

Ammonia based membrane
reactor for green Hydrogen



Welcome to this first ANDREAH newsletter!

ANDREAH is a four-year European project, whose main objective is to provide a quantum leap in the development of advanced ammonia decomposition technologies to produce ultra-pure hydrogen (>99.998%) by developing an innovative system based on a Catalytic Membrane Reactor (CMR) for the cracking of Ammonia. In this way, optimised heat management, improved conversion per pass and purification/recycling for more cost-efficient and resource-effective ammonia decomposition at lower temperatures compared to conventional systems will be achieved.

The present newsletter is the first release of the biannual letter that will be published by ANDREAH presenting the progress on the project and highlighting information related to the R&D fields addressed. Hope you will find the info in this newsletter interesting. On our website www.ANDREAHproject.eu you will find public presentations, all the public deliverables of the project and many other interesting news. Stay tuned!

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About the Project

ANDREAH is clustered around 3 phases, which will allow the smooth and sound transition from current development stage of the technologies to a validation at TRL 5.

As shown in the picture below, the ANDREAH methodology comprises upstream R&D activities of the proposed technologies, followed by selection and development of the final prototype.

Finally, the validation of the selected technology will take place and the main KPIs for hydrogen production from NH_3 will be analysed.

Phase 1 – R&D (M1-M24): led by the universities, RTOs and industrial partners, this phase is mainly focus on the optimization of key building blocks (membranes, catalysts, sorbents and Reactors). Most of the experiments during this phase are performed at laboratory or small scale. The key components in this phase will be developed by TEC (membranes), CNR and UMI (catalysts) and TUE (sorbents and reactors).

The main research areas that are explored within the R&D phase of ANDREAH as well as how they will go beyond the state of the art are explained in detail below, following the key components of the concept.

Moreover, this R&D phase is organised into three different pillars:

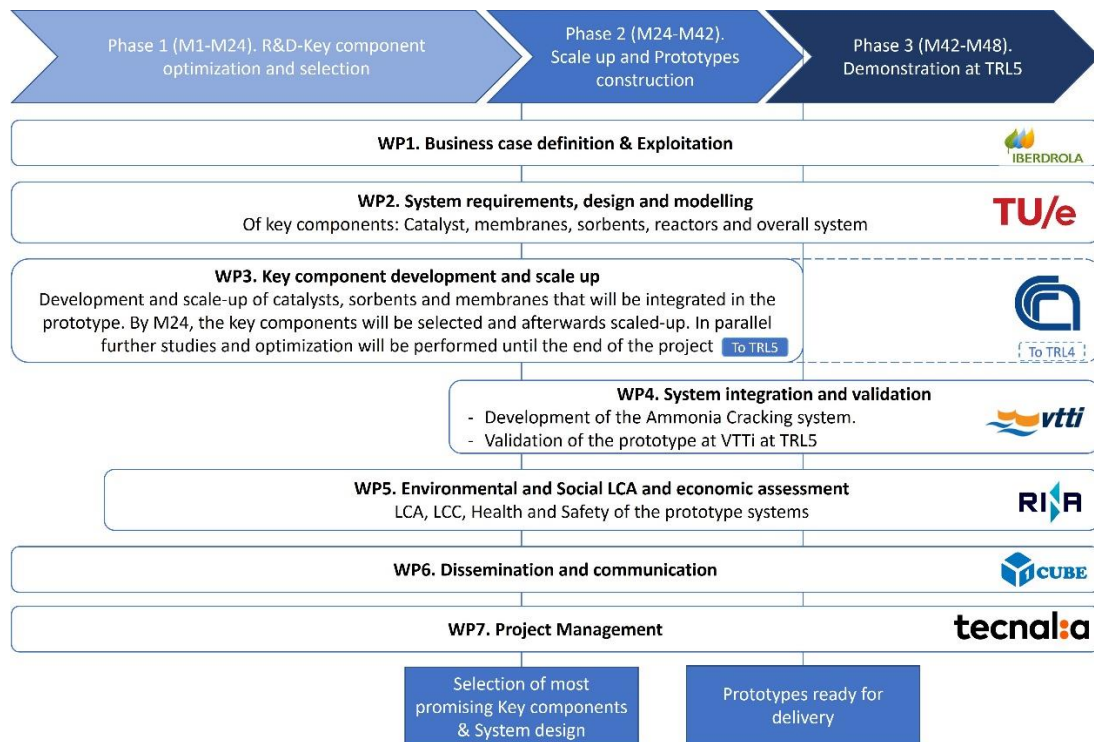
- The first pillar includes modelling activities (by TUE) to guide R&D partners on the best combination of catalyst, sorbents, reactors and membranes to define the experiments in an effective way.
- In the 2nd pillar, experiments with H_2 and NH_3 process that are well known for the R&D partners will be carried out first to validate the modelling.
- Gradually, R&D partners will move towards pillar 3 where they will perform experiments combining different components together as well as more complex streams based on the knowledge acquired in the first and second pillars.

A Design of Experiment approach will be used to find the best combination of parameters and processing routes for the different key components. This will reduce drastically the number of experiments needed in order to find the optimal combination of key building blocks.

The final outcome of Phase 1 will be the selection of the key components for their scale up in Phase 2. However, R&D on lower TRL components will also be made within the project to obtain direct indications on alternative solutions (up to TRL4).



In short:



Impacts

ANDREAH aims to reduce the environmental impacts of transport and energy by developing innovative ammonia cracking solutions. The LCA analysis will be a continuous process to firstly drive the development of the new materials (catalyst, membranes and sorbents) and process to be environmentally friendly, and then to ensure reaching such objective with validation data.

The development of ANDREAH systems will be supported also by a detailed techno-economic analysis with the aim of reducing the overall capital and operating costs, considering the whole value chain.

Currently, most of the jobs in the EU energy sector are linked to conventional energy sources such as oil, gas, coal and nuclear. But clean energy technologies are becoming a dynamic area for investment and employment; in 2020, 24% of the total EU employment in the renewable sector was linked to heat pumps (318,000 jobs), followed by 22% in biofuels (283,000 jobs) and 21% in wind power (280,400 jobs), and around 1.3 million persons were directly or indirectly employed in the sector.

With ANDREAH project one of the highest impact is promoting high value-added employment: 436 direct jobs and 3,223 indirect induced jobs.



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ANDREAH has an interdisciplinary approach which includes chemistry, material design, engineering, modelling, manufacturing, safety, business and economics. ANDREAH is back up by the experience and know-how of companies specialised in materials development (UMI), process design and plant construction and operation or energy multinational companies (IBER). Moreover, top-level European Research public/private Institutes and Universities will collaborate (TUE, CNR and TEC) to turn ANDREAH objectives into results that can later be scaled-up and exploited.

Finally, full LCA, LCC and HSA will be performed by RINA which together with tailored dissemination and communication strategies led by 1CUBE BV will make ANDREAH a success.

ANDREAH consortium is composed of 9 partners from 4 different countries:

TECNALIA



Fundación Tecnalia Research & Innovation (<https://www.tecnalia.com>) is the largest private, non-profit applied research centre in Spain, a benchmark in Europe, and member of the Basque Research and Technology Alliance (BRTA).

Tecnalia is a key agent in the European Research Area. Tecnalia actively participates in the governing bodies of several European Technology Platforms, PPPs and JTIs (EEB, FOF, SPIRE, ARTEMIS...) and associations. Tecnalia has participated in 252 H2020 projects, coordinating 73 of them, and on 94 HORIZON EUROPE projects by end 2022 coordinating 16 of them.

The Membrane Technology and Process Intensification group of the Hydrogen Materials and Processes Dept. in the Energy, Climate and Urban Transition Unit is involved in the project. The group develops advanced membranes and membrane reactors for industrial gas and liquid separation demands. Aiming at increasing the efficiency, reducing the operating and capital costs as well as physical and environmental footprint in different applications. Some examples, H₂ purification and production, CO₂ capture and conversion, natural gas processing, biogas upgrading and olefin/paraffin separation among others. We have extensive testing and membrane manufacturing capabilities, and we have experience on working from proof-of-concept to relevant industrial scale.

Role in ANDREAH:

TECNALIA is acting as Project coordinator and is in charge of the development of membranes for ammonia (NH₃) decomposition in a catalytic membrane reactor to allow



hydrogen production in a cost-efficient and resource effective process at lower temperatures and pressures compared to the conventional ammonia cracking technologies.

Website: www.tecnalia.com/en/

Eindhoven University of Technology



Eindhoven University of Technology (TU/e) is a research university specializing in engineering science & technology. Our education, research and knowledge valorisation contribute to: science for society:

- solving the major societal issues and boosting prosperity and welfare by focusing on the Strategic Areas of Energy, Health and Smart Mobility
- science for industry: the development of technological innovation in cooperation with industry
- science for science: progress in engineering sciences through excellence in key research cores and innovation in education

The research group Sustainable Process Engineering is part of the Faculty of Chemical Engineering and Chemistry at the Eindhoven University of Technology. The main objective of the research group is the development of novel integrated reactor concepts (such as membrane reactors, micro reactors, structured catalysts and reactors) based on improved fundamental knowledge using validated advanced (multi-phase) reactor models. This is achieved by employing a combination of state-of-the-art numerical models (at different levels of detail using the multi-level modelling approach), advanced (non-invasive) experimental techniques and experimental demonstration of novel reactor concepts (proof of concept).

Role in ANDREAH:

Development of membrane reactors, WP leader, Fausto Gallucci is Technical Manager of the project.

Website: www.tue.nl/spe



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Consiglio Nazionale delle Ricerche (National Council of Research – CNR, Italy, <http://www.cnr.it>), is a public research organisation; its duties are to carry out, promote, spread, transfer and improve research activities in the main sectors of knowledge growth and the application of this research for the scientific, technological, economic and social development of the country. The scientific network of the National Research Council of Italy consists of more than 100 Institutes, divided into 7 Departments. The Institute for Advanced Energy Technologies “Nicola Giordano” (ITAE), headquartered in Messina, operates within the Department of “Engineering, ICT and Energy and Transport Technologies”, being one out of a total of 21 research institutes grouped according to similar competencies and strategic priorities of the reference macro-area. ITAE develops and promotes energy-efficient, innovative technologies with low environmental impact through the use of fossil and renewable energy sources. The scientific expertise of ITAE is related to developing and optimising materials and chimica/technological processes for producing electric and/or thermal energy along with new fuels with specific reference to hydrogen. Approx. 100 people are employed at ITAE.

Role in ANDREAH:

Within the ANDREAH project, CNR-ITAE is leading the WP3 “Key components development and scale up”. CNR-ITAE is also responsible for developing new catalysts (CRMs free or with a reduced amount of CRMs) for ammonia decomposition, based on perovskites structure and capable of operating at low temperatures (400-450°C). The Team is also involved in the developing of structured catalysts with improved heat and mass transfer, based on Open-Cell Foams (OCFs), 3D printed Periodic Open Cell Structures (POCSs) and Triply Periodic Minimal Surface (TPMS) microarchitecture. Specifically, CNR-ITAE works on the activation of the supports, with novel catalytic materials, with the aim to reach a detailed rationalization of the adopted procedures. Different structured catalysts configuration concepts (coated and packed structured catalysts) for the integration with selective hydrogen membranes in a membrane reactor system will be investigated. The activities will help to generate a deep understanding of the underlying principles of the geometry-transport interactions and to define how the properties of the structured catalysts may determine advancement in the ammonia dehydrogenation process. Finally, CNR-ITAE will collaborate with UMICORE, to develop an efficient scale-up strategy capable of ensuring the necessary quantity of catalyst to prepare structured catalysts and validate the ANDREAH membrane reactor technology at the demonstrator scale.

Website: www.itae.cnr.it



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Umicore is a leading circular materials technology Group. It focuses on application areas where its expertise in materials science, chemistry and metallurgy makes a real difference. Its activities are organized in three business groups: Catalysis, Energy & Surface Technologies and Recycling. Each business group is divided into market-focused business units offering materials and solutions that are at the cutting edge of new technological developments and essential to everyday life.

Umicore generates the majority of its revenues and dedicates most of its R&D efforts to clean mobility materials and recycling. Umicore's overriding goal of sustainable value creation is based on an ambition to develop, produce and recycle materials in a way that fulfils its mission: materials for a better life.

Umicore's industrial and commercial operations as well as R&D activities are located across the world to best serve its global customer base. The Group generated revenues (excluding metal) of € 4.2 billion (turnover of € 25.4 billion) in 2022 and currently employs more than 11,000 people.

Website: www.umicore.com

Role in ANDREAH:

Within WP3 Umicore will develop, evaluate and scale-up catalysts.

INNOENERGY



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EIT InnoEnergy, recognised as one of Europe's top investors in cleantech, was established in 2010 with the support of the European Institute of Innovation and Technology (EIT). InnoEnergy operates as a fully independent commercial company, and still has close connection to the European Commission which co-fund

some activities.

InnoEnergy accelerates, de-risks and boosts global business cases through its unique and trusted ecosystem of more than 1200 partners, 35 shareholders and a 200+ strong team with offices across Europe and in Boston, US. The managed ecosystem incorporates industrial players of all sizes, investors (public and private, equity and debt), academia, research centres and public administration. InnoEnergy provides support to global



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innovators through their full life cycle (from early stage to industrial scale), with a one stop shop model.

InnoEnergy backs innovations across a range of areas. These include energy storage, transport and mobility, renewables, energy efficiency, hard to abate industries, smart grids and sustainable buildings and cities.

InnoEnergy's deal flow is in early-stage innovative technologies in cleantech, normally CAPEX heavy. Since its inception, InnoEnergy has screened more than 7,000 start-ups, launched more than 300 products to market and overseen its portfolio companies filing 370+ patents. InnoEnergy currently has a portfolio of 200 companies, three of which are unicorns, on track to generate €110 billion in revenue and save 2.1G tonnes of CO_{2e} accumulatively by 2030. Collectively, these companies have raised €9.7 billion in investment to date.

In September 2023 InnoEnergy had a successful private placement round of over €140 million of equity. Investors in this round are new strategic players (Société Generale, Santander CIB, PULSE - CMA CGM Energy Fund, Renault Group, Stena Recycling and NIIT), and existing shareholders (Siemens Financial Services, Schneider Electric, Capgemini, Volkswagen Group, ING, Koolen Industries, GROUPE IDEC and Engie).

InnoEnergy is active in four related areas bringing the technology and skills required to accelerate the energy transition:

Incubation

- Start-ups and scale-ups receive tailored support to boost and de-risk their business cases and speed up time to market and impact – from access to (pilot) customers, funding, and talent, insights on market developments and regulations to joint technology enhancement and promoting citizen engagement and social acceptance. InnoEnergy provides a combination of cash and in-kind support in return for an equity position.
- Examples of supported start-ups which turned into industrial champions: Northvolt, H2Green Steel, Skeleton Technologies

Innovation support

- We help established industrial companies and consortia create new business and overcome major industry transformation challenges through co-development of innovation projects.
- Examples of innovation projects providing new solutions and shaping industries: Hardt Hyperloop, CorPower Ocean, ECOP Technologies.

Strategic Value Chains

- We create our own industrial players in strategic European Value Chain Initiatives which include the European Battery Alliance (EBA), the European Green Hydrogen Acceleration Centre (EGHAC) and the European Solar Photovoltaic Industry Alliance (ESIA).



- Examples of new companies created decarbonising hard to abate industries and providing resilience and economic growth for European supply chains: Verkor, GravitHy, FertigHy, Holosolis.

Human Capital

- Our eight master's programmes at 16 top technical universities and business schools, equip students and learners to become the leaders of the green transformation of our economy and provide the necessary talent. There are already 1.600 alumni which are shaping the future of sustainable energy.
- Our Skills Institute is one of Europe's leading training skills providers for the sustainable energy workforce spanning energy storage, photovoltaics, and green hydrogen. End 2023 the InnoEnergy Skills Institute has announced a major commercial milestone; the completion of specialised training courses for over 50,000 individuals, a significant step towards addressing the growing workforce demands in the battery industry. The revenues generated from our activities (e.g. sales of an equity stake or proceeds from skills institute) are re-invested in new innovations, creating a self-sustaining flywheel for accelerating sustainable energy innovations, creating a continuous growing portfolio in number and value and hence the valuation of InnoEnergy.

VTTI



VTTI is a global leader in independent energy storage and develops critical energy infrastructure needed to move towards a carbon neutral future. Fueled by our purpose, "Energy to Move Tomorrow," we safely provide and expand access to essential energy, including fuels, chemicals, gasses, and other energy derived products and accelerate

the transition to sustainable sources for our customers and partners.

We safely and sustainably store, blend and process energy products to required specifications at our 16-energy storage and processing terminals, that provide 9 million cubic meters of storage capacity. We then facilitate the offloading and onloading of these products to ships, trains, trucks and pipelines at key crossroads of trade.

We also play an active role in shaping the energy infrastructure needed to help the world decarbonize, by developing and investing in more sustainable energy storage, which includes storage for biofuels and sustainable aviation fuels (SAF), among others. We are also developing the energy infrastructure needed to decarbonize, including liquified natural gas (LNG), as a transitional energy, renewable natural gas (RNG), hydrogen and energy and resource recovery from waste. By 2028, we aim to triple the size of our business, with over half our revenue coming from low-emission energies.

For the two decades we have been operating, we have always been a company with big ambitions. Our team of 1,300 does things the "VTTI way," ensuring we best serve our stakeholders today, with an eye towards tomorrow. Our people are curious, creative and in constant search for better solutions. Our collaborative thinking proactively solves problems and



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overcomes challenges. Working safely, smartly and with integrity is always our priority – doing right by each other and doing things right for those we serve.

1 CUBE BV



1 Cube BV is a Dutch company specialized in support for research projects management and dissemination. We organize, write, submit, manage research and development projects.

We also act as Partners for EU project, above all on business planning, exploitation, dissemination and management.

Role in ANDREAH:

WP leader for dissemination. Dissemination Manager

RINA



With a global network of over 5,300 talented professionals operating out of 200 offices in 70 countries, we are committed to simplifying complexities with a focus on energy transition, ESG and digitalisation.

We specialise in testing, inspection, certification, and engineering solutions across a wide range of markets, including Marine, Energy and Mobility, Real Estate and Infrastructure, Space and Defence, and Industry 4.0.

At RINA, we collaborate with our clients to find innovative solutions to complex problems, leveraging our expertise to anticipate and tackle any challenges along the way. Our ultimate goal is the improvement of the quality of life and building sustainable values for future generations. Our people come from different cultures, countries, and backgrounds and, respecting and embracing these differences, makes us much stronger.

Role in ANDREAH:

RINA is active in ANDREAH in mainly two macro-tasks:



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In the first one, RINA will support the management of results, working mainly on a strategy for IP protection and management, the market analysis, and the development of a business model. Putting all together, an exploitation strategy for project KERs will be drafted and the project's outcomes will be analysed to develop regulatory and standardization pathways.

In addition, RINA is focused on the assessment of results from an economic, social and environmental perspective. This task will be carried on according to the LCA and LCC methodologies and standards. The task will also include a comprehensive analysis of the Health and Safety aspects related to the developed products and processes. The expected economic profitability of the demonstrated processes will be quantified.

Website: www.rina.org/en/

IBERDROLA



With a history of over 170 years, today IBERDROLA is a global energy leader, the number-one producer of wind power and one of the world's biggest electricity utilities by market capitalisation. In its mission to lead the energy transition, Iberdrola is spearheading the development of green hydrogen and its derivatives with two real projects already built in Spain: the largest green hydrogen plant in Europe today, our 20 MW Puertollano plant for fertilisers and potentially for other industrial uses and heavy mobility, and our 2.5 MW green hydrogen refuelling station for buses in Barcelona. Overall, the Group currently has over 60 projects under different phases of development in eight countries (Spain, the United Kingdom, Australia, Brazil and the United States, among others) to meet the demand for electrification and decarbonisation in hard-to-abate sectors. Iberdrola is addressing the technological challenge of producing and supplying green hydrogen and derivatives, such as green ammonia, e-methanol or green steel, from clean energy sources, powering the electrolytic process with 100% renewable electricity. Iberdrola has the ambition to reach 3 GW of electrolyzers installed capacity worldwide by 2030.

Role in ANDREAH:

As the leader of the WP1 Business case definition & Exploitation, Iberdrola has the main role of setting the foundation for effective development and exploitation of results into the market, providing a clear picture of needs and legislative framework.



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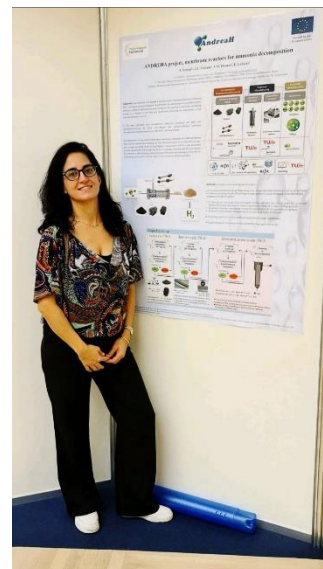
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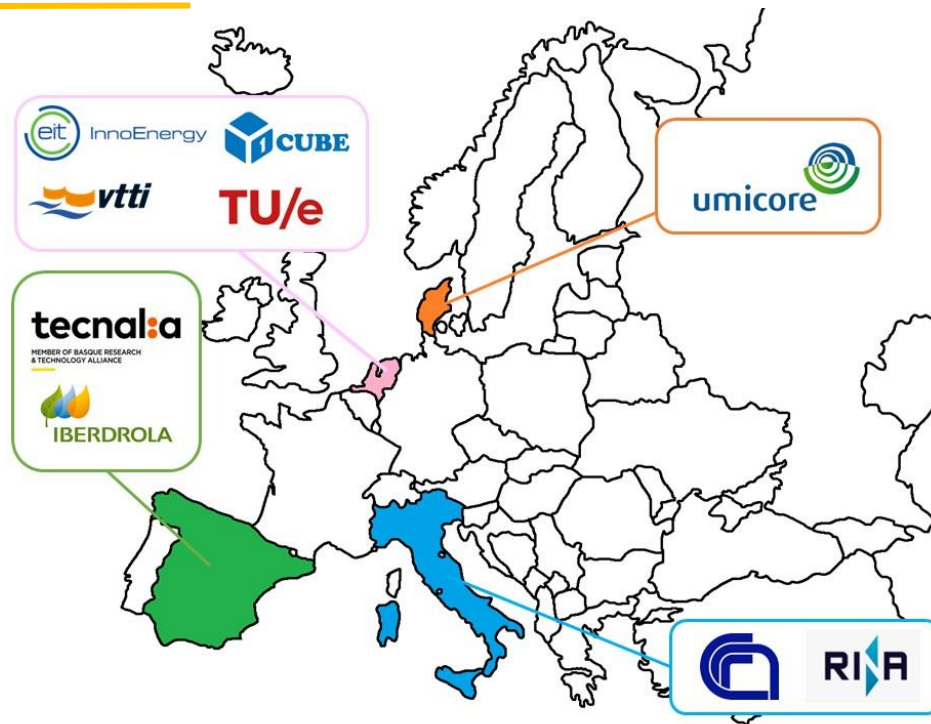


The ANDREAH project has been presented by our WP leader of Dissemination at the 16th International Conference on Catalysis in Membrane Reactors in San Sebastian (Spain), October 16-18, 2024

The ICCMR16 has been organized by Tecnalia Research & Innovation, (ANDREAH project coordinator) a member of the Basque Research and Technology Alliance in Spain. The purpose of this conference is to promote research and advancement in the field of catalytic membrane systems.

The event highlighted recent developments, introduced new ideas, and brought together academic scientists and industries working in the field of membranes.





Project details:

Project Number: 101112118
Title: AmmoNia based memBRane rEActor for green Hydrogen production
Project Acronym: ANDREAH
Call: HORIZON-JTI-CLEANH2-2022-2
Starting date: July 1st, 2023
Duration: 48 months
UE funding: 2,980,361 Euro
Coordinator: Fundación Tecnalia Research & Innovation
Project Coordinator: José-Luis Viviente, Jaione Ollo Loinaz



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