SCORELCA

Study No. 2024-04

Conditions for applicability of the CFF and changes in standardisation and weighting factors (PEF, planetary boundaries, etc.)

Summary

31 October 2025

Final version	**31/10/2025**	
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The SCORE LCA association is a study and research organisation dedicated to work relating to Life Cycle Assessment (LCA) and environmental quantification. It aims to promote and organise collaboration between businesses, institutions and scientists in order to foster shared and recognised development, at European and international level, of the Life Cycle Assessment method and its practical application.

- In the bibliography, this document will be cited under the reference:
  SCORE LCA, Conditions for the applicability of CFF and evolution of standardisation and weighting factors (PEF, planetary boundaries, etc.), 19 pages, No. 04-2024.
- This work has received support from ADEME (French Environment and Energy Management Agency): www.ademe.fr
- The views and recommendations expressed in this document are those of the authors alone and do not necessarily reflect the opinion of all SCORE LCA members, unless otherwise stated.
- The information and conclusions presented in this document have been established on the basis of scientific and technical data and the regulatory and normative framework in force at the time of publication.

Context and objectives of the study

Life cycle assessment (LCA) enables the environmental impact of products and services to be assessed throughout their life cycle.

The end of life of products is a critical phase of LCA, particularly for assessing the impact of products containing recycled materials or, more broadly, for all systems involved in the circular economy. The ISO 14044:2006 standard[1] , sets out guidelines for end-of-life management, but more detailed approaches, such as those developed by the European Commission as part of the Product Environmental Footprint (PEF), allow for more parameters to be included in the assessment of environmental impacts. The Circular Footprint Formula (CFF) is an approach that allows the environmental benefits of recycling to be allocated between the upstream and downstream phases of a product's life cycle. Several product systems are therefore involved, and defining the boundaries of these systems can be complicated from a technical point of view. The application of the CFF can also be complex in terms of modelling recycling processes, defining parameters (particularly allocation and secondary material quality parameters) and allocating environmental burdens. These challenges require in-depth understanding and meticulous application, and raise practical issues that can sometimes lead to unreliable results. The Environmental Footprint Technical Advisory Board (TAB) is working to clarify and modify the CFF to improve its accuracy and relevance[2] . These efforts aim to provide clear recommendations and improvements for consistent and sustained use of the CFF, thereby strengthening the credibility of the approach and the results obtained in assessing the environmental impact of products. **The primary objective of this study is to establish recommendations that will enable SCORE LCA members and, more generally, readers of the report to understand and use the CFF, but also to support consistent positions to inform the TAB's deliberations.**

Standardisation and weighting are crucial aspects of LCA, facilitating the interpretation and comparison of environmental impacts. ISO 14074[3] provides principles and guidelines for these practices, but it is recognised that the standardisation and weighting factors established in 2018 by PEF have certain limitations. Normalisation, which involves relating impacts to common references (e.g. the impact of one human per year), can be limited by the lack of up-to-date and representative reference data on a global scale. Furthermore, the choice of reference does not reflect the significance of impacts in relation to the global challenges facing humanity. On the other hand, weighting can introduce subjective bias, as it reflects the relative importance assigned to different environmental impacts, which may vary depending on stakeholder perceptions or regional contexts. The integration of planetary boundaries is an interesting avenue for overcoming some of these limitations by incorporating this concept, but requires a methodological review to align the LCA and planetary boundaries frameworks. Research on this topic is ongoing and aims to establish a correspondence between LCA impact categories and planetary boundaries. **The second objective of this study is to propose methodological improvements, taking into account planetary boundaries, to ensure that LCA assessments better reflect current environmental issues and guide more sustainable decisions.** These improvements should be quantified and based on sound scientific data in order to strengthen the credibility and effectiveness of LCA in promoting sustainable practices.

This study aims first to establish a set of recommendations to help SCORE LCA members and readers understand and adopt consistent positions that feed into the methodological reflections carried out within the PEF. It also seeks to propose methodological and practical improvements so that Life Cycle

Assessment (LCA) evaluations are more representative of contemporary environmental challenges and guide more sustainable choices. In concrete terms, the study aims to explore, in an educational manner, possible developments in LCA and standardisation and weighting factors, drawing on the latest normative, regulatory and scientific advances at both European and global level, in order to formulate practical recommendations aimed at moving beyond current LCA practices.

Part: LCA

To achieve the objective of the LCA part of the study, a state-of-the-art review of the limitations and prospects for improvement was carried out, while reviewing the main concepts of LCA and its application. In a second step, we listed and specified areas for improvement of the formula. Next, three case studies were developed with the support of certain members of SCORE LCA on low-alloy steel, polyamide (PA) and cobalt in order to test the areas for improvement in LCA practice. Finally, we were able to analyse the results and formulate the expected recommendations.

1. State of the art Scientific

1.1. Definitions and implementation

CFF is a methodology for taking into account material and energy recovery, which allows the impacts of these multifunctional processes to be distributed across two life cycles. It was incorporated into the Product Environmental Footprint (PEF) guidelines in 2018 by the European Commission. There are several approaches to this: cut-off, substitution and allocation.

The CFF allocates costs and benefits between the supplier and user of recycled materials or recovered energy on the basis of factors A and B. These factors represent a balance between supply and demand. The CFF formula also incorporates terms showing the interdependence of the two life cycles and the distribution of impacts. In fact, it could be said that it also belongs to the substitution approach. A visualisation of the CFF is shown in the figure below.

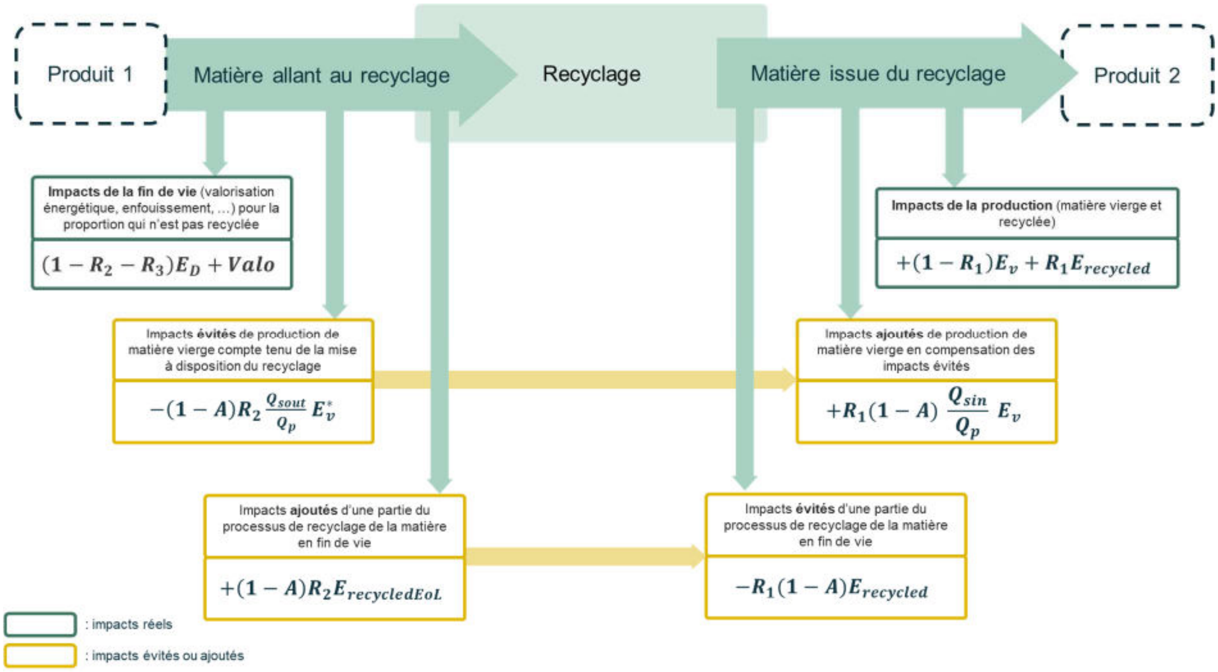


Figure 1: Schematic representation of the CFF logic

LCA is part of the ISO 14 044 standard as a multifunctional process allocation. It could even be said that it complements the standard by going further. Nevertheless, its implementation remains criticised and its use remains heterogeneous.

This was demonstrated by a survey of EVEA LCA consultants operating in various sectors of activity, a summary of which is presented below.

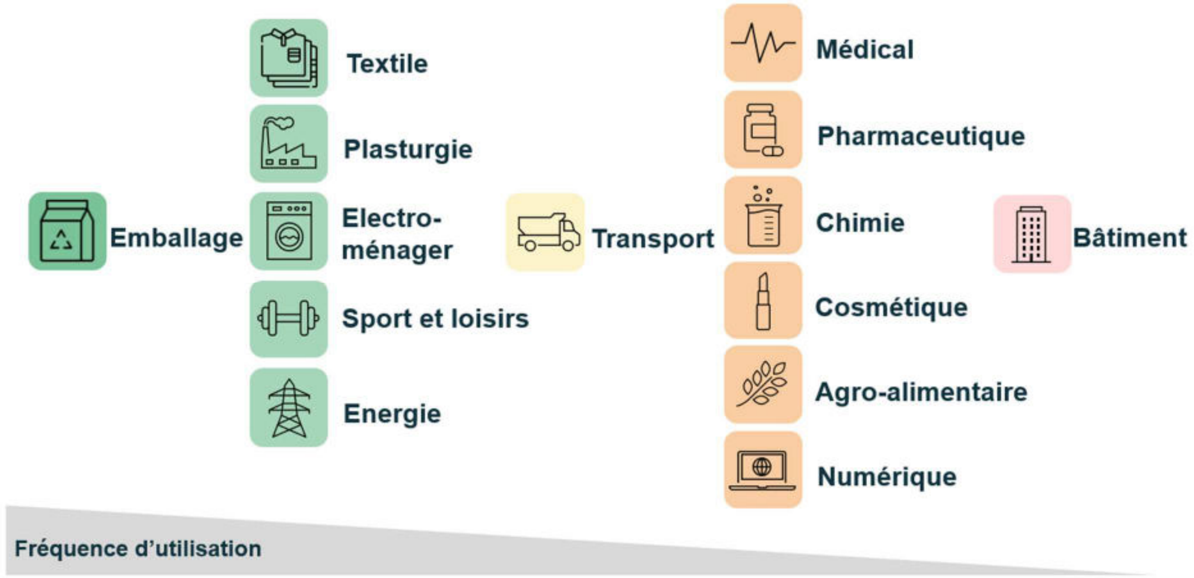


Figure 2: Infographic showing trends in the application of CFF in LCA by sector, based on an internal survey conducted at EVEA

CFF is mainly used for products with a short lifespan or those for which there are European reporting regulations (textiles, packaging).

In terms of applicability, CFF requires determining parameter values (those in the formula) and also selecting inventory data. This study provided an opportunity to detail how to implement CFF in LCA software by providing guidance on selecting parameter values and inventory data.

A key parameter in the formula is the recycled content R1. It is not easy to calculate the recycled content of a material when several types of recycled materials are involved. A distinction is often made between PIR (post-industrial recyclate) material, PCR (post-consumer recyclate) material and reclaimed material. In order to guide practitioners, the following decision tree has been established to clarify the issue of accounting for recycled content.

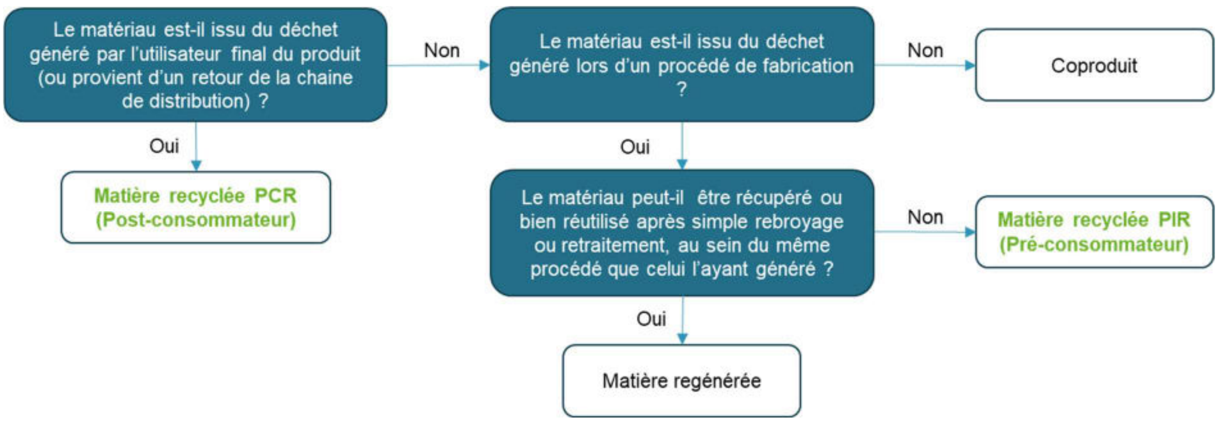


Figure 3: Decision tree for determining the use of CFF

In summary, PIR and PCR materials can be counted as recycled content. This is not the case for reclaimed material, which is obtained through process optimisation rather than recycling per se.

Once the CFF framework has been reviewed and the recommendations for its application presented, the objective is to identify points of friction and propose areas for improvement.

1.2. Proposals for changes to LCA practice

The proposals for change can be grouped into three main areas and are outlined below:

- Allocation factor A
  - Manage a database of different A values according to material, application, geography and time horizon
  - Maintain a parameter definition range between 0.2 and 0.8 inclusive, but with more possible values
  - Separate A into two independent parameters, A_{in} and A_{out}
- Allocation factor B
  - Calculate factor B so that it can be different from 0
- Inventory data
  - Can Ev* and Ev be different?
  - Can Ev* be adapted according to its geography?
  - Use prospective inventories
  - Determine inventory data for virgin or 100% recycled material when it does not exist

As an example, the two summary tables for the first two items are presented below.

Table 1 : Summary of proposed changes for parameter A of the CFF

Proposed changes	Advantages (+)	Disadvantages (-)
Manage a database of different A values according to material, application, geography and time horizon	• Market and time horizon variations taken into account • Greater accuracy • More realistic end of life	• More data to collect for the EC • More verification to be carried out for the EC • More calculation uncertainties
Maintain a parameter definition range between 0.2 and 0.8 inclusive, but with more possible values	• Greater precision • More differentiation between materials/sectors	• Need for a replicable and robust calculation method • More calculation uncertainties
Separate A into two independent parameters A_{in} and A_{out}	• Better representation of open-loop recycling cases or products with a long lifespan • Market variations taken into account	• Greater complexity • Risk of double counting or omission of impact • Clarification of open-loop recycling required

Table 2 : Advantages and disadvantages of possible improvements to factor B

Proposed changes	Advantages (+)	Disadvantages (-)
Calculation of factor B so that it can be different from 0	• Possible allocation of energy recovery gains = balance and potential control to encourage the use or recovery of energy and electricity • Rebalancing of the benefits of energy recovery for end-of-life products in relation to the benefits of recycling.	• Extension of the formula and need to model electricity and incoming energy differently if a portion comes from energy recovery (correction of background data) • Complexity • Risk of misappropriation leading to comparability issues between products

2. Case studies

In agreement with the SCORELCA members participating in the study, we have constructed three case studies:

- Case study no. 1: Low-alloy steel
- Case study no. 2: Polyamide
- Case study no. 3: Cobalt

We were able to imagine fictional but credible situations that remained as realistic as possible. This enabled us to quantitatively assess the changes that each improvement would bring about.

Areas for improvement	Case study 1	Case study 2	Case study 3
	Steel	PA	Cobalt
Definition of an A factor by material or regionalised			
Separation of factor A into two factors, A_{in} and $A_{(out)}$, taking into account differences in market distribution			
Determination of Ev* different from Ev			
Prospective definition of inventories and use (inventories, associated energy mix, etc.)			
Determination of virgin and recycled data inventory when virgin (0% recycled) and 100% recycled materials do not exist			
Definition of recycling to be framed			
Clarification of the flows to be included in the scope of the CFF (regrinding, concept of PIR/PCR)			

The case studies were carried out and documented following a common thread.

- Context

Details on the production chains under study. Scope. Functional unit.

- Application of the CFF and scenarios

Explanation of the scenarios to be evaluated as part of the selected areas for improvement. The parameter values and inventory data selected are specified for each of the scenarios evaluated.

- Results and interpretations

Results are obtained in the form of a histogram showing the contributions of each term in the formula. These results can be used to formulate analyses and explain the differences between scenarios. It is necessary to take a step back in order to formulate recommendations.

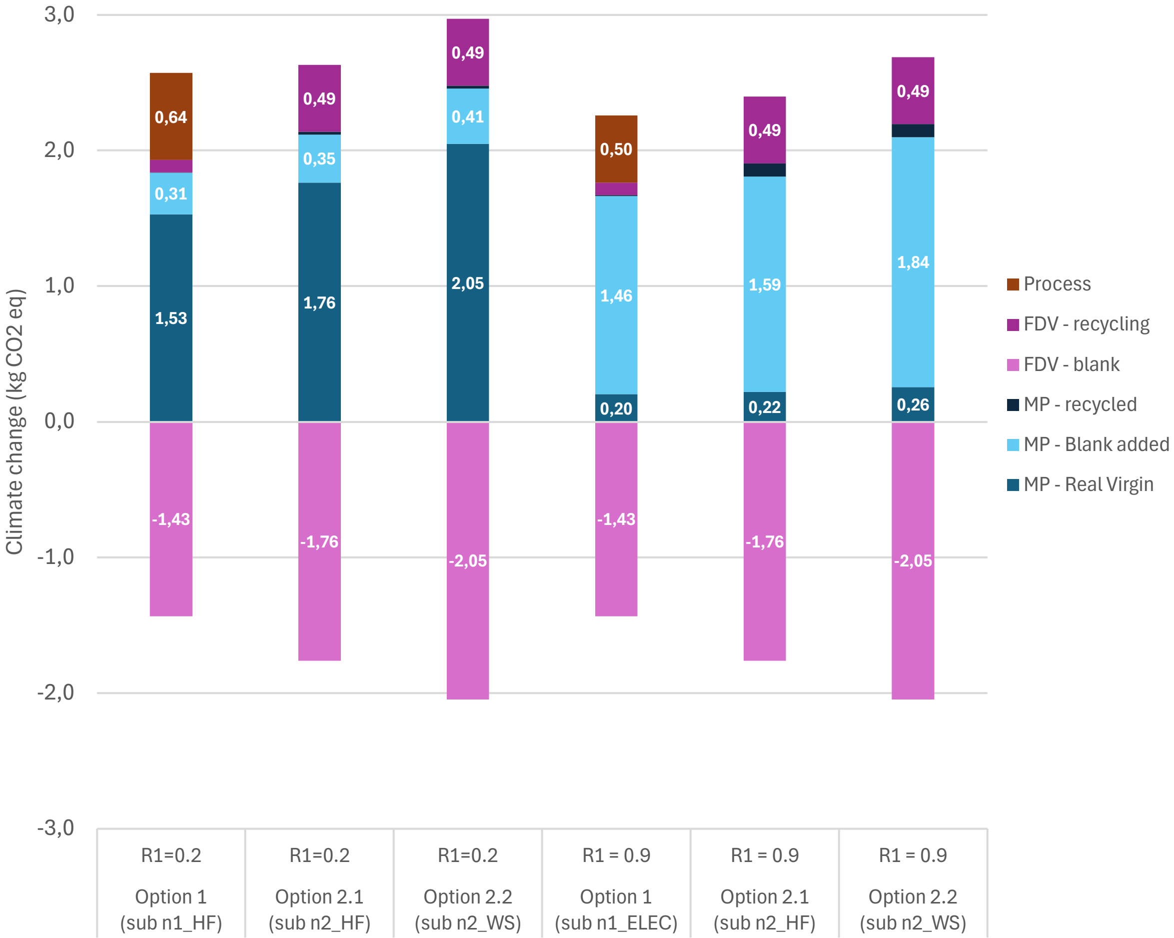


Figure 61 : Example of results for improvement options in the low-alloy steel case study

3. Conclusions and recommendations

The recommendations related to each area for improvement are summarised in the following table.

Areas for improvement	Steel	PA	Cobalt	Conclusions and prioritised recommendations
Definition of an A factor by material or region				Factor A is central and its determination leads to significant variations in the results. A must remain within the range [0.2-0.8]. A could be broken down by geography or according to different time horizons if significant variations in supply and demand are observed. A should not be broken down by sector of activity, as it is the grades of materials that lie behind the sectors. The relationship between supply and demand is specific to the material and not to the variations of that material in the value chains specific to different sectors.

Separation of factor A into two factors, A_{in} and $A_{(out)}$, taking into account differences in market distribution				With $A_{out} > A_{in}$, at the end of life there are more recycling processes and less virgin material substituted, so the end-of-life impact is higher (because the larger A is, the more we favour the use rather than the supply of recycled material). A different A at input and output results in an overall mass balance that is not representative of reality (masses that are higher or lower than reality if A_{out} is likely to change). Only change A_{out} in complementary sensitivity analysis if relevant; by default, keep $A_{out} = A_{in}$ Note that this avenue is currently being seriously explored by the TAB working on changes to the CFF formula.
Determination of Ev* different from Ev				In certain configurations, the virgin material substituted through recycling efforts is not the same as the incoming virgin material: it is therefore relevant to separate the Ev* inventory data from Ev. This makes it possible to consider the real substituted impact of recycled materials (sometimes overestimated if Ev*=Ev).
Prospective definition of inventories and use (inventories, associated energy mix, etc.)				The use of forward-looking inventories allows for better temporal and technological representativeness, particularly for products with a long lifespan. The difficulty lies in the methodology used to determine these forward-looking inventories.
Determining the inventory of virgin and recycled data when virgin (0% recycled) and 100% recycled materials do not exist				Choice of substitution point to which apply the CFF Level 1: Methodological relevance and compliance with the physical reality of the sector. Expertise and inventory data required Level 2: Use of existing inventory data even if it does not represent 100% virgin or recycled material (meaning of the R1 parameter degraded) Non-use of fictitious reconstructed inventory data in order to obtain a better reading of the results and avoid inconsistencies with the end-of-life part More accessible implementation and availability of inventories
Definition of recycling to be framed				Recycling is not considered systematically; the CFF only applies when recycling takes place.
Clarification of the flows to be included in the scope of the CFF (regrinding, concept of PIR/PCR)				When waste is generated during the manufacturing stage of a product and is reintroduced into the process: - a recycled material is considered if an intermediate reprocessing (recycling) stage is necessary (on the same site or a different site) = CFF

				- a reclaimed material is considered if no intermediate reprocessing stage is necessary (with the exception of simple regrinding) = no CFF

This study provides a more practical understanding of CFF with operational explanations of its implementation. It then seeks to look beyond this by identifying the positive and negative points as well as areas for improvement. Readers will come away with a better understanding of the avenues for improvement and the quantified elements of the changes they could bring about. As indicated in the introduction, the TAB's work, carried out in parallel with the study, will continue and will probably lead to changes in the formula.

Part: Standardisation and weighting

To achieve the objective of this part of the study, a state-of-the-art review was carried out on both the principle of standardisation and weighting in ISO and in the PEF method, as well as on the possible links between LCA and planetary boundaries (literature review and expert interviews). Three case studies were then selected and carried out in order to identify the full potential and limitations of a planetary boundaries LCA. Finally, we were able to analyse the results and make recommendations.

1. State of the art in science

General principles of standardisation/weighting

Normalisation and weighting:

- Are optional steps,
- Contribute to a better interpretation of the results,
- Facilitate decision-making
    - By making LCA results accessible and operational
    - By prioritising issues
- The following are defined and regulated in ISO/TS 14074: 2022

Standardisation and weighting lead to trade-offs in the importance of impact categories (the concept of value choice). These trade-offs are not always visible or explicit and vary according to spatial and temporal scales and cultural priorities.

Good practice consists of documenting the raw results (standardisation and weighting factors used) and choosing the reference system and weighting data according to their regional and temporal relevance.

PEF method

The Product Environmental Footprint (PEF) was developed by the European Commission in response to the fragmentation of environmental assessment approaches in Europe. In 2013, the Commission launched an initiative to harmonise these practices with the aim of creating a standardised, reliable and transparent method for measuring and communicating environmental impacts throughout the life cycle.

The method covers 16 categories of environmental impact. The methodological development was coordinated by the Joint Research Centre (JRC), the scientific service of the European Commission, in collaboration with academic experts and various stakeholders.

Standardisation within the EF framework is based on global rather than European data. This geographical scale was chosen to be consistent with the international scope of supply chains. The normalisation factors in the EF are expressed in terms of average per capita impacts for one year. This means that they represent the average contribution of one person to an impact category (e.g. greenhouse gas emissions for climate change).

The weighting methodology is based on two combined factors reflecting, on the one hand, the robustness of the impact categories and standardised results and, on the other hand, the relative importance of the impact categories. With regard to the relative importance of the indicators, the JRC decided to opt for a hybrid methodology, combining factual data (preliminary assessment of criteria based on evidence from the literature), expert judgements and a survey of European Union citizens to establish the weighting factors.

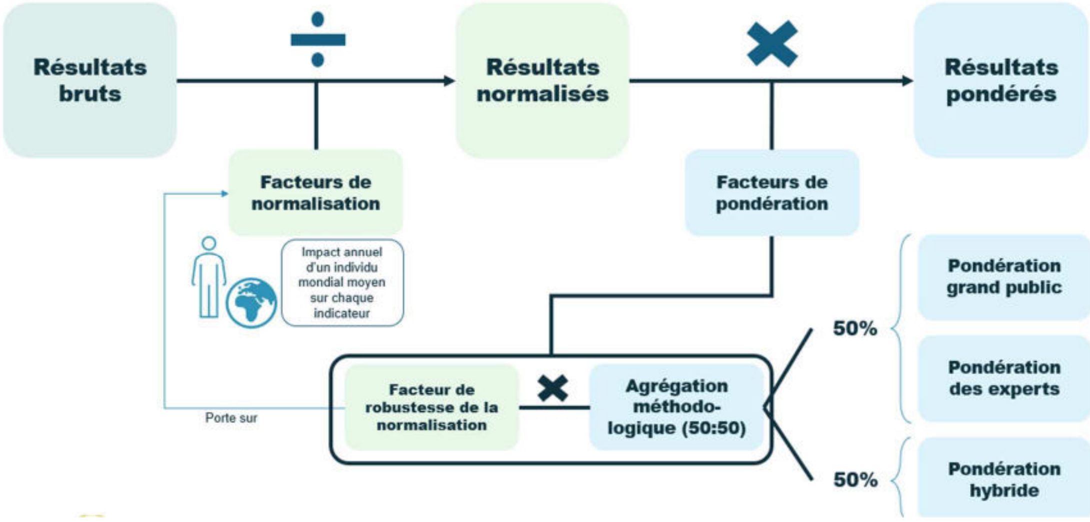


Figure 72 : standardisation and weighting of the PEF method, operating procedure

Presentation of the concept of planetary boundaries

Proposed by an international team of researchers in 2009 (Stockholm Resilience Centre), this concept identifies boundaries that must not be exceeded in order to ensure that the Earth's ecosystem remains in the Holocene, its current state for approximately 10,000 years. These boundaries define a safe operating space for the human species (Planetary Playground, or Safe Operating Space).

The latest update dates from September 2025, with 7 out of 9 boundaries exceeded.

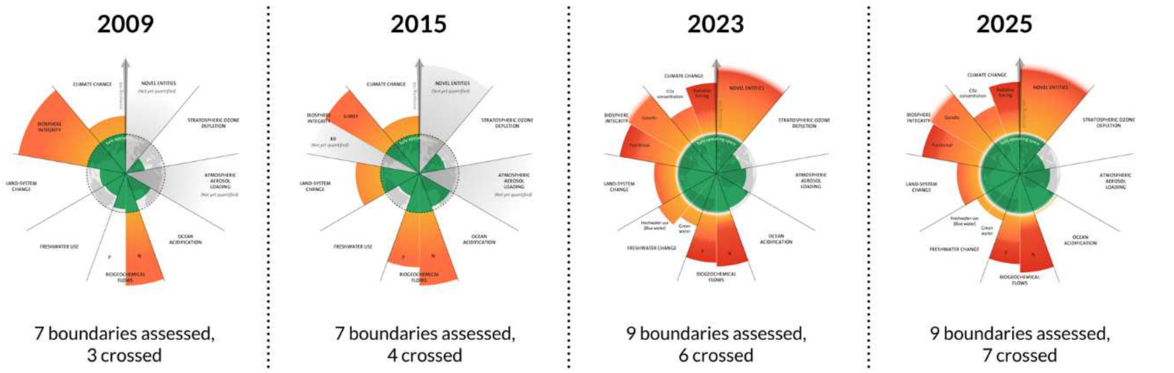


Figure 83 : evolution of the assessment of the nine planetary boundaries since 2009

Linking LCA and planetary boundaries

There are three ways to link LCA to the concept of planetary boundaries:

- At the characterisation stage,
- At the standardisation stage,
- At the weighting stage.

[1] *Azote for Stockholm Resilience Centre, Stockholm University. Based on Sakschewski and Caesar et al. 2025, Richardson et al. 2023, Steffen et al. 2015, and Rockström et al. 2009

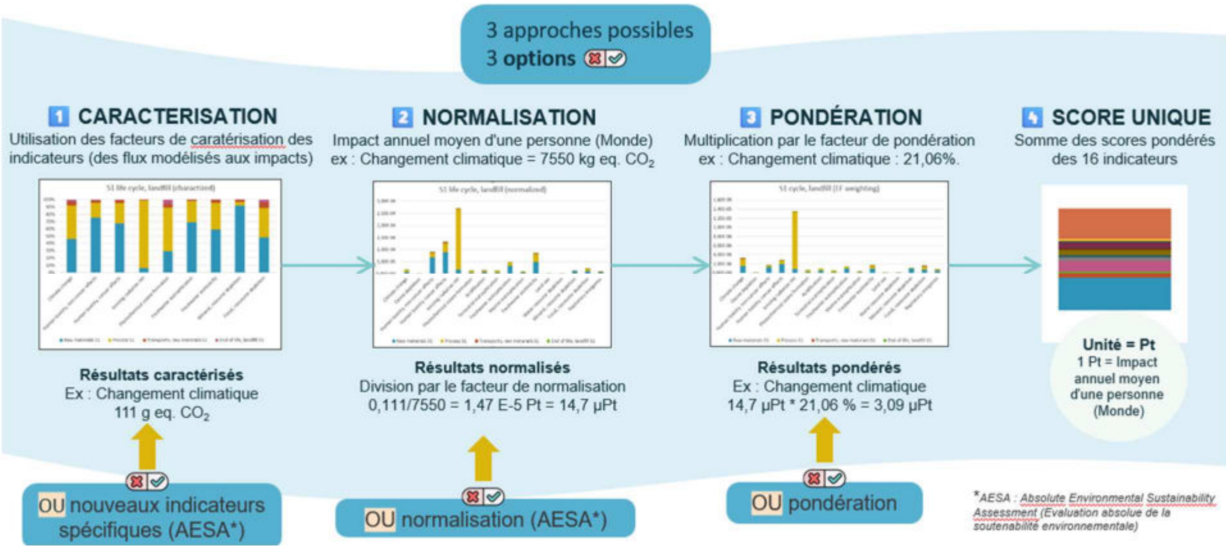


Figure 94 : graphical representation of the three possible approaches for combining LCA and planetary boundaries

Linking at the characterisation stage is outside the scope of this project but is discussed here to aid understanding of the whole. This involves creating new impact indicators directly aligned with the metrics of the nine planetary boundaries, enabling an absolute LCA or AESA to be carried out (with a detailed scaling process in the case studies).

The other coupling method that allows an AESA to be performed is the use of normalisation factors (thresholds not to be exceeded at the individual level), while then proceeding in the same way to a downscaling.

The final way of coupling LCA with planetary boundaries is therefore at the weighting stage.

It is important to note that:

- It is not possible to combine these three approaches; a choice must be made, otherwise there will be duplication.
- That weighting is not an "absolute" LCA or AESA (as there is no downscaling and allocation of a share of the remainder to be emitted).

2. Case study

For each case study, we used generic ecoinvent data and compared:

- The current PEF method (EF 3.1)
- The consideration of planetary boundaries via weighting (after conventional LCA normalisation)
- Absolute LCA or AESA, using planetary boundary normalisation factors and product or service downscaling/upscaling

With 3 case studies:

- Case study no. 1 🔧 : comparison of methods for generic material data, 1 kg of global steel
- Case study no. 2 ⚡: comparison of methods for generic energy data, 1 kWh of French electricity
- Case study no. 3 🚗 : comparison of methods for generic mobility data, 1 km travelled by private car in Europe

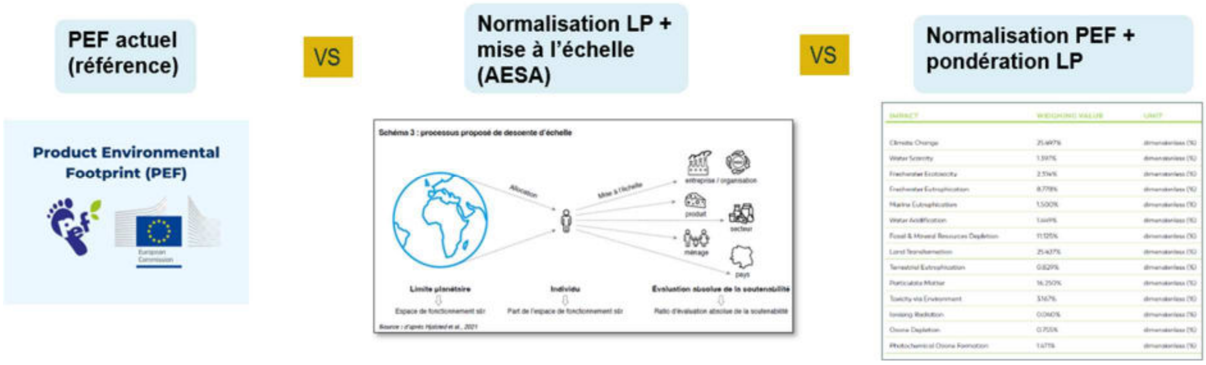


Figure 105 : schematic representation of the three methods compared

Comparison between the PEF method and the integration of the planetary boundary concept via weighting

For the comparison between the current PEF method and the integration of the concept of planetary boundaries via weighting, the result mainly consists of comparing:

- The selection of the indicators deemed most relevant, with the 80% cumulative rule contributing to the single environmental score
- The gross value of the single score in points

Comparison between the PEF method and absolute LCA or AESA

With regard to absolute LCA or AESA, below is a diagram showing the multi-step scaling procedure, which applies in the same way to the three case studies and ecoinvent data types.

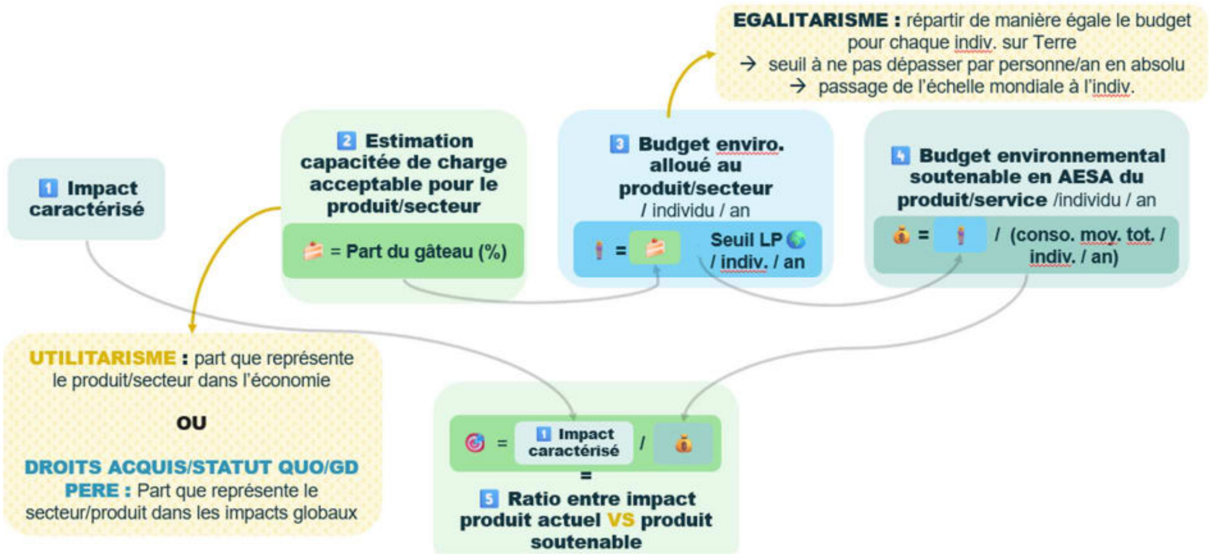


Figure 116 : downscaling procedure implemented in this project

There are several principles of distributive justice that can be used to perform downscaling or scaling. These principles or methods are used to estimate carrying capacity (step 2 , estimation of carrying capacity or allocation of the pie) and to allocate the environmental budget to the product or sector under study (step 3 , scaling).

In these case studies, three principles were selected and implemented (as they are the most commonly used[5]), namely:

- For estimating carrying capacity or allocation of the share of the pie (see**Erreur ! Source du renvoi introuvable.**) in step 2 :
    - Utilitarianism: monetary data, share of the product/sector in the economy (in terms of added value), to calculate a percentage allocation
    - The principle of acquired rights or status quo or grandfather clause: Share represented by the sector/product in overall impacts (e.g. textiles account for around 7% of global GHG emissions) to calculate an allocation percentage
- For downscaling in step 3 :
    - Egalitarianism: very often used in ESAs by default in order to distribute impacts or budgets equally for every human being on Earth, this is the very principle of normalisation in PEF and most often in LCA (normalisation factors, planetary boundaries or thresholds that should not be exceeded per person/year in absolute terms, and to move from the global scale to the individual)

Based on the ratio found for each indicator in step 5 at the end of the procedure, the system evaluated is either sustainable or not in absolute terms, and if it is not (ratio > 1), this provides information on the target or objective to be achieved (for a trajectory of impact reduction). The values in red in the case study results tables (below) indicate a ratio > 1, and therefore a product that is not sustainable given its distance from the target to be achieved.

In this summary, we present below the results of a single case study, French electricity.

Results for electricity in France

The generic ecoinvent data used is 1 kWh of "*Electricity, low voltage {FR}| market for electricity, low voltage | Cut-off, S*".

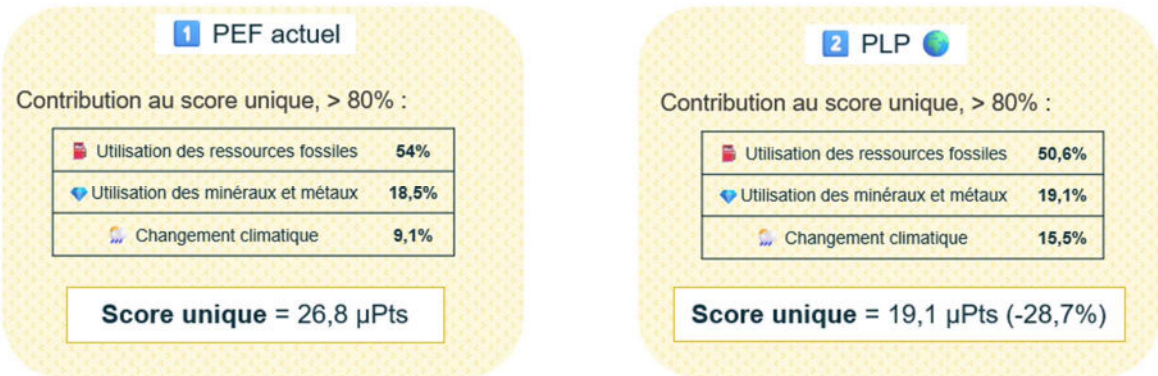


Figure 127 : comparative results of the PEF method vs. planetary boundary weighting (for decision-making)

<u>Weighting planetary boundaries vs PEF</u>:
The results are obviously identical (e.g. 87.6 gCO_2 e/kWh). The standardisation is identical between the two approaches (traditional PEF, global scale). The selection and order of indicators is identical. The single score is, in gross terms, lower with PLP (-28.7%).

[5] Gonzalo Puig-Samper et al (December 2024) - Quantifying uncertainties in absolute environmental sustainability assessment: A general framework applied to French electricity production

<u>AESA</u>:

Indicateurs ACV	Unité	1 Impacts caractérisés	2 allocation par secteur	3 budget enviro élec/personne/an	4 Budget enviro 1 kWh soutenable	5 Ratio et distance à la cible
Climat change	kg CO2 eq	8,76E-02	$= \frac{VA\ électricité\ FR}{PIB\ France} = \frac{40\ Mds}{2796\ Mds} =$ **1,42%**	1,40E+01	6,29E-03	13,9
Ozone depletion potential	kg CFC-11 eq.	3,09E-09		1,11E-03	4,98E-07	0,0
Human toxicity, cancer	CTUh	4,50E-10		1,97E-06	8,88E-10	0,5
Human toxicity, non-cancer	CTUh	3,62E-09		8,42E-06	3,79E-09	1,0
Particulate matter	Disease incidence	3,17E-09		1,06E-06	4,77E-10	6,6
Ionising radiation	kBq U-235 eq.	1,12E-01		1,08E+03	4,87E-01	0,2
Photochemical ozone formation	kg NMVOC eq.	3,30E-04		8,35E-01	3,76E-04	0,9
Acidification	mol H+ eq	6,10E-04		2,06E+00	9,26E-04	0,7
Terrestrial eutrophication	mol N eq	9,64E-04		1,26E+01	5,67E-03	0,2
Freshwater eutrophication	kg P eq	2,84E-06		1,19E-02	5,37E-06	0,5
Marine eutrophication	kg N eq	8,80E-05		4,12E-01	1,85E-04	0,5
Land use	Pt	6,85E-01		1,07E+04	4,81E+00	0,1
Ecotoxicity freshwater	CTUe	7,34E-01		2,70E+02	1,21E-01	6,0
Water depletion	m3 water eq	3,77E-02		3,73E+02	1,68E-01	0,2
Resource depletion – fossils	MJ	1,13E+01		4,60E+02	2,07E-01	54,8
Resource depletion - minerals	kg Sb eq	4,18E-06		4,52E-04	2,03E-07	20,6

Figure 138 : AESA results for 1 kWh of the French mix – utilitarianism in allocation for scaling

With utilitarianism in added value:

- Unsustainable product for 5 out of 16 indicators;
- Reducing impacts does not seem realistic or is too difficult (to be divided by 14 on climate change, when the French mix is already "low carbon");
- It would have been interesting to use utilitarianism with the share of household expenditure as a variable (the added value of an intermediate good or sector is not necessarily very representative of its usefulness to the economy and society).

LCA indicators	Unit	1 Characterised impacts	2 Allocation by sector	3 Environmental budget per person per year	4 Sustainable 1 kWh environmental budget	5 Ratio and distance to target
Climate change	kg CO2 eq	8.76E-02	6.048%	5.96E+01	2.68E-02	3.27
Ozone depletion potential	kg CFC-11 eq.	3.09E-09	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Human toxicity, cancer	CTUh	4.50E-10	17.127%	2.38E-05	1.07E-08	0.04
Human toxicity, non-cancer	CTUh	3.62E-09	766.918%	4.55E-03	2.05E-06	0.00
Particulate matter	Disease incidence	3.17E-09	1.377%	1.03E-06	4.63E-10	6.84
Ionising radiation	kBq U-235 eq.	1.12E-01	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Photochemical ozone formation	kg NMVOC eq.	3.30E-04	7.220%	4.25E+00	1.91E-03	0.17
Acidification	mol H+ eq	6.10E-04	3.817%	5.53E+00	2.49E-03	0.24
Terrestrial eutrophication	mol N eq	9.64E-04	1.689	1.50E+01	6.74E-03	0.14
Freshwater eutrophication	kg P eq	2.84E-06	2.297	1.93E-02	8.68E-06	0.33
Marine eutrophication	kg N eq	8.80E-05	2.152	6.24E-01	2.81E-04	0.31
Land use	Pt	6.85E-01	1.122%	8.45E+03	3.80E+00	0.18
Freshwater ecotoxicity	CTUe	7.34E-01	183.866%	3.49E+04	1.57E+01	0.05
Water depletion	m3 water equivalent	3.77E-02	0.938	2.47E+02	1.11E-01	0.34
Resource depletion – fossils	MJ	1.13E+01	45.497	1.47E+04	6.63E+00	1.71
Resource depletion - minerals	kg Sb eq	4.18E-06	0.037	1.19E-05	5.35E-09	782.2

Figure 149 : AESA results for 1 kWh of the French mix – vested rights in allocation for scaling up

With the principle of grandfathered rights:

- Product unsustainable for 4 out of 16 indicators;
- Reducing impacts seems more realistic or achievable (to be divided by 3.3 for climate change);
- Still requires the use of all the levers of energy transition scenarios, including sobriety and efficiency;
- Main limitations: a ratio of 782 for mineral resource depletion, and impacts not characterised in Exiobase France for ozone depletion and ionising radiation.

3. Conclusions and recommendations

AESA limitations and prospects

We observe that the results (ratios) vary greatly depending on the allocation method used, whether utilitarianism or acquired rights (not to mention other possible methods).
However, it seems quite clear that using utilitarianism in terms of added value is not really suitable for an AESA on "intermediate" products or sectors, which are nevertheless essential or even vital to the functioning of our societies. This is due to the low added value accorded to the primary and secondary sectors overall, compared to tertiary service activities. Alternatively, the added value of other sectors related to the activity being assessed would need to be included (e.g. the oil sector for the service "travelling 1 km by car").
Ultimately, the application of acquired rights (and the percentage applied) reflects the importance of these activities much better than utilitarianism, as it is linked to the actual physical flows on which they depend (and therefore linked to environmental impacts).

The scaling process is complex and generates a build-up of uncertainties as it progresses through the stages. Sources must be consolidated and "critiqued" as much as possible in order to obtain more reliable and realistic results. The type of source may vary, ranging from reference websites, scientific reports or publications, to the impacts used by the JRC (EU, World) and linked to input-output databases such as Exiobase. In this database, two of the 16 PEF indicators are not characterised.

A guide for the implementation of AESA is being prepared at European level (JRC) and should help to harmonise and develop this practice (publication in early 2026).

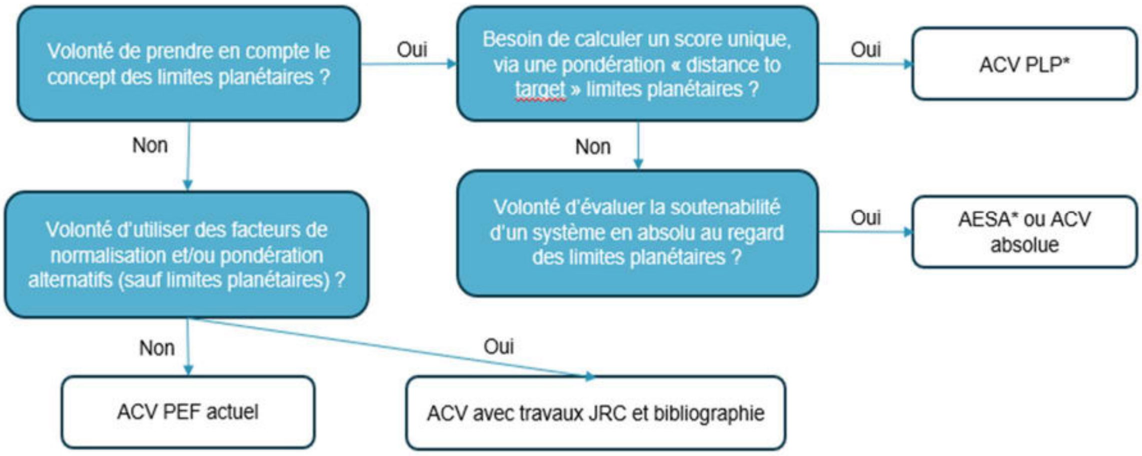
Another significant limitation of the case studies is the limited representativeness of the generic ecoinvent data used. On the one hand, this data may be quite old and, on the other hand, it does not represent the full range of production in the sectors/products assessed. The use of databases such as Exiobase can also help to consolidate an entire sector of activity, but this is not always possible depending on the activities covered (e.g. for car mobility).

Another important limitation concerns the assessment of thresholds that should not be exceeded at the global level (and therefore at the individual level via planetary boundary normalisation). This "planetary boundary" work, which has been continuously improved since its first publication in 2009, is more or less robust depending on the ecological processes involved, which vary in nature (particularly at the global and local levels) and involve a significant degree of uncertainty (based on the lower threshold for each limit or boundary).

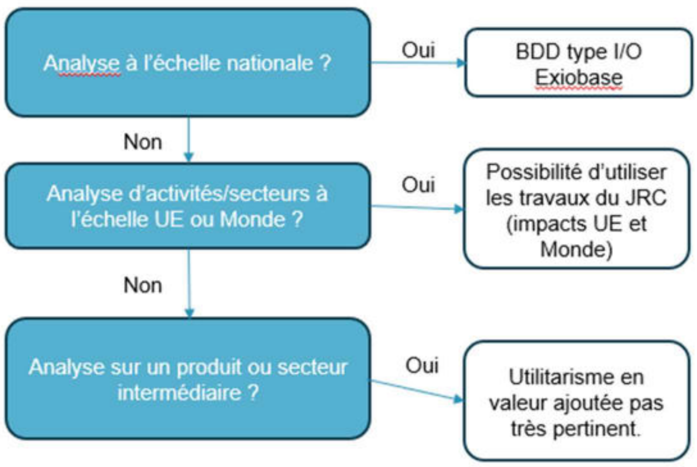
Recommendations

The evolution of PEF standardisation, depending on whether the approach is territorial or consumption-based, has not been studied in the case studies.
We assume here that the "classic" PEF standardisation factors are part of a process of continuous improvement to become increasingly representative and robust.

Types of LCA according to objectives:



Best practices for EFSA:



In the absence of specific data collection, it is possible to use generic data from databases (limited representativeness). In all cases, for the scaling of AESA, it is recommended to apply at least two allocation principles, as results can vary greatly from one method to another. It is also very important to consolidate sources for allocation as much as possible and to take a critical look at the results of AESA.

This study provides an understanding of the principle of standardisation and weighting stages in LCA, with ISO recommendations and practice within the framework of the PEF. It seeks to look beyond this by identifying opportunities to take into account the concept of planetary boundaries. Readers will come away with a better understanding of possible methodological approaches, their potential for the future of LCA, but also their limitations.