UNIVERSITÉ DU QUÉBEC À MONTRÉAL

ACCOUNTING FOR FRENCH CONSUMER'S BEHAVIOURS TO IMPROVE THE POCKET LIGHTERS LIFE CYCLE ANALYSIS

MÉMOIRE

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LIST OF ABBREVIATIONS

ACV : Analyse du cycle de vie

CIRAIG : Centre international de référence sur le cycle de vies de produits, procédés et services

CLCA L : Life cycle cost analysis

ELCA : Environmental life cycle analysis

LCA : Life cycle analysis

LCI : Life cycle inventory

LCIA : Life cycle impact assessment

POM : Polyoxymethylene

SLCA : Social life cycle analysis

RÉSUMÉ

Les briquets sont l'une des sources de plastique retrouvées dans l'environnement. Aujourd'hui, les mécanismes par lesquels les briquets se retrouvent dans l'environnement sont très mal compris et des scénarios hypothétiques sur le comportement des consommateurs sont pris en compte lors de l'analyse de cycle de vie (ACV), surtout en ce qui concerne la phase d'utilisation et de fin de vie du produit, ce qui fait en sorte que les résultats obtenus sont incertains et potentiellement sous-évalués. De ce fait, il est essentiel de documenter de manière plus fine les comportements d'usage et de fin de vie réelle des consommateurs à l'aide de données primaires. Ceci viendra contribuer de manière importante à la robustesse de ces études et permettra de mieux caractériser l'empreinte environnementale des briquets de poche. L'étude a donc comme objectif principal de mieux comprendre le comportement des utilisateurs, la manière dont ils disposent de leurs briquets en phase d'usage et de fin de vie dans le but d'améliorer la robustesse des études ACV. Pour ce faire, une méthodologie en deux phases a été développée. La première phase consiste à développer de nouvelles hypothèses plus réalistes à partir des données primaires collectées sur le comportement des utilisateurs français et Françaises en phase d'utilisation et de fin de vie des briquets. La deuxième phase consiste à intégrer nos nouvelles hypothèses à une ACV antérieure des briquets de poches et ainsi tester la sensibilité des modèles lorsque des hypothèses d'usage et de gestion de la fin de vie plus robustes sont intégrées dans ce type de travaux. Les résultats obtenus démontrent que les scénarios hypothétiques précédemment utilisés dans l'ACV du briquet surévaluent la durée de vie et le nombre d'utilisations de chaque briquet, et que les impacts environnementaux réels du briquet ont donc été significativement sous-évalués. En effet, l'un des principaux résultats de l'enquête démontre que le nombre d'activations - l'acte d'allumage du briquet - au cours de la durée de vie réelle du briquet est nettement inférieur à celui des études théoriques, 720 activations contre 3000 activations. En outre, différentes approches de fin de vie ont été détectées dans l'enquête qui n'avaient pas été prises en compte par l'ACV théorique: élimination formelle comme d'autres déchets domestiques qui finissent dans les canaux de gestion des déchets et des briquets perdus à l'extérieur et à l'intérieur. De ce fait, il a été constaté que l'utilisation de données primaires sur le comportement des utilisateurs en phase d'utilisation et de fin de vie, nous permet de faire des hypothèses plus robustes et ainsi nous permet de faire une analyse de cycle de vie plus robuste.

Mots clés: Analyse de cycle de vie, phase d'utilisation, phase de fin de vie, modèle comportementale, briquets.

SUMMARY

Lighters are one of the sources of plastics found in the environment. Today, the mechanisms by which lighters end up in the environment are poorly understood and hypothetical scenarios of consumer behavior are considered in life cycle assessment (LCA), especially in the use and end-of-life phase of the product, which makes the results obtained uncertain and potentially underestimated. As a result, it is essential to document in greater detail the actual use and end-of-life behavior of consumers using primary data. This will contribute significantly to the robustness of these studies and will better characterize the environmental footprint of pocket lighters. The main objective of the study is therefore to better understand the behavior of users, the way they dispose of their lighters in the use and end-of-life phase to improve the robustness of LCA studies. To do so, a two-phase methodology has been developed. The first phase consists in developing new and more realistic hypotheses from the primary data collected on the behavior of French users in the use and end-of-life phases of lighters. The second phase consists in integrating our new assumptions to a previous LCA of pocket lighters and thus testing the sensitivity of the models when more robust usage and end-of-life management assumptions are integrated in this type of work. The results show that the hypothetical scenarios previously used in the lighter LCA overestimated the lifespan and number of uses of each lighter, and that the actual environmental impacts of the lighter were therefore significantly underestimated. Indeed, one of the main results of the investigation shows that the number of activations - the act of lighting the lighter - during the actual lifetime of the lighter is significantly lower than in the theoretical studies, 720 activations versus 3000 activations. In addition, different end-of-life approaches were detected in the survey that were not considered by the theoretical LCA: formal disposal as other household waste that ends up in waste management channels and lost lighters outside and inside. As a result, it was found that the use of primary data on user behavior in the use and end-of-life phase, allows us to make more robust assumptions and thus allows us to make a more robust life cycle analysis.

Keywords: Life cycle assessment, use phase, end of life phase, behavioral model, lighters.

INTRODUCTION

This project has been realised in the context of a broader project in collaboration with BIC lighters company, aiming at better understanding lighters behaviour in term of use and end of life of lighters, understanding the determinant of this behaviour and how this behaviour could be influenced to reduce the environmental impact of lighters.

In this specific project, based on the survey that has been conducted in the broader project, my main objective has been to better understand the environmental performance of BIC lighters by improving an existing life cycle assessment of lighters to better account for the users declared behaviour (current behaviour, but also potential prospective behaviour if additional end of life facilities were offered).

LITTERATURE REVUE

Life cycle analysis

The energy crisis of the 1970s and the publication of the Limits of Growth report were two major events that gave rise to an increased awareness of the environment (Gisèle Belem, 2005). One of the consequences of this awareness was the implementation of the Environmental Profile and Resource Analysis (EPRA). This approach consisted of evaluating the energy resource impacts that a product could have and, in 1969, Coca-Cola was the first company to use this approach to compare the energy consumption of two types of containers for their drinks (Gisèle Belem, 2005). However, rather than being restricted to the evaluation of energy resources, LCA has extended its scope of analysis to include the use of other resources as well as the impacts of emissions and the creation of waste. (Gisèle Belem, 2005)
Today, according to the ISO organization, which standardized the methodology of life cycle assessment, LCA can be defined as "a method that studies the direct, indirect and potential impacts of a product throughout its life (i.e. from cradle to grave), from the acquisition of the raw material to its production, use and disposal" (ISO 14040, 1997).
Life cycle assessment is part of the sustainability framework and therefore encompasses three types of analysis; an environmental analysis (ELCA), a cost analysis (CLCA) and a social analysis (SLCA). Each of these analyses focuses on a different aspect of the concept of sustainability; environmental, social and economic and each has a distinct methodological framework.

Social LCA looks at the impact that a product/service might have on 5 stakeholders throughout its life cycle. These 5 stakeholders are workers, consumers, local communities, society and value chain actors (UNEP, N.A)

Cost LCA is a tool used to determine the most cost-effective option among competing alternatives for purchasing, owning, operating, maintaining, and ultimately disposing of an object or process, when each is equally appropriate to implement for technical reasons. (Manzo, 2016)

Environmental LCA on the other hand focuses on the sources of emissions throughout the life cycle of a product/service. It aims to identify which phase of a product emits the most emissions and allows some comparison between product A and product B. (ISO, 14040, 1997) There are four fundamental steps of an environmental LCA: Goal and scope definition, inventory analysis (or a model of the product's inflows and outflows), impact assessment (an assessment of the environmental significance of the inflows and outflows), and interpretation. (ISO, 14040, 1997)

The first step, goal and scope definition, establish the reason for executing the LCA and outline the questions which need to be answered. A detailed description of the life cycle and the function of the product or process should be included in the goal and scope since little alterations might create significant variances in LCA accounting. Similarly, a description of the inventory boundaries and the functional unit, or foundation for evaluation, should be supplied. While doing this step it is important to consider the amount of data the project will need, as well as the assumptions and constraints that obtaining that level of quality will have on the effort's output, while defining the scope of an LCA. (ISO, 14040, 1997)

The second step of an environmental LCA is LCA inventory where quantifying the amount of energy and raw material used, atmospheric emissions, waterborne discharges, solid waste, and other releases over the course of a produced good's life cycle is done using the LCA inventory method. The creation of a process flow diagram outlining the inputs and outputs (material and energy requirements) necessary for the life cycle of the product or process being analyzed is the first stage in the life cycle inventory process. The creation of a data collecting plan is the second phase in the life cycle inventory. The data collecting plan should include a list of data sources, and a list of any data gaps. Data gaps' importance must be assessed. May additional data be gathered, can assumptions be made, and will these gaps have an impact on the final LCA product's usability? Data gathering is the third phase in the life cycle inventory and the review and reporting of the findings is the last stage of the life cycle inventory. (ISO, 14040, 1997)

Third step of the LCA is the LCA impact assessment. In this step, data from the previous steps are classified (assign life cycle inventory findings to the impact categories) and describe for interpretation through the choice and defining of impact categories. These data can be standardized, aggregated, and weighted once they have been categorized and described. The act of normalizing involves describing prospective effects in a form that makes it possible to compare different items. Sorting or ranking the indicators is the process of grouping, while emphasizing the most significant possible consequences is the process of weighing. According to ISO 14044, weighing, a potentially subjective process, is not allowed in LCAs that contain comparison statements. (ISO, 14040, 1997)

The final step of the LCA process is the interpretation. According to ISO, this step's goal is to evaluate the outcomes of the inventory and assessment stages of the LCA, come to conclusions, clarify any limits, and offer suggestions. The results of the interpretation must be provided in a transparent manner and give a clear, comprehensive, and consistent presentation of the LCA study's findings. The following are the crucial steps in interpreting the results of the LCA: 1) identifying important issues for the product or process under study based on the life cycle inventory and life cycle assessment; 2) evaluating the results and taking into account consistency, completeness, and sensitivity checks; and 3) reporting the findings and making recommendations. (ISO, 14040, 1997)

Issue related to the lack of knowledge about the use phase and the end of life in LCA

The LCA approach is not without its flaws. In fact, the LCA literature shows that a significant gap exists between theory and reality regarding the behavior of users, especially when it comes to the usage and the end-of-life phases, two phases of the LCA that are very poorly considered (Polizzi et al, 2016). This is due to the fact that life cycle analyses (LCA) rely primarily on hypothetical scenarios that have been created to presume the behavior of users during the use and end-of-life phases. These assumptions are based on generic and hypothetical data, so the results obtained are uncertain and potentially undervalued.

For many items, the consequences induced by the usage and end-of-life phase can account for a major portion of the total environmental impact from the product's complete life cycle. In his 1998 research, Hanssen discovered that of the 18 products he researched, the products that alter chemically in their application or absorb energy when employed have the greatest environmental effect. These environmental repercussions arise because of a variety of interactions between the user and the product, which comprise user behavior. When designing a product, designers frequently have intentions or expectations about how the product should be used and create the product to meet the expected user behavior (Jelsma, 1997). However, behavior is influenced by a variety of circumstances (Jackson, 2005; Klöckner and Blöbaum, 2010), and how it is used may differ from the creators' goals (Pettersen and Boks, 2009). Variations in behavior may have a significant impact on the environmental impact of items during the usage phase and end-of-life phase. For products where the use phase accounts for a significant portion of the total impact, this may have a significant impact on the results of a Life Cycle Assessment (LCA) and is especially important to address, in accordance with Huijbregts' (1998) statement that parameters that cause the greatest spread in the model outcome should be prioritized. Uncertainty and variability have received extensive attention in the LCA literature and are critical to the assessment's reliability and quality. ‘LCA practitioners should explicitly define the uncertainties that are included in a study and discuss the reasons for and potential implication of omitting other types of uncertainty’ (Lloyd and Ries 2007). Huijbregts (1998) proposed a classification of how well different methods are suited to dealing with various forms of uncertainty and variability. According to Huijbregts' classification, the uncertainty of how a product is used in practise can be classified as 'parameter uncertainty,' which is caused by incomplete or missing data, or 'variability in objects/sources,' which is caused by inherent variations in the real world and differences between comparable sources (Huijbregts 1998). Both 'parameter uncertainty' and 'variability in objects/sources,' according to his advice, can be handled by probabilistic modeling, expert judgments/peer reviews, further literature study, new measurements, or correlation and regression analysis. However applying these recommendations to the problem of variations in the use phase and end-of-life may be challenging. These kinds of data are usually not available for how people interact with their products, mainly due to the resource intensity required for collecting enough data about human behavior in a reliable way. Each subject's behavior would have to be studied individually, in a way that captures the behavior without affecting it. This will also be a challenge if additional measurements are to be conducted. Additionally, data on human behavior is often qualitative and less suitable for statistical processing.

Better understanding the user’s behavior to improve LCA studies and product design

Design for Sustainable Behaviour (DfSB), a new area of design study, focuses on lowering the environmental effect caused by how people interact with objects (e.g., Tang and Bhamra 2012; Zachrisson and Boks 2012). To accomplish so, it is vital to comprehend how and why customers utilize items (Wever, Van Kuijk, and Boks 2008). This method, also known as human- or user-centered design (ISO-9241-210 2010), is based on user research to discover usability issues or specific characteristics that are significant to the user. Users' understanding may be used as input to create products that are simple to use and provide the intended user experience. It is possible to design items in such a manner that they are not only easy to use, but also direct how the products should be utilized (Norman 1988; Jelsma and Knot 2002). To that purpose, the DfSB research community has developed a variety of design solutions that cover a wide range of characteristics and may 'nudge' users in the right way (e.g., Lockton et al. 2010; Daae and Boks

2014a). To get insights into user behavior, design researchers often employ user-centered design methodologies such as applied ethnography and contextual inquiry (Daae and Boks 2014b). User-centered design can target variances in how people interact with things by triangulating data obtained via various techniques, and hence has the ability to reduce variation by contributing to the design of products that are more likely to be used in the intended manner. However, the use of these research methodologies is time and resource costly, making large-scale, high-fidelity studies difficult to execute. Furthermore, for designers, it is sometimes more essential to gather knowledge quickly than to have precise findings (Aldersey-Williams, Bound, and Coleman 1999), and hence data collected through user surveys frequently lack the quantitative rigor necessary for use in, say, an LCA setting.

CHAPITRE 1 CONTEXT

1.1 Research problem

Due to the increasing importance of sustainability and considering environmental consequences associated with the manufacturing, usage and disposal of a product, more and more companies are investing into more eco-friendly approaches. This phenomenon has sparked innovations in terms of methods to better understand, measure and reduce the overall environmental impacts of a product or service. A tool frequently used to make a full evaluation of potential impacts associated with a product throughout its entire life cycle, is the life cycle assessment (LCA), defined by the International Organization for Standardization (ISO) 14040-14044 standards.

LCA is a standardised and recognized approach that evaluates potential environmental and human health impact throughout a product's entire life cycle, beginning with the extraction of raw materials and ending with the disposal, including transportation, production, use, and end-of-life treatment. LCA also helps identify opportunities to improve the overall environmental performance of a product at various stages of its life cycle, inform decision-makers on the best course of action, and support marketing and communication efforts. (ISO 14040, 1997).

This approach is not without its flaws. In fact, the LCA literature shows that a significant gap exists between theory and reality regarding the behavior of a user especially when it comes to the usage and the end-of-life phases, two phases of the LCA that are very poorly considered (Polizzi et al, 2016). This is because life cycle analyses (LCA) rely primarily on hypothetical scenarios that have been created to presume the behaviour of users during the use and end-of-life phases. These assumptions are based on generic and hypothetical data, so the results obtained are uncertain and potentially undervalued.

Potential environmental and social impacts may differ depending on the use of a product, but also because of the specific characteristics of the user's status and the context in which he or she operates (Vanclay, 2002). Therefore, information collected directly through user questionnaires remains better than the assumptions made by current LCA practitioners. Questionnaires to establish these behavioral models can generally gather enough data to formulate hypotheses representative of the population of interest and thus target "eco-innovation" or "sustainable design" leading to potential reductions in environmental impacts in the future.

In the case of pocket lighter, a previous study done by EVEA for BIC on the J26 lighter shows that the main environmental impacts are generally attributable to the materials that make them up such as plastics, steel, etc. (BIC, 2020). In fact, according to that study the plastic (POM), which represents 49% of the lighter's weight, the Zamak[1], and the other components of the lighter are responsible for more than 60% of all environmental impact. The consumer's behavior and how long he/she keeps using the lighter before its end of life are not thoroughly explored in this study but are key parameters that are important to understand the impact of each flame (the longer the lifetime, the lower the impact). Other parameters, such as the level of fuel still available in the lighters when they are discarded, the choice of waste management bin in which the consumer decides to place the lighter (eg conventional garbage bin, recycling bin, etc.) or the direct emission of the lighter in the natural environment, may influence the LCA results. It is therefore important to document consumers' use and end-of-life behaviours in more detail using primary data collected through a survey. This will contribute significantly to the robustness of these studies and will help to better characterize the environmental impact and focus on the appropriate target to reduce this impact. The data collection has been done in France and the results will be for that region only.

1.2 GOAL

The goal of the study is to better understand the behavior of users, the way they dispose of their lighters during the use and end-of-life phases to improve the robustness of LCA studies There are three secondary objectives:

- Use data collected on French User's behavior through the two questionnaires developed in collaboration between CIRAIG and BIC to create two main user's archetypes.
- Create different use and end-of-life phase realistic scenarios for each archetype.
- Use those scenarios to do an LCA.
- Compare the results of the LCA done using realistic data with the theoretical one.

[1] Zamak is a metal alloy consisting of zinc, magnesium, aluminium and copper.

CHAPITRE 2 METHODOLOGY

The methodology for this project is divided into two parts: 1) the use of primary data on consumer's behaviour generated by two IPSOS survey in order to create more realistic assumptions about users' usage and end-of-life management, and 2) the incorporation of these new assumptions into an existing LCA model to assess the environmental impacts of pocket lighters and observe the influence of users behaviour on the results obtained (both current situation and prospective scenarios from this current situation).

2.1- Using primary data on consumer's behavior to generate more realistic scenarios for use and end of life phases:

Primary data have been collected from lighter users located in France using two online questionnaires that were developed in the context of the broader research project done by the CIRAIG in collaboration with BIC. The two questionnaires have been developed by BIC in collaboration with the CIRAIG and have been drawn up in such a way as to understand the experience, behaviours, and explanatory factors of consumers behaviors in a very concrete way to assess the behaviour's determinant and the consumers' willingness to adopt different behaviours in term of use an end of life of lighters. The survey based on these questionnaires has been managed by IPSOS. Furthermore, analysis of the answers obtained has been done by IPSOS and only considered answers from respondents who have completed the questionnaire in its entirety. So, answers from incomplete respondents have not been used.

Remark: Only some of the data from this analysis has been used in the present project to refine different assumptions about the use and end of life phases of lighters and make more realistic scenarios that have further been used to make the LCA of pocket lighters more robust. The analysis done by IPSOS has helped collect information regarding the use and end-of-phase such as the number of uses, the ways the lighter is disposed of (in trash, in the environment, etc) and by whom (as explained in the next chapter, two different archetypes; eco-conscious and non-eco-conscious users, have been drawn from the questionnaires). The detailed questionnaires are presented in annex A.

2.1.1. Determination of eco-consciousness:

The eco-consciousness of the respondent has been determined using the questions B3, B4, B5, and B9 of Questionnaire Volet A (presented below) which were aimed at assessing their declared eco-conciousness. The respondents answering the answers in bold in the following questions were classified as eco-conscious. In the improbable case of contradictory answers between those questions, the respondents were disregarded.

« B3- Parmi les actions suivantes en faveur de l'environnement, veuillez indiquer la fréquence à laquelle vous le faites.

- *Séparer vos déchets ménagers/Faire le tri sélectif des déchets*
- *Réduire vos déchets jetables, utiliser plus de recharges et moins de produits à usage unique ou jetables*
- *Choisir des moyens de transport plus respectueux de l'environnement*
- *Payer plus pour des produits qui aident à préserver l'environnement*
- *Limiter mon impact sur l'environnement en utilisant les produits le plus longtemps possible ou en utilisant davantage de produits d'occasion*
- *Rechercher des informations sur l'écologie et le développement durable (Internet, documentaires, articles, etc.)*
- *Choisir des marques impliquées dans le développement durable plutôt que d'autres*

Choix de réponse:

- *Jamais*
- *Rarement*
- ***Souvent***
- ***Systématiquement »***

« B4 -Que pensez-vous des marques qui affirment être engagées en matière de développement durable et qui communiquent leurs actions de développement durable?

- *J'ai tendance à choisir les ces marques choisir plutôt que d'autres*
- *Je crois qu'elles peuvent faire la différence pour améliorer l'environnement*
- *Je crois qu'elles n'ont aucun impact, peu importe ce qu'elles font*
- *Je pense que les actions individuelles sont plus importantes*
- *Je crois que la plupart de leurs actions sont du greenwashing/écoblanchiment (qui servent à se donner une image écologique alors qu'elles polluent)*

Choix de réponse:

- *Pas du tout d'accord*
- *Pas vraiment d'accord*
- ***Plutôt d'accord***

- ***Tout à fait d’accord »***

« B-5 Est-ce qu’il y a un moment particulier où vous êtes davantage sensible aux impacts écologiques des briquets de poche en plastique?

- ***Oui, au moment de l’achat***
- ***Oui, quand je l’utilise***
- ***Oui, quand il est terminé ou ne fonctionne plus***
- ***Oui, quand je décide de le jeter***
- ***Non, j’y suis sensibilisé tout le temps, pas à un moment spécifique***
- *Non, je ne suis pas particulièrement sensible aux impacts environnementaux des briquets* ***»***

« B9 - Est-ce que l’impact environnemental du produit est un critère d'achat important pour vous?

- ***oui***
- *non »*

The two resulting archetypes have been analysed separately as two baseline scenarios each, representing their current behaviour and their prospective behaviour when lighters recycling facilities will be available (see detailed assumptions for these scenarios below).

2.1.2- End of life scenarios

The end-of-life scenarios were generated based on the answers to Question A8 of Questionnaire Volet A (presented below). The distribution of respondents in each end-of-life process was used to generate the mix of end-of-life processes (one for each of the two archetypes – eco conscious and non-eco-conscious) used in the baseline scenarios (see section 2.1.8).

From the answers to some of the questions of the survey (detailed below, Volet A-question A8, Volet A, question C3 and volet B question 1.3), it has been possible to identify four ways a user may dispose his lighter : formal disposal (*Dans la poubelle d’ordures ménagères* and *A la déchetterie*), recycling (*Dans la poubelle pour les déchets recyclables)*, indoor disposal (*Dans les bacs de collecte prévus à cet effet dans les supermarchés*), and outdoor disposable (*Dans une poubelle de rue* and *Autre (précisez)*) as well as the willingness of lighter users to choose each of those alternatives.

“Volet A- A8: Où faut-il jeter les produits suivants - Briquets en plastique (briquets de poche, briquets utilitaires)

- *Dans la poubelle d’ordures ménagères*

- *Dans la poubelle pour les déchets recyclables*
- *A la déchetterie*
- *Dans les bacs de collecte prévus à cet effet dans les supermarchés*
- *Dans une poubelle de rue*
- *Autre (précisez):*

Question C3 – Volet A: « Déposeriez-vous ces produits dans des points de collecte afin de les recycler? - Briquets de poche en plastique

- *Oui*
- *Non »*

Question 1.3 – Volet B: « Rapporter mes briquets de poche dans un point de collecte prévu à cet effet lorsqu'ils sont disponibles dans ma région

Réponse: % moyen de fréquence pour chacun des choix

- *Non, Définitivement pas*
- *1 (25% du temps)*
- *2 (50% du temps)*
- *3 (75% du temps)*
- *Oui, Définitivement (100% du temps»*

Important note: In the actual waste management system available in France, lighters are not recycled. Therefore, in the actual waste management system, lighter placed in the recycling bin will end up at the same place as lighter in the formal disposal category. This is the assumption done in the current baseline scenarios. However, BIC has a great desire to make their lighter recyclable in the very near future and want to see the impact this decision may have considered a realistic endowment by users. Therefore, prospective scenarios will assume that all the lighters placed in the recycling bin, will be recycled as per BIC's vision.

Question C3 helped calculating the fraction of users that would recycle their lighter if a facility was available for each archetype of users.

From that fraction, we further narrowed it down by using question A8 of Questionnaire Volet A, which allows to better understand the current level of knowledge and behaviour of users on how to deal with their lighters at the end of their lives. This question has helped find the fraction of users who currently put their lighter in the recycle bin (it was considered that 100% of those users would keep on recycling if a facility was available) and the fraction of users who don't put their lighter in a recycling bin (it was considered that those users would potentially start recycling if there was a facility or a place available if they responded yes to question C3).

Question 1.3 of Questionnaire Volet B has then been used to determine the fraction/percentage of lighters that those respondents would recycle if there was a place available to do so. This has allowed us determining the potential percentage of lighters recycled if there was a facility available.

This information was then used to generate two “prospective baseline scenarios” in the case study section (one for each user's archetype) which represent the expected behavior of the users of each archetype when a recycling facility will become available.

2.1.3 - Lighter lifespan:

First, the **lighter lifespan,** expressed in number of activations, is defined as the lifespan that a lighter can last until it is no longer functional, either because its reservoir is empty (non-rechargeable lighters) or because the lighter undergoes a breakage.

Therefore, from this definition two terms can be distinguished:

- **The theoretical lifespan** which can be defined as a lighter lifespan without breakage.
- **The adjusted lifespan which is the lifespan** when considering the statistical risk of breakages of the lighter during its life.

Finally, it is also important to define the **occurrence of breakage** as the number of activations before a breakage occurs.

After setting these definitions, the theoretical lifespan for non-refillable lighters can be expressed for the different lighters as in Equation 1 :

$$theoretical\ lifespan = \frac{gas\ in\ the\ lighter\ tank\ (g)}{consumption\ of\ gas\ per\ activation\ (g/activation)} \quad \text{(Equation 1)}$$

In the EVA study, the theoretical lifespan has been used. In the current project, I adjusted the lifespan based on the survey using the answer from Question B13.1 and B13.2 of Questionnaire Volet A (detailed below). The answers to the question B13.2 gave a distribution of number of weeks a lighter lats before being disposed and the question B13.1 gave a number of flames per week. For each answer choice, the result is an interval, and the average value of this interval has been considered. A weighted average of those average values for each answer choice has been done using the distribution of the respondent answers as a weighting factor to obtain an average lifespan, in weeks, and an average number of uses per day. These two results were combined to obtain a lifespan in the number of uses by multiplying the average number of weeks by 7 and by the number of uses per day (eq 2).

$$number\ of\ activations = \frac{number\ of\ daily\ activation}{1\ day} * lifetime\ (in\ days) \qquad (Equation\ 2)$$

« B13.1 - À quelle fréquence utilisez-vous votre briquet de poche en plastique non-rechargeable (1 usage = 1 flamme)?

- *Plus de 5 fois par jour*
- *3 à 5 fois par jour*
- *1 à 2 fois par jour*
- *3 à 6 fois par semaine*
- *1 fois par semaine*
- *1 fois toutes les 2 à 3 semaines*
- *1 fois par mois*
- *1 fois tous les 2 à 3 mois*
- *1 fois tous les 4 à 6 mois*
- *1 à 2 fois par an*
- *Moins d'une à deux fois par an*

B13.2 - Quelle est la durée de vie habituelle (en semaines) de votre briquet de poche en plastique non-rechargeable?

- *Moins de 3 semaines*
- *3 à 6 semaines*
- *7 à 9 semaines*
- *9 à 12 semaines*
- *Plus de 12 semaines*

- *Je ne sais pas »*

2.1.4. Fuel content when disposed

Question B16 of Questionnaire Volet A (detailed below) was used to determine the quantity of fuel remaining in the lighter when it is disposed of or lost. When the user verified the fuel content before throwing it away, some of them specified if there was some fuel remaining or not in the lighter (none of them specified the quantity).

For the non-empty lighters, as no precise amount was available and as most users replied that only a little bit was left, a default assumption was made that 5 % of fuel was still remaining in the lighter when it was disposed of. For lighters lost in the environment, it has been assumed that 50% of fuel was remaining and that 25% of fuel was remaining when the lighter was lost indoors (these assumptions were done after discussions with BIC team). Further research would be necessary in order to determine the exact percentage of fuel left in lighters and sensitivity analysis will be conducted to assess the influence of this very uncertain assumption on the LCA result.

Volet A - Question B16: "Avant de considérer que votre briquet est « fini » validez-vous que le réservoir de combustible de votre briquet est bel et bien vide? Si oui, précisez de quelle manière?

- *Oui, expliquez*
- *Non »*

2.1.5 – distance a user is willing to travel to a point of collection

Question C9 of Questionnaire Volet A (detailed below) was used to determine the distance users are willing to travel to bring their lighter to the point of collection for recycling. The distance was an interval expressed in minutes. The average value of each interval was used, and a weighted average was calculated for each archetype. Furthermore, it was assumed that most users would use their car to go to the point of collection for recycling. Using the average speed on the road in France (we considered 50 km/h, the speed limit in a built area in France), we were able to estimate the distance people are willing to travel.

This distance a user is willing to travel to a point of collection will be considered in our baseline prospective scenarios as the distance they will travel to recycle their lighters.

Remark: these assumptions result in important uncertainties:

- *The choice of the speed is quite arbitrary. In some areas the speed limit is higher (80 or 90 km/h) and the average speed in a city is much less than the speed limit. As an example, the observatoire des déplacements à Paris (2020) estimates that the average speed by car in Paris is only of 11,3 km/h.*
- *The hypothesis that the users will travel the maximum distance they are willing to travel is leading to an overestimation of the impact: the collection facility may be closer than that.*

Hence, it will be important to do a sensitivity analysis on this traveling distance to the recycling facility.

« Question C9-volet A: Distance en minute du point de collecte

choix de reponse:

- *Moins de 5 minutes (1.5)*
- *Entre 5 et 10 minutes (7.5)*
- *Entre 11 et 20 minutes (15.5)*
- *Entre 21 et 30 minutes (25.5)*
- *Autre (précisez): ()*
- *Je ne sais pas ()"*

2.1.6 – Repartition of lighters between disposal, emission to the environment and accumulation at home

From the question B23 of Questionnaire Volet A (detailed below), it was possible to determine the portion of the total number of lighters lost that is lost in the environment. The data for the bolded answer were considered as the fraction of lost lighters directly emitted to the environment ($fr_{emitted}$). This fraction has been combined with the answer to questions B22 and B26 (detailed below) giving the numbers of lighers losts ($Lighters_{lost}$) and found ($Lighters_{lfound}$) yearly and to question 19 volet A giving the number of lighters bought to quantify the fraction of lighters lost in the environment "Fraction of $Lighters_{emitted}$ " (eq 3) :

$$\text{Fraction of } Lighters_{emitted} = ((Lighters_{lost} - Lighters_{found}) \times fr_{emitted}) / Lighters_{bought} \quad \text{(equation 3)}$$

For question 19-volet A and B26 volet A, answers are intervals so the average between the min and the max of the interval has been used in the calculation.

"Question B23-volet A: Endroits égarés - Summary

choix de reponse:

- *A l'intérieur (au bureau…)*
- *Dans un lieu public (un café, un restaurant, une salle de concert…)*
- ***A l'extérieur (à la plage, en forêt…)***
- ***Autre (précisez)**"*

Question 19-volet A: Au cours de la dernière année (12 derniers mois), combien de briquets de poche en plastique non- rechargeable avez-vous acheté ?

Choix de reponse:

- *1 unité*
- *2 à 5 unités*
- *6 à 9 unités*
- *10 à 12 unités*
- *Plus de 12 unités*
- *Je ne sais pas*

Question B26-volet A: Briquets trouvés

choix de reponse:

- *aucun*
- *1 à 2 (1.5)*
- *3 à 5 (4)*
- *6 à 10 (8)*
- *11 à 20 (15.5)*
- *21 à 30 (25.5)*
- *Plus de 30 (35.5)*
- *Je ne sais pas ()*

Question B22-volet A: Nombre de briquets égarés

choix de reponse:

- *0*
- *1*
- *2*
- *3*
- *4*

- *5*
- *6*
- *7*
- *8*
- *9*
- *10*

There is a fraction of lighters bought yearly which is lost indoor, in a public place or elsewhere and never found. This fraction is considered as the kept at home fraction of lighters (Fraction of Lighters_{kept}). It is determined as follow (eq 4):

Fraction of $\text{Lighters}_{kept} = ((\text{Lighters}_{lost} - \text{Lighters}_{found}) \times (1 - fr_{emitted})) / \text{Lighters}_{bought}$ (eq 4)

The total fraction of lighters that would "complete the cycle" (ie reach disposal at the end of their lives) Fraction of $\text{Lighters}_{disposed}$ has been determined as the fraction of lighters that are bought and neither lost in the environment nor kept at home, ie the lighters that are bougth or found minus the one that are lost outside (emitted to the environment) or inside (kept at home) and never found (eq. 5):

Fraction of $\text{Lighters}_{disposed} = (\text{Lighters}_{bought} + \text{Lighters}_{found} - \text{Lighters}_{lost}) / \text{Lighters}_{bought}$ (eq. 5)

2.1.7 – Building LCA scenarios

With all the information obtained from the two questionnaires, four baseline scenarios have been built – two for each archetype (eco conscious and non-eco-conscious) considering the current end of life (no recycling) and the prospective end of life once the facilities will be available to recycle:

- Scenario 1 – Baseline current scenario – non-eco-conscious users.
- Scenario 2 – Baseline current scenario – eco-conscious users.
- Scenario 3 – Baseline prospective scenario – non-eco-conscious users.
- Scenario 4 – Baseline prospective scenario – eco-conscious users.

To build those 4 baseline scenarios, the following assumptions have been made:

- End of life: for the "baseline current scenario" (for each archetype), 100% of disposed lighters were considered as disposed and non-recycled (representing the current situation). For the "baseline prospective scenario" the recycling rate obtained following the methodology of section

2.1.2 (representing what is expected once the recycling facilities will be available) has been considered for each archetype.

- When recycled, the approach used for this study is that the primary (first) production of materials is always allocated to the primary user of a material. If a material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. Consequently, recyclable materials are available burden-free to recycling processes, and secondary (recycled) materials bear only the impacts of the recycling processes. This is in line with the ecoinvent background database methodology used in this study ("Recycled Content, Cut Off).
- When disposed, the end-of-life scenario corresponds to the distribution between different types of waste treatments, which is the same for every material used in the ignition system except for cardboard. This distribution has been determined using European statistics on waste treatment based on Eurostat 2017 data and is consistent with the EVEA study. The scenario is the following:
    - 52,2 % of incineration with energy recovery. The energy recovery is modelled by avoiding the following energy production:
        - 28,22% from petroleum
        - 41,8% from natural gas
        - 21,96% from solid fuels
        - 8,02% from renewable
        - The net energy produced by the incineration is calculated with the data from *Gabor Doka, et al (2013).* The values are the following: 15,84% of the LHV of the input waste is converted in electricity and 28,51% into heat. The communicated value in this report for the low heating value of average municipal waste is used: 11,7 MJ/kg. 3 % of incineration is done without energy recovery
    - 44,8 % of landfill.
- The lighter lifespan obtained following the methodology of section 2.1.3 has been used.
- The fuel content when disposed obtained following the methodology of section 2.1.4 has been considered.
- For the lighters that did not reach the disposal (kept inside or lost in the environment), the number of flames has been adjusted proportionally to the fuel content considered at end of life (the lifespan obtained from 2.1.3 and the fuel content from 2.1.4 allowed calculating a quantity of gas per flame that was used to do this adjustment).

- The traveled distance to the recycling facility has been considered as the distance users are willing to travel, determined following the methodology of section 2.1.4 and this distance has been considered as being traveled by car in a dedicated trip.
- Furthermore, it was assumed that the user brings 10 lighters at the time to the collection point.
- The car that was considered for the transport of users to the collection point is the Euro-3 medium size car using diesel.
- Transport from Collection point to Recycling facilities was assumed to be performed in a >32-ton Euro-5 and the distance between the collection point and the recycling facility has been estimated to be 300km.
- Recycling process has been modeled using the following assumptions: the lighter is considered recyclables at 90% (BIC expert judgement) and the PAM, the Zamak and the steel would be recycled using the average processes available in France (see lighter composition in Annex C)
- The repartition of lighters between disposal, emission to the environment and accumulation at home obtained following the methodology of section 2.1.6 has been used.

Twenty additional scenarios were created to test the sensitivity of different relevant parameters for each archetype of users:

Influence of lighter fuel content at the end of its life:

As there is no precise information available on the fuel content when disposed of or when lost, I had to make a rough assumption on this (I considered 25% fuel content when disposed of and 50% when lost in the environment).

Scenarios 5 & 6 allow a sensitivity analysis on gas content when disposed for the two baseline scenarios. I therefore tested my assumption by multiplying by 3 this fuel content (15%) to see how sensitive my result was to this lack of precise data. Thus, the number of potential activations during the lifespan was consequently reduced and the additional gas end of life process quantity was increased.

Scenarios 7 & 8 allowed me to do a sensitivity analysis on gas content when lost in the environment for the two baseline scenarios. I therefore tested my assumption by increasing this fuel content up to 60% to see how sensitive my result was to this lack of precise data. Thus, the number of potential activations during the lifespan was consequently reduced and the additional gas directly emitted to the environment was increased.

Influence of the recycling rate:

According to BIC, the recycling optimal scenario would be that 99% of the lighter would be recycled in a BIC facility in France. Scenarios 9 & 10 are prospective scenarios that explore the influence of increasing the recycling rate considering, for example, the positive influence that a good communication campaign could have on users' behavior. To do so, the recycling rate has been increased by 10% compared to the two prospective baseline scenarios.

Influence of the loss rate outdoor:

Scenario 11 allows a sensitivity analysis on the loss rate to the environment and accumulation rate at home to test the hypothesis done in section 2.1.6 that all the lighters lost inside and never found are accumulating at home. To do so, all the lost lighters not found where considered as emitted to the environment. This sensitivity analysis scenario was only applied to the eco-conscious archetype prospective baseline scenario.

Influence of the distance to the collection point

The distance made ad-hoc to the Collection point for recycling has a significant influence on the impact as can be seen in the result section. The data collected during the questionnaire helped identify the maximum distance people are ready to travel to these collection points, but this distance, which I used in my baseline scenarios, does only represent a maximum distance users are willing to travel in the absence of any more precise knowledge of where the collection facilities will be situated. As this travel distance may be a key parameter in the eco-conception of the recycling facilities design, a sensitivity analysis was conducted to assess its influence.

In scenario 12, the travel distance has been increased by 10%. This was only done for the eco-conscious archetypes as the non-eco-conscious archetype representative would probably never accept to travel more for recycling.

In scenarios 13 and 14, no dedicated travel distance by car was considered. These two scenarios correspond, for example, to a hypothetical situation in which the collection points are situated in places where the lighters are sold (e.g tobacco shops).

Influence of the end-of-life hypothesis

Influence of the end of life of the lighter was also assessed in more detail by considering respectively hypothetical scenarios with:

- 100% disposal (no lighters lost in the environment, no recycling) in the baseline prospective scenario for non-eco-conscious archetype (Sensitivity analysis 15) and eco-conscious archetype (Sensitivity analysis 16);
- 100% recycling with a travel by car to the recycling facility (no disposal, no loss in the environment) in the baseline prospective scenario for non-eco-conscious archetype (Sensitivity analysis 17) and eco-conscious archetype (Sensitivity analysis 18);
- 100% recycling without any travel by car to the recycling facility (no disposal, no loss in the environment) in the baseline prospective scenario for non-eco-conscious archetype (Sensitivity analysis 19) and eco-conscious archetype (Sensitivity analysis 20);
- and 100% loss in the environment (no disposal, no recycling) in the baseline prospective scenario for non-eco-conscious archetype (Sensitivity analysis 21) and eco-conscious archetype (Sensitivity analysis 22).

2.2- Life cycle assessment of the scenarios emerging from the survey (with more realistic use phase and end of life assumptions):

The 22 scenarios presented in section 2.1.7 have been analysed using life cycle assessment. To do so, BIC allowed me to have access to the existing lighter life cycle assessment (LCA) of the lighter already done for them by EVEA and mentioned in the literature revue (BIC 2020). The analysis was therefore done on the SimaPro software found on the company virtual server. This LCA for usage and end of life was performed on Simapro V 8.2 using Ecoinvent 3.2, Idemat 2001 and Industry data 2.0 databases from BIC virtual server. The life cycle inventory of the EVEA study has been reused as is, excluding only data related to the use phase and user behavior at the end of life that has been adjusted to represent the different scenarios presented in section 2.1.7. Details of the inventory assumptions are available in the EVEA report (BIC 2020) and summarized in annex B.

The life cycle impact assessment was done using the same impact assessment methodology as previously done by EVEA to be compliant with the original study done and to be able to compare our results with the previous one, even if we acknowledge that these indicator's choice could have been improved by using a more up to date methodology such as IMPACT World+ or ReCiPe 2016. Some key environmental issues are omitted such as toxicity and the choice of impact categories seems to be based on the intuitive estimation of the relative importance of each category for the studied system.

Moreover, as currently plastic emissions are poorly characterized in LCA (meaning a lighter emitted in the environment is considered as having almost no impact – even the ecotoxicity of its constituents being omitted by the choice of indicators done), I considered an additional complementary indicator "Number of lighters lost in the environment" which was not considered in the EVEA study but seems important to me. The indicators selected are summarized in table 2.1.

- Table 2.1: Indicators considered for the Life Cycle Impact Assessment (LCIA).

Indicator	Unit	Method	Justification
Climate change (100y)	kg CO2 eq.	IPCC 2013 100y v1.02	Compliant with the EVEA study
Abiotic depletion	kg Sb eq.	CML-IA non-baseline, reserve base v3.02	Compliant with the EVEA study
Eutrophication	kg P eq.	ReCiPe 2008 midpoint H v1.12	Compliant with the EVEA study
Acidification	kg SO2 eq.	ReCiPe 2008 midpoint H v1.12	Compliant with the EVEA study
Photochemical oxidation	kg NMVOC	ReCiPe 2008 midpoint H v1.12	Compliant with the EVEA study
Non-renewable energy	MJ	Cumulative Energy Demand v1.09	Compliant with the EVEA study
Water depletion	m3	ReCiPe 2008 midpoint H v1.12	Compliant with the EVEA study
Agricultural land occupation	m2a	ReCiPe 2008 midpoint H v1.12	Compliant with the EVEA study
Number of lighters lost in the environment	# lighters	Inventory indicator	This indicator allows to account for lighters loss as plastic emission are poorly assessed by other indicators

In order to compare the different scenarios defined in section 2.1.7, this LCA considered also the lighter activation as the functional unit, as done by EVEA.

While this functional unit was assumed to be equal in all J26 lighters covered in the SURVEY, the adjusted lighter lifespan was found to be different among users depending on when and why the lighter finishes its lifespan. While the theoretical lifespan in the EVEA study was considered until the theorical point of no gas in the cartridge or breakage, the scenarios defined in section 2.1.7 allowed us to modify this lifespan.

2.2.1 Baseline current and prospective scenarios comparison with the previous study

The scenarios 1, 2, 3 & 4, which (as detailed in section 2.1.7) are baseline scenarios of respectively non-eco-conscious and eco-conscious archetypes using respectively the current end-of-life (no recycling) or the prospective process mix determined for each archetype using the methodology of section 2.1.2 (with a recycling rate representing what may happen when recycling facilities will be available) were compared to the previous results obtained by Evea (scenario 0) to see the influence of considering more robust primary data on the consumer behavior on the LCA of the lighter.

2.2.2 Assessing the influence of the gas content in the lighter at end of life

Scenarios 4, 5, 6 & 7 have been compared to scenarios 2 & 3 to assess the influence of the lighter gas content when disposed or lost in the environment.

2.2.3. Assessing the influence of the recycling rate

Scenarios 8 & 9 have been compared to scenarios 2 & 3 to assess the influence of the lighter recycling rate.

2.2.4 Assessing the influence of the loss rate outdoor and the accumulation rate at home

Scenarios 10 & 11 have been compared to scenarios 2 & 3 to assess the influence of the loss rate in the environment and the accumulation rate at home.

2.2.5. Assessing the influence of the distance to the collection point

Scenarios 12, 13 & 14 have been compared to scenarios 2 & 3 to assess the influence of the distance to the collection point.

2.2.5. Assessing the influence of the end-of-life hypothesis

Scenarios 15 to 22 have been compared to scenarios 2 & 3 to assess the influence of the end-of-life hypothesis.

CHAPITRE 3 RESULTS

In this chapter, hypothesis resulting from the analysis of the two questionnaires to better represent the use phase and the end-of-life behavior are presented and the resulting scenarios and their sensitivity analysis are analysed.

3.1 Primary data collection on the customer behavior to generate more realistic scenarios for use and end of life phases:

There were 15934 respondents to the survey of which only 5403 respondents have completed the survey: only the answers from those respondents have been used in this analysis.

3.1.1 Determination of eco-consciousness:

Out of the 5403 respondents, 2972 respondents, roughly 55% of respondents, have given answers corresponding to the Eco-conscious archetype while 2431 respondents, roughly 45% of respondents, have given answers corresponding to non-eco-conscious archetypes.

3.1.2 end of life scenarios:

Table 3.1 summarized the data collected on the end of life of lighter for our two archetypes. A good majority of lighter items are disposed of in a formal way (with other home waste or brought to the dechetterie) by 71.8% eco-conscious respondents and 76.4% non-eco-conscious (which is currently an appropriate behavior given the current absence of recycling facilities). Furthermore, the mix end-of-life scenarios are slightly different from one archetype to the other.

Table 3.1 End of life distribution for Eco and Non-Eco customers

Percentage of disposed and recycled lighters	Eco	Non-Eco
Formally Disposed	0.718	0.764
Recycled	0.153	0.077
Indoor disposed	0.111	0.134
Outdoor disposed	0.016	0.025

Combining this information with the answer about the willingness of users to recycle which is the following (similar result for both archetypes):

- 29% have stated that I would bring their lighter 100% of the time (1)
- 27% have stated that they would bring their lighter 75% of the time (0.75)

- 19% have stated that they would bring their lighter 50% of the time (0.50)
- 12% have stated that they would bring their lighter 25% of the time (0.25)
- 13% have stated that they would not bring their lighter (0)
- Weighted average = 24.7%.

I obtained the following values for each archetype for the willingness to recycle:

- 15,3 % of eco-conscious users are "already recycling" and 24,7% of the 71,8% of them who dispose formally their lighters are willing to recycle them, hence the total potential for recycling is of 20,45% of the lighters neither kept or lost for eco-conscious users
- 7,7% of non-eco-conscious users are "already recycling" and 24,7% of the 76,4% of them who dispose formally their lighters are willing to recycle them, hence the total potential for recycling is of 26,57% of the lighters neither kept or lost for non-eco-conscious users

3.1.3 Lighter lifespan:

According to the primary data collected, a user will use his lighter on average 4 times a day and the average lifespan of a lighter is roughly 6 months or 180 days. Therefore, using the equation 1, we were able to calculate the lifespan of a lighter used by a user to be 720 activations (or flames). Furthermore, according to the survey, there was no variation whether the user was eco conscious or non-eco conscious.

3.1.4. Fuel content when disposed

See assumptions in section 2.1.4.

3.1.5 distance a user is willing to travel to a point of collection:

According to the data obtained, the maximal distance that eco-conscious archetypes are willing to travel to a collection point for their lighter to be recycled is 10 minutes on average. With our assumptions, this corresponds to 8.3 km. On the other hand, for non-eco-conscious users, the average time was found to be 6 minutes. A 6-minute drive would be equivalent to 5 km

3.1.6 Repartition of lighters between disposal, emission to the environment and accumulation at home:

Table 3.2 and 3.3 depicts the distribution of location of lost lighters according to the answers to question B23 – volet A. Table 3.2 gives the answers to the survey and table 3gives the resulting fraction emitted.

Table 3.2: distribution of lost lighter outside (detailed answer to question B23)

Site of lost lighters outdoor	Eco	Non-Eco
Interior (office)	0.48	0.48
Public places (coffee shop,..)	0.27	0.27
environment (beach, forest…)	0.20	0.20
other	0.05	0.05

Table 3.3: resulting distribution of lighters loss (answer to question B23)

Site of lost lighters	Eco	Non-Eco
Interior (fr_{kept})	76,2%	75,1%
Exterior ($fr_{emitted}$)	20%	20%
Other	3.9%	4,9%

According to the answers to question B22 – Volet A, 3.5 and 3.9 lighters are lost on average per year per customer, for eco and non-eco customers respectively.

According to the answers to question B26 volet A, lighters are found on a rate of 2.2 and 1.96, respectively, for eco and non eco-conscious archetypes.

According to question 19 – volet A, the number of lighters bought annually was of 4,58 and 4,80 respectively for eco and non eco-customers.

Hence, using equation 3, I calculated the fraction of lighters emitted to the environment for each archetype, using equation 4, the fraction kept at home and using equation 5, the fraction of lighters disposed (either recycled or disposed conventionally):

Eco-conscious archetype:

Fraction of Lighters$_{emitted}$ = ((3,5 Lighters$_{lost}$ -2,2 Lighters$_{found}$) x 20%)/ 4,58 Lighters$_{bought}$ = **5,68 %**

Fraction of Lighters$_{kept}$ = ((3,5 Lighters$_{lost}$ -2,2 Lighters$_{found}$) x 80%)/ 4,58 Lighters$_{bought}$ **= 22,71%**

Fraction of Lighters$_{disposed}$ = (4,58 Lighters$_{bought}$ + 2,2Lighters$_{found}$ – 3,5 Lighters$_{lost}$) / 4,58Lighters$_{bought}$ = **71,61%**

Non-eco-conscious archetype:

Fraction of Lighters$_{emitted}$ = ((3,9 Lighters$_{lost}$ -1,96 Lighters$_{found}$) x 20%)/ 4,80 Lighters$_{bought}$ = **8,08 %**

Fraction of Lighters$_{kept}$ = ((3,9 Lighters$_{lost}$ -1,96 Lighters$_{found}$) x 80%)/ 4,80 Lighters$_{bought}$ = **32,33%**

Fraction of Lighters$_{disposed}$ = (4,80 Lighters$_{bought}$ + 1,96 Lighters$_{found}$ – 3,9 Lighters$_{lost}$) / 4,8 Lighters$_{bought}$ = **59,58%**

3.1.7 Building LCA scenarios:

For the current scenarios, there is no recycling, hence 100% of the Fraction of $\text{Lighters}_{disposed}$ is disposed. For the prospective scenarios, a fraction of the disposed fraction is recycled following the results presented in section 3.1.2:

Eco-conscious archetype: 20,45% of users are willing to recycle *76,61% of lighters disposed = 15,67% of lighters are recycled and 60,94% are conventionally disposed.

Non-eco-conscious archetype: 26,57% of users are willing to recycle * 59,58% of lighters disposed = 15,83% of lighters are recycled and 43,75% are conventionally disposed.

Table 3.5 summarizes the resulting main assumptions for the 20 scenarios described in section 2.1.7 with the values resulting from the survey for the baseline scenarios and the different assumptions made for the sensitivity analysis.

Erratum: *Those scenarios from table 3.5 were not the one that I analyzed as there were some mistakes in my earlier calculation on the different fractions of the lighters kept, emitted and disposed. However, as I no longer have access to the BIC Simapro software to correct my model, I will show in the next sections the results I obtained with my earlier version of the scenarios (table 3.6). The numbers in this table do not represent adequately the users behavior, but still, the sensitivity analysis I did are giving a good idea about the main contributors and the key parameters.*

I also did not analysed scenarios 1 and 2, hence the comparison I did with the EVEA scenario is biased as I only compared it with scenarios including recycling and travel to recycling facilities, which, as I will show later, is an important contributor to the impact.

Table 3.5 LCA baseline and sensitivity scenarios (right values, but not analysed). The white cells in the table highlight the parameters on which the sensitivity analysis is done in each Sensitivity analysis scenario.

Scenario	Disposal (incineration + landfill)	Travel distance to collection point	Recycling	Remaining gas when disposed or recycled	Kept at home	Remaining gaz when kept	Loss in the env.	Remaining gas when lost
1. Baseline current sc. – Non Eco	59,58%	5 km	0%	5%	32,33%	25%	8,08%	50%
2. Baseline current sc. - Eco	71,61%	8,3 km	0%	5%	22,71%	25%	5,68%	50%
3. Baseline prospective sc. – Non-Eco	43,75%	5 km	15,83%	5%	32,33%	25%	8,08%	50%
4. Baseline prospective sc. - Eco	60,94%	8,3 km	15,67%	5%	22,71%	25%	5,68%	50%
5. Sensitivity to gas when disposed (x 3) – Non-Eco	43,75%	5 km	15,83%	15%	32,33%	25%	8,08%	50%
6. Sensitivity to gas when disposed (x3)- Eco	60,94%	8,3 km	15,67%	15%	22,71%	25%	5,68%	50%
7 Sensitivity to gas when lost outdoors – Non-Eco (+10%)	43,75%	5 km	15,83%	5%	32,33%	25%	8,08%	60%
8. Sensitivity to gas when lost outdoors –Eco (+10%)	60,94%	8,3 km	15,67%	5%	22,71%	25%	5,68%	60%
9. Sensitivity to end-of-life scenario (+10% recycling) – Non-Eco	33,75%	5 km	25,83%	5%	32,33%	25%	8,08%	50%
10. Sensitivity to end-of-life scenario (+10% recycling) - Eco	50,94%	8,3 km	25,67%	5%	22,71%	25%	5,68%	50%
11. Sensitivity to end-of-life scenario (+10% outdoor disposal) - Eco	60,94%	8,3 km	15,67%	5%	12,71%	25%	15,68%	50%
12. Sensitivity to travel distance for collection (+10% distance) - Eco	60,94%	9,13 km	15,67%	5%	22,71%	25%	5,68%	50%
13. Sensitivity to no car used (no distance). - Eco	60,94%	0 km	15,67%	5%	22,71%	25%	5,68%	50%
14. Sensitivity to no car used (no distance). – Non-Eco	43,75%	0 km	15,83%	5%	32,33%	25%	8,08%	50%
15. Sensitivity to EoL – 100% disposal – non eco	100%	SO	0%	5%	0%	SO	0%	SO
16. Sensitivity to EoL – 100% disposal –eco	100%	SO	0%	5%	0%	SO	0%	SO
17. Sensitivity to EoL – 100% recycling – w travel – non eco	0%	5 km	100%	5%	0%	SO	0%	SO
18. Sensitivity to EoL – 100% recycling – w travel –eco	0%	8,3 km	100%	5%	0%	SO	0%	SO
19. Sensitivity to EoL – 100% recycling – wo travel – non eco	0%	0 km	100%	5%	0%	SO	0%	SO
20. Sensitivity to EoL – 100% recycling – wo travel –eco	0%	0 km	100%	5%	0%	SO	0%	SO
21. Sensitivity to EoL – 100% loss –non eco	0%	SO	0%	SO	0%	SO	100%	50%
22. Sensitivity to EoL – 100% loss –eco	0%	SO	0%	SO	0%	SO	100%	50%

Table 3.5 LCA baseline and sensitivity scenarios (wrong values, but which were the one I analysed). The white cells in the table highlight the parameters on which the sensitivity analysis is done in each Sensitivity analysis scenario.

Scenario	Disposal	Travel distance to collection point	Recycling	Remaining gas when disposed or recycled	Kept at home	Remaining gaz when kept	Loss in the env.	Remaining gas when lost
3. Baseline prospective sc. – Non-Eco	76,4%	5 km	7,7%	5%	13,4%	25%	2,5%	50%
4. Baseline prospective sc. - Eco	71,8%	8,3 km	15,3%	5%	10,7%	25%	1,8%	50%
5. Sensitivity to gas when disposed (x 3) – Non-Eco	76,4%	5 km	7,7%	15%	13,4%	25%	2,5%	50%
6. Sensitivity to gas when disposed (x3)- Eco	71,81%	8,3 km	15,3%	15%	10,7%	25%	1,8%	50%
7 Sensitivity to gas when lost outdoors – Non-Eco (+10%)	76.4%	5 km	7.7%	5%	13.4%	25%	2.5%	60%
8. Sensitivity to gas when lost outdoors –Eco (+10%)	71.8%	8,3 km	15.3%	5%	10,7%	25%	1.8%	60%
9. Sensitivity to end-of-life scenario (+10% recycling) – Non-Eco	66.4%	5 km	17.7%	5%	13.4%	25%	2.5%	50%
10. Sensitivity to end-of-life scenario (+10% recycling) - Eco	61.8%	8,3 km	25.3%	5%	11.1%	25%	1.8%	50%
11. Sensitivity to end-of-life scenario (+10% outdoor disposal) - Eco	71.8%	8,3 km	15.3%	5%	1.1%	25%	11.8%	50%
12. Sensitivity to travel distance for collection (+10% distance) - Eco	71.8%	9,13 km	15.3%	5%	10,7%	25%	1.8%	50%
13. Sensitivity to no car used (no distance). - Eco	76.4%	0 km	7.7%	5%	13.4%	25%	2.5%	50%
14. Sensitivity to no car used (no distance). – Non-Eco	71.8%	0 km	15.3%	5%	11.1%	25%	1.8%	50%
15. Sensitivity to EoL – 100% disposal – non eco	100%	SO	0%	5%	0%	SO	0%	SO
16. Sensitivity to EoL – 100% disposal –eco	100%	SO	0%	5%	0%	SO	0%	SO
17. Sensitivity to EoL – 100% recycling – w travel – non eco	0%	5 km	100%	5%	0%	SO	0%	SO
18. Sensitivity to EoL – 100% recycling – w travel –eco	0%	8,3 km	100%	5%	0%	SO	0%	SO
19. Sensitivity to EoL – 100% recycling – wo travel – non eco	0%	0 km	100%	5%	0%	SO	0%	SO

20. Sensitivity to EoL – 100% recycling – wo travel –eco	0%	0 km	100%	5%	0%	SO	0%	SO
21. Sensitivity to EoL – 100% loss –non eco	0%	SO	0%	SO	0%	SO	100%	50%
22. Sensitivity to EoL – 100% loss –eco	0%	SO	0%	SO	0%	SO	100%	50%

3.2- Life cycle assessment of the scenarios emerging from the survey (with more realistic use phase and end of life assumptions)

3.2.1 Baseline scenario and comparison with the previous study

Figure 3.2 shows the results for our scenario 4 (baseline prospective scenario for eco-conscious), scenario 3 (baseline prospective scenario for non-eco-conscious) and the theoretical scenario in the EVA study.

It can be seen that for indicators such as abiotic depletion, water depletion, Acidification, eutrophication and agricultural land occupation the theoretical scenario tends to have more impact than our two baseline scenarios. On the other hand, it is observed that scenario 1 (baseline scenario for eco-conscious) tends to have a higher impact for climate change, non-renewable photochemical ozone, while for scenario 2 (baseline scenario for non-eco-conscious the impacts are smaller in each parameter. The low difference in results between scenario 3 and scenario 4 and the EVEA scenario can be explained by the fact that for both our baseline prospective scenarios, the travel to the recycling facility dominates the impact, largely compensating for the benefits of recycling (and the eco-conscious archetype users therefore have more impact thant the non-ecoconscious with such a scenario).

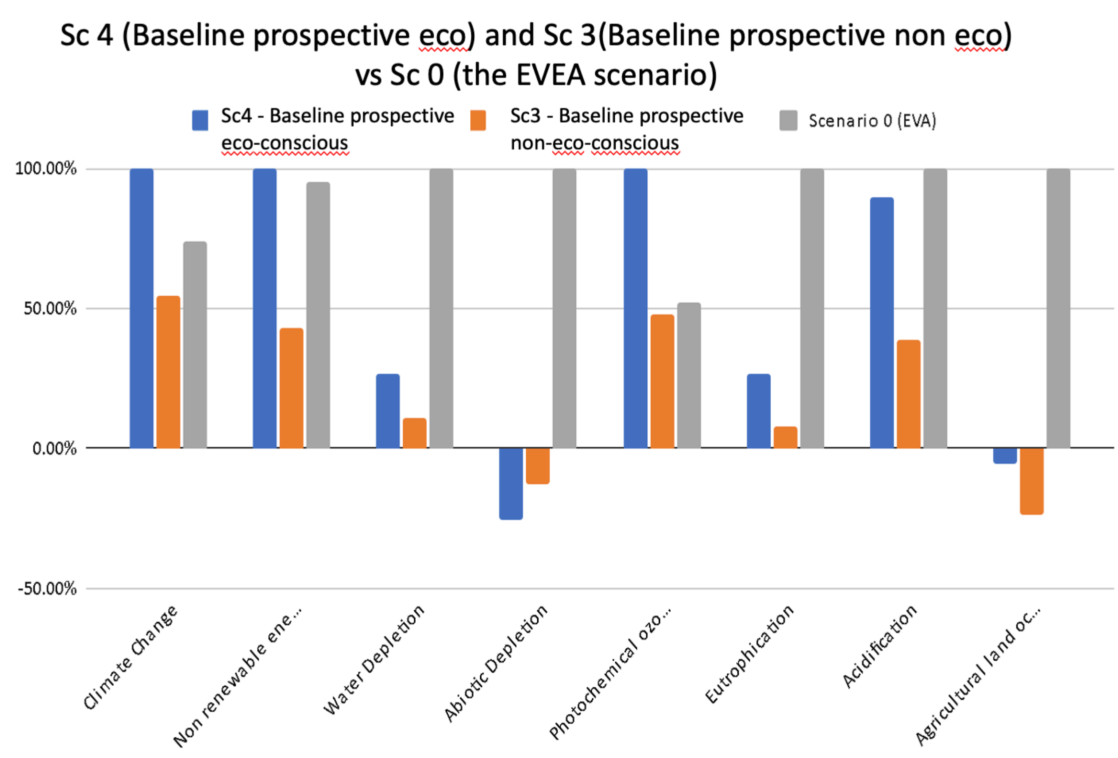

figure 3.2: comparing my two baseline prospective scenarios with the theoretical scenario made by EVA

To put things in perspective, the Sc4 prospective baseline scenario (making assumptions on how eco-conscious archetype consumers will recycle their lighters and travel to do so) has been compared to the S2 baseline scenario for the ecoconscious archetype, which represents better the current situation (no recycling) and represents how recycling affects negatively the impact with the assumptions I did.

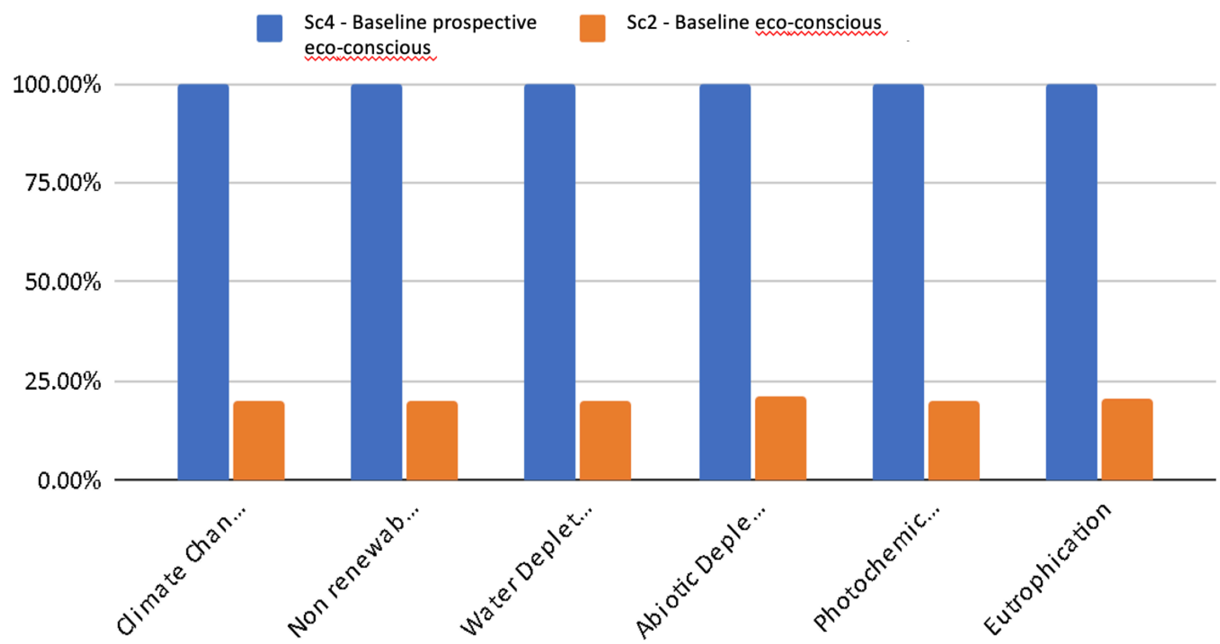

Figure 3.3: Comparing our baseline prospective scenario (Sc4) with predicted recycling and the current baseline scenario (Sc2) for the eco-conscious archetype.

3.2.2 Assessing the influence of the gas content in the lighter at end of life

Initially, scenarios 5 and 6 analyzed the impact of leaving 10% more gas in the lighter at the end of life for Formal Disposal and Collect & Recycle. Thus, the number of potential activations was consequently reduced. This decrease in activation has increased the impact on Climate Change from 5.1e-6 kgCO2e per activation to 6.0e-6 kgCO2e for formal disposal and 4.6e-4 to 5.1e-4 kgCO2e for Collect & Recycle, an increase of 17% and 10%, respectively. The other LCIA indicators, Water Depletion, Abiotic Depletion, Eutrophication, Acidification, and Agricultural Land Occupation also showed notoriously sensitive to the higher availability of gas -lower number of activations- in the lighter.

The sensitivity analysis of availability of gas in the lighter was also studied for Informal Outdoor Disposal with Scenarios 7 and 8. The Climate Change associated with the lighter activation increased by 30% when considering a reduction in the number of activations from 320 to 288.

The two figures 3.3 (for eco-conscious) and 3.4 for (non-eco-conscious) below summarize the impact the extra fuel content (formal disposal, collect and recycle and outdoor disposal) has on the LCA and that regardless of the archetype.

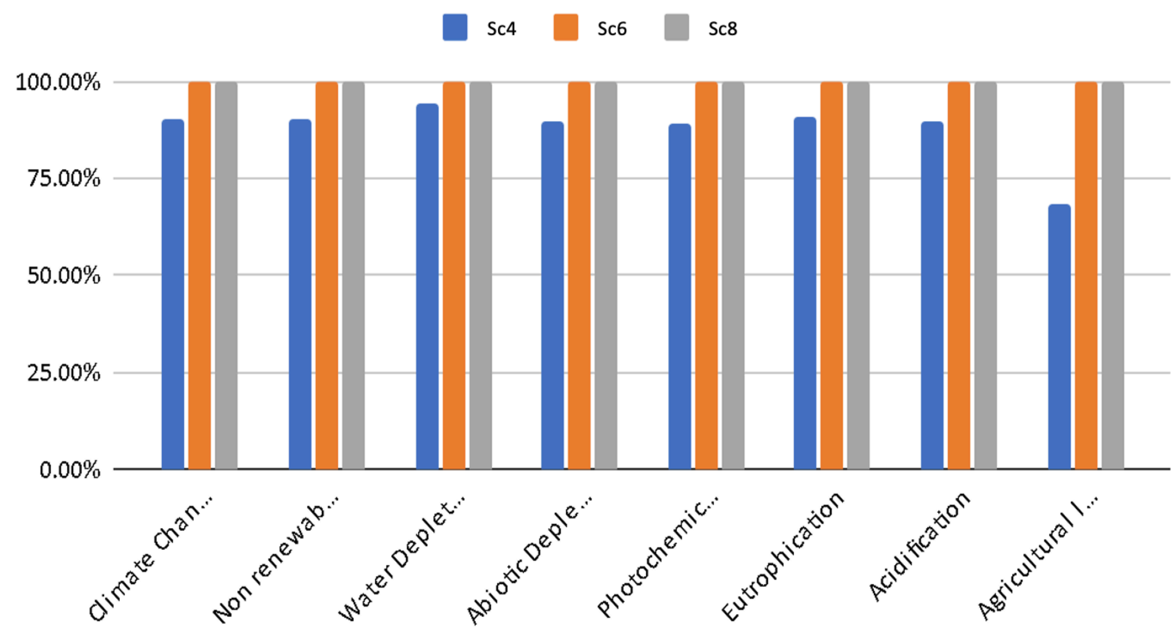

figure 3.4: Influence of gaz content in the lighter when disposed (Sc6) or lost (Sc8) when compared to baseline prospective scenario 4 for the eco-conscious archetype

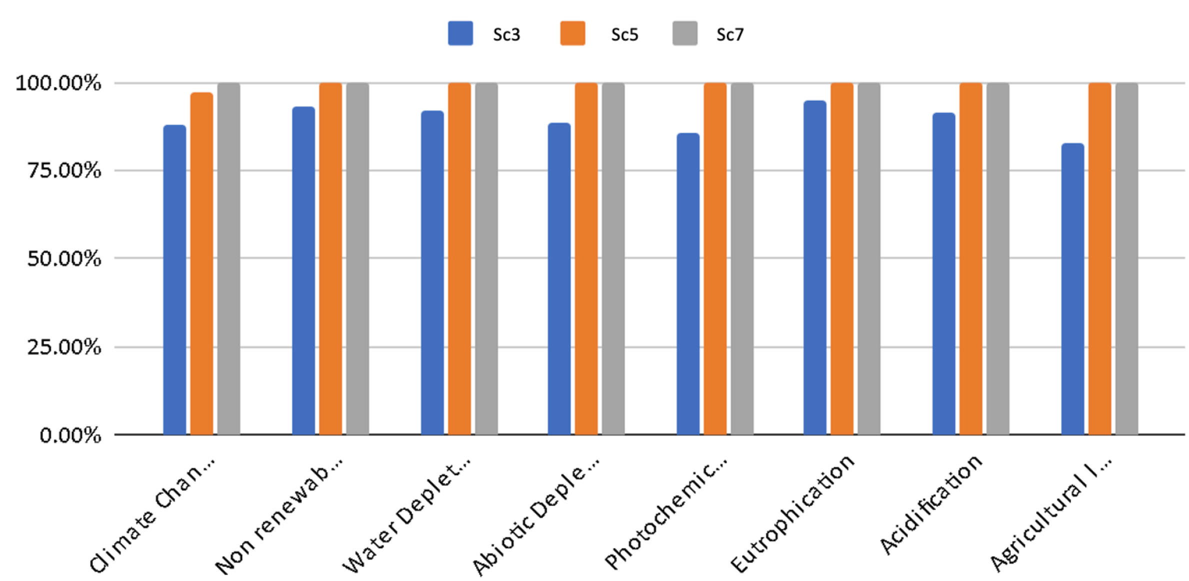

figure 3.5: Influence of gaz content in the lighter when disposed (Sc5) or lost (Sc7) when compared to baseline prospective scenario 3 for the non-eco-conscious archetype

3.2.3. Assessing the influence of the recycling rate

Figure 3.5 and Figure 3.6 shows the impact that increasing recycling rate would have on the LCA. I have analysed what would have happened if the recycling rate of the lighters would increase by 10% compared to the baseline prospective scenario. We can see from the two figures that compared to our baseline prospective scenarios (3 and 4) the scenarios with increased recycling tend to have a higher impact than the ones for formal disposal. This is due to the transportation used to get to the Collection Point. In the next section, we will discuss the impact of using a cleaner mode of transportation or no distance to the collection point has the LCA.

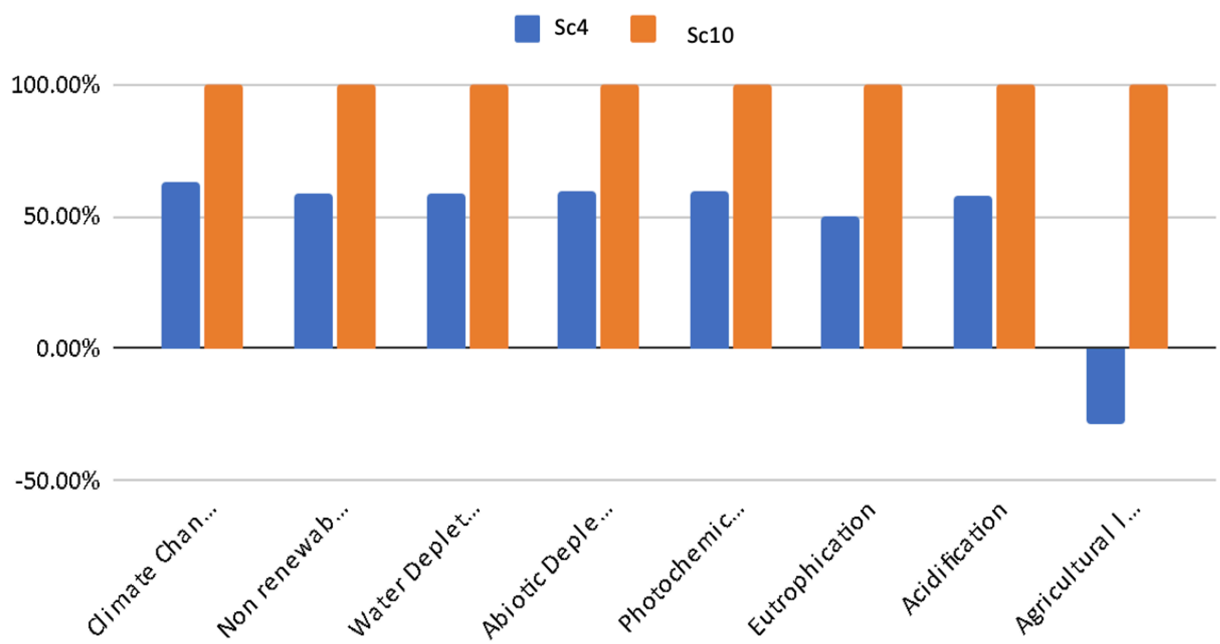

figure 3.6: Influence of increasing by 10% the recycling rate (sc10) compared to the baseline prospective scenario for the eco-conscious archetype (Sc 4)

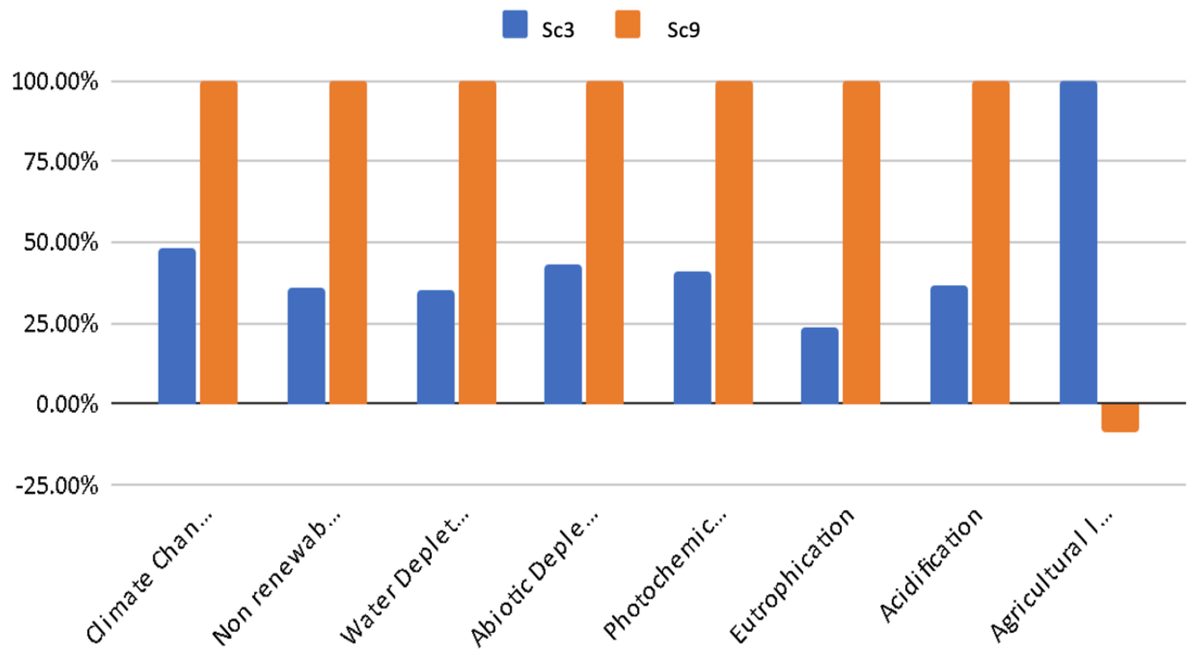

figure 3.7: Influence of increasing by 10% the recycling rate (sc9) compared to the baseline prospective scenario for the non-eco-conscious archetype (Sc 3)

3.2.4 Assessing the influence of the loss rate outdoor

Figure 3.8 shows the impact that losing lighter outdoors would have on the LCA. As we can see the loss rate does not appear to be so problematic in this study. This is because the impact assessment models chosen (like most EICV models) do not characterize the impact of plastics in the environment. Currently, there are studies being done (notably at the CIRAIG) to better characterize these impacts and it would be relevant to redo this analysis using the new models that take into account the impact of plastics in the environment. Hence I added another impact category at the inventory level : the quantity of lighter lost emitted to the nature.

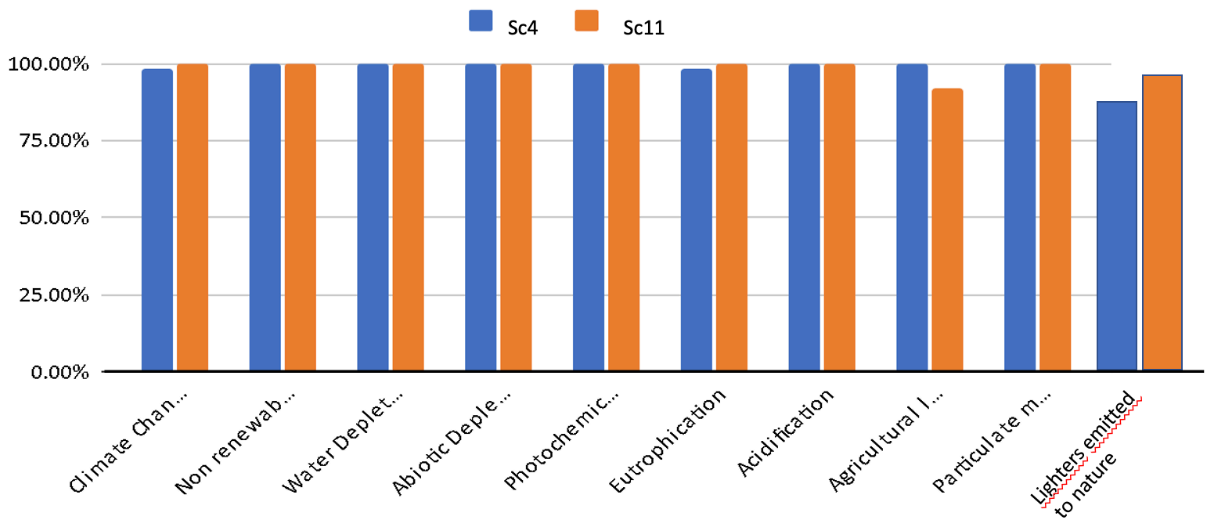

figure 3.8: Influence on 10% increase of loss of lighters in the nature (Sc 11) compared the baseline prospective scenario for the eco-conscious archetype (Sc4)

3.2.5. Assessing the influence of the distance to the collection point

The distance made ad-hoc to the Collection point was found to be critical for the LCA since the impact of the car distance made for this purpose is entirely attributed to the lighter end of life. This differs from the other end of life possibilities, such as Formal Disposal, in which the transportation impact of the lighter is shared with all the truck loads. Thus, it is expectable that under scenarios 4, in which it was considered Collect & Recycle considering 8.3 km for this purpose the impact of Recycling could be higher than the impact of Formal Disposal. For this reason, the scenarios 13 and 14 analyzed the end of life from the perspective of no car distance for Collect & Recycle. In these two scenarios, all the impacts were at their minimum compared to all the other scenarios as can be seen on figure 3.10. The eco-conscious archetype scenario with no travel (Sc 14) was lower compared to non-ECO conscious, indeed having an impact for Climate Change of -5.5e-6 and -4.98e-7 kgCO2e, for ECO and Non-ECO, respectively, strikingly lower than for the other end of life possibilities. This also applies for the other LCIA indicators such as the Abiotic Depletion with values of -9.34e-8 and -4.7e-8, respectively for ECO and Non-ECO.

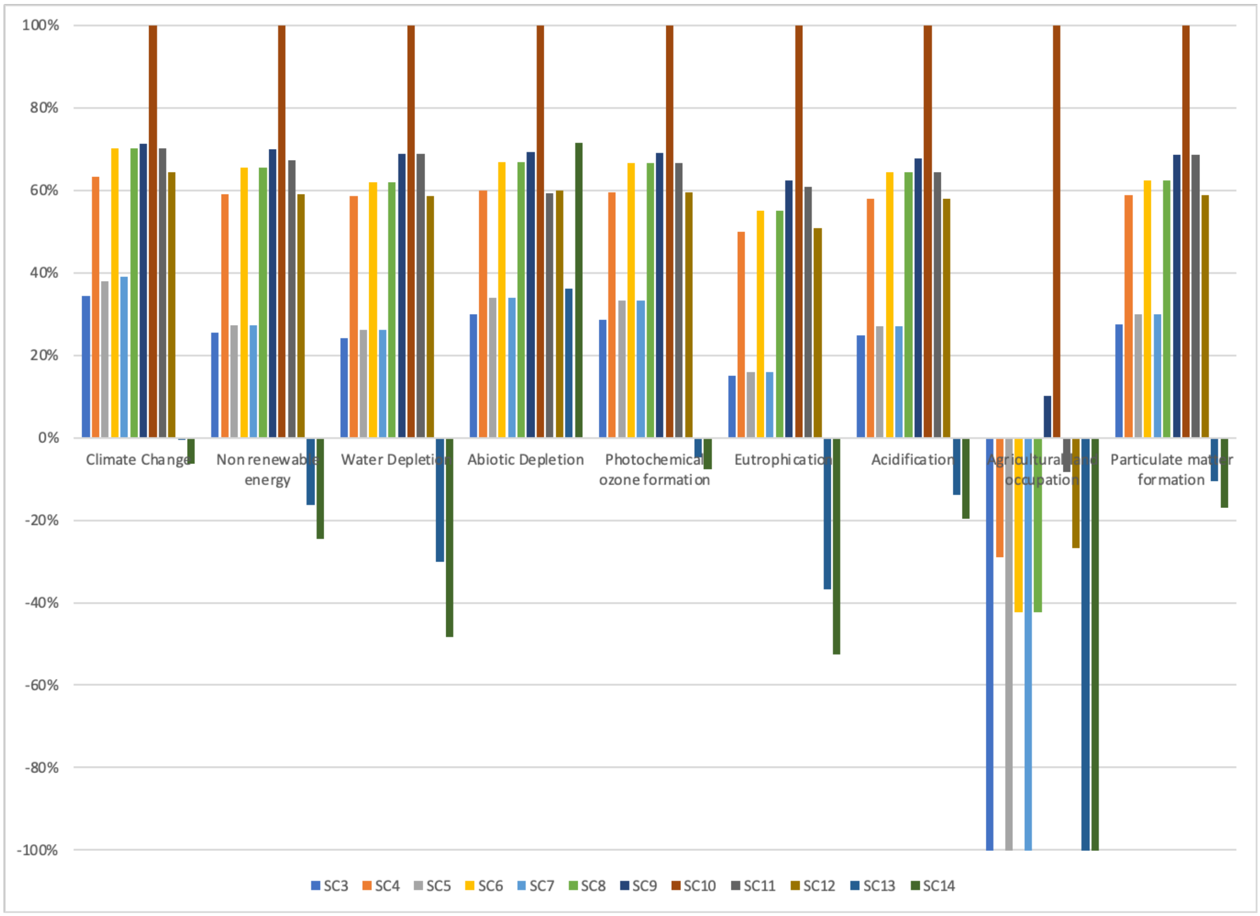

Figure 3.10: Influence of the travel distance to recycling facility : scenarios 13 &14 (non eco and eco-conscious archetypes respectively) with no travel to the recycling facility compared to all the other scenarios.

Figure 3.10 depicts the different LCA's indicator for our 12 scenarios. For Climate Change and Non-Renewable Energy, the impact of Collect & Recycle with no transportation to Collection point proved strikingly beneficial, scenarios 13 and 14, both for Eco and Non-Eco conscious customers. The same pattern can be observed for Water Depletion, Eutrophication and Acidification indicators. Both Scenario 13 and Scenario 14 outperformed the other indicators proving the striking importance of recycling and also the importance of keeping collection points at no additional travel distance, so users can dispose of it at the collection point at no extra car use.

To dig deeper the influence of transport and end-of-life scenarios, figure 3.11 shows the different end of life scenarios, highlighting that recycling with transportation is amongst the worst ant that recycling without transportation is amongst the best end-of-life scenario.

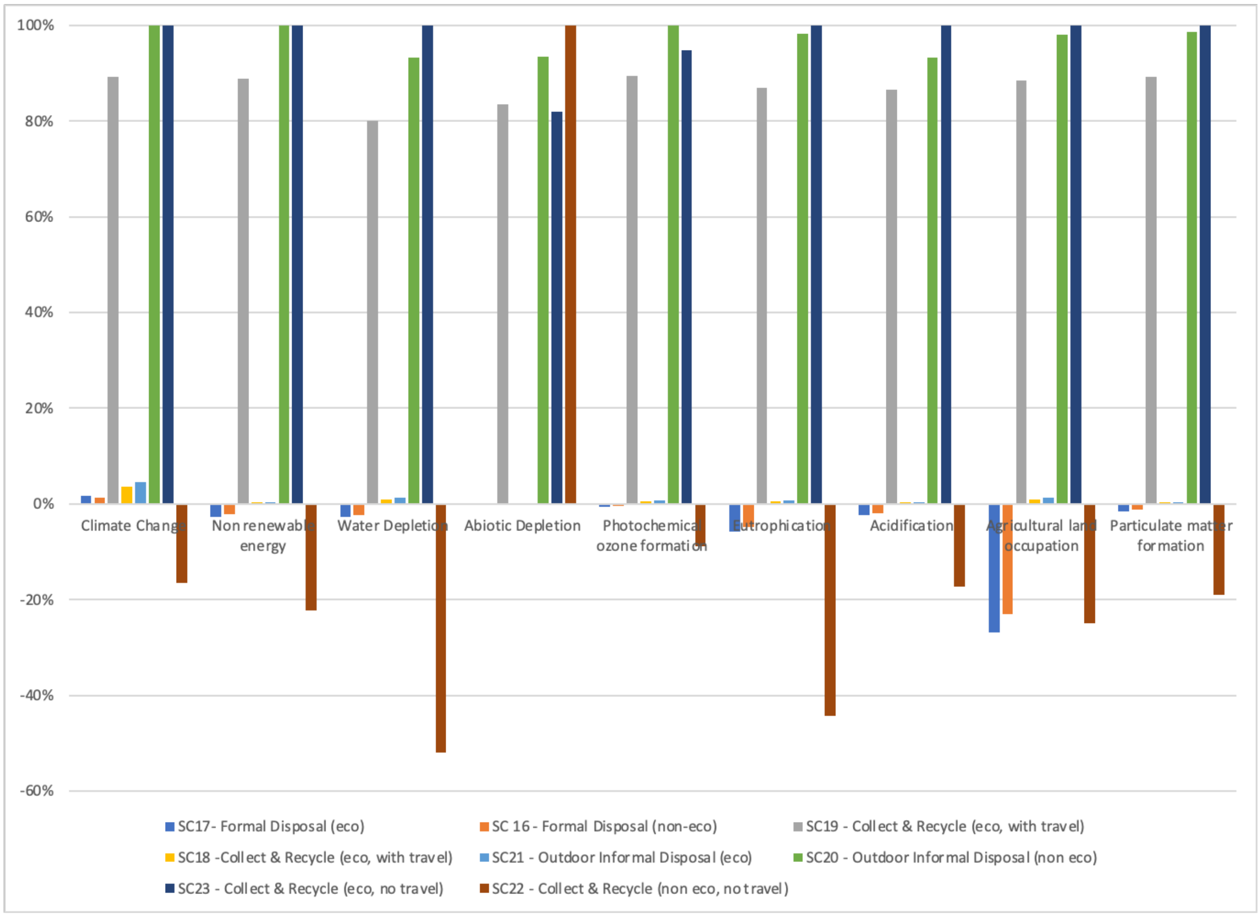

figure 3.9: comparing end of life scenarios

CHAPITRE 4 DISCUSSION

4.1 USAGE PHASE

Results obtained for LCA considering real data from IPSOS SURVEY were to be compared with theoretical values obtained in previous LCA by EVEA for usage and end of life phases. It is noteworthy that under the Theoretical study by EVEA the number of activations was 3,000 while in the IPSOS SURVEY it was found that the real number of activations was 720 activations, which represents 24% of the theoretical value. As the EVEA study highlighted that manufacturing was the main life cycle step contributing to the lighters footprint, this means that the lifespan may have a huge influence: if the lifespan is divided by 4, then the impact related to manufacturing the lighter is multiplied by 4. Unfortunately, I was not able to generate a contribution analysis for my scenarios as I received the primary data quite late and as I did not have access to the LCA software for a long time after that.

4.2 END OF LIFE PHASE

Regarding the end-of-life phase, it was found that the Collect & Recycle scenarios without impact of transportation to Collection point (Scenarios 11 and 12) showed much lower impact than Theoretical study, no matter the fact that the number of activations was strikingly lower for Scenarios 11 and 12. This shows how beneficial the Collect & Recycle scheme can be for the end of life of J26 lighter. However, it also shows the great impact that transportation distance to Collection point has into these results, with Non-Renewable Energy and Climate Change indicators highly above for the other 10 remaining scenarios when compared to Theoretical study. Indeed, if this distance is increased by 10%, the Climate Change increases from 4.6e-4 to 4.9e-04 kgCO2e/activation. For this reason, to reduce the environmental impact associated with the end of life associated with recycling it would be necessary to reduce or neutralize the required distance to the Collection point, or preferably considering that lighter sellers behave also as lighter collection points, so the impact of Collection distance can be minimized.

Furthermore, there is a difference between our two archetypes. This difference can be explained by the fact that potential environmental impacts of a product may differ depending on the end-of-life of a product. Because of the specific characteristics of the user's status and the context in which he or she operates, the way he or she will dispose of its product might differ. (Vanclay, 2002) this is also true with the use phase but in the case of this project the number of uses was found to be the same between both our archetypes.

4.3 study limits and recommendations

The Ecoinvent database was used, when possible, with the direct consequence of downgrading the quality of the BIC specific data by using generic data from this database. No data from real auditors of pockets lighters Recycling Facilities was collected for this study, which reduces the overall quality in the results obtained and represents a limit of this study. Furthermore, there were some parameters such as the amount of fuel left in the lighter when a user disposed of them due to malfunction that unfortunately, we could have the exact number. This represents a weakness of the user's survey based methodology. In fact, user surveys are very good to obtain qualitative data but not so much quantitative. Therefore, with the aim of mitigating this lack of data, hypothetical assumptions were made when necessary. It would be interesting, in order to make more robust scenarios, to investigate that parameter either through another questionnaire including a question regarding that parameter or by visiting waste management faculties and approximate the amount of fuel left in the cartridge. It would also be interesting to redo the analysis for the amount of lighter lost in the environment (section 3.2.4) using models that take into account the impact of plastics in the environment. There is presently a study being done by CIRAIG to integrate the parameter of plastic pollution in the environment in the LCA methodology.

CONCLUSION

This project has been mandated by BIC in collaboration with CIRAIG. The objective of the project was to improve the overall robustness of the LCA results using primary data on user's behavior in the use and end-of-life phases. The data for the two questionnaires has been collected in France and results are specific to that region.

The results obtained show that the hypothetical scenarios previously created in the lighter's LCA may have been underestimated due to the use of a theoretical lifespan. Indeed, according to the previous analysis, the lifetime of a lighter would be 3000 flames, but according to the data obtained, this number would be 720 flames. Furthermore, by comparing the results obtained for our different scenarios with the results obtained in the previous analyses, we can see that our prospective scenarios for end of life bring a new light on some potential impacts that may be important to take into account for BIC while transitioning toward implementing recycling facilities. The distance made ad-hoc to the Collection point for recycling had a significant impact on the Climate Change; if this distance increases 10%, the Climate Change increases from 4.6e-4 to 4.9e-04 kgCO2e/activation. However, when the travel distance is reduced, the recycling is really environmentally performant.

This project presents some limitations. Due to some mistakes and a lack of access to the LCA software, there in a discrepancy between the scenarios that were modeled and the scenarios better representing the survey results. Hence the LCA results do not represent adequately the users behavior and it may be interesting to model the actual scenarios resulting from the survey analysis. In addition, the loss rate does not appear to be problematic in this study (see section 3.2.4). This is due to the fact that the impact assessment models chosen (like most EICV models) do not characterize the impact of plastics in the environment. Further studies are being done in order to better characterize and include the impact of plastic in the environment.

However, event with those limitations, this master thesis brings a new light on the key elements for BIC to take into account to reduce the impacts of lighters end of life while implementing recycling facilities.

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ANNEXE A: Questionnaires A and B

Questionnaire Volet A

Link: Questionnaire_VoletA_BIC_FINAL (22-02-2021)

Questionnaire Volet B

Link:Questionnaire_VoletB_BIC_(07-04-2021)

ANNEXE B: EVA LCA (summary)

The objective of the EVA study was to evaluate the environmental performances of BIC lighter (J26), and compare them to other equivalent ignition systems that are available on the market such as rechargeable lighters, other non-rechargeable lighter, matches, zippos, etc.

The functional unit selected for this evaluation is: "The number of activation" and it is calculated as followed: amount of gas consumed/activation (1,6 mg/activation according to EN13869)*the amount of fuel available. In the case of the J26 lighter, it was determined that it is capable of producing 3000 activations/flammes.

Systems boundaries:

Figure B below gives a global vision of the system boundaries that have been set up to study the different systems.

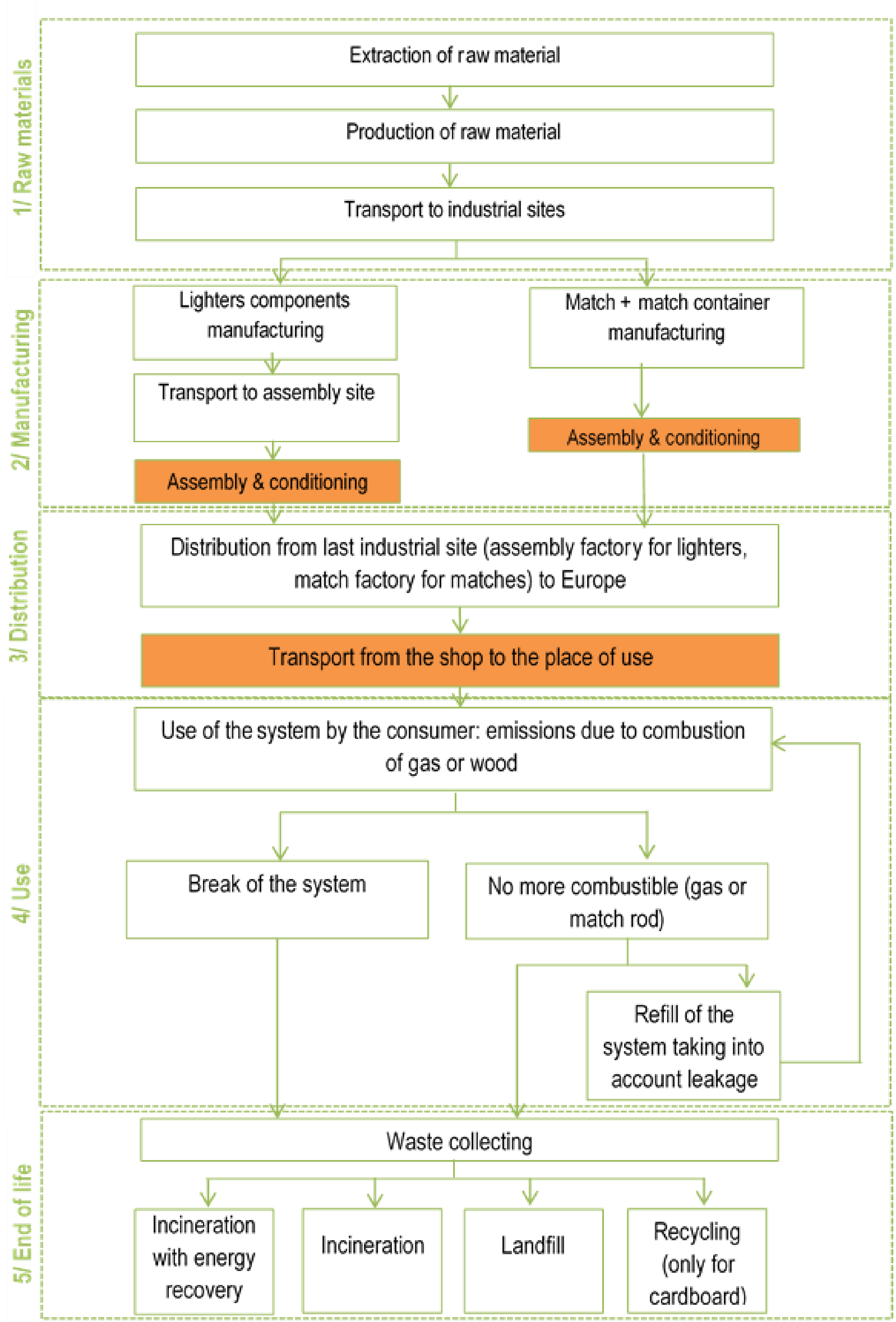

figure B: 4 Illustration of the system boundaries along the life cycle (orange steps are excluded)

A cradle to grave approach has been followed and, therefore, the following stages are included:

1/ The extraction of raw materials with their upstream transport.

The origin of the different raw materials was unknown. Therefore, EVA made hypotheses about the origin point and used average data for the origin of the raw materials (extraction and transport to the component plant).

2a/ The stage of component manufacturing, that is the process to create a component from the different raw materials.

This stage occurs in the component factory. No information about the country of the component plant is available. It has been chosen to consider that the components manufacturing country is the same as the country of their assembly plant. BIC J26 and Djeep D1 lighters are produced in France, Clipper CP11RH in Spain, Cricket flint in the Netherlands and the competitor flint, piezo Cricket lighters are produced in China. Matches have been produced in different countries; we consider a world average production.

2b/ The assembly stage was out of the scope of this study.;

3/ Distribution from the shop to the consumer:

It was assumed that the product will be distributed and used in Europe. Furthermore, the distances traveled by the customer (store to customer and customer to collecting point) have been excluded in EVA's study.

4/ The use stage considers the emissions to air generated by the combustion process. Furthermore, In their study, EVA has calculated the lighter lifespan in number of activations and has defined the lifespan of a lighter to be until the lighter is no longer functional, because its reservoir is empty (non-rechargeable lighters). From their data and research, they have calculated that the theoretical lifespan of the j26 lighter is 3000 flammes respectively.

5/ For the end of life the following European scenario with incineration with energy recovery, incineration, landfill, or recycling (for cardboard only) has been chosen.

European statistics on waste treatment based on Eurostat 2017 data. The scenario is the following:

- 52,2 % of incineration with energy recovery, the energy recovery is modelled by avoiding the following energy production:

- 28,22% from petroleum

- 41,8% from natural gas

- 21,96% from solid fuels

- 8,02% from renewable

- The net energy produced by the incineration is calculated with the data from Updates to life cycle inventories of waste treatment services, Gabor Doka, and al., 2013 (https://www.doka.ch/ecoinventMSWIupdateLCI2013.pdf). The values are the following: 15,84% of the LHV of the input waste is converted into electricity and 28,51% into heat. The communicated value in this report for the low heating value of average municipal waste is used: 11,7 MJ/kg.3 % of incineration without energy recovery

- 44,8 % of landfill" (BIC, 2020)

Table B: end of life LCI considered

Waste treatment process	Materials	Corresponding data
Incineration, energy recovery Europe	Ceramics, Chemicals, Electronics, Aluminum, Non-ferro, Coppers, Ferro-metals, Steel, Tin Sheet, Zincs, Brick, Paper, Plastics, PET, PVC, PE, PP, Biopolymers	Municipal solid waste {ROW} | treatment of, incineration | Alloc, Rec, S with 5,05E-1 kWh production of heat and 2,58E-1 kWh of electricity production Electricity: Electricity, medium voltage {Europe without Switzerland} market group for | Alloc Rec, S Heat: - 28,22% from petroleum: Heat, district or industrial, other than natural gas {Europe without Switzerland} heat production, heavy fuel oil, at furnace 1MW | Alloc Rec, S - 41,8% from natural gas: Heat, district, or industrial, natural gas {Europe without Switzerland} market for heat, district, or industrial, natural gas |Alloc Rec, S - 21,96% from solid fuels: Heat, district or industrial, other than natural gas {ROW} heat production, hardwood chips from forest, at furnace 10000kW |Alloc Rec, S - 8,02% from renewable: Heat, district or industrial, other than natural gas {ROW} heat production, at hard coal industrial furnace 1-10MW|Alloc Rec, S
	Cardboard	Waste paperboard {ROW} | treatment of, municipal incineration| Alloc Rec, S With the same production of heat and electricity than incineration with energy recovery for the other materials
	Wood	Waste wood, untreated {ROW} | treatment of waste wood, untreated, municipal incineration [Alloc Rec, S With the same production of heat and electricity than incineration with energy recovery for the other materials
Incineration, without energy recovery Europe	Ceramics, Chemicals, Electronics, Non-ferro, Ferro-metals, Zincs, Brick	Municipal solid waste {ROW} | treatment of, incineration | Alloc, Rec, S

	Aluminum	Scrap aluminum {ROW} | treatment of, incineration | Alloc, Rec, S
	Coppers	Scrap copper {CH} | treatment of, incineration | Alloc, Rec, S
	Steel	Scrap steel {ROW} | treatment of scrap steel, municipal incineration | Alloc, Rec, S
	Tin Sheet	Scrap tin sheet {ROW} | treatment of scrap tin sheet, municipal incineration | Alloc, Rec, S
	Cardboard	Waste paperboard {ROW} | treatment of, municipal incineration | Alloc, Rec, S
	Paper	Waste graphical paper {ROW} | treatment of, municipal incineration | Alloc, Rec, S
	Plastics, Biopolymers	Waste plastic, mixture {ROW} | treatment of waste plastic, mixture, municipal incineration | Alloc, Rec, S
	PET	Waste polyethylene terephthalate {ROW} | treatment of waste polyethylene terephthalate, municipal incineration | Alloc, Rec, S
	PVC	Waste polyvinylchloride {ROW} | treatment of waste polyvinylchloride, municipal incineration | Alloc, Rec, S
	PE	Waste polyethylene {ROW} | treatment of waste polyethylene, municipal incineration | Alloc, Rec, S
	PP	Waste polypropylene {ROW} | treatment of waste polypropylene, municipal incineration | Alloc, Rec, S
	PS	Waste polystyrene {ROW} | treatment of waste polystyrene, municipal incineration | Alloc, Rec, S
	Wood	Waste wood, untreated {ROW} | treatment of waste wood, untreated, municipal incineration [Alloc Rec, S
Landfill, Europe	Ceramics, Chemicals, Electronics, Non-ferro, Coppers, Ferro metals, Zincs	Municipal solid waste {ROW} | treatment of, sanitary landfill, Alloc Rec, S
	Aluminum	Waste aluminum {ROW} treatment of, sanitary landfill | Alloc Rec, S

	Steel	Scrap steel {ROW} | treatment of, inert material landfill | Alloc Rec, S
	Tin sheet	Scrap tin sheet {ROW} | treatment of, sanitary landfill | Alloc Rec, S
	Brick	Inert waste, for final disposal {ROW} treatment of inert waste, inert material landfill | Alloc Rec, S
	Cardboard	Waste paperboard {ROW} | treatment of, sanitary landfill | Alloc Rec, S
	Paper	Waste graphical paper {ROW} | treatment of, sanitary landfill | Alloc Rec, S
	Plastics, Biopolymers	Waste plastic, mixture {ROW} | treatment of waste plastic, mixture, sanitary landfill | Alloc Rec, S
	PET	Waste polyethylene terephthalate {ROW} | treatment of polyethylene terephthalate, sanitary landfill | Alloc Rec, S
	PVC	Waste polyvinylchloride {ROW} | treatment of polyvinylchloride, sanitary landfill | Alloc Rec, S
	PE	Waste polyethylene {ROW} | treatment of polyethylene, sanitary landfill | Alloc Rec, S
	PP	Waste polypropylene {ROW} | treatment of polypropylene, sanitary landfill | Alloc Rec, S
	PS	Waste polystyrene {ROW} | treatment of polystyrene, sanitary landfill | Alloc Rec, S
	Wood	Waste wood, untreated {ROW} | treatment of, sanitary landfill |Alloc Rec, S
Cardboard recycling	Cardboard	Data adapted with the PEF recommendation and including transport from consumer to recycling factory (1000 km, lorry <32 metric ton, EURO3 {GLO}) The recycled cardboard (material) is an adapted data from Folding boxboard/chipboard {GLO} |market for | Alloc, Rec without folding boxboard production, therefore there is only chipboard production, white lined
Steel recycling	Steel	Recycle steel (ecoinvent 3, BIC SIMAPRO). Recycling of 1kg of packaging steel according to PEF guidelines. Adapted by taking into account only R2 dependent terms (% of recycled material in end of life) and removing parameters related to % of recycled material incorporated.

Ferrocerium recycling	Ferrocerium	Recycle of Ferrocerium – Industrial Waste Treatment of Ferrocerium (BIC SIMAPRO).
ZAMAK recycling	Zamak	Recycle of Zamak – Industrial Waste Treatment of Zamak (BIC SIMAPRO)
POM recycling	POM	Recycle of POM – Industrial Waste Treatment of POM (BIC SIMAPRO)
Global plastic recycling	Global plastic	Recycle of global plastic (ecoivent 3, BIC SIMAPRO). Recycling of 1 kg of plastic waste generated during injection process from stationery. Plastic considered: polypropylene, polystyrene and polyethylene used for ball pen production. Yield recycling process considered = 90% according to PEF guidelines. Adapted by taking into account only R2 dependent terms (% of recycled materials in end of life) by removing parameters related to % of recycled material incorporated.
Transport for recycling	Medium size diesel car	Transport, passenger car, medium size, diesel, EURO 3 {GLO}| market for| Alloc Rec, S
	Transport freight	Transport, freight, lorry > 32 metric ton, EURO5 {GLO}| market for | Alloc Rec, S

ANNEXE C: J26 LIGHTER DESCRIPTION

The JC26 lighter belongs to the category of flint lighters, those composed of a metallic wheel and a stone (made of Ferrocerium) called a flint. The friction of the wheel on the stone induces the creation of a spark which will light the gas and generate an activation. Figure C represents an example of the different elements in a flint lighter the J26, while Table C depicts the material and weight associated with each component.

Tableau C: Composants et matériaux du briquet J26 BIC

Component	BIC J26
Body	POM 10,6g
Fork/ cheeks	Zamak 2,4 g
Gas (Isobutane + propane + butane)	4,8 g
Hood	Band steel 1,68 g
Stone Flint	Ferrocerium 0,4 g
Others	1,64 g
Total	21,52 g

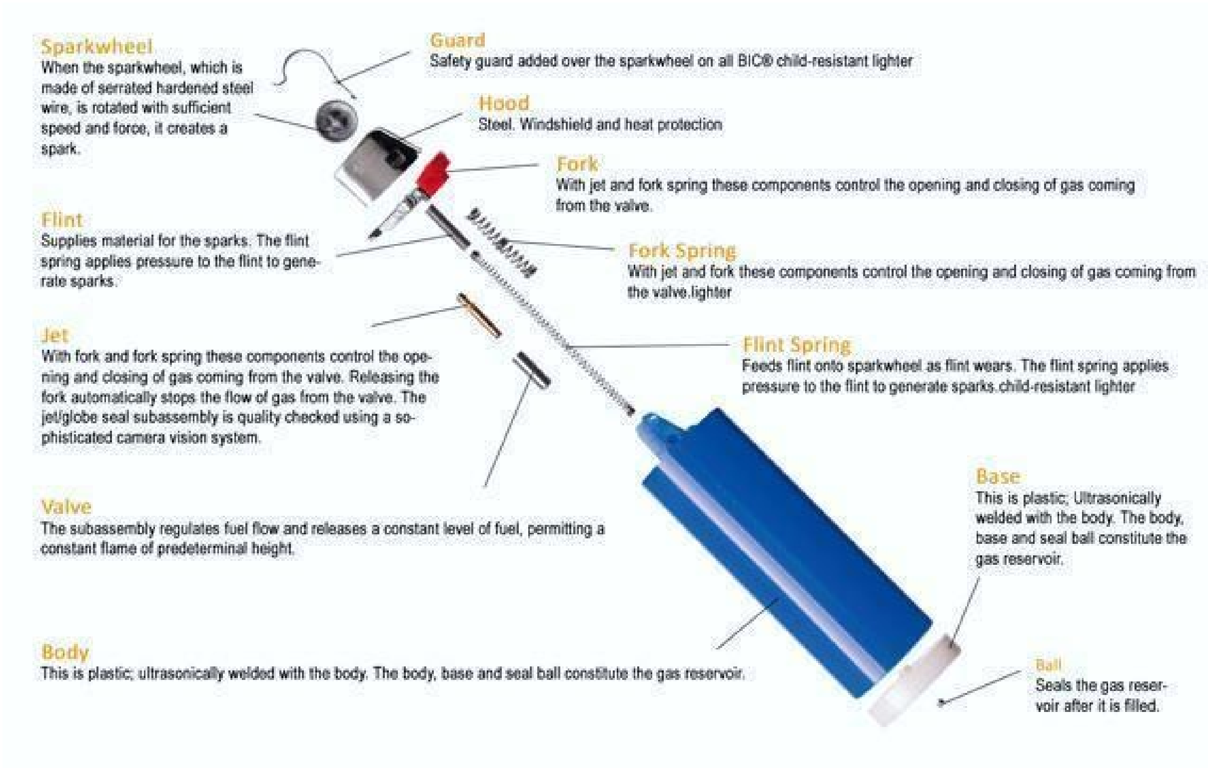

Figure C: BIC J26 lighter parts