D6.2 Draft convention for comparable LCA studies of fertilising products manufactured from primary and secondary raw materials

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OPTIMISING BIO-BASED FERTILISERS IN AGRICULTURE – PROVIDING A KNOWLEDGE BASIS FOR NEW POLICIES

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LEX4BIO aims to reduce the dependence upon mineral/fossil fertilisers, benefiting the environment and the EU's economy. The project will focus on collecting and processing regional nutrient stock, flow, surplus and deficiency data, and reviewing and assessing the required technological solutions. Furthermore, socioeconomic benefits and limitations to increase substitution of mineral fertiliser for BBFs will be analysed. A key result of LEX4BIO will be a universal, science-based toolkit for optimising the use of BBFs in agriculture and to assess their environmental impact in terms of non-renewable energy use, greenhouse gas emissions and other LCA impact categories. LEX4BIO provides for the first-time connection between production technologies of BBFs and regional requirements for the safe use of BBFs.

The project runs from June 2019 to May 2024. It involves 20 partners and is coordinated by Luke (LUONNONVARAKESKUS - Natural Resources Institute Finland).

More information on the project can be found at: http://www.lex4bio.eu

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1. INTRODUCTION

The objective of WP6 is to perform a comparative Life Cycle Assessment (LCA) of biobased fertilisers (BBFs), mineral fertilisers and traditional methods of using agricultural residues. The LCA will be based on a jointly established convention aiming at making future LCAs of fertilising products comparable, thus enabling policymakers, regulatory bodies and stakeholders at large to understand and compare the expected ecological impact of producing and using BBFs and mineral fertilisers.

Over the years ample guidelines on how to perform LCA have been developed, most notably the ISO standards 14040 and 14044, but also e.g. the European Commission ILCD handbook (EC-JRC 2010) and most recently the Product Environmental Footprint method (PEF, Zampori and Pant 2019). Yet, the review on how BBFs are currently treated in LCA in Deliverable 6.1 of the LEX4BIO project (D6.1, Tanzer et al. 2021) revealed that existing frameworks are often inadequately applied and too general to ensure comparability across studies. The aim of the present deliverable is thus not to reinvent the wheel with yet another convention. Instead, it presents a draft for a convention on how to apply existing guidelines in the context of fertilising products and summarises the key aspects granting comparability in existing guidelines.

After practical application to the LCA of new techniques studied in LEX4BIO a reviewed and adapted final version of the convention will be published.

2. General information

2.1. Purpose and use

The following convention provides guidance on how to perform LCA studies of mineral, chemical and biobased fertilising products in a harmonised way ensuring comparability across studies.

Familiarity with basic LCA concepts and theory are considered a prerequisite for application of the convention and are thus not elaborated here. Instead, recommendation on how to apply existing conventions such as the ISO standard 14040/14044, the ILCD handbook (EC-JRC 2010) and the PEF method (Zampori and Pant 2019) in the context of fertilising products are provided. However, key aspects of existing conventions that are essential for ensuring comparability and/or are often disregarded in LCA studies on fertilising products are repeated in a summarised way. Where no specific recommendations are given, the rules of the general guidelines shall be followed.

The focus of the present convention is on the goal and scope definition, as most decisions that can facilitate or hamper cross-study comparability are taken in this phase. Life-cycle inventory, impact assessment and interpretation shall be conducted according to the rules of general guidelines without the need for specific recommendations for fertilising products.

In alignment with general guidelines, this convention uses precise terminology to indicate the requirements, the recommendations and options that could be chosen when a study is conducted:

- The term "shall" is used to indicate what is required in order for a study to be in conformance with this convention.
- The term "should" is used to indicate a recommendation rather than a requirement. Any deviation from a "should" requirement has to be justified when developing the study and made transparent.
- The term "may" is used to indicate an option that is permissible. Whenever options are available, the study shall include adequate argumentation to justify the chosen option.

2.2. Consultation and stakeholders

There is no one "right" way of how to treat fertilising products in LCA, yet common assumptions are essential for making studies comparable. Therefore, the convention is jointly developed with an extended team of experts from practice and academia, including authors of other studies, database authors, interested stakeholders and members of the executive advisory board (EAB) of LEX4BIO.

Main points for discussion and preliminary ideas for harmonisation were derived from D6.1 of the Lex4Bio project (Tanzer et al. 2021) and existing conventions in similar fields such as the recommendations on the treatment of multifunctionalities and modelling of emissions for fertiliser application in the Product Environmental Footprint method (Zampori and Pant 2019), the growing media environmental footprint guideline (Growing Media Europe 2020) and the Agri-footprint 5.0 (van Paassen et al. 2019). These were shared with the extended team of experts for feedback.

Stakeholder consultation will be ongoing throughout all processes of the convention development in order to ensure the final convention represents current preferences of and best consensus available among experts in the field.

2.3. Scope of the convention

The present convention covers fertilisers in the meaning of the Fertiliser Product Regulation (2019/1009 EU), i.e.:

a substance, mixture, micro-organism or any other material, applied or intended to be applied on plants or their rhizosphere or on mushrooms or their mycosphere, or intended to constitute the rhizosphere or mycosphere, either on its own or mixed with another material, for the purpose of providing the plants or mushrooms with nutrient or improving their nutrition efficiency

The geographical scope is Europe (EU and EFTA member states).

3. Goal Definition

Precise and unambiguous goal definition is essential for correct interpretation and use of the LCA results. According to the ILCD handbook (EC-JRC 2010) it shall comprise the following:

- Intended applications
- Reasons for carrying out the study and decision context
- Limitations due to the method, assumptions and impact coverage
- Key stakeholders (target audience, commissioner of the study, etc.)
- Decision whether comparisons between products/processes that will be disclosed to the public will be made

In general, in LCAs on fertilising products, comparisons are necessary to fulfil the intended application. Common comparisons include:

- Comparison of environmental impacts of production of different fertilising products
    - *E.g. struvite vs. triple super phosphate (TSP)*
    - *E.g. digestate from biogas plants vs. untreated manure*
- Comparison of environmental impacts of different treatments of a waste stream
    - *E.g. composting vs. anaerobic digestion of municipal organic waste*
    - *E.g. sewage sludge incineration with P-recovery from ashes vs struvite recovery from sewage sludge*
- Comparison of environmental impacts of different specifications of a fertiliser production/treatment process
    - *E.g. biogas plant with combined heat and power (CHP) engine vs biogas plant with biogas upgrade to biomethane*
    - *E.g. manure storage in open vs. closed tanks*

Fertilising products are intermediate products for which environmental impacts at the use stage shall not be considered (Zampori and Pant 2019). Thus, impacts occurring during or after fertiliser application such as emissions of nutrients to air and water or introduction of contaminants to the food chain are not reflected in the LCA. This is an important limitation that shall be pointed out in all publications of the LCA results. Furthermore, to draw meaningful conclusions on the superiority of one fertilising product/treatment process over another, the LCA should always be accompanied by an assessment of environmental risk and agronomic efficiency. Methodological guidance on environmental risk assessment can, for instance, be found in the Technical Guidance Documents of the European Union Institute of Health and Consumer Protection (IHCP 2003a-d).

4. Scope Definition

4.1. Function, functional unit and reference flow

LCA systems of fertilising products often fulfil several functions simultaneously, e.g. when multiple nutrients are contained in one product or if the fertilising product is a by-product of a waste treatment or energy production process. All functions of the system shall be clearly defined in all publications of the LCA results. Examples of functions commonly occurring for the main types of fertilising product systems are shown in Table 1. The list is not exhaustive and may be supplemented by additional functions. Likewise, depending on the study purpose, some functions listed in Table 1 may not be relevant in a specific case.

The functional unit (FU) in LCA represents the main function of the system under study and is used as a reference unit. It shall be defined with respect to the following aspects (EC-JRC 2010, Zampori and Pant 2019):

- What
- How much
- How well
- How long

Examples of FUs for the main types of fertilising product systems are shown in Table 1. Comparisons in LCA shall always be made based on the FU, which shall be defined equally for all systems involved in the comparison (EC-JRC 2010).

Table 1: Functions and functional units in main types of fertilising product systems.

Fertilising product system	Main function	Co-function 1	Co-function 2
Mineral/chemical fertiliser	Production of a fertilising product containing nutrient a Recommended FU: *1 kg of nutrient a*	Production of a fertilising product containing nutrient b Recommended FU: *1 kg of nutrient b*	Production of a fertilising product containing nutrient c Recommended FU: *1 kg of nutrient c*
BBF derived from wastewater treatment	Wastewater treatment Recommended FU: *Treatment of wastewater of x person equivalent per day to the level of meeting the standards for discharge to surface waters of the EU Wastewater Treatment Directive*	Production of a fertilising product containing nutrient a Recommended FU: *1 kg of nutrient a* Additional FUs for other nutrients may be added	Production of heat Recommended FU: *Production of x kWh heat recoverable for the wastewater treatment process per day*
BBF derived from treatment of organic waste (e.g. compost)	Waste treatment Recommended FU: *Treatment of x t of organic waste of a certain composition towards a certain level (e.g. regarding hygienisation) per day.*	Production of a fertilising product containing nutrient a Recommended FU: *1 kg of nutrient a* Additional FUs for other nutrients may be added	

BBF derived from manure treatment	Treatment of manure Recommended FU: *Treatment of x t of manure with a water content of x% of a certain livestock type and housing system towards a certain level (e.g. regarding hygienisation) per day*	Production of a fertilising product containing nutrient a Recommended FU: *1 kg of nutrient a*	
		Additional FUs for other nutrients may be added	
BBF derived from biogas plants[1]	Energy production Recommended FU: *Production of x t of biomethane produced for end-user (excluding internal use of the plant)*	Waste treatment *Treatment of x t of organic waste of a certain composition towards a certain level (e.g. regarding hygienisation) per day.*	Production of a fertilising product containing nutrient a Recommended FU: *1 kg of nutrient a*
	Waste treatment *Treatment of x t of organic waste of a certain composition towards a certain level (e.g. regarding hygienisation) per day.*	Energy production Recommended FU: *Production of x t biomethane produced for end-user (excluding internal use of the plant*	Additional FUs for other nutrients may be added

[1] Depending on the purpose of the study, the main function of biogas plants can be either energy production or waste treatment

Especially for systems dealing with BBFs the main function is often not the production of a fertiliser, but the treatment of waste, wastewater or manure or the production of biogas. Thus, to generate comparability among different types of fertilising products additional FUs should be defined. Depending on the purpose of the study, additional FUs can be based on a quantity of input material treated in a process, the quantity of a nutrient in the produced fertilising product or both. Nevertheless, a FU corresponding to the main function of the system shall always be defined. Additional FUs should also be defined if several functions are equally important to a system, and it is not possible to define one main function. This is illustrated in the example below:

Two biogas plants co-treating energy crops and biowaste (manure, food waste) with different installations for nutrient recovery and recycling, are investigated. The main purpose of the system is the transformation of the biodegradable substrate to biomethane. However, as the plants have invested in nutrient recovery and recycling biowaste management can be considered as a second function of the system. If the plants are to be compared with respect to the efficiency of their management of biowastes, two FUs have to be defined:

- *"Production of 1 metric ton of CH_4" corresponding to the main function*
- *"Treatment of 1 metric ton of substrate" corresponding to the function of biowaste management*

As fertilising products are intermediate products the FU for the production of a fertilising product shall not be defined according to the criteria "what", "how much", "how well" and "how long", but as a declared unit, corresponding to the reference flow (Zampori and Pant 2019). For the main nutrients present in fertilising products these are:

- 1 kg of mineral N
- 1 kg of P_2O_5

4.2. Solving multifunctionality

All system functions that are not represented in the FU shall be considered in the LCA according to the following hierarchy (EC-JRC 2010):

- Subdivision of multifunctional processes:
  Multifunctional processes should be subdivided as far as possible into mono-functional unit processes, if not requiring a disproportionate effort. This might already solve the multifunctionality problem. However, also in cases, where the separated unit processes remain multifunctional, subdivision facilitates solving the problem and improves transparency.
  - *E.g. subdivision of a wastewater treatment plant into different process steps of wastewater cleaning and sewage sludge treatment*
- System expansion (including substitution)
  If systems with different co-functions are compared, functions (or products) only present in one system shall be substituted by equivalent functions (or products) whose impacts are subtracted from the system. Alternatively, equivalent functions (or products) can be added to the systems in which they are not provided. Based on the purpose and context of the study, one of the following substitution principles shall be chosen:
  - Attributional substitution: If substitution does not cause significant changes in the market where the substituted function/product is provided, it shall be based on the average market mix of this market
    - *E.g. Substitution of electricity produced by a biogas plant with national grid electricity*
  - Consequential substitution: If substitution is thought to cause significant changes in the market where the substituted function/product is provided, it shall be based on the marginal processes/products likely to be driven from the market
    - *E.g. If high quality N fertiliser was recovered from a significant part of manure in the EU it might replace the current marginal N fertiliser (urea) in the market mix*
- Allocation
  If substitution is not feasible or requires a disproportionate effort, inputs and outputs shall be partitioned between the co-functions (or co-products) according to the following allocation criteria, which shall be applied in a hierarchical order:
  - Causal (physical, chemical or biological) relationship
  - Economic or other (e.g. energy content) relationship
    - *E.g. Allocating impacts of agricultural production between cereal grain and straw based on their economic value, in a case where straw is only a minor input to a biogas plant and substitution would cause a disproportionate effort*

For most LCAs on fertilising products attributional substitution is the most appropriate solution to multifunctionality issues. If this is the case, the following recommendations should be followed:

- Substitution of N and P in multi-nutrient fertilisers or in systems where fertiliser production is not considered as a FU:
    - N: Substituted with N produced via the Haber-Bosch process
    - P: Substituted with TSP
- Substitution of waste treatment processes (e.g. manure management or treatment of sewage sludge, municipal organic waste and digestate from biogas plants) in systems where waste treatment is not considered as a FU: As common treatment practices are very variable between different countries/regions no general recommendation can be given. However, to make data as comparable as possible, all waste treatment options common in the setting under study should be used for substitution and compared in a sensitivity analysis.
- Substitution of energy produced in biogas plants where energy is not considered as a FU:
    - Electricity: EU/national grid electricity
    - District heat: EU/national heat mix
    - Biomethane: natural gas
- In line with common practice, upstream impacts of sulphuric acid, a common input to fertiliser production, stemming from crude oil processing, natural gas processing or cleaning of roasting gas shall be considered via allocation. Allocation factors are provided in LCA databases (e.g. ecoinvent, https://ecoinvent.org/the-ecoinvent-database/login/)
- In line with provisions of the PEF (Zampori and Pant 2019) upstream impacts of agricultural co/by-products (e.g. straw and hay) and of agricultural products that are part of a crop rotation system (e.g. cover crops) which are used in BBF production shall be considered following the guidelines of the FAO LEAP initiative (FAO 2016).

If different approaches are used, the recommendations above shall be applied in a sensitivity analysis. This facilitates comparability across studies.

The approach of solving each multifunctionality problem, exact specification of all substitution products/processes and exact specification of all relationships used for allocation (if applicable) shall be explicitly stated in all publications of the LCA results.

4.3. System boundaries

A precise definition of the system boundaries is important to ensure that all relevant processes and all relevant potential impacts on the environment are included in the system. All processes included in the system boundaries together with their inputs and outputs shall be depicted in a flow diagram (EC-JRC 2010).

According to the PEF (Zampori and Pant 2019) system boundaries for intermediate products shall be considered from cradle to gate, i.e. to the point where fertilising products leave the production facility. However, especially for BBFs, main differences of the systems might lie in the transportability of the fertilising product (e.g. raw manure or digestate vs manure or digestate after solid-liquid separation). Therefore, where relevant to the purpose of the study, system boundaries in fertilising product systems shall be considered from cradle to upper farm gate, i.e. including transport but excluding all processes related to fertiliser field application.

In general, the system shall be analysed as holistically as possible, avoiding any cut-off. This enhances comparability across studies. However, processes, that have proven to be of minor importance to the overall impact of the system and for which data collection requires a disproportionate effort may be cut-off (EC-JRC 2010).

Furthermore, processes identical to all systems under comparison shall be cut-off in order to reduce data collection and computation effort that does not have an impact on the conclusions drawn from the comparison (EC-JRC 2010). This is illustrated in the following examples:

In a comparison of nutrient recovery technologies from sewage sludge processes of wastewater collection and treatment can be cut-off, if identical for all systems under study

In a comparison of manure treatment technologies manure collection and storage systems in stables prior to treatment can be cut-off if identical for all systems under study

All cut-off points shall be explicitly stated in all publications of the LCA results.

In addition, the following points should be regarded, especially in the case of BBFs:

- Waste shall be considered as burden-free and upstream impacts of waste shall be cut-off from the system. However, impacts from waste transport shall be included.
- Co/by-products shall only be regarded as burden-free if the alternative to using them in fertiliser production is disposal as waste or if the impacts of the co/by-product have already been considered in the upstream process.
    - *E.g. Upstream impacts of sulphuric acid from crude oil or natural gas processing or from cleaning of roasting gas shall be partly considered according to the allocation and substitution principles described in Chapter 4.2., whereas reuse of waste sulphuric acid shall be regarded as burden-free as upstream impacts are already accounted for in the preceding process.*
    - *Biogas digestate shall be regarded as a by-product of biogas production and not as waste.*
- Upstream impacts of organic primary material used for fertiliser production, e.g. energy crops treated in biogas plants, shall be considered.
- Upstream impacts of crop by-products (e.g. straw and hay) and biogas digestate (as a by-product of energy production prior to processing to a fertilising product) shall partly be considered according to the principles described in Chapter 4.2.

4.3.1. Exclusion of the gate-to-grave stage

The reason for excluding the use stage in studies of intermediate products is that they fulfil multiple functions and the whole life cycle of the product is not known (Zampori and Pant 2019). This premise can be transformed to fertilising products. Although the function of using a fertiliser is always to supply nutrients to plants, impacts on fertiliser use are highly dependent on the following factors, which are often not known at the stage of fertiliser manufacture:

- Climate (temperature, precipitation)
- Soil (type, texture, cultivation history, etc.)
- Geographical parameters (slope, inclination)
- Farming type (conventional, organic, etc.)
- Tillage practices
- Crop parameters (species, nutrient requirements, standard yield)
- Fertiliser application technique

- Timing of fertiliser application (number of dosages and application months over the growing season)
- Fertiliser amount (per dose and total)

Moreover, scientific consent on how these factors influence the agronomic efficiency and environmental impacts of different fertilising products is to date lacking. At present it is thus not possible to provide comparable cradle-to-grave LCA results for fertilising products across studies. Instead, the cradle-to-gate (or cradle-to-upper farm gate) study should be accompanied by an assessment of environmental risk and agronomic efficiency (see Chapter 3).

If sufficient and reliable information on field behaviour and plant uptake for all fertilising products in a specific case is available (e.g. from field experiments or modelling) these may be included in a separate gate-to-grave LCA provided that:

- Results of the cradle-to-gate (or cradle-to-upper farm gate) study are reported separately
- All parameters of field application listed above are specified
- A statement pointing out that results of the gate-to-grave study are only valid for these specific conditions is included in all publications of the gate-to-grave study results

As it is only valid for a specific case, a gate-to-grave LCA shall not be used as a substitute for the assessment of environmental risk and agronomic efficiency.

4.4. Preparing the basis for the impact assessment

4.4.1. Defining impact categories and LCIA methods

Following common practise in the field life cycle impacts of fertilising products shall be assessed at midpoint level. To ensure comparability of results ReCiPe impact categories, LCIA methods and characterisation factors should be used. ReCiPe currently is the most frequently applied method in the field of fertilising products globally (Tanzer et al. 2021) and thus has the highest potential of ensuring cross-study comparability.

In general, the whole set of impact categories should be applied. However, impacts which have been proven to be of low relevance for the analysed system in past assessments of sufficiently similar systems or which prove to be of low relevance in the course of the iterative LCA procedure may be excluded. Any exclusion shall be justified (EC-JRC 2010).

Likewise, impact categories may be added provided that they are relevant to the system under study and meet the following requirements (EC-JRC 2010):

- International acceptance
- Documented scientific and technical validity
- Full coverage of the impact they relate to
- Relation to a distinct identifiable environmental mechanism or reproducible empirical observation
- Exclusive relation to elementary flows during normal and abnormal operation conditions (excluding spills, accidents, etc.)
- Avoidance of double counting of characterisation factors
- Avoidance of value choices and assumptions

In case of a newly developed impact category and LCIA method, the first point can be omitted. Any addition of an impact category shall be justified.

4.4.2. Defining normalisation basis (optional)

Normalisation may be included in the LCA to facilitate result interpretation. In that case, the normalisation basis shall be defined as recommended in the ILCD handbook (EC-JRC 2010):

- Normalisation basis: Environmental impact of an average (global, national or regional) citizen
- Year for the normalisation basis: year for which the latest appropriate data is available

Non-normalised results shall be reported additionally in all publications of the LCA results.

In line with the ISO standard 14040/14044 weighting shall not be used in studies where different systems are compared to each other, which applies to almost all studies of fertilising production systems.

4.5. Assumptions and limitations

Typically, in the course of the LCA several limitations (e.g. data gaps) are faced, so that assumptions need to be taken to carry out the analysis. All limitations and assumptions shall be transparently documented (Zampori and Pant 2019). In addition to the assumptions described in the previous chapters (e.g. on substitution products/processes, cut-off points, etc.) this includes:

- Specific ways or modes of operation of a technology/technique
    - *E.g. Vehicle, distance and load factor during transport of a fertilising product to the farm where it is applied*
- Deviations of process data used in the assessment from the process under study in terms of technological, geographical and temporal representativeness
- Sources of electricity for all processes requiring electricity input
- Any other assumptions

Any assumptions, including those on substitution modes, substitution products, cut-off points, LCIA method, etc., that might have a significant impact on the LCA results, should be subjected to sensitivity analysis. For that purpose, assumptions taken should be compared with reasonably worst case and reasonably best case assumptions (EC-JRC 2010).

5. Consistency of methods, assumptions and data

Throughout all phases and aspects of the LCA consistency of methods, assumptions and data shall be ensured as far as possible (EC-JRC 2010). This includes:

- Consistent way of making assumptions in different parts of a system and between systems
    - *E.g. choice of equal load factors for transport of fertilising products in different systems*
- Comparable degree of accuracy, completeness, and precision of LCI data
- Uniform application of all methods
    - *E.g. for methods to calculate emissions from unit processes*
- Consistent approach of solving multifunctionality
- Uniform application of a LCIA method to all systems under study

Inconsistencies that might have significant effects on the results of the LCA shall be reported in all publications of the LCA results and considered when drawing conclusions from the study (EC-JRC 2010).

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