





#### WELCOME TO THE SECOND APOLO NEWSLETTER

APOLO Project Consortium is proud to present its second public newsletter!

The goal of APOLO project is to decarbonise maritime industry by implementing alternate power conversion technologies. Over the past 15 months, APOLO consortium has been making good progress in key component development or the catalytic membrane reactors which are to be integrated with fuel cells and engines in the prototypes. This is also supported by preliminary modelling as well as life cycle analysis.

In this edition, we share details on APOLO project's key technology of membrane reactor, research updates, activity updates and insights from our partners. You'll also find details on upcoming events and opportunities to engage with the APOLO Project.

We hope you enjoy this update and continue to follow our journey toward a more sustainable maritime sector. For more details, visit <u>www.apoloproject.eu</u>.

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## Message from our coordinator

# APOLO celebrates more than 1000 followers on LinkedIn.

"I am extremely delighted to see that APOLO is receiving attention among fellow academics and industry enthusiasts. The appreciation for APOLO technologies reflects the growing global need for decarbonisation strategies, especially in the maritime sector. On behalf of APOLO consortium, I would like to express my heartfelt gratitude and would like to request all our followers to keep supporting APOLO in its efforts to fight global climate challenges through alternate decarbonisation strategies."



#### Visit APOLO's Linkedin page https://www.linkedin.com/company/apolo-project/





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# MEET OUR TECHNICAL MANAGER



It is our pleasure to introduce our technical manager: **Prof. Fausto Gallucci** from **Eindhoven University of Technology (TU/e)**. Prof. Gallucci studied Chemical Engineering at the University of Calabria where he obtained his MSc (2001) and PhD (2006) degrees. His PhD research was on hydrogen production from methanol in membrane reactors. He has been Coordinator, Technical Manager or PI in 35 European projects since he started his career in TU/e.

The membrane reactor research in Prof Gallucci's group is carried out through integration of in house developed advanced experimental techniques and experimental proof-ofconcept of novel reactor concepts. Prof. Gallucci has been working since 2019 on ammonia cracking with membrane reactors and has several patents on the Membrane Reactors technology, which is the base of the APOLO project key technology.

#### Meet our partners - Eindhoven University of Technology (TU/e)

The *Sustainable Process Engineering (SPE)* group at TU/e focuses on developing small-scale, intensified, and integrated systems for the distributed production of chemicals with minimal environmental impact and zero waste. By utilizing alternative energy sources such as light, electricity, and bio-based materials, the group designs innovative reactors capable of continuous, high-efficiency chemical production. Their multidisciplinary approach encompasses expertise in reaction engineering, separations, photo-catalysis, electrochemical engineering, and automation, aiming to revolutionize the chemical industry towards a more sustainable and circular economy.

#### Meet our researchers



**Roberto Fiorillo** is a PhD Candidate at TU/e. He contributes to the development of APOLO's ammonia cracking technology through modelling of key components and processes for ammonia-based power conversion, including developing kinetic models for catalysts and sorbents, studying Pd-based membrane permeation mechanisms, and optimizing the integrated ammonia cracking system.

**Sofia losifidou** is also a PhD Candidate at TU/e, contributing to the modeling and optimization of ammonia-based power conversion systems. Her work focuses on the techno-economic assessment of integrated ammonia cracking and power generation technologies, developing detailed process models for key components, including membrane reactors, PEM fuel cells, and internal combustion engines (ICEs). By integrating these components, the goal is to improve efficiency and cost-effectiveness in ammonia-to-electricity conversion.



# **Key Technology: Membrane reactor**

The **APOLO Project** explores ammonia-to-power conversion as a clean energy solution, with Work Package 2 (WP2) focusing on its techno-economic feasibility. This involves developing models for ammonia cracking reactors, fuel cells, and internal combustion engines (ICEs) using Aspen Plus®. A key challenge is ensuring high-purity hydrogen for PEM fuel cells, which **can only tolerate ammonia(NH3) concentrations below 0.1 ppm**, as even minimal amounts of NH<sub>3</sub> in the permeate can compromise the **fuel cell's operation**, reducing its efficiency and operational lifespan.

The **membrane reactor** addresses this issue by combining **reaction and separation** into a single unit. The use of **selective membranes**, **such as palladium-based ones**, allows real-time **hydrogen extraction**, preventing the permeate from containing ammonia above a critical threshold that could damage downstream fuel cells. Additionally, this technology shifts the reaction equilibrium towards a more complete NH<sub>3</sub> conversion, improving overall efficiency and lowering operational costs by eliminating the need for complex **post-treatment purification** processes.



At the **power generation level**, WP2 evaluates:

- Spark-ignition engines running on ammonia-hydrogen blends
- PEM fuel cells powered by high-purity hydrogen

These systems are modeled using ANSYS Chemkin and MATLAB, with results integrated into Aspen Plus® to assess overall efficiency and cost-effectiveness.

In the APOLO project, which aims to demonstrate the scalability of ammonia-based solutions beyond 3 MW, membrane reactors play a fundamental role in ensuring compatibility between ammonia cracking and fuel cells. One of the key developments within the project is a 125 kW power conversion system that integrates an ammonia cracker with a PEM fuel cell, achieving an overall efficiency between 51% and 54%. In addition, a partial ammonia cracker coupled with a 4-stroke engine is being developed, with an efficiency exceeding 45%. In both configurations, maintaining ultra-pure hydrogen is crucial, making membrane reactors the ideal solution to ensure system performance, reliability, and long-term viability.

# **HIGHLIGHTS AND UPDATES**

PROJECT FOLLOWUP

#### M12 CONSORTIUM MEETING



Last 8th January 2025, Nuvera hosted the M12 Consortium Meeting of the APOLO Project at its Osio Sopra facilities, bringing together all project partners for a day of collaboration, knowledge-sharing, and strategic planning.

The event began with insightful presentations, where partners showcased progress on their respective work packages and tasks, highlighting key advancements and reinforcing the project's spirit of innovation and teamwork.

Partners, then, toured Nuvera's state-ofthe-art laboratory, gaining firsthand insight into cutting-edge research and development efforts. This immersive experience further strengthened the collaborative atmosphere of the meeting.

The day concluded with a social dinner at Villa Appiani, where participants enjoyed local culinary specialties in a relaxed setting, fostering connections beyond the professional sphere.



This successful event underlined the strong partnership within the APOLO Project consortium, setting the stage for continued progress and innovation in the months ahead.



More details on the M12 Consortium meeting is included in the video uploaded in the project website:

https://www.apoloproject.eu/dissemination/videos/

# HIGHLIGHTS AND UPDATES

**DISSEMINATION ACTIVITIES** 

### **PARTICIPATION IN ISPCEM**

APOLO Project rollup was showcased at the 6th ISPCEM, International Symposium on Plasma for Catalysis and Energy Materials, held in Eindhoven (NL) at the beginning of July 2024.

This was a fantastic opportunity to share the mission, consortium and technologies of APOLO project to researchers and experts involved in other fields also through the leaflet.



### **PARTICIPATION IN 3SoAE**

From 23<sup>rd</sup> to 26<sup>th</sup>September 2024, a PhD Gaetano Anello from TU/e talked about "Advancements in lowtemperature ammonia decomposition on Cs-Ru/CeO2 catalysts: a kinetic study" at 3<sup>rd</sup> Symposium on ammonia Energy (https://soae.sjtu.edu.cn/) in Shanghai.



His presenation is available in APOLO project website: <u>https://www.apoloproject.eu/dissemination/presentations/</u>

### OTHER PARTICIPATION:

Our coordinator Angela Mary Thomas represented the APOLO project with a poster presentation at the "12<sup>a</sup> Conferencia del Programa Marco de Investigación e Innovación de la Unión Europea en España – Horizonte Europa", conducted by CDTI Innovación – Centro para el Desarrollo Tecnológico y la Innovación. The event took place on 28th November 2024 at the Palacio de Congresos de Oviedo, Spain.







PhD Gaetano Anello from our Partner TU/e, presented a poster at 19<sup>th</sup> Netherlands Process Technology Symposium in Groningen, held from 8<sup>th</sup> and 9<sup>th</sup> October 2024.

His poster talked about Cs-enhanced Rubased catalysts for low-temperature NH<sub>3</sub> decomposition.



# **FOLLOW APOLO PROJECT**

Stay updated with the latest news on the APOLO project by following us on LinkedIn and visiting our website. Get insights into our progress, events, and key developments as we work towards advancing sustainable maritime fuel solutions.



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