Proposals for improvements to the PEF method

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1 Introduction

The European Commission has asked for feedback on elements that could be potentially considered for the revision of the Commission Recommendation (EU) 2021/2279 of 15 December 2021 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations.

In addition to the replies to the survey circulated, we have prepared this document with specific proposals to the PEF method as described in Annex 1 of the Commission Recommendation (EU) 2021/2279 of 15 December 2021 (hereafter called the “2021 PEF method”).

Our proposls have three objectives: 1) To make it possible to follow the method description without unnecessary effort, while maintaining or enhancing the quality and practical applicability of the resulting PEF studies; 2) To clarify the text in places where the current text is ambiguous or can lead to mis-information relative to the decision that a PEF study intends to support; 3) To harmonise requirements, so that the same requirements apply across all products and across all elementary flows.

2 Section 1 PEFCRs

Proposal 1: In **Section 1 of the 2021 PEF method**, the primary objective of a PEFCR (Product Environmental Footprint Category Rule) is described as “to fix a consistent and specific set of rules for […] the product category in scope […] to focus on what matters most for a specific product category, to make PEF studies easier, faster and less costly.” In practice, PEFCRs have rather added to the difficulties and costs of producing and using PEF studies.

We therefore propose to explicitly limit the issues to be dealt with in a PEFCR to those for which it is meaningful that different product categories can have different requirements, and explicitly exclude issues that would better be (or are already) addressed consistently as general requirements in the PEF method for all products and/or as requirements to the EF database, instead of having to be included in each and every single PEFCR.

We propose to add the following new text after the first paragraph of Section 1 of the 2021 PEF method:
“Issues that could be relevant to include in PEFCRs/OEFSRs could be issues such as:

- specifying the means by which specific primary data should be collected,
- templates to facilitate harmonized data collection, metadata recording, and results reporting,
- requirements on the information that shall be provided to the customers for a specific product category.

Issues that would better be (or are already) addressed consistently as general requirements in the PEF method for all products and/or as requirements to the EF database shall not be be included in PEFCRs, especially:

- requirements on including or excluding capital goods and infrastructure,
- product lifetimes or standardized methods of computing lifetimes,
- the depreciation method to allocate the burden of capital goods over their service period,
- requirements for scenarios for use and End-of-Life,
- requirements on the use of primary data and the age of data,

- requirements for data sources,
- requirements on impact assessment methods and indicators,
- requirements on cut-off criteria,
- requirements on the use of best estimates versus worst-case,
- requirements and assessment methods for data quality, and
- requirements on methods for handling multi-functionality."

In this context, we also propose to remove the preferential status that is currently given to product-specific PEFCR requirements over the generic requirements of the PEF method, since this reverse logic creates inconsistencies and hampers cross-category product comparability.

Proposal 2: In the second paragraph of Section 1 of the 2021 PEF method an "equally important objective" for PEFCRs is stated as "to be able comparisons and comparative assertions in all cases where this is feasible, relevant and appropriate." The idea is that comparability requires functional equivalence and market substitutability to a benchmark reference product within each product category. However, it has turned out to be difficult to delimit product categories in a way that ensures this functional equivalence. In the end, it is the customers that define what is accepted as comparable. Thus, customers implicitly define functional units for comparability when making purchase decisions. The PEF method should thus allow comparisons at many different levels of granularity, reflecting the widely different decision contexts found in reality, which may imply comparisons that are both broader and narrower than any pre-defined product categories.

We therefore propose to make PEFCRs voluntary for comparative PEFs, i.e., removing the two first sentences of the second paragraph of Section 1 of the 2021 PEF method, and especially the requirement that "Comparisons and comparative assertions are allowed only if PEF studies are conducted in compliance with a PEFCR."

The above proposals (1 and 2) would significantly reduce the duration and effort for the development of new PEFCRs without negatively impacting on the quality of the PEFCRs. This would imply an important streamlining and significant cost saving for the PEF system and for the construction of a harmonised and consistent database.

3 Section 2.2 Principles for PEF studies

Proposal 3: Considering that the general principles are not always followed in practice, especially in many PEFCRs/OEFCRs, we propose to complement each of the general principles with a sentence clarifying their importance, as well as adding the missing principle of 'Priority of scientific approach' from ISO 14040:

2.2.Principles for Product Environmental Footprint studies

Users of this method shall observe the following principles in conducting a PEF study:

(1) Relevance: All methods used and data collected for the purpose of quantifying the PEF shall be as relevant to the study as possible. This implies that unit processes added to the product system are those that would actually be affected when producing or consuming an additional amount of the product under study (cf. ISO 14040 Clause A.2 and ISO 14049 Clause 6.4).

(2) Completeness: Quantification of the PEF shall include all relevant material/energy flows as required for adherence to the defined system boundary, the data requirements, and the impact assessment methods employed. This implies that unit processes and life cycle stages should only be excluded when insignificant for the footprint.

(3) Consistency: Strict conformity to this method shall be observed in all steps of the footprint study, to ensure internal consistency and comparability. This implies that the same calculation rules shall be applied for the linking of unit processes into product systems, for all unit processes and all PEFs.
(4) Accuracy: All reasonable effort shall be taken to reduce uncertainties in product system modelling and the reporting of results. This implies that uncertainty shall be quantified as far as possible and that the most accurate data available shall be used and presented.
(5) Transparency: Data shall be disclosed in such a way as to provide intended users with the necessary basis for decision-making, and for stakeholders to assess its robustness and reliability.
(6) Priority of scientific approach: Decisions within a PEF study are preferably based on natural science. If this is not possible, other scientific approaches (e.g. from social and economic sciences) may be used. This implies that normative choices shall be avoided and decisions shall be guided by respect for physical conservation laws, economic accounting principles, and plausible cause-effect relations."

4 Section 3 Defining the goal(s) and scope of the PEF study

Proposal 4: Make the Example of goal definition in Table 1 more precise, by adding the missing decision context:
In **Table 1**, change “Respond to a request from a customer” to “Provide information that can allow the target group to compare the environmental impact of the T-shirt to that of comparable products”.

Proposal 5: In particular for the application of PEF/OEF to consumer-oriented labelling, it is important to note that product comparisons are only valid when taking the 'monetary rebound' effect into account, i.e., that the choice of the cheaper option will leave the consumer with saved money that can then be used to purchase other products with their own environmental impacts. For a fair comparison of the environmental impacts from products with different prices, the environmental impacts of these alternative purchases would therefore have to be added to the cheaper product. A simple way to achieve this is to instead compare the products based on their impact per euro spent on the products. Thereby, the cheaper products will obtain a higher footprint value per euro, mimicking an internalisation of the monetary rebound effect. At the same time, this allows *all* products to be compared across *all* product categories, without need to define a specific size for a declared unit, to specify the reference flow, or to identify functional units for technical equivalence and market substitutability. The resulting incentive for the consumer is to move away from products with a high environmental impact intensity to products with a low environmental impact intensity, compared to a labelling scheme that limits comparability to within product categories and therefore cannot be used to steer consumer choices away from high impact intensive product categories, such as beef or cars.

Note, however, that applying the simple functional unit of 'consumer expenditure' for all consumer-facing products does not eliminate the need for determining technical functional units for intermediate products and waste flows in the context of the linking of the unit processes in a product life cycle or life cycle database. Every unit process in a product life cycle has inputs of specific intermediate products (including treatment services) that can come from many different suppliers and have many different product formulations, even though these inputs are substitutable from the perspective of the customer. For example, a dairy farmer buying feedstuffs for his animals will have a certain requirement for the crude protein content in the feed composition, but this requirement may be fulfilled by many different types of protein-containing feedstuffs. Without a functional unit for feed, defined in terms of technical functional equivalence and market substitutability, it will not be possible to model how the feed industry will respond to the specific demand of the dairy farmer. It is in this context of unit process datasets in a database that it is necessary to have unambiguous requirements for the identification of functional units for intermediate products.

The proposal is therefore to revise section 3.2.1 of the PEF method entitled "Functional unit and reference flow" to provide additional specific guidance and examples, and remove the option to apply 'declared units', as follows:

"**3.2.1 Functional units and reference flows**

For products sold to the end-consumer, a functional unit shall be specified, expressed as the total consumer expenditure for the product in monetary units, e.g. Euro, measured at the point of final consumption, i.e., after preparation for use, including losses and costs of storage, maintenance, repair, and treatment of wastes and sewage. For each input to final consumption, its average price during the previous calendar year shall be used to quantify the consumer expenditure.

When adding new intermediate products to a product system or the EF database, a functional unit shall be specified that quantifies the obligatory product properties, i.e., the properties that the product must have in order to be at all considered as a relevant alternative by the customers on the relevant product market, covering at least the functionality (what), the expected level of quality (how well) and the duration/life time of the product (how long). Nationally implemented legal compliance requirements should be seen as obligatory. The obligatory product properties can differ depending on the customers in the market as well as the geographical location and time. The same product might be sold on more than one market (i.e., for more than one purpose and with different functional units). And very different products may serve the same purpose (= have the same obligatory properties), thus being in competition in the same market. For example, an institutional kitchen may have specific requirements to nutritional content of the meals, while this will seldom be among the obligatory product properties for a home-cooked or restaurant meal. Therefore, the relevant product markets shall be described in terms of its geographical and temporal segmentation, and in terms of the customers in the market. Further guidance on the definition of functional units and identification of obligatory product properties and relevant product markets can be found in Weidema (2017) [1].

Having defined the functional unit, the reference flow shall be defined for each product system. The reference flow is a measure of the outputs from unit processes in a given product system required to fulfil the function expressed by the functional unit. Thus, the reference flow translates the functional unit into specific amounts of product flows, in physical units, for each product system. The reference flow thus includes any required packaging, auxiliary products, and losses, that are not already considered as upstream inputs in the product system."

Proposal 6: **In Section 3.2.2 on 'system boundary'**, make the requirements for completeness and no cut-offs more precise by changing the first sentence to: "The exclusion of life cycle stages, activities, inputs or outputs shall only be done if it does not significantly change the overall conclusions of the study." (cf. ISO 14044, Clause 4.2.3.3.1).

Proposal 7: There is very limited information in the 2021 PEF method on how to construct the product system. The two relevant requirements provided are "the system boundary shall be defined following a general supply-chain logic including all upstream processes" and "all non-elementary flows in the LCI shall be modelled up to

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[1] Weidema B P (2017). Short procedural guideline to identify the functional unit for a product environmental footprint and to delimit the scope of product categories. 2.-0 LCA consultants, report to the Nordic Council of Ministers. https://lca-net.com/p/2527

the level of elementary flows, apart from the product flow (product and co-product) for the product in scope". A sufficiently precise description of "supply-chain logic" is missing, but since PEF studies have the purpose of providing information to support decisions, it follows logically that a "supply-chain logic" must ensure that the products and processes included in the product system are "those affected by the decision that the LCA intends to support" (ISO 14040, Annex A.2).

The proposal is therefore to revise paragraph 2 in **Section 3.2.2 on 'system boundary'** to clarify the meaning of 'supply-chain logic': "The system boundary shall be defined following a general supply-chain logic, tracing each required product input, physical or monetary, *from* the activity in which the functional unit is defined, *through* the upstream chain of unconstrained suppliers, and tracing each co-product output *through* the downstream chain of activities affected by the accumulated change in supply of co-product, *until* all flows at the system boundary are elementary flows."

5 Section 4 Life cycle inventory

Proposal 8: To reduce ambiguities, add the following clarification to the **last paragraph of Section 4 of the PEF method (before Section 4.1):** "When encountering multi-functional (co-production) activities that have more than one product output, the determining product of interest is isolated from the other co-products by subdivision following physical causalities in cases of combined production, and by applying the circular footprint formula to eliminate the excess supply of by-products from joint production activities." This sentence should be added before the last two sentences that read: "The LCI modelling is therefore only complete when all non-elementary flows are expressed as elementary flows. Therefore, the LCI dataset of the PEF study shall contain only elementary flows, apart from the product flow for the product in scope."

6 Section 4.2 Life cycle stages

Proposal 9: **Section 4.2 of the 2021 PEF method** requires the subdivision of the product life cycle into a small number of pre-defined life cycle stages. However, experience has shown that it is difficult to determine what is to be included in the different stages. Grouping activity datasets and PEF results into pre-determined 'life cycle stages' can easily add two hours of work for each PEF study, and thus corresponding additional costs. More fundamentally, it is unclear what the purpose is of the subdivisions, which essentially just groups different activities in the life cycle in different categories ('life cycle stages'). Such a pre-defined categorisation appears unnecessary in a situation where there is access to the unaggregated gate-to-gate activity datasets (see proposal 19 and 20), since each user of the information can group the activities in the product system according to what is most relevant for any specific question. Not having to group activity datasets and PEF results into pre-determined 'life cycle stages' will reduce the potential errors of placing activities in a "wrong" category and the consequent misleading communication. Instead, adding a requirement to keep gate-to-gate datasets unaggregated will increase transparency and usability of the results.

The proposal is therefore to replace the text of Section 4.2 of the PEF method by this text: "The activity datasets shall be created and kept unaggregated as gate-to-gate datasets [reference Section 4.6.2 of the revised requirements document, cf. proposal 19]. There is no requirement to group or aggregate activity datasets into life cycle stages. Activity datasets may be grouped and regrouped freely, to serve according to the needs of different purposes, such as specific analyses, interpretations, and communication settings."

7 Section 4.4 Modelling requirements

Proposal 10: **Section 4.4.2** in the 2021 PEF method, on the use of generic and residual markets when modelling inputs of electricity, is no longer relevant if our proposal 19 is accepted, since this includes this kind of modelling as a general requirement.

Proposal 11: **Section 4.4.4** in the 2021 PEF method requires that "Capital goods (including infrastructure) and their EoL should be excluded, unless there is evidence from previous studies that they are relevant", and in that case to include a clear and extensive explanation on why they are relevant. Nevertheless, the PEF method also requires the use of EF compliant data sets, for which inclusion of capital goods is a requirement. This internal inconsistency in the PEF method is best solved in line with the completeness principle, by requiring inclusion of all capital goods and infrastructure, and reversing the documentation requirement to apply only if capital goods are *not* included. This corresponds to the requirement in the mandatory format guide for EF compliant data sets. Compared to the current requirement in the 2021 PEF method, this would imply a significant reduction in effort required by the LCA practitioners, that now no longer need to justify the relevance of their inclusion of capital goods.

Excluding capital goods formation has been shown to lead to significant underestimation of footprint results, especially for agricultural products that have relatively high capital goods requirements. Capital goods, i.e. the inputs to the product life cycle that have lifetimes exceeding one year, are modelled in the same way as all other products. The activities of capital goods formation typically provide the capacity for other activities to produce their outputs. For example, the capital good required by an activity 'electricity generation' with an annual output of 2 TWh electricity could be a 'power plant' with 250 MW nameplate capacity and an expected lifetime of 30 years, i.e. one such power plant would be needed per 60 TWh produced. The capital goods formation activity that supplies the power plant would then have inputs of concrete, steel, turbines, electronic control equipment, construction and demolition work, etc. In the same way, a wheat producing activity with an annual output of 1000 metric tonne could require an input of 4000 tractor-hours, 400 hours of self-propelled harvester, 200 hectare-years of arable land, etc., each of which is produced by an upstream capital goods formation activity that again require further upstream inputs.

Proposal 12: Add precision, additional clarifications, and detailed guidance, as well as detailed requirements that simplify the use of the CFF, to the text in **Section 4.4.8 of the PEF method,** as follows:
"Recycled content and end of life (inputs and outputs of by-products and wastes in any activity in the product system) shall be modelled using the circular footprint formula (CFF) at the life-cycle stage where the activity occurs. The following describes the formula and parameters to be used and how they shall be applied. The same formula applies equally to by-products and wastes.

4.4.8.1. The circular footprint formula (CFF)

The CCF is a combination of 'material + energy + disposal': [reproduce the three parts of the formula from the PEF method, and the explanation of the parameters, then continue with this new text:] "Thus, the circular footprint formula addresses four different situations in the product life cycle, namely:

- When recycled materials are demanded as an input (recycled content)
- When materials are supplied to material recycling
- When materials or energy are supplied for energy recycling (recovery)
- When materials are supplied to final disposal without energy recovery

4.4.8.2. Material recycling and the A factor

For material recycling, the CFF includes a quality ratio for secondary compared to primary material. This ratio shall by default be set to 1, because the quality is already reflected in the *quantity* of the primary material that is displaced by the recycled material, qua the functional unit of the material and respective reference flows. This also ensures the mass balance of the resulting inventory, which might not be ensured if applying a quality ratio different from 1.

For material recycling, the CFF applies a factor A that distinguishes two market situations:

- One represented by **A = 0**, in which demand for the material exceeds secondary supply so that additional demand will not be able to increase recycling. Both the recycling effort and the avoided primary production is included in the product system that by its supply stimulates additional reuse or recycling. This provides an incentive for additional recycling whenever impact of primary production is large and recycling impact is small.
- One represented by **A = 1**, in which the market is saturated or recycling capacity is constrained, implying that some secondary product of sufficient quality for recycling is instead treated as final waste. All recycling efforts and the reduced final waste treatment is included in the product system that uses the recycled product. This provides an incentive for additional recycling whenever recycling impacts are small and avoided waste treatment impacts are large.

In summary:

When a recycled material is demanded as an input (**R_1**) in the market situation where demand for the material exceeds secondary supply (**A = 0**), the CFF reduces to **E_v**, representing that all the material input comes from virgin production.

When a recycled material is demanded as an input (**R_1**) when the market is saturated (**A = 1**), the CFF reduces to **$(1-R_1)E_v + R_1 * E_{recycled}$**, representing that all the recycled material input demanded comes from increased recycling and reduced final waste treatment. It should be noted that the reduced final waste treatment was not included in the 2021 version of the PEF method, but has now been included in **$E_{recycled}$** for completeness.

When a material is supplied to recycling (**R_2**) in the market situation where demand for the material exceeds secondary supply (**A = 0**), the CFF reduces to **$R_2 * (E_{recyclingEoL} - E^*v)$**, representing that both the recycling effort and the avoided primary production is included in the product system that supplies the material to recycling.

When a material is supplied to recycling (**R_2**) when the market is saturated (**A = 1**), the CFF reduces to **E_D**, representing the increase in final disposal of the excess supply.

At any given point in time a market cannot both be saturated and non-saturated, which explains that A either equals 0 or 1 in the above description. It should be noted that the 2021 PEF method restricted the allowed values for A to between 0.2 and 0.8, reflecting that the markets considered in the PEF method were intended to be calculated or estimated as averages over several geographically or temporally distinct situations. This restriction has now been removed, so that the method is now also applicable to geographically or temporally distinct markets. When aggregated markets are created, this aggregation should be made transparently. If no information on the market situation is available, a value for A of 0.5 shall be applied.

4.4.8.3. Energy recovery and the B factor

The CFF for energy recovery applies a B factor that shall, by default, be equal to zero. The CFF for energy recovery then reduces to the same meaning as the second part of the CFF for materials, representing that both the recovery effort and the avoided primary energy production is included in the product system that supplies the material or energy for energy recovery.

To avoid double-counting between the current and the subsequent system in case of energy recovery, the subsequent system that uses the recovered energy shall model its own energy use from energy recovery processes as primary energy."

Proposal 13: In the 2021 PEF method, **Section 4.4.10.1, second paragraph,** contains the following requirement: "Fossil CO_2 uptake and corresponding emissions (e.g. due to carbonation) shall be modelled in a simplified way when calculating the PEF profile (meaning no emissions or uptakes shall be modelled)." This exemption does not carry any justification. As a consequence of the PEF completeness principle, the proposal is to delete the second paragraph of Section 4.4.10.1 requiring the omission of fossil CO_2 uptake and corresponding emissions.

Proposal 14: In line with the PEF completeness principle, the text in **section 4.4.10.2** in the PEF method should be replaced with the following text that includes the requirements from ISO 14067 on biogenic carbon, carbon sequestration, and the importance of timing of the carbon flows:
"This sub-category covers (i) carbon emissions to air (CO_2, CO and CH_4) originating from the oxidation and/or reduction of aboveground biomass by means of its transformation or degradation (e.g. combustion, digestion, composting, landfilling), and (ii) CO_2 uptake from the atmosphere through photosynthesis during biomass growth, i.e. corresponding to the carbon content of products, biofuels, or above-ground plant residues such as litter and dead wood. Biogenic carbon from crop residues and forest residues shall be modelled under land use and land use change (see section 4.4.10.3).
The emissions and uptakes of biogenic carbon shall be modelled in the following way:
1) all emissions of 'methane (biogenic)' shall be included;
2) biogenic CO_2 uptake and emissions shall be included, with the following exception: When matching amounts of biogenic carbon uptake into food, feed, biofuel, and chemical products are re-emitted < 1 year after uptake, from combustion and chemical transformation processes, food and feed metabolism (CO_2 from respiration), or via fast decay of carbon in excretion products.
3) When biogenic emissions are emitted >1 year after uptake, they shall be accounted for with indication of the number of years that have passed since the uptake. The decay of biogenic carbon in waste shall be calculated following IPCC (2019), volume 5, chapter 3, on solid waste disposal. When biogenic carbon in waste materials is stabilised, e.g., via pyrolysis, the decay of biochar shall be modelled as exponential, with a half-life of 500 years."

Proposal 15: In **Section 4.4.10.3 in the PEF method**, the requirements of the PAS 2050 standard mixes historical, direct, and indirect land use. Also in the Definitions in Annex 1 of the 2021 PEF method, there is a need to make the definitions more precise, as follows:
Direct land use change (dLUC) – Change resulting from land use occurring on the same land as the land use.
Indirect land use change (iLUC) – Change resulting from occupation of a land area and occurring upstream in the life cycle from the occupied area. iLUC is independent of the specific nature of the land use on the occupied area. As for other uses of capital inputs, the indirect effects may be mainly estimated by means of economic modelling of the demand and the resulting relocation of activities on a global scale.

Based on these clarified definitions, it is also possible to improve the description in Section 4.4.10.3 by replacing the reference to PAS 2050 and the last two paragraphs on soil carbon stock (carbon sequestration) by:
"For land use change, distinction shall be made between at least the three land categories of arable land, forest land, and grassland. Land use change always involves two types of land use change, direct and indirect, abbreviated dLUC and iLUC, respectively.
For dLUC, accounting shall be made for the difference between the actual land use and the national average crop cultivation for the land category. For the aboveground biomass, the emission 'carbon dioxide (land use

change)'[2] is calculated as the difference in carbon stock (tonne carbon/hectare) for the actual land use (hectare-year) and the national average for all crops within the land use category, multiplied by 44/12. In most cases of crop production, the difference in carbon stock between the actual land use and the average crop within each land category is negligible. For the soil carbon, the difference caused by the actual land use relative to the national average crop cultivation for the land category shall be calculated as the actual minus average delayed CO_2 emissions from decay of the crop residues left in the field, calculated in GWP_{100}-equivalents (in tonne per hectare) using the RothC model, plus the average minus the actual carbon uptake during growth (in tonne per hectare) of the crop residues left in the field, multiplied by 44/12. Unless better data are available, default values for carbon uptake during growth of crop residues shall be taken from IPCC (2019), volume 4, chapter 11. Unless better data are available, default values from the RothC model shall be taken for data type 'CO_2 emissions with delay (GWP100)') from by summing the data for type of residue (crop residue or manure) and level of tillage (conventional, reduced, or no tillage). [The default values could be added as an appendix or as an online tool]

For iLUC, which represents the upstream capital goods formation of land, with the functional unit of 'capacity for biomass production' (expressed in net-primary-productivity-equivalent hectare-years; 'NPP0-eq. ha-yr')[3], the calculation follows the general requirements in Section 4.6.2 for generic product data and secondary data: For each of the relevant product markets (at least one global markets for each of the land categories of arable land, forest land, and grassland), a generic market dataset is created, in the form of the mix of unconstrained suppliers. For the global market for arable land, the unconstrained supply of 'capacity for biomass production' shall be calculated as partly coming from land conversion from secondary forest to annual crops, identified from FAOSTAT as the increases in NPP0-weighted cropland hectare-years for the latest five-year time-series for all countries, and partly from intensification of production on land already converted, identified from FAOSTAT as the increase in crop output (in tonnes) over the latest five-year time-series for all crops in all countries, converted to 'NPP0-eq. ha-yr' by using average yields (tonne/ha-yr) per crop in each country over the five years and NPP0-weighting. For the global market for forest land, the unconstrained supply of 'capacity for biomass production', identified from FAOSTAT as the national increases in wood removal (in m^3/hectare-year) for the latest five-year time-series for all countries, converted to 'NPP0-eq. ha-yr', shall be calculated as coming firstly from a conversion of primary forest to managed forest as identified by the latest FAOSTAT five-year time series on loss of primary forest, and secondly from a conversion of secondary forest area to managed forest area, where the area converted to managed forest is calculated as:

- converted to intensive forest area with an additional yield of 4 m^3/NPP0-equivalent hectare-year until the national annual increase in wood removal has been reached, in countries where the current annual wood removal exceeds what can be obtained from extensive forests, assuming a minimum wood yield of 1 m^3/NPP0-corrected hectare-year from the areas of FAOSTAT categories for managed forest (planted forest and other naturally regenerating forest)
- converted to extensive forest area with an average yield of 1 m^3/NPP0-equivalent hectare-year, in all other countries, i.e., countries that currently exclusively have extensive forests.

For the global market for grassland, the unconstrained supply of 'capacity for biomass production', shall be calculated as coming from conversion of natural grassland to managed rangeland, quantified as the national increases in carbon uptake by grazing animals for all countries, using FAOSTAT increases in heads of grazing

[2] The corresponding characterisation factor is 0.0072 kg CO_2-eq./kg 'carbon dioxide (land use change)', which is the GWP_{100} difference of preponing emission of 1 kg CO_2 by 1 year.

[3] Productivity weighting factors based on NPP0 per land category in all countries can be obtained here: https://lca-net.com/projects/show/indirect-land-use-change-model-iluc/)

animals by type, multiplied by IPPC default values for carbon uptake per head, and converted to 'NPP0-eq. ha-yr' with a yield of 0.45 * country-specific NPP0 for permanent pasture (in tonne C/hectare-year).
CO_2 emissions from preponed land conversion are calculated as the CO_2 emission caused by carbon stock change between the previous and the new land use, weighted by the effect of moving this CO_2 emission 1 year in time, represented by the emission 'carbon dioxide (land use change)'; see under dLUC above. iLUC emissions from intensification of production on already converted arable land shall as a minimum be calculated as the increase in GHG emissions (following the emission models in IPCC 2019, volume 4, chapter 11) from the average change in inputs of fertilisers per 'NPP0-eq. ha-yr' based on the global increase in fertiliser use (tonne N, P2O5, K2O) for the last five years (FAOSTAT/IFA fertiliser data [4] can be used) divided by the global amount of 'NPP0-eq. ha-yr' of arable land. As default, when no specific information is available, precalculated factors iLUC GHG intensities per country and land category from https://lca-net.com/wp-content/uploads/iLUC-GHG-summary-per-country-and-land-market_OPEN_20230630-2.xlsx can be applied."

8 Section 4.5 Handling multi-functional processes

Proposal 16: As a result of the precisions to the requirements in Section 4.4.8 to always use the CCF for by-products (see proposal 12), the decision hierarchy for handling multi-functional processes in **Section 4.5 in the PEF method** can be significantly re-written and simplified, with additional clarifications and detailed guidance, as provided here:
After the first paragraph in Section 4.5, jump directly to the sentence: "As per EN ISO 14044:2006, wherever possible, subdivision or system expansion should be used to avoid allocation." and then continue with the following new text: "Subdivision is possible in case of combined production, where the amounts of the co-products can be varied independently. System expansion is possible in case of joint production, where the amounts of co-products cannot be varied independently, i.e., when the proportions are fixed. All cases of multi-functionality (co-production) can be classified as either combined or joint production.
In case of combined production, one dataset shall be created per combined product, modelling the specific consequences (changes in inputs and outputs of the co-producing activity) that result from changing the output of the co-product of interest while keeping the output of the other co-products constant. A farm that provides both food products and farm holidays would be an example of combined production that can be completely subdivided into separate activities for each co-product produced alone, with each of these separate pure productions having its own dataset, even if there may be trade between the two separated activities. However, combined production is most often done to take advantage of some benefit of co-production, e.g., use of the same capital equipment, reduction in energy or raw material consumption, or reduction in waste generation. Since a description of the separate pure production would not encompass these advantages, it would not provide a correct reflection of the actual conditions. Therefore, the modelling of each of the subdivided datasets shall include the specific consequences (changes in inputs and outputs of the co-producing activity) that result from changing the output of the co-product of interest while keeping the output of the other co-products constant. In this way, the benefits of the combined production will be inherent to the description and will be reflected in the outcome. This is effectively the same as subdividing the activity according to physical causalities (ISO 14044 allocation hierarchy, step 2), since the modelling can be repeated independently for each of the combined co-products, resulting in one dataset per co-product. In general, a physical parameter can be identified, which – in a given situation – is the limiting parameter for the co-production, e.g., weight or volume in different situations of combined transport. It is the contribution of the co-product of interest to the limiting parameter that determines the consequences of the demand for the co-product of interest.

[4] FAOSTAT/IFA fertilizer data: https://www.fao.org/faostat/en/#data/ESB

In case of joint production, each joint product shall be identified as either a determining co-product or a dependent by-product. Dependent by-products shall be modelled with the circular footprint formula; see Section 4.4.8. Thereby, the determining product becomes the only remaining intermediate product output for the joint production.

A determining product of an activity is a product for which a change in demand will affect the production volume of the activity [add 'determining product' to 'Definitions'?]. In the typical situation, one of the joint products can be identified as determining, leaving all the others as dependent by-products to be modelled with the circular footprint formula. Most simply, a co-product can be identified as determining if the co-production is the only competitive way to produce the product. An example is bread wheat that can only come from a wheat field, and where the straw is then a dependent by-product. In the more typical situation, where all joint products have alternative production routes, the following stepwise procedure should be applied to provide an unambiguous identification and documentation of which of the joint products is the determining one:

1) Exclude joint products that provide insufficient revenue to contribute to the ability of a combination of the remaining joint products to exceed the net marginal cost of changing the production volume, as default set to 80% of the total revenue. For example, a soy mill can obtain 57% of its revenue from protein meal and 42% from soy oil, while free fatty acids contribute less than 1% of the revenue. Free fatty acids cannot play a role in raising the revenue of either of the other co-products above 80%, and can therefore be excluded from further consideration. This step is optional.
2) Calculate the market trends of all remaining joint products, normalised to the relative outputs of the products from the co-producing activity. For example, if the market for protein meal has an annual trend of 3.7 Tg crude protein and the market for vegetable oil has an annual trend of 3.1 Tg, and the relative output of a soybean mill is 1.9 kg crude protein per 1 kg soy oil, the normalised market trends are 3.7/1.9 = 1.95 and 3.1/1 = 3.1, respectively. Thus, the oil has the largest normalised market trend of the two co-products from the soy mill.
3) Starting with the joint product with the largest normalised market trend, consider whether the revenue from this product exceeds 80% of the total revenue, in which case it is the determining product. Else, add the joint product with the next largest normalised market trend, and continue until the sum of revenues exceeds 80% of the total revenue. The last product added will be the determining product, since the demand for this co-product imposes an economic constraint on the ability of the combination to change its output. In the soy mill example, the last added product will be the crude protein, which can therefore be identified as the determining product of the soy mill.

In the more seldom situation where a joint production has more than one product without relevant alternative production routes – and therefore has more than one determining product – one dataset shall be created per determining product, modelling the specific consequences (changes in inputs and outputs of the co-producing activity) that result from changing the demand for the co-product of interest. The ratio of revenue provided by this product relative to the total revenue from all the determining products shall be used as a scaling factor on the joint production activity, reflecting that a change in demand for one of the jointly determining products will only provide enough change in revenue to influence the production volume of the joint production in proportion to its share in the revenue from all the determining products. The scaled joint production activity thus responds to a specific increase in demand for its determining products with a smaller output than what is needed to meet the increase in demand. Since there are no alternative production routes, the missing supply shall be modelled as a reduction in consumption by other users of the demanded product, which in practice is induced via the change in price signals resulting from the increase in demand. The demanded product is thus supplied partly by the joint production activity itself and partly by the reduction in marginal consumption necessary to compensate for the missing supply from the joint production activity. Note that by this procedure the joint production activity is not partitioned, but only scaled to the change in demand, and it is therefore still a multi-functional activity where the outputs of the other co-products are scaled proportionally. The determining products for which there was no change in demand will therefore be produced in excess of demand. Since there are no alternative production routes to be substituted, the excess supply shall be modelled as an increase in consumption, which in practice can be seen as a waste treatment activity induced via the change in price signals resulting from the excess supply. If the determining products have similar applications and price levels, they may be regarded as having the same functional unit and modelled as one single product, thereby avoiding the more complex modelling involving induced changes in consumption activities."

Also, the specific requirements in **Sections 4.4.1.1 and 4.5.1 of the 2021 PEF method**, on handling multi-functional processes in agricultural production and allocation in animal husbandry, are no longer relevant if proposal 12 on the general use of the CFF is accepted.

9 Sections 4.6.1 and 4.6.2 on Company-specific data and Secondary data

Proposal 17: Section 4.6 of the 2021 PEF method contains requirements for both company-specific datasets for specific products and secondary gate-to-gate datasets for generic products. However, clarification is needed on when to apply specific data and when to use generic and secondary data.

It is important to clarify that while a footprint of a company-specific product applies company-specific data whenever possible and relevant, it also necessarily includes secondary gate-to-gate datasets for a large part of the product system, sometimes because of data availability, but also simply because the induced impacts of purchasing a company-specific product are best reflected by datasets for generic products. When tracking the additional demand for a product upstream to a market, there will be some suppliers to that market that are more sensitive to the change in demand than others, and it is these sensitive producers and their environmental impacts that matter for the environmental impact of an additional purchase. Beyond a market, it is not possible to influence specific producers other than the most sensitive ones, except if you establish a specific relationship where producers commit to change their production in terms of quantity, quality, or production method. Such a commitment can be formalised by a contract or by monitoring within a certification scheme. The requirement for change-oriented commitments implies that the related datasets are necessarily company-specific, but otherwise there are no difference in the requirements to the datasets.

The proposal is to add to the beginning of **Section 4.6.1 of the PEF method**:
"For PEFs for company-specific products, company-specific data are relevant for the company that produces the specific product. It is also relevant to include company-specific data in the supply chain when the affected suppliers are already known, i.e., if only one supplier exists, or if a specific group of companies are so closely linked in the supply chain that the production volumes of the specific suppliers can be shown to fluctuate with the demand of the specific customers. Examples when the latter situation can occur are:

- Products have a low price compared to their weight, so that transport costs prohibit all other than the local producers, as for example for the supply of straw for heat and power production, where only the farmers closest to the power plant will supply the straw. Other examples of this can be found in the forestry sector and the building- and glass-industries.
- Two or more companies are tied together by tradition, or when a supplier has developed its product to meet specific demands of the customer. Such relationships can be formalised by a contract or by monitoring within a certified labelling scheme. This may include dedicated offsetting activities, such as

purchase of certified additive conservation projects, or otherwise uncompetitive expansion of renewable energy capacity.
- The choice of supplier is not subject to normal market conditions, e.g., monopoly or monopsony situations.

When including company-specific data from the supply-chain, documentation shall be available showing that the production volumes of the specific suppliers fluctuates with the demand of the specific customers. In all other cases, data from the supplying market shall be used, even when the specific suppliers may be known. The reason for this is that when tracing a demand to a market, there will be some producers that are more sensitive to the change in demand than others, and it is these sensitive producers and their environmental impacts that matter for the resulting environmental impact of the specific purchase. Beyond a market, specific producers other than the most sensitive ones cannot be influenced, except in the case of the existence of specific relationships as exemplified in the above bullet points. Thus, beyond a market, traceability to a specific producer is only relevant when it involves ability and commitment by the specific producer to change production in terms of quantity, quality, or production method. It is important to be aware that most standards and schemes for traceability do not require such change-oriented commitments, and that in these cases the data that shall be used, for both generic and company-specific PEFs, are the generic background data, reflecting how the change in demand generally affects the sensitive producers."

This also **covers the text in Section 4.6.5.4** of the 2021 PEF method on 'The Data Needs Matrix (DNM)' for option 1 and 2, which can therefore be deleted.

The precision in proposal 17, that a company-specific PEF does not imply that company-specific data should be collected for the entire life cycle, should be welcomed by small and medium-sized companies.

Proposal 18: Because the residual consumption mixes and market datasets described in proposal 19 are calculated as the difference between the total generic market volume and the country- or company-specific market volume, it is necessary that all company-specific datasets declare their production volume. Furthermore, to ensure the credibility of company-specific datasets and footprints it is necessary that the products with declared footprints represent unique and additional products. Therefore, company-specific datasets must include reference to documentation that the production volume of the company is unconstrained, i.e. that the company will change its production capacity in response to an accumulated change in demand for the products, and reference to the procedures applied by the company to ensure that the volume of declared products does not exceed the volume of products produced (e.g. by audit, third party certification, or through other disclosure registries, systems, or mechanisms), as currently required by the PEF method for electricity products in Section 4.4.2.

The proposal is therefore to add at the end of **Section 4.6.1** in the PEF method:
"Company-specific datasets shall include:
- the annual production volume for its determining products,
- reference to documentation that the production volume of the company is unconstrained, i.e. that the company is able to change its production capacity in response to an accumulated change in demand for the products,
- reference to the procedures applied by the company to ensure that the volume of declared products does not exceed the volume of products produced (e.g. by audit, third party certification, or through other disclosure registries, systems, or mechanisms)."

The proposal builds on the requirements of the PEF method for electricity and expands them to apply to all company-specific datasets. This builds on common practice from current certification schemes, supplemented by an additionality requirement that is current best practice for, e.g., Guarantees of Origin for electricity.

Proposal 19: Rename **Section 4.6.2 of the PEF method** to "Generic product data and secondary data" and add the following introductory text: "For each relevant product market for which a functional unit is defined according to Section 3.2.1 of this Annex, a *generic market dataset* shall be created, in the form of the mix of unconstrained suppliers, i.e. the suppliers that are able to change their production capacity in response to an accumulated change in demand for the product [This definition of unconstrained suppliers should probably be added to the definitions section]. Besides documenting the balance of supply and demand on each market, further explained below, the generic market datasets shall model the relevant market activities, i.e., inputs from trade and transport activities and their associated costs, product losses during trade and transport, and data on product taxes or subsidies.
Generic market datasets shall document the trend in market volume, relative to the average replacement rate for the capital equipment. The trend in market volume shall be documented by data from future scenarios or other forms of industry forecasts for the markets, when available, and otherwise documented by the trend of a timeseries that includes data for the current or most recently known market volume and the market volume for the preceding 4 years. When neither forecasts nor market volumes are available, the trend shall by default be assumed to be increasing, since this is the general situation for most products, due to the general increase in population and wealth.
The mix of suppliers (or groups of suppliers with the same technology) to a generic market dataset shall only include unconstrained suppliers. Constrained suppliers that are excluded from the market mix are those providing inputs of by-products in the market situation where demand for the material exceeds what can be supplied from by-products (see Section 4.4.8 and 4.5), suppliers (or technologies) that are constrained by regulatory quota or forced phasing in or out of their technology, and suppliers (or technologies) that require inputs of specific raw materials with constrained availability.
The contribution from each unconstrained supplier (or technology) to the balance of supply and demand on each market shall be proportional to its annual change in capacity, relative to the replacement rate for the capital equipment, as documented from future scenarios or other forms of industry forecasts for the markets, when available, and otherwise documented by the trend of a timeseries that includes data for the current or most recently known market volume and the market volume for the preceding 4 years. When neither forecasts nor historical market shares are available, the current market shares shall by default be used for the relative contributions. Note that in markets with market trends above the average replacement rate for the capital equipment, the contributions will be positive, i.e., representing an expansion in capacity, while in markets with market trends below the average replacement rate for the capital equipment, the contributions will be negative, i.e., representing a decommissioning of capacity.
In markets where all suppliers are constrained, the market mix shall be modelled as a mix of all unconstrained customer applications, i.e., applications in which the product is dispensable, documented from future scenarios or other forms of industry forecasts for the markets, when available, and otherwise documented by the trend of a timeseries that includes data for the current or most recently known shares of customers applications and the shares for the preceding 4 years. By regulating their consumption, the unconstrained customers effectively become the unconstrained suppliers to the market. The contribution from each unconstrained customer (or application) to the balance of market supply and demand shall be proportional to its annual change in

consumption, following the same procedure and documentation requirements as for the unconstrained suppliers above.
On markets that have inputs of products for which country- or company-specific datasets are available and where the consumers have access to distinguish and purchase these country- or company-specific products, while still having access to generic products for which country- or company-specific datasets are not available, *residual market datasets* shall be created for those generic products, calculated in the same way as a generic market dataset, but excluding the supply of products for which country- or company-specific datasets are available.
Except for the inputs of the traded products to the generic and residual market datasets described above, and the product inputs from company-specific datasets described in Section 4.6.1 [referencing the text of proposal 17], the product inputs to all other datasets that model production and consumption activities shall be modelled as coming from the output of residual market datasets (or generic market datasets when residual market datasets are not available) for the geography covering the location of the activity.
For PEFs of generic products, all datasets in the product system shall be either generic or residual market datasets or secondary gate-to-gate datasets."

This also covers the **text in Section 4.6.5.4** of the 2021 PEF method on 'The Data Needs Matrix (DNM)' for option 3, which can therefore be deleted.

10 Section 4.6.3 Datasets to be used (Background data)

Proposal 20: It has appeared as difficult to ensure that EF-compliant datasets are openly available, transparent, and up-to-date, which limits both usability and comparability. Furthermore, there is no requirement for EF-compliant datasets to be complete, neither at the level of unit processes nor for the set of EF-compliant datasets to provide complete coverage of the global economy and its environmentally relevant flows. When EF-compliant datasets are not available for an activity, the 2021 PEF method refers to a hierarchy of other sources of datasets that may be added. This leads to an inconsistent combination of data from different databases.

Instead of requiring specific datasets, it would be more meaningful to put up a list of requirements or quality criteria for a database and subsequently requirements on how to add further datasets to provide more detail to the chosen database. This would result in a database where all footprints can be calculated from the same data and with the same calculation procedures, thus significantly improving their comparability.

By requiring the use of a single database, rather than a collection of datasets from different sources, it would also be possible to use the database to provide automated contribution analyses, reporting, as well as important parts of verification and validation, that are otherwise hard-to-fulfil requirements on individual PEFs.

For the EF database, it could be reasonable to require the database to be at least:

- *Complete:* in the sense of covering the global economy. This is important, both because products on the European market are sourced from or have ingredients from across the world, and because completeness of the database is the basis of completeness of the individual footprints.
- *Consistent:* with the PEF requirements, both with respect to data quality and calculation rules.
- *Unit process based:* A database with unallocated and unlinked gate-to-gate unit process datasets will allow the database to be used not only for the European market but also by European companies that export to other markets with different standards, since it is mainly the artificial allocations and the rules for market linking of the unit process datasets that creates differences in results between

standards. When the unit processes are linked via market datasets, each unit process can be updated in isolation and the changes will then propagate through to all the footprints. For example, an update to a unit process dataset for cereals will automatically lead to a change in the results obtained for pigs, which then again automatically will give an updated result for sausages, etc. This makes a unit process database much easier to maintain than a collection of unrelated aggregated datasets. When more detailed datasets become available, for example for specific varieties of tomatoes rather than just for generic tomatoes, it can easily be ensured that the sum of all the new specific tomato datasets sum to the original generic dataset, thus maintaining the overall consistency of the database. Furthermore, the use of market datasets for linking unit process datasets into product systems allows to reflect current changes in the markets without having to edit the individual unit processes.

Furthermore, if more than one database fulfils the above three requirements, the following quality criteria could be used (in decreasing order of importance):

- *Transparent*: Allowing users to view the underlying data and the specifications and code for the calculation procedures will increase credibility and the likelihood that errors will be discovered and reported. This will also ease interpretation, verification, and validation procedures.
- *Open:* Openness implies that data and software code for the calculation procedures are freely available for reuse. In addition to the benefits of transparency, openness also increases the ability to reuse and thereby increases the societal value of the data and software code.
- *Up to date:* Ideally, the database should be updated annually, to reflect the most recent availability of statistical data on volumes, prices, and production recipes.
- *Easy to maintain:* The requirement for manual interaction for updating should be minimised by automating as many procedures as possible. It will also be an advantage if the database is embedded in an organisation with experience in database management and life cycle assessment.
- *Geographically disaggregated:* Due to the high geographical variability of production processes and their environmental impacts, especially within agriculture and electricity generation, the database should have as high geographical resolution as possible.
- *Able to handle data quality and uncertainty calculations:* Uncertainty, both that stemming from natural variability, sampling error, and low data quality, is an important aspect of data communication and credibility. The ability of the database to handle uncertainty on the individual flows and propagate them through to an expression of uncertainty on the footprints is relevant for comparison of footprints with confidence.
- *Support automated verification and validation:* Automated routines for the verification of the database calculation routines against the PEF requirements and the validation of the database completeness and data quality of individual datasets are important to reduce manual labour requirements for verification and validation of PEFs.
- *Support contribution analyses:* The ability to trace back from a PEF result to the contributing activities ('hotspot identification') is important as part of error checking, but more important for database users to understand the origin of the results, to build confidence, and as an inspiration for reductions in the life cycle impacts.
- *Support reporting:* The ability to provide automated reports per PEF can reduce the requirements for manual labour.

The proposal is therefore to replace the text of **Section 4.6.3 'Datasets to be used'** in the PEF method by:
"All datasets used to model the product system for a PEF shall come from the same database. The database shall fulfil the following three minimum requirements:

- *Completeness:* The database shall cover the entire global economy, so that summing over all industry value added obtains the Gross National Product for each country and globally, and the annual elementary flows sum to plausible global estimates for current annual and annually induced elementary flows.
- *Consistency:* The database shall be in compliance with all requirements in the present document, with respect to data quality and calculation rules.
- *Unit process based:* The database shall consist of unallocated and unlinked gate-to-gate unit process datasets for all included production and consumption activities and at least one market dataset for each determining product, as required in Section 4.6.2 on 'Generic product data and secondary data'. Automated procedures shall be available for adding more detailed datasets without this affecting the overall completeness and consistency of the database.

If more than one database fulfil these minimum requirements, the choice of database shall be the highest-ranked in a quality-ranking based on the sum of the following criteria:

- *Transparency*: 10 points are given if users have access to view all underlying data and the specifications and code for the database calculation procedures.
- *Openness:* 10 points are given if data and software code for the calculation procedures are freely available for reuse, with subtraction of 2 points for Share-Alike restriction and subtraction of 1 point for Non-Commercial restriction.
- *Average age of data:* 10 points are given when the average dataset represents production conditions no more than than two years back in time, and one point is subtracted for each year of additional age of temporal representativeness of the average dataset.
- *Maintenance:* 5 points is given if the database is embedded in an organisation with at least 5 years documented experience in database management and life cycle assessment.
- *Geographical disaggregation:* 1 point is given for each 10 countries that are covered by at least 100 gate-to-gate unit process datasets for production activities.
- *Ablility to handle data quality and uncertainty calculations:* 4 points are given for the ability of the database to handle uncertainty on the individual flows and propagate them through to an expression of uncertainty on the footprints with inclusion of a correlation matrix for all combinations of products. Additional 2 points for the ability to obtain contribution analyses for the sources of uncertainty of a pairwise comparison of two footprints.
- *Support for automated verification and validation:* 3 points are given for fully implemented automation of routines for the verification of the database calculation routines against the PEF requirements and the validation of the database completeness and data quality of individual datasets.
- *Support for contribution analyses:* 2 points are given for the ability to trace back from a footprint result to the contributing activities.
- *Support for reporting:* 1 point is given for the ability to provide automated reports per footprint following the requirements in Section 7 of this document."

We have identified at least two existing databases that would be able to fulfil the three minimum requirements of the proposal, and that at least one of these is an open database, so that no additional cost of database development and use would be required for a least-cost solution. The costs would thus be limited to the costs of adding more detailed datasets to an existing database and possibly supporting the continued maintenance of the chosen database.

The proposal would significantly reduce ambiguity about which data sources to apply when creating footprints. The proposal would significantly improve the quality of the resulting footprints compared to a solution based on existing or future EF-compliant datasets.

11 Uncertainty and Data quality requirements (Section 4.6.5)

Proposal 21: In the 2021 PEF method, uncertainty is only mentioned as precision and this only as one of the four data quality criteria to be scored on a 5-point semi-quantitative scale at the dataset level. However, it is important for the comparability of footprints that the user can credibly access the confidence level with which two footprints can be said to be different. This would require a broader inclusion of other uncertainty sources than just precision (which is essentially variability and measurement error), notably the low accuracy stemming from low data quality on the individual flows. An empirical-based pedigree matrix for converting semi-quantitative data quality indices *for individual flows* into quantitative uncertainty was developed by Ciroth et al. (2016)[5] and the further propagation of the uncertainty through to an expression of uncertainty on the footprint can be done by Monte Carlo simulation.

The 2021 PEF method requires the use of the PEF Data Quality Rating (DQR) method, which is based on a semi-quantitative scoring of four 'data quality criteria' scored on a 5-point semi-quantitative scale *at the activity dataset level,* which are then aggregated as the arithmetic average of the four 5-point scores. Since the numerical data in a dataset are flow data, data quality at the level of activity datasets has no quantitative meaning and can therefore not be converted to numerical uncertainty, and even less so when expressed as the arithmetic average of data quality criteria which have very different levels of empirical uncertainty for each of the individual 5-point scores. In conclusion, the PEF DQR method prevents data quality information to be converted to quantitative uncertainty that can be propagated through to uncertainty on the footprints, in contrast to the method by Ciroth et al. (2016).

The proposal is therefore to replace the text in Section **4.6.5 in PEF method** by:

"**4.6.5 Uncertainty and data quality**

Two kinds of uncertainty shall be quantified for each flow in each dataset:

- Variation and stochastic error of the values which describe the exchanges, due to e.g. measurement uncertainties, activity specific variations, temporal variations, etc. This is expressed in the basic uncertainty. When relevant information to completely describe an activity in detail is unavailable, so that the exchanges are only reported in an unspecific way or at a high aggregation level of activities, the average data applied, with inadequate specification of important exchanges, will have a basic uncertainty that reflects the lack of knowledge on their precise nature. If the sample data are available, the probability distribution and standard deviation of the sample can be calculated directly. If the sample is small, an approximate standard deviation can be calculated from the range (the difference between the largest and the smallest observed value). For the normal distribution, the range is approximately 3, 4, and 5 times the standard deviation when the sample size is 10, 30, and 100, respectively. Life cycle data often result from a small number of observations, so it is reasonable to use the factor 3 when the number of observations is unknown. Quite often the uncertainty of a specific value cannot be derived from the available information, when there is only one source of information and this only provides only a single value without any information about the uncertainty of this value. A

[5] Ciroth A, Muller S, Weidema B P, Lesage P. (2016). Empirically based uncertainty factors for the pedigree matrix in ecoinvent. The International Journal of Life Cycle Assessment 21(9):1338–1348.

simplified standard procedure shall be applied in these cases: The lognormal distribution is *always* assumed when applying the simplified standard procedure and Table [add #] gives basic uncertainty factors (as coefficients of variance) based on expert judgements for various types of exchanges.

- Uncertainty due to use of estimates, lacking verification, incompleteness in the sample, or extrapolation from temporally, spatially and/or technologically different conditions. These additional uncertainties are based on the empirically based pedigree matrix approach of Ciroth et al. (2016). Data sources are assessed according to the five independent characteristics "reliability", "completeness", "temporal correlation", "geographic correlation", and "further technological correlation" (see Table [XX]). Each characteristic is divided into five quality levels with a score between 1 and 5. Accordingly, a set of five indicator scores is attributed to each individual input and output exchange (except the reference products) reported in a data source. Table [XX] is called a pedigree matrix (after Funtowicz & Ravetz 1990)[6] since the data quality indicators refer to the history or origin of the data, like a genealogical table reports the pedigree of an individual. Overall uncertainty is increased by the addition of normal distributions to the underlying normal distribution derived from the basic uncertainty. A normal uncertainty distribution is attributed to each score of the five characteristics. Each of these distributions has a mean value of zero, and a variance based on expert judgement, and shown in Table [YY].

Table [add #] Default basic uncertainty (coefficients of variance of an assumed lognormal distribution) applied to intermediate and elementary exchanges when no sampled data are available (from Frischknecht et al. 2007)[7]; c: combustion emissions; p: process emissions; a: agricultural emissions

input / output group	c	p	a	input / output group	c	p	a
demand of:				**pollutants emitted to air:**			
thermal energy, electricity, semi-finished products, working material, waste treatment services	1.05	1.05	1.05	CO_2	1.05	1.05	
transport services (tkm)	2.00	2.00	2.00	SO_2	1.05		
Infrastructure	3.00	3.00	3.00	NMVOC total	1.50		
resources:				NO_X, N_2O	1.50		1.40
primary energy carriers, metals, salts	1.05	1.05	1.05	CH_4, NH_3	1.50		1.20
land use, occupation	1.50	1.50	1.10	Individual hydrocarbons	1.50	2.00	
land use, transformation	2.00	2.00	1.20	PM>10	1.50	1.50	
pollutants emitted to water:				PM10	2.00	2.00	
BOD, COD, DOC, TOC, inorganic compounds (NH_4, PO_4, NO_3, Cl, Na etc.)		1.50		PM2.5	3.00	3.00	
individual hydrocarbons, PAH		3.00		Polycyclic aromatic hydrocarbons (PAH)	3.00		
heavy metals		5.00	1.80	CO, heavy metals	5.00		
pesticides			1.50	inorganic emissions, others		1.50	
NO_3, PO_4			1.50	radionuclides (e.g., Radon-222)		3.00	
pollutants emitted to soil:							
oil, hydrocarbon total		1.50					
heavy metals		1.50	1.50				
pesticides			1.20				

[6] Funtowicz S, Ravetz J R. (1990). Uncertainty and quality in science for policy. Dordrecht: Kluwer.

[7] Frischknecht R, Jungbluth N, Althaus H-J, Doka G, Dones R, Heck T, Hellweg S, Hischier R, Nemecek T, Rebitzer G, Spielmann M. (2007) Overview and Methodology. ecoinvent report No. 1, v2.0. Dübendorf: Swiss Centre for Life Cycle Inventories.

Table [XX]. Pedigree matrix used to assess the quality of data sources (from Weidema et al. 2013)[8]

Indicator score	1	2	3	4	5 (default)
Reliability	Verified[1] data based on measurements[2]	Verified data partly based on assumptions ***or*** non-verified data based on measurements	Non-verified data partly based on qualified estimates	Qualified estimate (e.g. by industrial expert)	Non-qualified estimate
Completeness	Representative data from all sites relevant for the market considered, over an adequate period to even out normal fluctuations	Representative data from >50% of the sites relevant for the market considered, over an adequate period to even out normal fluctuations	Representative data from only some sites (<<50%) relevant for the market considered ***or*** >50% of sites but from shorter periods	Representative data from only one site relevant for the market considered ***or*** some sites but from shorter periods	Representativeness unknown or data from a small number of sites ***and*** from shorter periods
Temporal correlation	Less than 3 years of difference to the time period of the dataset	Less than 6 years of difference to the time period of the dataset	Less than 10 years of difference to the time period of the dataset	Less than 15 years of difference to the time period of the dataset	Age of data unknown or more than 15 years of difference to the time period of the dataset
Geographical correlation	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar production conditions	Data from area with slightly similar production conditions	Data from unknown ***or*** distinctly different area (North America instead of Middle East, OECD-Europe instead of Russia)
Further technological correlation	Data from enterprises, processes and materials under study	Data from processes and materials under study (i.e. identical technology) but from different enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials	Data on related processes on laboratory scale ***or*** from different technology

1) Verification may take place in several ways, e.g. by on-site checking, by recalculation, through mass balances or cross-checks with other sources.
2) Includes calculated data (e.g. emissions calculated from inputs to an activity), when the basis for calculation is measurements (e.g. measured inputs). If the calculation is based partly on assumptions, the score would be 2 or 3.

Table [YY]. Uncertainty factors (variances of the underlying normal distributions) used to convert the data quality indicators of the pedigree matrix in Table [xx] into additional uncertainty (modified from Muller et al. 2016)[9]

Indicator score	1	2	3	4	5
Reliability	1.00	1.01	1.21	1.25	2.36
Completeness	1.00	1.02	1.05	1.10	1.63
Temporal correlation	1.00	1.08	1.55	2.22	2.49
Geographical correlation	1.00	1.14	1.23	2.30	2.30
Further technological correlation	1.00	1.19	1.52	1.95	2.23

The uncertainty estimations shall be given for each flow at the unit process level. The uncertainty of the PEF results can then be calculated with by Monte-Carlo simulation. The average probabilistic mean values (i.e. the cumulative results determined with Monte Carlo simulation) differ from the deterministic results. This difference occurs because deterministic cumulative results are not always calculated with the mean values of the underlying uncertainty distributions. The PEFs shall be displayed as the deterministic mean values."

Proposal 21 suggests to replace the PEF DQR method for scoring data quality *at dataset level* by the pedigree matrix approach for scoring data quality *at the flow level,* which allows calculation from the uncertainty at flow

[8] Weidema B P, Bauer C, Hischier R, Mutel C, Nemecek T, Vadenbo C O, Wernet G. (2013) Overview and methodology. Data quality guidelines for the Ecoinvent database version 3. Ecoinvent report 1 (v3). St. Gallen: The ecoinvent centre.
[9] Muller S, Lesage P, Samson R. (2016). Giving a scientific basis for uncertainty factors used in global life cycle inventory databases: an algorithm to update factors using new information.

level through to the PEFs. The time it takes to score data quality in the two methods is very similar when assessed per dataset, and the change is therefore not estimated to have any cost implications. The actual calculation of uncertainty of the PEFs by Monte Carlo simulation is separate from the data quality scoring method, and is a feature of several existing LCA software, including open software.

Proposal 21 improves the quality and relevance of the semi-qualtitative data quality scores and furthermore allows the calculation of the uncertainty of the PEFs, which would give a significant improvement to the comparability and credibility of the PEFs. The proposal applies equally to PEFs for both generic and company-specific products, and would enhance the consistency and comparability between them. Especially, the proposal would allow to quantify and display the lower uncertainty of PEFs for company-specific products relative to PEFs of generic products.

In the context of labelling, a proposal for how to communicate uncertainty to the end-consumers of PEFs has been provided in Weidema & Eliassen (2023, p. 28-29)[10].

12 Sections 6 to 8 on Interpretation, reporting, verification and validation

Proposal 22: Section 6 of the PEF method, essentially requires a contribution analysis ('hotspot analysis') to be performed and reported, identifying the most relevant life cycle stages, processes, and elementary flows. Since a contribution analysis is not always relevant for the user of a PEF study, i.e., it depends on the goal and scope of the study, it appears to be unnecessary as a general requirement. Rather, it would be appropriate to let this be an option to be performed upon user request, which would be possible when requiring the data to be made available in a transparent and preferably open database format. This would even facilitate that the contribution analyses be tailored to the specific needs of each user.

The proposal is therefore for **Section 6 of the PEF method** to make interpretation ('hotspot identification') optional rather than a general requirement, referring to the option for users to request contribution analyses directly in the EF database.

Proposal 23: The reporting requirements in **Section 7 of the 2021 PEF method**, and specifically the reporting template in Annex II Part E of the 2021 PEF method are rather extensive but mostly on issues that are general to all footprints produced from the same database. Part of the information in footprint reports (e.g., inventory data) may favourably be embedded into the database documentation, thus limiting the issues required to be manually filled in for each individual footprint.

The proposal is to edit the text of Section 7 in the PEF method to read: "The reporting of PEFs shall follow the requirements in the reporting template in Annex II – Part E of the PEF method. For PEFs that are calculated via a dedicated database, the main part of the reporting requirements can be fulfilled by a general document that covers all footprints that are calculated from the database, limiting the issues required to be manually filled in for each individual PEF study to the following:
2.a) Name of the product (including a photo),
2.b) Product identification (e.g. model number),
2.c) Product classification (CPA) based on the latest CPA list version available,

[10] Weidema B P, Eliassen J (2023). Establishing a horizontal European climate label for products. Study for the Panel for the Future of Science and Technology, European Parliamentary Research Service, PE747.453. https://www.europarl.europa.eu/RegData/etudes/STUD/2023/747453/EPRS_STU(2023)747453_EN.pdf

2.d) Company presentation (name, geographic location),
2.e) Date of publication of the PEF study (the date shall be written in extended format, e.g. 25 June 2015, to avoid confusion over the date format),
2.f) Geographic validity of the PEF study (countries where the product is consumed/sold),
2.i) Name and affiliation of the verifier(s)
3.e) Commissioner of the study
4.2.d) Company specific data used."

The proposal implies a standardisation of the footprint reports from the same database, which means that any identified ambiguities in the wording of footprint reports can more easily be eliminated across all future reports.

Proposal 24: The verification of the database calculation routines against the PEF requirements and the validation of the database completeness and data quality of individual datasets are covered in a 7-pages long text in **Section 8 of the 2021 PEF method**. In line with the previous issue on reporting, all the issues required to be verified and the majority of the issues to be validated are issues that are common to all footprints produced from the same version of a footprint database, and which therefore needs only to be verified and validated once. When new functionalities or data are added to a footprint database, this of course then requires a new database verification or validation but only of the parts of the database that are affected by the additions.

In spite of the extensive validation requirements, some of the most simple and effective completeness and consistency checks are not currently required.

Therefore, the proposal is to add the following to Section 8 of the PEF method: "A completeness check for the product system shall be performed, checking that the sum of all inputs equals the sum of all outputs (including by-products, wastes, and emissions) when measured in the same unit (e.g., dry mass or currency). The same completeness check may also be performed for water and specific elements, such as carbon or nitrogen. If a completeness check results in significant deviations from zero, the causes for this shall be investigated by performing similar completeness checks for significant contributing unit processes datasets. If any significant deviations from zero remain after error correcting, these shall be reported." Furthermore, it is proposed to edit the current text of Section 8 to clarify that for PEFs that are calculated via a dedicated database, all the issues required to be verified and the majority of the issues to be validated can be fulfilled by a general verification and validation that covers all PEFs that are calculated from a specific version of the the database, limiting the issues required to be verified for each individual PEF study.

The proposal means that verification and validation will be performed in the same way for all footprints from a specific database version, which increases the comparability of the PEFs and reduces the likelihood of corruption of verifier(s).

The three proposals (22, 23, and 24) in this section each contribute significant reductions in the efforts (and thus costs) of creating footprints, in total estimated to reduce costs by at least 50% compared to the the costs estimated by the European Commission in the introduction to the proposed Green Claims Directive of 8000 Euro per product.

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