Techno-economic evaluation of systems for the production of negative emission fuels through biomass carbonisation processes

Tutor: Dr. Diego Marazza

Project: Horizon Europe – NET-Fuels

Location: University of Bologna – Ravenna

Duration: 6 months

Research Area: Sustainability and techno-economic assessment, Life Cycle Analysis (LCA), Bioenergy, EU regulations

Overview of the Project

The NET-Fuels project aims to develop an innovative, integrated process for the production of carbon-negative fuels using biogenic residues (e.g. digestate, waste wood, agricultural pruning). The system combines thermochemical conversion of biomass, hydrogen separation from syngas, oxyfuel combustion, bio-electrochemical CO_2-to-methane conversion, and carbon sequestration via second-generation carbons production. An additional output of the process includes high-quality pyrolysis oil, a drop-in biofuel proven in previous EU-funded projects (e.g., TO-SYN-FUEL).

The project will bring this technology to technology readiness level (TRL) 5, providing the foundation for future industrial demonstrations. By second-generation carbons (2G-C), a wide range of carbon-based substances are intended, different in composition, structure, properties, and use. The common ground is the technological manufacturing process: they are obtained through the carbonization of carbonaceous substances and possible mineral components (metals, alkalis and other inorganic components) whose composition and preparation is designed in terms of chemical, physical and microbiological action for uses such as agriculture, the treatment of industrial/liquid and gaseous effluents as a replacement for activated carbons, the removal of contaminants with recovery of nutrients (P and N) and chemical elements (e.g. B, Mg, Mn), use in catalysis and improvement of industrial processes, electrochemistry and building materials.

In this category, the best-known product is biochar, i.e. charcoal produced specifically for agronomic and environmental use through soil application. Both the carbonaceous substances and the mineral component of 2G-C can be obtained from production waste (by-products or waste) of renewable biological origin (sustainable sources of waste biomass) as well as from production waste materials and carbonaceous substances of fossil origin. The

term ‘charcoal’ refers to the carbonaceous component of 2-GC, while the term ‘second-generation’ indicates both the production of charcoal from waste, with a view to material circularity, and the technological advancement related to the design and engineering of the substances and materials obtained. This group of products expresses new properties, the most important of which is carbon storage, which varies depending on the destination from a few years to hundreds of years.

The research project aims at developing methods for the economic environmental assessment of second-generation biomass processing within the framework of the Horizon Europe NET-Fuels project.

Research Focus and Responsibilities

The research fellow will support the development of sustainability assessment tools and models aligned with the NET-Fuels objectives. The role involves four main work areas:

Life Cycle Impact Assessment – Sensitivity analysis

Unibo will develop a parametric model (in MATLAB, Vensim, or spreadsheet) based on a Life Cycle Inventory developed by the Silesian University of Technology, in order to quantify GHG emissions caused by the NET-Fuels system. The research fellow will perform a sensitivity analysis to identify 4 to 10 key influencing parameters to the GHG balance (e.g. feedstock moisture, process energy input), each one of them with its specific assigned confidence interval. Afterwards, functions that link key parameters to the model's output will be developed. A dynamic model will also be implemented to calculate GHG emissions as specific inventory data changes.

EU policy scenarios will be included to evaluate future developments. In particular, EU 2030 renewable energy targets and energy efficiency ones will be analysed to assess the effects of the Fit-for-55 package. This, with the objective of studying possible related changes in relevant elementary and non-elementary flow impacts.

A simplified decision-support spreadsheet for end users and policymakers will be delivered to visualize emission performances under different scenarios.

Support in Techno-Economic and Social Impact Analysis

The research fellow will support the research Team in linking NET-Fuels system to product flows and related industrial sectors included in EXIOBASE 3 dataset. Industrial sectors and regional data are aggregated and NET-Fuels technology is scaled-up based on biomass availability. Subsequently, economic and social effects of the system are quantified, interpreted and communicated through a dedicated spreadsheet. Moreover, Unibo will assess economic, labor, and environmental ripple effects by sector and geographical area.

Regulatory and Policy Landscape Analysis

The researcher will assess the EU regulatory frameworks for NET-Fuels technology, processes, and products. General objectives include both the assessment of regulatory requirements and the possible NET-Fuels system contributions to the EU energy, environmental and climate targets. In particular, requirements are identified for:

- Methane injection into the gas grid
- Biochar certification and usage
- Hydrogen storage/compression standards
- Waste/end-of-life feedstock management

The work plan includes a collaboration with project partners to define regulatory priorities and propose viable plant configurations.

Dissemination and Public Engagement

The research fellow will participate in public outreach initiatives such as “Researchers' Night”, external training events (e.g., Biochar School), workshops, educational initiatives, and third-mission activities promoting second-generation carbon technologies and circular economy principles.

Participation in periodic project meetings with different project partners is also foreseen.

Candidate Profile

i. A background in environmental engineering, sustainability science, energy systems, and/or industrial ecology.
ii. Experience with techno-economic analysis, sensitivity assessments, and environmental modeling tools.
iii. Proficiency with tools such as MATLAB, Vensim, Python, or advanced spreadsheet modeling.
iv. Knowledge of and/or experience with environmental regulatory frameworks at the EU level.