ENERGETICS

DENERG - Modelling and experimental approaches for decarbonising Hard-to-Abate sectors

Funded By	Dipartimento DENERG
Supervisor	CHIARAMONTI DAVID - david.chiaramonti@polito.it
Contact	NEGRO VIVIANA - viviana.negro@polito.it PRUSSI MATTEO - matteo.prussi@polito.it
Context of the research activity	This PhD will develop modelling tools and experimental insights to support the decarbonisation of hard-to-abate sectors. The research will explore thermochemical conversion of biogenic residues for supporting the transition for hard to abate sectors. The analysis will assess performance of the alternatives for energy-intensive industries, and evaluate environmental and technical impacts to guide sustainable industrial transitions.
Objectives	The decarbonisation of hard-to-abate sectors, such as steelmaking, cement, chemicals and heavy transport, represents one of the most pressing challenges for achieving climate neutrality. These industries highly depend on fossil-based feedstock that have no straightforward alternatives. Progress requires a combination of innovative materials, low-carbon energy carriers and advanced modelling tools capable of assessing system-level impacts, sustainability, and technical feasibility. This PhD project aims to contribute to this transition by integrating experimental research and energy system modelling to evaluate and optimise low-carbon pathways based on thermochemical conversion of biogenic residues. Biogenic residues, including municipal sludge, lignocellulosic waste, agricultural by-products and green waste, offer a promising resource for the production of carbon-rich solid fuels or feedstocks. Thermochemical processes such as pyrolysis, gasification and hydrothermal carbonisation can transform these heterogeneous residues into stable, energy-dense solids with coal-like properties (biochar). Despite this potential, several barriers hinder large-scale deployment. This PhD will address these needs through a structured combination of laboratory experimentation and integrated modelling. Experimental work will focus on the thermochemical conversion of selected biogenic residues, investigating the influence of feedstock properties and process conditions on product yield, composition, stability and suitability as a fossil-coal replacement. The experimental results will serve as key inputs for the modelling activities.

	The research activity will pursue the following objectives: 1. Analyse the current state of the art regarding alternative feedstocks and integrated conversion pathways for biomethane production. 2. Identify opportunities for process integration, with a focus on coupling anaerobic digestion with thermochemical and hydrothermal technologies. 3. Develop and implement modelling frameworks capable of representing integrated process chains and assessing their performance under different operating conditions. 4. Conduct targeted laboratory experiments to provide empirical data supporting model calibration and validation. 5. Perform a techno-economic analysis of the proposed solutions to evaluate their feasibility, scalability, and potential contribution to sustainable biomethane value chains. The outcomes of this research will contribute new knowledge on the production and use of biogenic carbon carriers for industrial decarbonisation, provide robust datasets for industry and policymakers, and support the development of sustainable alternatives to fossil inputs.

Skills and competencies for the development of the activity	The PhD candidate is expected to develop: • Competences on process modelling. • Competences on energy modelling. • Competences on programming (e.g. Phyton). • Other relevant soft skills, such us: o Team working. o Autonomy at work. o Problem solving. o Communication skills. o Basics of project management.