PhD Program in Civil, Chemical and Environmental Engineering
Curriculum in Chemical, Materials and Process Engineering

June 2026 Call, XLII cycle - Starting date: November 1 st 2026

The research projects submitted for the admission to the PhD program must be prepared in accordance with one of the projects listed in this file, which are organized by general thematics. Click on the Thematic you are interested in to see the full list of projects.

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Projects in Plants and bioprocesses

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Thematic: Projects in Plants and bioprocesses

Project: Treatment of agro-industrial wastewaters and emerging pollutants using microalgae

Keywords: emerging pollutants, microplastics, new plant development, microalgal biomass exploitation.

Brief Description:
The increasing of urbanization and industrialization leads to the production of large quantities of wastewater around the world. Part of this waste can be treated and exploited for the growth of microalgae, reducing their cultivation costs, and making chemicals recovery and biofuel production more feasible.
Using the mixotrophic metabolism, microalgae are able to absorb and use many of the organic molecules contained in wastewater (antibiotics, heavy metals, microplastics, etc.), reducing its polluting load, leading to the production of additional microalgal biomass and to the purification of the water used.
After the growth, the microalgae biomass can be collected and used for the production of biofuels and for the recovery of chemicals of interest.
Batch and continuous microalgal growth systems are available in the laboratory of the research group. By means of these plants, wastewater (e.g.: olive mill and winery wastewaters, landfill leachate, sewage wastewaters, etc.) will be micro-phytotrophically treated and then analysed.
An *ad hoc* plant for the growth and the collection of microalgae in wastewaters will be studied and tested, reaching the goal to work in a full continuous mode. A pumping system, operating with variable flow rates, will be carefully developed to make the device less energy intensive and to reduce the hydraulic retention time. Downstream of the cultivation system, a plant will be designed for microalgal biomass settling, and the microalgal biomass will be collected using new methodologies, such as electro-coagulation.

Referent: Alessandro Alberto Casazza, (alessandro.casazza@unige.it)

Link to the list of projects

Thematic: Projects in Plants and bioprocesses

Project: Anaerobic digestion of agro-industrial residues with a view to a zero-waste approach

Keywords: Agro-industrial waste, zero-waste approach, anaerobic digestion, biogas, microalgae

Brief Description:

This project concerns the application of anaerobic digestion to recover energy from agro-industrial residues. Olive pomace from olive oil production will first be dried to stabilize it and later diluted in water and treated in a 7-liter bench-scale digestor equipped with an agitation and temperature control system. Two different research topics will concern biogas upgrading in biomethane and digestate reuse. In the first case, the produced biogas will be conveyed to a photobioreactor in which a microalga will be cultivated autotrophically using the biogas CO_2 as the only carbon source. As a result, biogas will be converted to biomethane with percentage higher than 90%. The second approach will take advantage of the ability of microalgae to grow under mixotrophic conditions in the presence of organic carbon source such as the contaminants still present in the digestate. In this case, the digestate produced in the first step will be treated in the photobioreactor in fed-batch mode in order to significantly reduce its chemical oxygen demand demand (COD). It is aimed, with the combination of the two approaches, to transform an agro-industrial residue such as olive pomace (or other similar residues) exclusively in biomethane and microalgal biomass to be used as a biofuel and as a raw material for biodiesel production, respectively, thus pursuing the zero-waste goal.

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Attilio Converti (converti@unige.it)

Link to the list of projects

Thematic: Projects in Plants and bioprocesses

Project: Production and characterization of polymeric nanoparticles loaded with monoclonal antibodies

Keywords: biopolymers, encapsulation process, surface engineering, drug delivery,

Brief Description:
The proposed Ph.D. project aims to develop, optimize, and validate immuno-engineered PLGA-PEG nanoparticles functionalized with the L19 antibody fragment for targeted delivery of therapeutic monoclonal antibodies to atherosclerotic plaques.

The research will focus on the integration of chemical engineering principles, nanomaterial design, formulation technologies, and translational biomedical applications to establish a robust platform for targeted cardiovascular nanomedicine.

The project will pursue the following objectives:

1) Design and optimization of biodegradable PLGA-PEG nanoparticle formulations capable of encapsulating therapeutic monoclonal antibodies.

2) Surface engineering and functionalization of nanoparticles with L19 antibody fragments to enhance selective recognition of EDB-fibronectin expressed in vulnerable atherosclerotic plaques.

3) Physicochemical characterization of nanoparticle systems, including: particle size and morphology, surface charge, colloidal stability, encapsulation efficiency, antibody loading capacity, and release kinetics.

4) Investigation of formulation-process relationships and scale-up strategies using advanced manufacturing approaches.

5) Development of predictive correlations between nanoparticle properties and biological performance to support future clinical translation.

Referent: Patrizia Perego (p.perego@unige.it)

Relevant links: www.belong.unige.it

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Projects in reliability and safety of process plant engineering

[Project: Data-driven Risk Assessment under the new challenges posed by Climate Change and Energy Transition]

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Thematic: Projects in reliability and safety of process plant engineering

Project: Data-driven Risk Assessment under the new challenges posed by Climate Change and Energy Transition

Keywords: Climate change, Energy transition, NaTech risk assessment, Data driven predictive model, Major accidents.

Brief Description:

Background and Motivation

Climate change and connected increasing of the frequency and severity of extreme weather events imply that Natural Hazard Triggering Technological Disasters (NaTech) represent a growing threat in the process sector posing complex and dynamic challenges to risk assessment (RA) frameworks that were not designed for evolving hazard landscapes. These aspects are strictly connected to the ongoing energy transition towards new energy vectors e.g. hydrogen covering the whole pipeline from sustainable production to the transport and distribution (hydrogen refueling station, HRS), including the fuel cell applications in naval context. Traditional risk models often rely on static historical data, limiting their effectiveness in anticipating and managing real-time emerging scenarios under rapidly changing environmental conditions.

Research Aim

The PhD project aims to develop a novel framework for dynamic risk assessment (DRA) integrating real-time environmental monitoring with advanced Machine Learning (ML) algorithms to face the challenges posed by energy transition and climate change. The goal is to enhance the predictive capability and responsiveness of current RA systems by combining data-driven approaches with domain expertise in environmental and industrial safety.

Objectives

Overview: critical assessment of the state-of-the-art, bibliometric analysis and research gap selection.

Data Acquisition and Integration: Collect and harmonize multi-source real-time data, including satellite imagery, sensor networks, climate forecasts, and industrial safety reports.

Feature Extraction and Event Detection: Develop ML pipelines to detect early signals of emerging risks from unstructured and high-frequency data streams.

Dynamic Risk Modeling: Design and validate ML-driven models (e.g., LSTM networks, spatiotemporal Bayesian models) to update risk profiles in response to environmental and complex system modification.

Development: Build a real-time decision support tool for emergency managers and industrial operators, incorporating explainable AI techniques for transparency and trust.

Expected Contributions

The research aims at providing a robust, scalable, and explainable ML-based framework that improves situational awareness and response times, shifting from shift from static to adaptive risk assessment. This work supports climate adaptation strategies and the exploitation of new energy vectors by enabling proactive risk mitigation in critical infrastructure systems and port environments.

Supervision and Collaborations

The project will be developed in collaboration with regional environmental risk protection agencies, industrial safety bodies, and academic partners expert in machine learning and complex systems.

Referent: Bruno Fabiano (brown@unige.it)

Relevant links: https://dicca.unige.it/laboratori/lab_chimica/sicurezza_industriale_ambientale

References:

Energy transition technology comes with new process safety challenges and risks Pasman, H., Sripaul, E., Khan, F. Fabiano, B. Process Safety and Environmental Protection, 2023, 177, pp. 765–794.

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Projects in materials engineering

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Thematic: Materials Engineering

Project: Engineering Drug Delivery Devices via Microfluidic Manufacturing Approaches

Keywords: microfluidics, emulsions, polymeric particles, liposomes, mathematical modelling

Brief Description:
Microfluidics is an emerging field that deals with the manipulation of fluids at the micrometric scale, offering high control over fluid behaviour, mixing, and interface formation. This innovative technique has numerous advantages with respect to conventional techniques, including precision in tuning droplet size, composition, and morphology, resulting in highly monodisperse populations. Moreover, microfluidic devices are highly versatile, as evidenced by the ability to customize microfluidic chips in terms of geometry and materials. Thanks to their versatility, precision and efficiency, microfluidic systems have become powerful tools for the synthesis of carrier systems, such as emulsions, liposomes, hydrogel beads, and polymeric nanoparticles. These carriers are of great interest in areas including targeted agriculture, food, cosmetic, biomedical, pharmaceutical, and environmental sectors, where particle size, monodispersity, and structural uniformity are critical parameters. This PhD project will focus on the design and fabrication of microfluidic chips capable of generating different kinds of carriers with high reproducibility and tunability and will combine experimental work with mathematical modelling to better understand and optimize the fluid dynamics and formation mechanisms involved.

Referent: Roberta Campardelli (roberta.campardelli@unige.it)

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Thematic: Materials engineering

Project: Experimental and energy modelling study of a selective electroleaching process for Solid Oxide Cell regeneration

Keywords: Solid oxide cells; Electrochemical production; cell regeneration; selective electroleaching; energy modelling

Brief Description:

This project focuses on the development and preliminary assessment of a selective electrochemical process for the regeneration of Solid Oxide Cells. The main objective is to remove degraded cathodic layers from spent or end-of-life cells while preserving the underlying half-cell structure. The process is based on electroleaching in sulfate solution, where persulfate species are electrochemical generated in situ. These oxidizing species promote the selective dissolution and removal of cathodic materials.

The experimental part investigates the mass-loss kinetics during electroleaching, comparing simplified cathode samples with real multilayer SOC cells. Particular attention is given to the selectivity of the process, with the aim of confirming the preservation of the non-cathodic layers. The work also considers the recovery of leached cathode constituents from the spent electrolyte, with the purpose of assessing possible material valorisation routes. A further part of the study is devoted to the regeneration of the treated half-cell through the deposition of a new cathode. The regenerated cell will be tested electrochemically in order to evaluate the recovery of its functional performance and to compare it with the initial or reference cell behaviour. This step is crucial to demonstrate that the proposed process can enable not only material recovery, but also the functional reuse of Solid Oxide Cell components.

The final part of the work develops an energy model of the batch electroleaching process. The model estimates the mass of cathodic material removed over time and evaluates the integration of the process with a renewable energy system and battery energy storage. This allows a preliminary assessment of energy demand, operating cost and potential environmental benefits. Overall, the work aims to demonstrate that selective cathode electroleaching can be a promising route for SOC regeneration, shifting the focus from simple material recovery to functional reuse of the cell structure.

Referent: Prof. Davide Clematis (davide.clematis@unige.it)

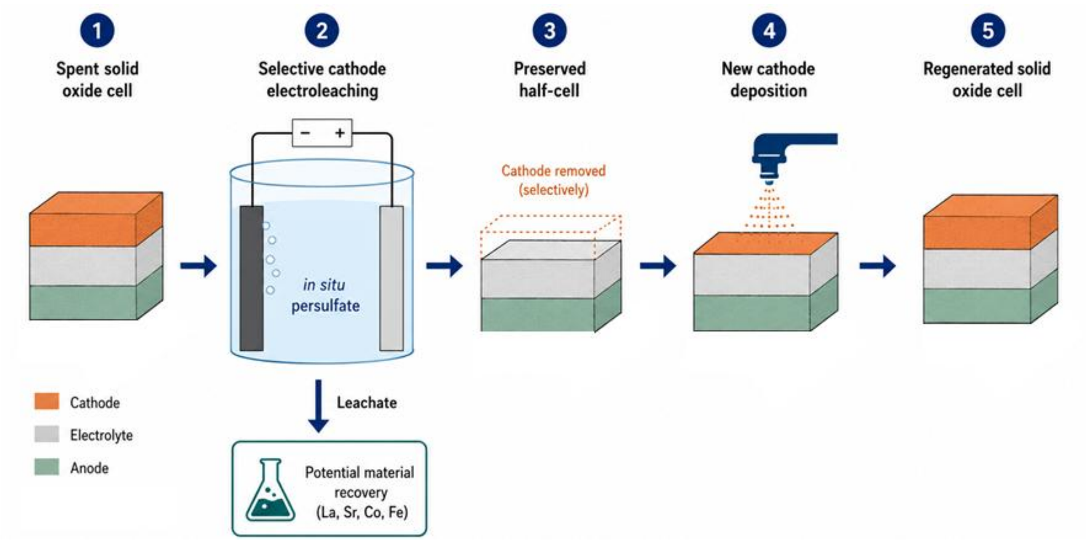

Figure: Process description

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Thematic: Projects in materials engineering

Project: Development of novel catalytic materials for conventional and unconventional heated reactors

Keywords: catalysis, unconventional heating, reactor engineering

Brief Description:

The development of unconventional heated reactors sets new challenges in the framework of the introduction of new reactor designs in the chemical industry, outlining a completely new approach. The present project aimed at understanding the key parameters for the use of unconventional heating, studying and accounting for main process parameters, and investigating their performances in the frame of energy transition relevant reactions i.e., for H_2 production, or other relevant applications. The present project has an experimental nature and will focus on the development and design of engineered materials and processes, by focusing on performance assessment, mechanism, and kinetic investigations.

Referent: Prof. Gabriella Garbarino (gabriella.garbarino@unige.it)

Link to the list of projects

Thematic: Projects in materials engineering

Project: C-based catalysts understanding: activity, selectivity, and possible use of waste graphite

Keywords: catalysis, Carbon-based catalyst, reactor engineering, waste valorization

Brief Description:
Nowadays, there are more than 40 million plug-in electric vehicles circulating worldwide. These vehicles are powered by lithium-ion batteries with an average guaranteed lifespan of eight years. This contributes to a potential waste output of 4 million tonnes of carbon. This project aims to develop C-based catalysts and valorize graphite waste from lithium batteries to produce robust, active heterogeneous catalysts for energy applications, exploring the feasibility of efficiently developing active materials. The project is experimental and will focus on developing engineered materials from waste graphite for CO_2 utilization reactions to produce syngas or e-fuels, with particular emphasis on performance assessment, reaction mechanisms, and kinetic investigations.

Part of the activities will be within the framework of the granted research mobility project "Recovery and Valorization of graphite from spent Lithium-ion batteries for the development of catalysts with applications in energy and CO_2 capture" between the University of Genova and CINDECA (Argentina), funded by MAECI-SiCyT.

Referent: Prof. Gabriella Garbarino (gabriella.garbarino@unige.it)

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Thematic: Projects in materials engineering

Project: Doping of calcium phosphate bone cements with metal ions to enhance the bioactivity of the orthopedic implants

Keywords: bone cement, calcium phosphate, metal ions doping, hydroxyapatite, FT-IR spectroscopy

Brief Description:
The scope of this research program will be to study novel ceramic-based bone cements obtained by doping calcium phosphate with metal ions, evaluating their efficiency in term of morphological, mechanical and biological properties.

All the bone substitutes available on the market have osteoconductivity property (the capacity to create a network for the blood cells of the host in order to provide a 3D architecture into the bone defect), but not osteoinductivity (the direct action of the material as a molecular signal on the native stem cells of the bone), that is confined only to autografts bone substitute. Unfortunately, due to the limited amount of bone that can be harvested, autologous bone transplantation is not feasible for repairing large bone defects. Calcium phosphates as hydroxyapatite (HA), tricalcium phosphate (TCP), brushite and monetite are considered alternative to autologous bone grafts. HA is the main component of human hard tissue; however resorption rate of HA is extremely slow as compared with TCP, that presents high mechanical properties and exceptional bone remodeling capacity. Brushite is also a biomaterial that can be resorbed under physiological conditions. Although monetite has similar chemical composition of the brushite, recent animal studies have demonstrated its good osteoconductive and osteoinductive properties.

The incorporation of selected doping elements into calcium phosphates can be used advantageously to tune the bioactivity of the implant: i.e. antibacterial, anti-inflammatory or angiogenic properties. Within this project, HA and TCP, used directly and as reactants to produce brushite and monetite, will be doped with metal ions: Zn, Sr and Cu. Experimental evaluation of mechanical, chemical and morphological characteristics of the doped bone cements will permit to assess the materials modification connected with the doping, and to check the evolution in the microstructure and of the biological response in vitro.

Referent: Alberto Lagazzo (alberto.lagazzo@unige.it); Elisabetta Finocchio (elisabetta.finocchio@unige.it)

Link to the list of projects

Thematic: Projects in materials engineering

Project: Interfacial Engineering of Graphene-Modified Composite Electrodes

Keywords: Graphene; Composite Electrodes; Lithium-Ion Battery

Brief Description:

This proposal aims to systematically investigate the role of graphene as a functional additive in composite electrodes for both supercapacitors and lithium-ion batteries. Particular emphasis is placed on how graphene exfoliation media (water vs. N-methyl-2-pyrrolidone, NMP) alter surface chemistry, hydrophobicity, and defect density, and how these parameters influence interactions with binders and structured electrolytes.

The study introduces a second critical dimension: electrolyte structuring, especially in highly concentrated systems such as water-in-salt electrolytes (WiSE) and hybrid WiSE. The influence of kosmotropic (structure-making) and chaotropic (structure-breaking) ions on water organization, ion solvation, and interfacial charge storage will be systematically examined. The central hypothesis is that graphene surface chemistry and electrolyte structure are strongly coupled, and this coupling governs ion transport, charge storage efficiency, and self-discharge behavior.

Referent: Maria Paola Carpanese (Maria.Paola.Carpanese@unige.it)

Link to the list of projects

Thematic: Projects in materials engineering

Project: Morphology-driven reversible solid oxide cells for hydrogen energy systems

Keywords: rSOFC, microstructure-property correlation, degradation, multiscale characterization, Hydrogen energy systems

Brief Description:
The project studies the impact of three-dimensional microstructure on the performance and durability of reversible solid oxide fuel cells (rSOC). The objective is to define quantitative relationships between electrode architecture, mass and charge transport as well as degradation mechanisms (e.g., nickel agglomeration and delamination) in SOFC/SOEC cycles. Through advanced fabrication (e.g., freeze-casting) and multiscale characterization (FIB-SEM tomography, EIS/DRT diagnostics), innovative, highly stable electrodes will be developed. In the final phase of the project, experimental data will drive predictive multiphysics models to optimize operational reversibility. The results will accelerate the application of high-temperature technologies for the hydrogen energy transition.

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Thematic: Sustainability of products

Project: Development of green chemistry technologies and processes for the valorization of waste or bio-derived resources

Keywords: catalysis, reactor engineering, biomass conversion, high value-added products

Brief Description:

Industrial chemistry is seeking new catalysts for the development of "green" processes arising from renewables and by maximizing renewable resources. In this frame, the production of green and bio-hydrogen, chemical commodities or pseudo-commodities has attracted the attention of scientific research by also addressing important challenges from material and reactor points of view. Together with H2, the production of aldehydes, dienes, solvents, and emulsifiers could be foreseen starting from renewables (biomass, bioethanol etc.) or through unconventional processes. This doctoral project involves the development of processes, technologies, and catalytic materials for the conversion of organic molecules to products of industrial interest with a focus on green industrial chemistry and energy transition. The present project has an experimental nature and will focus on the development and design of engineered materials and processes in the frame of green industrial chemistry by focusing on performance assessment, *operando* studies, reaction mechanism, and kinetic investigations.

Referents: Prof. Gabriella Garbarino (gabriella.garbarino@unige.it), Prof. Elena Spennati (elena.spennati@unige.it)

Link to the list of projects

Thematic: Sustainability of products

Project: Valorisation of liquid and solid waste from the production of craft beer

Keywords: exhausted malt, hops, energy, water treatment, circular economy

Brief Description:

The brewing industry constitute an important economic segment of any country, with beer being the fifth most consumed beverage in the world behind tea, carbonates, milk and coffee. The production of craft beer generates a large quantity of residues as water effluents and solid exhausted materials (malts, hops and yeasts). The valorisation of this waste could help in maximising the profits, the production yield and the energy efficiency of the process.

It is estimated that for the production of 1 L of beer, 3–10 L of waste effluent is generated depending on the production and specific water usage. It must also be noted that effluents from individual process steps are variable. For example, bottle washing results in a large wastewater volume, but it contains only a minor part of the total organics discharged from the brewery processes. On the other hand, effluents from fermentation and filtering are high in organics/biochemical oxygen demand (BOD), but generally low in volume, accounting for about 3% of the total wastewater volume but 97% of the BOD.

Also, spent grains, rich in cellulose, hemicellulose and lignin, contribute up to 85% of the waste residue for most brewing facilities and therefore the potential for spent grain as a value-added product is essential to address to ensure an economic and ecologically successful operation.

In this context, the objective of this thesis will be to assess, evaluate and apply the most efficient valorisation techniques for the exhausted solid materials and apply them inside the brewing process, either for water treatment or energy obtainment, constituting an example of a circular economy strategy.

Referents: Elisabetta Arato (elisabetta.arato@unige.it), Cristina Moliner (cristina.moliner@unige.it)

Link to the list of projects

Thematic: Sustainability of products

Project: Circular hydrogen production from waste

Keywords: thermochemical processes, pilot plant, circular economy

Brief Description:

The decarbonization of the European and global energy systems requires the development of effective energy carriers that can complement electrification in specific high energy density applications. In this space, renewable hydrogen is attributed a crucial role, although the replacement of the current 120 million tonnes global annual demand requires a major effort in the development of a spectrum of technologies.

Gasification represents a pathway to hydrogen with great potential, as it can couple the production of a renewable vector with the conversion of large flows of waste, in a circular approach. In this project, we propose the design and demonstration of an integrated process for hydrogen production from textile waste and biomass through pyrolysis-gasification, where biochar as a by-product finds an application as an adsorbent in the purification of hydrogen itself.

In specific, we will upgrade and validate a 0.5 MWth spouted bed oxygen-steam gasifier fed with biomass and textile waste and optimize its operation for hydrogen production through an extensive experimental campaign based on detailed process modelling activities. Moreover, we will recover the biochar produced during gasification and treat it in a fixed bed reactor to activate it for use as an adsorbent in substitution to commercial activated carbon in a pressure swing adsorption unit. The adsorption unit's efficiency in separating hydrogen will be tested on an artificial syngas stream replicating the average gas composition obtained in the spouted bed to determine the hydrogen purity and recovery rates attainable in comparison with a commercial product. In addition, purified syngas with specific gas composition could also be converted into chemicals through synthesis catalytic reactions to produce methanol (ratio $H_2/CO=2$), ammonia (gas-phase catalytic reaction) or Fischer-Tropsch liquids as naphtha, diesel and gasoline (ratio $H_2/CO=0.6\text{-}2$), showing the high versatility of the system.

The project will demonstrate the efficiency and feasibility of a closed-cycle process where hydrogen can be generated from waste and renewable biomass, and its purification can be achieved with the use of a pre-treated by-product generated within the same process. The research efforts accomplished will contribute towards the development of circular hydrogen technologies on the Italian territory and towards enhancing the country's competitiveness in energy innovation through dissemination to fellow academic and research institutions as well as key industrial actors.

Referents: Elisabetta Arato (elisabetta.arato@unige.it), Cristina Moliner (cristina.moliner@unige.it)

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Chemical processes with reduced environmental impact

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Thematic: Chemical processes with reduced environmental impact

Project: CO_2 to use: catalytic processes design and investigation

Keywords: CO_2, e-fuels, CO_2 utilization, chemical reaction engineering, catalysis

Brief Description:
CO_2 use is becoming one of the key challenges for the future and the development of new technologies and processes is pivotal for achieving sustainable development goals, set out by the United Nations, thus contributing to the carbon neutrality goal in the set target of 2050. The PhD project proposed here will focus on catalysis and chemical reaction engineering to develop new processes for this application, aiming to reduce environmental impact and possibly outline new technological solutions by examining the processes, reaction mechanisms of chosen reactions, and kinetics for producing e-fuels and e-chemicals. Of utmost importance will be the coupling with renewable resources. An experimental point of view, including _operando_ studies, will address the present project.

Referent: Prof. Gabriella Garbarino (gabriella.garbarino@unige.it)

Link to the list of projects

Thematic: Chemical processes with reduced environmental impact

Project: Valorisation of liquid and solid waste from the production of craft beer

Keywords: exhausted malt, hops, energy, water treatment, circular economy

Brief Description:

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Referents: Elisabetta Arato (elisabetta.arato@unige.it), Cristina Moliner (cristina.moliner@unige.it)

Link to the list of projects

Thematic: Chemical processes with reduced environmental impact

Project: Circular hydrogen production from waste

Keywords: thermochemical processes, pilot plant, circular economy

Brief Description:

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Referents: Elisabetta Arato (elisabetta.arato@unige.it), Cristina Moliner (cristina.moliner@unige.it)

Link to the list of projects

Thematic: Chemical processes with reduced environmental impact

Project: Advanced MCFC cell components for carbon capture and industrial decarbonization

Keywords: Molten carbonate fuel cells, carbon capture, electrochemical systems, ceramic materials, process scale-up

Brief Description:

The decarbonization of hard-to-abate industrial sectors requires innovative technologies capable of combining energy efficiency, CO_2 reduction and industrial scalability. In this context, molten carbonate fuel cells (MCFCs) represent a promising solution thanks to their ability to simultaneously generate electrical power and selectively capture carbon dioxide.

This PhD project aims to develop and optimize advanced MCFC cell components for carbon capture applications, with particular attention to ceramic matrices, porous electrodes, interfaces and stack-relevant elements. The research activity will combine experimental material development, process engineering and numerical modelling in order to establish a process–structure–performance methodology for scalable MCFC technologies.

The experimental work will focus on the fabrication and characterization of porous ceramic and electrochemical components through techniques such as tape casting, thermal treatments and surface modification. Particular attention will be devoted to microstructure control, electrolyte retention, transport properties, interfacial stability and manufacturability. In parallel, modelling activities will be developed to correlate component properties with electrochemical performance, thermal behaviour and stack operation.

The project also includes preliminary scale-up and pilot-oriented considerations, including process reproducibility, energy consumption, quality control and industrial feasibility. The final objective is to contribute to the development of robust and scalable MCFC technologies suitable for carbon capture and industrial decarbonization applications.

The project requires multidisciplinary competences in chemical engineering, materials science, electrochemical systems and modelling tools, together with strong interest in experimental laboratory activities and sustainable energy technologies.

Referent: Barbara Bosio (barbara.bosio@unige.it)

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Others Projects

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