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Economic Assessment of Negative Emissions from Sustainable Biomass in Europe

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Biochar, produced by pyrolytic decomposition of biomass, offers stable carbon storage and potential for CO_2 removal. Biochar carbon removal (BCR) is an established technology that offers added value over gaseous CO_2 removal through sustainable by-products and ease of handling. There is a significant lack of techno-economic assessments of BCR, especially in the European context.

This study presents a mathematical model to assess the economics of BCR across supply chains. The aim is to determine the optimal carbon credit for the BCR supply chain, tha is a breakeven benefit at which a carbon removal project achieves a net present value (NPV) of zero. A mixed-integer nonlinear programming (MINLP) model is developed, along with its linear approximation. The model is applied to two case studies using all available paper sludge and sewage sludge from 32 European countries as input for a pyrolytic process known as Thermo-Catalytic Reforming (TCR®).

Results of case studies reveal that economic feasibility varies significantly depending on the type of feedstock and regional factors. Although paper sludge has a higher carbon sequestration potential per tonne compared to sewage sludge, the net present value is positive for sewage sludge with a carbon credit of over €29/t-CO_2, while for paper sludge it is positive up to €255/t-CO_2. Sewage sludge is economically more attractive as a large share of the costs can be offset by revenues from by-products. Optimal carbon credit could potentially drop to -132 €/t-CO_2 (sewage sludge) and 65 €/t-CO_2 (paper sludge), assuming that biochar is sold at a market price of 100 €/t. Additionally, this study explores the overall potential of BCR from the total sustainable potential of biogenic waste and residues in 42 European countries. According to our analysis, the total carbon sequestration through biochar can potentially range from 203 to 619 Mt CO_2 per year. Total potential of bio-oil as by-products is 126 TWh, which could increase to 619 TWh in an optimistic scenario. This biofuel can replace fossil diesel or serve as a feedstock for sustainable aviation fuel.

The study takes a conservative approach by giving priority to carbon removal through the disposal of biochar rather than its use as fertiliser. However, the technology would be more economically attractive if revenues could be generated from utilizations. The costs associated with BCR are primarily due to capital investments in conversion technology and energy requirements, and there is potential for reducing costs in these areas. Although the model is limited to a few case studies, it provides a basis for expanding BCR and designing sustainable carbon removal networks. BCR offers a sustainable alternative to waste management and improves the cost-benefit ratio by taking opportunity costs into account. Overall, regulations and certification frameworks are needed to incentivise carbon removal and reduce risks for stakeholders.

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