the solutions proposed in the project.

SMEs

Membrasenz SARL
Switzerland

MEMBRASENZ led and coordinated the efforts of partners engaged in the membrane and ionomer development, ensuring the outlook on products' possible commercialization phase from the initial technology readiness levels.

ProPuls GmbH
Germany

ProPuls was responsible for the development and realization of harmonized AEM testing devices, including test cells as well as a fully automated test bench that was established in the laboratory of FBK. Further, together with WHS, ProPuls performed the common development of the prototypic NEWELY stack.

Cutting-Edge Nanomaterials UG - (CENmat)
Germany

CENmat was Leader of work package 3, Electrode Packages, developed and delivered all electrocatalysts and supported the project in the cell testing section with CENmat's proprietary AEM testbench.

RESEARCH INSTITUTES

Fondazione Bruno Kessler (FBK)
Italy

The Centre for Sustainable Energy of Fondazione Bruno Kessler lead the Work Package on Communication, Dissemination and Exploitation and was responsible of testing and assessing the performance of the materials and components, like membranes and electrodes, that Partners were developing within the project.

Korea Institute of Science and Technology (KIST)
South Korea

The Korea Institute of Science and Technology (KIST) invented a new strategy to strengthen membranes with nanofiber mats, developed a method to minimize dimensional changes of membranes during electrolyser assembly and established novel characterization methods to test membrane properties.

University of Chemistry and Technology Prague (UCTP)
Czech Republic

UCTP characterized newly developed membranes under the conditions of alkaline water electrolysis and optimized the approach of the catalyst coated membrane preparation.

Westfälische Hochschule University of Applied Sciences (WHS)
Germany

Westfälische Hochschule (WH) was responsible for adapting the approach of hydraulic single cell compression to AEMWE technology and building up the final demonstrator stack in close cooperation with ProPuls. within the project.

CEA French Alternative Energies and Atomic Energy Commission
France

CEA/Liten was in charge of electrodes manufacturing and single cell testing. Moreover, CEA was also responsible for the development a model for performance and the ageing of AEM WE.

Ústav Makromolekulárni Chemie AV ČR (IMC-CAS)

Ústav Makromolekulárni Chemie AV ČR (IMC-CAS) developed new anion exchange polymers with high ion exchange capacity, prepared membranes and ionomers with high conductivity and stability for testing and electrode preparation and provided the membranes for NEWELY stack. Basic membrane and ionomer testing was also done by IMC-CAS.

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