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Product waste footprint

Methodological approach for quantification and communication

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Summary

Waste is generated along the production of products (i.e. during extracting resources, processing and production) and also when unwanted products are discarded. Although most consumers are aware of the amount of waste they dispose of, relatively few are aware of the waste generated in the course of producing the goods that they consume. This project builds upon previous work to advance a methodological approach for quantification and communication of the pre-consumer waste footprint of products. The purpose is to address the main criticism that the work received in a peer-review process: how to deal with the subjectivity of waste, are the indicator appropriated for communicating results, what is the usefulness of a product waste footprint.

An online open consultation was carried out in order to gather opinions and inputs of several stakeholder groups (e.g. life cycle assessment (LCA) experts and practitioners, waste management experts, consumers, and authorities) on 5 methodological details (MDs) of the approach: MD1 effectiveness for differentiating waste and by-products, MD2 effectiveness for defining which material flow shall be accounted for, MD3 adequacy for representing an indicator to convey environmental significance of waste types, MD4 usefulness of a product waste footprint metric for stakeholder groups and MD5 usefulness of a product waste footprint metric in different contexts.

Most of the respondents expressed that the guidelines described in the methodology are good enough for the purposes of MD1-2. Part of the respondents found the draft guidelines for MD1-2, which were based the Interpretative Communication on waste and by-products of the European Commission, to be unnecessarily complex for the exercise; hence not sufficiently adequate.

Furthermore, some responses from prominent LCA experts and practitioners declared that qualitatively attributing environment significance to different types of wastes may not be adequate (MD3). The results also suggested that a product waste footprint metric would be mostly useful and/or needed (MD4) for (1) consumers and (2) government; and in contexts (MD5) of (a) improving environmental awareness of consumers, (b) environmental policy making, (c) visualising waste flows in a circular economy and (d) improving resource efficiency in industry, and less useful/needed (MD5) in a (e) business-to-business context.

Finally, although the PWF is fundamentally a simple measure of resource use and not of eventual environmental damage (e.g. abiotic resource depletion, eutrophication, land use change), further studies could examine whether the PWF is a good proxy of life cycle environmental impacts in specific categories of product or manufacturing process. The LCA community is encourage to devote more attention to how consumers may or may not use product related environmental information and apply this knowledge in advancing metrics that are useful for consumers.

1. Introduction

In recent years consumers have become increasingly aware of the impact that their consumption may have on the environment, and resource use and waste generation are major issues. Although most consumers are aware of the amount of waste they generate themselves, relatively few are aware of the total waste generated in the course of producing the goods they consume. In fact, a large part of the total waste generated in our consumer society occurs before products reach the consumer; generated primarily in upstream production processes (extracting resources, transporting, producing fuels and electricity, manufacturing).

Figure 1 illustrates the life cycle of products, emphasizing the waste produced during raw materials extraction and production, manufacturing, electricity production, packaging and end-of-life. The waste generated upstream from the point of consumption, i.e. pre-consumer waste, is defined as product waste footprint (PWF).

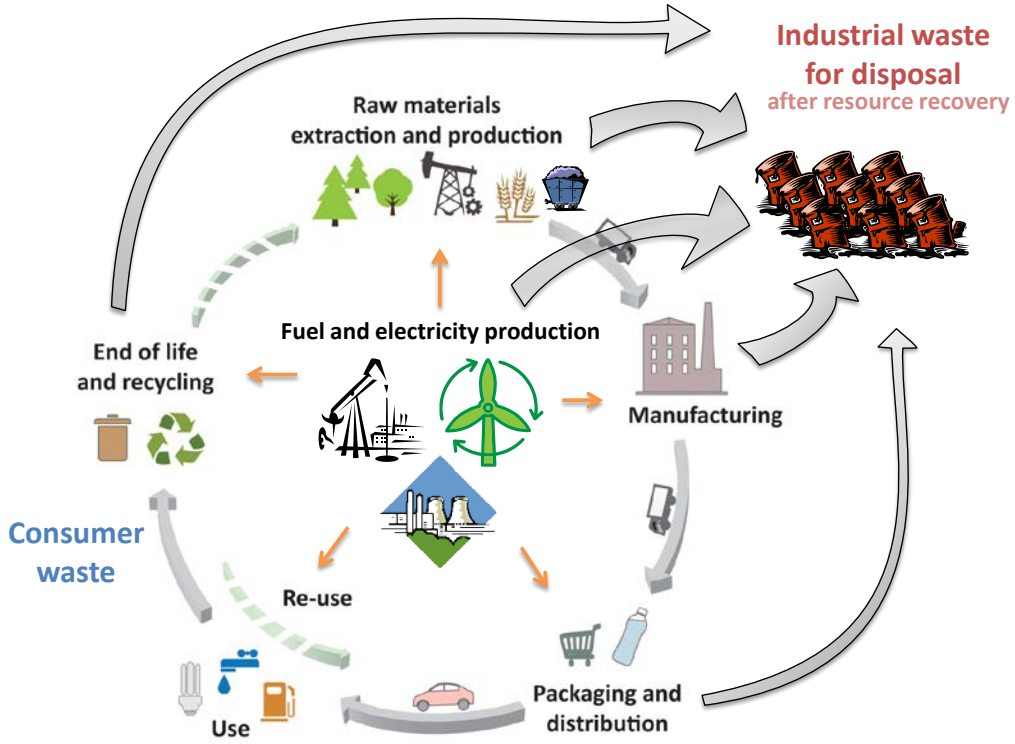

Figure 1 - Life cycle stages of a product and waste generated. Grey arrows represent flows of materials; orange arrows represent energy flows; flows recovered on site are omitted. Source: (Laurenti and Stenmarck 2015)

In a previous study a waste footprint method for calculating the total waste generated during the production of a product has been proposed and tested in 11 generic products (Laurenti and Stenmarck, 2015, Laurenti et al., 2017). The results received immense attention from a large suite of media; including Swedish television and in printed and online news channels. This coverage of our earlier results strengthens our view that this is information (which we consider to be not well known) is of interest of many stakeholder groups.

Nevertheless, some aspects of this initial study needed further consideration and development, namely:

- the deliberated subjectivity of waste; what is defined as waste by an actor, industrial sector or country can differ quite considerably;
- defining which flows should be accounted for as waste;
- further refining the single/aggregated indicator initially proposed into several others, in order to improve what is communicated as the waste footprint of a product; and
- clarifying the purpose or need of a PWF metric for different stakeholders and contexts.

1.1 Aim and objectives

This project pursued advancing the product waste footprint methodology by addressing three primary research questions (RQ):

> *RQ1. How to define the waste to be accounted? How to differentiate waste and by-product?*
> *RQ2. Should the environmental significance of the different types of wastes be explicitly expressed and communicated in a simple way?*
> *RQ3. Is this metric useful/needed? For whom and for what purpose?*

The aim of this project was *to develop a methodological approach for the quantification and communication of the waste footprint of a product.* The research objectives (RO) thus included:

> *RO1. To develop a stepwise approach and a set of guidelines for conducting product waste footprint studies.*
> *RO2. To perform an open consultation of the framework for revising a draft version of the methodological framework and assessing the usefulness/need of a product waste footprint metric.*

2. Method

Literature review and online survey were the methods and procedure applied. First, pertinent literature was revised and a draft of the PWF approach was generated. Then a questionnaire was created concerning 5 methodological details (MDs) of the draft PWF approach and then used in an online open consultation aimed at gathering inputs from diverse stakeholder groups on the MDs.

MD1 Effectiveness for differentiating waste and by-product

MD2 Effectiveness for defining which waste should be accounted

MD3 Adequacy for communicating the environmental pressure from a waste generation perspective

MD4 Usefulness of or need for a PWF metric for different stakeholder groups

- Consumer
- Industry
- University/research institute
- Government

MD5 Usefulness of or need for a PWF metric for different contexts

- Improving environmental awareness of consumers
- Environmental policy making
- Business-to-business
- Visualising waste flows in a circular economy
- Improving resource efficiency in industry

Effectiveness *was regarded as the ability to produce the intended results*

Adequacy *was regarded as the quality of being good enough for a particular purpose*

The stakeholder groups of MD4 and the contexts of MD5 were predefined based on the results of the previous PWF study (Laurenti and Stenmarck, 2015, Laurenti et al., 2017).

The target audience of the online consultation was the general public (consumers), LCA experts, industry and the government. Suggestions for improvement gathered in the open consultation served as inputs for consolidating the development of the product waste footprint methodology. This was an iterative process. Figure 2 illustrates the procedure applied in this project. More details on the literature review and open consultation are given in the subchapters that follow.

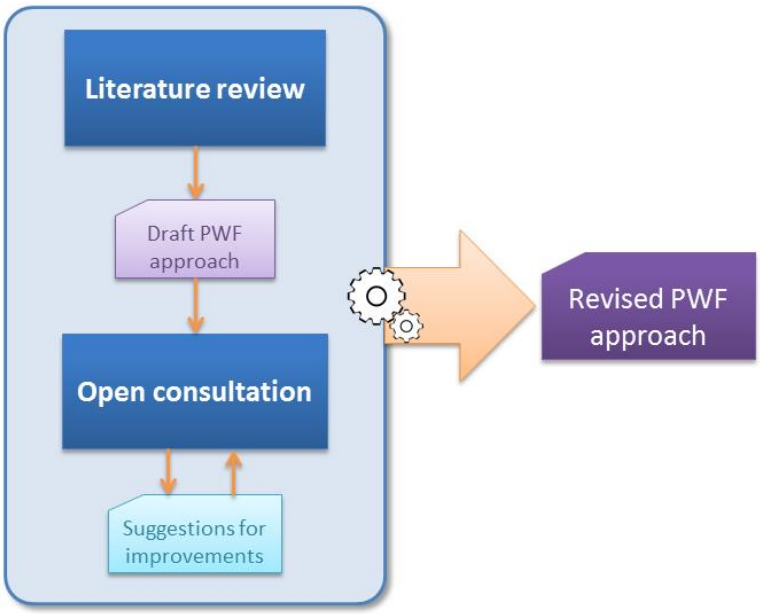

Figure 2 – Illustration of the process of developing the PWF approach. The gears in the figure denote an iterative process.

2.1 Literature review

The literature review formed the basis for composing a first draft of the methodological approach encompassing objectives i-iii. The publications consulted were:

- Related environmental standards – life cycle assessment (ISO, 2006b, ISO, 2006a), carbon footprint (ISO, 2013), water footprint (Hoekstra et al., 2011).
- Waste directives – EU directive on waste (The European Parliament the Council of the European Union, 2008), EU directive on waste from extractive industry (European Parliament and of the Council, 2006)
- Waste list and classifications – EU list of waste[1], European Waste Classification for Statistics[2]
- Documentation of the Environmental Product Declaration (EPD) system and product category rules (PCR) (EPD Environmental Product Declaration, 2015a, EPD Environmental Product Declaration, 2015b).
- Interpretative Communication on waste and by-products. Brussels, 21.2.2007. COM(2007) 59 final.

2.2 Open consultation

Public consultation on 'quantification and communication of pre-consumer waste footprint' was launched April 2017 running until the middle of May 2017. Using an online questionnaire, the

[1] http://ec.europa.eu/eurostat/ramon/other_documents/ewc/index.cfm?TargetUrl=DSP_EWC
[2] http://ec.europa.eu/eurostat/ramon/other_documents/ewc_stat_3/index.cfm?TargetUrl=DSP_EWC_STAT_3

consultation offered an opportunity to all interested parties to express their views and give their opinion on the proposed framework. The questionnaire was structured in five sections:

- General questions
  - Name, contact details, organisation type, field of activity
- Subjectivity of waste
  - MD1-2
- Indicators for communicating results
  - MD3
- Usefulness of a product waste footprint
  - MD4-5
- Further participation
  - Interest in revising the draft text of the PWF approach

The questions presented a 'multiple choice' approach, requesting opinions on a graduated 5 point-scale representing the level of expected effectiveness or adequacy of the respective part of the framework and usefulness/need of a product waste footprint metric for several stakeholder groups and contexts. Respondents were requested to express their opinion on the graduated scale, and were also given the opportunity to include open comments for clarification. 'I don't know' options were possible to be chosen as well. The estimated time to complete the survey portrayed to take15-20 minutes. Additionally, respondents had the option to indicate interest in revising the full preliminary version of the framework document. The full questionnaire can be found in Annex 1 and the comments from the respondents in Annex 2 of this report.

Invitations to answer the questionnaire were sent to an LCA email list[3], shared in relevant LinkedIn groups, shared in Facebook pages and interested stakeholders from IVL's external network. The target audience was LCA experts, waste experts, general consumers, industry and authorities.

The responses were fully analysed:

- qualitatively by reading written comments and drawing inferences to the developing PWF approach; and
- statistically by categorising respondents and responses, calculating percentages of responses, and drawing inferences to the developing PWF approach.

A synthesis of the online consultation is presented in chapter *3 Synthesis of the online consultation*. Responses which were recorded with written comments are presented in *Annexe 2 – Answers and written comments from respondents.* A screen shot of the open page of the online questionnaire is shown in Figure 3.

[3] This is a subscription-based email list, managed by PRé-consultants, with over 2500 users worldwide, for discussing issues related to LCA and related sustainability issues. On a regular basis LCA experts and practitioners make important contributions regarding methodology, the sharing of data, and important events in the LCA community.

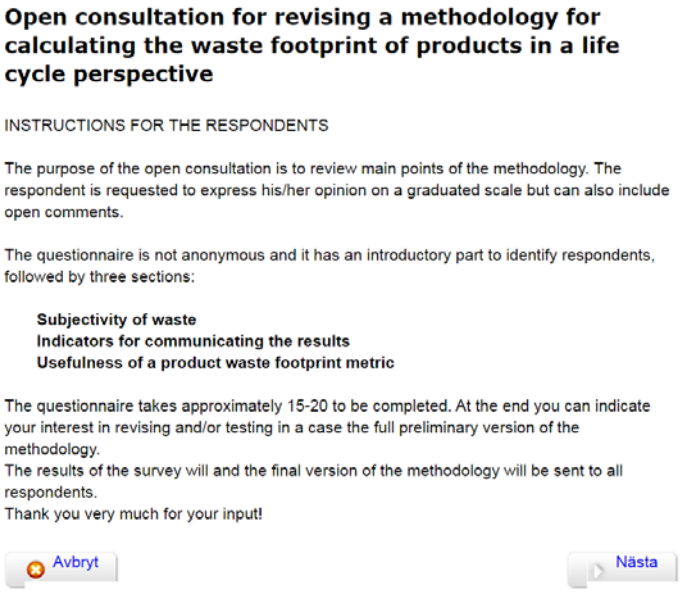

Figure 3 – A screen shot of the open page of the online questionnaire.

3. Synthesis of the online consultation

In total, 312 people accessed the questionnaire through invitation link. From these 312 people, and assuming that a person only accessed or responded the online questionnaire only once, 257 people accessed the questionnaire but did not start responding; 28 started responding but did not complete; and 27 completed the questionnaire.

As previously stated, the last section of the online questionnaire inquired about interest of further participation. About 10 respondents showed interest in revising the full draft version of the PWF. After contacting them by email, 4 of the respondents were interviewed through video-conferencing and 3 respondents provided written additional comments on the draft PWF approach..

3.1 Who the respondents were

Respondents can be broken down in two broad categories (see Figure 4):

- 38% Consumers (answers from individual citizens)
- 62% Organisations (answers from representatives of private or public organisations)

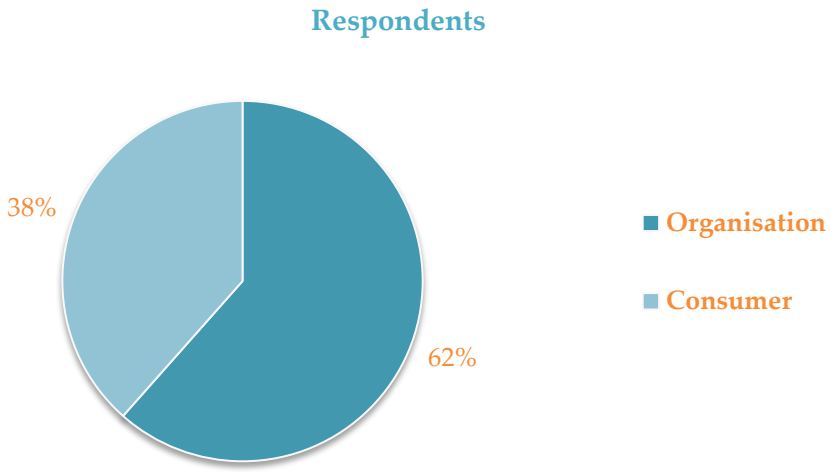

Figure 4 – Distribution of type of stakeholder group among respondents

Regarding the type of organisation of the respondents, of the 62% of those who recorded as 'Organisation', 43% were from a university, 29% research institute, 14% industry, 6% government, 6% consultant firm and 3% from other service sector. These percentages are represented in Figure 5.

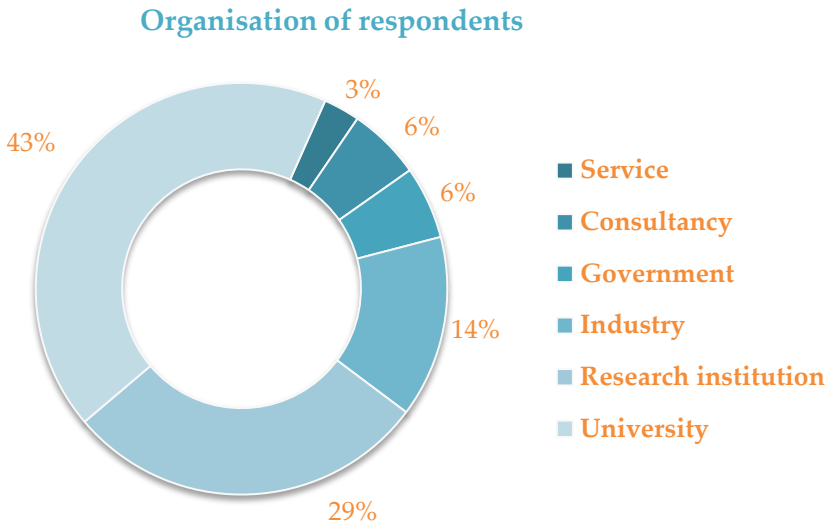

Figure 5 - Distribution of type of organisation of respondents

Most of the respondents indicated that they with life cycle assessment (30%), environmental technology (16%) and waste management (13%). However, 41% of the respondents covered a broad range of other fields. Figure 6 displays the field of activity of the respondents. A respondent could indicate to be working in more than one field of activity.

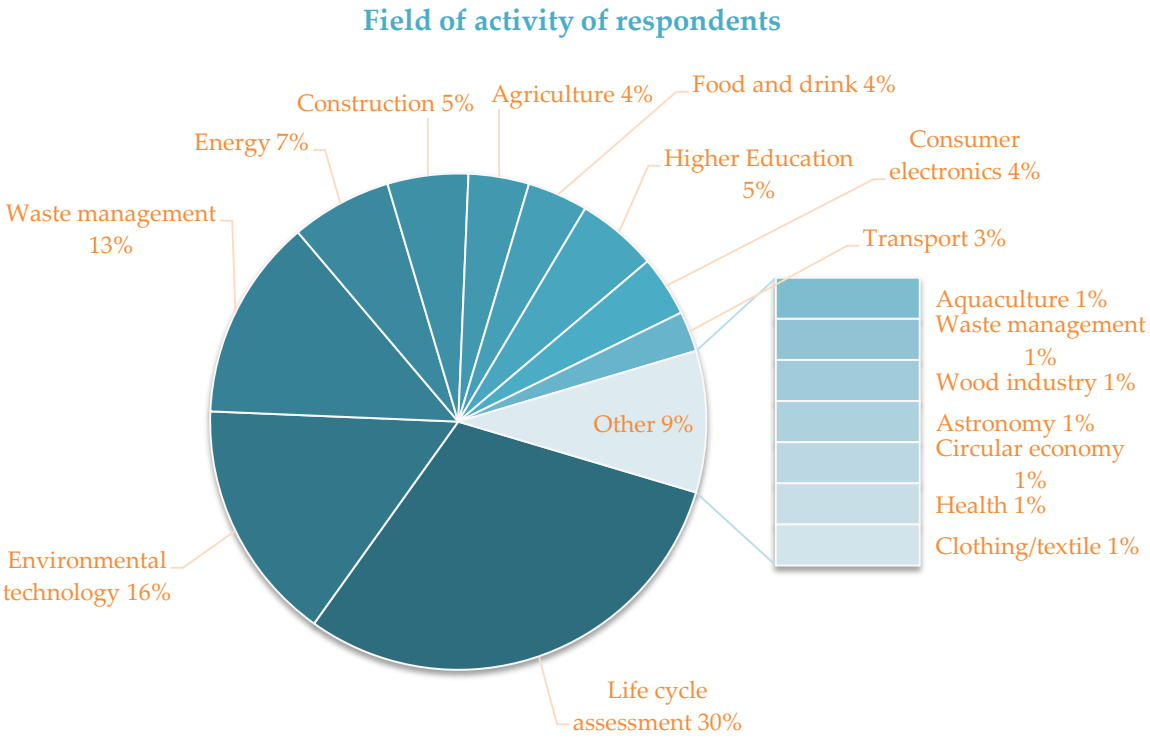

Figure 6 – Distribution of the field of activity of respondents

3.2 Main outcomes

Effectiveness and adequacy of the methodology

The explanation and guidance given in the draft methodology for MD1 differentiating waste and by-product(s) and MD2 defining which waste should be accounted for in product waste footprint studies were evaluated for respondents as *satisfactorily effective*. There was also a clear indication that what was proposed for MD3 communication of the environmental pressure from a waste generation perspective was *insufficient adequate*. Thus, for MD1 and MD2, the final text of the proposed methodology was kept as the draft text and for MD3 marginally changed. See explanation in chapter *3.3 List of changes*.

Figure 7 shows the detailed percentages of the evaluation of these three specific points of the draft methodology.

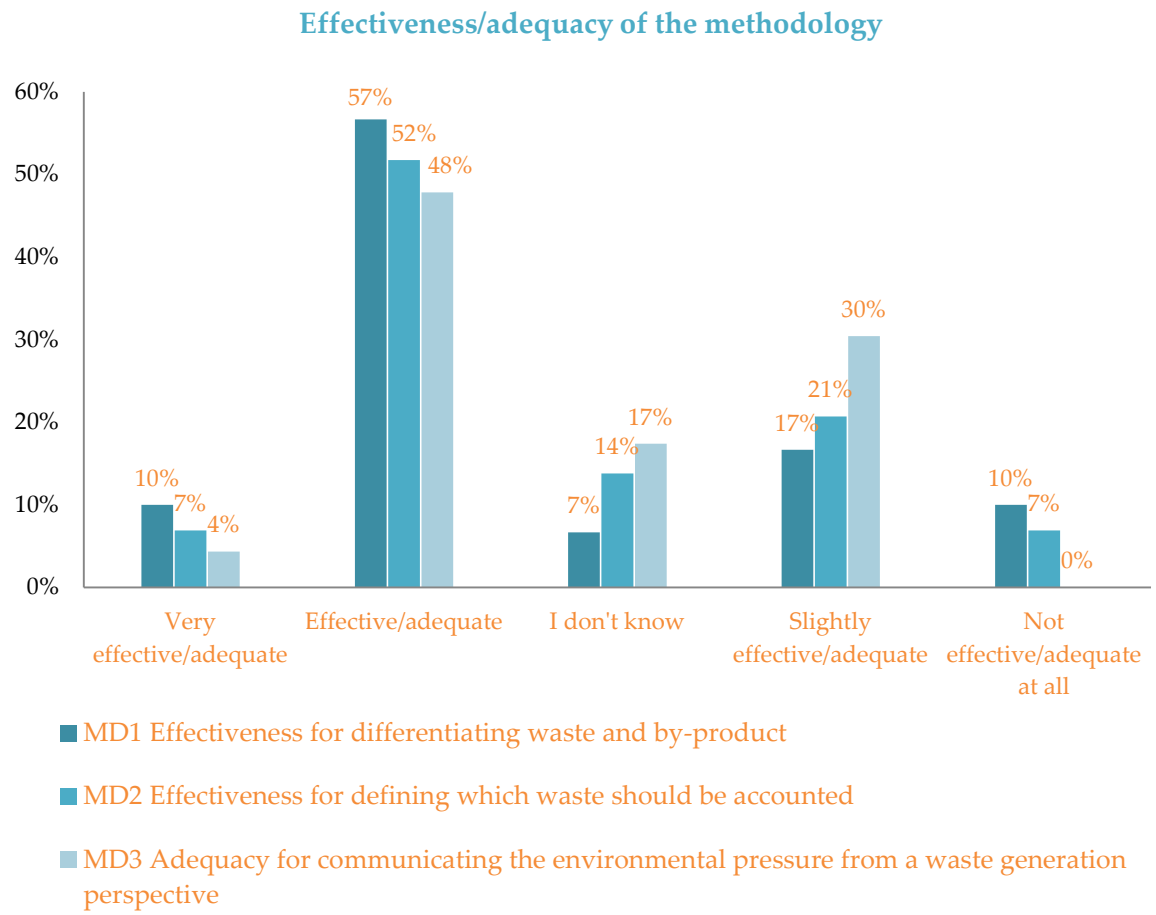

Figure 7 – Responses regarding: effectiveness of the methodology for differentiating waste and by-product; effectiveness of the methodology for defining which waste should be accounted for in product waste footprint calculations; adequacy of the indicators proposed for communicating the environmental pressure of the analysed product from a waste generation perspective.

Usefulness and purpose of the metric

Regarding the usefulness or need of the PWF for stakeholder groups (MD4), responses pointed out that such product waste footprint metric would be predominantly useful/needed for (1) consumers and (4) government, and less useful/needed for (2) industry and (3) university/research institution. 64% of the respondents recorded that the metric would be very useful/needed (21%) or useful/needed (43%) for consumers; 82% responded that the metric would be very useful/needed (37%) or useful (19%) for governments; 33% indicated that the metric would be slightly useful/needed (26%) or not useful/needed at all (7%) for industry; and 32% opined that the metric would be slightly useful/needed (14%) or not useful/needed at all (18%) for university/research institution. Figure 8 shows the detailed percentages.

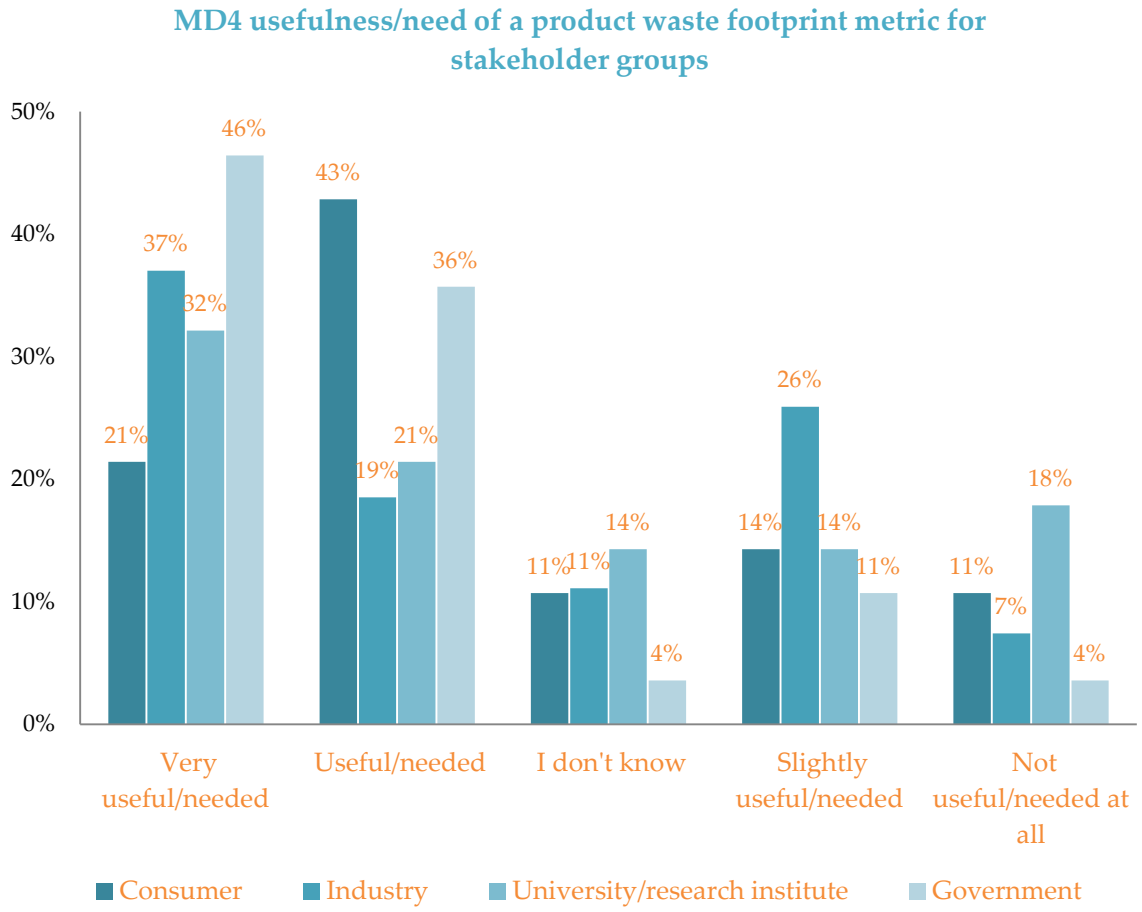

Figure 8 – Responses regarding how useful/needed a product waste footprint metric is for different stakeholder groups (consumer; industry; university/research institute; government)

Concerning purpose of the PWF for different contexts (MD5), respondents specified that a waste footprint metric for products would be mainly useful/needed in contexts of (a) improving environmental awareness of consumers, (b) environmental policy making, (c) visualising waste flows in a circular economy and (d) improving resource efficiency in industry; and doubtfully useful/needed in a (e) business-to-business context. Detailed percentages are show in Figure 9.

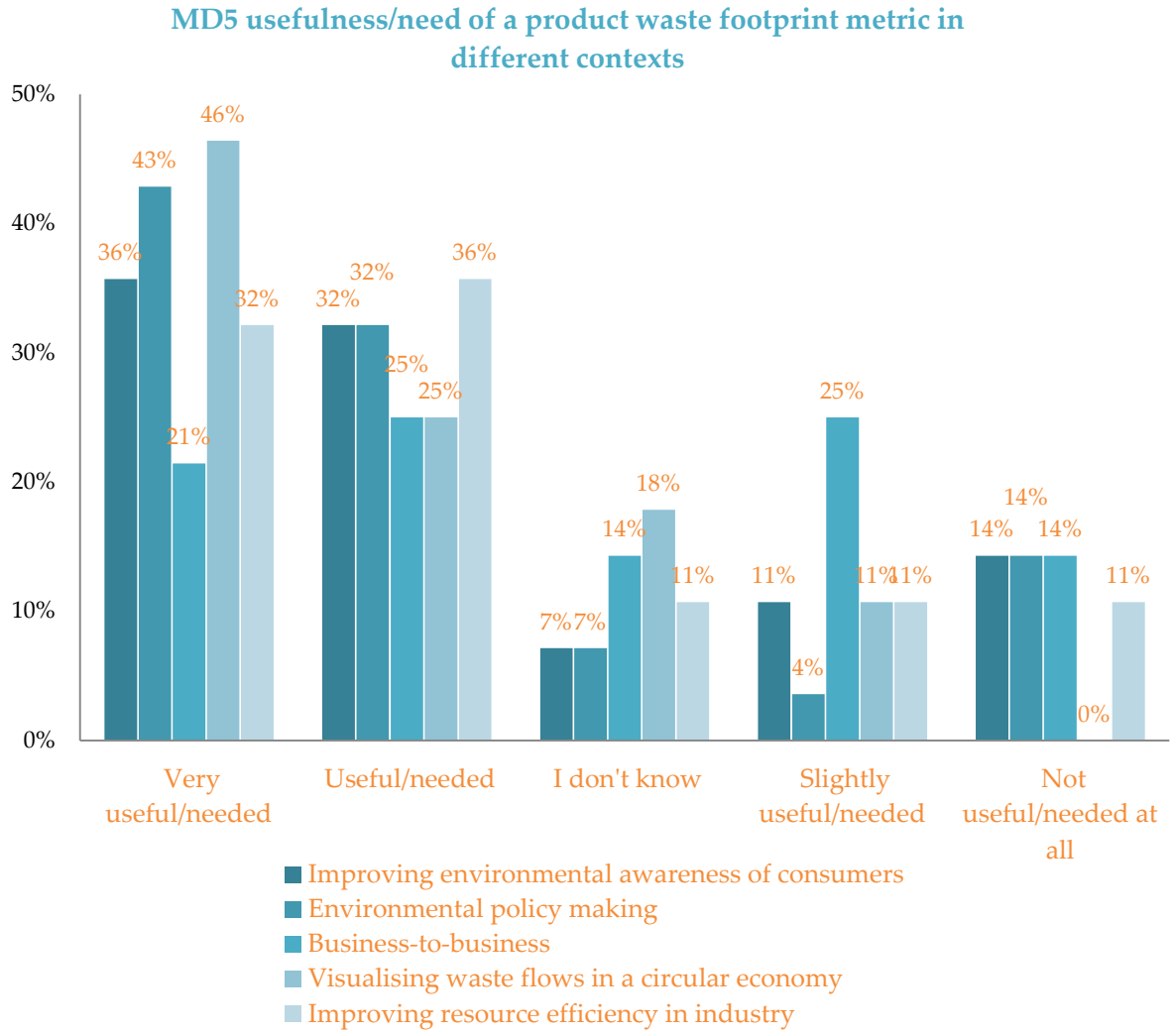

Figure 9 – Distribution of responses regarding how useful/needed a product waste footprint metric would be in the different contexts (improving environmental awareness of consumers; environmental policy making; business-to-business; visualising waste flows in a circular economy; Improving resource efficiency in industry)

3.3 List of changes

The three specific points of the draft methodology (MD1 effectiveness for differentiating waste and by-product; MD2 effectiveness for defining which waste should be accounted for in product waste footprint studies; MD3 adequacy for communication the environmental pressure from a waste generation perspective) were amended.

Although MD1 and MD2 were highlighted as efficient in the closed questions, the draft guidelines were determined to be too complex in the open comments and revision. Therefore, these guidelines were simplified. The draft version can be seen in *Annexe 1 – Online questionnaire* and the amended version in chapter *4.2.2.1 Identifying sources and quantities of waste*.

Regarding the point 2, respondents objected to a classification of low/high risk to environment and human health. Some argued that this risk classification is not understandable, it could leave too much space for subjectivity thus misleading results, and the classification was too simplistic and

hard to define. Others argued that what matters is the environmental impact and that a proper environmental impact assessment needs to be done.

The qualitative classification according to the environmental significance of waste types was therefore removed from the methodology. The proposal of categorizing waste according to subsequent use (recycling, incineration, composting, backfilling, landfilling) was kept however.

As the result of a iterative process, the methodological choices adopted to specify which material flows leaving the product system to be analysed shall be accounted for in the PWF calculation were based on:

- the waste framework directive of the European Commission[4],
- the interpretative communication on waste and by-products of the European Commission[5]
- inputs collected from LCA and waste management experts during the open consultation

4. Methodological approach for product waste footprint studies

4.1 Introduction

This chapter introduces the methodological framework for the quantification and communication of the waste footprint of products. The quantification and communication refer to a life cycle inventory of the waste flows generated upstream from the point of consumption, composed of a set of recommendations and guidelines presented in phases.

It is primarily aimed at technical experts (e.g. engineers, environmental managers, life cycle assessment practitioners) who need to investigate the waste profile of a product. Some expertise in environmental assessment methods may be desirable in order to use this methodological approach to develop a PWF study.

The potential applications of the PWF studies may depend on in-house or external objectives. However, this methodological framework may offer benefits to industrial organizations through assisting in visualising waste flows in extended supply-chains for improved resource efficiency, and potentially in identifying points at which legal definitions of waste are applied.

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[4] The European Parliament the Council of the European Union (2008) Directive [2008/98/EC] of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. In: Official Journal of the European Union.

[5] COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT on the Interpretative Communication on waste and by-products. Brussels, 21.2.2007. COM(2007) 59 final.

In decision-making contexts and for final consumers, it is highly recommended that the results of a PWF study are communicated together with a set of other footprints (e.g. carbon, water, energy) in order to avoid misleading decisions. Furthermore, environmental impacts primarily due to emissions of toxic substances are poorly represented by a PWF indicator.

THE PWF IS ESSENTIALLY A MEASURE OF RESOURCE USE AND NOT OF EVENTUAL ENVIRONMENTAL DAMAGE!

4.1.1 Terminology: shall, should and may

- The term "shall" is used to indicate what is required for a PWF study
- The term "should" is used to indicate a recommendation rather than a requirement
- The term "may" is used to indicate an option that is permissible

4.2 Phases of a PWF

A PWF study is based in three of the four phases of LCA; i.e. goal and scope definition, life cycle inventory and interpretation. These phases comprise of several steps which are described in this section. A logic-structure of PWF is presented in Figure 10. A logic structure is a structured breakdown of a method or task into different parts or conditions required to fulfil a task.

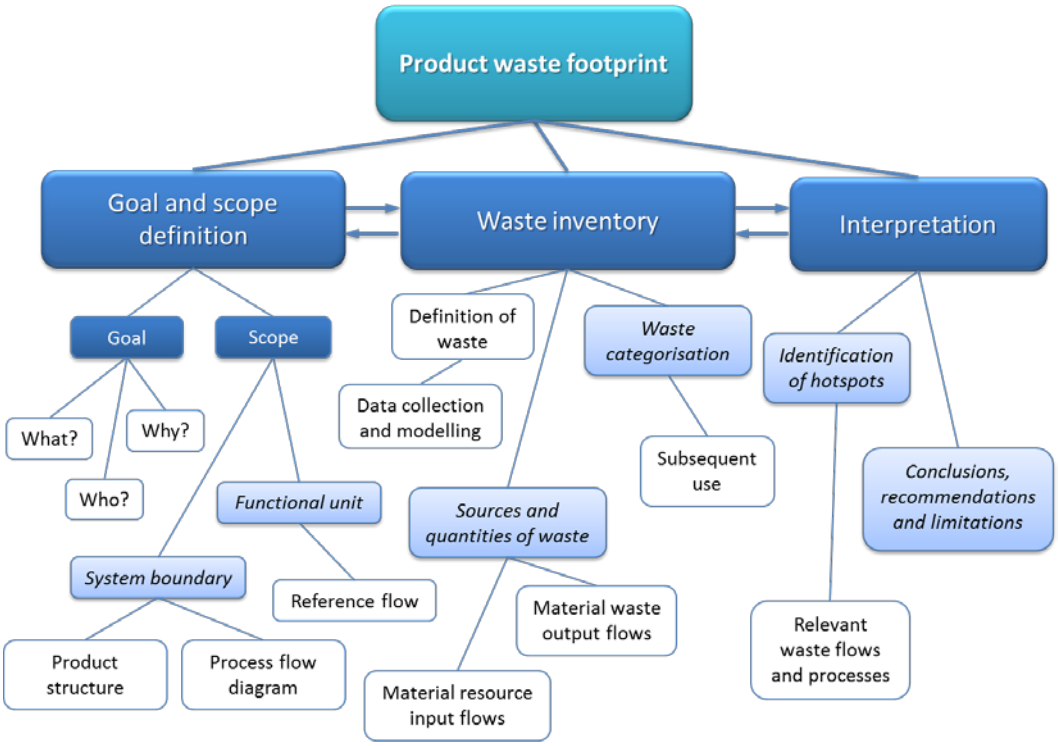

Figure 10 – Logic structure of the PWF.

4.2.1 Goal and scope definition

Goal and scope definition is the first step of a PWF study, and sets the overall context for the study. The purpose of clearly defining goals and scope is to ensure that the analytical aims, data used, results, intended applications and target audience are optimally aligned. This should be reflected in the defined study limitations (scope).

4.2.1.1 Goal

In defining the goal of a PWF study, it shall be stated:

- the intended application
- the reasons for carrying out the study
- the intended audience, i.e. to whom the results of the study are intended to be communicated

4.2.1.2 Scope

The breadth, depth and detail of the study of the study should be defined to ensure that the scope is compatible and sufficient to address the stated goal.

In defining the scope of the PWF, the following items shall be considered:

i) functional unit

ii) system boundary

Functional unit

The functional unit of the product and the reference flow shall be clearly defined. The functional unit qualitatively and quantitatively describes the function(s) and lifespan of the product (what, how much, how well, how long). The reference flow is the amount of product needed in order to provide the defined function. All other input (material, energy and water resources) and output flows (waste and emissions) in the analysis quantitatively relate to it. The reference flow can be expressed in direct relation to the functional unit or in a more product-oriented way.

System boundary

The system boundary shall be the basis used to determine which unit processes are included or excluded from the study, in other words, it specifies which parts of the product life cycle and which associated processes belong to the analysed system (i.e. are required for carrying out its function as defined by the unit of analysis). The unit processes comprising the product system shall be grouped into life cycle stages, e.g. raw material extraction, benefication and production.

A process flow diagram showing the reference flow, main life cycle stages and interrelationships in the product system shall be elaborated. A system boundary diagram can be a useful tool in defining the system boundary and organising subsequent data collection activities.

4.2.2 Waste inventory

In the life cycle waste inventory phase, the material resource use and waste profile of the product system under analysis is created. However, **material flows are not modelled until they are transformed in elementary flows (and hence connected to environmental impact categories) like in strict LCA practice**.

An inventory of (1) all material resource input flows to the product system and (2) all material waste output flows from the product system shall be compiled. For material inputs (i.e. point (1)), the analysis begins with an initial selection of inputs to be studied. This selection should be based on an identification of the inputs associated with each of the unit processes to be modelled. All material entering the product system being studied that has been drawn from the environment without previous human transformation (elementary flows entering in the system) are the material resource inputs. For waste output flows (i.e. the aforementioned point (2)).

The goal here is to *identify* sources and quantities and *categorising* types of waste materials generated along production chains.

4.2.2.1 Identifying sources and quantities of waste

The following hierarchy shall be used for identifying whether a material stream is considered waste in a PWF

- Are there any outputs beside the product that have a market value for them?
  - No: Material is a waste
  - Yes: material is a product or by-product

- Are there any outputs beside the product considered waste by the relevant competent legal authorities?
  - No: material is a by-product
  - Yes: Material is a waste

The identified waste streams are then assigned to the source (i.e. life cycle stage) in which they occur (i.e. extraction of raw material, processing and production)[6].

Ideally, this effort may be undertaken with data collected from specific sites; i.e. the model of the product supply chain would be constructed using facility- or product-specific data, modelling the exact life cycle depicting the supply chain. In practice, directly collected, facility-specific inventory data should be used wherever possible. For processes where the practitioner does not have direct access to specific data, generic data (from scientific papers, reports, life-cycle-inventory databases, etc.) can be used.

If the practitioner has access to waste generated from fuel and energy used, these may also be included in the inventory analysis.

4.2.2.2 Categorising waste

The amount of the accounted waste shall be categorised according to *subsequent use* as:

- Waste to recycling
- Waste to incineration
- Waste to landfill/deposit/backfilling
- Waste to biological treatment[7]

There are 2 systems levels for recycling. First is post-production waste recycled back into the production process (e.g. offcuts of glass back into re-melt) and the second is external recycling outside of the factory gate (e.g. rejected single-use packaging). The former would be a process not designated legally as waste (but still clearly a waste through an inefficient process) and the second would be the same as the first but also legally a waste as it leaves the factory gate.

[6] The raw material acquisition and pre-processing stage starts when resources are extracted from nature or synthesised from existing stock and ends when the product components enter the product's production facility. The production stage begins when the product components enter the production site and ends when the finished product leaves the production facility.
[7] E.g. composting, anaerobic digestion.

Figure 12 illustrates a product system and input/output material flows related to this product system. The figure also shows which types of material flows that shall be accounted for as a waste and how they shall be categorised (waste to recycling, incineration, deposit/landfill/backfilling, biological treatment). What happens with the waste material further in the subsequent product systems is outside the scope of the PWF under analysis.

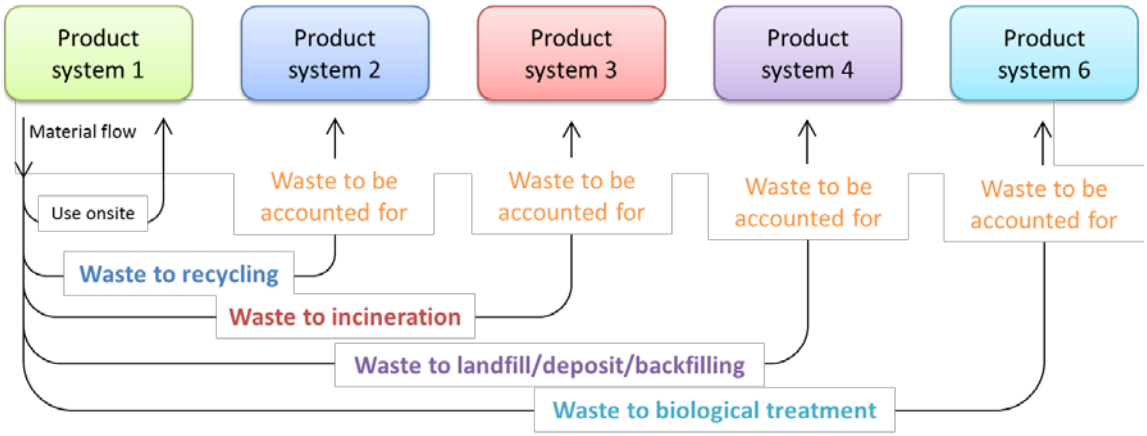

Figure 11 – Ilustration of a possible waste treatments options for categorising accounted wastes in the PWF.

4.2.3 Interpretation

The interpretation phase of the PWF study should evolve in an iterative way, until the study goals are met. The aims of the interpretation phase are twofold:

1. to ensure that the performance of the PWF model corresponds to the goals of the study
2. to derive robust information from the analysis, certifying that the results of the PWF quantification are not communicated in a misleading way

In order to meet these dual aims, the interpretation phase shall include the steps: identification of hotspots; estimation of uncertainty; and conclusions, limitations and recommendations.

4.2.3.1 Identification of hotspots

What would be useful is to show what wastes occur where in the process in order to identify hotspots. Thus a *screening analysis* is required when performing a PWF study. It leads to the identification of the most relevant processes and waste flows. It should lead to the **identification of the most relevant processes and waste flows along the life cycle production chain of products**. The most relevant waste flows are identified based on *how large (amount)* they are.

Once the most relevant waste flows have been identified they shall be linked to the *processes* emitting them. This is not a serial step but a parallel one as each process will need to be interrogated to determine the wastes in the first place. In this way the most relevant processes are identified; thus the most relevant processes are those at which the most relevant waste *flows* occur.

Identifying the *most relevant processes and waste flows* are relevant in the context of the communication of the PWF study. For communication purposes, at least the 3 most relevant waste flows and where and why they occur shall be declared.

4.2.3.2 Conclusions, Recommendations and Limitations

The final aspect of the PWF interpretation phase is to draw conclusions based on the analytical results, answer the questions posed up front in the study, and advance recommendations appropriate to the intended audience. As previously stated, the PWF needs to be seen as complementary to other product environmental assessments such as carbon footprint, water footprint, energy footprint and ecological footprint. One primary limitation of the PWF is that it only focusses on post production waste and not on whole product lifecycle waste (use and disposal) – this needs explaining in setting the PWF in context with other footprints which include use phases.

Conclusions, recommendations and limitations shall be described in accordance with the defined goals and scope of the PWF study. The conclusions should include a summary of the most significant wastes identified in the supply chain and the potential improvements associated with management interventions.

4.2.4 Reporting and communication

A PWF report should provide a relevant, comprehensive, consistent, accurate, and transparent account of the study and of the calculated PWF. It should reflect the best possible information in such a way as to maximise its usefulness to intended current and future users, whilst transparently communicating limitations. It shall present a summary of the:

- main points defined in the goal and scope (study goals, functional unit, reference flow, main assumptions and data used)
- most significant waste flows
- most relevant processes
- conclusions, recommendations and limitations

5. Discussion

5.1 Risks and weaknesses

From a life cycle thinking practice perspective, there are many problematic aspects related to the PWF methodology and its use. During the open consultation some LCA experts roundly condemned the PWF metric. Here is a list of criticism collected during personal communication and social media (LinkedIn groups):

- There is a risk of it becoming a marketing tool for greenwash – companies with low volume toxic wastes say scoring marketing points over companies with large volumes of totally benign waste. A similar problem is observed on the metric of food miles, where low food miles from an overland transporter (with high relative production impact) being compared often misleadingly with large food miles by ship (with a tiny relative production impact)
- From an impact assessment perspective, it is the impacts resulting from the net flows of waste after all reuse/recycling/incineration that matter. For instance, in LCA concerned with buildings and infrastructure, wastes and their disposal are nearly always tiny issues relative to all the implications of energy use, even though the physical quantities may be huge. This is because the wastes are benign and energy is the highest hotspot.
- In sectors where the wastes have a large impact, it is due to their toxicity not their quantity and it is the product of mass x quantity and the receiving environment that then is of concern.
- Waste by itself does not have any environmental impacts, emissions and other environmental exchanges do. So it is not how much waste is generated, but what happens with it. A small quantity of toxic wastes is far more environmentally damaging than a large mass of inert waste. Hence a "waste footprint" seems to be a step backwards rather than forward in the environmental assessment of products. A lot of waste mass can be avoided staying away from products that have a lot of mining in their value chain to avoid high quantities of tailings, but is that really what consumers should worry about?

From a strict LCA perspective, the concerns of LCA experts are understandable. However, looking at the PWF with such strict lens one may miss the point and disregard many opportunities that the metric could bring about. For example, it is often overlooked by LCA experts what type of product-environmental-related information and at which level of aggregation can contribute to orienting consumers' behaviour towards more environmentally friendly consumption practices. The PWF concept may be enough to make most of the ordinary consumer at least aware of the link between consumption and waste generation.

Some of the opportunities for the PWF are discussed below.

5.2 Opportunities

Increasing environmental awareness of consumers

Other LCA experts expressed, less harshly, words of caution and also recognised the need for translating complex environmental information into something simple enough that consumers can understand, relate and be sensible to. The challenge of any endeavour in this direction seems to lie on how to provide such simplified metric that delivers meaningful outcomes (not misleading) for consumers.

Visualising waste flows in a circular economy

A significant number of LCA experts recognised that the exercise identifying waste flows in extended supply chains are particularly important in the context of a circular economy where waste types and quantities need to be visualised and progress measured. Accordingly, in the context of the circular economy, identifying point-sources and quantities of waste and categorising them according to their subsequent use may be as important as assessing their potential environmental impact.

Expanding the scope

In life cycle terms limiting the scope of the PWF concept at the production stage (post-production waste) and not including disposal (consumption) may skew the results. For instance, highly efficient production process can create a product that is 100% non-recyclable which can claim a low to zero waste footprint, but in reality is not circular; which may be implied from a zero waste footprint.

Therefore, as with carbon emissions, it is important to address whether there is a need or potential to create Scope I (production), II (production & use), III (production, use and disposal) type footprints to minimise confusion and misleading end users etc.?

Addressing the concerns of LCA experts

Further studies could examine if the PWF is a good proxy of life cycle environmental impact categories (e.g. human health, extinction of species) in specific categories of product or manufacturing process. The relationship between PWF results and environmental impacts can be systematically quantified by using LCA databases (e.g. ecoinvent) for quantifying PWFs and environmental impacts associated with a large amount of types of products and manufacturing processes. This knowledge of the relationships between both sets of indicators and categories would clarify the extent to which the PWF may serve as a proxy for damage to humans and the environment, addressing the concerns of the LCA experts.

6. Conclusion

This study developed a methodological framework for the quantification and communication of the waste footprint of a product. The methodological approach comprises of a stepwise approach and a set of guidelines (RO1). Specific points of the methodological approach (MD1-3) and the usefulness (MD4) and purpose (MD5) of a product waste footprint metric were assessed in an online open consultation (RO2).

Most of the respondents of the online survey expressed that the guidelines described in the methodology are effective for MD1differentiating waste and by-product (tacking the subjectivity of waste) and MD2 defining which material flow shall be accounted for as waste in PWF quantifications (RQ1). Part of the respondents found these draft guidelines, which were based the Interpretative Communication on waste and by-products of the European Commission, to be too complex for the exercise of accounting for wastes; hence not sufficiently adequate for the PWF methodology. Furthermore, some responses from prominent LCA experts and practitioners affirmed that qualitatively attributing environment significance to different types of wastes may not be adequate (MD3 and RQ2).

There was a clear indication from the open consultation that a product waste footprint metric would be useful or needed for (MD4) consumers and government; and in contexts of (MD5) improving environmental awareness of consumers, environmental policy making, visualising waste flows in a circular economy and improving resource efficiency in industry, and less useful or needed in a business-to-business context (RQ3).

The results seem to corroborate to and give evidences of a growing demand of the general public (consumers) for simpler indicators, rather than complex LCA results for disclosing product related environmental information. Moreover, some LCA experts were (understandably) reluctant for accepting simplistic attempts to communicate complex environmental information. The reasons for their (reasenable) hesitancy may lie on the rational that (1) simpler metrics inherently carry limitations of some sort; (2) there has been a proliferation of simple environmental metrics that lack scientific stringency; (3) these limitations may leave space for misuse by industry, green washing for consumers, lead to claims of superior products and mislead advice for sustainable conduct/consumption.

Evidently, more attention needs to be given to (1) what the needs of consumers from different income levels are and (2) how consumers may or may not use product related environmental information. In order to meet these consumers' needs whilst delivering environmental information founded on scientific rigour, should the LCA community, especially those involved in method development, devote efforts to address the consumer demand for simple indicators of product related environmental information? How could the LCA community constructively contribute to initiatives that advance the frontier of this field forward?

Consumers have limited means to be sensible about how, why and to what extent their consumption contributes to environmental degradation, due mainly to the temporal and spatial separation of extraction of materials, production and consumption. Accordingly, setting an adequate level of trade-off between complexity and simplicity, when conveying information about environmental impacts occurring distant in time and geographical location from the point of consumption, is a highlighted area needing further consideration.

The PWF approach and the open consultation carried out in this project were attempts to find this fundamental balance. Whether this simple inventory-oriented footprint is a reasonably good proxy for environmental impact assessments is still needed to be verified.

Acknowledgements

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Annexe 1 – Online questionnaire

Email invitation

Do you know how much waste has been produced in order to provide the products you consume?

A methodology for calculating the waste footprint of products are under development at IVL Swedish Environmental Research Institute and we would be grateful if you could spare about 15-20 minutes to answer an online questionnaire for revising three specific points of a methodology. Below you can find the link to the questionnaire, the context of the project and a link to a reference article. Please feel free to forward to potentially interested people in your network and friends too. The questionnaire will be online until 31 May 2017. Thank you very much for your time and input!

Context

In the recent years consumers have become increasingly aware of the impact that their consumption may have on the environment, and resource use and waste generation are major issues. Although most consumers are aware of the amount of waste they generate themselves, relatively few are aware of the total waste generated in the course of producing the goods they consume. In fact, a large part of the total waste generated in our consumer society occurs before products get in the hands of consumers, generated in production processes (extracting resources, transporting, producing fuels and electricity, manufacturing).

In order to address this knowledge gap, in 2015 a waste footprint metric for calculating the total waste generated during the production of a product was proposed and tested in a number of products. The results of this project not only drew quite some attention from the Swedish television and social media but was also severely criticised by some experts in a peer-review process.

In this questionnaire you will revise three specific points in the methodology for addressing main concerns of the expert.

ONLINE QUESTIONNAIRE

Open consultation for revising a methodology for calculating the waste footprint of products in a life cycle perspective

INSTRUCTIONS FOR THE RESPONDENTS

The purpose of the open consultation is to review main points of the methodology. The respondent is requested to express his/her opinion on a graduated scale but can also include open comments.

The questionnaire is not anonymous and it has an introductory part to identify respondents, followed by three sections:

- Subjectivity of waste
- Indicators for presenting the results
- Usefulness of a product waste footprint metric

The questionnaire takes approximately 15-20 to be completed. At the end you can indicate your interest in revising and/or testing in a case the full preliminary version of the methodology.

The results of the survey will and the final version of the methodology will be sent to all respondents.

Thank you very much for your input!

1. General questions

1.1 Full name:

1.2 E-mail for contact:

1.3 Are you replying as general public/consumer or as a professional working in an organisation?

o General public/consumer	o University/research institution	o Industry
o Government	o Association	o NGO

Other interest group:

1.4 What is the field of activity of your organisation?

	o Waste management	o Agriculture
o Environment	o Food and drink	o Transport
o Clothing/textiles	o Footwear	o Construction
o Consumer electronics	o Energy	o Health

Other:

1.5 What is your role/field in your organisation?

o Life cycle assessment (LCA) expert	o Waste management expert	o Sustainability expert

Other:

Please indicate the name of your organisation:

2. Subjectivity of waste

In order to make it clear which material flows should be accounted as waste flows in product waste footprint calculations, (1) the waste framework directive of the European Commission and (2) the interpretative communication on waste and by-products of the European Commission have been incorporated in the methodology. This description is presented in the highlighted text bellow.

Please read the text and then answer the questions that follows.

Beginning of the excerpt from the methodology:

The first question to be asked when determining whether a material is waste or not is did the manufacturer deliberately choose to produce the material in question. If the manufacturer could have produced the primary product without producing the material concerned but chose to do so, then this is evidence that the material concerned is not a production residue. The characteristics of the material in terms of its readiness for further use in the economy can mean that it should not be considered to be a waste.

The following three part test shall be applied in order to determine if a production residue can be considered as waste:

1. *Is the further use of the material a certainty not a mere possibility?* If the further use of the material was not a mere possibility but a certainty, without any further processing prior to reuse and as part of a continuing process of production, then the material would not be a waste. If there is a possibility that the material is in fact not usable, does not meet the technical specifications that would be required for it to be usable, or there is no market for that material, then it should continue to be considered as a waste. Similarly, if the material is going to be stored for an indefinite amount of time, prior to a potential but not certain re-use, then it should be considered as a waste while it is being stored.
2. *Can the material be used again without any further processing?* if an additional recovery process is required before further use, even if such subsequent use is certain, this is evidence that the material is a waste until the process has been completed.
3. *As part of the continuing process of production?* If, however, the material is made ready for a further use as an integral part of the continuing process of production, and is then effectively sent for such a further use, then it is a by-product.

The following decision tree can be used for identifying which waste shall be accounted for in product waste footprint calculations:

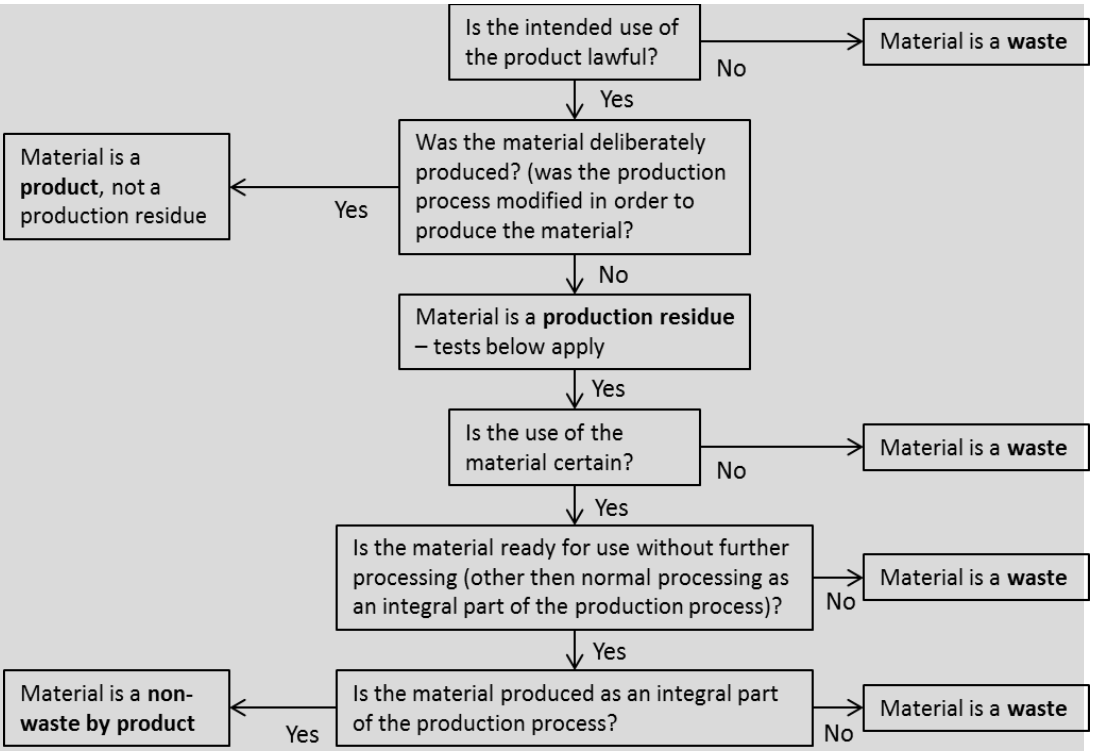

Figure – Decision tree for waste versus by-product decisions.

Other factors that distinguish waste and by-product:

- No other use than disposal can be envisaged, or the use has a high environmental impact or requires special protection measures
- The treatment method for the material in question is a standard waste treatment method
- The undertaking perceives the material as waste
- The undertaking seeks to limit the quantity of material produced
- Outputs of the system used for energy production processes (waste to energy processes) shall never be considered by-products.

End of the excerpt from the methodology.

Please indicate your opinion on the effectiveness[8] of what this part of the methodology for:

2a. differentiating waste and by-product.

o Very effective	o Effective	o I don't know	o Slightly effective	o Not effective at all

Comments:

[8] the ability to produce the intended results.

2b. defining which waste should be accounted for in product waste footprint calculations.

o Very effective	o Effective	o I don't know	o Slightly effective	o Not effective at all

Comments:

3. Indicators for communicating the results

Please read the excerpt from the methodology below on the indicators for communicating the results of product waste footprint calculations and then answer the question that follows.

Beginning of the excerpt from the methodology:

Accounted waste (material that cannot be used again without further processing) shall be categorised according to *subsequent use* and *human health and environmental risk* in the product waste footprint metric.

According to *subsequent use*, waste types should be declared as:

1. Waste to recycling
2. Waste to incineration
3. Waste to landfill/deposit

For each of these categories, the amount of waste shall be qualitatively classified as:

a. Low risk to human health and the environment (kg)

b. High risk to human health and the environment (kg)

Ranking the environmental significance should taking into account a long term perspective (e.g. nuclear wastes present high risk to human health and the environment taking into account a long time perspective). Examples of waste types that represent low risk to human health and the environment are inert waste and organic waste. Examples of waste types that represent high risk to human health and the environment are toxic wastes and hazardous wastes.

Figure 5 illustrates a product system and input/output material flows related to this product system. The figure also shows which types of material flows that shall be accounted for as a waste and how they shall be categorised (waste to recycling, incineration, deposit/landfill; low/high risk to human health and the environment).

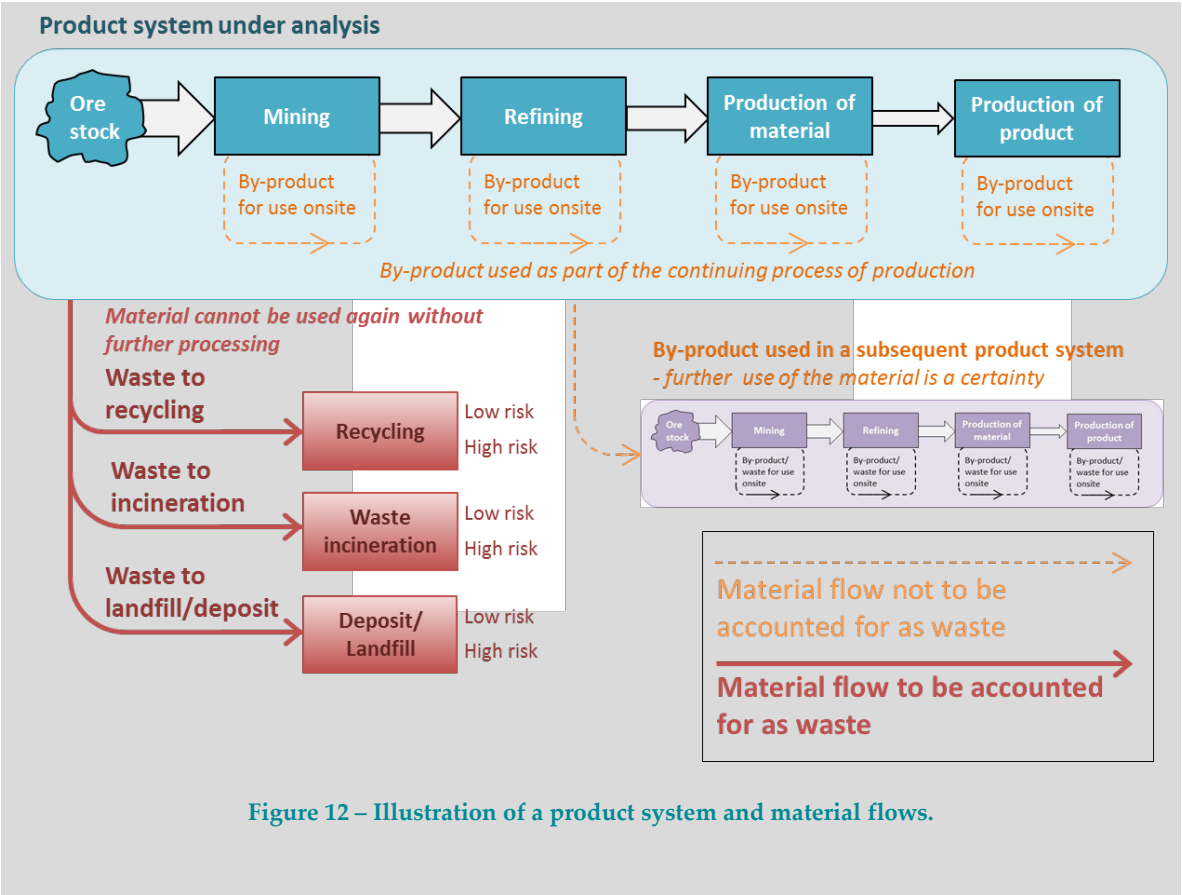

Figure 12 – Illustration of a product system and material flows.

End of the excerpt from the methodology.

Please indicate your opinion on the adequacy[9] of the indicators proposed for communicating the environmental pressure of the analysed product from a waste generation perspective.

o Very effective	o Effective	o I don't know	o Slightly effective	o Not effective at all

Comments:

4. Usefulness of a product waste footprint metric

4.1 Please indicate your opinion how useful/needed these metrics would be for the following stakeholder groups:

Consumer

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

[9] the quality of being good enough for a particular purpose.

Industry

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

University/research institute

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

Government

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

Other:

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

4.2 Please indicate your opinion on how useful/needed these metrics would be in the following contexts:

Improving environmental awareness of consumers

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

Environmental policy making

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

Business-to-business

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

Visualising waste flows in a circular economy

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

Improving resource efficiency in industry

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

Other:

o Very useful/needed	o Useful/needed	o I don't know	o Slightly useful/needed	o Not useful/needed at all

Comments:

5. Further participation

Would you be interested in voluntarily reviewing and providing additional comments on the full document proposal (preliminary version) of the methodology? It would take about 4 hours work.

o Yes	o No

Comments:

Would you be interested in providing data for testing in a case the preliminary version of the methodology?

o Yes	o No

Comments:

Annexe 2 – Answers and written comments from respondents

This annexe discloses answers and written comments of the respondents of the online survey (see Table 1). The box bellow presents a coding system for reading Table 1.

Subjectivity of waste

Respondent's opinion on the effectiveness of what this part of the methodology for:

MD1differentiating waste and by-product

MD2 defining which waste should be accounted for in product waste footprint calculations.

Indicators for communicating results

MD3 respondent's opinion on the adequacy of the indicators proposed for communicating the environmental pressure of the analysed product from a waste generation perspective.

Usefulness of a product waste footprint metric

MD4 Respondent's opinion how useful/needed these metrics would be for stakeholder groups:

MD4a Consumer

MD4b Industry

MD4c University/research institute

MD4d Government

MD5 Respondent's opinion on how useful/needed these metrics would be in the contexts:

MD5a Improving environmental awareness of consumers

MD5b Environmental policy making

MD5c Business-to-business

MD5d Visualising waste flows in a circular economy

MD5e Improving resource efficiency in industry

Table 1 – Area of expertise, responses and comments of respondents. Only responses recorded with at least one comment are listed here. The names of the respective organisation are omitted for confidentiality reasons.

Life cycle assessment (LCA) expert MD1. Slightly effective *While I think the text provided is accurate, I doubt very much that you can use the tests in the flowchart to determine whether something is a waste. For example, whether there are any legal uses does not define something as a waste. I think you need to narrow the scope to a specific production process to give the reviewer more information about what materials this could be useful for.* MD2. Slightly effective
Sustainability expert MD1. Effective *Co-production is a grey area and depends on geographic as well as temporal factors. The nature of a by-product may change from a waste to a valued co-product regularly depending on market demand. Logistics in collection and utilisation are also important factors, especially for highly perishable agricultural by-products in rural locations.* MD2. Effective *See above.* MD3. Adequate *This seems adequate for industrial wastes. I would have questions if applied to agricultural or food "waste".* MD4a Useful/needed MD4b Slightly useful/needed MD4c Slightly useful/needed MD4d Useful/needed *This is about making something very complex into something accessible for the consumer and decision makers. Industry would probably have other views on the drivers behind it and academia may have reservations about the methodology in something that is not "one size fits all"* MD5a Useful/needed MD5b Useful/needed

MD5c Slightly useful/needed

MD5d Slightly useful/needed

MD5e Slightly useful/needed

Life cycle assessment (LCA) and Waste management expert

MD1. Effective

I find this bit "If the manufacturer could have produced the primary product without producing the material concerned but chose to do so, then this is evidence that the material concerned is not a production residue. "problematic. In many cases in the industry, manufacturers chose to produce more waste by selecting a cheaper manufacturing process (that produces more waste). I think the economic element should somehow be involved here (zero or negative economic value is indication of waste).

MD2. Effective

MD3. Slightly adequate

How can one define in absolute terms the low/high risk to human health and the environment?

MD4a Slightly useful/needed

MD4b Very useful/needed

MD4c Useful/needed

MD4d Very useful/needed

MD5a Not useful/needed at all

MD5b Useful/needed

MD5c Very useful/needed

MD5d Very useful/needed

MD5e Useful/needed

Life cycle assessment (LCA) expert

MD1. I don't know Slightly effective

This sounds as if there is a supervisor that understands a complete system and the intentions. In practice different actors base their actions on market forces. So if you ask if the use is certain, this depends on prices and nothing else.

MD2. Slightly effective

MD3. Not adequate at all

I do not understand what is high or low risk; as long as this is not clear, it does not mean anything.

MD4a I don't know

MD4b I don't know¨

MD4c I don't know

MD4d Useful/needed

The government as it can develop policies; for others it is not so meaningful unless it is the waste they create themselves.

MD5a Not useful/needed at all

MD5b Useful/needed

MD5c Slightly useful/needed

MD5d Very useful/needed

MD5e Useful/needed

Life cycle assessment (LCA) and Systems modelling expert

MD1. Effective

If I think deeper I can make distinguish. I agree with your definition. But it is not direct what you mean. It would be good to provide an example to visualize what you are trying to say, especially #2 and #3.

MD2. Effective

Sorry I did not understand the question completely.

MD3. Adequate

The figure can be explained in detailed.

MD4a Very useful/needed

MD4b Very useful/needed

MD4c Useful/needed

MD4d Very useful/needed

We need it!

MD5a Very useful/needed

MD5b Very useful/needed

MD5c Useful/needed

MD5d Very useful/neededMD5e Very useful/needed

Life cycle assessment (LCA) expert

2a. Effective

Do you mean "is the intended use of the material lawful" in the first box? What do you mean by "undertaker"? It is unclear what you mean by "ready for use" and "without further processing". For example, does the rinsing of glass bottles to be reused count as "further processing", meaning that post-consumer glass bottles should be seen as waste? I don't understand the part about continuing/integral production?

2b. I don't know

I am not sure I see the use of such a waste/no-waste exercise

3. I don't know

I understand the categorization into recycling/incineration/landfilling, in accordance with the waste hierarchy, although. Note that it is sometimes worse for the environment to recycle than to incinerate, but for consumer communication, this is probably a complexity that can be sacrificed. My main concern is the classification of materials to "low risk" and "high risk". Obviously, there is a spectrum of risk and this can be unique to each environmental problem/impact category. I therefore suggest that you provide additional information to interested consumers, e.g. in the form of a website, where the classification of each material is justified.

MD4a Useful/needed

MD4b Slightly useful/needed

MD4c Slightly useful/needed

MD4d Slightly useful/needed

I think the main use is to the consumer, for whom it may be difficult to understand results of more complex assessments (such as LCA).

MD5a Useful/needed

MD5b Not useful/needed at all

MD5c Slightly useful/needed

MD5d I don't know

MD5e I don't know

Expert on waste modelling

MD1. Slightly effective

The three rules are internally consistent, but the following "Other factors that distinguish waste and by-product" are inconsistent with the three rules. Why is it relevant to distinguish waste from by-products at all?

MD2. I don't know

It is not clear to me at this point why a waste footprint is relevant.

MD3. Not adequate at all

What matters is the environmental impact, which can be quantified on a continuous scale. A classification is a very rough and error-prone method.

MD4a Not useful/needed at all

MD4b Not useful/needed at all

MD4 Not useful/needed at all

Not useful/needed at all

You have not put forward any arguments for the relevance of the footprint.

MD5a Not useful/needed at all

MD5b Not useful/needed at all

MD5c Not useful/needed at all

MD5d Very useful/needed

MD5e Not useful/needed at all

Ah, so we identified here an application: Visualisation of waste flows (when waste is defined as you have done). But still, the societal relevance of this is absent.

Life cycle assessment (LCA) expert

MD1. Effective *I think it is an interesting way to avoid the revenue criterion to define waste and by-product. It has the advantage AND the problem of being a common definition, independent of local market conditions.* MD2. Effective *Warning: "ready for use without further processing" is not clear. It is defined by the recycling company which will decide what is correct to take and what is not. Are soiled PET scraps acceptable? they will require shredding and washing before use, but this is normal for PET, so could it be considered as a by-product?* MD3. Slightly adequate This categorization is a bit too simplistic in my view. It might be relevant for public, but still, I am not really convinced by the interest/purpose of this classification if not followed by proper assessment. MD4a Useful/needed MD4b Useful/needed MD4c I don't know MD4d Useful/needed MD5a Very useful/needed MD5b Very useful/needed MD5c Useful/needed MD5d Very useful/needed MD5e Useful/needed
General public/consumer Effective Not sure who audience is but seems to make sense. Effective I think for laypeople like me, examples would help. Adequate I think some visual size differentiation would help if this is looking at only one material. What's mined is refined and in each stage, it gets smaller as impurities are removed or whatever else happens. This might help communicate how concrete waste is. Very useful/needed Very useful/needed Very useful/needed Very useful/needed I think it would need to be particularly well-presented for consumers, to help people start to think beyond the item that they see and into its history and future. But I think that's particularly valuable/necessary even with additional regulations to help alleviate the sense of loss and fear of change that can come with changing consumer behaviors. Very useful/needed Very useful/needed Very useful/needed Very useful/needed Very

useful/needed	I don't know what similar tools exist in professional spheres.

General public/consumer

MD1. Effective

Not sure who audience is but seems to make sense.

MD2. Effective

I think for laypeople like me, examples would help.

MD3. Adequate

I think some visual size differentiation would help if this is looking at only one material. What's mined is refined and in each stage, it gets smaller as impurities are removed or whatever else happens. This might help communicate how concrete waste is.

MD4a Very useful/needed

MD4b Very useful/needed

MD4c Very useful/needed

MD4d Very useful/needed

I think it would need to be particularly well-presented for consumers, to help people start to think beyond the item that they see and into its history and future. But I think that's particularly valuable/necessary even with additional regulations to help alleviate the sense of loss and fear of change that can come with changing consumer behaviors.

MD5a Very useful/needed

MD5b Very useful/needed

MD5c Very useful/needed

MD5d Very useful/needed

MD5e Very useful/needed

I don't know what similar tools exist in professional spheres.

Life cycle assessment (LCA) expert

MD1. Effective

MD2. Effective

MD3. Adequate

MD4a Useful/needed

MD4b Very useful/needed

MD4c Useful/needed

MD4d Very useful/needed

MD5a Very useful/needed

MD5b Very useful/needed

MD5c Very useful/needed

MD5d Very useful/needed

MD5e Very useful/needed

Waste management expert

MD1. Effective

The method is clear and effective but for some cases it can be very limiting compared to use of virgin natural resources as raw materials though the environmental and health impacts are not much different.

MD2. Effective

MD3 Slightly adequate

Selection between low and high risk will be difficult and there will be different opinions of that. The selection will leave space for subjective decision making and manipulation of results. Different environmental impact categories have to be taken into account. Risk level is also dependent on the volumes of waste, not only properties of waste. Recycling is also a bit limited term because material recovery can be also e.g. use of compost which is not easily included to actual recycling. So should there be different categories for e.g. recycling for new manufacturing and other material recovery. Also it is important to make it clear if selection of waste treatment option (recycling, incineration, landfill) is done on the basis of primary treatment or final destination of the materials. There can be significant residue flows from material recovery and waste-to-energy processes.

MD4a Useful/needed

MD4b Slightly useful/needed

MD4c Slightly useful/needed

MD4d Useful/needed

MD5a Useful/needed MD5b Useful/needed MD5c Slightly useful/needed MD5d Useful/needed MD5e Slightly useful/needed
Life cycle assessment (LCA) expert MD1. Slightly effective I think it should have a difference between a material that will be reaused (and this is certain) and a material that will not be reuse. A material reuse allow a reduction of the use aof primary material. MD2. Effective MD3. Very adequate MD4a Useful/needed MD4b Useful/needed MD4c Slightly useful/needed MD4d Useful/needed It depends how waste are take into account MD5a Very useful/needed MD5b Useful/needed MD5c Slightly useful/needed MD5d Useful/needed MD5e Useful/needed
Stakeholder working on behalf of Governments MD1. Not effective at all *I think the method has to take account fully of the legal definition of waste and work from there. It would create a method at odds with reality if not.*

MD2. Not effective at all

As above - the statements allow for materials that are legally considered waste to be discounted from the method.

MD3. Slightly adequate

Illustration is a singular but not a generic system. Waste is created at all stages and consumption is not included (Its and LCA?) Not all processes are mining related so need to ensure it is relevant to all mainstream materials and not just mining.

MD4a Slightly useful/needed

MD4B Very useful/needed

MD4c Very useful/needed

MD4d Very useful/needed

Consumer is less aware of waste but for national and sectoral stakeholders this would be a sensible addition to water and carbon footprints. Waste adds to all other environmental burdens so reducing impact of waste reduces those other burdens too.

MD5a Useful/needed

MD5b Very useful/needed

MD5c Useful/needed

MD5d Very useful/needed

MD5e Very useful/needed

This would be very useful in linking LCA to CE.

Life cycle assessment (LCA) and Sustainability expert

MD1. Effective

MD2. Effective

MD3. Adequate

MD4a Very useful/needed

MD4b Very useful/needed

MD4c Very useful/needed

MD4d Very useful/needed MD5a Very useful/needed MD5b Very useful/needed MD5c Slightly useful/needed MD5d Very useful/needed MD5e Useful/needed
General public/consumer MD1. Very effective MD2. Very effective MD3. Adequate MD4a Useful/needed MD4b Very useful/needed MD4c Very useful/needed MD4d Very useful/needed MD5a Very useful/needed MD5b Useful/needed MD5c Useful/needed MD5d Very useful/needed MD5e Very useful/needed
Life cycle assessment (LCA), Waste management, Sustainability expert MD1. Not effective at all *Mainly because of the step 'is the material ready for use without further processing (other then normal processing as an integral part of the production process).* MD2. Effective MD3. Adequate

MD4a I don't know

MD4b Useful/needed

MD4c Not useful/needed at all

MD4d Useful/needed

A waste footprint has the potential to be useful, but might be misleading. We would like to indicate that the name given above 'product' waste footprint is not adequate, suggestion : production waste footprint.

MD5a Slightly useful/needed

MD5b Not useful/needed at all

MD5c Slightly useful/needed

MD5d Useful/needed

MD5e Useful/needed

Knowledgeable person

MD1. Effective

Markets for low-value co-proucts may exist at some times and not at others. The concept of a "standard waste treatment method" is vague. For example is anaerobic digestion a "standard waste treatment method" or an energy generation method?

MD2. Slightly effective

A major problem arises with food made form animals. When a fish is processed c. 50% is waste by this mechanism, because of the skeleton, fins, etc. Is it useful to say that fish products have a waste footprint of 1kg/kg? I suggest it isn't. The focus should be on avoidable waste

MD3. Slightly adequate

I begin to think that landfill is excessively maligned, particularly for C-containing materials. Is incineration of polymers or wood (even with energy recovery) really better than burying them (C "sequestration" of a sort) if the alternative energy generation technology is wind power or solar PV? Perhaps not, especially in light of other impacts and low efficiency of EfW plants.

MD4a Not useful/needed at all

MD4b Slightly useful/needed

MD4c Not useful/needed at all

MD4d Slightly useful/needed

MD5a Slightly useful/needed

MD5b Not useful/needed at all

MD5c Not useful/needed at all

MD5d Useful/needed

MD5e Not useful/needed at all

In both cases, the downside is that the issue is not "how much waste" per se, but what becomes of it when there is any. Taxation has been very effective at reducing waste disposal.

Life cycle assessment (LCA) expert Waste management expert Sustainability expert

MD1. Slightly effective

Any output that has econoomic value is either a co-product or a recyclable waste, all else is waste. I haven't experienced any situation where this does not work perfectly adequately and it is much simpler and unambiguous.

MD2. Slightly effective

MD3. Not adequateat all

This is far too simplistic - waste going to recycling should net out the material that is productively reused (for a differentiated product i.e primary steel or recycled steel). Waste to incineration should get credit for any reuse of energy/cogen electricity (or cement produced if used in clinker production) - then the waste is just the ash from the incinerator. This could be sooooo misleading of the public and promote the wrong changes.

MD4a Useful/needed

MD4b Slightly useful/needed

MD4c Not useful/needed at all

MD4d Useful/needed

Scores based on a more meaningful methodology and metrics.

MD5a Useful/needed

MD5b Slightly useful/needed

MD5c Not useful/needed at all

MD5d I don't know

MD5e Slightly useful/needed *Scores based on done well, but CE is just the latest buzz word forgotten in a few years. CE mostly doesn't work at all except for high impact products where the transport burden to collect from a dispersed market before recycling will be small compared to the materials impacts.*
Professor MD1. Effective MD2. Effective MD3. Adequate MD4a Useful/needed MD4b Useful/needed MD4c Very useful/needed MD4d Very useful/needed MD5a Useful/needed MD5b Very useful/needed MD5c I don't know MD5d I don't know MD5e Useful/needed
General public/consumer MD1. Very effective MD2. Effective MD3. Slightly adequate MD4a Not useful/needed at all MD4b Not useful/needed at all MD4c Useful/needed MD4d Useful/needed MD5a Not useful/needed at all

MD5b Useful/needed MD5c Not useful/needed at all MD5d Slightly useful/needed MD5e Not useful/needed at all
Waste management expert MD1. Slightly effective MD2. Slightly effective MD3. I don't know MD4a I don't know MD4b I don't know MD4c I don't know MD4d I don't know MD5a I don't know MD5b I don't know MD5c I don't know MD5d I don't know MD5e I don't know
Sustainability expert MD1. I don't know MD2. . I don't know MD3. Adequate MD4a Very useful/needed MD4b Very useful/needed MD4c Very useful/needed MD4d Useful/needed

MD5a Very useful/needed MD5b Useful/needed MD5c Very useful/needed MD5d Very useful/needed MD5e Very useful/needed
Life cycle assessment (LCA) expert MD1. Very effective MD2. Very effective MD3. Slightly adequate *Downgrading should be avoided if possible.* MD4a Slightly useful/needed MD4b Very useful/needed MD4c Useful/needed MD4d Very useful/needed *It will be difficult to get reliable data for consumers. For tthem footprint can be calculated but it is based on average data.* MD5a Slightly useful/needed MD5b Very useful/needed MD5c Very useful/needed MD5d Useful/needed MD5e Very useful/needed
General public/consumer MD1. I don't know *Hard to see the big picture.* MD2. I don't know

MD3. I don't know MD4a Useful/needed MD4b Slightly useful/needed MD4c Not useful/needed at all MD4d Slightly useful/needed MD5a I don't know MD5b I don't know MD5c I don't know MD5d I don't know MD5e I don't know
General public/consumer MD1. Effective MD2. Effective MD3. I don't know MD4a Slightly useful/needed MD4b Very useful/needed MD4c Useful/needed MD4d Useful/needed MD5a Useful/needed MD5b Useful/needed MD5c Useful/needed MD5d Slightly useful/needed MD5e Useful/needed
Life cycle assessment (LCA) expert MD1. Effective

MD2. Effective

MD3. Adequate

MD4a Useful/needed

MD4b Very useful/needed

MD4c Very useful/needed

MD4d Very useful/needed

The consumers need more information and continuous learning about sustainability (not waste or eco labels). University and Government need works together in order to guide to industry.

MD5a Useful/needed

MD5b Very useful/needed

MD5c Very useful/needed

MD5d Very useful/needed

MD5e Very useful/needed

General public/consumer

MD1. Effective

MD2. Effective

The main issue I perceive is the "Can the material be used again without any further processing?". I agree that, as stated by the authors, it is indeed waste until said process is complete. However, industrial stakeholders will hardly accept that the by-products (waste) that someone else is reusing are labled (and accounted for as) waste. It is easy to accept that, if the material does not end up being disposed of, it should not be accounted as waste.

MD3 Adequate

While it's true that human health is an important aspect for risk assessment, environmental hazards (ecological damage) should be accounted for as well. After all, we humans are intrinsically embedded into the environment. I believe that the separation of concerns (humans vs environment) should be avoided as much as possible in sustainability studies, in order to change the cultural discourse that puts humans on a shrine above all other life forms and beyond the limits of the environment that supports us.

MD4a Very useful/needed

MD4b Useful/needed

MD4c Very useful/needed MD4d Very useful/needed MD5a Very useful/needed MD5b Very useful/needed MD5c Useful/needed MD5d Very useful/needed MD5e Very useful/needed
Life cycle assessment (LCA) expert MD1. Effective MD2. Effective MD3. Slightly adequate *I really Wonder about the relevance of the notions of "high risk" / "low risk". Should'nt you talk about impacts rather than risks? The scale that you consider (low or high, but nothing in-between) might also be too limitative. In the end, how do you assess if a waste fraction is of high or low risk? Should'nt you consider a LCA approach (LCI of waste fractions management + impact calculation)? Then how do you consider benefits from recycling ? (if you consider them)* MD4a Very useful/needed MD4b I don't know MD4c Very useful/needed MD4d Very useful/needed MD5a Useful/needed MD5b Very useful/needed MD5c I don't know MD5d Useful/needed MD5e Useful/needed

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