Briefing Note

Umbrella formula (UF)

23 July 2016

V1.0

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Scope, purpose, addressees of this document[1]

In follow-up to the end-of-life workshop that was held in context of the Environmental footprint pilot phase in Brussels on 3rd June 2016, the announced further developed Umbrella formula is now made available by us. The UF builds upon our Integrated formula that has been tested in a range of pilot projects and is one of the contenders for the EoL formula to be used for PEF/OEF implementation. The UF formula can depict, depending on its parameterisation – next to the Integrated formula – several other formulas and EoL approaches.

This little briefing note is directed at the TAB of the Environmental footprint pilot phase and made available for testing and performing example calculations by the JRC in preparation of the upcoming second End-of-Life WS to be held early September at the JRC in Ispra.

[1] This document can also be downloaded for free at: http://maki-consulting.com/?p=363

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Overview

The EoL Umbrella formula (UF) expands on the Integrated formula (IF), introducing to the IF a generic approach for multi-material products, that may also use multiple energy carriers / refurbished parts, and that are generating at their end of life multiple secondary materials and recovered energy forms, as well as possibly recovered parts for further use. The formula moreover now includes a sharing factor that allows for sharing burdens and benefits of recycling/recovery processes and of the thereby obtained secondary materials and energy carriers between consecutive life cycles. It moreover introduces elements into the formula, that were previously only described in the text of the White paper on the Integrated formula, such as to capture the effect of using secondary materials as recycled content on the life cycle inventory of the production process . Finally, and for clarity and unambiguity of the formula components, the formerly used formula-structure used for the PEF/OEF Annex V 50/50 formula is not used anymore.

Principles and elements

The UF is composed of the following elements/principles that are provided to guide implementation/modelling in LCA software and that are subsequently formularised. The coloured boxes correspond to the formula elements more below. The green text describes the additions to the Integrated formula:

- Primary contents of materials and energy carriers (R0i) are modelled with cradle-to-gate LCI data sets of the same amount of the respective primary material and energy carrier (Note: primary parts are not explicitly considered but modelled as usual in all Environmental footprint (EF)-discussed formulas). For differentiating the various individual materials etc. and summing them up for the analysed product, the formula now has an index (i) and sum for all materials, energy carriers, further used parts used for the product and recycled/recovered at its end-of-life. Where several routes or qualities are used for the same material (e.g. two different qualities of secondary Polyethylene would be used as recycled content for the same product, or twice the same Polyethylene material but from different production routes), these can be formally considered distinct materials and via the index I they are individually modelled / represented.

- Secondary material (aka recycled content) and energy carrier input are modelled as quality-corrected cradle-to-gate LCI data sets of the respective primary material and energy carrier. A sharing factor (ai) is now introduced, allowing to share burdens between consecutive life cycles that provide and use the respective secondary material or energy or refurbished part. The sharing factor can be set based on political, market, or other consideration and moreover per material etc. individually or commonly for all of them. Note that if ai = 0.5 for all materials, energy carriers and parts, this is equivalent to 50/50 sharing..

- The previous element implies that the EoL processing efforts that lead to obtaining the secondary material, energy or part that was used as recycled content etc. in the analysed product is to be included in the UF. The burden from those operations from the preceding life cycle are shared between the consecutive life cycles via the same sharing factor (ai).

- In addition, the formula now allows – if wished so – to capture the specific burdens or savings during product production due to the recycled content (e.g. glass from cullet, cooling scrap), i.e. corrects the specific impact effect of replacement of primary material during processing.

- Secondary materials and recovered energy at the analysed product's end of life are modelled as credit for the quality-corrected specific secondary material, energy carrier or refurbished part obtained at the point of substitution, i.e. where it enters a new product system and replaces principally functionally equivalent (but potentially somewhat different in quality / performance) the same or different primary material(s), energy carrier(s) or part(s). The burdens from running the processes to produce secondary materials and energy carriers as well as refurbished parts from the end-of-life product are of course included. New is that also here the same sharing factor (ai) as for recycled content allows to share burdens and credits between consecutive life cycles, as needed for symmetry and non-overlapping system boundaries without gaps if such a sharing factor other than 1 is used for the input side (recycled content etc.) as well.

- Landfilling of materials that are directly landfilled (Di), i.e. do not undergo recycling or energy recovery processes, or refurbishing efforts, are modelled as material-specific landfilling processes. Note in this context: If the sharing factor (ai) is not equal 1 but e.g. 0.5 as in case of 50/50 approaches (i.e. if not all burdens and credits of recycling/recovery are allocated to the producer of the analysed product), the following problem occurs: landfilling of losses/reject during recycling and recovery (e.g. bottom ash from waste incineration plants) where the burdens are shared between the life cycles, lead to inconsistent treatment compared to materials that are directly landfilled, as the burdens from those landfillings are 100% allocated to the producer of the analysed product, as specified in the UF. That means that for a consistent modelling under the UF either landfilling of losses during recycling and recovery are to be specifically assigned 100% to the producer of the analysed product (what is the most logical approach, but very complicated to implement in LCI models), or that the burden of the direct landfilling of materials is also to be shared via the sharing factor (ai), while this would lead to some odd results such as assigning landfilling burdens to a product that is 100% recycled.

Note: reuse of parts or products, such as the returning pallets or bottles are not expected to be modelled with the UF end-of-life formula, but the burden of each e.g. return transport, cleaning etc. and a proportional share of primary production are to be carried by each loop. Such loops are understood as part of the normal use of such parts "as designed", hence, there is no end-of-life situation involved. The actual EoL treatment of such reusable products after many loops, however, is supposed to be modelled with this formula.

Formula

These principles / the approach translates into the following UF formula (plus comments on implementation):

$$E = \left(\sum_{i=1}^{n} R_{0,i}\right) \times E_{V,i} + \sum_{i=1}^{n}\left(R_{1,i} * a_i \times Q^{\S}_{s,i}/Q^{\S}_{p,i} \times E_{V,i}\right) + \sum_{i=1}^{n}\left(R_{1,i} * (1-a_i) \times E_{recIN,i}\right) + E_P + \sum_{i=1}^{n}\left(R_{2,i} * a_i \times \left(E_{recEoL} - E^{*}_{V,i} \times Q_{s,i}/Q_{p,i}\right)\right) + \sum_{i=1}^{n} D_i \times E_{D,i}$$

With:

E	is resources consumed/emissions for the production and the EoL stages of the analysed product and one product life cycle, across all materials, energy carriers and parts
i	is the index of the specific material, energy carrier or (further used) part
a	is the share of burdens from recycling, energy recovery, parts refurbishment use at the analysed product's end-of-life that is assigned to the analysed product; "1 – a" is then the remaining share that is shared by the subsequent life cycle. Note that for the benefits of these processes, i.e. credits of the secondary materials, recovered energy carriers and refurbished parts, in contrast a debit "–a" has to be accounted for at the beginning of the subsequent life cycle . $0 \leq a \leq 1$
E_V	is resources consumed/emissions for the actual virgin material or energy substituted through recycling, energy recovery or part further use
E^{*}_{V}	is resources consumed/emissions for the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials or of parts assumed to be substituted by further used parts/products or energy assumed to be substituted by energy recovery. If only closed-loop recycling takes place: $E^{*}_{V} = E_V$
E_P	is the extra (or saved) resources/emissions in the production process, due to using recycled content. E.g. the use of glass cullet reduces the energy needed for melting and the amount of CO_2 emissions from the melt (due to replacing soda that releases CO_2 when melted), i.e. generates a tangible saving of burdens during production of a new glass bottle).
E_{recIN}	is resources consumed/emissions for the production process of the input of recycled material (including collection, sorting and transport processes), secondary energy or further used part
E_{recEoL}	is resources consumed/emissions for the energy recovery process, part

	refurbishment, or material recycling process , including collection, sorting, transportation and recycled material production processes. Landfilling of losses during the end-of-life processes that go to landfill are either included here (i.e. shared as well) or assigned 100% to the analysed product (analogous as directly landfilled end-of-life product; see also brief discussion in the preceding text. Note that in some cases, when technologies used are similar, E_{recIN} can be similar/identical to E_{recEoL}
E_D	is resources consumed/emissions for the disposal of waste material, (e.g. landfilling, incineration pyrolysis). Note that energy recovered e.g. from land fill gas is to be included ideally in the expression for recycled material and recovered energy (light blue frame).
D	is the amount of the specific material/part that is directly landfilled, before going to recycling, energy recovery or refurbishing processes
R_0	is the content of virgin material or energy used to produce the analysed product ($0 \leq R_0 \leq 1$)
R_1	is the recycled content at of the material, i.e. the proportion of the material input to the production process that has been recycled in a previous system ($0 \leq R_1 \leq 1$)
R_2	is the amount of the specific secondary material, energy carrier or part for further use that are obtained as output from the recycling, energy recovery or refurbishing processes of the end-of-life product, at the point of substitution where such can be used to replace primary materials, energy or parts. That implies that R_2 takes into account any inefficienciesin the collection and recycling/recovery/refurbishing processes.
Q_s/Q_p	is the ratio of any differences in quality between the secondary material of the EoL recyclate (e.g. down-cycling) where Q_s is the quality of the secondary material in the EoL recyclate and Q_p is the quality of the superseded primary material. The decision on how to determine the Q factors is independent of the UF formula. Possibilities include the market price or political decisions per material/energy/part type or groups thereof, similar to the French Grenelle approach. Note that a secondary material may on input side of the product supersede one or several materials, also different ones (e.g. glass cullet supersedes the mix of primary glass making ingredients, OR recycled low quality plastics that are used for a park bench, replace a mix of wood, concrete and primary plastic that would otherwise be used to make the park bench.)
$Q_s^{§}/Q_P^{§}$	is the ratio of any differences in quality between the individual secondary material (energy carrier, or further used part) used as recycled content and the functionally superseded (i.e. replaced, avoided) primary material(s), energy carrier(s) or part, where $Q_s^{§}$ is the quality of the secondary and $Q_p^{§}$ is the quality of the primary material, energy or part. Note that for energy carriers it might be agreed to set Qs = Qp, based on Lower calorific value. For parts, the Qs could e.g. be set based on the proportion of its lower expected life time compared to a new part.

- Note that $\sum_{i=1}^{n} R_{0,i} \quad + \sum_{i=1}^{n} R_{1,i}$ = 1, i.e. the entirety of all materials and energy carriers that go into the product are to be considered and jointly make up 100% of the mass and energy content of the product. Same applies for all output elements that jointly make up 100% of the energy and mass content of the product.

- Note furthermore that consistent implementation in a life cycle model would preferably see the application of the formula to all cases also of production waste, i.e. material recycled or landfilled etc. If a production waste (e.g. trimmings) are used inside the same production, effectively only the efforts of processing the trimmings would be accounted for, as the crediting/debiting balances each other. If they are sold externally, even for the same kind of product, where the results should be the same from plausibility perspective, the results can change relevantly IF the sharing factor (ai) is not equal 1.

Parameterisations

Several parameterisations of the formula are foreseen that lead to specific other formulas:

- Without the sharing factor assigning all burdens and benefits of end-of-life rec. activities to the analysed product, i.e. if (ai) = 1, the original Integrated formula / approach (IF) is obtained. [Note that other differences between the IF and UF, such as how to model secondary energy input, are covered by the text of the White paper of the IF and had not been expressed in the IF formula as such, to keep symmetry with the formula structure of the 50/50 formula. Similar applies to the landfilling part of the formula. Such a new formulation of the IF, based on the UF is clearer and should to be preferred.]

- Since the formula that is proposed for use in EN 15804 by the metals industry, is mathematically identical to the Integrated formula while it is restructured and reformulated to depict the modules of EN 15804, also that formula can be expressed by the UF

- Note that ai can be set individually per material / energy carrier / part or groups thereof, allowing to achieve EoL approaches that reflect the principles of the French Grenelle EoL approach.

- If ai is set to 0 for all cases, a 100/0 formula is obtained (optionally with or without considering the effect on production processes by using recycled content (i.e. Ep)

- If applied to only one material (i.e. i = 1), and with (ai) = 0.5, and selecting Ep=0, a further developed 50/50 formula can be obtained.

Original Integrated formula 2014:

$$E = (1 - R_1) \times E_V + R_1 \times Q_S^{\S}/Q_P^{\S} \times E_V + R_2 \times \left(E_{recycling,EoL} - E_V^{*} \times Q_s/Q_p\right) + \\ + R_3 \times \left(E_{ER} - LHV \times X_{ER,elec} - LHV \times X_{ER,heat} \times E_{SE,heat}\right) + (1 - R_2 - R_3) \times E_D$$