SCORELCA

STUDY No. 2019-02

RECYCLING OF PLASTICS AND LCA

Summary

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Scientific Managers

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The SCORE LCA association is a study and research structure that focuses on the Life Cycle Assessment (LCA) and environmental quantification. It aims to promote and organise cooperation between companies, institutions and scientific bodies to encourage shared and recognised changes, both in Europe and internationally, in the Life Cycle Assessment method and its practical application.

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- ✓ The views and recommendations expressed in this document are those of the authors only and do not necessarily reflect the opinion of all members of SCORE LCA unless stated otherwise.

- ✓ The information and conclusions presented in this document are based on scientific and technical data and on the regulatory and normative framework in force at the time of publication.

SYNTHESIS

A. CONTEXT AT STUDY LAUNCH

Plastic materials have gradually become important in miscellaneous sectors of our economy and their production has more than tripled worldwide in some thirty years (about 350 million tonnes against 105 million tonnes in 1990). The packaging, construction and automotive sectors alone account for nearly 70% of plastic consumption in Europe.

This growth goes hand-in-hand with increasing concerns over their effects on health and the environment. What becomes of them at end of life is a central to these concerns: limited recycling rate, impossibility of recycling them due to presence of additives or a problem of compatibility with other materials or between polymers, effects on the environment and living beings when dumped in nature, etc.

In addition, China, which until now has been importing huge amounts of plastic waste from Europe and the USA, has tightened its import conditions in recent years (under its Green Fence programme launched in February 2013), thereby accelerating the need to find alternative recycling and recovery solutions.

These multiple challenges have forced public authorities and players in the plastics sector to accelerate the number and scope of regulatory and voluntary measures to prevent and recycle plastics and integrate recycled plastics.

A key measure in France is to make sorting instructions standard for all household plastic packaging, which is a major lever in developing recycling of plastics.

More recently, the Circular Economy Road Map (FREC) set a target of fully recycled plastics in 2025 with the aim of preventing an additional 8 million tonnes of CO_2 from being emitted every year thanks to plastic recycling. The FREC is also aiming to accelerate voluntary commitments to increase the integration of recycled plastics, particularly in the packaging, construction, automotive and electronic and electrical equipment sectors.

Several members of SCORE LCA view plastic recycling and the integration of recycled plastics as important and even strategic matters given their direct involvement in the production of virgin plastics and/or in plastic recycling activities or their commitments to using recycled plastics.

B. AIMS OF WORK

▼ Observation

The members of SCORE LCA and Bleu Safran share the view that many LCA studies fail to take into account fully the end-of-life management of plastic waste, especially its recycling, due to the following limitations:

- **Limited knowledge of what actually happens in the plastic waste recycling chain**: the work can especially rely on a simplistic - and therefore inadequate - representation of the successive steps required to move from waste to be collected to recycled plastic. There is a noted tendency to under-estimate these steps, with the possible corollary of under-estimating the impacts as well as possibly misjudging the plastics lost along the chain (issue on the recycling rate).
- **Recourse to data and statistics that are not always appropriate** to describe the key parameters of LCA modelling (e.g. collection rate, regeneration output, etc.)
- **Insufficient consideration given to recycling disruptors and more generally recyclability issues**, which can depend on the intrinsic characteristics of plastics, other design choices by marketers as well as technical-economic orientations and the organisation of existing recycling channels.
- **Accounting and allocation rules** that are not always explained or do not always seem appropriate to the aims of the work.

▼ Ambition

SCORE LCA wishes through this study **to encourage and harmonise LCA work on plastic waste recycling**.

In agreement with the members of SCORE LCA, the work, launched during 2019, focuses on the mechanical recycling of plastic waste.

The "business" description of recycling chains covers:

- Plastic waste known as "post-consumption" waste
- The polymers that are already widely recycled or which represent significant recycling potential
- Industrially well-established recycling techniques, bearing in mind that mechanical recycling processes account for 99% of recycled plastic tonnage in France to date according to 2ACR.

The following sectors that produce plastic waste are thus described in this study:

- household and industrial packaging
- end-of-life vehicles
- electrical and electronic equipment

Polymers studied	Packaging		ELV	WEEE		
	Domestic	Industrial		SDA	LHA cold	LHA non cold
PP	x		x	x	x	x
PS		x (PSE)		x	x	x
PET	x					
HDPE	x		x			
LDPE	x					

x: Mechanical recycling only, current French context

ELV: end-of-life vehicles
SDA: small domestic appliance
LHA: large household appliance

FIGURE 1 - POLYMER/SECTOR/RECYCLING TYPE COMBINATIONS TARGETED IN THE STUDY

Chemical recycling processes for plastic waste are not studied as part of this work. Initial thought is nevertheless given to the technical aspects and methodological challenges raised by this family of processes and is therefore presented in Section J of the full report.

C. RECYCLABILITY OF PLASTICS

For an LCA study covering a specific given product[1] which is made up partially or totally by plastics, the quantification of the impacts from the end-of-life management of plastic waste from this product raises the question of the recyclability of the constituent plastic(s) of the product studied.

For example, the PEF (Product Environmental Footprint) guidelines drawn up on environmental labelling in Europe state that the design and composition of a given product must be taken into account to determine whether or not a material found in this product is suitable for recycling. The PEF method therefore lays down several criteria on recyclability and states that where one of these criteria is not met, the R2 value (recycling rate) must be considered as nil (0%).

The full study report therefore includes a section specific to the question of recyclability, which explains and illustrates the "business" implications raised by the use, including historic, of certain plastic additives and more broadly certain design choices of products made up of plastics in recycling chain operations.

Based on the end-of-life channels and successive sorting steps applied by the sorting and recovery operators for these channels, the plastics found in the waste in question are likely **to be eliminated from the recycling flows** because of:

- **Their density when this is similar or greater** than that of plastics containing additives subject to restriction and needing to be extracted from recycling flows
- **Technical and economic trade-offs** by plastic sorting and recovery operators, as these choices mean separating certain "target" polymers that will be recycled from other "non-target" polymers that will not be recycled.

  These trade-offs are not necessarily the same from one end-of-life channel to the next and can change over time in line with economic conditions, the arrival of products placed on the market, technical evolutions in processes, etc.
- For the "target" polymers, **changes in density** from using fillers or blowing agents compared with the usual density of the polymer
- **Their colour** (e.g. dark colours)
- **Other design choices** that can culminate in eliminating these materials from the recycling

In addition, certain non-recycled plastics are also likely **to disturb the recycling of other plastics**, by complicating the sorting/refining steps and even by downgrading the properties of recycled plastics by being present.

In terms of "target" plastics, **correctly identifying the successive** treatment **steps** and **efficiently separating** these plastics during sorting are key points.

D. SECTOR ANALYSES

Specific sector analyses have been conducted for plastic waste generated by:

- The household packaging sector
- The ELV sector
- The WEEE sector, by treating cases of household WEEE from large equipment (refrigerators, washing machines, ovens, etc.) and small household appliances.
- The industrial and commercial packaging sector in the particular case of expanded PS

These sector analyses aim to present the effective organisation of plastic waste recycling in these channels and to highlight the key points to be retained for LCA work in terms of these channels and plastic waste recycling under these channels.

[1] For example, situation A "Micro-level decision support" and situation C "Accounting" in the "ILCD Handbook - General guide for LCA"

Each sector analysis is handled according to the same standard plan which includes the following aspects:

- An introductory section on the sector including especially regulatory and operational aspects, a comment on the type of polymers concerned and on the quantities involved.
- A section offering MFA (multi-factor authentication) qualitative overviews
- A section detailing plastic waste management for its step-by-step recycling

MFA qualitative overviews

These overviews are shown as commented figures. Each figure proposed covers the special case of a resin in a type of product or type or part specified. For example, for the household waste channel, qualitative MFA overviews are proposed for:

- Bottles and flasks in clear PET
- Pots and trays in clear PET
- Pots and trays in PS
- Films and flexible wrappers in PE

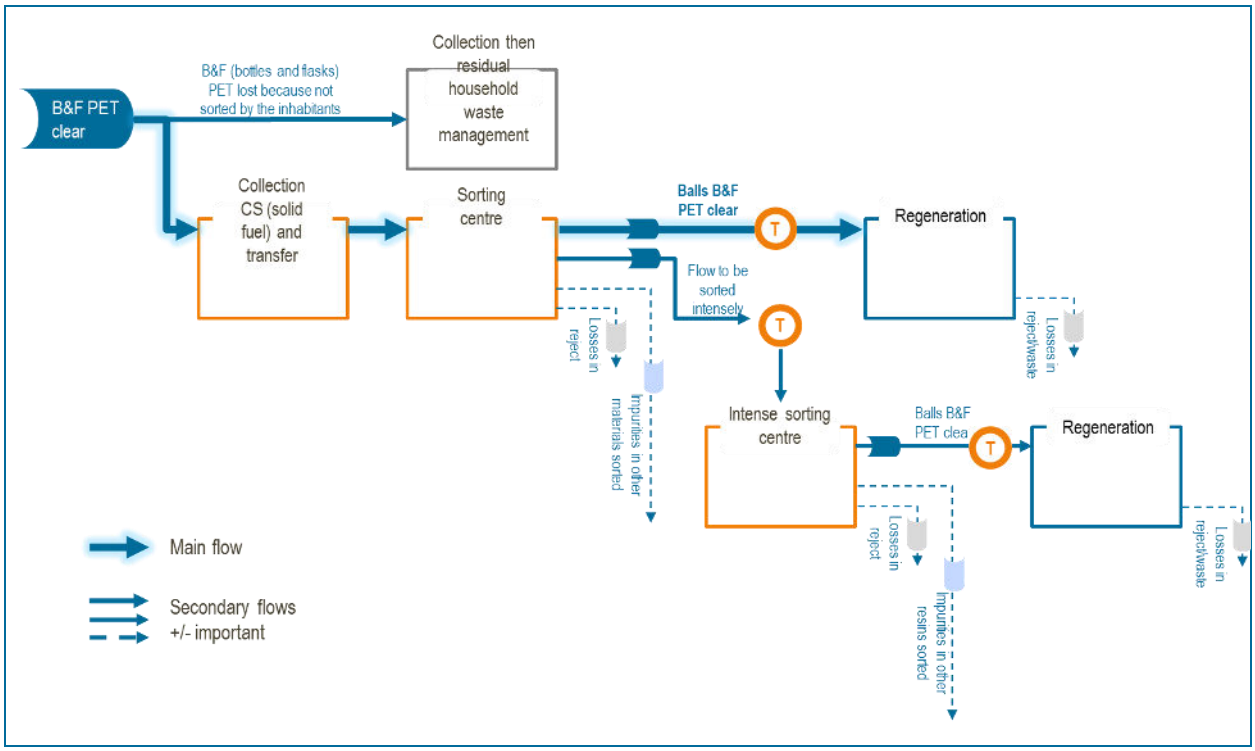

FIGURE 2: EXAMPLE OF MFA QUALITATIVE OVERVIEW - CASE OF BOTTLES AND FLASKS IN CLEAR PET

These overviews can highlight the flows mainly followed by a category of plastic packaging and to distinguish them from secondary flows which may be important to a more or less marked degree.

The representations proposed under this work remain qualitative and apply to the organisation of waste management in France. These representations should be quantified for the purpose of an environmental assessment. They cannot be ignored for the following reasons:

- They identify the steps to be considered in the assessment scope and the tonnages to which these steps apply;
- They may possibly identify the steps that could be approximated or ignored (minimum tonnages);
- Lastly, they determine all the flows likely to correspond to losses of material.

The representations proposed apply to end-of-life management in France for the current period. They may be different for a same polymer/product pairing:

- In another country;
- In France at another time, for example in ten years.

Detail per step for recycling management

This type of section details the various steps in plastic waste management in the sector in question from the selective collection stage up to regeneration.

The same structure is used for each step addressed:

- A summary of key issues or points of attention for an environmental assessment
- A figure highlighting the quality of the incoming flow(s) and outgoing flow(s) as well as the utilities, consumables, discharges and emissions; similarly, this figure shows a diagram of possible sub-steps within the step.

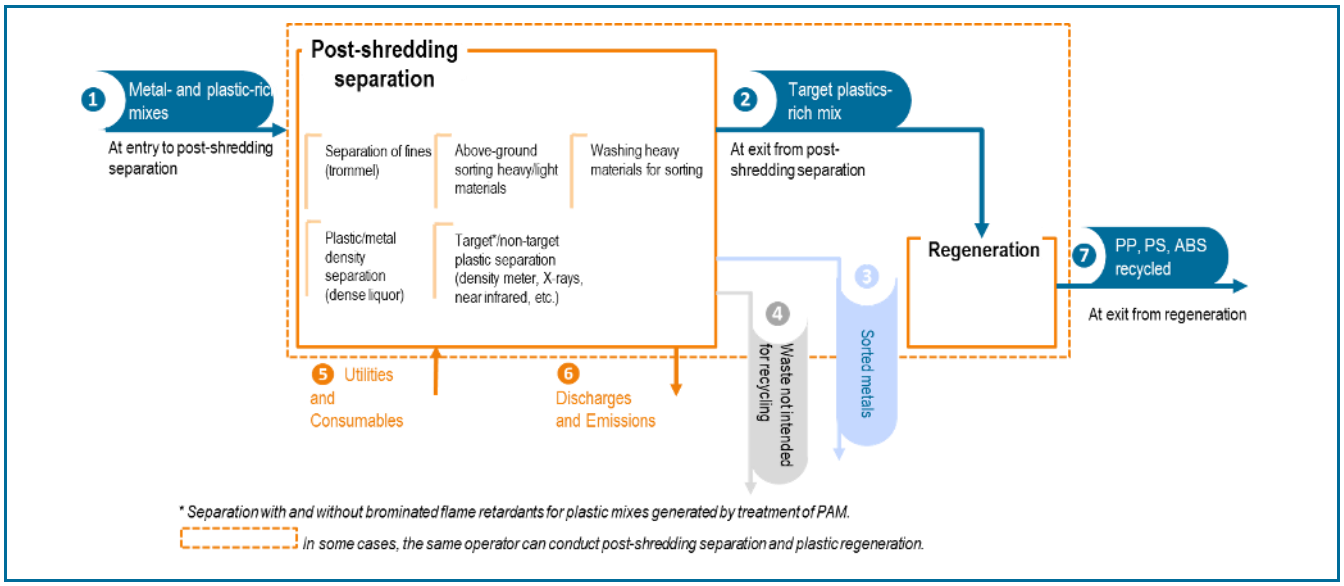

FIGURE 3: EXAMPLE OF SCHEMATIC FIGURE OF A STEP - CASE OF POST-GRINDING SEPARATION OF PLASTIC- AND METAL-RICH MIXES FOLLOWING WEEE PROCESSING

- A general explanation about the step;
- More detailed information on:
  - Incoming flow(s);
  - Outgoing flow(s);
  - Utilities and consumables;
  - Discharges and emissions.

Potentially useful information or data for the environmental assessment can be presented as time goes on. The section devoted to a given step concludes with a presentation of the potentially useful bibliography.

E. PLASTIC RECYCLING RATE - A FEW MARKERS

The recycling rate is an indicator used to try and account for the proportion of a category of given waste that is recycled. It is calculated on the basis of conventions; these may vary according to the type of waste and over time and should preferably be known when wishing to exploit this type of quantity.

The work conducted does not aim to produce an exhaustive, commented list of the values of plastic recycling rates that may be published. Conversely, by exposing a few peculiarities in these calculations, the study aims to call on the users of these data to be constantly vigilant so that they are sure that the quantity exploited corresponds to what they wish to represent.

The reader will thus find in the detailed section included in the full report:

- A comment on the data published by EUROSTAT regarding the plastic recycling rates
- A reminder of a few critical observations that have been formulated on these data
- A comment on current changes in these European statistics
- An illustrative presentation of a few conventions that can be used in recycling rate calculations
- Consideration of the recycling rates under the PEF

F. BIBLIOGRAPHICAL ANALYSIS

This part of the study covers the analysis of a selection of relevant bibliographical resources proposing life cycle inventories of recycled materials or life cycle analyses of plastic recycling. The works covered by this in-depth analysis are as follows:

- **Work by SRP** on the eco-profiles of plastic recycled materials: http://www.srp-recyclage-plastiques.org/index.php/donnees-recyclage/icv-des-mpr.html
- **Work by Franklin Associates**: Franklin Associates. Life cycle impacts for post-consumer recycled resins: PET, HDPE, and PP. Submitted to The Association of Plastic Recyclers. December 2018. 49 p.
- **Work by Haupt and Kägi**: Haupt M., Kägi T., Hellweg S. Life cycle inventories of waste management processes. Data in Brief. Volume 19, August 2018, Pages 1441-1457
- **Work by Shen**: Shen, Li & Worrell, Ernst & Patel, Martin. (2010). Open-loop recycling: A LCA case study of PET bottle-to-fibre recycling. Resources, Conservation and Recycling. 55. 34-52. 10.1016/j.resconrec.2010.06.014.
- **Work by Wäger et Hischier**: Patrick A. Wäger, Roland Hischier, Life cycle assessment of post-consumer plastics production from waste electrical and electronic equipment (WEEE) treatment residues in a Central European plastics recycling plant, Science of The Total Environment, Volume 529, 2015, Pages 158-167, ISSN 0048-9697.

		SRP	Franklin	Kägi & Haupt	Shen *et al.*	Wäger *et al.*
Type of recycled materials studied (FG/NFG: Food Grade/Non Food Grade)						
PET	Flakes	✓	✓	✓	✓	
	Pellets	✓	✓FG	✓FG	✓ NFG	
PP	Shredded	✓				✓
	Pellets		✓	✓		
PS	Shredded	✓				✓
	Pellets			✓		
HDPE	Flakes	✓	✓			
	Pellets	✓	✓	✓		
PEBD	Flakes					
	Pellets	✓				
Other	Shredded	PVC				ABS
	Pellets					
Geographical area of recycled material production						
PET		FR	US, CA, MX	CH	CN, EU	AT
PP			US, CA			
PS						
HDPE			US	CH		
PEBD						
Other						

These works can be from a top-down or bottom-up perspective; they can relate to various types of plastic recycled materials (PET flakes, PET pellets, shredded PP, PP pellets, shredded PS, PS pellets, etc.), different geographical areas (France, Europe, United States, China, etc.) and different sectorial origins (packaging, WEEE, unspecified).

Top-down perspective: the starting point is a given waste source, often defined by a sector of activity and a geographical collection area (e.g. household plastic packaging waste in the US) and we follow the steps in the recycling chain of this waste source from collection to regeneration

Bottom-up perspective: the starting point is the activity of one or more regenerators, for example members of the same trade union, and the sources of waste supplying their activity and we go backwards to identify the previous stages in the recycling chain and their geographical location

This review of the literature can highlight or confirm a certain number of issues and limitations on the current practices in LCA modelling of plastic recycling.

Pre-regeneration steps sometimes under-estimated

Depending on the study, the consideration of the management steps from collection to entering regeneration may be insufficiently explained and documented, or even conducted in a simplistic manner. In certain cases, these pre-regeneration steps are even excluded as assumed negligible.

Under post-consumer waste management channels, the environmental contribution of the pre-regeneration steps must be considered significant compared with the regeneration steps and must therefore be analysed and quantified with the same care as the latter steps.

Variable granularity of work to establish recycled plastic LCI

Work on the environmental profiling of recycled plastics addresses the nature of the recycled plastics in different ways:

- Some work states the type of format covered (e.g. flakes, shredded, pellets).
- Other work establishes profiles that cover the diversity of formats produced within a regenerator or group of regenerators without otherwise documenting the format mix thus covered.

This should be considered in view of the fact that the use of a recycled plastic may depend on its format (and more generally on all its characteristics). Moving from one format to another, for example transforming plastic flakes into pellets or food-grade pellets, necessitates steps that make a potentially significant contribution to the environmental profile.

Accounting for the subsequent management of outgoing flows from management steps other than the flow containing the target plastics

Save for exceptional cases, the pre-regeneration steps produce different outgoing flows, these being all the waste flows. One flow can be considered as the target flow that contains the target resin(s); it is destined to continue its route through the successive steps necessary to recycle the target resins. The other outgoing flows (non-target flows) will continue to be managed specifically, based on their composition and their characteristics and the recovery and clean-up/treatment goals they have to meet.

The rules followed by the authors in terms of accounting for the subsequent management of these outgoing flows other than the target flow are rarely explained very clearly. Practices can nevertheless be seen to vary.

Some authors account for the subsequent management of non-target flows, whether these flows are ultimately destined for treatment or for recovery operations. Recovery operations can be accounted for by following the rules for extending the system boundaries: the benefits of energy substitution (for example, when recovering a non-target flow as CSR in high energy performance installations) or material substitution (for example, for a metal-rich fraction that may be recycled) are then allocated to the recycling of target plastics or to the production of recycled plastic.

Other authors prefer to consider the non-target flows which leave a given step as co-products of the target flow; the impacts of this step are then split between the different co-products including the non-target flow.

Depending on the work objectives, these various methodological orientations can or cannot be justified. In all circumstances, it is important to be aware of their potentially significant influence on the results, especially in the case of plastic recycling of post-consumer waste of complex products.

Allocation of loads of a management step between the different "co-products"

When the miscellaneous outgoing flows from a step are considered to be co-products, the literature shows that the authors can adopt a variety of rules in allocating these loads between co-products:

- Some allocate all loads to a single target flow; the other co-products thus receive no load from the step in question.
- Other authors allocate loads between co-products; some by mass allocation; others by economic allocation.

It is also noted that within a same study, the allocation rules applied can differ according to the load "items" in question (e.g. energy consumption, waste management) or according to the type of co-product.

Activity data relating to the process emissions/discharges are not always explained

This can reveal a risk of failing to take certain discharges into account sufficiently, for example, emissions generated by dust, volatile organic compound or micro-plastics.

G. RECOMMENDATIONS FOR TRANSPARENCY AND METHODOLOGICAL IMPLEMENTATION

This final section of the study is devoted to formulating methodological recommendations and documentation for work covering the environmental assessment of plastic waste recycling.

A first part of the section focuses on the question of traceability and transparency of environmental assessment work relating to the issue of plastic recycling. From this perspective, this study proposes a "sheet" that lists and structures the aspects that merit being documented and submitted when the results of the environmental assessment on plastic recycling are broadcast. In addition to ensuring the traceability and transparency of the work, this documentation is intended to encourage its subsequent appropriate use by third parties.

The documentation is arranged under the following headings that are commented and illustrated in the full report as they are presented:

Heading A | Scope of the assessment

- A1 | Identification/characterisation of the target plastic
- A2 | Identification/characterisation of the recycled material
- A3 | Type of approach (top-down or bottom-up)
- A4 | Identification/characterisation of waste containing the target plastic studied
- A5 | Geographical representativeness
- A6 | Reference unit

Heading B | Attributional LCA/Consequential LCA/Other

Heading C | Perimeter

Heading B | Methodological accounting and allocation rules

- D1 | Accounting for the impacts and benefits of subsequent management of non-target flows
  - D11 | Subsequent management of non-target flows - constituents other than the target plastic
  - D12 | Subsequent management of non-target flows - target plastic
  - Compatibility with the calculation point of recycling rate R2
- D2 | Allocation of loads between co-products

In the full report, the second part of this section provides additional explanations and clarifies the underlying issues in the headings that would merit being documented.

As recycling is at the border between two life cycles, the supplier life cycle of the waste to be recycled and the user life cycle of the recycled material raises, for example, the question of how to allocate the impacts and benefits associated with the steps in the recycling chain between these two cycles.

The report also sets out elements of analysis as to the specific features of steps in waste treatment and their consideration when allocation choices have to be made. Thus, certain methodological options are discussed in connection with the different environmental assessment goals and contexts, in particular for work falling under the PEF methodological framework (Product Environmental Footprint, Europe). A view on the choices that would have to be made in a particular assessment context can also be presented in this part.