INTEGRATING BIOMASS SUPPLY CURVES INTO AN ENERGY MODEL: INSIGHTS INTO THE ECONOMIC AND ENVIRONMENTAL IMPACTS OF REFUEL EU

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Overview

The decarbonization of Europe's aviation and maritime sectors, driven by policies such as ReFuel EU and Fuel EU Maritime, necessitates a large-scale shift towards sustainable fuels to reach carbon neutrality by 2050. These policies rely heavily on biogenic carbon sources, raising fundamental questions about the availability, economic feasibility, and environmental trade-offs of biomass supply. Traditional Integrated Assessment Models (IAMs) have provided broad insights into such transitions ***[1]*** but often rely on simplified assumptions, including carbon neutrality of bioenergy and static representations of land-use emissions. Indeed, as a spatialized resource, biomass potentials are difficult to assess in top-down approaches. Capturing the complexities of biofuel adoption requires models capable of integrating spatial and sectoral dynamics. Following the recommendations of Creutzig et al. ***[2]***, more inductive approaches are needed to verify the compatibility of large-scale sustainable fuel integration with biophysical and socio-economic constraints. providing insights into regional and market-driven impacts

Methods

This study proposes a novel, bottom-up assessment framework combining the multi-energy optimization model EnergyScope ***[3]*** with prospective land-use model and data ***[4]***. Previous works ***[5], [6]*** addressed the carbon loop issue in this highly interconnected energy system model by introducing carbon flows for better traceability. However, a more detailed assessment of biomass availability is needed to help close the loop. To do so, Haberl et al. ***[7]*** originally proposed the concept of emission supply curves. Key innovations of the work include a methodological adaptation from a Brazilian case study developed by Lap et al. ***[8]*** to a European context, applying marginal biomass supply functions and emission factors specific to the French landscape. By replacing average supply costs and emissions factors for biomass production with regional marginal supply curves, the framework allows for spatially explicit evaluations of biofuel production's economic and environmental implications.

Results

Preliminary applications of the proposed framework indicate significant variability in biomass availability and environmental impacts across regions. Furthermore, the inclusion of spatially explicit emission factors shows considerable variation in greenhouse gas (GHG) emissions depending on land-use practices and crop yields. Initial optimization results from EnergyScope should clarify the role of second-generation biofuel and e-biofuel deployment in reducing fossil fuel reliance under ReFuel EU scenarios, with trade-offs to be made between GHG emission factor, demand reduction and economic competitiveness.

Conclusions

This approach offers a transparent and spatially resolved tool for evaluating the trade-offs of biofuel strategies. The integration of regionalized biomass supply data into the EnergyScope model enhances the understanding of the spatial and economic dynamics critical to biofuel adoption. This bottom-up approach provides a more nuanced perspective on the feasibility and sustainability of large-scale biofuel integration under European policies. The results underscore the importance of aligning biofuel deployment strategies by 2050 with regional land-use practices to maximize benefits while minimizing unintended impacts. Future work should extend the analysis to broader European contexts and study the complementarity with other synthetic fuel pathways from non-biological origin to reduce pressure on biomass resources. The proposed methodology could also be used as part of a consequential life-cycle assessment of large-scale biofuel ("biomass to liquids") and e-biofuel ("power and biomass to liquids" — PBTL) adoption under European regulations.

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