Politecnico di Torino

SUSTAINABLE MATERIALS, PROCESSES AND SYSTEMS FOR ENERGY TRANSITION

Integrated thermo-bio-catalytic processes for biomass and CO2 utilization

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Context of the research activity	The research activity aims at the combined use of lignocellulose feedstock and CO2 as carbon sources to produce bio-based drop-in fuels and chemicals. Technologies based on catalytic fast pyrolysis and enzyme biocatalysis will be purposely developed. Experimental and theoretical investigations will be applied to novel biorefinery platforms design. Process design tools will predict the performances of integrated platforms based on the use of thermo-bio-catalytic processes for a selection of relevant lignocellulosic feedstock and CO2-rich streams.

	Scholarship funded by the project "iENTRANCE@ENL - Infrastructure for Energy Transition and Circular Economy@EuroNanoLab" CUP: B33C22000710006 Consiglio Nazionale delle Ricerche – Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili (CNR STEMS) Main seat to carry out the research: CNR STEMS – Napoli Supervisors: Dr. Giovanna Ruoppolo (giovanna.ruoppolo@stems.cnr.it), Dr. Maria Elena Russo (mariaelena.russo@stems.cnr.it) and Dr. Massimo Urciuolo (massimo.urciuolo@stems.cnr.it) – CNR STEMS According to the former definition of biorefinery, these processes were developed to transform a single feedstock (typically energy crops) into a single product (bio-energy and bio-fuels). The evolution of the biorefinery concept includes multi-feedstock and multi-product platforms (Patel e Shah, 2021 Journal of Bioresources and Bioproducts 6,108-128). This recent approach has been pushed forward and supported by the need of reusing and valorize waste carbon sources and produce multiple bio-based commodities to replace those from fossil carbon sources. This approach has still few applications at full scale while several initiatives have been developed. Among these, pyrolysis-oil and fermentation products are the most common. Pyrolysis allows the transformation of lignocellulose

Objectives	feedstock as well as not-biogenic carbon waste (e.g. plastics) into three main products bio-oil, bio-char and pyrolytic gas which yields are strongly depending on the experimental condition adopted. In the fast pyrolysis the main fraction, the bio-oil (up to 75wt%) results from a complex network of chemical reactions initiated by the depolymerization of feedstock components (i.e. cellulose, hemicellulose and lignin in lignocellulosic biomass) and that moves forward secondary steps including cracking, isomerization, polymerization reactions as well as volatilization and condensation processes. The current running full-scale plant (TRL9) producing pyrolytic bio-oil as its main product is located in The Netherland has a 24 kton/year productivity and is owned by Twence Hengelo. Demonstration scale plants (TRL 6-7) are active in Finlad (50 kton/year by Fortum Joensuu) and Germany (24 kton/year by Karlsruhe Institute of Technology). Upgrading of bio-oil to refined products having use as fuel components or chemical building blocks is still at a developmental scale and no large-scale plants currently exist. The sugar-based platform is the other common route to recover part (sugar fraction) of the biomass carbon and convert it into bio-fuels (mainly bio-ethanol) and other fermentation products (e.g. bio-polymers). The process is based on four core steps including biomass feedstock delignification, intermediate feedstock enzymatic hydrolysis, sugar fermentation, and product recovery/purification. The main by-product of the whole process is the residual lignin-rich solid whose common fate is burning to support the heat duty of the plant. According to Jorissen et al. (2020 Biofuels, Bioproducts and Biorefining 14, 1028–1045) currently, 224 running biorefineries are registered in Europe, including a significant number based on sugar/starch (63) and oil/fat (64) conversion. Twenty-four are wood-based biorefineries, and 13 biorefineries process food waste, while 5 use non-wood lignocellulose. The reported scenario shows vast potential for second-generation biorefineries processing the food waste and agricultural residues. In addition, the co-transformation of biomass and non-biogenic carbon sources including plastic waste and captured CO2 may open further new opportunities to increase the fraction of recycled carbon as well as the pool of possible bio-based products to be produced. The objective of the research activity is the development of novel platforms guided by the use of process design techniques. The work will be aimed at re-arranging the existing biorefinery schemes to minimize waste and energy consumption. To this aim, thermos-catalytic technologies (fast pyrolysis and co-pyrolysis) as well as biocatalytic processes (mainly enzymatic hydrolysis of polysaccharides) will be integrated following a cascade approach. The novelty of the project resides in the inclusion of plastic wastes and CO2-reach off-gas as potential additional sources of carbon. Case studies emerging from previous experiences at the CNR_STEMS will be selected as starting points. The experimental activity will be focused on the development of tailored advanced pyrolytic reactor units as a versatile tool for conversion and valorization of both intermediate carbon stream and mixed-raw feedstock with a specific purpose intended for bio-oil fractionation and upgrading.

Skills and competencies for the development of the activity	Candidates should preferrably have a relevant Master Degree e.g., Chemical Engineering, Industrial Chemistry. They have to be familiar with performing basic chemical laboratory procedures and bench-scale reactor operations with solids handling and characterization. Basic knowledge of process modelling tools (e.g. Aspen Plus) is required.

the activity	Proved oral and written communication skills in English.