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## The role of residual biomass in the French transition towards low fossil C use: spatial quantification, current uses, and life cycle assessment of the baseline

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Reducing greenhouse gas emissions, and in particular fossil carbon dioxide, is essential to sustain future human life on Earth. In this perspective, residual biomass becomes a potentially valuable resource to substitute fossil carbon, in particular when considered under the angle of national strategic planning. Yet, diverting this flow from its current (or baseline) use implies ensuring a net societal benefit, i.e. an overall enhanced environmental and economic performance. Here, we present an assessment covering the whole of France. The purpose of our study is three-fold: (i) providing and demonstrating a methodology for high-resolution spatial quantification of key residual biomass streams including Primary Forestry Residues (PFR), Agricultural Residues (crop residues, manure, prunings), Sewage Sludge, Garden Waste, Food waste (household, industrial); (ii) identifying the current use of these streams and (iii) quantifying, by life cycle assessment, the environmental impacts related to this baseline management. The vision is to supply the quantified minimal environmental performance that future bioeconomy uses of the residual biomasses must have in order to generate an overall improvement compared to today's baseline. The aim is additionally to develop methods that can be reproduced and used for strategic circular- and bioeconomy planning in other countries (or regions) worldwide.

According to our results, the total biophysical available potential (in  $\text{PJ y}^{-1}$ ) is: PFR:  $158 \text{ PJ y}^{-1}$  [83-261]; Crop residues:  $1178 \text{ PJ y}^{-1}$  [988-1369]; Manure:  $433 \text{ PJ y}^{-1}$  [345-520]; pruning residues:  $57 \text{ PJ y}^{-1}$  [30-85]; garden waste:  $61 \text{ PJ y}^{-1}$  [49-73]; household biowaste currently separately collected:  $103 \text{ PJ y}^{-1}$  [83-124]; household biowaste not collected today:  $89 \text{ PJ y}^{-1}$  [81-97]; agri-industrial biowaste:  $81.4 \text{ PJ y}^{-1}$  [65-98]; sewage sludge:  $15.2 \text{ PJ y}^{-1}$  [12-18]. This totals  $\sim 2100 \text{ PJ y}^{-1}$ , the equivalent of 20% of the primary energy supply in France. The current uses vary among the streams, including on-land decay, open-air burning, domestic heat use, direct use as organic fertilizer, use as organic fertilizer after composting or use as bedding, production of heat and power following biogas production through anaerobic digestion, mulch production and incineration amongst the most common ones. When services are supplied (e.g. heat, electricity, fertilizers), the life cycle assessment considered the avoided impacts induced by the substituted products (e.g. natural gas, mineral fertilizers).

To our knowledge, such a wide platform covering as many residual streams at this level of spatial

resolution (from 10-m to the European NUTS-3 level), incorporating uncertainties and life cycle inventories on the current uses of streams, has never been elaborated until now.