Integrated Environmental Assessment and Management — Volume 9999, Number 9999—pp. 1–11
Received: 16 October 2018 | Returned for Revision: 27 March 2018 | Accepted: 25 May 2018

Life Cycle & Sustainability

Developing Product Environmental Footprint Category Rules (PEFCR) for Shampoos: The Basis for Comparable Life Cycle Assessments

Laura Golsteijn,† Lindsay Lessard,‡ Jean-Florent Campion,§ Alexandre Capelli,‖ Virginie D'Enfert,# Henry King,†† Joachim Kremer,‡‡ Michael Krugman,§§ Hélène Orliac,‖‖ Severine Roullet Furnemont,## Werner Schuh,‡‡ Mark Stalmans,††† Natasha Williams O'Hanlon,‡‡‡ and Manuela Coroama§§§*

†PRé Sustainability, Amersfoort, The Netherlands
‡Quantis, Lausanne, Switzerland
§L'Oréal, Asnières sur Seine, France
‖LVMH, Paris, France
#Febea, Paris, France
††Unilever, Cedex, France
‡‡Henkel, Düsseldorf, Germany
§§Estée Lauder, Melville, New York, USA
‖‖Chanel, Cedex, France
##Pierre Fabre, Castres, France
†††Procter & Gamble, Strombeek-Bever, Belgium
‡‡‡Oriflame Cosmetics, Bray, Ireland
§§§Cosmetics Europe, Brussels, Belgium

ABSTRACT

In 2013, the European Commission launched the Environmental Footprint Rules pilot phase. This initiative aims at setting specific rules for life cycle assessment (LCA: raw material sourcing, production, logistics, use, and disposal phase) studies within 1 product category, called product environmental footprint category rules (PEFCR), and for organizations, called organizational environmental footprint sector rules (OEFSR). Such specific rules for measuring environmental performance throughout the life cycle should facilitate the comparability between LCA studies and provide principles for communicating environmental performance, such as transparency, reliability, completeness, and clarity. Cosmetics Europe, the association representing the cosmetics industry in the European Union, completed a voluntary study into the development of PEFCR for shampoo, generally following the guidelines and methodology developed by the European Commission for its own pilot projects. The study assessed the feasibility and relevance of establishing PEFCR for shampoo. Specifically, the study defines a large number of modeling assumptions and default values relevant for shampoo (e.g., for the functional unit, the system boundaries, default transport distances, rinsing water volumes, temperature differences, life cycle inventory data sources) that can be modified as appropriate, according to the specificities of individual products, manufacturing companies, and countries. The results of the study may be used to support internal decision making (e.g., to identify "hotspots" with high environmental impact and opportunities for improvement) or to meet information requests from commercial partners, consumers, media, or authorities on product environmental characteristics. In addition, the shampoo study also highlighted many of the challenges and limitations of the current product environmental footprint (PEF) methodology, namely its complexity and resource intensiveness. It highlighted 2 areas where improvements are much needed: (1) data quality and availability, and (2) impact assessment methodologies and robustness. Many of the findings are applicable to other rinse-off cosmetic products, such as shower gels, liquid soaps, bath products, and hair conditioners. *Integr Environ Assess Manag* 2018;00:000–000. © 2018 The Authors. *Integrated Environmental Assessment and Management* published by Wiley Periodicals, Inc. on behalf of Society of Environmental Toxicology & Chemistry (SETAC)

Keywords: Standardization Life cycle assessment Cosmetics Environmental footprint Impact assessment

This article includes online-only Supplemental Data.

* Address correspondence to MCoroama@cosmeticseurope.eu

Published 5 June 2018 on wileyonlinelibrary.com/journal/ieam.

INTRODUCTION

Environmental footprint initiative

There is an endless availability of "green labels," which may result in confusion for consumers and costs for companies that wish to market their products as environmentally friendly in multiple European countries. Therefore,

in 2013, the European Commission published a recommendation on the use of a common methodology to measure and communicate the environmental performance of products and organizations (EC 2013). The basis of this common methodology is life cycle assessment (LCA). LCA addresses the environmental aspects and potential environmental impacts (e.g., use of resources and the environmental consequences of releases) throughout a product's life cycle, from raw material acquisition through production, use, end-of-life treatment, recycling, and final disposal (i.e., cradle to grave) (ISO 2006). The initiative from the European Commission aimed at setting specific rules for LCA studies within 1 product category, called product environmental footprint category rules (PEFCR), and for organizations, called organizational environmental footprint sector rules (OEFSR). Such specific rules for measuring environmental performance throughout the life cycle should facilitate the comparability between LCA studies and provide principles for communicating the environmental performance, such as transparency, reliability, completeness, and clarity.

Through this official communication, the Commission also launched a 3-year Environmental Footprint Rules pilot phase (EC 2013). Twenty-six product groups and sectors from a wide variety of industries were selected to participate. Among them were apparel and footwear, beverages, chemistry-based final products, construction products, electrical products and electronics, food products (including products not for human consumption), and materials and intermediate products. Common challenges included, among other things, the state of the art for C modeling (interaction between different indicators for climate change), granularity (width of scope per product category or sector), the use stage (expected use by the end user), or how to determine "hotspots" (i.e., the most relevant life cycle stages, processes, and elementary flows).

Category rules for shampoos

Cosmetics Europe is the European association representing the cosmetics industry in the European Union. For more than 50 years, Cosmetics Europe has been the authoritative voice of the cosmetics and personal care industry in Europe. Its members include cosmetics and personal care manufacturers and associations representing the industry at the national level across Europe. In total, they represent more than 4000 companies.

The branch association is very aware that the entire cosmetics supply chain, from the initial sourcing of raw materials through to consumer use and disposal, can have an effect on the environment (Figure 1). Therefore, they work hard to identify how to support the development of an innovative, sustainable, competitive, and respected industry in Europe that best serves consumers and society. Their efforts focus at providing information and guidance to cosmetic manufacturers and to assist them in their efforts toward the sustainable production and consumption of cosmetic products.

In 2013, Cosmetics Europe applied to be part of the European Commission's Environmental Footprint pilot phase with a pilot on shampoo. The reasons for choosing this product category were 2-fold: (1) because it is such a widely used product and (2) because of the experience, life cycle inventory database, and knowledge developed so far (AFNOR 2014). Even though they were not among the selected product groups and sectors, Cosmetics Europe and its members wanted to follow and contribute to the "single market for green products" (EC 2016). Therefore, in parallel with the official pilot phase, they voluntarily decided to proceed internally with the development of category rules for shampoos in a "shadow" product environmental footprint (PEF) study. They followed as closely as possible the guidance from the European Commission and collaborated on this with the International Association for Soaps, Detergents, and Maintenance Products (AISE), whose experts were involved in and leading the pilot on household detergents (AISE 2014).

Ultimately, Cosmetics Europe aims at providing its members with comprehensive and high-quality guidelines for assessing the environmental impact of shampoos. The current article describes the development process for specific rules for performing environmental LCAs on shampoos, including experiences and findings. As a result, it reflects the recommended structure for establishing PEFCR for shampoo.

METHODOLOGY

Stepwise approach

The development of PEFCR started with the establishment of a technical secretariat (TS), which was composed of experts from 9 member companies and associations, an external consultant, and TS manager from Cosmetics Europe. Furthermore, Cosmetics Europe liaised with AISE, the leader of the pilot on household detergents, to ensure alignment and consistency between approaches, as much as possible. PEF guidance version 5.1 was followed (EC 2015), and the same steps were taken as the official pilots (Figure 2), except for the development of a benchmark with performance classes (see *Discussion*).

Definition of product category. The scope of the PEFCR was shampoo for different types of hair, such as fine hair or greasy hair. Four different functions were identified for this product group: (1) hair cleansing (including a minimum of hair care efficacy), (2) hair conditioning, (3) antidandruff activity, and (4) protection of sensitive target groups (children or other people with a sensitive scalp).

The combination of these functions results in the delivery of different benefits and needs to the consumer. These benefits or functions form the basis for the definition of 5 subcategories for the product shampoo: (1) hair cleansing, (2) hair cleansing and hair conditioning (2-in-1 product), (3) hair cleansing and antidandruff activity, (4) hair cleansing, hair conditioning, and antidandruff activity, and (5) hair cleansing and protection of sensitive target groups (children or other people with a sensitive scalp). It is important to note that the environmental footprint should only be compared between products from the same subcategory and/or with the representative product for hair cleansing that has been defined for the product category shampoo.

Definition of representative product. The representative product is chosen to represent all products covered by the

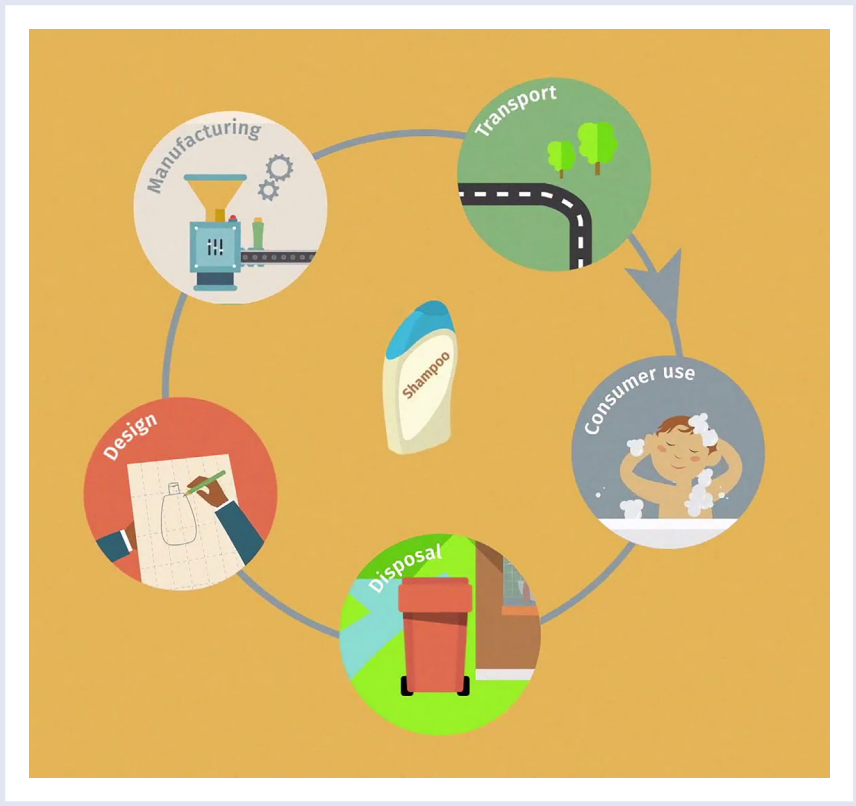

Figure 1. Possible ways to reduce the environmental footprint of a cosmetic can be found throughout the entire supply chain (Cosmetics Europe 2016).

PEFCR. It serves as the basis for the PEF screening. In line with the PEF guidance, a virtual representative product was chosen. This is a nonexisting product based on a combination of existing technologies. In the current study, the virtual representative product was constructed slightly different than in the guidance (see "Continuous EF Developments" in the *Discussion*). The choice of a virtual representative product, over a real product sold on the European Union market, substantially reduces the risk that technologies with relatively small market shares are neglected.

Although there were 5 subcategories of shampoo defined, for the sake of simplicity only 1 representative product was defined (see also suggestions for further research in Table 2). Formulation composition of the representative product was defined by a standard formulation based on typical ingredients and functions (Table 1). A representative ingredient for each function was selected with a typical composition based on market volume. Relevant sources of information were L'Oreal internal data and consensus and studies by Mottram et al. (2000), Arif (2010), Making Cosmetics Inc. (2016), Escamilla et al. (2012), and Kaps et al. (2012). For additional functions, additional ingredients must be added, e.g., zinc pyrithione or salicylic acid for antidandruff function. Packaging product composition was defined by selecting the most widely used material on the market for the bottle and cap, i.e., polyethylene and polypropylene, respectively.

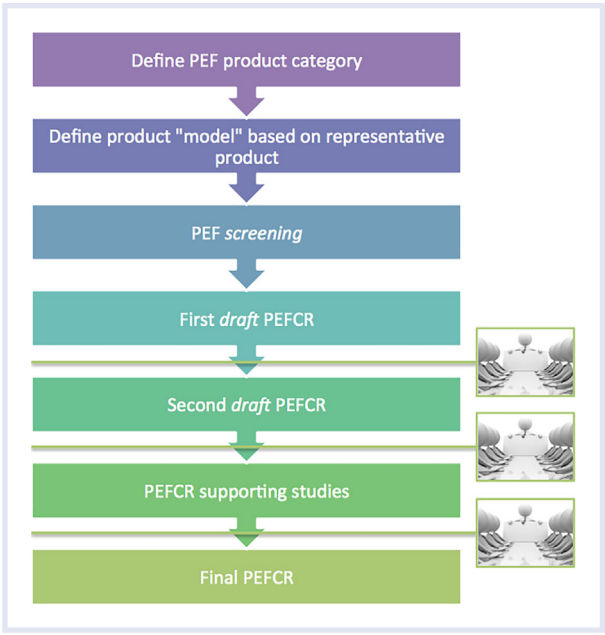

Figure 2. Schematic overview of the steps taken in the PEFCR development process.

PEF screening. Following the definition of the representative product, a life cycle model of this representative product was developed. With this, we performed an LCA, the PEF screening study. It resulted in information about the most relevant impact categories, life cycle stages, processes, and elementary flows. Particularly the latter 2 aided in the

 DOI: 10.1002/ieam.4064

Table 1. Ingredients of the representative product

Function	Ingredient	CAS	DID-list no.	Concentration (wt%)
Anionic surfactant	Sodium laureth sulfate	68891-38-3	8	13.00
Amphoteric surfactant	Cocamidopropyl betaine	61789-40-0	61	8.00
Nonionic surfactant	Cocamide MEA[a]	68140-00-1	50	1.25
Viscosity controlling agent	Propylene glycol	57-55-6	174	1.00
Preservative	Sodium benzoate	532-32-1	95	0.30
pH adjustor	Chlorhydric acid	7647-01-0		0.80
Fragrance	alpha-Hexyl cinnamaldehyde	101-86-0	142	0.10
	beta-Pinene	127-91-3		0.05
	Dihydromyrcenol	2436-90-0		0.25
	Hexyl salicylate	115-95-7		0.075
	Patchouli oil	84238-39-1		0.025
Additional functions[b]	Dimethicone	63148-62-9	110	1.00
Additional functions[b]	Polyquaternium-10	68610-92-4		0.40
Appearance[c]	Glycol distearate	627-83-8	185	0.50
Solvent	Water			73.25

[a] MEA = monoethanolamine.
[b] For example, hair conditioning agent, hypoirritancy agent.
[c] Pearlescent and opacifying agent.

identification of the processes that require primary data collection.

First draft PEFCR. The TS and the external consultant used the results from the PEF screening to draft a first PEFCR for shampoos. Together with the PEF screening, the draft PEFCR was then submitted for an internal stakeholder consultation.

Stakeholder consultation (internal). The first round of stakeholder consultations was held internally; 14 member companies and 4 national associations were involved.

Second draft PEFCR. The comments from the stakeholder consultation were used to improve the PEFCR.

Stakeholder consultation (internal). The second draft PEFCR was again sent around for internal stakeholder consultation. This time, stakeholders from 16 member companies and 26 national associations were involved. The PEFCR report was further improved with the feedback received. This draft PEFCR was the guiding document to carry out the PEFCR supporting studies.

PEFCR supporting studies. Three supporting studies were performed to test the improved draft PEFCR: (1) Gliss Kur Total Repair Shampoo from Henkel, (2) Shampooing antipelliculaire Eucalyptus et Citron—Ultra Doux de Garnier from L'Oréal, and (3) Shampoo for Delicate Hair from Pierre Fabre.

Stakeholder consultation (external). The draft PEFCR was then sent around for an external stakeholder consultation. Thirteen external stakeholders were invited, and feedback was received from BASF, the European Federation of Cosmetic Ingredient Suppliers, and the French Environment & Energy Management Agency (ADEME). A number of valuable comments were considered for inclusion in the final PEFCR. Examples include the scope of the PEFCR, the choice of ingredients, and the use of secondary data.

Final PEFCR. The technical specifications of the final PEFCR can be found in the article by Lessard et al. (2016) and are summarized in the Results section, in Figure 4, and in the Supplemental Data.

Research scope

PEFCR scope. The PEFCR provides guidance for shampoos only (see "Definition of Product Category"). Although other personal care products, such as shower gels, may have similar functions, these are not considered within the scope of this PEFCR.

Functional unit. The basis for an LCA is the functional unit (FU), i.e., the quantification of the function of the product. In the present research, the FU was defined as "A hair wash carried out in Europe (EU 28), on average length hair." The accompanying reference flow, i.e., the amount of product needed to fulfill this FU, was set to 10.46 g of shampoo (Hall et al. 2011). When applying the PEFCR to a shampoo that has functions in addition

Table 2. Overview of our recommendations for further work on the footprinting of cosmetics

PEFCR aspect	Limitation	Recommendation
Product definition	The PEFCR includes one representative product for 5 subcategories of shampoos. Differences between subcategories are the addition of specific ingredients or a change in concentrations.	It would be very difficult to find a representative product for every subcategory. In the PEFCR development process, supporting studies were performed for products from 3 subcategories. It is recommended to address all 5 subcategories.
Data availability	The availability of inventory data for many chemicals and packaging materials is very limited.	We recommend the development of a database of primary data, considering sourcing locations and manufacturing processes.
	The current PEFCR lists a secondary data set composed of ecoinvent processes, which are not free of charge.	
	There is a general lack of quantifiable information on domestic water heating, shower types, and water usage by consumers.	We recommend future research on this matter.
EF methodology	There is a lack of data to fully assess all biodiversity effects.	We recommend future research on this matter.
	Some impact assessment models used are questionable, such as for land use and water consumption effect.	Later versions of the guidance document—e.g., version 6.2 compared to 5.1 used here (EC 2015)—were adapted to reflect the state of the art regarding effect. Additional technical issue papers were developed to provide clear rules, and additional guidance on, e.g., reporting was developed.
	Also, the issues related with LCAs of biobased materials are relevant for shampoos. Particularly the treatment of biogenic carbon storage (Pawelzik et al. 2013).	
	The way end-of-life allocation is performed was changed during development of this PEFCR.	Once the EF methodology is final, it would be good to align the current PEFCR with the final guidance document and available technical issue papers.
	Reporting, communication, and verification are not addressed.	
	The normalization factors rely on European domestic figures for 2010.	Robust and recent normalization data are needed. The consideration of international trade in normalization factors would allow for a more comprehensive picture of the actual environmental effects due to EU production and consumption processes.
	Alternative, global normalization approaches may be explored (Sala et al. 2016).	The concept of planetary boundaries, as introduced by Rockström et al. (2009), could be of great interest.

to hair cleansing (e.g., antidandruff, sensitive scalp), this must be specified in the FU as well and cross referenced to the 5 subcategories of shampoo identified previously (see "Definition of Product Category").

System boundaries. All stages of the life cycle of shampoo were included in the PEFCR development (Figure 4). Upstream processes included those related to the production of ingredients (e.g., extraction of resources, preprocessing, and transportation) and the production of packaging (e.g., production of raw materials, manufacturing, transportation). Manufacturing included among other things energy and water use, packaging of the shampoo, and the treatment of waste and wastewater. Downstream processes included those related to distribution and storage (e.g., energy and heat for warehouses, transportation), use (e.g., water and energy use for shower), end-of-life for packaging (e.g., transport to treatment facilities, recycling, incineration, and landfilling), and end-of-life for product (e.g., wastewater treatment).

Input data. Specific data for the PEF screening and the supporting studies were collected within the member companies of the TS, supplemented with data from literature (Provo et al. 2013). Background data were mainly taken from the ecoinvent database version 2.2 for the PEF screening and version 3.2 for the supporting studies (Frischknecht et al. 2005; Wernet et al. 2016). Note that the use of ecoinvent data is not in line with the PEF guidance, as these data are not available free of charge.

The PEF guidance states that a PEFCR should specify the data quality requirements for both specific and background data. When calculating an environmental footprint (EF), there will be situations in which a choice must be made between using specific or background data. The PEF guidance aims at focusing where it really matters. Therefore, the data quality requirements depend on the relevance per process and the access a company applying the PEFCR has to the process.

In general, the PEFCR developed in the current research recommended the use of primary sources for specific data, whereas generic sources may be used for background data. When available, semispecific data should be replaced by

 DOI: 10.1002/ieam.4064

specific. Details about the requirements for data collection and data quality, as well as default values and guidance for data gaps, can be found in the study by Lessard et al. (2016).

Analysis

The LCA modeling for the PEF screening and supporting studies was performed with SimaPro version 8.3. In accordance with the PEF guide, the impact assessment was done with use of the default 15 EF impact category indicators (EC 2013), supplemented with a method described by Garnier-Laplace et al. (2008) to assess the effects of ionizing radiation on ecotoxicity.

RESULTS

PEFCR

Apart from some general issues, a PEFCR should address scope, input data, interpretation, and reporting. Reporting has not been addressed in the current PEFCR, as the EF guidance on verification and communication was not finished at the time of development for this PEFCR (see "Continuous EF Developments" section in the *Discussion*). A summary of the scope and guidance provided in the PEFCR is given in Figure 4. More details on the category rules in the newly developed PEFCR for shampoos are given in the Supplemental Data and in the full PEFCR report by Lessard et al. (2016).

Hotspots analysis

The screening LCA is the basis for the PEFCR or OEFSR development process, as it leads to the identification of the most relevant contributions, i.e., the most relevant impact categories, life cycle stages, and elementary flows (EC 2015). The former 2 are relevant for external communication, whereas the latter 2 are relevant for decision making in data requirements. For internal decision making at the company level, the so-called hotspots, the most relevant life cycle stages, processes, and elementary flows, are relevant. The hotspots might serve the purpose of "warning" an organization about the area where they should focus their attention to improve the environmental performance of their product.

It was found that the most relevant impact categories for shampoos are climate change, water resource depletion, mineral and fossil resource depletion, and freshwater ecotoxicity. These impact categories were selected with use of the normalization method from the EF methodology and confirmed by normalization factors from various studies (De Schryver et al. 2009; Goedkoop and Spriensma 2001; Jolliet et al. 2003; Humbert et al. 2012; Pfister et al. 2009; Bulle et al. 2013), an approach suggested in the OEFSR for Retail (Humbert et al. 2017). The relevance of climate change and water resource depletion can be explained by the use of water and energy for showering, whereas the relevance of freshwater ecotoxicity relates to the treatment of wastewater and the product's end of life. The depletion of mineral and fossil resources is a recurrent issue throughout the life cycle and is mainly caused by the energy required in the use stage, the distribution and storage (to be precise, the maintenance of transport vehicles), and the production of shampoo ingredients (namely fatty alcohol sulfate, a proxy for sodium laureth sulfate).

The screening LCA of shampoo identified the use stage as the most relevant life cycle stage for all impact categories, except for freshwater ecotoxicity (Figure 3). For the latter, the shampoo end-of-life was the most relevant life cycle stage. Production of ingredients and distribution and storage were also the most relevant stages for several impact categories. In contrast, manufacturing of the shampoo, packaging production, and packaging end-of-life were not among the most relevant life cycle stages. The absolute values for the characterized results of the screening study, as well as additional results, can be found in the screening study report (https://www.cosmeticseurope.eu/how-we-take-action/driving-sustainable-development/). It may seem counterintuitive that the use stage is also the most relevant life cycle stage for effects on land use, more relevant than the production of ingredients or packaging materials. The effects on land use from energy in the use stage can be explained by the wells for natural gas exploration and production. The production of shampoo ingredients is also relevant, particularly the fatty alcohol sulfate. The production of packaging materials contributes very little. The largest share of this life cycle stage is coming from cardboard for secondary packaging, but this contribution is very small compared to the energy in the use stage.

Regarding the identification of the most relevant processes, the exact list and order varied from one impact category to another. However, the most recurrent processes included the following: electricity consumption; natural gas consumption; light fuel oil consumption; water use; waste water treatment related to product end of life; transport to distribution center; transport from distribution center to point of sale; production of primary packaging; production of sodium laureth sulfate, a shampoo ingredient; and production of cocamidopropyl betaine, a shampoo ingredient.

Data quality

The vast majority of cosmetic products are composed of a fairly large number of ingredients from a variety of sources, both feedstocks and suppliers. The screening and supporting studies showed that there is very limited primary data for many chemicals. Nevertheless, the PEFCR states that the formula of the shampoo and the primary packaging data should come from primary sources of data. Primary data sources were also recommended for manufacturing data. For background generic data, ecoinvent 3.2 was recommended, but semispecific data should be replaced by specific data when available.

DISCUSSION

The development of PEFCR for shampoos resulted in specific guidance for LCA studies on shampoos and important findings that may also be applicable to other

cosmetics. Here, we will discuss the limitations of this PEFCR, the findings from the PEFCR development process, the applicability of results to other cosmetics, the practical implications, and the ongoing developments related to EF.

Limitations

In general, the Environmental Footprint Rules pilot phase has highlighted many of the challenges and limitations of the current LCA methodology, including data availability and required expertise. The experiences of Cosmetics Europe while developing the shadow PEFCR illustrate similar limitations on a smaller scale.

Input data. First, the availability of inventory data for many chemicals and packaging materials is very limited. Generally, the data for key ingredients are made available as industry averages or are obtained from external databases such as ecoinvent. An important example can be found in the wide variety of minor ingredients such as fragrances and polymers. As the generation of life cycle inventory data is an expensive and time-consuming activity, it is often impossible to account for the benefits of sustainable sourcing for ingredients (e.g., palm oil) and the potential benefits of certification. Yet, a certain minimum level of detail in the inventory data can be of crucial importance for the results of the LCA. The use of data that are not supplier specific limits the relevance of LCA Comparisons for similar products. The same also holds for packaging materials. For example, petroleum-based and biobased polyethylene terephthalate are chemically the same but have different types of effects.

Related to that, it should also be noted that the current PEFCR lists secondary data sets composed of ecoinvent processes. The use of ecoinvent data is not in line with the PEF guidance, as these data are not free of charge. Companies applying the PEFCR for shampoos should therefore mention the use of ecoinvent data in their limitations section.

Thirdly, in addition to the lack of specific data, there was a general lack of quantifiable information on domestic water heating, shower types, and water usage by consumers. It is important to note that the LCA model appeared sensitive to some of the most relevant processes, such as water use during showering. For the sake of simplicity, in the screening and supporting studies, the use of hot water during showering is completely attributed to the use of shampoo. A default value of 15 liters per shower was assumed, based on data from a hair dresser (Cellule éco-conception UCM 2013) and expert judgment. Obviously, the hot water may also serve other functionalities, such as comfort and rinsing of other cosmetics. Therefore, the environmental effect of shampoo may be overestimated.

Impact assessment methodology. The current PEFCR is based on an impact assessment with use of the default 15 EF impact category indicators (EC 2013), supplemented with a method by Garnier-Laplace et al. (2008) to assess the effects of ionizing radiation on ecotoxicity. The latter method was part of the International Reference Life Cycle Data System (EC-JRC 2011) and anticipated to become part of the recommended EF method as well. However, during this study, it was not retained in the EF method, as it was considered too immature to be recommended. For some activities and processes relevant for shampoo, appropriate impact methods are lacking or poorly developed. For example, effects on biodiversity are not assessed within the recommended EF impact assessment method. If biodiversity is relevant, a PEFCR should describe how biodiversity effects will be assessed by the applicant. In that case, this is part of the additional environmental information. Since there is a lack of data to fully assess all biodiversity effects, the current PEFCR recommends future research on this matter.

Some models are questionable, such as for land use and water consumption impact. Later versions of the guidance document—e.g., version 6.2 compared to 5.1 used here (EC 2015)—were adapted to reflect to state of the art regarding impact assessment methodologies (see also Continuous EF Developments).

Also relevant for shampoos are the issues related to LCAs of biobased materials. In particular, the treatment of biogenic carbon storage is critical for quantifying greenhouse gas emissions of biobased materials in Comparison with petrochemical materials (Pawelzik et al. 2013). For the impact assessment of carbon flows, there are 2 important guidance documents to consider: the PEF guide (EC 2013), which provides rules on the modeling approach for biogenic carbon, and an additional guidance document from De Schryver et al. (2016), which will aid in the development and implementation of the PEFCRs and also addresses biogenic carbon storage. The latter document was published only shortly before finalization of the current PEFCR. Therefore, it may be of added value next to the current PEFCR when calculating an EF for shampoos.

A last point to comment on the impact assessment methodology relates to the normalization, i.e., the step in which impact results are divided by a reference situation's results. The methodology and so-called normalization factors are published by the EC (Benini et al. 2014). The consideration of international trade in normalization factors would allow for a more comprehensive picture of the actual environmental impacts due to European Union production and consumption processes. To calculate the effects of consumption only, the effects attributed to imported goods should be added to, and the effects attributed to exported goods should be deducted from, the domestic figures for the EU-27. However, the present level of methodological development and data availability are not sufficiently mature to be recommended for application in EF studies. The normalization factors published by the EC (Benini et al. 2014) rely on European domestic figures for 2010, as these have been identified as being the most robust for this kind of application. However, the reference year for the normalization data is a recurrent topic for discussion within EF contexts. In addition, alternative, global normalization approaches may be explored (Sala et al. 2016). Rockström et al. (2009)

 DOI: 10.1002/ieam.4064

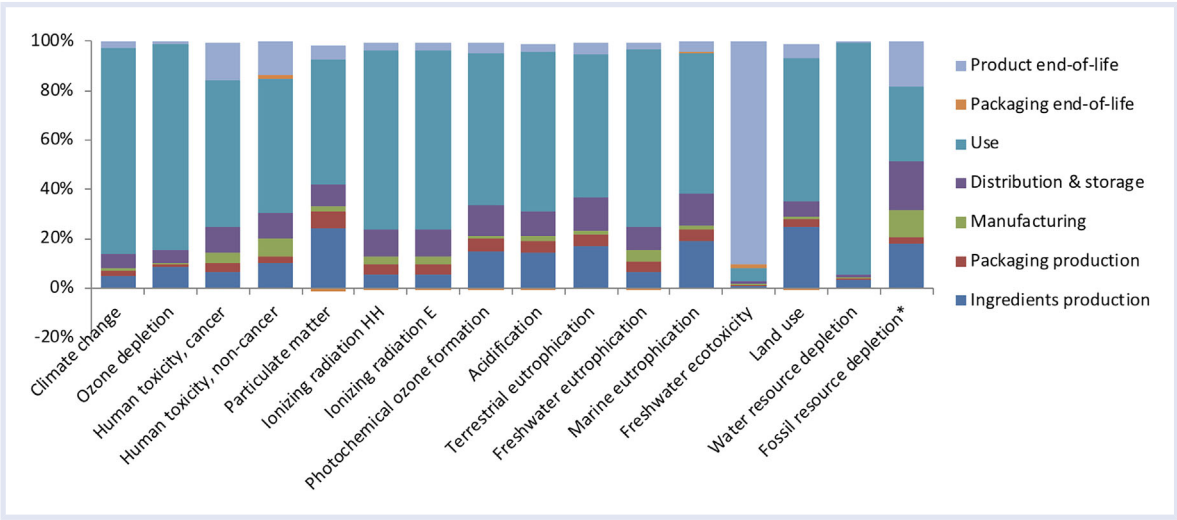

Figure 3. Screening study characterization results for one hair wash.
* Mineral, fossil, and renewable resource depletion.
E = ecosystems; HH = human health.

introduced the concept of planetary boundaries to identify the distance to the ideal reference state, and this could be of great interest.

Findings from the PEFCR development process

Development of a PEFCR for shampoo made it crystal clear that conducting a PEF requires specific scientific expertise, access to relevant data related to the product or service under investigation, and tailored software to handle and further process the huge data set. Even though the essential elements of a PEF calculation were already standardized by International Organization for Standardization norms years ago (i.e., ISO 14040 and 14025, both published in 2006), the huge complexity of calculating a PEF still requires substantial improvement (e.g., in terms of data quality), more harmonization, and improved standardization of methodology to ensure that results are driven by the product under study rather than by the methodology used or data variability. Just like the European Commission, Cosmetics Europe is committed to comprehensive, science-based assessment methodologies that take into account the full life cycle of products.

To date, only a very few cosmetic companies have sufficient internal resources and adequate in-house expertise enabling them to conduct PEF calculations on their own. Interested companies can, however, rely on external service providers for most of these elements and have PEFs on their products conducted with a minimum of their own contributions. The PEFCR for shampoos can be used for inspiration.

Applicability of results to other cosmetics

The currently developed PEFCR provides guidance for shampoos only, even though other personal care products may have similar functions. Yet, part of the results, and the findings derived from the development process, may also be applicable to other cosmetics.

For instance, the current study showed that the energy consumed to heat the water is one of the largest contributions to the overall impact of shampoo. Other studies confirm the importance of water temperature in the use stage for home care and personal care products (Koehler and Wildbolz 2009; Golsteijn et al. 2015). So, it is very plausible that this finding will also hold for other cosmetics with comparable chemical composition and use conditions (e.g., shower gels, liquid soaps, bath products) or other rinse-off products with ingredients of different chemical characteristics (e.g., hair conditioners).

The current study also resulted in default values for all life cycles stages. The PEFCR documentation provides justifications for all choices made, including references to important information sources that can be consulted for more information. In case of limited data availability for LCAs on other cosmetics, the values presented in the current study can be used as proxies or the literature referred to can be consulted for guidance otherwise.

In addition to the results and default values, the current study also resulted in important findings regarding the effect of the data quality, the general level of precision of PEF calculations, and the limitations regarding application of PEF results. The PEFCR should enable users to avoid overinterpretation of results, prevent wrong decisions on the basis of PEF calculations (e.g., product "optimization" into the wrong direction), and inadvertent abuse of the results by direct Comparison of footprint data for grading similar products. Other cosmetics that consider the use of PEF guidance for their LCA can benefit from these insights.

Finally, other cosmetics could also benefit from the potential steps to come. The vast majority of cosmetic products are composed of a substantial list of ingredients from a variety of sources. As indicated before (see Limitations), there are very limited primary data for many chemicals, and such data are expensive to generate and are updated infrequently. The current study recommends the development of a cost-efficient database of primary data, considering sourcing locations and manufacturing processes.

Such development would also be beneficial for cosmetics other than shampoos.

Practical implications

The current study showed that the use stage has a significant contribution to the EF. This is related to the energy that is required to heat the water. Consumer behavior is of crucial importance, and the variation between individuals is large. The importance of the use stage is also the main reason why the TS decided not to develop a benchmark and performance classes for product Comparisons but rather to focus on the consumers' use. Another reason is the limited

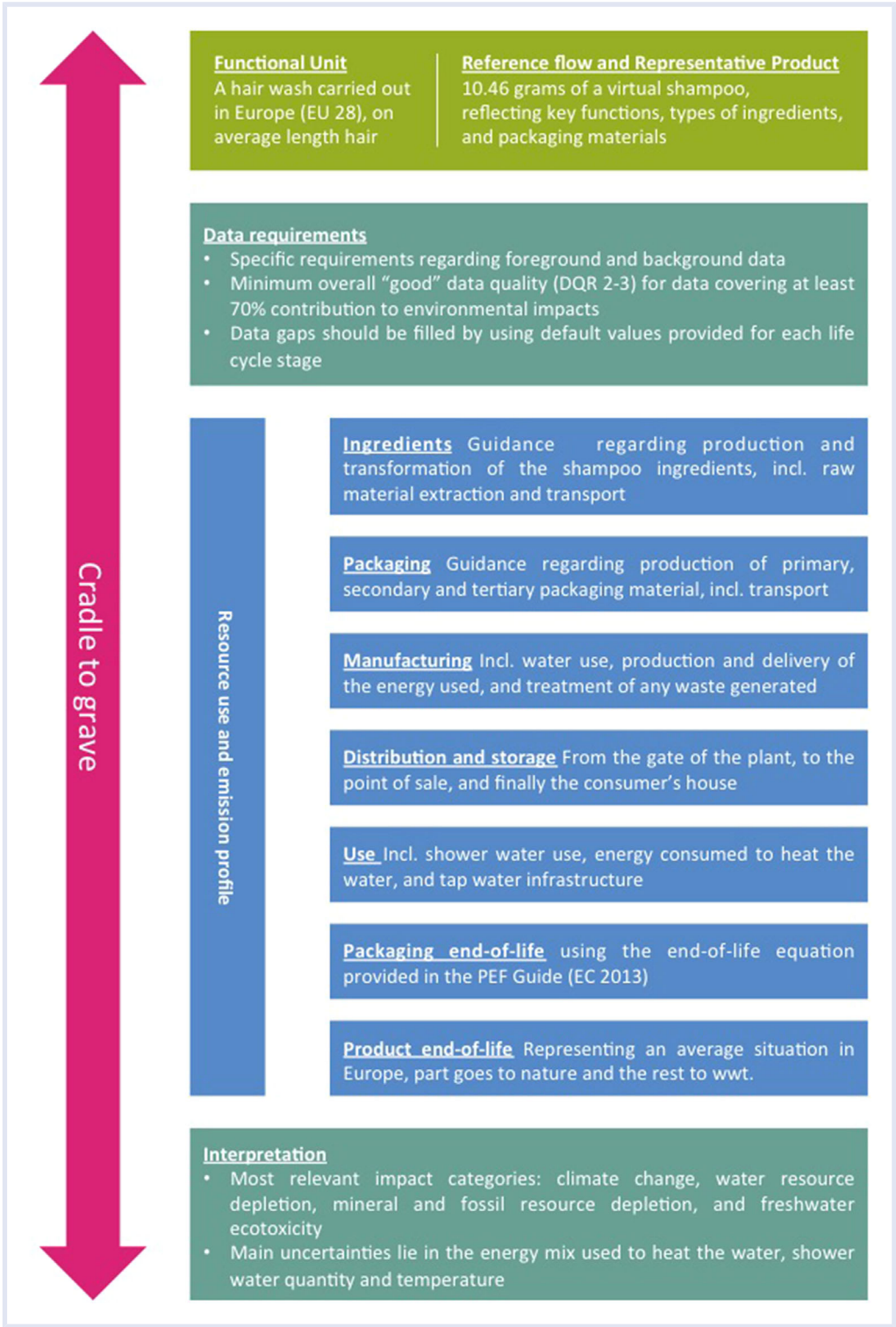

Figure 4. Summary of the PEFCR scope and guidance.

 DOI: 10.1002/ieam.4064

availability of primary data, which makes it very difficult to compare similar products. It has been shown before that the effect of personal care products on the environment would be reduced substantially if consumers could be encouraged to apply only correct product dosages and reduced water temperatures (Koehler and Wildbolz 2009). Showering habits are obviously difficult for the cosmetics companies to influence via product design. However, the industry has worked on the formulation of personal care products to improve rinse-off efficacy.

Although most of the environmental effect comes from product use and disposal, the industry is taking its responsibilities seriously and is acting at every life cycle stage. Individual member companies have taken initiatives to reduce the environmental impact of cosmetics and educate consumers. In addition, Cosmetics Europe developed a number of initiatives that support sustainable development. Examples include, for instance, the phasing out of solid plastic microbeads in wash-off personal care products or the development of best practices for complying with the European Union regulations regarding the access to and use of genetic resources.

In order to help consumers understand how to use shampoo sustainably, Cosmetics Europe has developed a package of publicly available communication materials. Part of this is a video that explains the EF of shampoo and ways to reduce it (https://www.cosmeticseurope.eu/videos/environmental-footprint-shampoo-and-possible-ways-reduce-it). Figure 1 is a still image from this video. Cosmetics Europe encourages the free use of their communication materials.

The current study assessed the feasibility and relevance of establishing PEFCR for shampoo. Cosmetics Europe aimed to provide its members with comprehensive and high-quality guidelines for assessing the environmental impact of shampoos. By sharing their experiences and findings in a specialized journal, Cosmetics Europe aims to enhance the communication of their work to a larger audience. After all, environmental footprinting studies may be used for a variety of purposes, including in-house management and participation in voluntary or mandatory programs.

Continuous EF developments

The current research project is based on PEF guidance version 5.1 (EC 2015). However, during the pilot phase, ongoing discussions within the official pilots led to continuous updates of the guidance documents and publication of additional technical issues papers. Important changes since version 5.1 include, for instance, the way end-of-life allocation is performed and the recommended impact assessment methodologies. However, updates in methodology were not taken into account because the project duration was much shorter than the EU Environmental Footprint Pilot Phase. To date, the official EF methodologies are not final. Guidance on reporting and verification, as well as the possibilities to convert a shadow PEF into an official PEF, is still to be decided.

At the time of study, a few deviations from the official guidance were already identified. To start, the formulation of the virtual representative product was not based on average European Union sales-weighted characteristics of all existing technologies. Instead, the TS constructed a virtual representative product containing commonly used ingredients from each functional group, as well as typical and realistic concentrations. The motivation for this deviation is that the overall pool of shampoo components amounts to several hundred chemicals, and individual formulations differ widely with regard to their qualitative and quantitative composition. However, shampoo formulations have common characteristics, in terms of ingredient functions: cleansing, viscosity control, pH adjustment, hair care and conditioning, perfuming, preservation. Therefore, the representative product was constructed as explained.

Furthermore, regarding the guidance on background data, the use of ecoinvent data is not in line with the PEF guidance, as these data are not available free of charge (see also "Input Data" section in *Discussion*).

In addition, the supporting studies of this "shadow" pilot have not been verified by the Commission, whereas for official PEF pilots the Commission will verify at least 1 of the PEF supporting studies. Moreover, in official PEF pilots, the final PEFCR will undergo review by an independent third-party panel composed of a minimum of 3 members. The shampoo PEFCR has not undergone such a review. Lastly, the shampoo PEFCR does not provide recommendations concerning reporting, disclosure, and communication.

In 2018, the official pilot phase ended with the approval of the final documents. At that point, there are PEFCR and OEFSR for measuring and communicating life cycle environmental performance of 23 product groups and sectors. Next, the Commission will assess the results of the pilot phase and consider possible policy options for a follow-up.

The current paper describes the development process for specific rules for performing environmental LCAs on shampoos, including difficulties encountered and recommendations for further research. It is not yet known what the future possibilities for the legal status of this document are, but at least it summarizes the recommended structure for establishing PEFCR for shampoo, based on the experiences and findings from Cosmetics Europe. This way, the PEFCR is an effective first step toward comparable LCAs for shampoos. As a result, it aids in raising public awareness of the EF of shampoo and in outlining ways in which companies and consumers can reduce this footprint. Our recommendations for further work on footprinting of cosmetics are summarized in Table 2.

Acknowledgment—The development of this PEFCR benefited from discussions with Dimitri Caudrelier and Sebastien Humbert (both Quantis).

Disclaimer—The companies that performed the supporting studies (i.e., Henkel, L'Oréal, and Pierre Fabre) declare that they have no conflict of interest.

Data Accessibility—Data are available upon request to Manuela Coroama, Cosmetics Europe, mcoroama@cosmeticseurope.eu.

SUPPLEMENTAL DATA

Table S1. Shampoo PEFCR summary.

REFERENCES

AFNOR. 2014. BP X30-323-5. General principles for an environmental communication on mass market products—Part 5: methodology for the environmental impacts assessment of shampoos and shower gels. St Denis (FR): AFNOR Groupe. [cited 2018 March]. https://www.boutique.afnor.org/standard/bp-x30-323-5/general-principles-for-an-environmental-communication-on-mass-market-products-part-5-methodology-for-the-environmental-impac/article/819330/fa183524

[AISE] International Association for Soaps, Detergents and Maintenance Products. 2014. Product Environmental Footprint (PEF). Brussels (BE): AISE. [cited 2017 July 17]. https://www.aise.eu/our-activities/sustainable-cleaning-78/contributing-to-the-eu-agenda/product-environmental-footprint-pef.aspx

Arif S. 2010. Technical Bulletin: Hair shampoos: The science & art of formulation. Cincinnati (OH): Pilot Chemical. [cited 2016 April]. http://ihrb-story.com/wp-content/uploads/2010/03/Shampoos-the_science_of_formulating_SM.pdf

Benini L, Mancini L, Sala S, Manfredi S, Schau E, Pant R. 2014. Normalisation method and data for environmental footprints. Luxembourg (LU): Publications Office of the European Union.

Bulle C, Fantke P, Jolliet O, Humbert S, Margni M, Kashef S. 2013. IMPACT World+. IMPACT World+ Team. [cited 2016 April]. http://www.impactworldplus.org/en/

Cellule éco-conception UCM. 2013. Quelles sont les activités consommatrices d'eau dans un salon. Brussels (BE). [cited 2016 April]. http://eco-conception.be/fr/page/eau.html

Cosmetics Europe. 2016. The environmental footprint of a shampoo and possible ways to reduce it [video]. [cited 2017 July]. https://www.cosmeticseurope.eu/videos/environmental-footprint-shampoo-and-possible-ways-reduce-it

De Schryver A, Brakkee K, Goedkoop M, Huijbregts M. 2009. Characterization factors for global warming in life cycle assessment based on damages to humans and ecosystems. *Environ Sci Technol* 43(6): 1689–1695.

De Schryver A, Galatola M, Goedkoop M, Kougoulis J. 2016. Guidance and requirements for handling the use stage in PEFCRs. Version 5.1. Brussels (BE): European Commission. [cited 2016 July 25]. https://webgate.ec.europa.eu/cas/login

[EC] European Commission. 2013. Commission recommendation on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations (2013/179/EU). Official Journal of the European Union. [cited 2017 July]. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013H0179

[EC] European Commission. 2015. Environmental Footprint Pilot Guidance document—Guidance for the implementation of the EU Product Environmental Footprint (PEF) during the Environmental Footprint (EF) pilot phase, version 5.1. Brussels (BE): European Commission. [cited 2017 July]. https://webgate.ec.europa.eu/cas/login

[EC] European Commission. 2016. Single market for green products initiative. Brussels (BE): European Commission. [cited 2017 July 17]. http://ec.europa.eu/environment/eussd/smgp/

[EC-JRC] European Commission–JRC. 2011. ILCD handbook. Recommendations for Life Cycle Impact assessment in the European context—based on existing environmental impact assessment models and factors. Ispra (IT): European Commission Joint Research Centre. [cited 2017 July]. http://eplca.jrc.ec.europa.eu/uploads/ILCD-Recommendation-of-methods-for-LCIA-def.pdf

Escamilla M, Ferrer A, Fuentes N, Hidalgo C, Kaps R, Kougoulis JS. 2012. Revision of the European Ecolabel criteria for soaps, shampoos and hair conditioners: Preliminary results from the technical analysis. Seville (ES): European Commission (JRC-IPTS) and Barcelona (ES): LEITAT Technological Center. [cited 2017 July]. http://susproc.jrc.ec.europa.eu/soaps_and_shampoos/docs/Technical%20analysis%20draft%20report.pdf

Frischknecht R, Jungbluth N, Althaus H-J, Doka G, Dones R, Heck T, Hellweg S, Hischier R, Nemecek T, Rebitzer G, Spielmann M. 2005. The ecoinvent database: Overview and methodological framework. *Int J Life Cycle Assess* 10:3–9.

Garnier-Laplace J, Copplestone D, Gilbin R, Alonzo F, Ciffroy P, Gilek M, Agüero A, Björk M, Oughton DH, Jaworska A, Larsson CM, Hingston JL. 2008. Issues and practices in the use of effects data from FREDERICA in the ERICA Integrated Approach. *J Environ Radioact* 99:1474–1483.

Goedkoop M, Spriensma R. 2001. The Eco-indicator 99: A damage oriented method for Life Cycle Impact Assessment. Methodology Annex. Amersfoort (NL): PRe Sustainability. [cited 2017 July]. https://www.pre-sustainability.com/download/EI99_annexe_v3.pdf

Golsteijn L, Menkveld R, King H, Schneider C, Schowanek D, Nissen S. 2015. A compilation of life cycle studies for six household detergent product categories in Europe: The basis for product-specific A.I.S.E. Charter Advanced Sustainability Profiles. *Environ Sci Eur* 27:23.

Hall B, Steiling W, Safford B, Coroama M, Tozer S, Firmani C, McNamara C, Gibney M. 2011. European consumer exposure to cosmetic products, a framework for conducting population exposure assessments Part 2. *Food Chem Toxicol* 49(2):408–422.

Humbert S, De Schryver A, Margni M, Jolliet O. 2012. IMPACT 2002+: User Guide—Draft version Q2.2 (version adapted by Quantis). Lausanne (CH): Quantis. [cited 2016 April].

Humbert S, Dubois C, Guignard C, Pedrazzini S, Adams A, Léglise P, Lim L, Vets V, Vermaut E, Vermeiren F, et al. 2017. Organisation environmental footprint sector rules (OEFSR): Retail. Lausanne (CH): Quantis. [cited 2017 August]. https://webgate.ec.europa.eu/cas/login

[ISO] International Organization for Standardization. 2006a. Environmental labels and declarations: Type III environmental declarations—Principles and procedures. Geneva (CH): International Organization for Standardization. 25 p.

[ISO] International Organization for Standardization. 2006b. ISO 14040-2006, Environmental management—Life cycle assessment—Principles and framework. Geneva (CH): International Organization for Standardization. 20 p.

Jolliet O, Margni M, Charles R, Humbert S, Payet J, Rebitzer G, Rosenbaum R. 2003. IMPACT 2002+: A new life cycle impact assessment methodology. *Int J Life Cycle Assess* 8(6):324–330.

Kaps R, Kougoulis JS, Escamilla M, Hidalgo C, Fuentes N, Escudero R. 2012. Revision of the European Ecolabel criteria for soaps, shampoos and hair conditioners: Background report including revised draft criteria proposal. Seville (ES): European Commission (JRC-IPTS) and Barcelona (ES): LEITAT Technological Center. [cited 2017 July]. http://susproc.jrc.ec.europa.eu/soaps_and_shampoos/docs/Technical%20background%20draft%20report.pdf

Koehler A, Wildbolz C. 2009. Comparing the environmental footprints of home-care and personal-hygiene products: The relevance of different life-cycle phases. *Environ Sci Technol* 43(22):8643–8651.

Lessard L, Pedrazzini S, Humbert S, Dubois C, Coroama M. 2016. Study into the development of Product Environmental Footprint Category Rules for shampoo. Lausanne (CH): Cosmetics Europe. [cited 2016 April]. https://www.cosmeticseurope.eu/how-we-take-action/driving-sustainable-development/

Making Cosmetics Inc. 2016. Shampoo formulas. Redmond (WA). [cited 2017 July]. http://www.makingcosmetics.com/Shampoo-Formulas_ep_90.html

Mottram FJ, Lees CE. 2000. Hair shampoos. In: Butler H, editor. Poucher's perfumes, cosmetics and soaps. 10th ed. Dordrecht (NL): Springer Science+Business Media. p 289–306.

Pawelzik P, Carus M, Hotchkiss J, Narayan R, Selke S, Wellisch M, Weiss M, Wicke B, Patel MK. 2013. Critical aspects in the life cycle assessment (LCA) of bio-based materials: Reviewing methodologies and deriving recommendations. *Resour Conserv Recycl* 73:211–228.

Pfister S, Koehler A, Hellweg S. 2009. Assessing the environmental impacts of freshwater consumption in LCA. *Environ Sci Technol* 43(11): 4098–4104.

Provo J, Zahller M, Marincovic C, Koffler C. 2013. Life cycle assessment of selected fragrance materials. Boston (MA): PE International & Five Winds Strategic Consulting. 64 p.

Rockström J, Steffen W, Noone K, Persson A, Chapin III FS, Lambin E, Lenton TM, Scheffer M, Folke C, Schellnhuber H, et al. 2009. Planetary boundaries: Exploring the safe operating space for humanity. *Ecol Soc* 14(2):32.

Sala S, Benini L, Crenna E, Secchi M. 2016. Global environmental impacts and planetary boundaries in LCA; EUR 28371 EN; JRC technical report. Ispra (IT): European Commission–JRC. [cited 2017 July]. DOI: 10.2788/64552

Wernet G, Bauer C, Steubing B, Reinhard J, Moreno-Ruiz E, Weidema B. 2016. The ecoinvent database version 3 (part I): Overview and methodology. *Int J Life Cycle Assess* 21(9):1218–1230.

