COMPARATIVE ANALYSIS OF THE ENVIRONMENTAL, CLIMATE AND OVERARCHING ECONOMIC IMPACT OF BIO-BASED FERTILISER PRODUCTION, USING A CUSTOM-MADE METHODOLOGY

H. L. Foged1*, I. Sylwan[2], P. de Morais Lima[2], O. Valetska[3]

[1]Organe Institute (ORGANE), Skødstrup, Denmark. *henning@organe.dk
[2] Environmental Engineering Group, Research Institutes of Sweden (RISE), Uppsala, Sweden.
[3]Soil and Environment Department, Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden

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CIRCULAR ECONOMY CiNURGi

INTRODUCTION

- Large cost gap remains between BBFs and mineral fertilisers
- Stronger policy frameworks could help return the value of BBF-related environmental services to producers
- Improved BBF quality can increase farmers' willingness to pay
- Higher perceived agronomic value supports better market valuation of BBFs

AIM

Identify the best practice and innovative solutions of BBF production and evaluating their environmental, climate, and economic outcomes within a market and policy context

METHODOLOGY

- Market screening identified 24 BBF value chains across waste collection, processing, and field application.
- 11 value chains met scope and data requirements for full environmental and socio-economic impact assessment (Figure 1).
- A custom assessment method was developed, using a Single Operation Unit Process approach (Figure 2). The method isolates BBF production from broader facility operations to evaluate only processes with a primary nutrient-recycling function.

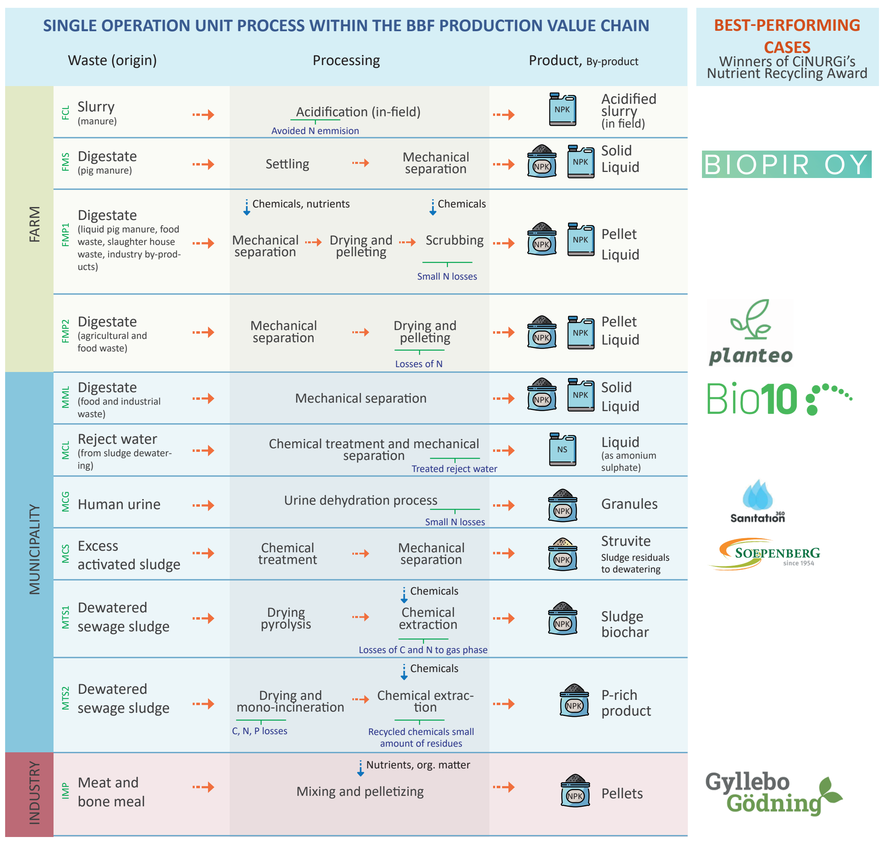

Figure 1. Single Operation Unit Process within the BBF production

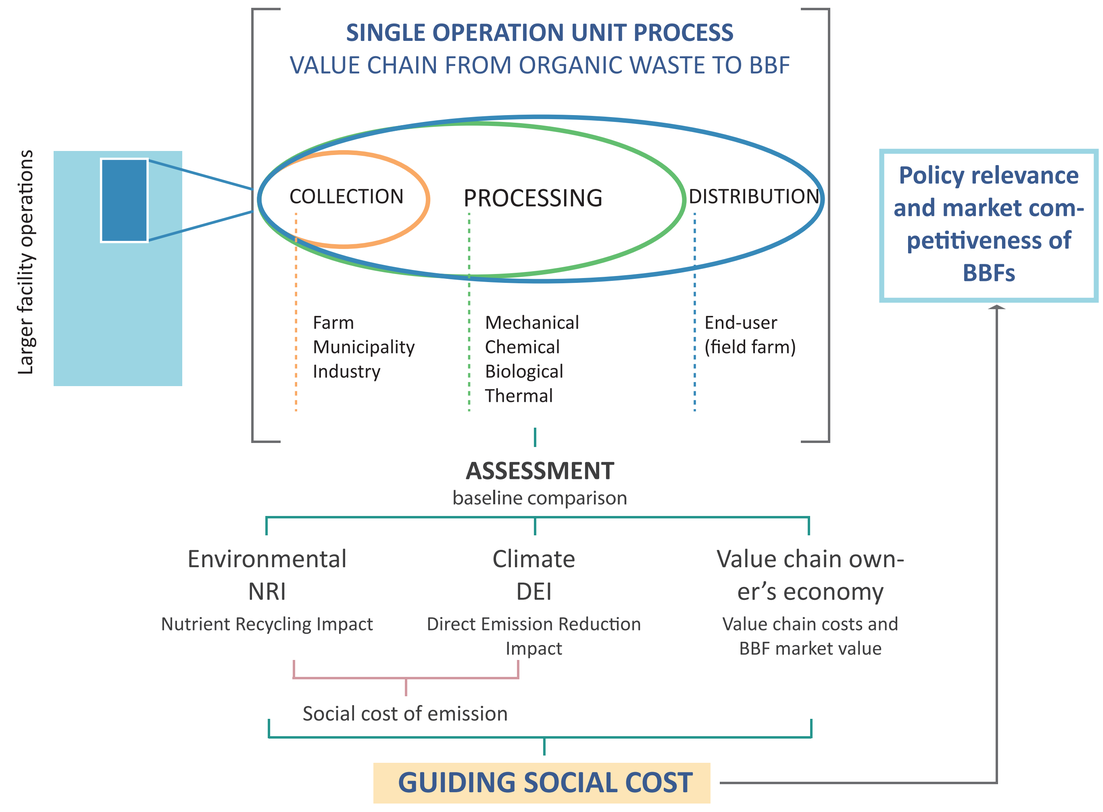

Figure 2. Conceptual framework for assessing BBF value chains

RESULTS

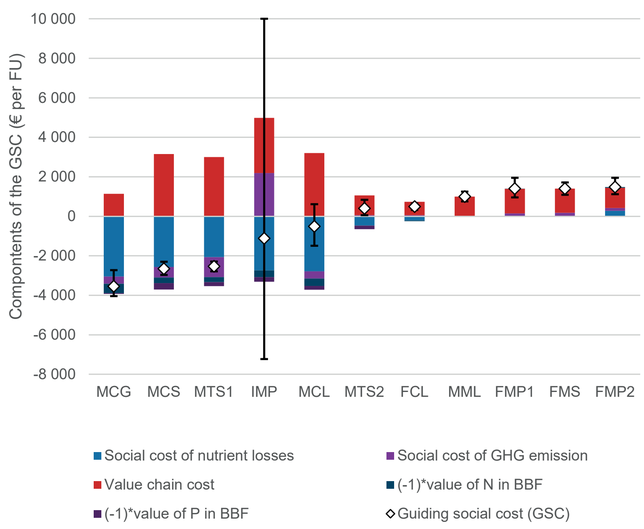

Figure 3. Components of the guiding social cost (GSC), per FU
The variation in GSC is indicated with error bars, based on variations of energy mix across Europe and the uncertainty in value chain cost.

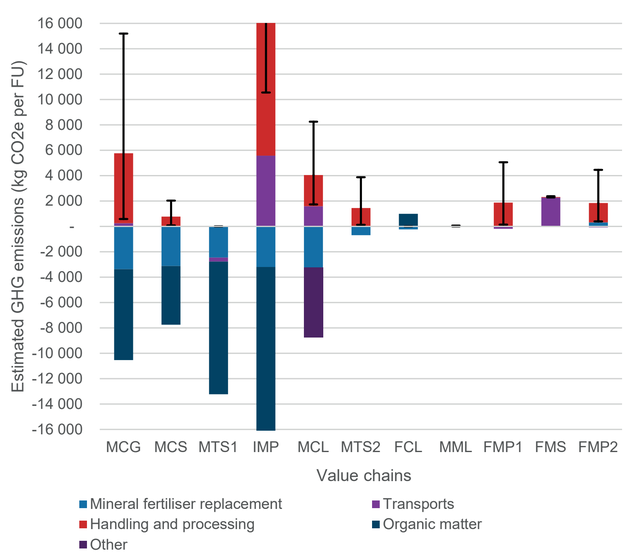

Figure 4. Estimated GHG emissions per category and value chain
Error bars are given with respect to emissions from handling and processing based on variation in electricity mix across Europe.

- The Nutrient Recycling Impact averaged 47%, meaning increased nutrient recycling compared to the baseline, with values ranging from -9% to 100%. The Direct Emission Impact indicated that GHG emissions would on average increase with an average of 0.517 t CO_2-eq per fu defined as 1,000 kg N+P in influent organic wastes, with variations ranging from −13.2 to +28.4 t CO_2-eq.
- The Guiding Social Cost averaged € -1,257 per fu, indicating an overall societal gain, with variations from €−3,048 to € 280 (Fig. 3).
- BBF production was generally uncompetitive with mineral fertilisers: the average production cost was € 2.62 per kg N + P, compared with a long-term market price of € 1.08 per kg N + P for mineral fertiliser.

CONCLUSIONS

- BBF benefits depend on the baseline — gains occur mainly when replacing nutrient-inefficient waste management.
- Nutrient retention is the key driver of societal value, consistently outweighing climate benefits; greenhouse-gas mitigation alone cannot justify BBF investments.
- Societal benefits and market incentives are misaligned — several BBF pathways deliver clear public value but remain commercially uncompetitive without policy mechanisms that reward avoided nutrient losses.
- Selective, strategic deployment is essential, targeting waste streams with high nutrient losses and technologies that achieve strong nutrient retention with reasonable energy demand, supported by policies that align private and societal value.

NUTRIENT RECYCLING AWARD

The CiNURGi Nutrient Recycling Award recognises leading nutrient-recycling innovations selected from 24 submissions evaluated for nutrient retention, environmental performance, and socio-economic value. Six standout cases were chosen as winners across agriculture, municipal wastewater, and industrial by-product streams (Figure 1).