Guide to accounting for avoided GHG emissions in waste recovery and recycling

Good practices and application to different sectors

Version 1.1

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GUIDE TO ACCOUNTING FOR AVOIDED GHG EMISSIONS IN WASTE RECOVERY AND RECYCLING

GOOD PRACTICES AND APPLICATION TO DIFFERENT SECTORS

VERSION 1.1

FINAL REPORT

October 2022 (updated June 2023)

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www.record-net.org

This report contains two parts:

Part One: Guide to accounting for avoided GHG emissions in waste recovery and recycling. Good practices ans application to different sectors (version 1.1)
Authors: D. SCHRIJVERS, C. BOLLE - WeLOOP

Second part: Comparison of RECORD’s guide with methodologies from NZI (June 2022 version) and WBCSD (July 2022 version)
Authors: V. LOZA, A. LANFRANCONI – EcoAct

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PART ONE

GUIDE TO ACCOUNTING FOR AVOIDED GHG EMISSIONS IN WASTE RECOVERY AND RECYCLING

GOOD PRACTICES ANS APPLICATION TO DIFFERENT SECTORS

(VERSION 1.1)

AUTHORS : D. SCHRIJVERS, C. BOLLE - WELOOP

SUMMARY

To stimulate innovation in low-carbon solutions, companies must be able to calculate and communicate the greenhouse gas (GHG) emissions avoided by their solutions, particularly in the recycling and waste valorisation sector, a key sector in the circular economy. While the relevance of methodological considerations has been underlined in the recent past, no consensus has emerged on the specific methodological choices to be implemented in the evaluation. Within this project, key methodological parameters were identified via a literature study on the calculation of avoided emissions. A common methodological framework, based on a consensus among actors in recycling and waste valorisation sectors, has been established to calculate avoided GHG emissions. The requirements of this framework are applied in the calculation of Reference Emission Factors for diverging recycling and valorisation sectors. These Emission Factors are presented in the form of Excel sheets, that can serve as calculation templates and can be used in future data updates. It is recognized that avoided emissions are achieved by the contribution and efforts of multiple actors in the value chain, which is also put forward in the communication recommendations that are formulated for a non-expert audience, LCA experts, as well as in the context of corporate reporting. Finally, recommendations are provided for the implementation and refinement trajectory of the methodological guide, as well as for the future revision of the Reference Emission Factors.

KEY WORDS

Avoided emissions, Recycling, Waste valorisation, Life Cycle Assessment, Corporate GHG emissions

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RESUME

Pour stimuler l’innovation dans les solutions bas carbone, les entreprises doivent être en mesure de calculer et de communiquer les émissions de gaz à effet de serre (GES) évitées par leurs solutions, en particulier dans le secteur du recyclage et de la valorisation des déchets, secteur clé de l’économie circulaire. Bien que la pertinence des considérations méthodologiques ait été récemment soulignée, aucun consensus n’a émergé sur les choix méthodologiques spécifiques à mettre en œuvre dans ce type d’évaluation. Dans le cadre de ce projet, des paramètres méthodologiques clés ont été identifiés par le biais d’une étude bibliographique sur le calcul des émissions évitées. Un cadre méthodologique commun, basé sur un consensus entre les acteurs des secteurs du recyclage et de la valorisation des déchets, a été établi pour calculer les émissions de GES évitées. Les exigences de ce cadre sont appliquées dans le calcul des facteurs d’émission de référence pour les différents secteurs du recyclage et de la valorisation. Ces facteurs d’émission sont présentés sous la forme de feuilles Excel, qui peuvent servir de modèles de calcul et peuvent être utilisés pour les futures mises à jour des données. Il est reconnu que les émissions évitées sont obtenues grâce à la contribution et aux efforts de multiples acteurs de la chaîne de valeur, ce qui est également mis en avant dans les recommandations de communication formulées à l’intention d’un public non expert, experts en ACV, ainsi que dans le contexte du corporate reporting. Enfin, des recommandations sont fournies pour la mise en œuvre et l’affinement de la méthode inclue dans le guide méthodologique, ainsi que pour les futures révisions des facteurs d’émission de référence.

MOTS CLES

Emissions évitées, Recyclage, Analyse du Cycle de Vie, Bilan GES *Corporate*

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Glossary

Term (English)	Definition (inspired by the "preliminary guidance"[1], unless otherwise specified)	Term (French)	Definition (French)
Assessed solution	The solution that generates avoided emissions in comparison with a reference solution.	Solution évaluée	La solution qui génère des émissions évitées par rapport à une solution de référence.
Attribution of benefits	Qualitative or quantitative sharing of the benefits estimated through the avoided emissions accounting, between all actors of the value chain committed in the implementation of the assessed solution.	Attribution des bénéfices	Partage qualitatif ou quantitatif des bénéfices estimés grâce à la comptabilisation des émissions évitées, entre tous les acteurs de la chaîne de valeur engagés dans la mise en œuvre de la solution évaluée.
Attributional approach (A-LCA)	[adapted] Approach used in LCA to attribute potential impacts to a given product/service/process without considering the potential effects and consequences associated with the implementation of the assessed solution beyond the studied value chain.	Approche attributionnelle (A-LCA)	[Adaptée] Approche utilisée en ACV pour attribuer les impacts potentiels à un produit/service/processus donné sans tenir compte des effets et conséquences potentiels associés à la mise en œuvre de la solution évaluée au-delà de la chaîne de valeur étudiée.
Avoidance period	Period of time during which solutions are studied and their GHG emissions compared.	Période d'évitement	Période pendant laquelle les solutions sont étudiées et leurs émissions de GES comparées.
Avoided emissions	[adapted] Reduction of GHG emissions that occur as a result of the implementation of the assessed solution, compared to a reference solution during the defined avoidance period	Emissions évitées (dans le cas d'analyses comparatives)	[Adaptée] Réduction des émissions de GES résultant de la mise en œuvre de la solution évaluée, par rapport à une solution de référence, pendant la période d'évitement définie
Consequential approach (C-LCA)	[adapted] Approach used in LCA to assess the environmental consequences of the assessed solution on global GHG emissions, beyond the studied value chain.	Approche conséquentielle (C-LCA)	[Adaptée] Approche utilisée en ACV pour évaluer les conséquences environnementales de la solution évaluée au-delà de la chaîne de valeur étudiée.
Energy recovery from waste	Energy recovery from waste is the conversion of waste materials into	Valorisation énergétique des déchets	La valorisation énergétique des déchets (W2E) est la conversion des déchets en

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[1] Veolia, Veolia Research & Innovation, Quantis, Gold Standard Foundation, WBCSD, Paprec, Séché Environnement and Suez, *Preliminary Guidance for Avoided Emissions Accounting in Waste Management and Recycling*, 2019.

Term (English)	Definition (inspired by the "preliminary guidance"[1], unless otherwise specified)	Term (French)	Definition (French)
	useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolysis, anaerobic digestion, and landfill gas (LFG) recovery. This process is often called waste-to-energy (W2E).		chaleur, électricité ou carburant utilisables, par une variété de processus, y compris la combustion, la gazéification, la pyrolyse, la digestion anaérobie et la récupération des gaz de décharge (LFG).
Functional unit	Reference unit used in LCA, based on the solution's quantified performance (equivalence of service provided). The definition of a functional unit should ensure that evaluated solution and the reference scenario can be compared.	Unité fonctionnelle	Unité de référence utilisée en ACV, basée sur la performance quantifiée de la solution (équivalence de service rendu). La définition d'une unité fonctionnelle doit permettre de comparer la solution évaluée à un scénario de référence
Multifunctional process modelling	[adapted] Strategy to make two processes or systems comparable, of which one is multifunctional, by dividing the process into two or more subprocesses or by expansion or reduction of the system. When multifunctionality is solved by system reduction, substitution of a similar or equivalent solution is done, leading to avoided impacts. If system expansion, reduction, or substitution is not applicable, allocation can be done via partitioning or the cut-off approach.	Modélisation des processus multifonctionnels	[Adaptée] Stratégie pour rendre deux processus ou systèmes comparables, dont l'un est multifonctionnel, en divisant le processus en deux ou plusieurs sous-processus ou en élargissant ou en réduisant le système. Lorsque la multifonctionnalité est résolue par la réduction du système, la substitution d'une solution similaire ou équivalente est effectuée, conduisant à des impacts évités. Si l'expansion, la réduction ou la substitution du système n'est pas applicable, l'allocation peut être effectuée via le partitionnement ou l'approche cut-off.
Recycling	[adapted] Industrial processes/operations that add value to waste and transform it into an input that can be used as a substitute to alternative inputs	Recyclage	[Adaptée] Processus/opérations industriels qui ajoutent de la valeur aux déchets et les transforment en un intrant pouvant être utilisé en remplacement d'intrants alternatifs.
Reference scenario	Scenario used as a reference, against which the assessed solution is compared, on the bases of the same function	Scénario de référence	Scénario utilisé comme référence, à laquelle la solution évaluée est comparée, sur la base de la

Term (English)	Definition (inspired by the "preliminary guidance"[1], unless otherwise specified)	Term (French)	Definition (French)
	provided (the same functional unit).		même fonction fournie (la même unité fonctionnelle).
Solution	[adapted] Refers to an action involving the increased or decreased production, use, or operation of products, processes, or projects (in this guide associated to waste management and recycling activities)	Solution	[Adaptée] Fait référence à une action impliquant l'augmentation ou la diminution de la production, de l'utilisation ou de l'exploitation de produits, de processus ou de projets (dans ce guide associée à des activités de gestion des déchets et de recyclage)
System boundaries	[adapted] Set of processes and stages of the value chain that are considered in the analysed solution and the reference scenario.	Frontières du système	[Adaptée] Ensemble de processus inclus dans la solution analysée et le scénario de référence.
Recycling/ valorisation value chain	[adapted] All the operations associated to the recycling and valorisation activities of wastes.	Filière de recyclage/valorisation	[Adaptée] Toutes les opérations associées aux activités de gestion et de recyclage ou valorisation des déchets.

Acronyms

Acronym	Definition	Acronym	Definition	Acronym	Definition
ADEME	Agence de l'environnement et de la maîtrise de l'énergie	FNADE	Fédération Nationale des Activités de la Dépollution et de l'Environnement	OECD	Organisation for Economic Co-operation and Development
AFNOR	Association française de normalisation	GHG	Greenhouse Gases	PE	Polyethylene
A-LCA	Attributional Life Cycle Assessment	HDPE	High density polyethylene	PEF	Product Environmental Footprint
ASR	Automotive Shredding Residue	ICCA	International Congress and Convention Association	PEFCR	Product Environmental Footprint Category Rule
BIR	Bureau of International Recycling	ILCAj	The Institute of Life Cycle Assessment, Japan	PET	Polyethylene terephthalate
CEWEP	Confederation of European Waste-to-Energy Plants	INERIS	L'Institut national de l'environnement industriel et des risques	PGMs	Platinum Group Metals
CFF	Circular Footprint Formula	INRAE	Institut national de recherche pour l'agriculture, l'alimentation et l'environnement	PP	Polypropylene
C-LCA	Consequential Life Cycle Assessment	IPCC	Intergovernmental Panel on Climate Change	PPO	Orientated Polypropylene
C-PCR	Complementary Product Category Rules	ISO	International Organization for Standardization	PVC	Polyvinyl Chloride
CSTB	Centre Scientifique et Technique du Bâtiment	JRC	Joint Research Centre	REF	Reference Emission Factors
CTBM	Le Centre de traitement de la biomasse de la Montérégie	LCA	Life Cycle Assessment	RPM	Recycled Primary Material
EAF	Electric arc furnace	LFG	Landfill gas	SEDDRe	Syndicat des Entreprises de Déconstruction, Dépollution et Recyclage
ECS	European Committee for Standardization	LNG	Liquefied Natural gas	SRF	Solid Recovered Fuels
EF	Emission Factor	MBS	Mechanical-Biological Sorting	SRP	Syndicat national des Régénérateurs de matières Plastiques
ELV	Electric Ligh Vehicle	MS	Mechanical Sorting	STEP	Septic Tank Effluent Pumping
EPD	Environmental Product Declaration	MSW	Municipal Solid Waste	W2E	Waste to Energy
EpE	Entreprises pour l'Environnement	NGO	Non-government organization	WBCSD	World Business Council for Sustainable Development
FEAD	Fédération Européenne des Activités de la Dépollution et de l'Environnement	NGV	Natural Gas Vehicle	WEEE	Waste from Electrical and Electronic Equipment
FEDEREC	Fédération professionnelle des entreprises du recyclage	NHIW	Non-hasardous industrial waste	WRI	World Resources Institute
FFB	Fédération Française du Bâtiment	NHWSF	Non-hasardous waste storage facility		

1. Introduction and objectives

1.1. Context

Combatting climate change is one of the key priorities of current governmental policies (e.g. via international agreements such as COP2015 and the Sustainable Development Goals), in the public debate, as well as in the strategic considerations of many companies. Companies play a crucial role in providing technical, business, and consumer solutions to reduce greenhouse gas (GHG) emissions. These innovative solutions often require significant investments, e.g. in the form of R&D and capital. To justify these investments, to facilitate the implementation of the solutions on the market, and to formulate needs for supportive policy frameworks, **it is important that the company is able to quantify and communicate its contribution to reduced GHG emissions**, to policymakers, to investors, to their suppliers and clients, and to the wider society.

The transition to a more circular economy is often considered as a strategy that could support the required reduction in the GHG emissions of our economic activities (Ellen MacArthur Foundation, 2015; European Commission, 2015), via a decreased energy consumption and a decreased reliance on primary resources and associated damages to the planet. The circular economy supports increased resource efficiency via numerous strategies, including reuse, repair, remanufacturing, and refurbishment. However, to recover the valuable materials and energy contained in products that reach the end of their life cycle, even after several loops, **recycling and energy recovery are crucial activities** to close the final loop.

The environmental benefits of a (circular) innovation can be evaluated via a Life Cycle Assessment (LCA), in which the environmental performance of a product system (including resource extraction, manufacturing, transport, use, and end-of-life treatment) is assessed in relation to a functional unit; the quantified function that is provided by the product system. Evaluating the environmental performance of a recycling or waste valorisation process is relatively challenging, as the process serves two distinct product systems: one in which the primary product is used, and one in which the recovered material or energy is used. This makes the end-of-life process multifunctional, and an allocation strategy must be defined to distribute the environmental impacts of the processes among the two functions. A comparison of the environmental performance of the recycling/recovery process (i.e. “the solution scenario”) to a reference scenario can indicate whether the former is environmentally beneficial. If this is the case, **GHG emissions could be avoided** by opting for the solution scenario instead of the reference scenario. In LCA, such avoided emissions are evaluated at the scale of the product system. Indeed, avoided emissions could be a collective effort of product designers, waste collectors, recyclers, and users of the recycled material. However, for company reporting and communication, it is important to be able to demonstrate **what avoided emissions can directly be ascribed to the company.**

Several guidance documents have been developed to provide guidance to support company’s assessments in the evaluation of avoided emissions (ADEME, 2016; Entreprises pour l’Environnement, 2018; Grönman et al., 2019; ICCA and WBCSD, 2017, 2013; The Institute of LCA Japan, 2015). Guidance is provided in the formulation of the solution scenario, the reference scenario, allocation rules for multifunctional processes, and whether avoided emissions can be allocated to specific companies in the value chain. The provided guidance is often broad and the documents are not aligned on all points, such as the possibility to “claim” avoided emissions by a single company. Within the project SCORELCA 2018-03, Schrijvers et al. (2019) conducted a review and provided recommendations in line with scientific practices in conducting an LCA. A consortium of companies also provided "*preliminary guidance*" for the assessment of avoided emissions, focusing on the recycling and waste recovery sector[2]. They recommend a structured procedure for the assessment of avoided emissions, which is shown in Figure 1. These recommendations highlighted important considerations regarding methodological choices and transparency of communication, while **a range of methodological options remain open for application by the company** or LCA practitioner.

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[2] Veolia, Veolia Research & Innovation, Quantis, Gold Standard Foundation, WBCSD, Paprec, Séché Environnement and Suez, *Preliminary Guidance for Avoided Emissions Accounting in Waste Management and Recycling*, 2019.

In a technical note, ADEME underlined that this lack of consensus on methodological choices will result in a lack of credibility and comparability of avoided emission claims (ADEME, 2020). ADEME emphasised the need for a calculation method that is homogeneous, shared, and acknowledged by companies, public authorities, and stakeholders. Therefore, a logical continuation of earlier reviews and recommendations is the establishment of consensus among actors in the recycling and waste valorisation sector on the methodological requirements for the evaluation of “avoided emissions”. The calculation and agreement on (avoided) Emission Factors enables to put these requirements into practice.

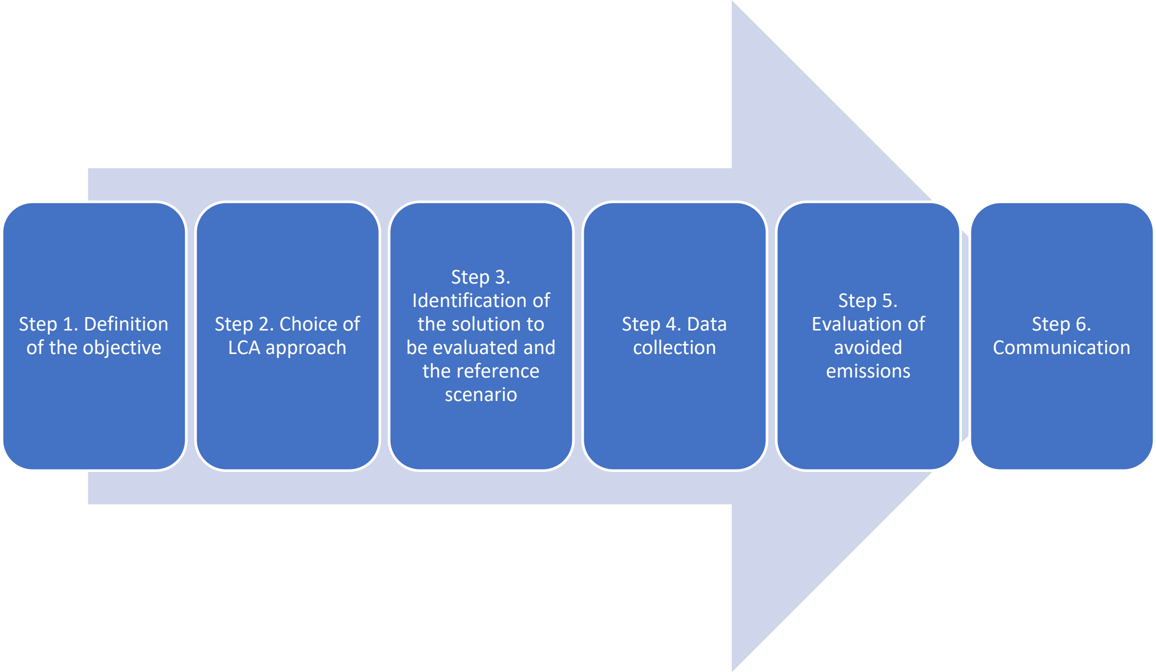

Figure 1 Steps to follow for avoided emissions assessment according to the Preliminary Guidance (2019) (RECORD, 2022)

1.2. Project Objectives

This project has the following objectives:

- Construct a common methodological framework, based on consensus among actors in recycling and waste valorisation value chains, as well as affiliated stakeholders. The methodological framework will contain **requirements and detailed recommendations** allowing for the quantification of avoided emissions, especially in comparison to reference scenarios,
- Collectively validate **avoided Emission Factors** following the prescribed methodology, specifically for energetic valorisation and different recycled materials in the European and the French context,
- Collectively validate allocation keys to **attribute avoided emissions among value-chain actors**,
- Formulate recommendations allowing for a **credible and transparent communication** of avoided emissions

1.3. Work plan

The work plan contains 4 phases, as shown in Figure 2. The objectives, work methodology, resources deployed and deliverables for each of these phases are presented in this section.

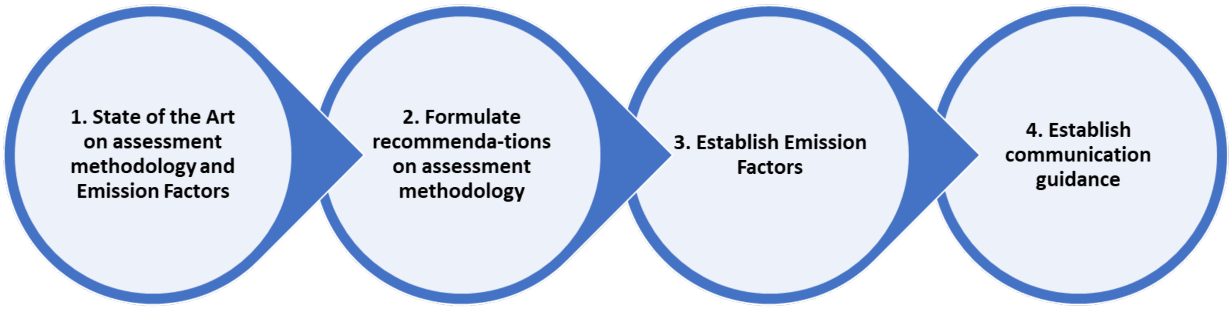

Figure 2 Work plan summary (RECORD, 2022)

1.3.1. PHASE 1: STATE OF THE ART ON ASSESSMENT METHODOLOGY AND EMISSION FACTORS

An overview is presented of the analyses of SCORE LCA 2018-03 and the "*preliminary guidance*" on the methodology of calculating avoided emissions. The discrepancy between these reference documents is highlighted. Attention is paid to the recommendations in these documents, as well as to the guidance documents discussed here, regarding the distribution of "avoided emissions" among actors in the value chain, considering the advantages and disadvantages of these recommendations.

Developments since the end of 2019 (e.g. (ADEME, 2020)) are identified and added to the analyses. The recommendations of the recent documents are reviewed against the analyses and recommendations of the "*preliminary guidance*" and SCORELCA 2018-03 reports.

Tables are developed to show the possible methodological choices for the calculation of "avoided emissions". These tables serve as the basis for the Phase 2 consensus-building process. The following is taken into account:

- Internal consistency of modelling requirements,
- The implications of modelling choices on the interpretation of "avoided emissions".

The recycling chains included in the state of the art of avoided emission factors are presented in Table 1. A survey is conducted in collaboration with RECORD and WeLOOP partners to obtain relevant industry information on, among other things, the following aspects:

- Overview of relevant inputs and outputs of recycling/recovery processes.
- Parameters determining quality
- Identification of potential uses of recovered materials/energies and substitutes.
- Overview of relevant alternative processes

Table 1 Considered recycling chains for the state of the art of avoided emissions factors (RECORD, 2022)

Recycling chain
Paper/cardboard recycling
Mechanical recycling of plastics
Chemical recycling of plastics
Recycling of metals (e.g. steel, copper, aluminium)
Glass recycling
Recycling of construction waste
Composting of organic waste
Methanization of organic waste (with cogeneration or direct injection of biogas into the natural gas network)
Energy recovery from waste in the form of solid fuels
Mixed waste incineration with energy recovery
Valorization of biogas from landfilling facilities

Recent work on the establishment of Emission Factors (EFs) in the sectors presented in Table 1 is identified. The starting point is ADEME's Base Carbone, which is complemented by recent communications from:

- European Confederation of Waste-to-Energy Plants (CEWEP)
- European Waste Management Association (FEAD)
- National Union of Plastics Regenerators (SRP) (e.g. concerning the "carbon saving certificate")
- Other associations identified by RECORD members and relevant WeLOOP partners.

The methodological choices applied in the avoided emission factors published by the sources examined are compared to the methodological choices identified by the analysis of the guidelines.

1.3.2. PHASE 2: FORMULATION OF RECOMMENDATIONS ON THE EVALUATION METHODOLOGY

Methodological requirements are determined and validated collectively with RECORD members via 3 consensus-building workshops.

The following procedure is applied:

- WeLOOP presented key methodological parameters and potential methodological choices in an intermediate meeting
- A first collection of opinions regarding key methodological parameters took place in the first consensus workshop. Based on the workshop outcomes, WeLOOP prepared a draft methodological guide. Members of RECORD provided feedback directly to the guide and via an evaluation survey.
- Feedback of the members of RECORD to the draft guide was further discussed in a second consensus workshop. The same procedure was applied: WeLOOP updated the draft methodological guide, and the members of RECORD provided their feedback.
- This process was repeated in a third consensus workshop. After this workshop, WeLOOP prepared the final report, on which RECORD members were provided the opportunity to comment. The comments were discussed in a final meeting, and WeLOOP prepared a final version of the report.

A guidance document is drawn up containing transparent and justified principles and requirements for calculating avoided emissions from recovery and recycling activities. This guidance document could serve as a C-PCR for the calculation of avoided GHG emissions for waste treatment sectors. The document contains requirements for different application cases:

- Two scales: *reporting/corporate* and site/project
- Two types of recovery: recycling and energy recovery

1.3.3. PHASE 3: ESTABLISHMENT OF EMISSION FACTORS

Methodological requirements of existing EFs (identified in Phase 1) are compared with the requirements formulated in Phase 2. Non-existing EFs or those that do not correspond to the methodological requirements formulated in Phase 2 are completed. During this step, a list of EFs is presented in Excel sheets that represent as many of the sectors mentioned in Table 1 as possible. These EFs are applicable at European level and will accommodate:

- The French electric mix
- The European electricity mix

The Excel sheets reflect the key methodological requirements of Phase 2 that allow for tracing the reasoning applied and data sources, and that allow for future updates that are consistent with the methodology. The EFs are validated by RECORD members.

1.3.4. PHASE 4. IMPLEMENTATION OF A COMMUNICATION GUIDE

Guidelines are formulated for the communication of "avoided emissions". The guidance is tailored to the target audiences (as identified in Phase 2), ensures credibility, transparency and follows clear reasoning/storytelling, and implements the communication requirements and recommendations of ISO 14044 and its Amendment 1 (communication of comparative assertions), ISO 14020, ISO 14025, ISO 14067, ISO 14064-1 and other relevant (ISO) standards.

2. State of the art

2.1. State of the art on the methodology for assessing "avoided emissions"

This section provides an overview of methodological aspects and requirements in the evaluation and communication of avoided emissions. This state of the art is based on earlier review studies on the topic of "avoided emissions". These earlier reviews are supplemented with recent relevant publications. The following documents follow the basis of the state of the art, with in bold the short name to which it is referenced throughout the report:

- The SCORE LCA 2018-03 report (Schrijvers et al., 2019) examines several guides on this subject, including:
    - **QuantiGES**: Quantifying the GHG impact of an emission reduction action - V2 (ADEME, 2022, 2016)
    - **ILCAj**: Guidelines for Assessing the Contribution of Products to Avoided GHG Emission (The Institute of LCA Japan, 2015)
    - **EpE**: Avoided emissions - Companies assess their climate solutions (2018)
    - **ICCA**: Avoiding Greenhouse Gas Emissions - the Essential Role of Chemicals: Guidelines - Accounting for and Reporting Greenhouse Gas (GHG) Emissions Avoided along the Value Chain based on Comparative Studies (ICCA and WBCSD, 2017, 2013)
    - **Carbon Handprint**: Carbon handprint – An approach to assess the positive climate impacts of products demonstrated via renewable diesel case (Grönman et al., 2019)
    - **Consequential LCA**: Based on (Schrijvers et al., 2021; Sonnemann and Vigon, 2011; Weidema et al., 2009)

Other documents were also reviewed:

- The report "**Preliminary Guidance** for Avoided Emissions Accounting in Waste Management and Recycling" (Veolia, Veolia Research & Innovation, Quantis, Gold Standard Foundation, WBCSD, Paprec, Séché Environnement and Suez, *Preliminary Guidance for Avoided Emissions Accounting in Waste Management and Recycling*, 2019) and documents cited in it (e.g. Mission Innovation, Greenhouse Gas Protocol Policy and Action standard (Greenhouse Gas Protocol, 2014)).
- World Resources Institute (**WRI**) - Estimating and Reporting the Comparative Emissions Impacts of Products (Russell, 2019)
- **ADEME** technical sheet "Avoided emissions, what are we talking about?" (ADEME, 2020)
- **Empreinte projet**: assess the environmental footprint of a project (RETHORE et al., 2021).
- **ENGIE**, Saint-Gobain, and Suez: Measuring the Contribution to Decarbonization of Customers: The Need for Coherent Industry Standards (ENGIE et al., 2021)
- The unpublished document "Greenhouse gases - Quantification and reporting of GHG emissions for organizations - Guidance for the application of ISO 14061-1" (**ISO/DTR 14069**, 2021)

2.1.1. AREAS OF APPLICATION OF "AVOIDED EMISSIONS"

What is meant with "avoided emissions" is a crucial aspect of guidance documents and company communications. This interpretation is dependent on the application area of the evaluation. (Russell, 2019) distinguishes between corporate inventory accounting (for corporate reporting), and the assessment of the carbon footprint of products and projects, which are complementary GHG assessment strategies. An overview of different types of comparative assessments and corresponding guidance documents is provided in Table 2. Unlike comparative assessments, corporate accounting is not intended to result in a comparison with alternative scenarios or other options available on the market.

Table 2 Overview of application areas in which "avoided emissions" can be quantified (RECORD, 2022)

Assessment type	Entity that can lead to avoided emissions	Specifics	Mentioned by guideline
Comparative assessment	Product	Goods and services	ICCA, EpE, Carbon Handprint, Preliminary Guidance, ISO/DTR 14069
		Intermediate and final products	ILCAj, WRI
		Only final products	ENGIE
		Products unique to value chain	ICCA
	Technology		Preliminary Guidance
	Manufacturing process		ISO/DTR 14069
	Project/management system/programme		Consequential LCA
	Decision		QuantiGES, consequential LCA, (Greenhouse Gas Protocol, 2014; ISO, 2012)
	Action		
	Policy		ADEME, ISO/DTR 14069, ISO 14064-1
Corporate Report	Company		ICCA, EpE, Carbon Handprint, Preliminary Guidance, ISO/DTR 14069

2.1.2. DEFINITION OF AVOIDED EMISSIONS IN BENCHMARKING

The Preliminary Guidance defines "avoided emissions" as "Reduced GHG emissions that occur as a result of the assessed waste management and recycling solution, compared to a reference solution". EpE and ADEME (2020) interpret avoided emissions as emission reductions achieved through solutions provided (or financed) by a company beyond the scope of that company. In the draft ISO/DTR 14069, avoided emissions are defined as the difference between the level of GHG emissions induced by the reporting organization's activity outside its organizational boundaries and the level of GHG emissions of a reference, counterfactual scenario that would have happened otherwise. These definitions have a few aspects in common:

- Mentioning of a *change* in emissions (e.g. reduction, "difference induced by", etc.)
- Mentioning of a *solution* introduced by a company, which induces the change in emissions
- Mentioning of a *reference scenario*, in which the solution does not take place, on which basis the change in emissions is calculated
- Mentioning that the change in emissions takes place *outside this company's operational boundaries*

WRI (Russell, 2019) mentions that the avoided emissions should be the result of an increased market *share* of the solution, which implies that **the solution provided in the reference scenario must be substituted**, i.e., its market share is decreased. On the contrary, an increased market *size* of a solution (obtained by additional sales of the solution, without subsequently substituting an alternative solution) has the risk of resulting in additional emissions rather than avoided emissions.

The fact that avoided emissions should take place outside the company's system boundaries is explicitly stated in a few documents, that indicate which emission reductions should *not* be considered as avoided emissions:

- Reductions that are the result of the comparison of direct and indirect GHG emissions (i.e. Scope 1, 2, and 3) between year n-1 and n (ADEME, 2020; Entreprises pour l'Environnement, 2018; Grönman et al., 2019; ISO/DTR 14069, 2021; Preliminary Guidance, 2019).
- Emission removals (which correspond to a physical process by which carbon is removed from the atmosphere through the absorption by carbon sinks) (ISO/DTR 14069, 2021)

In short, avoided emissions in the context of a comparative assessment could be summarized as "**reductions of GHG emissions that occur as a result of the implementation of the assessed solution, substituting a reference solution**". As Table 2 shows, comparative assessments include comparisons of products, processes, technologies, as well as of actions, decisions, and policies. Following the aforementioned definition, the implementation of the assessed solution and the subsequent substitution of a reference solution implicitly refer to an "action", hence, all comparative assessments could be formulated in the form of an action, such as the increased production, sales, or purchase of a product, the increased operation of a process, or the increased implementation of a technology, which could, in turn, be the consequence of a decision or a policy. Therefore, at this stage, no further distinction is made between the different types of comparative assessments.

Below, a more detailed analysis of the potential definition of "avoided emissions" is provided, based on the review of the state of the art.

2.1.3. DEFINITION OF AVOIDED EMISSIONS IN CORPORATE ACCOUNTING

In the context of corporate accounting, the term "avoided emissions" is used differently. Corporate GHG accounting allows to establish the carbon footprint of a company on the levels of scope 1 (direct emissions), scope 2 (emissions related to the use of electricity), and scope 3 (indirect emissions related to purchased and sold products). In many cases, for example due to the optimization of a company-operated process, company investments that lead to lower GHG emissions in the market will result in a favourable corporate GHG profile. However, in a few situations, these investments result in an *increased* GHG footprint on the level of the company, and only to GHG reductions beyond the company boundaries. To allow companies to communicate on the benefits generated beyond the boundaries of the company's operations, guidance documents on corporate GHG accounting allow for the mentioning of avoided emissions in the three following situations (Ministère de l'Environnement de l'Énergie et de la Mer, 2016; WBCSD and WRI, 2004):

- Material and energy recovery of waste
- Cogeneration of electricity and heat
- The production of electricity from renewable sources

These avoided emissions are not to be confused with reductions of corporate emissions over time, which refer to the scope 1, 2, and 3 emissions. Hence, a commonality of the use of "avoided emissions" in a comparative assessment and corporate reporting is that the emission reductions are achieved beyond the company's operational boundaries.

2.1.4. OBJECTIVE OF THE STUDY AND INTENDED AUDIENCE

Companies may evaluate their avoided emissions to fulfil various goals. The specific goal could influence certain methodological choices, such as the applied LCA approach, the formulation of the functional unit, the identification of the most appropriate reference scenario, but also the need to allocate avoided emissions to specific supply-chain actors or aggregate avoided emissions at a company level. The definition of the goal is therefore indicated as the first step of an avoided emissions assessment by the Preliminary Guidance.

In this report, the goals are classified by goals for comparative assessments, corporate reporting and goals that may be formulated in both application contexts (Table 3). Besides the formulation of the assessment goal, the intended audience should be considered as well, as in Table 4. The intended audience could affect the choice of LCA approach (what type of GHG emissions is the audience concerned about), the suitable reference scenario (e.g. what alternative solution is the specific stakeholder likely to adopt in absence of the assessed solution), and, for example, requirements on data quality (e.g. what would be the risk of a misinformed assessment, for example on the company's reputation?).

Table 3 Overview of the potential goals for assessment of avoided emissions (RECORD, 2022)

Potential objectives of the assessment of "avoided emissions"	Mentioned by guideline	Application area
Benchmarking the environmental performance of a new low- carbon technology/product /action	QuantiGES, EPE, WRI	Comparative assessment
Evaluation of contribution to GHG reduction goals	QuantiGES, EpE, ICCA	
Product/process differentiation	EpE, WRI	
Choose between different actions/products	QuantiGES, EpE, Consequential LCA, WRI	
Inform/Optimize the GHG emissions of a product/action	QuantiGES, ILCAj, ICCA, Carbon Handprint, WRI	
Respond to call for tenders		
Annual reporting	Preliminary Guidance, ILCAj	Corporate reporting
Inform portfolio planning	WRI	
Assess company risk and opportunities for investment	WRI	Comparative assessment / corporate reporting
Marketing	QuantiGES, ILCAj, EpE, ICCA, Carbon Handprint, WRI	
Implement new business models	WRI	

Table 4 Overview of potential target audiences of assessments of avoided emissions (RECORD, 2022)

Target audience		Mentioned in the methodological report
Investors		EpE, ICCA, WRI
General public		QuantiGES, ICCA
Researchers		
Internal	Not specified	ILCAj, ICCA
	Business developers	ICCA
	Product Developers	EpE, ICCA, Carbon Handprint, Consequential LCA
	Environmental Managers	QuantiGES
	Project Managers	QuantiGES
Legislators		QuantiGES, ILCAj, EpE, ICCA, Consequential LCA, WRI
Decision makers		QuantiGES, consequential LCA
Consumers		ILCAj, EpE, Carbon Handprint, Consequential LCA, ADEME
NGOs		EpE
Actors in the value chain		WRI

2.1.5. *CHOICE OF LCA APPROACH*

As described in the Preliminary Guidance, the second step of the study is the choice of applied LCA approach. The assessment can be done via an attributional or a consequential LCA. An attributional LCA aims to provide an overview of the environmental impacts of the products and processes that take place within the value chain of the assessed solution (e.g. the product, process, technology, or action of a company). These environmental impacts can be directly associated with the evaluated solution, and are, via allocation rules, *attributed* to the solution. Alternatively, one can conduct a consequential LCA. Consequential LCAs aim to evaluate the consequences of a solution. The processes that are affected by the solution (e.g. the increased implementation of a technology, or increased sales of a product) are identified, and the environmental impacts generated by these processes are evaluated. The calculated environmental impacts can take place outside the solution's value chain, for example through market-mediated effects, such as substitution or rebound effects (e.g. changed consumption patterns due to the use of a product with a lower price or with a higher energetic efficiency).

Often, it is argued that the choice between an attributional and consequential LCA is based on the size of the decision (European Commission, 2010), or whether the evaluated solution is considered static (e.g. an existing product) or dynamic (e.g. the increased sales of a product) (Preliminary Guidance, 2019).

Several guidance documents hence consider that "avoided emissions" are ideally evaluated via a consequential approach (ADEME, 2016; Greenhouse Gas Protocol, 2014; Rethore et al., 2021; Russell, 2019; Schrijvers et al., 2019; Preliminary Guidance, 2019). The Preliminary Guidance recommends an attributional approach for corporate reporting, and (Russell, 2019) recommends an attributional approach as an interim solution that allows the evaluation of the scope 3 emissions of a company. In practice, many other guidance documents also recommend an attributional approach, either explicitly or implicitly (Schrijvers et al., 2019).

As mentioned previously, the assessment of "avoided emissions" implies a dynamic situation, in which the assessed solution is increasingly implemented and increases its market share, at the expense of the reference solution. The distinction between a static and a dynamic approach therefore does not explain the mixed recommendations of the guidance documents. In the context of the evaluation of avoided emissions, a more relevant distinction between the applicability of an attributional or a consequential LCA is the scope of GHG emissions that is evaluated, as presented in Table 5. From Table 5 it can be deducted that **an attributional LCA is most suitable for corporate reporting**. **For a comparative assessment, the choice between an attributional or a consequential LCA depends on the scope of GHG emissions that is of interest to the intended audience of the assessment.** For example, a consumer might wish to decrease his/her own GHG footprint (requiring an ALCA), or might wish to decrease global GHG emissions with his/her actions (requiring a CLCA). Likewise, policymakers may wish to identify policies that contribute to global GHG reduction targets (requiring a CLCA) or that decrease the national GHG footprint (requiring an ALCA).

Table 5 Scope of evaluated GHG emissions in attributional and consequential LCA approaches (RECORD, 2022)

LCA approach	Avoided emissions refer to reductions of GHG emissions that are attributed to* …	GHG emissions considered in the assessment
Attributional LCA	- A product's value chain/life cycle - A process - A (regional) sector - A client - A company - A country/region	Only GHG emissions of processes that are present in the solution's value chain (scope 1, scope 2, and scope 3) are included in the assessment. Burden-shifting of GHG emissions to other value chains is excluded from the assessment.
Consequential LCA	- The global economy	GHG emissions of processes that are affected by the implementation of the solution are included in the assessment, regardless of whether they take place within the solution's value chain or beyond this value chain, e.g. via market-mediated effects. Burden-shifting to other value chains is included in the assessment.

*"Attributed to" implies that the emissions are evaluated that can be traced back to the assessed scope, e.g. because the GHG emissions are emitted by processes taking place in the solution's value chain.

2.1.6. FORMULATION OF THE ASSESSED SOLUTIONS AND DEFINITION OF SYSTEM BOUNDARIES

Step 3 for the formulation of avoided emissions according to the Preliminary Guidance is the "identification of the assessed solutions and the definition of system boundaries".

The following aspects should be considered in the formulation of the assessed and reference solutions:

- The type of solution and the functional unit
- The system boundaries (i.e. the processes and life cycle stages to include in the analysis)
- The approach to model multifunctional processes
- The relevant geographical scope
- The relevant temporal scope
- The relevant technologies in the assessed solution and the reference solution

FUNCTIONAL UNIT

In a comparative assessment, the emissions of the assessed and reference scenarios are calculated for a functional unit, which must be the same for the two scenarios. Following the observation that avoided emissions are the result of an action, the functional unit can contain the following parameters:

- The nature of the action
- The quantity of the subject
- The subject

Examples of options reflecting the nature of the action or the subject are provided in Table 6. Note that several options result in an increased operation of a process or an increased use of products. For example, the *implementation of a decision* to use renewable energy in a recycling process results in the increased *use of the product* "renewable energy". The *implementation of a policy* to increase the recycling rate of a waste results in the increased *operation of a recycling process*.

Functional flows, i.e. produced products and treated waste flows, should be described in terms of functionality (e.g. potential application areas) and waste composition, respectively, such as organic dry matter content and carbon content in the case of biological treatment of fermentable waste (ISO/DTR 14069, 2021).

Table 6 Examples of parameter values in the formulation of the functional unit (RECORD, 2022)

Nature of the action	Subject
Production	Product
Use	Waste
Sales	Service
Treatment	Process
Provision	Technology
Implementation	Decision
Execution	Action
Operation	Project
Investment in	Policy
Etc..	Etc..

SYSTEM BOUNDARIES

The system boundaries describe the processes that are included in, and excluded from, the assessment. Whereas all guidelines apply an approach that is in line with Life Cycle Assessment, there is a relevance between the system boundaries of an attributional and of a consequential LCA. Both LCA approaches require **the inclusion of processes that have a relevant contribution to increased or decreased GHG emissions in the evaluated scope** (see Table 5 for an overview of potential scopes) and that can be evaluated by (proxy) data. However, the scope of ALCAs is limited to processes within the product's value chain, whereas the scope of CLCAs include processes affected by the implementation of the solution outside the product's value chain (Table 7) – unless specifically stated that these processes are excluded.

Table 7 Processes Potentially Included or Excluded from System Boundaries (RECORD, 2022)

Included processes	Potentially omitted processes	Mentioned by guideline	Relevance for LCA approach
Entire life cycle of a product		ILCAj, ICCA, EpE	Attributional LCA
Waste collection, preparation, treatment, and recycling		Preliminary Guidance	Attributional LCA
Inclusion of life cycle stages in which the environmental benefits take place		Carbon Handprint	Attributional LCA
Inclusion of a panel of representative final products (for intermediate products)		ILCAj, WRI, Carbon Handprint	Attributional LCA
Indiquer le client et le profil de l'utilisation du produit final		Carbon Handprint	Attributional LCA
All direct and indirect consequences		QuantiGES, consequential LCA, ADEME, Empreinte Projet	Consequential LCA
Include (Rebound) effects outside the product value chain		QuantiGES, Mission Innovation, Consequential LCA, (Greenhouse Gas Protocol, 2014)	Consequential LCA
	Omission of (rebound) effects outside the product value chain to simplify	QuantiGES	Consequential LCA
	Omission of the processes that are identical in the assessed and reference scenario	ILCAj, ICCA, Preliminary Guidance, EpE, Carbon Handprint, WRI	Attributional and consequential LCA
	Omission of processes for which no data can be collected	WRI	Attributional and consequential LCA
	Omission of processes with negligible estimated emissions	QuantiGES, consequential LCA, WRI	Attributional and consequential LCA

REFERENCE SOLUTION

The choice of the technologies to include in the reference scenario is made at a conceptual and an applied level. Conceptually, most guidance documents state that the reference solution should reflect the situation in absence of the assessed solution. In practice, it is impossible to know with certainty what this reference situation looks like, as it never takes place, and can therefore not be measured. Hence, pragmatic assumptions need to be made to be able to estimate the most likely situation in the absence of the assessed solution. Most variation appears in the selection of technologies that reflect this scenario, therefore, the quantification of avoided emissions is highly dependent on this methodological step. The potential reference scenarios mentioned in Table 9 act as proxy scenarios for the conceptual reference scenarios in Table 8. Some pragmatic options of Table 9 can furthermore be considered as simplifications of other options. For example, it could be assumed that "conventional technologies" are most likely to be substituted, and these conventional technologies could be approximated by the average market share of all technologies. If not all available technologies are known, this could furthermore be simplified by selecting only the dominant technologies in the market, or the single technology with the highest market share. **The choice of the reference technologies can be motivated by a balance between, on the one hand, an applied logical reasoning striving for accuracy and, on the other hand, the acknowledgement of the uncertainty in the identification of the most suitable technology, as well as the availability of data.**

It should be noted that, in guidance documents focusing on corporate reporting, no conceptual description of the reference scenario in the calculation of avoided emissions was found. However, as corporate reporting is not done with the purpose of comparison, the identification of a reference scenario is of lesser importance. Instead, **for corporate reporting it may suffice to transparently describe the chosen reference scenario on which the avoided emissions are based.**

The geographical and temporal scope of the reference scenario should of course be aligned with the geographical and temporal scope of the GHG emissions of interest. For example, if the scope of the evaluated GHG emissions is "GHG emissions attributed to the French electricity sector in 2021" or "to the European economy throughout the lifetime of the product", technologies should be identified that contribute to GHG emissions in the same geographical and temporal scope.

Table 8 Alternative potential reference scenarios at a conceptual level (RECORD, 2022)

Conceptual identification of the reference solution	Mentioned by the methodological guide
The most likely situation in the absence of the assessed solution	Carbon Handprint, QuantiGES, ILCAj, ISO/DTR 14069, ENGIE, ICCA, Consequential LCA, ADEME, WRI
The solution that is going to be replaced	ICCA, Preliminary Guidance, Carbon Handprint
The product that fulfils the same function	ICCA
The situation in the past	ICCA, ISO/DTR 14069
A regulatory requirement	Preliminary Guidance, Carbon Handprint, Empreinte Projet

Table 9 Alternative potential reference scenarios at an applied level (RECORD, 2022)

Identification of the reference applied solution	Mentioned by the methodological guide
Market average (including or excluding the alternative studied)	ICCA, EpE, ISO/DTR 14069, ENGIE, Preliminary Guidance, Carbon Handprint, Consequential LCA (for large-scale decisions)
Product with the largest market share	ICCA, ILCAj, EpE, Carbon Handprint, ISO/DTR 14069
Conventional technologies	ICCA, Carbon Handprint, ILCAj
The best available technologies	Carbon Handprint, EpE, ADEME, ISO/DTR 14069, WRI
Marginal technology	WuantiGES, Consequential LCA (for small-scale decisions), ICCA, ADEME, ISO/DTR 14069, WRI
A specific technology	ICCA, Carbon Handprint
A specific average market	ICCA
The dominant technology in the specific market	ICCA
Extension of a historical situation (including or excluding external factors)	QuantiGES, ISO/DTR 14069
A regulatory standard	Preliminary Guidance, QuantiGES, ILCAj, ISO/DTR 14069, EpE, ENGIE
A control sample	Empreinte Projet, QuantiGES
The old version of the product from the same company	ILCAj
A solution available at the same time as the alternative studied	Preliminary Guidance, Carbon Handprint
Product publicly known as the "average product" or "standard" of the product category	ILCAj, EpE, ISO/DTR 14069
The average of a company	EpE, ISO/DTR 14069
Alternative choice for consumers	EpE, ICCA
Initial situation of consumers	EpE, Carbon Handprint
Products about to be discontinued	ICCA
Requirements of a 2°C scenario	ISO/DTR 14069

Table 10 Alternatives that should not be considered a reference scenario (RECORD, 2022)

Solutions excluded from the reference scenario	Mentioned by the methodological guide
Solutions about to be banned	ICCA
The old version of a product of the same company	Carbon Handprint

MODELLING OF MULTIFUNCTIONAL PROCESSES

Processes that have more than one functional input and/or output (e.g. the production of a product and the treatment of a waste, such as recycling processes) are multifunctional. In many cases, it must be identified which share of environmental burdens of a multifunctional processes are attributed to the assessed solution. In that case, an allocation procedure must be applied. First strategies to be considered are system expansion, system reduction, or substitution. Other allocation procedures are partitioning and the cut-off approach. These options are further described in more detail below, and a summary of their applicability is provided in Table 11.

System expansion, system reduction, and substitution

One solution that avoids the partitioning of a process is the application of system expansion: the functional unit is extended to include the additional functions provided by a process, such as “the treatment of polypropylene (PP) waste and the production of PP” by a recycling process. Alternative processes that provide the same functions are included in the reference scenario, e.g. the treatment of PP waste via incineration and the production of PP by a primary production process. However, such alternative processes can only be identified if they exist within the scope of evaluated GHG emissions, as presented in Table 5.

For example, if one is interested in decreasing the GHG emissions attributed to the plastic waste treatment sector in France, the evaluated scope of GHG emissions does not contain emissions related to the alternative production of PP, e.g. via a primary process. In other words, the recycling process (which may have higher impacts than the incineration process) may not lead to a decreased footprint of the French waste treatment sector, as the waste treatment sector was previously not associated with impacts related to the primary production of PP. Contrarily, if the evaluated scope of GHG emissions reflects the GHG emissions attributed to France, this scope contains emissions caused by both the incineration of PP waste and the primary production of PP. Hence, in that case, system expansion would be applicable.

An often-mentioned alternative of system expansion is system reduction, which is recommended by the Preliminary Guidance. Instead of adding the additional functions to the functional unit, and the emissions of the alternative processes that provide these additional functions to the reference scenario, the emissions of these alternative processes are *subtracted* from the assessed solution. It is often argued that this operation is mathematically equivalent to system expansion. This is correct, if one only evaluates the *absolute difference in GHG emissions* between the two scenarios (Schrijvers et al., 2020). However, the above-mentioned limitation of system expansion, that it is only applicable if the evaluated scope of GHG emissions already contains these alternative processes, also holds for "system reduction". If the evaluated scope of GHG emissions does not contain an alternative process that provides the additional function, it must be defined which *other* scope of GHG emissions is considered to benefit from the multifunctional process. For example, if recycling instead of incinerating PP waste does not decrease the GHG emissions attributed to the French waste treatment sector, this sector may *jointly* with the French plastic production sector benefit from reduced GHG emissions. System expansion and system reductions may therefore not only require a change in the functional unit, but also a change in the evaluated scope of GHG emissions as determined in Table 5. A similar reflection is valid for corporate reporting. As mentioned above, there is no specific guidance in the identification of the reference scenario in the reporting of avoided emissions for recycling or energy recovery. Also here, the interest of the intended audience of the assessment could indicate whether the corporate scope is extended to a regional, national, or perhaps global scope of GHG emissions. The alternative processes are then selected among the processes that contribute to this scope. Using the wording "substitution" is discouraged by (Schrijvers et al., 2019) in an attributional LCA, as this process is merely removed from the assessed value chain. It is not evaluated whether the process actually decreases its output – it is possible that its output is increasingly used in another value chain, resulting in increased GHG emissions elsewhere.

In a consequential LCA, in which the evaluated scope of GHG emissions is global, this problem does not arise, as the global scope contains both the incineration of PP waste and the primary production of PP. Hence, the process that is most likely to be affected can be subtracted from the assessed solution, i.e. this process is substituted.

Allocation

It may not always be an option to expand the functional unit and potentially the evaluated scope of GHG emissions, for example if the goal of the assessment is to evaluate the emission reductions of a specific product, company, or sector. Then, it must be identified which share of the multifunctional process can be attributed to this specific product, company or sector, via an allocation rule. A choice can be made between partitioning and a cut-off approach (i.e. attributing certain processes to the life cycle that provides the waste, and other processes to the life cycle that uses the secondary material). Double counting or "forgetting" of impacts can be avoided by following strict rules agreed upon among value-chain actors. None of these options are mentioned in the specific guidance documents on "avoided emissions".

Table 11 Applicability of modeling techniques for multifunctional processes under different circumstances (RECORD, 2022)

LCA approach	Multifunctionality modelling	Applicability
Attributional LCA	System expansion/system reduction	Evaluated scope of GHG emissions contains alternative processes that provide the additional function(s)
	Partitioning/cut-off	Evaluated scope of GHG emissions does not contain alternative processes that provide the additional function(s)
Consequential LCA	Substitution	Always applicable

TEMPORAL SCOPE

The temporal scope of the assessment can be subdivided into two aspects:

- The timing of assessment of the avoided emissions in the past (ex-post) or in the future (ex-ante) (Russell, 2019)
- The quantification of avoided emissions throughout the relevant time horizon, also referred to as “the avoidance period” (see Preliminary Guidance).

Timing of the assessment

Whether the evaluation of avoided emissions is done ex-ante or ex-post depends on the foreseen goal of the assessment. Corporate reporting is generally done ex-post, allowing for the collection of primary data and an informed vision about relevant reference scenarios, potential regulations, or the evolvement of external factors affecting a product’s performance over time. An ex-ante assessment is more useful if the purpose of the assessment is to attract potential investors for a new low-carbon technology or process. Data collection is more uncertain and the evolution of (avoided) emissions over time is rather based on hypotheses.

The avoidance period

The relevant time horizon of the assessment, i.e. the avoidance period, depends on the distribution of the processes that are included in the system boundaries over time. The system boundaries could include a single process, multiple processes of a single life cycle stage, multiple life cycle stages, or the full life cycle of a product. The more consecutive processes are included in the analysis, the longer the time horizon for which increased and avoided emissions are assessed, ranging from the operations of a process at a specific point in time (e.g. a certain day in a year), up to the lifetime of a product. In the case of a punctual operation of a process, it is interesting to consider a yearly average performance of a process to correct for the variability of important parameters, such as waste composition or process performance. Also for corporate reporting, a general time horizon is one year. If a long time horizon is relevant for the assessment, the development of the assessed and reference scenarios over time should be considered. Table 12 shows different considerations that could be made in the scenario development, and Table 13 provides an overview of options that could be applied in the formulation of a scenario based on hypotheses regarding the future.

Table 12 Conceptual consideration of the evolution of scenarios over time (RECORD, 2022)

Scenario development over time	Consideration of time-sensitive effects	Mentioned by the methodological guide
Static	Continuation of current technologies	Preliminary Guidance, ICCA, WRI
Dynamic	Average over time	
	Consideration of improvement of competing technologies (e.g. via a discount factor)	ICCA, QuantiGES, Preliminary Guidance, (Greenhouse Gas Protocol, 2014), Empreinte Projet
	Considering changes in market size (e.g. assuming an increasing demand for electricity)	QuantiGES, EpE
	Considering changes in market composition (e.g. assuming an increasing share of renewable electricity)	QuantiGES, EpE
	Considering climate factors (e.g. increased rainfall, higher temperatures)	QuantiGES, EpE
	Considering changes in demographics/human behaviour	Empreinte Projet
	Considering changes in regulations	QuantiGES, EpE

Table 13 Applied consideration of the evolution of scenarios over time (RECORD, 2022)

Scenario development strategy	Mentioned by the methodological report
Extrapolate the evolution of GHG emissions before the implementation of the action	QuantiGES
Exclude all future developments	ICCA
Use conservative assumptions leading to the lowest amount of avoided emissions	EpE, ISO/DTR 14069
Analysis of different scenarios (e.g. the least beneficial, the most beneficial, and the most probable scenario)	SCORE LCA, WRI, ENGIE, ICCA, consequential LCA, ILCAj, QuantiGES, ISO 14044, WRI, Carbon Handprint
Establish scenarios in agreement with stakeholders or experts	EpE, ENGIE
Sensitivity analysis to identify key parameters that affect the outcome of "avoided emissions"	SCORE LCA, WRI, ENGIE, ICCA, consequential LCA, ILCAj, QuantiGES, ISO 14044, WRI, Carbon Handprint

GEOGRAPHICAL SCOPE

Two geographical scopes should be distinguished in the assessment of avoided emissions by the implementation of a solution:

- The geographical scope of the implemented solution (e.g. the recovery of electricity in France)
- The geographical scope of the evaluated GHG emissions (e.g. GHG emissions attributed to users of electricity in France, or to the French/European economy).

Example:
Avoided emissions = Reduced GHG attributed to the average user of PP in **Europe** due to the production of recycled PP by Veolia in **France.**

2.1.7. DATA QUALITY REQUIREMENTS

The quality of the data used in the assessment of avoided emissions can be assessed in different aspects:

- Temporal representativeness
- Geographical representativeness
- Technological representativeness
- Precision
- Exhaustiveness
- Coherence
- Reproducibility
- Data sources
- Uncertainty
- Reliability

There are different strategies to evaluate the quality of the data and its influence on the calculated avoided emissions, which are summarized in Table 14. QuantiGES (ADEME, 2016) connects the quality of the data with the potential utility and target audiences of the results, hence, data quality requirements could be defined dependent on the goal and intended audience of the assessment.

Table 14 Data Quality Assessment Strategies (RECORD, 2022)

Data quality assessment strategy	Mentioned by the methodological report
Validate data quality with value chain partners	EpE
Apply a grading system to evaluate the robustness of the results	QuantiGES, Empreinte Projet
Disclose confidentiality intervals	Preliminary guidance
Conduct uncertainty analyses	SCORE LCA, ILCAj, ISO 14044, WRI, Empreinte Projet

2.1.8. ATTRIBUTION OF BENEFITS TO VALUE-CHAIN ACTORS

Companies often wish to communicate to what extent they contributed to avoided emissions. Reasons of this desire could be to understand opportunities to increase environmental benefits, or helping partners assessing impacts of their decisions (Russell, 2019). However, attributing avoided emissions to specific value-chain actors is controversial. There is a risk that the overall benefits of a solution are underestimated if only a company's share to those are communicated, and it disregards the fact that avoided emissions are often the result of cooperation of value-chain actors (ADEME, 2020; ICCA and WBCSD, 2013; Preliminary Guidance, 2019). Therefore, most guidance documents state that avoided emissions should ideally not be claimed by a single actor in the value chain. Instead, value-chain actors could communicate that they "contribute to an X amount of avoided emissions" (ADEME, 2020; ENGIE et al., 2021; Entreprises pour l'Environnement, 2018; ICCA and WBCSD, 2013; ISO/DTR 14069, 2021; Russell, 2019). Nonetheless, some guidelines provide suggestions how a potential distribution of avoided emissions to value-chain actors could be done, which are presented in Table 15. The main requirement is that all relevant value-chain actors should agree with the distribution approach.

Table 15 Strategies to allocate avoided emissions to specific value-chain actors (RECORD, 2022)

Strategies to allocate avoided emissions to specific value-chain actors	Mentioned by the methodological report
Establish consensus among actors (e.g. regarding a % distribution)	WRI, Mission Innovation, ILCAj, ICCA
Equal attribution among value-chain actors	Mission Innovation
Financial cost or value attribution	Mission Innovation, ILCAj, ICCA
Benefits are attributed to the organization that provides the assessed solution	Carbon Handprint, QuantiGES, consequential LCA
Benefits are attributed according to the contribution ratio of an actor to the solution	EpE, ILCAj
Provide a qualitative explanation of the additional information on the contribution of the target product to avoided life-cycle emissions	ILCAj, ICCA
Consumer can report all avoided emissions	EpE, ICCA
When several company entities deliver products/services that lead to common avoided emissions, only retain the avoided emissions of the entity that generates the highest product/service value	ENGIE

2.1.9. SCALING UP AND AGGREGATION AT COMPANY LEVEL

Companies may wish to calculate their total (yearly) contribution to avoided emissions caused by the company's product portfolio. Again, the distinction between corporate reporting and a comparative assessment is relevant.

For **corporate reporting**, the avoided emissions generated by the total production of recycled materials, recovered energy, or renewable energy can be aggregated and mentioned in the corporate annual report.

The avoided emissions calculated by a **comparative assessment** first require to be scaled up to the total company output, before aggregation is possible. Scaling-up at a company level is recommended by (The Institute of LCA Japan, 2015), by multiplying the avoided emissions per product by the number of final products in use. (Russell, 2019) recommends to use actual sales records, production, or shipment numbers – ideally adjusted to reflect only the number of products estimated to replace existing or future stock, considering that only an increased market share (and not an increased market size) generates avoided emissions (Entreprises pour l'Environnement, 2018; Russell, 2019). Ideally, the functional unit already reflects the total scale of the action, as there is not always a linear relationship between the avoided emissions generated by a single product and the total avoided emissions of all products sold (ADEME, 2016; Entreprises pour l'Environnement, 2018; Schrijvers et al., 2019). Furthermore, scaling-up amplifies uncertainties based on the hypotheses that were done in the development of the scenarios (Entreprises pour l'Environnement, 2018).

(The Institute of LCA Japan, 2015) recommend aggregating the contribution to avoided emissions of the company's products at a company level. However, (Schrijvers et al., 2019) discourage aggregating avoided emissions of the company's portfolio, especially considering the controversy regarding the attribution of avoided emissions to a single value-chain actor. There is a risk of "cherry-picking", as companies tend to only communicate about products that generate avoided emissions, and do not publish which products generate higher GHG emissions than their alternatives in the market (Russell, 2019). Therefore, (Russell, 2019) mentions that company-wide aggregation could be allowed only when the GHG inventories are comprehensive and conform to GHG Protocol requirements, *and* the impacts have been estimated for a company's entire product portfolio using a consequential approach covering both additional and avoided impacts. The workload involved with the scenario modelling and data collection to conduct a consequential LCA on every product within a company's portfolio makes this condition very difficult to fulfil, at the moment, in practice.

The following recommendations can be identified if aggregation needs to take place nonetheless (ADEME, 2016; ENGIE et al., 2021; Russell, 2019):

- Only aggregate avoided emissions of actions that are independent
- Exclude the contributions of products/services delivered to other entities of the company
- Describe how products were selected for the inclusion in the portfolio-wide estimate, and describe the methods used to obtain this estimate
- Describe the number of products assessed and the percentage these products represent in terms of the company's total product portfolio
- Consider external stakeholder feedback on the credibility of the accounting methodology

2.1.10. COMMUNICATION

The communication of avoided emissions is very sensitive to potential greenwashing. Misinterpretation of results could jeopardize the credibility of similar communications of (other) companies in the future. It is therefore important that the communication is understandable, transparent, relevant, and not misleading (ADEME, 2020; Russell, 2019; Preliminary Guidance, 2019).

In order to fulfil the aforementioned communication requirements, the following aspects should be mentioned in the presentation of the results of the assessment (ADEME, 2016; Entreprises pour l'Environnement, 2018; Grönman et al., 2019; ICCA and WBCSD, 2013; ISO, 2006; The Institute of LCA Japan, 2015; Preliminary Guidance, 2019):

- Justification of assumptions and methodological choices
- Justification of emission factors
- Data gaps
- Justification of allocation method, if avoided emissions are claimed by a single company
- Joint publication of avoided emissions and the GHG profile of a company
- Evaluation of the sensitivity of the results to hypotheses
- Presentation of diagrams reflecting the assessed and reference solutions, and present only one assessed and reference scenario at a time
- Include an overview of direct and indirect consequences of the implemented action (in consequential-based analyses)
- Mention omitted life cycle stages
- Data quality requirements and quality of the used data
- Data sources
- Discussion of the limitation of the evaluated emissions

Table 16 summarizes strategies that could be implemented to ensure that the communication requirements are met.

Table 16 Strategies to meet communication term requirements and ensure transparency, relevance and understanding of the study (RECORD, 2022)

Strategies for meeting communication requirements	Mentioned in the report
Fill in a communication template	ICCA, EpE, QuantiGES, Carbon Handprint
Subject the assessment to a critical review by an independent panel	ISO 14044, ILCAj, ICCA, ISO/DTR 14069, Carbon Handprint, Consequential LCA, ADEME
Report avoided emissions separately from corporate GHG emissions	SCORE LCA, WRI, ICCA, Preliminary Guidance, ADEME, ENGIE, ISO/DTR 14069
Use specific diagrams/vocabulary	SCORE LCA
Align the communication with requirements from ISO 14025, ISO 14067, ISO 14064-1/14064-2	ADEME, ISO/DTR 14069
Report results per functional unit separately from results at a market level	WRI
Present information concisely but provide an additional context	EpE
Present potential trade-offs with other impact categories	LCA SCORE, WRI, ISO 14044

2.2. State of the art on emission factors for recycling/recovery chains

2.2.1. KEY FEATURES OF RECYCLING SYSTEMS

Via a survey among members of RECORD, as well as among partners of WeLOOP, key characteristics were identified in various recycling chains. These characteristics are summarized in Table 17. A detailed synthesis of the survey responses can be found in Annex 1. In some sectors, such as the treatment of plastic and metal waste, recycling is already the predominant technique in France and Europe. However, in other sectors (e.g. construction waste), conventional waste treatment is landfilling or incineration. The recycling and waste valorisation chains produce secondary materials and/or energy, which can displace the production of primary materials and energy from fossil resources. **Recycling is in many cases limited by costs, or the quality of the input waste, the (perceived) quality of the secondary material, or existing regulations, which means that close collaboration between consumers, collectors, sorters, recyclers, and policymakers is required to make the recycling chain operational.**

Table 17 Key characteristics of recycling chains (RECORD, 2022)

Chain	Main sources of waste	Secondary products and their use	Valorisation limits	Predominant treatment processes (France and Europe)
Paper/cardboard recycling	Offices, industrials, household waste and packaging cartons from households (e.g. parcels, bricks, newspapers, food, etc.)	Paper (e.g. hygiene, newspapers, magazines), cardboard (flat), corrugated paper (PPO), pulp packaging for reuse, transformed into paper reels. These products replace primary paper and cardboard.	- Quality - Number of recycling cycles - Markets and integration of raw materials from recycling by paper manufacturers	Mechanical recycling
Mechanical recycling of plastics	- Production/industrial waste (e.g. medical products, agricultural (PE film), - Post-consumer and household waste (e.g. automotive, packaging (PET), razors, etc.)	Polymers of the same quality or degraded quality (downcycled) in granulate form or finished products, used in packaging, construction, agriculture & horticulture, automotive industry (e.g. non-visible technical elements), consumer products, medical/hygiene, plastic objects. Virgin polymers are substituted	- Difficult to sort because of mixtures - Very expensive sorting and transport, - Markets and integration of recycled material - Aesthetics, psychological barriers - Poor waste quality	- Landfilling - Incineration - Mechanical recycling (extrusion, injection, blowing, roto-molding, thermoforming)
Recycling of metals (e.g. steel, copper, aluminium)	- Production/industrial waste (scrap) - Post-consumer and household waste (e.g. automotive carcasses, wiring, and catalysts, WEEE, demolition)	Recycled metals, e.g. - Steel (plates, coils, bars or wires) - Aluminium (plates, ingots) - Copper (granulate) - Secondary PGMs These metals are used in construction, cast irons, household products and appliances, to substitute primary metals	- Impurities that are difficult to extract, which reduces the quality and use cases of secondary materials	- Electromagnetic overband/ permanent magnet (ferrous waste) - Electric Arc Furnace (EAF), e.g. for the ELV sector - Wiring grinding and mechanical/optical sorting - Pyro/hydrometallurgy

Chain	Main sources of waste	Secondary products and their use	Valorisation limits	Predominant treatment processes (France and Europe)
				- Eddy current (non-ferrous waste)
Recycling of construction waste	Waste collected through construction, renovation, demolition of buildings and civil works. - PVC windows - 65% is inert waste (stones, concrete, demolition materials, bricks, glass)	Materials used in construction (e.g. road sub-foundation, foundation, car parks, site access stonework). These materials replace virgin materials.	- Regulations - Insurance	- Landfilling - Incineration
Composting of organic waste	- Industrial waste (e.g. industrial sludge (sewage treatment plants (STEP), paper mill, agricultural) - Household waste (MSW, bio-waste, green municipal waste, sludge, food waste)	- Stabilized fertilizer rich in humic compounds (62% of the market in France in 2015) - Heat - Carbon dioxide (biogenic CO2, excludes methane) - Compost Use in organic soil improvers, organic fertilizers, growing medium (potting soil) in agriculture in the broad sense. Mineral fertilizers (synthetic nitrogen, imported potash and phosphorus) are substituted.	- Inflammatory, immuno-allergic, or infectious effects caused by gaseous and particulate emissions - Smell - Competition with methanization, which has a positive energy balance - Quality and variability of NPK content of composts	- Landfilling - Incineration - Methanization

Chain	Main sources of waste	Secondary products and their use	Valorisation limits	Predominant treatment processes (France and Europe)
Methanization of organic waste (with cogeneration or direct injection of biogas into the natural gas network)	- Industrial waste (e.g. industrial sludge (STEP, paper mill), agricultural) - Household waste (MSW, bio-waste, green municipal waste, sludge, food waste)	- Biomethane - BioNGV - H2 Used in the Agro-Food Industries (greenhouse enrichment, algae cultivation, gasification, cooling), chemistry (e.g. bicarbonate), and energy, to replace fossil methane, NGV, diesel, etc.	- The quality of the inputs (depending in part on the quality of the sorting) - Lack/weakness of coordination between the energy sector and the agricultural sector (e.g. different legislation, ministries, objectives) - Cost of access to MSW	Conventional treatment: - Landfilling - Incineration Different anaerobic digestion units that favour different inputs: - Centralized units (waste from different origins related to the territory of establishment), - Industrial units (waste from the food industry, chemical or paper mill), - Units specialized in the treatment of wastewater treatment sludge, - Household waste methanization units (managed by local authorities or specialized companies). Different biogas recoveries in France and Germany:

Chain	Main sources of waste	Secondary products and their use	Valorisation limits	Predominant treatment processes (France and Europe)
				- FR: injection of biomethane into the biogas network - DE: biogas to produce renewable energy
Energy recovery from waste in the form of solid recovered fuels (SRF)	- Any type of non-hazardous solid waste (not consisting of biomass only) whose calorific value is high enough to be of interest in combustion recovery (e.g. tyres, plastics, RBA, Paper/cardboard, wood and wood waste (class B), sludge and STEP, textiles, household waste) - Non-mineral and non-hazardous waste	- Energy - Heat Use in industries (e.g. cement plants, power plants, lime kilns/bricks). Energy from natural gas, petroleum coke, and coal is substituted.	- Not yet recognition of recovered heat from solids as a partially renewable recoverable heat - Technical characteristics (quality) - Scarcity of the deposit (e.g. waste prevention, increased recycling) - Inaccessible grant - Societal acceptability of projects/neighbourhood	- In France: TMB - In Germany: TM at 66% (2018 data) (directly from DIB) - Countries with developed SRF production (Germany, Italy, Austria): TMB mainly - Countries whose SRF production is developing (Ireland, Netherlands, Finland, Norway): in 2018, a dozen installations including many TMB producing SRF and several were under construction - Spain: 350Kt of SRF quality DIB

Chain	Main sources of waste	Secondary products and their use	Valorisation limits	Predominant treatment processes (France and Europe)
	- Refusal of TMB with or without BRS - Bulky garbage dumps - Refusal to sort Separate collection of household packaging - Non-fermentable DIB (especially in France)			- Europe: mostly co-incinerators (the most demanding in terms of quality) - Landfill and incineration
Mixed waste incineration with energy recovery	Household waste and sorting rejects	- Clinkers (recycling of metals for use in construction) - Heat/electricity to supply a district heating network or distribution to public companies/establishments, replacing fossil fuels	- Decrease in incineration	- Landfilling - Incineration
Valorization of biogas from landfilling facilities	- Previously sorted organic waste - Landfilled organic waste	- Biogas/methane (50/60%) for electrical recovery (by cogeneration or injection into the natural gas network after purification) or thermal, or production of biological fuel (NGV or	- Costs	- "Rural" methanization (facilities that use agricultural resources or LPN by-products) - Non-Hazardous Waste Storage Facility (ISDND)

Chain	Main sources of waste	Secondary products and their use	Valorisation limits	Predominant treatment processes (France and Europe)
		LNG), which substitutes fossil fuels - CO2 (40/45%) - Digestate used as an agricultural fertilizer, which substitutes fertilizers		- STEP: Wastewater treatment plant (urban sludge) - Landfill flaring - Do nothing - Incineration - Composting - Methanization of the Fermentable Fraction of Household Waste

2.2.2. EMISSION FACTORS (AVOIDED) FOR WASTE RECOVERY AND RECYCLING CHAINS

The waste valorisation and recycling sectors have done considerable efforts to evaluate and communicate the potential environmental benefits of the waste treatment chain, via the quantification of the environmental performance of the collection, sorting, and recycling processes, as well as the avoided impacts due to alternative waste treatment and alternative production routes of primary materials and energy. These results are often presented as (avoided) emission factors, available in databases such as Base Carbone of ADEME or in separately published industrial reports. Table 18 provides an overview of sources of these emission factors, based on a screening of the Base Carbone database, the methodologies cited herein, and supplemented by feedback provided by members of RECORD and industrial collaborators via the aforementioned survey. Again, a more detailed overview of the survey responses can be found in Annex 1.

Table 18 Sources of (avoided) emission factors (EFs) analysed and identified (RECORD, 2022)

Recycling chain	Source of the EFs analysed	Other potential sources
Paper/cardboard recycling	CITEO, FEDEREC	Prognos, BIC, FNADE
Mechanical recycling of plastics	CITEO, SRP, FEDEREC	BIR
Chemical recycling of plastics	-	-
Recycling of chemical substances (solvents)	-	-
Recycling of metals (e.g. steel, copper, aluminium)	CITEO, FEDEREC, SEDDRe	Prognos
Glass recycling	CITEO, FEDEREC	
Recycling of construction waste	CITEO, SRP, FEDEREC, SEDDRe	Ecomobilier, InfoCiments
Composting of organic waste	ADEME	Citepa, FNADE, INRAE
Methanization of organic waste (with cogeneration or direct injection of biogas into the natural gas network)	ADEME	GRDF, Solagro, CTBM
Energy recovery from waste in the form of solid fuels	CITEO	GT Déchets, Citepa, FNADE, RECORD, FEDEREC
Mixed waste incineration with energy recovery	ADEME	GT Déchets, FNADE, Prognos
Valorization of biogas from storage facilities	ADEME	INERIS
Neutralization of gaseous or liquid fluids with high global warming potential	-	-

In this report, the methodologies applied in the evaluation of the (avoided) emission factors for the waste valorization and recycling sector are analysed. The applied methodologies are compared with the key methodological parameters identified in Section 2.1. of this report. The result of this analysis is presented in Table 19. Based on this comparison, it can be identified whether the emission factors can be used in different application areas than the ones initially foreseen by the developers, and whether the emission factors can be adapted to individual situations, e.g. if access to intermediate calculation steps and data is provided. **Of the evaluated documents, only FEDEREC, ADEME, and SEDDRe provide sufficient information to calculate adapted (avoided) emission factors**, for example using different electricity mixes. Furthermore, information provided in the documents could serve as an inspiration on important additional methodological choices in similar studies, such as the processes to include or exclude from the system boundaries, or the appropriate functional unit. Not all information on key methodological choices is clearly presented. In some cases, this information can be deducted from the methodological description (such as the application of an attributional approach), whereas in some other cases this additional information may be presented in accompanying documents that are not analysed in this study.

Table 19 Summary of key parameters of avoided emissions studies (ADEME, 2022a; CITEO, 2022; FEDEREC, 2017; SEDDRe and Crowe Sustainable Metrics, 2019; SRP, 2017) (RECORD, 2022)

Study parameters	FEDEREC	CITEO[3]	SRP[4]	ADEME – Bilans-GES	SEDDRe
Waste analysed	- Steel - Aluminium - Copper - Paper and paperboard - Packaging glass - Pet and HDPE packaging - Aggregate - Textile	Recycling: - Steel - Aluminium - Plastics: PET, HDPE, PP, PS, LDPE - Paper/cardboard Incineration: - Metals - Glasses - Crystal - Ceramics - Plastics - Wood - Paper/cardboard	Plastics	Incineration: - Paper - Cardboard - Food waste - Plastics: HDPE/LDPE, PET, OM modecom 07, Plastic Medium M07 (dry), PVC, Polypropylene Landfilling with methane recovery: - Paper/cardboard - Food waste - Garbage	- Concrete - Mixed inert waste - Mixed non-hazardous waste - Wood B - Plaster - Metals
Objective of the study	- Carry out the national GHG and energy consumption assessment of recycling channels using LCA - Identify the main contributors and the levers for improvement	-	-	Realization of GHG balance sheets for companies	Refine and make reliable estimates of greenhouse gas (GHG) emissions from building waste treatment and obtain average emission factors across the France
Target audience	- Federec Members - ADEME	-	-	-	- Users of the BatiCarbone tool of the French Building Federation

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[3] Only the BEE Data Guide is evaluated.

[4] The project report, the conclusions of the critical review committee and the responses of the SRP are available by appointment at the SRP headquarters..

Study parameters	FEDEREC	CITEO[3]	SRP[4]	ADEME – Bilans-GES	SEDDRe
					for the realization by its members of the carbon footprint of a construction site; - Users of the emission factors of the ADEME Carbon® Base for the calculation of end-of-life emissions of building waste; - LCA experts in the context of the production of Environmental Declarations on construction products; - Institutional and sectoral actors: FFB, SEDDRe, ADEME, CSTB etc.
Functional unit	Analysis of the collection, sorting and processing of one tonne of waste to produce intermediate materials from MPR to replace intermediate materials from virgin resources	-	One kg of plastic MPR, ready to use, packed and loaded, factory output of the regenerator.	-	One tonne of waste collected at the foot of the construction site and sent to a recovery sector in order to produce recycling raw materials instead of virgin materials
Taking into account variability	Average values used	-		-	Average values used
Study period	Ex post: analysing the results of recycling in France for 2014				Ex ante, use of 2017 data to represent the period up to 2024

Study parameters	FEDEREC	CITEO[3]	SRP[4]	ADEME – Bilans-GES	SEDDRe
Geographical scope of the solution	Collection in France, advanced treatments vary on annual exports (France, Europe, Asia)	France			France
Emissions of concern	GHG emissions attributed to French territory				GHG emissions attributed to French territory
LCA approach	Attributional	Attributional	Attributional		Attributional
Scope of evaluation	The recycling chain, including - the collection of waste to be recycled, - waste sorting, - the production of raw materials for recycling (MPR), - MPR consumption, - the avoided production of intermediate materials of virgin origin, - collection and end-of-life avoided	Collection Sorting center Post-sort transport Regeneration Production of virgin material	**Initial collection and sorting** Transport **Regeneration** Packaging Infrastructure		- Waste collection at the foot of the construction site - Sorting/grouping of waste - transformation stage related to waste recovery - avoided production through the transformation of waste into secondary materials or energy Includes: - Direct emissions from stationary combustion sources from treatment/recovery sites; - Indirect emissions related to electricity consumption from treatment/recovery sites; - Emissions related to the upstream and

Study parameters	FEDEREC	CITEO[3]	SRP[4]	ADEME – Bilans-GES	SEDDRe
					downstream transport of waste; Emissions related to the disposal of "ultimate" waste leaving the recovery chain. The following are excluded: - Lighting, heating and cleaning of workshops; The energy consumption of administrative buildings; Employee travel on site; - The manufacture and heavy maintenance of the production tool and transport systems for each stage; - Consumables of products and equipment necessary for the operation of the process
Reference Solution	- Consideration of a substitution rate that makes recycled material similar to virgin materials - French/European production mix for the substitution of virgin materials	Subjects: Medium Technology in Europe Energy: energy produced by conventional means. Electricity: mix of electricity from French production and import	-	Electricity: French Mix - Heat: European Mix	

Study parameters	FEDEREC	CITEO[3]	SRP[4]	ADEME – Bilans-GES	SEDDRe
	The scenarios represent waste treatment practices in France. Swiss generic data (ecoinvent) are used for alternative waste treatment.				
Multifunctional process modeling	- End-of-life formula recommended by ADEME (AFNOR, 2011) - Substitution of waste treatment and production of virgin materials - Inclusion of a substitution rate	-	Substitution (e.g. energy recovery of waste from regeneration)	-	-
Data quality requirements	- The most up-to-date data possible - French, if not European, data - Data representative of the average technologies currently in use - Relevance: Primary data collection only for highly impactful activities (Pareto principle)	Detailed information is provided on the scope of the inventories that are taken into account, the geographical and temporal representativeness of the data and their source	-	It is recommended that elements of uncertainty be presented on the main items concerned. These elements can be qualitative or quantitative.	Calculation of a percentage of uncertainty of the data via a method proposed by ADEME
Data sources	- Miscellaneous, published in the report - Ecoinvent 2.2	- Various - Ecoinvent	- Primary data - Ecoinvent 3.2	-	- Primary - Statistics - Carbon Base - Validation of experts or stakeholders
Cut-off criteria	- According to BPX-30-323-0	-	-	-	-

Study parameters	FEDEREC	CITEO[3]	SRP[4]	ADEME – Bilans-GES	SEDDRe
Scaling	- Scaling up the total amount of waste recycled in France for one year (2014)	-	-	-	- Multiplication with the total amount of waste from the building in France (by type of waste)
Aggregation	Aggregation of all recycled waste in France, to obtain the total amount of emissions avoided for the recycling sector in France in 2014.	-	-	-	-
Sensitivity analyses	- Accuracy of activity data (uncertainty analysis) - The quality of secondary evidence - type of material avoided, - the consideration of biogenic carbon, - modeling the electricity mix	-	-	-	Qualification of the sensitivity level of key parameters
Environmental indicators considered	- Greenhouse effect (JRC method) - Primary energy consumption (renewable and non-renewable)	- Contribution to the greenhouse effect - Acidification - Eutrophication - Primary energy consumption - Water consumption	-	-	- Contribution to the greenhouse effect
Biogenic carbon	- Not counted	-	-	-	-
Communication strategies	- Critical review - Data quality by material and by indicated process, including the	- Qualitative indication of data quality	According to EN 15804, in two forms: □ Impacts of regeneration	Avoided emissions from recycling are given for information in the spreadsheet, since the method recommends	- Rationale for process inclusions and exclusions within the detailed system limits

Study parameters	FEDEREC	CITEO[3]	SRP[4]	ADEME – Bilans-GES	SEDDRe
	contribution of the process to the results - In order to simplify communication with the general public, it is proposed to express the comparison between the two industries (virgin industry and recycling industry) as a percentage - Limitations of the study are mentioned		processes to obtain 1 kg of MPR Impacts of 1 kg of MPR -	taking into account recycling in the % of material from recycled in the inputs (and we can not give twice the same benefit).	- Limitations of the study are mentioned
Intermediate data available	- Yes	- No	- No	- Yes	- Yes

2.3. Synthesis of the state-of-the-art

This state of the art presents the parameter that define what is implied with an assessment of “avoided emissions”. **Avoided emissions are defined as “reductions of GHG emissions that occur as a result of the implementation of the assessed solution, substituting a reference solution**”. However, to avoid variation in the applied assessment methodology, which reduces the comparability of different avoided emissions assessment, additional parameters need to be made explicit.

The parameters that influence the assessment methodology and results identified in this report are:

- The assessment goal,
- The intended audience,
- The scope of the evaluated GHG emissions,
- The formulation of the assessed solution,
- The formulation of the reference solution,
- The LCA approach,
- Data quality requirements,
- System boundaries,
- Modelling of multifunctional processes,
- And the consideration of the evolution of scenarios over time.

The harmonization of these parameters is necessary in order to make studies on avoided emissions comparable. These parameters are not separate entities, but they are interrelated. Figure 3 shows how the definition of one parameter influences others. **There are no right or wrong parameter choices, hence, the harmonization of these choices must be based on consensus among the relevant stakeholders of the assessment.**

Besides the aforementioned calculation parameters, consensus needs to be reached on the communication requirements of avoided emissions, in order to ensure the credibility of the evaluation and communication industry wide.

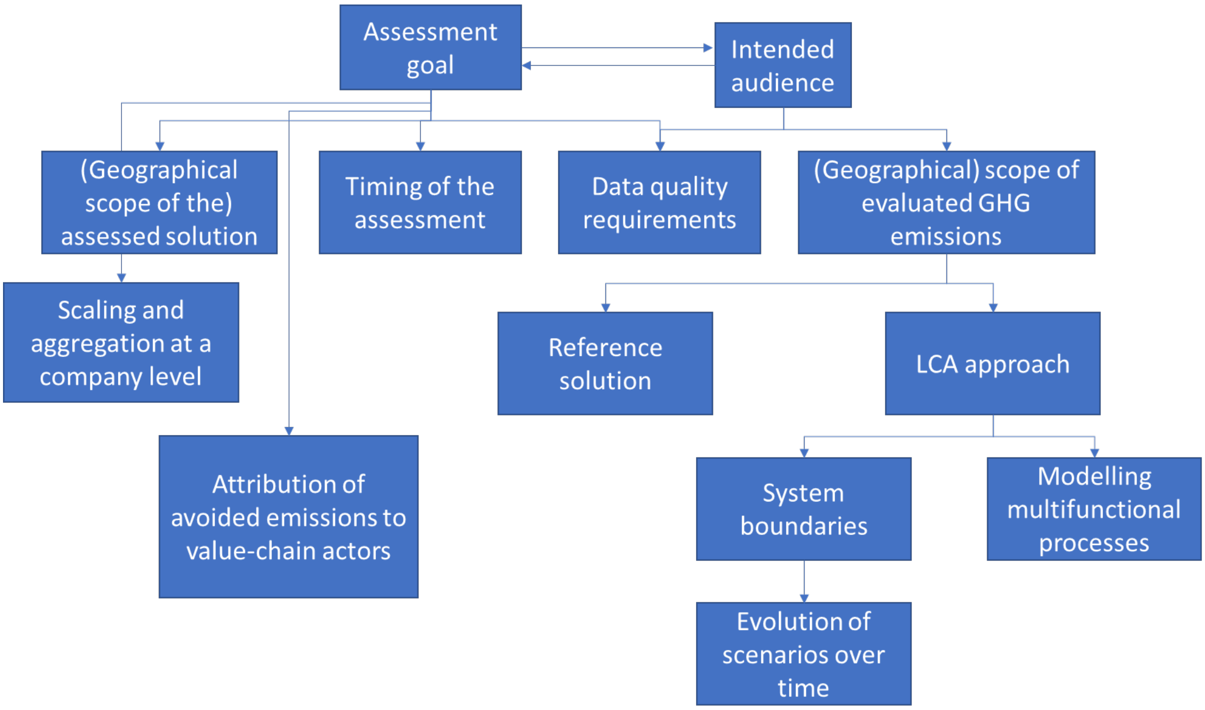


Figure 3 Relationship between relevant parameters involved in the calculation of avoided emissions (RECORD, 2022)

An overview of the methodological choices made by the actors of the waste recovery and recycling sector in France with (avoided) emission factors is presented. This overview indicates the extent to which the emission factors presented can be used in other studies and inspires the development of a comprehensive methodology for the development of emission factors in the waste recovery and recycling sector in France.

3. Methodological guide for the evaluation and communication of avoided emissions

This chapter is developed to provide methodological guidance in the analysis of "avoided emissions" **from waste recycling and recovery systems**. Avoided emissions are GHG emission reductions that are made possible by implementing a solution (such as production from recycled materials or end-of-life recycling), compared to a reference solution.

In this guide, avoided emissions are defined as **"GHG emission reductions resulting from the implementation of the evaluated solution, instead of a reference solution",** as illustrated in Figure 4.

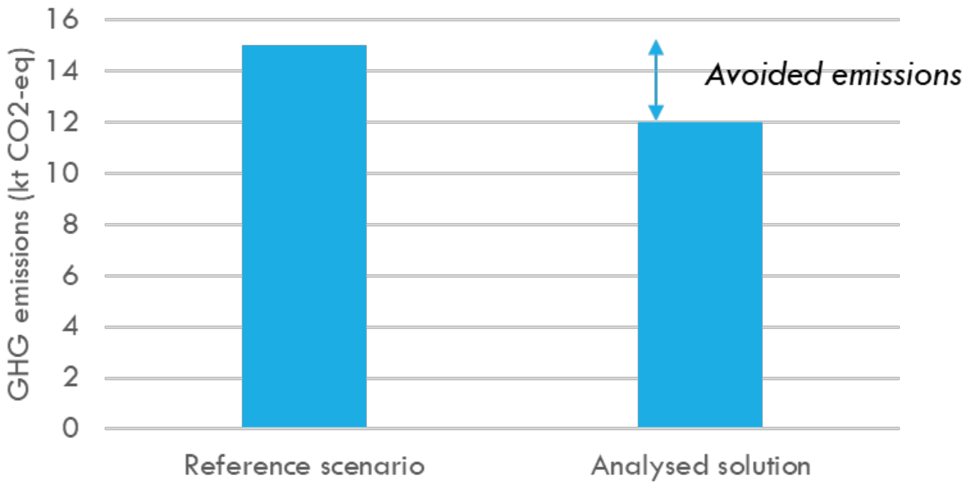


Figure 4 Assessment of avoided emissions from a solution compared to a reference scenario (RECORD, 2022)

In most existing methodological documents, all agree that **avoided emissions should be assessed over the entire life cycle of the solution**, as illustrated in Figure 5.

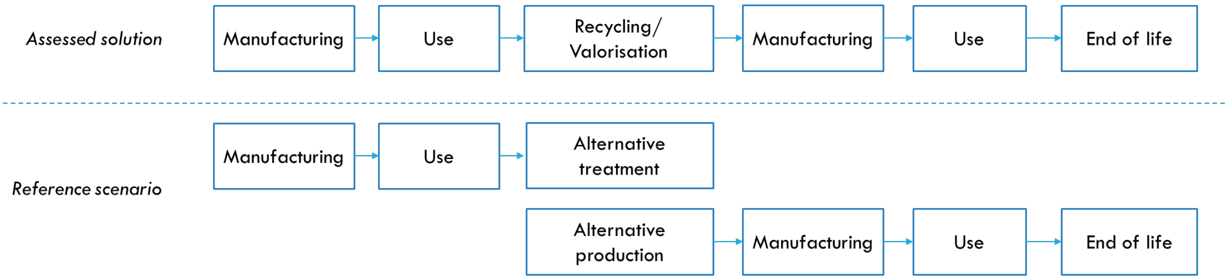


Figure 5 Consideration of the entire life cycle of a solution in assessing the avoided emissions of a solution, compared to a reference scenario. The "recycling/recovery" box includes the steps of collection, preparation, sorting and management of reject materials, production of recycled raw materials or energy (RECORD, 2022)

Note that a distinction could be made between "avoided emissions" and "avoided impacts". Avoided impacts are often interpreted as the environmental benefits generated in other product life cycles, as the result of the inclusion of a multifunctional process in a product life cycle under study. A study on avoided emissions does not aim to quantify the emissions of a specific product life cycle, but instead evaluates the total emissions and benefits of an implemented solution, which could take place in multiple product life cycles.

Avoided emissions can be assessed in different contexts, such as the GHG assessment of a project, process, or portfolio of solutions. **They are systematically reported separately from the emissions induced by the product/process/project/organization and are to be distinguished from a carbon footprint or a GHG balance**, in line with international consensus.

The decision to implement a waste recycling or recovery solution is not the action of a single isolated actor in the value chain. For this, it is necessary to have recyclable waste, recycling technology and a market for recycled/recovered materials and energy. The involvement of each actor in the value chain is therefore essential for the sustainability of the recycling sector. Therefore, each actor in the value chain could assess the environmental benefits of engaging or not in the recycling chain. Figure 6 shows the different points of view that each actor in the waste recycling or recovery chain could take to evaluate in a study the avoided emissions the actor induces.

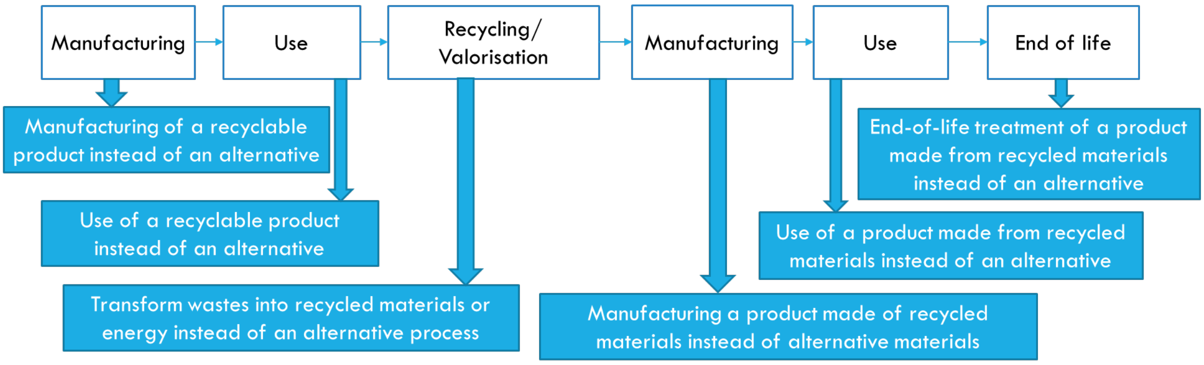


Figure 6 Presentation of the point of view of each actor in the value chain who could thus assess the avoided emissions it induces. The definition of the "alternative" scenario is specified in Step 3 (RECORD, 2022)

STRUCTURE OF THE GUIDE

The Preliminary Guide recommends a structured procedure for the assessment of avoided emissions, which is shown in Figure 7. This current guide is built according to this procedure. Each methodological choice is briefly introduced, in order to clarify the relevance of the choice and the potential alternative methodological pathways.

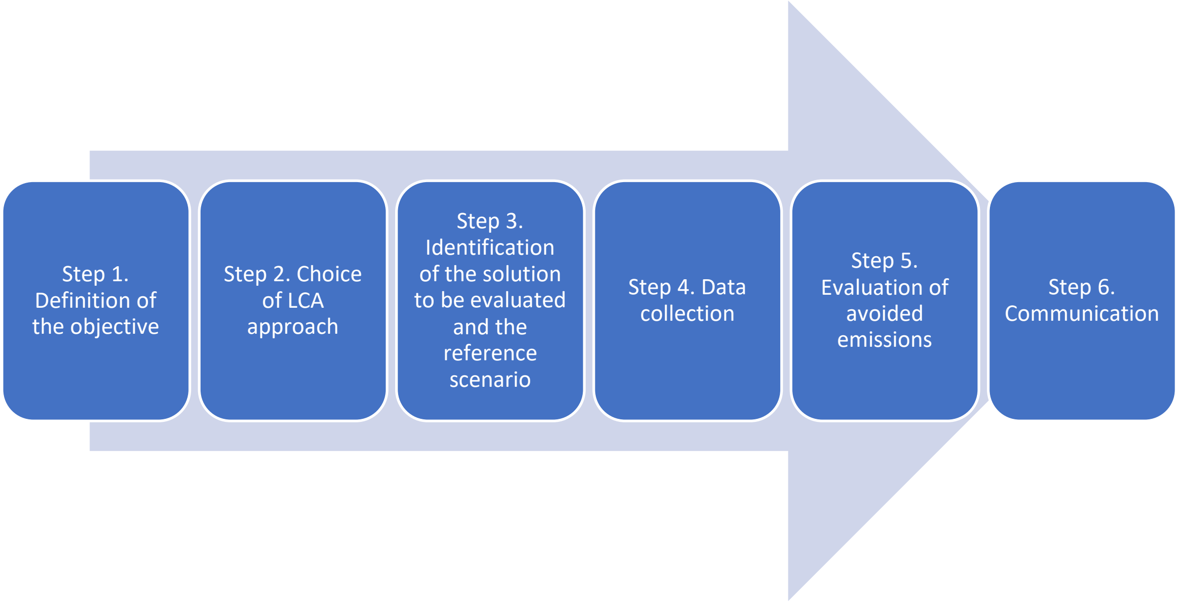


Figure 7 Steps to follow in an analysis of avoided emissions, according to the Preliminary Guidance (RECORD, 2022)

3.1. Color code for the methodological guide

The framed paragraphs in blue present the specific methodological choices and perspectives recommended in this guide. These recommendations are based on a consensus among RECORD members, allowing for a common and shared approach.

The cursive paragraphs in green show how the recommended methodology is applied in an example of a test case. The example that is used as a "red thread " throughout the guide is the use of recycled plastics, from end-of-life bottles, for the manufacture of cars. Table 20 shows the solution that each actor in this value chain can implement and evaluate in an analysis of avoided emissions.

Table 20 Different actors in the value chain of recycled PET from end-of-life bottles and the potentially implemented recycling solution (RECORD, 2022)

Actor of the value chain	***Evaluated solution***
Manufacturer of a recyclable bottle	*Make a recyclable bottle instead of an alternative bottle*
User of a recyclable bottle	*Use a recyclable bottle instead of an alternative bottle*
Bottle recycler	*Treat a plastic bottle through a recycling process instead of an alternative process*
Manufacturer of a car with recycled PET	*Making a car with recycled PET instead of an alternative material*
User of a car with recycled PET	*Use a car with recycled PET instead of an alternative product*
End-of-life vehicle waste manager	*Treating a car with end-of-life recycled PET instead of an alternative product*

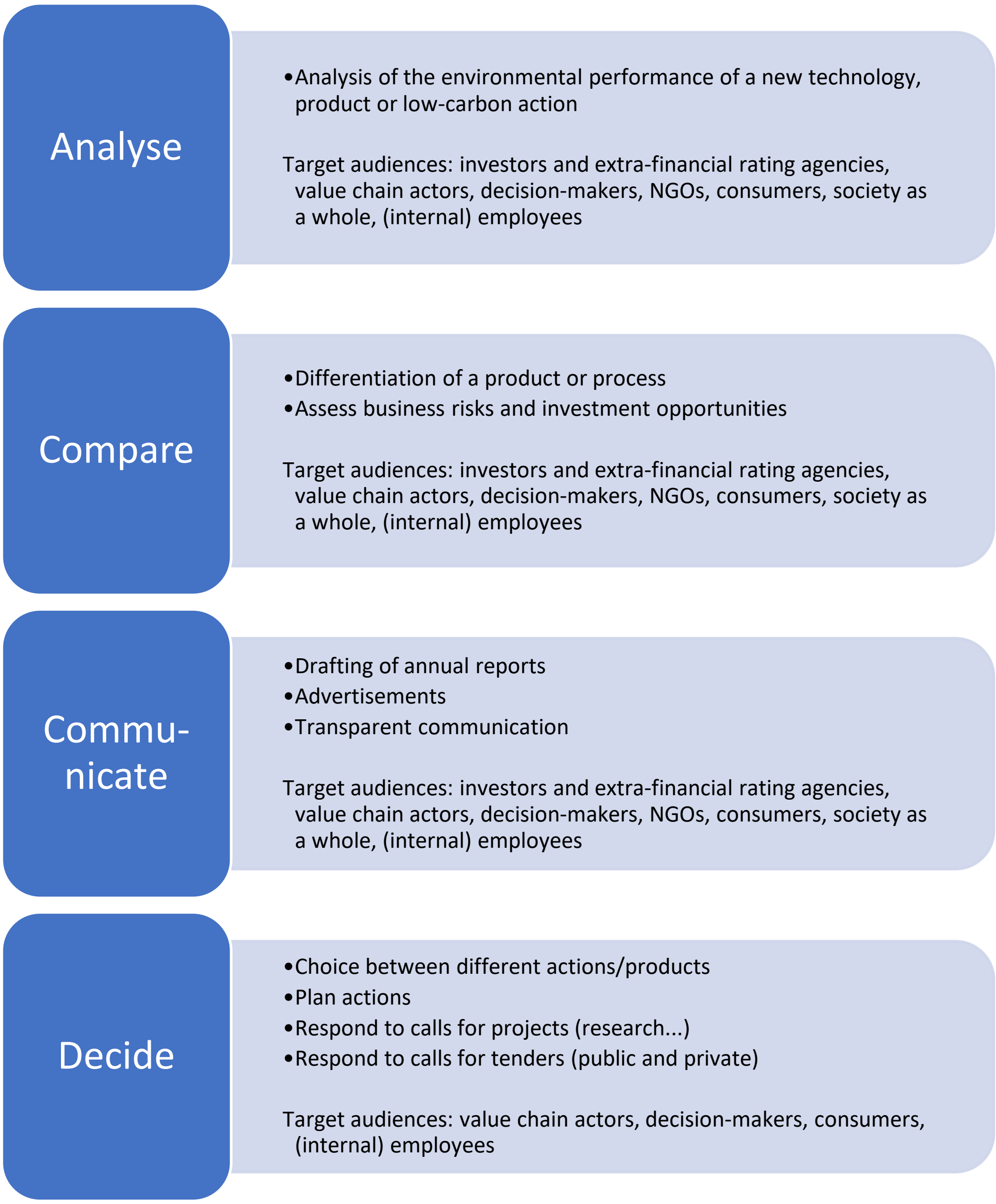
Finally, the paragraphs underlined in orange indicate other methodological choices or modelling strategies that can be used in an assessment of avoided emissions. However, these strategies have not been favored by RECORD members and are not developed in more detail in this guide. A comparison between the application of the guide and the Circular Footprint Formula of the Product Environmental Footprint (PEF) guide is presented in the Annex.

3.2. Step 1: The purpose of the analysis

The first step in a study to assess the avoided emissions of a product/service/project is the definition of the objective of the study and the target audience for the results. This guide does not define a specific objective. Instead, a non-exhaustive set of potential objectives and target audiences that can be foreseen in a study on avoided emissions is presented.

3.2.1. THE OBJECTIVE OF THE CALCULATION AND COMMUNICATION OF AVOIDED EMISSIONS AND TARGET AUDIENCES

Avoided emissions can be assessed against the objectives presented in Figure 8. The potential target audiences foreseen in this guide are investors and extra-financial rating agencies, actors in the value chain, decision-makers, NGOs, consumers, society as a whole, as well as (internal) employees.



Analyse

- Analysis of the environmental performance of a new technology, product or low-carbon action

Target audiences: investors and extra-financial rating agencies, value chain actors, decision-makers, NGOs, consumers, society as a whole, (internal) employees

Compare

- Differentiation of a product or process
- Assess business risks and investment opportunities

Target audiences: investors and extra-financial rating agencies, value chain actors, decision-makers, NGOs, consumers, society as a whole, (internal) employees

Commu-nicate

- Drafting of annual reports
- Advertisements
- Transparent communication

Target audiences: investors and extra-financial rating agencies, value chain actors, decision-makers, NGOs, consumers, society as a whole, (internal) employees

Decide

- Choice between different actions/products
- Plan actions
- Respond to calls for projects (research...)
- Respond to calls for tenders (public and private)

Target audiences: value chain actors, decision-makers, consumers, (internal) employees

Figure 8 : Presentation of the different possible objectives and target audiences for an assessment of avoided emissions (RECORD, 2022)

Actors in the recycled plastic value chain could study the avoided emissions to decide whether this change fits into the company's low-GHG emissions strategy. In addition, these actors could share the information with decision-makers (e.g. in grant applications), or their investors in order to highlight the company's efforts to reduce its GHG emissions.

3.3. Step 2: The LCA approach

In the second stage of a study to assess the avoided emissions of a product/service/project, an LCA approach must be defined. This is necessary, as it influences several methodological choices, such as the definition of a reference scenario, the system boundaries, and the modelling of multifunctional processes. The two existing approaches, commonly used and mutually exclusive, are attributional LCA and consequential LCA, which are described in more detail below.

3.3.1. LCA APPROACH

In LCA, two approaches can be distinguished: attributional LCA and consequential LCA.

An attributional LCA aims to provide an overview of the environmental impacts of the products and processes involved in the value chain of the evaluated solution (for example, the product, process, technology, or action of a company). These environmental impacts can be directly associated with the evaluated solution, and are, via allocation rules, attributed to the solution.
Consequential LCAs aim to assess the consequences of a solution. The processes that are affected by the solution (for example, the increased implementation of a technology or the increase in sales of a product) are identified and the environmental impacts generated by these changes in an economic system broader than that of the value chain of the process studied are evaluated. The calculated environmental impacts can take place outside the solution value chain, for example via market-mediated effects, such as substitution or rebound effects (e.g. a change in consumption patterns due to the use of a product at a lower price or higher energy efficiency).
In an attributional LCA (A-LCA), it could be assessed that a recycled material may be associated with lower GHG emissions compared to a primary material.

Example of an A-LCA analysis from the recycler's perspective: The GHG emissions from the PET recycling process are lower than the sum of the emissions from the PET incineration and primary PET production process. The difference can be considered "avoided emissions".

In a consequential LCA (C-LCA), it is identified which processes are affected by the increased use or supply of a recycled material. This could be an increase in the productivity of recycling processes. However, it could also be a decrease in recycling in other value chains, where more raw materials are now needed or where more alternative waste treatment processes are used, respectively. A C-LCA assesses which processes are impacted by the solution, within and beyond the value chain, and then how GHG emissions evolve due to the increased use or supply of recycled materials, taking into account market dynamics.

Example of a C-LCA analysis from the perspective of a car manufacturer: The increased use of recycled PET in vehicles can lead to an increase in the recycling of PET bottles and can avoid other end-of-life treatment processes, such as incineration. In this case, the substituted emissions from incineration can be considered "avoided emissions". However, it is possible that the increased use of recycled PET in vehicles will not lead to an increase in bottle recycling, for example if all economically recyclable bottles are already recovered elsewhere. Instead, other sectors will use less recycled PET and instead use an alternative material (e.g., primary PET). In this case, the avoided emissions may not be observed and the use of recycled PET in cars will result in the same GHG emissions as the use of primary PET in cars.

In this methodological guide, it has been chosen to use an **attributional approach** to quantify the avoided emissions. This makes it possible to assess avoided emissions using the same methodology as direct and indirect emissions related to the recycling process, whether they are assessed in the context of an EPD or for corporate carbon footprint reporting – which also follow an attributional approach. This allows for a transparent assessment of GHG emissions (due to the recycling process) and GHGs being reduced (i.e. GHG emissions that would occur in the event of non-implementation of the recycling process). The limitation of an attributional approach is that only the reduced GHG footprint of a predefined value chain is assessed and potential increases in GHG emissions in other value chains of the global economy are excluded from the analysis.

A consequential LCA is recommended if the study commissioner is interested in the contribution of a solution to the reduction of global GHG emissions, rather than the potential reduction of emissions from a specific value chain. While a C-LCA provides a more complete view of a solution's environmental benefits, the processes affected by the solution that take place beyond the solution's value chain cannot be traced back to the company implementing the solution, making this analysis more complex, uncertain, and disconnected from the company's sphere of influence. However, the assessment of avoided emissions could benefit from a (qualitative) analysis of potential consequences on a global scale, through the inclusion of a consequence tree as recommended (ADEME, 2022b; RETHORE et al., 2021) for example.

3.3.2. MULTIFUNCTIONALITY MODELING

The waste recycling and recovery processes are multifunctional: they perform the function of a waste treatment service and the function of material/energy production. This poses a problem in the assessment of avoided emissions, as it becomes necessary to determine which emissions generated by the recycling process (and potentially other processes) should be attributed to the life cycle that makes the end-of-life product available, and what part of the emissions goes to the user of the recovered materials/energy. This problem is illustrated in Figure 9.

In the example of the production of recycled plastic for use in cars, how does the GHG footprint of cars change if recycled plastics are used instead of other materials (e.g. primary plastics)? What emissions related to the recycling process can be attributed to cars, and what emissions to plastic bottles?

In an attributional LCA, there are two strategies for modeling this multifunctionality:

1. Application of system extension (which is prioritized by ISO 14044 (ISO, 2006))
2. Distribution of emissions on the recycling chain (and potentially other life-cycle processes, such as the primary production of materials) between the life cycle that provides the waste and the life cycle that uses the recovered materials/energy according to an allocation criterion.

In accordance with the priority strategy of ISO 14044, **system expansion is recommended** in this guide. This has the following consequences:

- The functional unit of the evaluated solution covers the two functions of the recycling/recovery process: the treatment of a product at the end of its life *and* the recovery of materials/energy
- Avoided emissions from a recycling/recovery solution represent a reduction in emissions in two life cycles: the life cycle in which recovered waste is supplied and the life cycle in which recovered materials/energy are used, as illustrated in Figure 9.

Recycling PET results in lower GHG emissions than alternative PET production, due to the low emissions of the recycling process. This results in avoided emissions in the life cycle of the car. However, the recycling process also avoids emissions in the life cycle of end-of-life recycled plastic bottles, as the recycling process replaces another end-of-life treatment process that would have been used. Therefore, the evaluated solutions presented in Table 20 all avoid emissions over both life cycles: that of cars and that of plastic bottles.

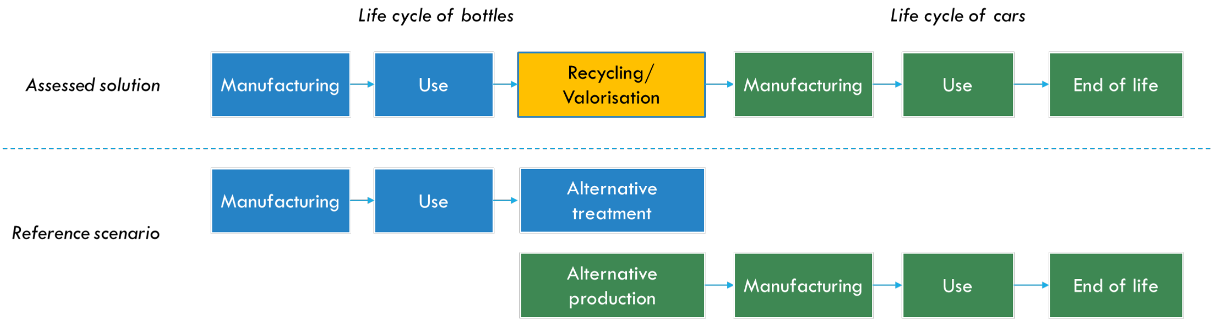


Figure 9 Assessment of avoided emissions through the use of recycled plastics in car manufacturing. Processes in green frames are assigned to the life cycle of a car, processes in blue frames are assigned to the life cycle of a bottle. The process in the orange frame could be partially attributed to the life cycle of a bottle, and partially to the life cycle of a car (RECORD, 2022)

According to the system expansion approach, the calculated avoided emissions from a waste recycling or recovery solution reflect emission reductions along the value chain. Avoided emissions are not attributed to specific product life cycles. If the study sponsor wishes to assess the reduction of GHG emissions from a specific product's life cycle through the implementation of a solution, an allocation method will need to be applied to identify the emissions attributed to the life cycle of the specific product.

3.3.3. OTHER METHODOLOGICAL CHOICES

Methodological choices that are not further specified in this guide (e.g. the modelling of biogenic CO2 emissions) shall be transparently described and justified, and applied consistently to the analysed solution and the reference scenario.

3.4. Step 3: Identification of the solution to be evaluated and the reference scenario

In order to interpret "what are avoided emissions", the solution that leads to avoided emissions must be described in detail, as well as the reference scenario to which emissions are compared. As shown in Figure 6, each actor in the value chain in a recycling/recovery chain could calculate avoided emissions. **To increase the credibility and comparability of the values obtained, the avoided emissions calculated by each actor in the value chain are ideally based on the same reference scenario**.

3.4.1. EVALUATED SOLUTION

DESCRIPTION OF THE EVALUATED SOLUTION

The evaluated solution should be described in detail.

At a minimum, the following information must be provided:

- Type and composition of valorised flows
- Description of recycling/recovery technology (include a diagram)
- The reference year (i.e. the year of implementation of the solution)
- The geographical area(s) in which waste is collected, transformed, and where intermediate products are sold

For energy recovery:

- Type of energy carrier (e.g. methane, solid fuels)
- Electricity and heat production (in MJ)
- Efficiency of the energy recovery process
- Specific uses (sales to a company, national grid, etc.)

For the production of secondary materials:

- Degree of quality of the materials obtained (see section 3.3.5. for a more detailed description)
- Process efficiency and losses
- Specific uses of the secondary materials

THE FUNCTIONAL UNIT

The functional unit is the quantified basis for comparison between the evaluated solution and the reference scenario.

In line with the expansion of the system, the functional unit includes the two functions of the recycling/recovery sector:

- Treatment of end-of-life products
- The production or consumption of recovered materials and/or energy

The quantity of the functional unit will be based on the manufacture, use, or processing of end-of-life products or the production of materials/energy **average over one year initiated by the analyzed solution**. This allows the inclusion of variability in electricity consumption, waste streams, etc. at the annual level. However, the results can be expressed "per kg" of waste treated or material produced, specifying that this is an annual average. **Avoided emissions are therefore expressed over a period of one year.**

*An example of a functional unit formulated by a car manufacturer that implements the solution of using recycled PET is "**the production of PET and the end-of-life treatment of plastic bottles to fulfil the annual demand for PET by a car manufacturer**". This formulation allows the development of the system of the implemented solution and the reference scenario, considering the following elements:*

- *Choice between recycled PET and primary or market-average PET*
- *Different end-of-life treatment options of plastic bottles (e.g. recycling, incineration, or landfilling)*
- *Consideration of quality differences between recycled PET and primary PET*

The quantities of the reference flows *(e.g. the production quantities of primary/recycled PET)* included in the two compared scenarios is determined after the iterative application of system expansion, which has as aim to make the functionalities of the two systems comparable. A numerical example of the calculation of these quantities is provided in section 3.5.1.

THE EVALUATION PERIOD

Avoided emissions can be calculated for a solution implemented in the past, for a solution implemented in the same year as the analysis, or for a solution that is envisaged to be implemented in the future.

This guide focuses on the analysis **of solutions implemented "today",** which means in the recent past or in the near future. The methodology could also be applicable for solutions implemented in the past, provided that the necessary data are accessible. Solutions to be implemented in the distant future require a "prospective" analysis, which is not analyzed by this guide. **The evaluation of a solution that will be implemented in more than 3 years is considered a "prospective evaluation".** This type of analysis can follow the recommendations of (Bouvart and Hache, 2017).

3.4.2. REFERENCE SCENARIO

Avoided emissions are calculated by comparing the scenario with the implementation of the analyzed solution with a reference scenario. The reference scenario provides the same functionality as the analysed solution. All assumptions made in the construction of the reference scenario should be described in a transparent manner.

Each actor in the recycling value chain, as shown in Figure 6, can assess the avoided emissions of the solution they have implemented. In theory, each actor can choose a different reference scenario, given its context. *For example, the plastic bottle manufacturer could make a comparison with steel or glass bottles, the recycler could compare the production of recycled PET with the production of primary PET, and the car user could compare the car in which the recycled PET is used with a car that uses polyamide.* This could lead to a different calculation of "avoided emissions" for each actor in the value chain.

In order to harmonise the assessment of "avoided emissions" between actors in the value chain, the following aspects must be taken into account. The reference scenario is **the most representative situation possible** for the market without implementing the solution based on the following considerations:

1. The reference scenario refers to the life cycle of the **same type of material** that is processed at the end of its life and/or is produced, where the distinction is made between the recycling/recovery solution and generic material streams *(i.e. recyclable PET bottles should be compared with medium PET bottles and recycled PET should be compared with average market PET)*

If the goal is to compare two products that offer the same function and use different materials, then a life cycle analysis is recommended. Indeed, such a comparison goes beyond the assessment of the emissions avoided through a recycling/recovery solution and is therefore not covered by this guide.

2. The processes included in the reference scenario reflect **the market-weighted combination of processes implemented during the reference year** (i.e., this mix includes recycling/recovery processes that already existed prior to the implementation of the solution).

A distinction can be made between the selection of *average* processes or *marginal processes* in the reference scenario. Marginal processes reflect the processes most likely to be replaced by the solution. For example, it could be argued that the use of recycled PET in a car only replaces the primary production of PET and does not compete with other recycling routes. The selection of marginal processes in the reference scenario makes it possible to calculate the avoided emissions that are likely to be achieved by the solution. The identification of marginal processes requires a market analysis, compatible with a C-LCA approach. These processes need to be justified if used as a reference scenario.

In this guide, the *average* processes are selected for the reference scenario. This is a conservative approach, reflecting the fact that it is often unclear which processes will actually decrease their activity based on the implementation of a solution. The selection of average processes avoids optimistic assumptions in the identification of the marginal process leading to an overestimation of avoided emissions. However, the disadvantage of considering average processes is that the calculated avoided emissions may be underestimated or overestimated compared to the avoided emissions that are likely to occur. In practice, **by following this guide, a solution only generates avoided emissions if it performs better than the market average, which stimulates the continuous development of low-carbon solutions.**

In addition to a comparison with average processes on the market, a comparison can be made with marginal processes in a sensitivity analysis, under the following conditions:

- The relevance of marginal processes must be justified. The marginal processes considered should be the most likely marginal processes.
- The selection procedure of marginal processes must be justified, for example, by market research
- The robustness of the scenario (the likelihood that other processes will be substituted in place of the marginal process identified as likely) must be justified.

3. **The smallest possible market** is taken into account (for example, if the waste treated by the recycling/recovery sector is collected in France, then the French market must be considered for alternative waste treatment. If the recycled material is sold in Europe, then the European market for the consumption of the generic material is considered).

4. The reference scenario takes into account the market at the time of implementation of the solution, as well as future regulations confirmed at that time provided that they are put in place in the near future, which is compatible with the avoidance period considered. Apart from the evolution of regulations in the near future, **the market is considered "static".** Potential changes in technology and market composition, as well as external factors (e.g. climate, demographics, human behaviour) are not taken into account in the development of the reference scenario, as the calculation is restricted to the recent and near future.

Finally, the following information must be provided for the reference scenario:

- Process details (e.g. incineration with/without energy recovery, landfilling, recycling)
- Process emission factors (mention the modelling of the multifunctionality of substituted processes)
- Relative contribution (in %) of each process to the market average
- Justification for the reference scenario

3.4.3. PERIOD OF VALIDITY OF "EMISSION FACTORS"

An analysis of avoided emissions can be simplified by the use of "emission factors", which represent the GHG emissions of specific processes included in the analysis. From the moment of the calculation of these "emission factors", developments on the market can take place that limit the representativeness of these factors.

The validity of the emission factors calculated in this guide is **5 years**, reflecting a balance between rapidly changing and relatively stable sectors, and delays in the availability of data sources used in the development of these emission factors. After 5 years, the relevant parameters (e.g. the energy mix) must be updated to ensure the representativeness of the emission factors.

Potential users of emission factors should be advised on the interpretation of the representativeness of the calculated emission factors, specifying that the regulations and technologies considered in the reference scenario are subject to change. **A sensitivity analysis with the best technologies available on the market (instead of average technologies) is recommended.**

3.4.4. SYSTEM BOUNDARIES

System boundaries define which processes are included in the scenarios of the analyzed and reference solution. The boundaries of the system of the two scenarios must be well defined and comparable.

In principle, all stages of the life cycle of waste treated by recycling/recovery processes and the life cycle of recovered materials/energy are considered. However, steps that show identical emissions between the evaluated solution and the reference scenario can be omitted from the analysis. Often, this implies that the production and use of the products underlying the recovered materials at the end of their life are excluded from the analysis, as well as the use and end of life of the recovered materials (and energies), as shown in Figure 10.

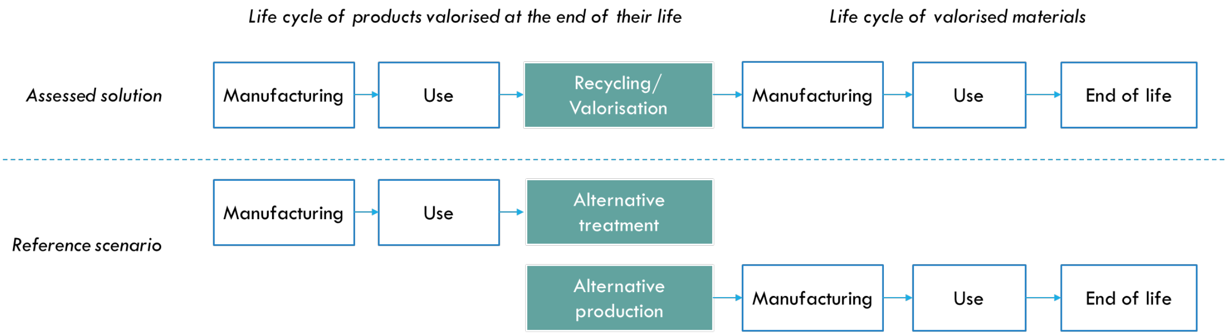


Figure 10 Omission of life cycle stages (boxes not filled) with identical emissions during analysis (RECORD, 2022)

Any processes for which inventory data is available and which is different between the solution and the reference scenario should be included in the analysis. Processes for which data are not available may be excluded from the analysis, if their contribution is estimated to be negligible according to the cut-off criteria. The cut-off criteria, taken from EN-15804 (CEN, 2012), are 1% of the consumption of renewable and non-renewable primary energy and 1% of the total mass input of a unit process. Total neglected input flows must be a maximum of 5% of mass and energy consumption. Conservative assumptions combined with plausibility considerations and expert judgment can be used to demonstrate compliance with these criteria.

At a minimum, the boundaries of the system should include the collection, preparation and recycling of recovered end-of-life products. The point of substitution – i.e. the point in the production chain where recycled material can substitute virgin material – must be defined. Diagrams should be included to clarify the inclusion (and exclusion) of processes within the boundaries of the systems studied. Any exclusion from a process must be mentioned and justified.

In the analysis on the production of recycled PET for use in car manufacturing, the life cycle stages "production" and "use" of plastic bottles, as well as "manufacture", "use" and "end of life" of cars can be removed from the analysis, as emissions are identical in both scenarios.

3.4.5. THE QUALITY OF THE RECOVERED MATERIALS

The quality of recycled materials may be lower than the quality of substituted primary materials, which is often the case for recycled plastics and paper. This can impact the stages of use (e.g. by a shorter lifetime) and end of life (e.g. by reduced end-of-life recyclability, which could be illustrated by a reduced number of recycling loops).

Differences in quality between virgin and recycled materials should be mentioned in the study. In this case, a **quality factor,** which limits the substitutability between recycled and virgin material, can be applied. Studies based on this guide should use, by default, the quality factors published in

Table 21, which are the most conservative among the factors published by (European Commission, 2020; FEDEREC, 2017). Other factors may be used if this deviation is justified and described in a transparent manner. If a material is not mentioned in

Table 21, a factor of 1 may be taken, if justified. The quality factor must reflect the consequences of

Table 21 Values of the quality factor to be used by default. These factors are reviewed regularly by RECORD (RECORD, 2022)

Recycling chain	Quality factor (European Commission, 2020; FEDEREC, 2017)
Steel	1
Copper	1
Aluminium	1
Paper	0.85
Cardboard	0.85
PET (mechanical recycling)	0.9
HDPE (mechanical recycling)	0.9
LDPE (mechanical recycling)	0.75
PP (mechanical recycling)	0.9
Plastic (chemical recycling)	1
Aggregates	1
Textile	1
Glass	1

Table 22 Examples of calculation to establish a quality factor (Q) (RECORD, 2022)

Consequence of a difference in quality between the recycled material and the raw material	Example of a calculation to establish a quality factor
Limited number of recycling loops	Recycling is limited to 4 loops; recycling avoids primary production and incineration 4 out of 5 times: Q = 0.8
Recycled material must be mixed with raw material, but the substitution rate is 1:1	The recycled content of a final product is limited to 60%. However, the final product has the same weight as a product with a recycled content of 0%. Q = 1
Recycled material must be mixed with raw material, but the substitution rate is different than 1:1	1 kg of recycled material can substitute 0.8 kg of virgin material: Q = 0.8 In addition, stages of transport, use, and end of life of the life cycle of the recycled material must be included in the analysis, because these stages will be impacted by the difference in weight of the product
The recycled product has a shorter lifespan	The recycled product must be replaced twice as often as the primary product; 2 recycling cycles replace 1 raw material cycle: Q = 0.5

If several quality factors are possible, take the **most unfavorable factor.**

If the difference in quality between the recycled material and the generic material does not affect the use of a recycled material in certain applications, the assessment of avoided emissions may be limited to those specific uses of the recycled materials and it is not necessary to apply a quality correction factor. In this case, **the potential applications** of the recycled material considered in the analysis must be mentioned in the study.

In the example of the production of recycled PET for use in the manufacture of cars, the difference in quality of recycled PET compared to primary PET should be described. In this case, it is possible that the recycled plastic has only a dark color, which limits the applicability of recycled PET only to certain parts of the vehicle. However, if a substitution rate of 1:1 can be achieved for these applications and no additional effects occur throughout the subsequent life cycle, no quality correction factors should be applied. If, however, other limiting aspects of quality are present, which would require, for example, the replacement of a part during the life of the vehicle, substitutability by primary PET should be reduced through a quality correction factor.

3.5. Step 4: Data collection

The quality of the data used has a strong influence on the robustness of the calculated avoided emissions. Data can be collected from a variety of sources.

Primary data should be used as much as possible. These data can be supplemented by data from LCA databases, such as ecoinvent (cut-off system model) or Base Carbone®/Base Impact®. Unit process databases should be prioritized over aggregated databases, and recent data over older data.

Data quality should be assessed based on the following:

- Reliability
- Completeness
- Temporal representativeness
- Geographical representativeness
- Technological representativeness

The level of uncertainty of the data should be assessed according to the method « Gestion de l'incertitude dans les tableurs du Bilan Carbone® » (Association Bilan Carbone, 2017), using the scoring published by (SEDDRe and Crowe Sustainable Metrics, 2019). This scoring is based on the data quality categories used in ecoinvent V3 (Table 23) (Weidema et al., 2013).

Data quality is evaluated for the collected data values, secondary emission factors (i.e. emission factors taken from external sources, such as LCA background databases), and technology market shares.

Figure 11 shows that process data points (e.g. the collection distance, energy consumption, etc. of a specific technology) are evaluated on all 5 data quality indicators. Secondary emission factors are not evaluated on their reliability and completeness (as these criteria are generally evaluated at the level of process data points, i.e. dataset flows (see for example (Ciroth et al., 2019)). Instead, besides their temporal, geographical, and technology representativeness, their inherent uncertainty is evaluated via one of the following options (in order of priority):

- The uncertainty rate communicated by the publisher of the secondary emission factor is used to represent the inherent uncertainty, if available
- An uncertainty range is calculated, e.g. via a Monte Carlo analysis (10.000 runs). Based on a low and high value and a 95% confidence interval a (corrected – in the case of a log-normal distribution) mean value with a corresponding uncertainty range can be established. *This is illustrated for the secondary emission factor for the incineration of PET in the Excel sheet published as an annex to this report.*
- A default value of 30% for the inherent uncertainty of the secondary emission factor is applied (based on a hypothetical scoring of 5% for reliability and 30% for completeness)

Technology market shares are only evaluated regarding geographical, temporal, and technological representativeness.

Table 23 Uncertainty scoring for specific data quality ratings, based on (SEDDRe and Crowe Sustainable Metrics, 2019; Weidema et al., 2013; Weidema and Wesnæs, 1996) (RECORD, 2022)

	5%	15%	30%	50%	75%
Reliability	Verified data based on measurements	Verified data partly based on assumptions Or non-verified data based on measurements	Non-verified data partly based on qualified estimates	Qualified estimate (e.g. by industrial expert)	Non-qualified estimate
Completeness	Representative data from all sites relevant for the market considered, over an adequate period to even out normal fluctuations	Representative data from >50% of the sites relevant for the market considered, over an adequate period to even out normal fluctuations	Representative data from only some sites (<<50%) relevant for the market considered or >50% of sites but from shorter periods	Representative data from only one site relevant for the market considered or some sites but from shorter periods	Representativeness unknown or data from a small number of sites and from shorter periods
Temporal representativeness	Less than 3 years of difference to the time period of the dataset	Less than 6 years of difference to the time period of the dataset	Less than 10 years of difference to the time period of the dataset	Less than 15 years of difference to the time period of the dataset	Age of data unknown or more than 15 years of difference to the time period of the dataset
Geographical representativeness	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar production conditions	Data from area with slightly similar production conditions	Data from unknown or distinctly different area (North America instead of Middle East, OECD-Europe instead of Russia)
Technological representativeness	Data from enterprises, processes and materials under study	Data from processes and materials under study (i.e. identical technology) but from different enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials	Data on related processes on laboratory scale or from different technology

The uncertainty factors are aggregated as follows, based on (Association Bilan Carbone, 2017):

1. Aggregation of uncertainty factors of process data points:

Eq. 10 $$U_{data} = \sqrt{U_R^2 + U_C^2 + U_{TpR}^2 + U_{GR}^2 + U_{TchR}^2}$$

With:
U_{data} = the total uncertainty rate of the process data point
U_R = the uncertainty rate related to reliability,
U_C = the uncertainty rate related to completeness
U_{TpR} = the uncertainty rate related to temporal representativeness
U_{GR} = the uncertainty rate related to geographical representativeness
U_{TchR} = the uncertainty rate related to technological representativeness

Example: The average transport distance of the collection of end-of-life bottles is 50 km, with an uncertainty of 30%. ***This uncertainty factor is interpreted as follows: there is a 95% probability that the transport distance ranges between 50 ± 30%, i.e. between 35-65 km*** *(see (Association Bilan Carbone, 2017)).*

2. Aggregation of uncertainty factors of the secondary emission factors at a flow level:

Eq. 11 $$U_{EF} = \sqrt{U_i^2 + U_{TpR}^2 + U_{GR}^2 + U_{TchR}^2}$$

With:
U_{EF} = the total uncertainty rate of the secondary emission factor
U_i = the inherent uncertainty of the secondary emission factor, as published by the original source
U_{TpR} = the uncertainty rate related to temporal representativeness
U_{GR} = the uncertainty rate related to geographical representativeness
U_{TchR} = the uncertainty rate related to technological representativeness

Example: Transport by truck has an emission factor of 3 kg CO2-eq/tkm, with an uncertainty of 15%.

3. Aggregation of the uncertainty rate of the data point and the secondary emission factor at a flow level:

Eq. 12 $$U_{process} = \sqrt{U_{data}^2 + U_{EF}^2}$$

With:
$U_{process}$ = the total uncertainty rate of the process emissions
U_{data} = the total uncertainty rate of the process data point
U_{EF} = the total uncertainty rate of the secondary emission factor

Example: Transport by truck for the collection of end-of-life bottles generates 150 kg CO2-eq, with an uncertainty of 34%.

4. Aggregation of emission factors at a technology level:

Eq. 13 $$U_{technology} = \frac{\sqrt{(U_{process1} * X_1)^2 + (U_{process2} * X_2)^2 + \cdots + (U_{process-n} * X_n)^2}}{X_1 + X_2 + \cdots + X_n}$$

With:

$U_{technology}$ = the total uncertainty rate of the emission factor of a technology (i.e. a reference or solution technology) at dataset level
$U_{process-i}$ = the total uncertainty rate of the emissions of each process

Example: Recycling of plastic bottles, including collection, sorting, and processing, generates 700 kg CO2-eq/kg of collected waste, with an uncertainty of 45%.

5. Aggregation of uncertainty factors of a technology that is represented by a secondary emission factor:

Eq. 14 $$U_{technologyEF} = \sqrt{U_i^2 + U_{TpR}^2 + U_{GR}^2 + U_{TchR}^2}$$

With:

$U_{technologyEF}$ = the total uncertainty rate of a technology emission factor represented by a secondary emission factor
U_i = the inherent uncertainty of the secondary emission factor, as published by the original source
U_{TpR} = the uncertainty rate related to temporal representativeness
U_{GR} = the uncertainty rate related to geographical representativeness
U_{TchR} = the uncertainty rate related to technological representativeness

Example: Incineration of plastic bottles, as represented by a secondary emission factor from the ecoinvent database, generates 300 kg CO2-eq/kg of collected waste, with an uncertainty of 60%.

6. Aggregation of uncertainty factors of the technology market shares:

Eq. 15 $$U_{market\ share} = \sqrt{U_{TpR}^2 + U_{GR}^2 + U_{TchR}^2}$$

With:

$U_{market\ share}$ = the total uncertainty rate of the market share of each technology contributing to the market
U_{TpR} = the uncertainty rate related to temporal representativeness
U_{GR} = the uncertainty rate related to geographical representativeness
U_{TchR} = the uncertainty rate related to technological representativeness

Example: The average end-of-life treatment of plastic bottles in Europe is 40% collection for recycling, 30% landfilling, and 30% incineration with energy recovery, with an uncertainty of 15%.

7. Aggregation of the uncertainty rate of the contribution of a technology in a scenario:

Eq. 16 $$U_{technology\ in\ scenario} = \sqrt{U^2_{market\ share} + U^2_{technologyEF}}$$

With:

$U_{technology\ in\ scenario}$ = the total uncertainty rate of the technology in the scenario

$U_{market\ share}$ = the total uncertainty rate of the market share of each technology contributing to the scenario

$U_{technologyEF}$ = the total uncertainty rate of the emission factor of a technology (i.e. a reference or solution technology) at dataset level

Example: The inclusion of emissions related to incineration within the reference scenario has an uncertainty of 35%.

Example: The reference scenario with which the solution (recycling of plastic bottles for the use of recycled PET in cars) is compared generates 4.5 kt CO2-eq per year, with an uncertainty of 35%.

8. The aggregation of uncertainty factors for a scenario including multiple technologies (e.g. the reference scenario):

Eq. 17 $$U_{scenario} = \frac{\sqrt{(U_{technology\ in\ scenario1} * X_1)^2 + (U_{technology\ in\ scenario2} * X_2)^2 + \cdots + (U_{technology\ in\ scenario-n} * X_n)^2}}{X_1 + X_2 + \cdots + X_n}$$

With:

$U_{scenario}$ = the total uncertainty rate of the emission factor at scenario level

$U_{technology\ in\ scenario}$ = the total uncertainty rate of the emission factor of each technology in the scenario, at dataset level

X_i = the emissions associated to each technology in the scenario

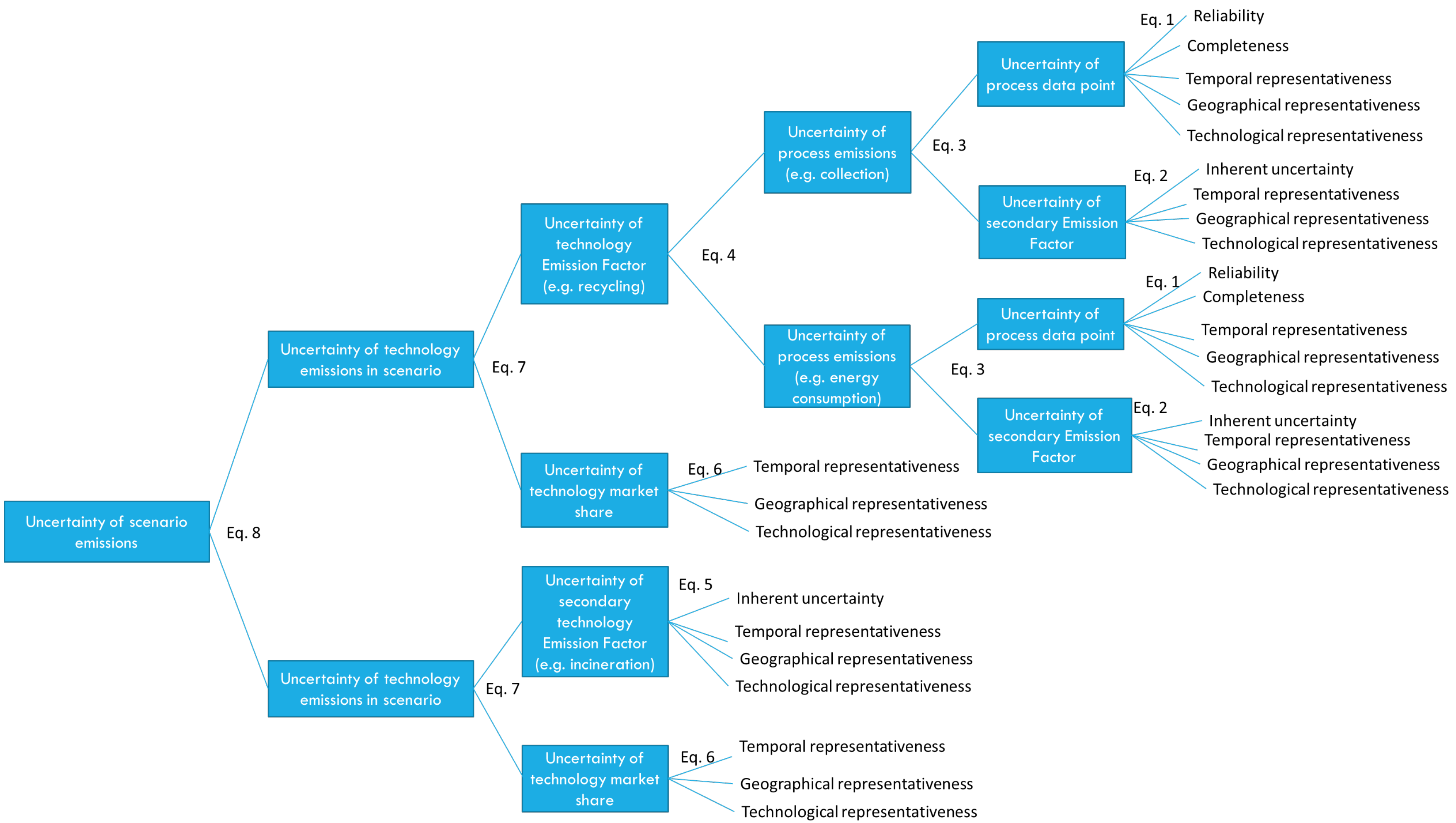


Figure 11 Overview of data quality indicators applied to process data points, secondary emission factors, and technology market shares, and their subsequent aggregation to calculate the uncertainty range of the emissions of a scenario (RECORD, 2022)

3.6. Step 5: Assessment of avoided emissions

3.6.1. *QUANTIFICATION OF THE ANALYSED SOLUTION AND THE REFERENCE SCENARIO*

As introduced in section 3.3.2., the functional unit represents the quantified functionality of the implemented solution and the reference scenario. Considering that this guide has a focus on recycling and waste valorisation processes, the solution is most probably multifunctional: a waste treatment function and a material/energy production function are provided.

The evaluated solution and the reference scenario are rendered comparable by means of system expansion. Via an iterative addition of processes, the functional outputs of the two systems are made equal. The iterative process of system expansion is applied as follows:

1. Quantify the implementation of the evaluated solution, from the perspective of the value-chain actor under study that evaluates its avoided emissions.
2. Quantify the additional functionality provided by the evaluated solution:
3. Establish the reference scenario, based on the following elements:
    - Consumption rate of recycled and primary materials without the implementation of the analysed solution, based on the market-average recycled content.
    - Consideration of the recycling efficiency in the market.
    - Consideration of the mix of end-of-life treatment technologies in the market.
4. Supplement the systems with additional processes to guarantee a similar functionality.

An example of the quantification of the functional unit that includes the consideration of the quality difference between recycled and primary material is added in Annex 3. The quantification of the scenarios is simplified if the average recycled content and/or the end-of-life recycling rate of a material in the market is negligible, due to a decreased multifunctionality in the reference scenario.

Example: application of system expansion to the implementation of the solution "use of recycled PET in the manufacturing of cars" (throughout this example, hypothetical values are used):

1. *The annual use of 3 kt of recycled PET in cars.*
2. *To produce 3 kt of recycled PET, a waste treatment service is provided for 3.5 kt of end-of-life plastic bottles. The initial representation of the analysed solution is presented in Figure 12.*

Figure 12 Initial representation of the analysed solution. The actor that evaluates the implemented solution is highlighted in green (RECORD, 2022)

3. *The subsequent considerations are illustrated in Figure 13. In this hypothetical example, the recycled content of PET in the European market is currently 7%. 93% of the PET supplied on the European market is from primary sources. In the reference scenario, the car manufacturer would use 0.21 kt of recycled PET and 2.79 of primary PET.*

    In the reference scenario, the same quantity of waste must be treated as in the solution scenario. In this example, it is assumed that the same recycling efficiency is valid in the market as in the analysed solution: to produce 3 kt of recycled PET, 3.5 kt of plastic bottles are collected. It is assumed that, without implementation of the solution, 19% of end-of-life bottles are already collected for recycling.

    Incorporating the recycling efficiency into the reference scenario shows that the producers of the waste and the recyclers do not only provide recycled PET to the actor that conducts the analysis, but also to other users of PET in the market.

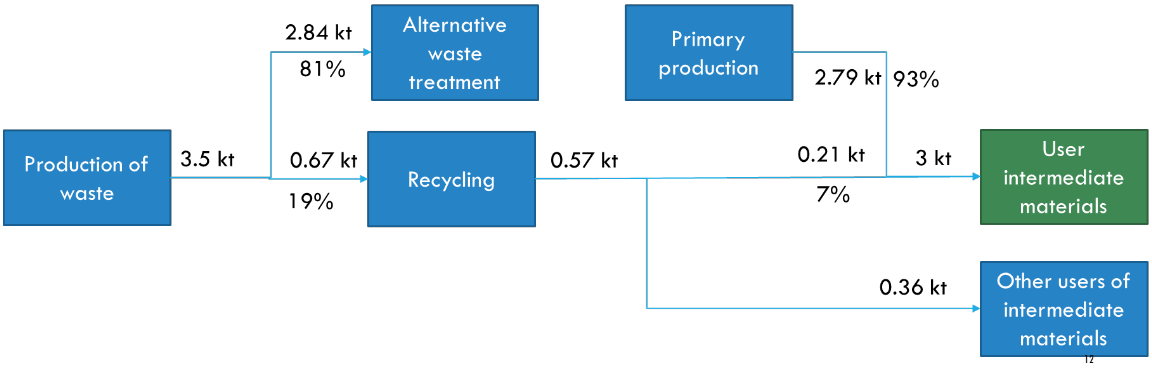


Figure 13 Representation of the reference scenario, considering the end-of-life recycling rate and the recycled content of PET in the market (RECORD, 2022)

4. *Comparing Figure 12 with Figure 13, it can be observed that the two systems do not yet provide the same functional output. In the reference scenario, other users of PET have access to recycled PET. System expansion is applied to compensate for this difference in the supply of PET. The production of primary PET is added to the analysed solution (Figure 14).*

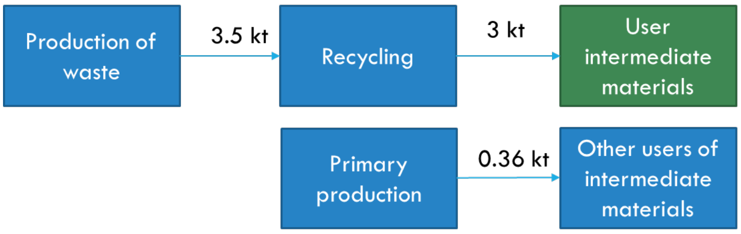


Figure 14 Analysed solution after the application of system expansion (RECORD, 2022)

Part of the increased consumption of recycled PET by the car manufacturer is hence produced by an increased valorisation of bottles at the end of life. However, the amount of available waste being limited, part of the recycled material is diverted from other users, that now use more primary material. These "other users" are former value-chain actors of the recycling system in the reference scenario, and therefore should be considered in the evaluation of the total avoided emissions generated by the implemented solution.

The final functionality of the two systems (the analysed solution and the reference scenario) is now equivalent and can be formulated as "the production of PET and the end-of-life treatment of plastic bottles to fulfil the annual demand for PET by a car manufacturer". The quantified processes that provide these functionalities in the two systems are listed in Table 24.

Table 24 Technologies included in the analysed solution and the reference scenario after system expansion (RECORD, 2022)

Technology	***Analysed solution***	***Reference scenario***
Primary production of PET (kt)	*0.36*	*2.79*
Production of recycled PET (solution scenario*) (kt)	*3*	
Production of recycled PET (reference scenario*) (kt)		*0.57*
Alternative waste treatment (kt)		*2.84*

**Note that the recycling process considered in the solution may be different than the recycling process considered in the reference scenario*

These quantities are subsequently multiplied with the corresponding technology-specific emission factors to calculate the total emissions attributed to the analysed solution and the reference scenario, respectively.

3.6.2. CALCULATION OF AVOIDED EMISSIONS

The avoided emissions with associated uncertainty range are calculated as follows:

Eq. 1 $$GHG_{avoided} = GHG_{reference} - GHG_{solution} \pm (GHG_{reference} * U_{reference} + GHG_{solution} * U_{solution})$$

With:

$GHG_{avoided}$ = GHG emissions avoided

$GHG_{solution}$= GHG emissions from all processes in the recycling or recovery sector, which includes the steps of collection, preparation, sorting and refusal management, production of raw materials for recycling and intermediate materials these raw materials, or energy, as well as, potentially, other life cycle stages that are included in the system boundaries. The total amount of GHG emissions of the analysed solution is based on the GHG emissions of the processes included in the scenario after system expansion.

$GHG_{reference}$= GHG emissions from all processes included in the reference scenario, after the application of system expansion

$U_{solution}$= the total uncertainty rate of the emission factor of the solution

$U_{reference}$ = the total uncertainty rate of the emission factor of the reference scenario

Example: Recycling of plastic bottles for the use of recycled PET in cars avoids 3 kt CO2-eq ± 1 kt CO2-eq per year compared to the reference scenario.

3.6.3. ROBUSTNESS OF AVOIDED EMISSIONS

Even if lower GHG emissions can be attributed to the analysed solution than to the reference scenario, the uncertainty ranges of the reference scenario and the analysed solution may be overlapping (Figure 15). In that case, it cannot be claimed that the analysed solution generates avoided GHG emissions.

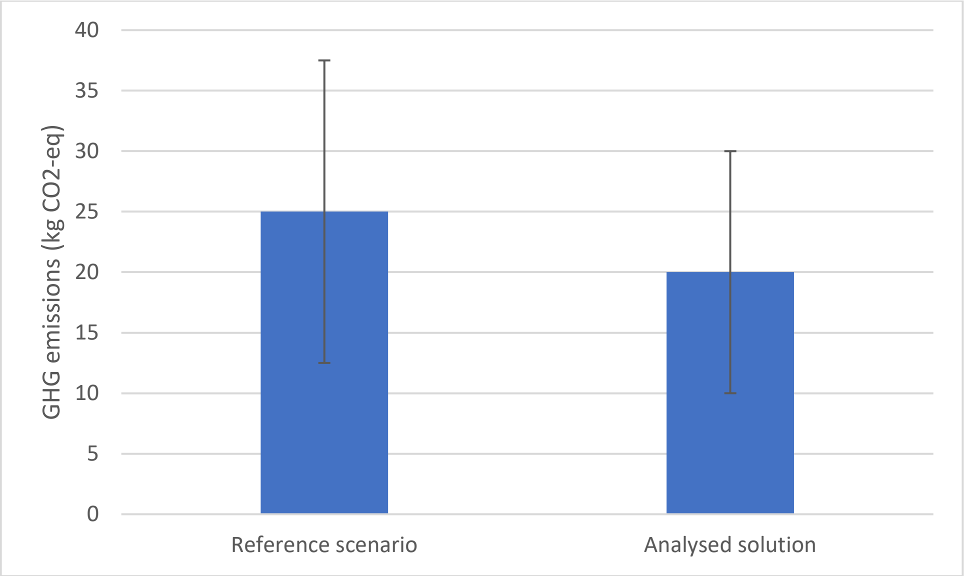


Figure 15 Example comparison of a solution with a reference scenario, with overlapping uncertainty ranges (RECORD, 2022)

Only when the uncertainty ranges show no overlap, as shown in Figure 16, it can be claimed that the GHG emissions of the analysed solution are significantly lower than the GHG emissions of the reference scenario.

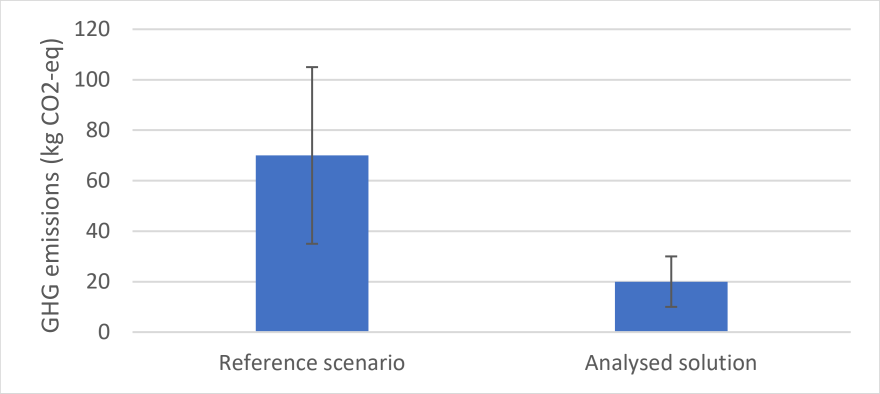


Figure 16 Example comparison of a solution with a reference scenario, with a statistically significant determination of avoided emissions (RECORD, 2022)

The following strategies could be applied in case the performance of the two scenarios is not statistically distinguishable:

- Identify the datasets, data points, and/or emission factors that contribute to a high uncertainty range, and either
    - Search for replacement data sources with a lower uncertainty rating,
    - OR conduct a sensitivity analysis with a justified high and low value, replacing the associated uncertainty rating
- OR communicate the results of the analysis as follows: "The analysed solution has the potential to generate avoided emissions. Reliable and representative data must be collected for the specified process(es) before such a claim can be confirmed."

3.6.4. IMPACT CATEGORIES

This guide focuses on assessing avoided GHG emissions. However, to comply with ISO 14044, potential trade-offs with other impact categories should also be assessed.

At a minimum, it is recommended that the following impact categories be assessed using the Environmental Footprint (EF) method (Zampori and Pant, 2019) :

- Climate change, total;
- Acidification;
- Eutrophication, freshwater;
- Water use;
- Resource use, fossils; and
- Resource use, minerals and metals.

Note that the EF 3.0 method as applied in the calculation of the Emission Factors in Chapter 4 calculates the total of fossil, biogenic, and land use and land transformation-induced GHG emissions. However, only biogenic methane is characterized. Biogenic carbon dioxide and biogenic carbon monoxide have a characterisation factor of 0, also in the category “biogenic carbon”.

The used impact assessment method and version number (e.g. IPCC 20XX, EF X.X) must be communicated with the study results. A disclaimer shall be added to all communication of avoided GHG emissions stating that either trade-offs with other environmental problems may take place, or that (no) trade-offs are identified in the study (if other impact categories are evaluated as well).

3.6.5. *ATTRIBUTION TO ACTORS IN THE VALUE CHAIN*

Several actors play a role in the recycling chain that transforms an end-of-life product into a valuable material or energy. There may be a desire for individual actors in the value chain to assess their specific contribution to avoided emissions, potentially with the aim of later aggregating all avoided emissions generated by a company in a specific year.

This guide does not encourage the attribution of avoided emissions to certain actors in the value chain. Recycling may be limited, inter alia, by collection costs, costs related to the separation of waste streams, the availability and technical maturity of recycling technologies, as well as the existence of applications in which recycled materials can be used, potentially at a higher price or at a lower quality than substituted alternative materials, etc. The dependence of the success of the recycling/recovery sector on the involvement of all actors in the value chain is shown in Figure 6.

Therefore, the proper functioning of a recycling value chain requires the contribution and significant efforts of multiple actors, which could be overlooked via an allocation of avoided emissions to specific actors in the value chain. Thus, **this guide does not recommend attributing avoided emissions to individual actors**. Instead, each actor can communicate that *"our participation in the recycling/recovery sector contributes to a cumulative reduction in the GHG emissions of the actors involved of X tonne of CO2 equivalent per year".*

For this reason, the calculation of avoided emissions as defined in this guide is not intended to be used in potential certification/labelling schemes or the distribution of potential costs/credits of GHG emissions among actors in the value chain.

3.7. Step 6: Communication of results

In order for the communication of "avoided emissions" to be credible, transparent, and not misinterpreted, the communication requirements of ISO 14044 (ISO, 2006) and ISO 14020 (ISO, 2002) could be followed, as outlined by (Schrijvers et al., 2019). This section presents the types of claims that could be made regarding "avoided emissions" evaluated by this guide, and how this information is best communicated to different audiences.

3.7.1. *FORMULATION OF AVOIDED EMISSION CLAIMS*

This guide to evaluate avoided emissions preconises methodological choices that influence the type of claim that can be made regarding the evaluated "avoided emissions", which are summarized in Table 25.

Table 25 Limitation of claims regarding avoided emissions based on methodological choices (RECORD, 2022)

Methodological choice	What can be claimed	What cannot be claimed	Why not?
Attributional LCA	Avoided emissions are reduced GHG emissions of a specific entity	Avoided emissions are reduced global GHG emissions	This would require a consequential LCA
System expansion	Avoided emissions are reduced GHG emissions of all processes involved in the removal of a waste and the production of a valuable intermediate product	Avoided emissions are reduced GHG emissions of: - A product - A single product life cycle - A single value-chain actor	This would require an allocation of GHG emissions

Based on the above limitations, the claim of "avoided emissions" should clarify that the avoided GHG emissions refer to the whole recycling/waste valorisation chain, and that it is this chain of actors that benefit from reduced GHG emissions.

The GHG emissions avoided by the recycling/recovery sector are interpreted as **"a reduction in GHG emissions of X ton of CO2-equivalent per year attributed to the recycling/waste valorisation chain",** where "the chain" includes both the actors who generate the waste and the users of the recovered materials/energy.

The use of recycled PET instead of market-average PET in the manufacturing of cars results in avoided GHG emissions attributed to the entire value chain, which includes consumers of plastic bottles as well as potential buyers of the company's cars. The car manufacturer could report avoided GHG emissions as follows: "Our participation in the plastics recycling chain translates into a total of X tons of avoided GHG emissions attributed to the value chain". Other examples of communication phrases for all actors in the value chain are presented in Table 26.

Table 26 Examples of reporting on avoided emissions from the perspective of different actors in the value chain (RECORD, 2022)

Actor of the value chain	***Reporting avoided emissions***
Manufacturer of a recyclable bottle	*The manufacturing of our recyclable bottles avoids the emission of A* ton of CO2 equivalent per year within the value chain.*
User of a recyclable bottle	*Our use of recyclable bottles avoids the emission of B* ton of CO2 equivalent per year within the value chain.*
Bottle recycler	*The production of recycled PET from plastic bottles by our processes avoids the emission of C* ton of CO2 equivalent per year within the value chain.*
Manufacturer of a car with recycled PET	*The use of recycled PET in our cars avoids the emission of D* ton of CO2 equivalent per year within the value chain.*
User of a car with recycled PET	*The use of a car with recycled PET avoids the emission of E* ton of CO2 equivalent per year within the value chain.*

**The quantity is relative to the annual production/consumption of the specific actor*

The claim of "avoided emissions" must be accompanied by an **overview of the limitations of the study**, which provides an interpretation of the robustness of the results based on at least the following elements:

- Study hypotheses
- System boundaries
- Data sources
- Data gaps
- Data uncertainty
- Impact categories and used emission factors

Additional sensitivity analyses may be conducted to support the robustness of the avoided emission claim.

3.7.2. COMMUNICATION OF AVOIDED EMISSION CLAIMS

The communicated information regarding the calculated avoided emissions should be adapted to the targeted audiences. In this section, a distinction is made between LCA experts and a non-expert (professional) audience. It must be noted that, to be compliant with ISO 14044, **all communication with a third party requires a critical review by an independent panel.** A critical review by external experts is recommended to evaluate the correct implementation of the methodology, which could protect the commissioning company against potential external allegations regarding the study results.

COMMUNICATION TO NON-EXPERT AUDIENCES

All audiences should be given access to the full report of the analysis, in which the functional unit, relevant assumptions, and the applied LCA approach and its corresponding limitations are described (Schrijvers et al., 2019). However, the initial information provided to non-expert audiences can be reduced to a minimum level of communication requirements:

- Total amount of avoided emissions
- Description of the analysed solution
- Description of the reference scenario
- Reference year

Furthermore, a reminder must be communicated that avoided emissions are not to be subtracted from a carbon footprint.

Avoided emissions can be communicated visually via a figure such as presented in Figure 4.

Example: "The use of recycled PET instead of market-average PET in our cars in 2020 avoided the emission of 3 kt of CO2-equivalent per year within the value chain. This, however, does not decrease the carbon footprint of our company and our products."

COMMUNICATION TO LCA EXPERTS AND SUPPLEMENT TO FULL REPORT

If the communication is targeted to LCA experts, more information should be provided up-front to allow the audience to determine the relevance of the study results. Table 27 provides a communication template that summarizes the most relevant study parameters required for the interpretation of the results. It is recommended to **present this template in the executive summary of the full report**, for all audiences. The template and the full report can be complemented with additional communication elements as described in Section 5 of ISO 14044 (ISO, 2006).

Table 27 Reporting template for the communication of avoided emissions to LCA experts. Lines marked in green should, at a minimum, also be accessible to non-expert audiences (RECORD, 2022)

Study parameters	Example answers
General aspects	
LCA commissioner and LCA practitioner	Car manufacturing company and external consultant
Date of the report	June 2022
Methodological reference	The study has been conducted according to the requirements of the *Guide to accounting for avoided GHG emissions in waste recovery and recycling – Good practices and application to different sectors (Version 1.0)* (RECORD, 2022)
Objective of the study	Inform and potentially justify a decision to use recycled PET in car components
Target audiences	Internal decision makers of the car manufacturing company, as well as investors, (potential) clients, and the general public
Methodology	
LCA approach	Attributional
Modelling of multifunctional processes	System expansion

Study parameters		Example answers
Functional unit		The production of PET and the end-of-life treatment of plastic bottles to fulfil the annual demand for PET by a car manufacturer
Main data sources		- Primary data collection at suppliers - ... - Ecoinvent V3.8 (cut-off system model)
Additional methodological choices		
Evaluated impact categories, impact assessment method and version number, and (if applicable) software and version number		Climate change (method EF 3.0), evaluated in SimaPro v.X
Analysed solution		
Description of the solution		The production of PET and the end-of-life treatment of plastic bottles to fulfil the annual demand for 100% recycled PET by a car manufacturer
Reference year		2020
Valorization process	Description	Specific recycling process, which is a direct supplier of the car manufacturer
	Geographical area of valorisation	Operation of recycling factory in France
Valorized waste stream	Type	End-of-life plastic bottles
	Geographical area of waste collection	Europe
	Quantified reference flow	3.5 kt of plastic bottles
Production of intermediate products	Type	Recycled PET granulates
	Geographical area of consumption	Europe
	Quantified reference flow	3.88 kt of PET, of which 3 kt recycled
System boundaries	Included life cycle stages	- Collection - Sorting - Pre-treatment - Production of PET granulates
	Excluded processes	
Quality and foreseen uses of the valorized material/energy	Quality differences between the valorized material and the reference material	Substitution takes place at a 1:1 ratio, recycled PET has a different colour then primary PET, and part of the recycled PET needs to be additionally replaced
	Applied quality correction factor	0.9
	Foreseen uses of the valorized product	Use in plastic components in cars
Relevant assumptions		
GHG emissions of the analysed solution		... kt CO2-eq
Data quality	Uncertainty level of the GHG emissions	30%
Reference scenario		
Description of the reference scenario		The production of PET and the end-of-life treatment of plastic bottles to fulfil the annual demand for market-average PET by a car manufacturer
Valorized waste stream	Point of substitution	Discarding of plastic bottles at end-consumer
	Reference process(es) - Identified technologies	Average end-of-life treatment of plastic bottles in Europe

Study parameters		**Example answers**
	- Relative contribution of each technology to the scenario	- Incineration without energy recovery: 35% - Landfilling: 15% - Recycling: 50%
	Quantified reference flow(s)	3.24 kt of plastic bottles
Production of intermediate products	Point of substitution	Production of recycled PET granulates at factory
	Reference process(es) - Identified technologies - Relative contribution of each technology to the scenario	Average production of PET granulates consumed in Europe - Primary production: 85% - Recycling: 15%
	Quantified reference flow(s)	3.72 kt of PET, of which 1.39 kt recycled
System boundaries	Included life cycle stages	Incineration/landfilling: - Collection - Final treatment Recycling: - Collection - Sorting - Pre-treatment - Production of PET granulates Primary production: - Raw material extraction - Production
	Excluded processes	
Relevant assumptions		
Comparability between the analysed solution and the reference scenario		
GHG emissions of the reference scenario		... kt CO2-eq
Data quality	Uncertainty level of the GHG emissions	40%
Avoided emissions		
Average value		3 kt CO2-eq / year
Minimum value		2 kt CO2-eq / year
Maximum value		4 kt CO2-eq / year
Access to full report and critical review		URL / QR-code
Avoided emissions are not to be subtracted from the carbon footprint of a company or a product. Furthermore, trade-offs may take place regarding other environmental problems, such as acidification, eutrophication, water use, or resource use, which are however not evaluated within the scope of this study ***OR (No) trade-offs are identified regarding other environmental problems, such as acidification, eutrophication, water use, or resource use.***		

CORPORATE REPORTING

A company can communicate about avoided emissions in the context of corporate reporting under the following conditions:

- A critical review of the study report is conducted by an independent review panel
- To avoid a confusion with the corporate GHG balance:
  - Avoided emissions may never be subtracted from the company's GHG balance
  - Avoided emissions must be presented in a separate chapter or section than the company's GHG balance
- The minimum communication requirements for non-expert audiences must be followed, and access to the full report and critical review must be provided

Aggregating the avoided emissions of multiple solutions of a company may give the impression that the company's actions only result in avoided emissions, whereas other actions (that are not mentioned or assessed) may result in increased GHG emissions. Therefore, if the company aggregates the avoided emissions of multiple solutions, an overview must be provided of the solutions included in the aggregation. The total avoided emissions may be communicated as "the solutions 1, 2, and 3 implemented by this company contribute to a total avoided emission of X tons of GHG emissions within their respective value chains."

4. Emission factors

As an annex to this report, Reference Emission Factors (REFs) (emission factors that can be used in a reference scenario) are developed that can be used in the evaluation of avoided emissions within the value chains listed in The complete list of flows for which REFs are established is provided in **Erreur ! Source du renvoi introuvable.**. Although the REFs may require adaptations or updating based on specific future uses of the values, the provided Excel sheets can be used as a template for such future modification and development of future (Reference) Emission Factors. Furthermore, the Excel sheets allow for a step-by-step calculation of the emissions of a scenario based on multiple (reference) technologies and can therefore also be used as a template for the calculation of the emissions of the analysed solution.

Table 28. These REFs are made available to the members of RECORD in the form of 3 versions:

- Complete Excel files including the REFs, the underlying calculations, and the data sources. Due to the use of proprietary data, these Excel files are available to ecoinvent licence holders only,
- Preview Excel files presenting the calculated REFs, without access to the underlying calculations and data sources,
- One Excel template for the calculation of future (Reference) Emission Factors, based on the methodology presented in Chapter 3. The user of this file must update the highlighted cells with case-specific data.

The complete list of flows for which REFs are established is provided in **Erreur ! Source du renvoi introuvable.**. Although the REFs may require adaptations or updating based on specific future uses of the values, the provided Excel sheets can be used as a template for such future modification and development of future (Reference) Emission Factors. Furthermore, the Excel sheets allow for a step-by-step calculation of the emissions of a scenario based on multiple (reference) technologies and can therefore also be used as a template for the calculation of the emissions of the analysed solution.

Table 28 Recycling and waste valorisation chains for which Reference Emission Factors are calculated (RECORD, 2022)

Recycling chain
Paper/cardboard recycling
Mechanical recycling of plastics
Chemical recycling of plastics
Recycling of metals (e.g. steel, copper, aluminium)
Glass recycling
Recycling of construction waste
Composting of organic waste
Methanization of organic waste (with cogeneration or direct injection of biogas into the natural gas network)
Energy recovery from waste in the form of solid fuels
Mixed waste incineration with energy recovery
Valorization of biogas from landfilling facilities

4.1. Structure of the Excel files

The Excel files contain the following sheets:

- Title page presenting the context of the publication of the file, the file type (complete, preview, or template), and if applicable restrictions of use and sharing.
- Goal and Scope of the Emission Factors, including the following elements:
    - Reference year
    - Reference geography
    - Reference flow of the collected waste

    - Reference flow of the produced intermediate material(s)
    - Description of the reference technologies and processes, supported by a diagram that indicate the system boundaries
    - Main data sources
- Market and Emission Factors
    - Overview of different technologies that contribute to the average market (e.g. recycling, incineration, landfilling) and their contribution rate
    - Emission Factors of the different technologies that contribute to the average market. For the recycling processes, the EFs are expressed per unit of incoming waste as well as per unit of produced product, to accommodate different types of functional units.
- Technology sheets (only in the Complete version):
    - Technology-specific datasets, containing:
        - Inputs and outputs of the specific technologies
        - References to secondary emission factors
        - Modeling assumptions
        - Data quality scoring
- Secondary data (only in the Complete version)
    - Overview of secondary emission factors and their sources

Most technology REFs are entirely based on secondary emission factors. However, for the metals aluminium, copper, and steel (all based on (FEDEREC, 2017)), a remodelling of the secondary data is reproduced in the Excel sheets to demonstrate the use of the Excel sheets as a data collection template for primary data.

4.2. Practical use of the Emission Factors

4.2.1. ROLE OF EMISSION FACTORS IN A CALCULATION

The calculated Emission Factors are "Reference Emission Factors", i.e. Emission Factors that represent the GHG emissions associated with processes included in the reference scenario. Avoided emissions are the result of a comparison between the GHG emissions of a solution and the GHG emissions of the reference scenario. **The published Emission Factors can be considered as building blocks to construct the total emissions of the reference scenario. If the solution contains similar technologies, the EFs can furthermore be used to calculate the total emissions of the evaluated solution.**

The GHG emissions of the evaluated solution are compared with the GHG emissions of the reference scenario, based on the same:

- Point of substitution of the collected waste and produced intermediate material
- Inclusion and exclusion of processes within the system boundaries
- Functional unit

The user of the Emission Factors is responsible for:

- Evaluating the suitability of the REFs in a specific calculation exercise of avoided emissions
- Ensuring alignment of the scope of the Emission Factors with the scope of the evaluated solution
- Ensuring the comparability of the evaluated solution with the reference scenario, by adapting the inclusion of processes and life cycle stages to a common functional unit.

4.2.2. SCOPE OF THE EMISSION FACTORS

The Reference Emission Factors can be used in a study that aims to evaluate the avoided emissions generated by a recycling or waste valorisation solution. The combination of the collected data, the secondary emission factors, and the data quality evaluation are strictly reserved for the use in a study that applies the same scope, as outlined in Table 29.

Table 29 Scope of the Reference Emission Factors published as annex to the guide (RECORD, 2022)

Reference element	Scope of the Emission Factor
Reference year	2020
Reference geography (for the collection of waste and the consumption of intermediate materials)	Europe*
Technological reference	As specified in the according Excel sheet
System boundaries	From the point of substitution of the collected waste** to the point of substitution of the produced intermediate materials/energy at factory gate

*For some processes, no secondary emission factors were available for Europe. In that case, a representative dataset is selected, e.g. with a Swiss, Rest-of-World, or Global scope. The uncertainty of these secondary emission factors is adapted accordingly.

**Some REFs do not include collection of unsorted waste. If this is relevant for a specific comparison, this should be added by the user of the REFs.

The REFs may be used in studies with different scopes (e.g. with a reference geography of France), after applying the following modifications:

- Revision of the included processes and data values, where relevant
- Revision of secondary emission factors (e.g. using the French electricity production mix, instead of the European mix)
- Revision of the data quality evaluation (i.e. the scoring of the geographical, technological, and temporal representativeness of the data values and the secondary emission factors)
- Expansion of the system boundaries (addition of upstream and/or downstream life cycle stages) if the life cycles of the implemented solution and the reference scenario show differences beyond the defined system boundaries of the Reference Emission Factors. These life cycle stages must be added to both the implemented solution and the reference scenario.

4.2.3. ILLUSTRATIVE EXAMPLE

The practical use of the Reference Emission Factors is illustrated via the example of the use of recycled PET in the manufacturing of cars. The functional unit is formulated as "the production of PET and the end-of-life treatment of plastic bottles to fulfil the annual demand for PET by a car manufacturer".
The quantified processes included in the analysed solution and the reference scenario are calculated in Section 3.5.1 of the report[5] and reproduced in Table 30, which are based on the end-of-life recycling rate and the recycled content of PET in the European market in 2020. For simplicity, it is assumed that the recycling process in the analysed solution is the same process as the recycling process in the reference scenario. The Reference Emission Factors for PET are presented in Table 31.

From Table 31, it appears that the alternative waste treatment processes in the reference scenario (incineration and landfilling) provide an additional output of recovered electricity and heat. To ensure the comparability of the two analysed systems, alternative electricity and heat production are added to the scenario of the analysed solution in

Table 30 via system expansion. The corresponding Reference Emission Factors for electricity and heat are presented in Table 32 and Table 33.

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[5] Note that the consideration of a quality correction factor influences the quantities of the processes included in the analysed solution and the reference scenario (e.g. such as calculated in Section 3.5.1. and Annex 3). However, they do not affect the emission factors of these processes, and are therefore not integrated into the Excel sheets.

Table 30 Processes included in the analysed solution and the reference scenario after system expansion (RECORD, 2022)

Process	Analysed solution	Reference scenario
Primary production of PET (kt)	0.36	2.79
Production of recycled PET (solution scenario*) (kt)	3	
Production of recycled PET (reference scenario*) (kt)		0.57
Incineration and landfilling (kt)		2.84
Production of electricity (GJ)**	2.84*3.24E+03 = 9.20E+03	
Production of heat (GJ)**	2.84*6.24E+03 = 1.77E+03	

*Note that the recycling process considered in the solution may be different than the recycling process considered in the reference scenario

**Additional expansion of the system due to the energy recovery in the reference scenario

Table 31 Reference Emission Factors for the end-of-life treatment and production of PET (RECORD, 2022)

	Inputs	**Outputs**							
Technology	**Waste collected (ton)**	**Intermediate (recycled) materials (ton)**	**Recovered electricity (MJ)**	**Recovered heat (MJ)**	**Emission Factor**		**Uncertainty rate technology Emission Factor**	**Uncertainty technology market share**	**Uncertainty rate technology in scenario**
Incineration and landfilling	**1.00E+00**		**3.24E+03**	**6.24E+03**	**1.27E+03**	**kg CO2-eq/ton collected waste**	29%	51%	59%
Primary production		**1.00E+00**			**3.10E+03**	**kg CO2-eq/ton intermediate materials**	64%	50%	82%
Recycling	**1.00E+00**	**8.00E-01**			**8.35E+02**	**kg CO2-eq/ton collected waste**	34%	50%	61%
	1.25E+00	**1.00E+00**			**1.04E+03**	**kg CO2-eq/ton intermediate materials**	34%	50%	61%

Table 32 Reference Emission Factor for the production of electricity in Europe (RECORD, 2022)

Process	**Emission Factor**		**Uncertainty rate**
Average production of electricity	**0.11**	**kg CO2-eq/MJ**	34%

Table 33 Reference Emission Factor for the production of heat in Europe (RECORD, 2022)

Technology	**Emission Factor**		**Uncertainty rate**
Average production of heat	**0.06**	**kg CO2-eq/MJ**	53%

Table 34 and Table 35 show the total breakdown of the GHG emissions of the analysed solution and the reference scenario, and the corresponding uncertainty rates. These tables are reproduced in the Excel file of PET. A comparison between the two scenarios is presented in Figure 17. The final avoided emissions are calculated via Eq. 10 (see also Eq. 9):

Eq. 10 $$GHG_{avoided} = 1.28E07 - 5.36E06 \pm (1.28E07 * 0.57 + 5.36E06 * 0.31)$$

Figure 17 shows the comparison of the GHG emissions of the analysed solution with the reference scenario. The avoided emissions are represented in Figure 18. The uncertainty range shows that there is a possibility that the analysed solution does not generate avoided emissions, but instead increased emissions. This possibility may be eliminated by reducing the uncertainty range via the collection of more representative data.

The result of Eq.10 may be communicated by the car manufacturer as follows: *"Fulfilling the annual demand for PET in our cars in 2020 via recycled PET instead of market-average PET had the potential to avoid the emission of 7.5 kt CO2-equivalent per year within the value chain. More reliable and representative data must be collected for the relevant processes before such a claim can be confirmed. Avoided emissions, however, do not decrease the carbon footprint of our company and our products."*

Table 34 GHG emissions and corresponding level of uncertainty of the reference scenario (RECORD, 2022)

Process	Reference scenario	GHG emissions (kg CO2-eq)	Uncertainty rate
Primary production of PET (kt)	2.79	8.64E+06	82%
Production of recycled PET (reference scenario*) (kt)	0.57	5.95E+05	61%
Incineration and landfilling (kt)	2.84	3.55E+06	59%
Total		*1.28E+07*	*57%*

Table 35 GHG emissions and corresponding level of uncertainty of the analysed solution (RECORD, 2022)

Process	Analysed solution	GHG emissions (kg CO2-eq)	Uncertainty rate
Primary production of PET (kt)	0.36	1.11E+06	96%[1]
Production of recycled PET (solution scenario*) (kt)	3	3.13E+06	34%[2]
Production of electricity (GJ)**	2.84*3.24E+03 = 9.20E+03	1.01E+06	61%[3]
Production of heat (GJ)**	2.84*6.24E+03 = 1.77E+04	1.06E+05	74%[3]
Total		*5.36E+06*	*31%*

[1] Compound uncertainty of the primary production EF and the combined uncertainty of the end-of-life recycling rate and the recycled content in the reference market

[2] Uncertainty of the recycling EF

[3] Compound uncertainty of the energy EF and the uncertainty of the incineration rate in the reference market

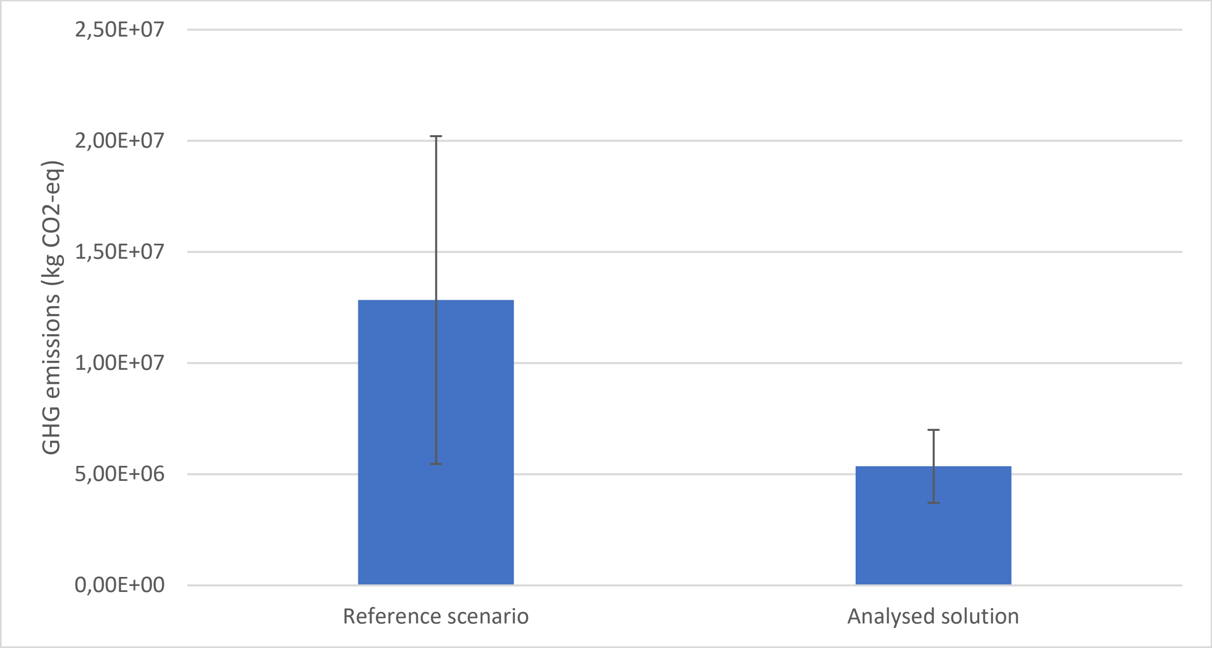

Figure 17 Comparison of the emissions of the analysed solution with the emissions of the reference scenario (RECORD, 2022)

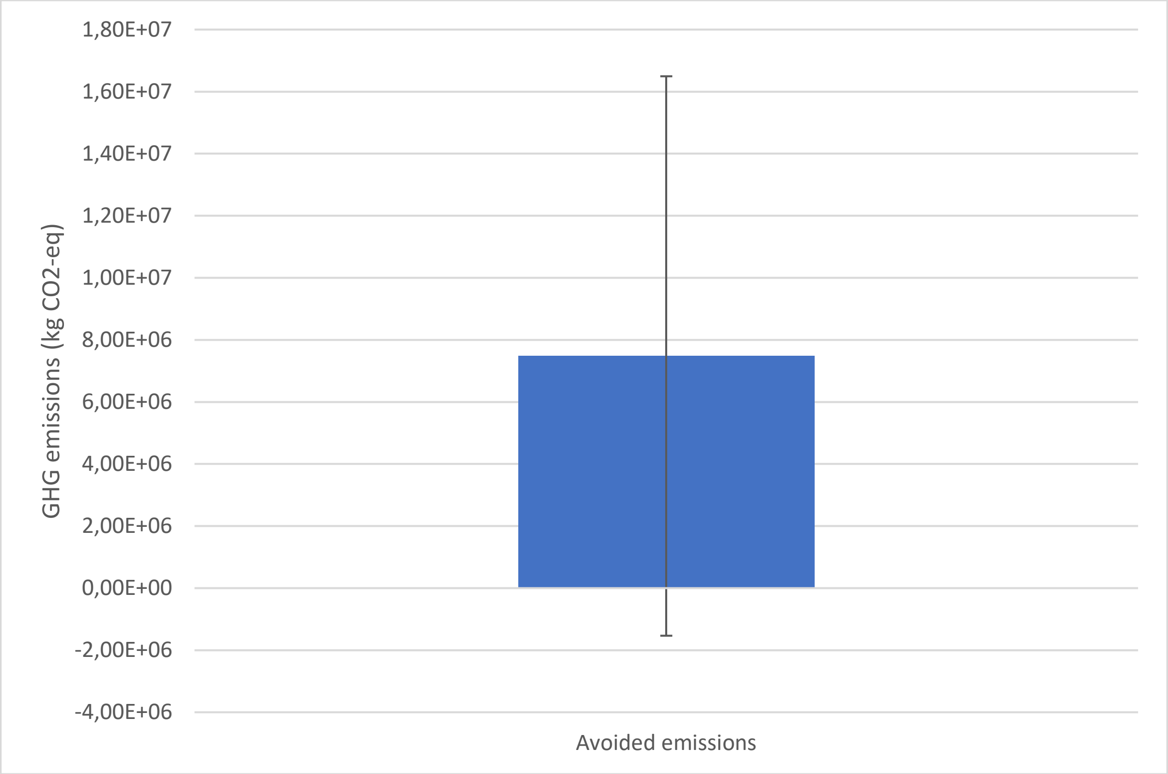

Figure 18 Avoided emissions comparing the analysed solution with the reference scenario (RECORD, 2022)

4.3. Evaluation of the emission factors

4.3.1. COMPARISON OF RECYCLING WITH NON-RECYCLING

The Reference Emission Factors aim to represent the average market scenario of Europe in 2020. This may include both primary production, incineration and landfilling, and recycling, according to their relative market share.

However, it is interesting to evaluate to what extent recycling appears to be environmentally beneficial over the non-recycling of materials (i.e. primary production and alternative waste treatment). Figure 19 shows such a comparison for a selection of materials for which Reference Emission Factors are calculated.

According to the used data, recycling is beneficial with regard to climate change for PET, PE, PP, aluminium, copper, steel, glass, and paper. Recycling leads to higher impacts on climate change for inert construction waste and wood. With regard to inert construction waste, environmental benefits may be achieved for other impact categories than climate change, as GHG emissions are not a main concern in the end-of-life treatment of this type of waste. For wood, the modelling of biogenic carbon via the EF method results in a negligible contribution of wood incineration to climate change. Results may be strongly impacted by a different characterisation factor for biogenic carbon.

4.3.2. QUALITY AND RELIABILITY OF THE REFERENCE EMISSION FACTORS

The Excel sheets presenting the Reference Emission Factors reflect an illustration of the methodological guide in Chapter 3, as well as a template for the future calculation of avoided emissions. The Excel sheets are occupied with readily available data on recycling processes, primary production processes, waste treatment processes, as well as technology market shares. The user of the Excel sheets should therefore evaluate the suitability of the data in a specific avoided emissions calculation.

At a minimum, the following limitations should be taken into consideration:

- No specific data were available for the different types of plastics. Therefore, the market shares of different technologies are based on the information of PE.
- Secondary emission factors have been used from background databases, notably ecoinvent. Many datasets have a relatively low scoring on the geographical, temporal, or technological representativeness, leading to high uncertainty rates. Ideally, future users of the REFs evaluate whether more representative data are available in an effort to decrease these uncertainty rates.
- The inherent uncertainty of the secondary emission factors is by default established at 30%. This value is ideally updated by conducting a Monte Carlo analysis, that allows to generate specific uncertainty ranges for each of these secondary emission factors.
- Data on market-average recycling rates were not readily available and benefit from a more sector-specific analysis.
- Ideally, the REFs represent the European consumption patterns of raw materials, considering the import of primary and recycled materials, extra-European production processes, as well as the export of waste and corresponding waste treatment processes. Import and export rates have so far not been included in the analysis. The REFs currently cover European production and waste treatment averages. This should be revised in an updated version of the REFs.
- The REFs represent a first illustration of the methodological guidance. The emission factors would benefit from a review conducted by sector-specific experts.

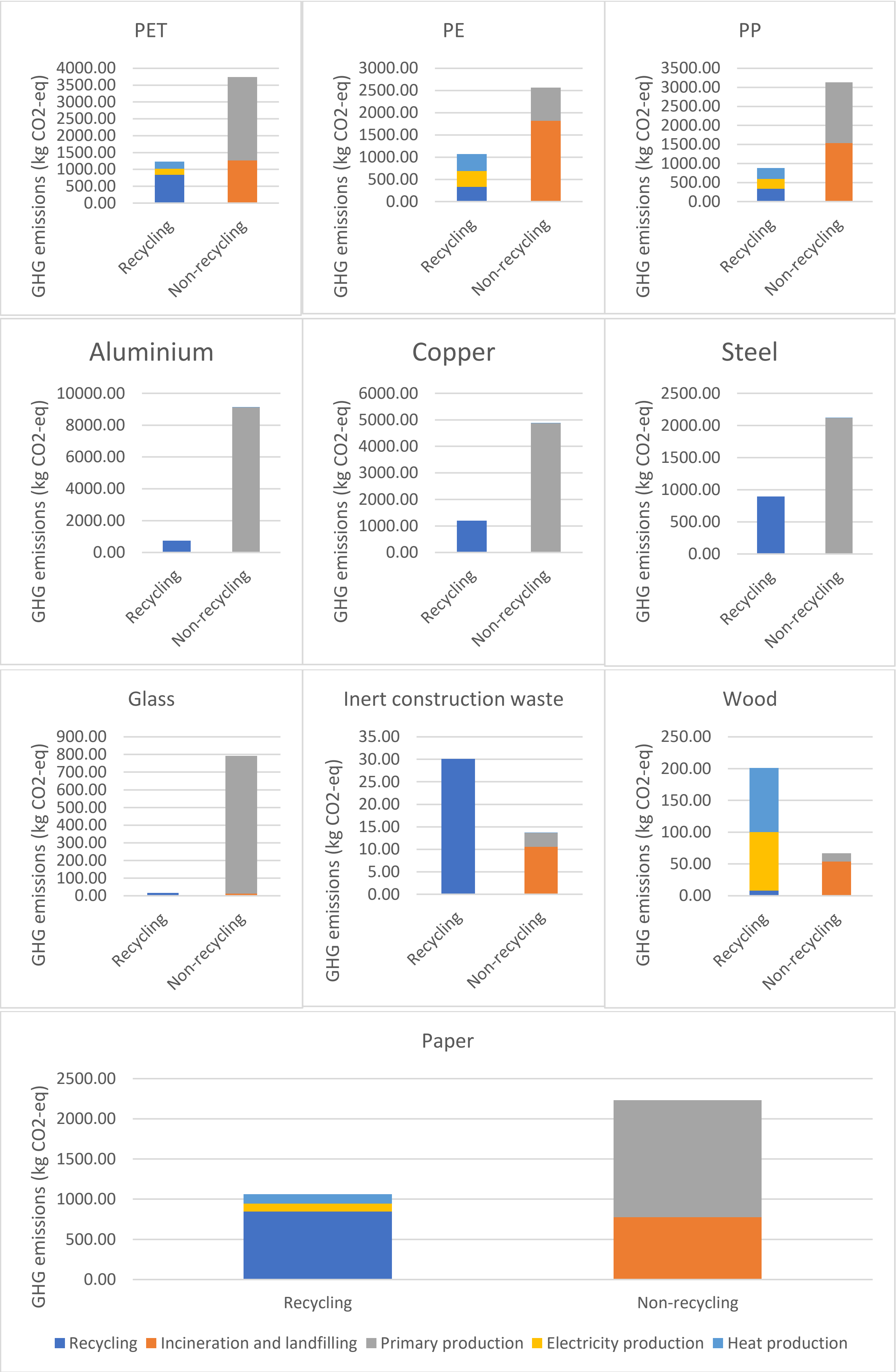

Figure 19 Comparison of the collection of 1 ton of waste in a recycling scenario with a non-recycling scenario, as represented by the Reference Emission Factors, for a selection of materials (RECORD, 2022)

5. Conclusions and outlook

This report presents the first version of a methodological guide to evaluate and communicate avoided GHG emissions generated by the recycling and waste valorisation sector. The guide aims to propose a consensus-based harmonized approach, equally applicable to all actors in the recycling/valorisation value chain, which enhances the credibility, transparency, and comparability of avoided emission claims. Reference Emission Factors are developed that could be used to establish a reference scenario in specific studies among a broad range of sectors.

5.1. Future implementation of the methodological guide

The methodological guide is time-independent, meaning that the guidance is not expected to become outdated and therefore does not require an inherent updating procedure. However, as this report presents a first version of the guide, an implementation and refinement trajectory should be foreseen.

The following recommendations enable the guidance document to become a widely applicable and recognized methodology:

- The alignment and divergence with other, ongoing, initiatives should be monitored, such as the initiatives of WBSCD and Carbone 4 in the area of carbon neutrality.
- The methodological guide should enter a pilot phase, in which members of RECORD and potentially other interested parties apply the guide in company-specific case studies in which the avoided emissions of the solutions implemented by the RECORD members are evaluated.
- During this pilot phase, a contact person should be assigned that operates as a "help-desk". Members of RECORD could be directed to this person with follow-up questions regarding the guide, or to address methodological choices that are not yet covered by the guide. The contact person is responsible for collecting all the feedback.
- Aside from the collected feedback, an independent review team (that may or may not include the above contact person) should be assigned to review the application of the methodological guide in the pilot case studies. This review will address whether the implementation of the guide is done in a harmonized manner, whether different members of RECORD interpret the methodology similarly, whether methodological choices are made in the study that could be standardised, and whether certain aspects of the guide impede its practical implementation, e.g. due to complexity or lack of practical feasibility.
- A revision project should be launched, in which the feedback and the results of the review process are discussed, and consensus is built on potential adaptations of, or additions to the methodological guide. A similar procedure could be implemented as in the current project, in which several rounds of discussion, drafting, and feedback collection are organised. The revision of the methodological guide could be foreseen at the same time as the revision of the Reference Emission Factors (as discussed below), i.e. 5 years after its initial publication.

After this revision project, it could be decided whether the updated version of the guide is considered final, or whether it is subject to another testing round. To guarantee the quality of studies that claim to adhere to the methodological guide, a review panel may be assigned to evaluate the correct application of the methodology before publication of the study results.

5.2. Future update of the Reference Emission Factors

The Reference Emission Factors may be used in studies evaluation the avoided emissions of a solution with a reference year of 2020-2025, without a modification of the current factors and uncertainty scores. After this timeframe, the emission factors and the corresponding uncertainty scores need to be revised. It is recommended that a working group assigned by members of RECORD revise the Reference Emission Factors every 5 years, either by an integration of recently published inventory data and/or emission factors, or by a modification of current inventory data and/or emission factors based on consultation with relevant industrial experts. Data quality factors shall be updated accordingly.

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Annex 1 – Survey results

Table 36 Detailed results of the questionnaire distributed in the RECORD and WeLOOP networks (in French) (RECORD, 2022)

Filière		Recyclage du papier/carton	Recyclage mécanique des plastiques	Recyclage chimique des plastiques	Recyclage des métaux (e.g. acier, cuivre, aluminium)	Recyclage du verre	Recyclage des déchets de construction	Compostage des déchets organiques
Quelles sont les principales sources de déchets pour cette filière ?		Bureaux et industriels Ordures ménagères et cartons d'emballages issus des ménages (colis, briques, journaux, alimentaire, etc)	Déchets de production, post-consumer (automobile) Industries et ménages PSE, PP, PE, PVC dans le secteur automobile, distribution, agro-alimentaire, déconstruction des bâtiments (PVC, PP), emballage (PP, PET notamment), textile. Produits médicaux, agricoles (film PE), et autres produits de consommation (rasoirs…) provenant des différentes canaux (ménages, déchets municipaux) Déchets ménagers / Déchets des activités économiques DIB	Tous plastiques à "faible valeur ajoutée" (PET, PE, PVC). Le bâtiment, surtout lors de la déconstruction (PVC, PP, PSE), la distribution et l'agro-alimentaire surtout pour les emballages intermédiaires et finaux (PP, PET, PSE), l'automobile, le textile	Pour la filière automobile, il s'agit d'abord des carcasses des véhicules dépolluées au préalable qui sont broyées. Les câblages cuivre font parfois l'objet d'un démontage préalable avant broyage pour passer dans une filière spécifique. Les catalyseurs sont eux systématiquement démontés pour le recyclage de leurs PGM. Chutes propres – chutes des usines – ferrailles de récupération, Collectes sélectives, Déchetteries, Industrie, Démolition, D3E, VHU Déchets ménagers et déchets des activités économiques	Verre (bouteilles, matériaux de construction)	Béton, briques, métaux, plâtre, PVC, verre, Terres, bois Déchets collectés par la construction, la rénovation, la démolition de bâtiments et de travaux de génie civil. Collecte sélective telle que les systèmes industriels pour les fenêtres en PVC. Les déchets inertes (pierres, bétons, matériaux de terrassement et de démolition, briques, verre…) représentent environ 65 % des déchets du bâtiment.	Déchets biodégradables : déchets alimentaire, déchets verts, boues industrielles (STEP, papeterie…), déchets des IAA, déchets agricoles, ordures ménagères résiduelles et TMB Déchets ménagers (OM, biodéchets) déchets municipaux verts boues
Quels sont les produits secondaires fabriqués par cette filière de recyclage/valorisation (matériau, énergie...), quelle est	Produit secondaire (si plusieurs produits, indiquer (1), (2), (3), etc.)	Papier carton, PPO (Papier pour Ondulés) ou dans la fabrication du papier d'hygiène, carton plat. Pâte à papier pour réemploi, transformé en bobines de papier (directement pour les journaux et magazine)	PP secondaire, matières plastiques downcyclées ou pour même application, plastique vierge intégrant du plastique recyclé, granulats, produits finis	Gaz, plastique purifié ; pour même usage ou boucle ouverte mais avec mêmes propriétés ; PP / PEHD	(1) Acier électrique, (2) Granulat de cuivre, (3) PGM secondaires (1) Acier : sous forme de plaques, bobines, barres ou fils, (2) Aluminium : sous forme de plaques ou de lingots, qui seront ensuite utilisés dans la création de nouveaux produits finis.	Verre (bouteilles, matériaux de construction)		(1) Matière fertilisante stabilisée riche en composés humiques (62% des débouchés en France en 2015) (2) Chaleur (3) Gaz carbonique (CO2 biogénique mais pas de CH4) Compost

Filière		Recyclage du papier/carton	Recyclage mécanique des plastiques	Recyclage chimique des plastiques	Recyclage des métaux (e.g. acier, cuivre, aluminium)	Recyclage du verre	Recyclage des déchets de construction	Compostage des déchets organiques
leur utilisation principale, et quel matériaux/ source d'énergie est substitué?	Utilisation principale de ce produit (si plusieurs produits, indiquer (1), (2), (3), etc.)	Papier : ramette de papier. Emballages et papier journal	Passage de roue, éléments techniques non-visibles dans les voitures, intérieur de tuyaux PVC, réincorporation de la matière recyclée dans des bouteilles ou en habillement pour le PP/PE, emballage, construction, agriculture & horticulture, bien de consommation durable, médical/hygiène, objets plastiques	Cf Recyclage mécanique des plastiques	(1) Construction, (2) Fontes de fer, (3) Idem PGM primaires (1) Acier : boîtes de conserve, canettes, appareils ménagers, chariots de supermarché, armatures pour béton, structures métallique, clefs, trombones (2) Aluminium : boîtes de conserve, canettes, papier aluminium, barquettes, bombes aérosols, fenêtres, portes, gouttières, appareils ménagers, ustensiles de cuisine, pièce automobile, vélo, trottinette	Agroalimentaire Construction	Matériau ; pour même usage (béton recyclé en béton, plâtre, métaux, verre) ou pour downcycling (béton recyclé en remblais, briques en remblais, PVC pour intérieur de tuyaux, bois pour panneaux particules) voire upcycling avec les terres (substrat fertiles, éco-produits à base de terres) Sous-fondation de voirie (chemin d'accès, lotissement…). Fondation, sous-fondation de bâtiments industriels. Parkings. Construction : bétons maigres et graves stabilisés. Empierrement d'accès de chantier	(1) Amendement organiques, engrais organiques, support de culture (terreau), en agriculture au sens large (horticulture, espace verts). Compost : pour apporter engrais et Matière Organique au sol
	Matériaux/source d'énergie substitué par ce produit (si plusieurs produits, indiquer (1), (2), (3), etc.)	Papier et carton vierge	PE, PP, PVC, PS, PET vierge PVC, PP et PE downcyclé	Plastiques vierges	(1) Acier haut fourneau, (2) Cuivre primaire, (3) PGM primaires Matériaux vierges / 1ere production	Verre non recyclé	Matériaux vierges / 1ere production	(1) Engrais minéraux (azote de synthèse, potasse et phosphore importés) Engrais minéraux et/ou amendements alternatifs ; enfouissement/ incinération si on a une perspective déchets
Quels paramètres limitent l'utilisation potentielle des matériaux recyclés/énergie valorisée ?		Qualité, nombre de recyclage Débouchés et intégration de matière première issue du recyclage par les papetiers	Barrière psychologique Tri des gisements, plastiques très coûteux à démonter, trier et transporter chez les démolisseurs et ils sont complètement mélangés (automobile) Débouchés et intégration de la	- Coûts - Souvent encore au stade laboratoire ou pré-industriel - Sourcing de la matière à transformer (collecte municipale ou chez les industriels)	Les résidus de broyage pour l'acier comme le cuivre ont beaucoup d'impuretés difficiles à extraire, ce qui diminue la qualité et les cas d'emploi des matières secondaires.	Couleur du verre (le verre coloré ne peut être décoloré et ne peut donc servir que pour certains usages) - Coût vs	Les caractéristiques physico-chimiques des terres et béton ; la perte de caractéristiques pour le PVC ; les conditions d'acceptabilité des filières (pas de boues de curage de plâtre par exemple) Règlementation, assurance	Emissions gazeuses et particulaires > effets inflammatoires, immuno-allergiques et infectieux connus . Odeur (2/3 du tonnage français audit ADEME 2006) . Concurrence avec la méthanisation qui présente un bilan énergétique positif (car

Filière	Recyclage du papier/carton	Recyclage mécanique des plastiques	Recyclage chimique des plastiques	Recyclage des métaux (e.g. acier, cuivre, aluminium)	Recyclage du verre	Recyclage des déchets de construction	Compostage des déchets organiques
		matière recyclée Esthétique Mauvaise qualité des déchets Propriétés fonctionnelles et couleur Coût du sourcing et du tri des gisements Recyclage ne fonctionne pas bien avec des matières encapsulées les unes dans les autres Matières moins bien triées si multi-matières => prix de rachat moins important et flux moins "pur"			production de verre à partir de matériau vierge - Coexistence de systèmes de "REP" (consigne) et de systèmes de collecte urbaine qui peuvent limiter le sourcing et l'équilibre économique des filières		production de biogaz biologique riche en méthane) Qualité et variabilité de la teneur en NPK des composts, présence de substances indésirables (cf normes AFNOR sur le compost)
Quels sont les procédés prédominants de traitement de ces déchets en France ? En Europe ? (Recyclage et des traitements alternatifs inclus)	Recyclage mécanique	Enfouissement ou incinération (pour environ 75% du gisement) Recyclage mécanique (extrusion, injection, extrusion-soufflage, roto-moulage, thermoformage) Broyage, ré-extrusion	- Enzymatique, pyrolyse - Solvolyse, dissolution, dépolymérisation chimique, dépolymérisation thermique (cf Etude Record Octobre 2015)	Pour la filière auto : (1) Introduction des ferrailles dans la filières haut fourneau ou utilisation dans la filière électrique (EAF). (2) broyage des câblage et tri mécanique / optique. (3) Pyro puis hydro métallurgie. Overband électromagnétique ou à aimant permanent (déchets ferreux), courant de Foucault (déchets non ferreux tels que l'aluminium, le laiton, le bronze)	Broyage (calcin) puis chauffage	Concassage, broyage pour les matériaux minéraux et le bois (+additifs) ; fonte pour le métal, le verre et le PVC (plus réextrusion), formulation pour les terres	- Enfouissement puis incinération - Concurrence avec la méthanisation - Compostage des déchets organiques
Est-ce que les acteurs de cette filière de recyclage/valorisation sont réunis par une ou plusieurs associations au niveau français ou européen ? Si oui, lesquelles ?	FEDEREC, FNADE, SNEFID, EuRIC	FEDEREC, BIR, FNADE, SNEFID EuRIC, VinylPlus, PlasticsEurope, SRP, Afipeb, Elipso	Federec fnade, plastic europe, SRP, Afipeb, Elipso, VinylPlus	FEDEREC et BIR	Federec / Fnade	SEDDRe – Syndicat des Entreprises de Déconstruction, Dépollution et Recyclage FFB ; FNADE, FEDEREC (mais globaux)	Syprea, FNADE, Astee

Filière	Recyclage du papier/carton	Recyclage mécanique des plastiques	Recyclage chimique des plastiques	Recyclage des métaux (e.g. acier, cuivre, aluminium)	Recyclage du verre	Recyclage des déchets de construction	Compostage des déchets organiques
Avez-vous connaissances de performances environnementales disponibles ou publiés pour ce filière de recyclage/valorisation? (Surtout les émissions GES)	Base carbone, prognos 2008, FEDEREC, BIC et FNADE	FEDEREC, BIR, SRP, « Recycled Textile Fibres and Textile Recycling », Be sustainable, Décembre 2017 ; « ECAP - Mapping clothing impacts in EECAP – European Textiles and Workwear Market – the role of Public Procurement in making textiles circular», Sustainable Global Resources Ltd, mars 2017 ; « Analyse de Cycle de Vie d'un Pantalon en Jean - Rapport Final », ADEME, Octobre 2006 ; MADE-BY Bernardo, C.A., Simoes, C.L., Costa Pinto, L.M. Environmental and economic life cycle analysis of plastic waste management options. A review. AIP Conference Proceedings. 2016, 1779. ; Stichnothe, H., Azapagic, A. Life cycle assessment of recycling PVC ; Commission, European. Final Report - Life Cycle Assessment (LCA) of PVC and of principal competing materials. juillet 2004 ; Ye, L., Qi, C., Hong, J., Ma, X. Life cycle assessment of polyvinyl chloride production and its recyclability in China. Journal of Cleaner Production. 20 janvier 2017, Vol. 142, part. 4. .		Prognos, Base Carbone, FEDEREC Gilstad, G., Hammervold, J. Light Metal. Life Cycle Assessment of Secondary Aluminium Refining. 2014. ; Bureau, J., Duval, M. Recyclage de l'aluminium. Centre d'expertise sur l'aluminium - aluQuébec. [En ligne] 7 décembre 2017. https://ceal-aluquebec.com/recyclage-aluminium/.	Prognos, Base carbone	Expertise Neo-Eco Ciments : déclaration environnementale, inventaire & analyse du cycle de vie https://www.infociments.fr/ciments/ciments-declaration-environnementale-inventaire-analyse-du-cycle-de-vie 1. SEDDRe. Empreinte carbone de la valorisation des déchets du bâtiment en France. Décembre 2019. 2. ADEME. Traitement des déchets - Emissions évitées. Documentation Base Carbone. https://www.bilans-ges.ademe.fr/documentation/UPLOAD_DOC_FR/index.htm?emissions_evitees.htm. 4. Farjana, S.H., Huda N., Mahmud, M.A.P. Impacts of aluminium production : A cradle to gate investigation using life-cycle assessment. Science of The Total Environment. 1 mai 2019, Vol. 663. 5. Hossain, M. U., Poon, C. S. Comparative LCA of wood waste management strategies generated from building construction activities. Journal of Cleaner Production. 10 mars 2018, Vol. 177.	FNADE, Deloitte, 2020, Le secteur des déchets et son rôle dans la lutte contre le Changement climatique ADEME, 2015, Le compostage, fiche technique. Ministère environnement allemand, 2015, Potentiel d'atténuation du changement climatique dans le secteur des déchets INRAE, Base Carbone, 4 pour 1000

Filière	Recyclage du papier/carton	Recyclage mécanique des plastiques	Recyclage chimique des plastiques	Recyclage des métaux (e.g. acier, cuivre, aluminium)	Recyclage du verre	Recyclage des déchets de construction	Compostage des déchets organiques
						6. Gilstad, G., Hammervold, J. Light Metal. Life Cycle Assessment of Secondary Aluminium Refining. 2014. 7. Bureau, J., Duval, M. Recyclage de l'aluminium. Centre d'expertise sur l'aluminium - aluQuébec. [En ligne] 7 décembre 2017. https://ceal-aluquebec.com/recyclage-aluminium/. 8. Carlisle, S, Friedlander,F. The influence of durability and recycling on life cycle impacts of window frame assemblies. The International Journal of Life Cycle Assessment. 6 avril 2016, Vol. 21. 9. Ye, L., Qi, C., Hong, J., Ma, X. Life cycle assessment of polyvinyl chloride production and its recyclability in China. Journal of Cleaner Production. 20 janvier 2017, Vol. 142, part. 4. 10. Commission, European. Final Report - Life Cycle Assessment (LCA) of PVC and of principal competing materials. juillet 2004. 11. Bernardo, C.A., Simoes, C.L., Costa Pinto, L.M. Environmental and economic life cycle analysis of plastic waste management options. A review. AIP Conference Proceedings. 2016, 1779.	

Filière	Recyclage du papier/carton	Recyclage mécanique des plastiques	Recyclage chimique des plastiques	Recyclage des métaux (e.g. acier, cuivre, aluminium)	Recyclage du verre	Recyclage des déchets de construction	Compostage des déchets organiques
						12. Stichnothe, H., Azapagic, A. Life cycle assessment of recycling PVC window frames. Resources, Conservation and Recycling. Février 2013, Vol. 71.	
Voulez-vous partager d'autres informations par rapport au calcul des émissions évitées pour cette filière ?	Intégrer le nombre de cycle de recyclage (circular carbon footprint formula)	Double fonction : déchets / produits... à statuer selon la situation, pour enjeu "site ou projet" ou corporate	Voir peut être le contenu de l'étude Record d'Octobre 2015				Prendre en compte le potentiel de stockage de carbone dans le bilan ou pas ?

Filière	Méthanisation des déchets organiques (avec cogénération ou injection directe de biogaz dans le réseau de gaz naturel)	Valorisation énergétique des déchets sous forme de combustibles solides	Incinération de déchets mixtes avec récupération d'énergie	Valorisation du biogaz des installations de stockage
Quelles sont les principales sources de déchets pour cette filière ?	Uniquement liés à l'activité humaine (à la différence de la méthanisation agricole et territoriale) : déchets des IAA, déchets de la restauration, déchets de GMS, biodéchets des ménages, déchets verts (tontes, non ligneux) Déchets ménagers (OM, biodéchets), déchets municipaux verts, boues	Tout type de déchets non dangereux solides, non constitués de biomasse uniquement, dont le pouvoir calorifique est suffisamment élevé pour présenter un intérêt en valorisation par combustion (composé de tout ou partie : pneus, plastiques, RBA, Papiers/carton, bois et déchets de bois (classe B), boues et STEP, textiles, déchets ménagers. Hors PVC car dégagement de dioxine Déchets non minéraux et non dangereux Refus de TMB avec ou sans BRS. Encombrants de déchèteries Refus de tri Collecte sélective d'emballage ménagers DIB hors fermentescible (notamment en France) DIB (modèle Allemagne)	Ordures ménagères et refus de tri OMR	Déchets organiques préalablement triés (ISDND) Déchets organiques enfouis

Filière		Méthanisation des déchets organiques (avec cogénération ou injection directe de biogaz dans le réseau de gaz naturel)	Valorisation énergétique des déchets sous forme de combustibles solides	Incinération de déchets mixtes avec récupération d'énergie	Valorisation du biogaz des installations de stockage
			TMB Déchets activités économiques refus de tri déchets bois		
Quels sont les produits secondaires fabriqués par cette filière de recyclage/valorisation (matériau, énergie...), quelle est leur utilisation principale, et quel matériau/source d'énergie est substitué ?	Produit secondaire (si plusieurs produits, indiquer (1), (2), (3), etc.)	Biométhane, bioGNV, H2 etc.	Energie / production de chaleur pour quelques industries et notamment les cimenteries. D'ailleurs demande de sécurisation économique via une reconnaissance de la chaleur CSR comme une chaleur de récupération partiellement renouvelable (100% EnR&R) CSR	(1) Mâchefers (2) Chaleur – électricité Electricité et chaleur (cogénération)	(1) Biogaz (CH4 (50 à 60%) et CO2 (40 à 45%) (2)Digestat / énergie (élec, chaleur, cogé)
	Utilisation principale de ce produit (si plusieurs produits, indiquer (1), (2), (3), etc.)	CO2 > enrichissement de serres, ou de culture d'algues, IAA (gazéification, refroidissement) et usage en chimie (bicarbonate et autres composés). Energie	Co-incinérateurs : Cimenterie, centrale énergétique, fours à chaux et fours à briques Equipement industriels de combustion (ou « centrales thermiques dédiées ») Incinérateurs d'OM Centrales industrielles	(1) Recyclage des métaux, techniques routières, remblais de mine de sels en Allemagne (2) Valorisation thermique : alimentation d'un réseau de chauffage urbain ou distribution à des entreprises et/ ou établissements publics. Autre valorisation possible : énergétique ou cogénération	(1) Biogaz > . Valorisation électrique : combustion pour la production d'électricité et de chaleur (par cogénération) . Valorisation thermique : Production de chaleur qui sera consommée à proximité du site de production (en combustion dans une chaudière). Injection dans le réseau de gaz naturel après épuration pour le débarrasser (le biogaz devient alors biométhane) . Production de carburant biologique après épuration sous forme de gaz naturel véhicule (GNV) appelé Bio GNV ou sous une forme liquéfiée appelé Bio GNL (2)Digestat > fertilisant agricoles (éléments organiques N, P et K se

Filière		Méthanisation des déchets organiques (avec cogénération ou injection directe de biogaz dans le réseau de gaz naturel)	Valorisation énergétique des déchets sous forme de combustibles solides	Incinération de déchets mixtes avec récupération d'énergie	Valorisation du biogaz des installations de stockage
					retrouvent sous une forme plus minérale)
	Matériaux/source d'énergie substitué par ce produit (si plusieurs produits, indiquer (1), (2), (3), etc.)	CH4 fossile, GNV, diesel etc.	Le CSR se substitue à l'énergie provenant du gaz naturel, du coke de pétrole et du charbon Gaz, fuel, lignite / ou enfouissement, incinération selon le point de vue	(2) Energies fossiles (par exemple, les fours à ciment, les usines de pâte à papier, les installations de gazéification pour la production d'électricité). Electricité réseau / chaleur produite à partir de gaz	(1) CO2 évitée par la substitution des énergies fossiles (2)Energie économisée par la substitution des engrais CH4 fossile / kwh FR / kwh de gaz
Quels paramètres limitent l'utilisation potentielle des matériaux recyclés/énergie valorisée ?		La qualité des intrants (dépendant en partie de la qualité du tri) Absence ou faiblesse de la coordination entre le secteur de l'énergie et le secteur agricole : différentes législations, différents ministères, différents objectifs Coût d'accès à la MO	Caractéristiques techniques, autrement dit obtention de qualité suffisantes pour les utilisateurs. Ex : en co-incinération privilégient les CSR issus de DIB > or cette qualité ne permet un taux de substitution de la chaleur produite par les fours que de 20% (moyenne de 35% de valorisation thermique des déchets). Ex : filtre à chlore et tuyères à hautes impulsion permettent d'augmenter ces taux de substitution jusqu'à 30 ou 60% Potentielle raréfaction du gisement (due à la prévention des déchets, l'évolution démographique et l'augmentation du recyclage) Subvention (ADEME) inaccessible pour les installations de cogénération Acceptabilité sociétale de ces projets/ relation avec le voisinage	Baisse de l'incinération	Coûts
Quels sont les procédés prédominants de traitement de ces déchets en France ? En Europe ? (Recyclage et des traitements alternatifs inclus)		Différentes unités : Unités centralisées (déchets de différentes origines liés au territoire d'implantation), * Unités industrielles (déchets de l'industrie agro-alimentaire, de la chimie ou de la papeterie), * Unités spécialisées dans le traitement des boues d'épuration des eaux usées, * Unités de méthanisation d'ordures ménagères (gérées par les collectivités ou des entreprises spécialisées). En plus de privilégier différents intrants ; différentes valorisations du biogaz	En France : TMB En Allemagne : TM à 66% (données 2018) (directement de DIB) Pays dont la production de CSR est développée (Allemagne, Italie, Autriche) : TMB principalement Pays dont la production de CSR est en développement (Irlande, Pays-Bas, Finlande, Norvège): en 2018, une 10zaine	Enfouissement et incinération	. Méthanisation « rurale » (installations qui utilisent ressources agricoles ou des sous-produits des IAA) : unité à la ferme ((inférieur à 10 000T d'intrants/an) ou installation collectives territoriales (entre 10 000 et 20 000T d'intrants /an) . Installation de Stockage

Filière	Méthanisation des déchets organiques (avec cogénération ou injection directe de biogaz dans le réseau de gaz naturel)	Valorisation énergétique des déchets sous forme de combustibles solides	Incinération de déchets mixtes avec récupération d'énergie	Valorisation du biogaz des installations de stockage
	en France et en Allemagne : Fr > injection du biométhane dans le réseau de biogaz All > biogaz pour produire de l'énergie renouvelables (en 2019, seules 200/ 11 000 unités allemandes injectaient le biométhane dans le réseau de biogaz) Enfouissement puis incinération	d'installation dont beaucoup de TMB produisant des CSR et plusieurs étaient en construction Espagne : 350Kt de CSR qualité DIB Europe : majoritairement des co-incinérateur (les plus exigeants en qualité) Enfouissement et incinération		de Déchets Non Dangereux (ISDND) . STEP : Station d'épuration des eaux usées (boues urbaines) Torchage en landfill ne rien faire le type de traitement alternatif = incineration / compostage methnaisation de la FFOM
Est-ce que les acteurs de cette filière de recyclage/valorisation sont réunis par une ou plusieurs associations au niveau français ou européen ? Si oui, lesquelles ?	AAMF, Club Biogaz ATEE, CTBM, CSF biogaz, atee monde agricole	FEDEREC, FNADE	FNADE, SVDU	CSF filiere metha atee fnade astee
Avez-vous connaissances de performances environnementales disponibles ou publiés pour ce filière de recyclage/valorisation? (Surtout les émissions GES)	. GRDF, ADEME, 2021, Biodéchets : du tri à la source jusqu'à la méthanisation Solagro, 2018, la méthanisation rurale, outil des transitions énergétiques et agroécologiques, Note de positionnement ADEME, Solagro, 2018, La méthanisation, levier de l'agroécologie, Synthèse des résultats du programme MéthaLAE Rose, S.K., Kriegler, E., Bibas, R. et al. Bioenergy in energy transformation and climate management. Climatic Change 123, 477–493 (2014). https://doi.org/10.1007/s10584-013-0965-3 Thrän, D., Schaubach, K., Majer, S. et al. Governance of sustainability in the German biogas sector—adaptive management of the Renewable Energy Act between agriculture and the energy sector. Energ Sustain Soc 10, 3 (2020). https://doi.org/10.1186/s13705-019-0227-y CTBM, 2020, Valorisation du CO2 de méthanisation étude inrae déc 2021, étude Quantis GRDF 2017 et 2020	ADEME/ FNADE 2010, Caractérisation des combustibles solides de récupération RECORD, 2018, Utilisation des CSR et RDF (CSR OM) en Europe FNADE et SN2E, 2015, Elaboration d'un modèle économique global de production et valorisation de CSR FEDEREC et Compte-R, 2015, Combustibles solide de récupération (CSR), Caractérisation et évaluation de leurs performances en combustion	FNADE, Deloitte, 2020, Le secteur des déchets et son rôle dans la lutte contre le Changement climatique Base Carbone, Prognos	Base Carbone, ADEME, FEDEREC, 2017, Evaluation environnementale du recyclage en France selon la méthodologie de l'ACV INERIS, 2006, Etude comparative des dangers et des risques liés au biogaz et au gaz naturel
Voulez-vous partager d'autres informations par rapport au calcul des émissions évitées pour cette filière ?	Attention à la prise en compte de la compétition des usages possibles ? Prendre en compte les digestats dans le périmètre	Tenir compte des composantes des CSR : teneur en chlore et en mercure (pondération afin de comptabiliser l'impact environnemental ?) Tenir compte des étapes nécessaires en amont. Ex pour le CSR issus du TMB, tenir compte du « cout énergétique » de l'étape de séchage, de séparation et de broyage nécessaires à sa valorisation	Nous pouvons regarder les sources d'émissions : ici à priori principalement due au CO2 fossile issu de la combustion de plastiques, textiles et autres déchet ménagers et assimilés (3) Prendre en compte les différentes	Nous pouvons prendre en compte la qualité des usines : Exemples : Cuves de stockage de digestat bien étanches et curage régulier afin de ne pas avoir d'émission de méthane (PRG 25 fois plus puissant que le gaz carbonique)

Filière	Méthanisation des déchets organiques (avec cogénération ou injection directe de biogaz dans le réseau de gaz naturel)	Valorisation énergétique des déchets sous forme de combustibles solides	Incinération de déchets mixtes avec récupération d'énergie	Valorisation du biogaz des installations de stockage
		Tenir compte des émanations des cheminées : HCl, HF, SOx, Hg, Cd, Tl, Cd & Tl. Un traitement est nécessaire (Directive Incinération) . Penser intérêt énergétique global du CSR : C° d'énergie lors de la préparation du CSR vs rendement d'utilisation v/v incinération directe (// hiérarchie traitement des déchets) prendre plusieurs types de CSR (avec des FE différents selon le taux de biogénique) prendre en compte l'aspect multifonctionnel ? (déchets et produits)	phases du procédé : combustion (dont séchage et extinction des résidus solides), récupération et valorisation de chaleur, traitement des fumées valo énergétique : les émissions évitées = émissions qui auraient été générées pour la même quantité de kwh produite par mix de référence?? ou doit-on intégrer les émissions de l'incinération aussi?! (cf. regarder les hypothèses dans le doc du CKIC)	Couverture des fosses de stockage afin de limiter les émissions de protoxydes d'azote (PRG N2O, 310 fois celui du gaz organique)

Annex 2 – Circular Footprint Formula

The Circular Footprint Formula (CFF) is an allocation method prescribed as part of a Product Environmental Footprint Assessment (PEF) (European Commission, 2018). The purpose of this annex is to clarify the potential links between the avoided emissions assessment guide and CFF. Differences are highlighted in Table 37.

Scope

The aim of the methodological guide to evaluate avoided emissions is to assess the avoided emissions generated by a waste recycling/recovery solution, taking a value chain perspective. This is in contrast to the PEF method, which aims to assess a product's environmental footprint at the product lifecycle level. This difference in the field of application leads to a different requirement for the modelling of multifunctional processes, such as the recycling/recovery process.

From a value chain perspective, there is no need to identify which (impacts of) processes belong to which product lifecycles. Therefore, the recycling/recovery process is modelled via "system expansion", which makes it possible to assess impacts and benefits along the entire value chain.

On the other hand, from a life-cycle perspective, it is necessary to determine which impacts related to the recycling/recovery process should be attributed to the life cycle that provides the waste or to the life cycle that uses the recycled material. The CFF is used for this purpose. The allocation factors used in the CFF are life-cycle oriented and therefore cannot be used to attribute avoided emissions to specific actors in the value chain.

Use of emission factors

Emission factors developed in accordance with the avoided emissions guide cannot be used as such in CFF or in a PEF study, as the factors are limited to GHG emissions, and a PEF study requires the assessment of additional impact categories. However, the raw data used for the calculation of emission factors, such as the establishment of market combinations for the reference scenario, can be reused in a PEF study. However, it should be verified whether the formulation of the evaluated solution and the establishment of the reference scenario are compatible with the requirements developed in the PEFCRs.

Table 37 Comparison of application between the guide to evaluate avoided emissions and the CFF (RECORD, 2022)

	Guide to evaluate avoided emissions	CFF
Application scope	Entire value chain	Product life cycle
Environmental impacts	Climate change	Multi-criteria

Annex 3 – Quantifying the functional unit including a quality correction factor

This annex complements Section 3.6.1., in which the quantification of the functional unit is explained. The example shown below is a more complex version of the example in the main text, due to the **inclusion of a quality-correction factor**.

The evaluated solution and the reference scenario are rendered comparable by means of system expansion. Via an iterative addition of processes, the functional outputs of the two systems are made equal. The iterative process of system expansion is applied as follows:

1. Quantify the implementation of the evaluated solution, from the perspective of the value-chain actor under study that evaluates its avoided emissions.
2. Quantify the additional functionality provided by the evaluated solution:
3. Establish the reference scenario, based on the following elements:
    - Consumption rate of recycled and primary materials without the implementation of the analysed solution, based on the market-average recycled content.
    - Consideration of the quality difference between recycled and primary material.
    - Consideration of the recycling efficiency in the market.
    - Consideration of the mix of end-of-life treatment technologies in the market.
4. Supplement the systems with additional processes to guarantee a similar functionality.

Example: application of system expansion to the implementation of the solution "use of recycled PET in the manufacturing of cars" (throughout this example, hypothetical values are used):

1. *The annual use of 3 kt of recycled PET in cars.*
2. *To produce 3 kt of recycled PET, a waste treatment service is provided for 3.5 kt of end-of-life plastic bottles. The initial representation of the analysed solution is presented in Figure 20.*

Figure 20 Initial representation of the analysed solution. The actor that evaluates the implemented solution is highlighted in green (RECORD, 2022)

3. *The subsequent considerations are illustrated in Figure 21. In this hypothetical example, the recycled content of PET in the European market is currently 7%. 93% of the PET supplied on the European market is from primary sources. A quality factor of 0.9 must be applied to recycled PET, compared with primary PET. To illustrate the application of this factor, we justify this factor by assuming that a piece of recycled material needs to be replaced, whereas this would not be necessary in the reference scenario. The weight of the car is not affected by the quality difference.*
In the reference scenario, the car manufacturer would use 2.72 kt of PET, of which 0.19 kt from recycling and 2.53 kt from primary sources (calculated by $2.72 = \frac{3}{0.07+\frac{0.93}{0.9}}$). The replaced part has a total weight of 0.28 kt. This results in an additional production of waste in the case of the implemented solution of 0.28 kt of PET. Instead of adding this additional waste treatment to the analysed solution, it is subtracted from the reference scenario (i.e. system reduction), which is justified by the assumption that the end-of-life treatment of this waste is the same as the end-of-life treatment of plastic bottles.

In this example, it is assumed that the same recycling efficiency is valid in the market as in the analysed solution: to produce 3 kt of recycled PET, 3.5 kt of plastic bottles are collected. It is assumed that, without implementation of the solution, 19% of end-of-life bottles are already collected for recycling.

Incorporating the recycling efficiency into the reference scenario shows that the producers of the waste and the recyclers do not only provide recycled PET to the actor that conducts the analysis, but also to other users of PET in the market.

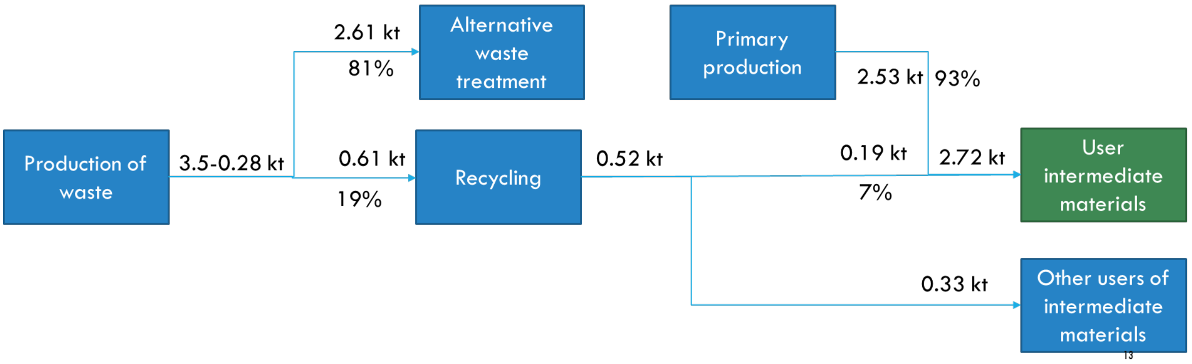

Figure 21 Representation of the reference scenario, considering the quality correction factor of recycled PET, the end-of-life recycling rate in the market, and the recycled content of PET in the market (RECORD, 2022)

4. *Comparing Figure 20 with Figure 21, it can be observed that the two systems do not yet provide the same functional output. In the reference scenario, other users of PET have access to recycled PET. System expansion is applied to compensate for this difference in the supply of PET. The production of primary PET is added to the analysed solution (Figure 22), after application of the quality correction factor of 0.9.*

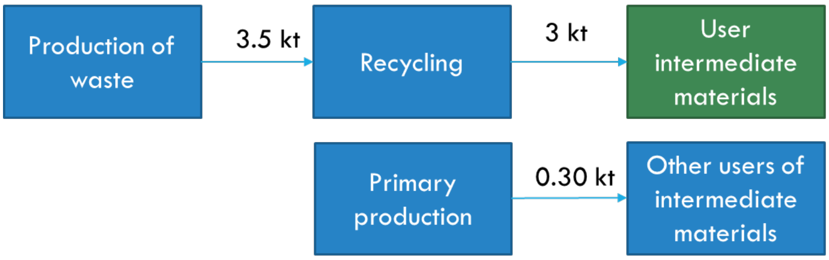

Figure 22 Analysed solution after the application of system expansion (RECORD, 2022)

Part of the increased consumption of recycled PET by the car manufacturer is hence produced by an increased valorisation of bottles at the end of life. However, the amount of available waste being limited, part of the recycled material is diverted from other users, that now use more primary material. These "other users" are former value-chain actors of the recycling system in the reference scenario, and therefore should be considered in the evaluation of the total avoided emissions generated by the implemented solution.

The final functionality of the two systems (the analysed solution and the reference scenario) is now equivalent and can be formulated as "the production of PET and the end-of-life treatment of plastic bottles to fulfil the annual demand for PET by a car manufacturer". The processes that provide these functionalities in the two systems are listed in Table 38.

Table 38 Processes included in the analysed solution and the reference scenario after system expansion (RECORD, 2022)

Process	*Analysed solution*	*Reference scenario*
Primary production of PET (kt)	*0.30*	*2.53*
Production of recycled PET (solution scenario*) (kt)	*3*	
Production of recycled PET (reference scenario*) (kt)		*0.52*
Alternative waste treatment (kt)		*2.61*

**Note that the recycling process considered in the solution may be different than the recycling process considered in the reference scenario*

These quantities are subsequently multiplied with the corresponding technology-specific emission factors to calculate the total emissions attributed to the analysed solution and the reference scenario, respectively.

SECOND PART

COMPARISON OF RECORD'S GUIDE WITH METHODOLOGIES FROM NZI (JUNE 2022 VERSION) AND WBCSD (JULY 2022 VERSION)

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V1.1

RESUME

En collaboration avec différents acteurs des secteurs du recyclage et de la valorisation des déchets, RECORD a mis au point une méthodologie de comptabilisation des émissions évitées spécifique à cette filière. Elle vient préciser les cadres méthodologiques existants, développés par la NZI et le WBCSD. Cette partie du document analyse les similitudes et les différences entre ces trois méthodologies.

MOTS CLES

AE : Emissions évitées
NZI: Net-Zero Initiative
WBCSD: World Business Council for Sustainable Development

SUMMARY

Along with several players from the recycling and waste valorization sector, RECORD developed a specific guide to accounting avoided GHG emissions. It is released after two existing methodologies from NZI and WBCSD. This part of the report analyses the similarities and differences between these three methodologies.

KEY WORDS

AE : Avoided emissions
NZI: Net-Zero Initiative
WBCSD: World Business Council for Sustainable Development

<u>**TABLE OF CONTENTS**</u>

Introduction

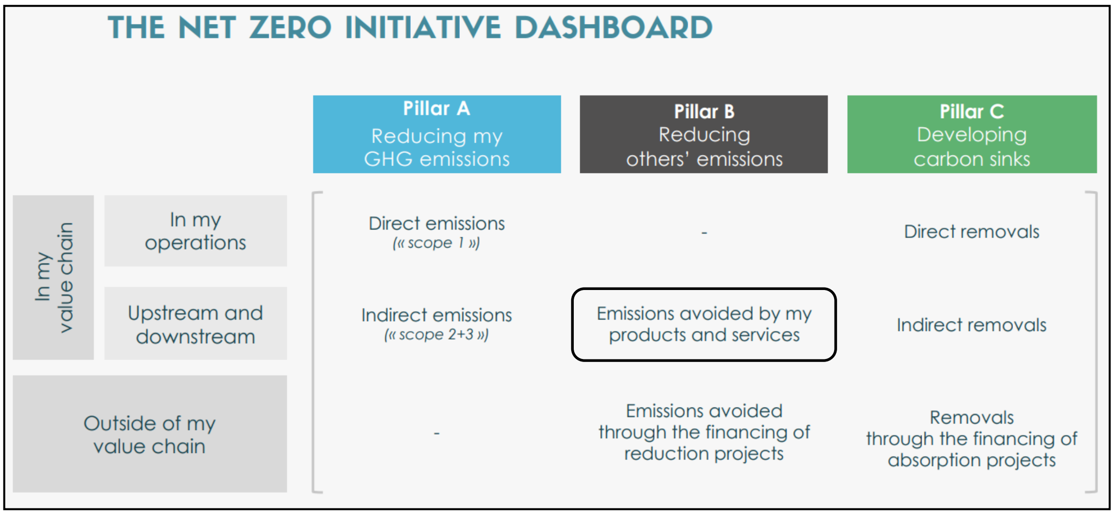
Developing new solutions that are less GHG-intensive than a reference scenario allows companies to avoid emissions, which is a powerful tool used to mitigate climate change. Companies can also leverage avoided emissions (AE) by claiming them publicly and stand out from competitors. To do so, avoided emissions must be comparable, and computation methodologies aligned. The current lack of consensus on methodological choices results in a lack of credibility and comparability of avoided emission claims (ADEME, 2020). This is why RECORD sought consensus among actors in the recycling and waste valorization sector to publish its GUIDE TO ACCOUNTING FOR AVOIDED GHG EMISSIONS IN WASTE RECOVERY AND RECYCLING.

The present document, redacted by EcoAct, compares the RECORD's guide with other existing methodologies from Net-Zero Initiative (NZI) and the World Business Council for Sustainable Development (WBCSD).

The Net Zero Initiative was launched in April 2020, presenting a methodology enabling companies to contribute to the global goal of reaching net zero emissions. It is broken down in three pillars:

A. Reduce the GHG emissions of the company
B. Reduce the GHG emissions of the company's ecosystem
C. Remove CO2 from the atmosphere

Avoided emissions fall into Pillar B. NZI's Pillar B is considered as the reference framework regarding AE computation and reporting. Although it contains a "toolkit" for the mobility, building and energy sectors, its guidelines remain quite generic.



THE NET ZERO INITIATIVE DASHBOARD

		Pillar A Reducing my GHG emissions	**Pillar B** Reducing others' emissions	**Pillar C** Developing carbon sinks
In my value chain	In my operations	Direct emissions *(« scope 1 »)*	-	Direct removals
	Upstream and downstream	Indirect emissions *(« scope 2+3 »)*	Emissions avoided by my products and services	Indirect removals
Outside of my value chain		-	Emissions avoided through the financing of reduction projects	Removals through the financing of absorption projects

The World Business Council for Sustainable Development (WBCSD) is also developing its own "Guidance on assessing GHG benefits of solutions contributing to global Net Zero efforts".

The specific context of the recycling and waste treatment sectors make it challenging for companies to compute their avoided emissions. To provide them with industry-specific guidance and ensure comparability among them, RECORD published a dedicated "Guide to accounting for avoided GHG emissions in waste recovery and recycling".

The objective of this paper is to highlight what the RECORD's Guide brings to the NZI (June 2022 version) and WBCSD (July 2022 version)[1]. Their common structure will enable us to go through their respective methodologies and pinpoint for every step what industry-specific information/guidance the RECORD Guide adds.

- ➢ See Annex 1 for the comparison recap (table format) and their references in the reports (page numbers).
- ➢ See Annex 2 for the list of tables and figures available in the RECORD Guide.

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[1] In case of changes in these methodologies, the present document would need to be updated

1. Purpose and approach

The NZI and WBCSD clearly explain the importance of AE. The NZI places avoided emissions into the net zero goal context, by explaining the net zero initiative methodology. It also delivers macro insights regarding the formulation of a “Pillar B strategy”

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Precisions brought by the RECORD Guide

- It precises why performing an AE assessment is **relevant for the waste recovery and recycling sectors**.
- The Guide can also help the reader set the **goal of the study** based on the **target audience**, using industry-specific examples.
- While the NZI and WBCSD mention the necessity to include emissions from the whole life cycle into the AE computation, neither of them recommends a particular lifecycle analysis (LCA) approach. But RECORD specifies that an attributional LCA is more adapted to the waste treatment and recycling sector, rather than a consequential one. It is a key recommendation because the **LCA approach** determines the reference scenario, the scope of assessed GHG emissions, and the modelling of the multifunctional processes.

Example of RECORD’s guidance for the choice of the LCA approach (extract from the guide):

- “**Example of an A-LCA** analysis from the recycler's perspective: The GHG emissions from the PET recycling process are lower than the sum of the emissions from the PET incineration and primary PET production process. The difference can be considered "avoided emissions".
- **Example of a C-LCA** analysis from the perspective of a car manufacturer: The increased use of recycled PET in vehicles can lead to an increase in the recycling of PET bottles and can avoid other end-of-life treatment processes, such as incineration. In this case, the substituted emissions from incineration can be considered "avoided emissions". However, it is possible that the increased use of recycled PET in vehicles will not lead to an increase in bottle recycling, for example if all economically recyclable bottles are already recovered elsewhere. Instead, other sectors will use less recycled PET and instead use an alternative material (e.g., primary PET). In this case, the avoided emissions may not be observed and the use of recycled PET in cars will result in the same GHG emissions as the use of primary PET in cars

In this methodological guide, **it has been chosen to use an attributional approach to quantify the avoided emissions**. This makes it possible to assess avoided emissions using the same methodology as direct and indirect emissions related to the recycling process, whether they are assessed in the context of an EPD or for corporate carbon footprint reporting – which also follow an attributional approach. This allows for a transparent assessment of GHG emissions (due to the recycling process) and GHGs being reduced (i.e. GHG emissions that would occur in the event of non-implementation of the recycling process). The **limitation** of an attributional approach is that only the reduced GHG footprint of a predefined value chain is assessed and potential increases in GHG emissions in other value chains of the global economy are excluded from the analysis.”[2]

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[2] Page 60

2. Assessed solution and reference scenario

The NZI provides a list of optional eligibility criteria for a given solution to be assessed. Indeed, it allows a company to focus on the most relevant and impactful solutions that would avoid the most emissions. It prevents waste of time, so that companies don't complete the assessment for all their solutions.

As for the WBCSD, it considers three mandatory eligibility criteria that must be met so a company can claim AE. For example, the solution must be "1.5°C consistent", meaning it can't be applied to activities involving exploration, extraction, mining and / or production, distribution and sales of oil, natural gas, coal as well as other fossil fuels.

Once the solution is selected, additional guidance is provided regarding temporality and whether to compute AE annually or for the whole solution's lifecycle, to better reflect reality and align with GHG emissions reporting. Indeed, the WBCSD prescribes a forward-looking approach for sold products, and a year-on-year one for leased products and services.

Precise guidelines by the NZI and WBCSD, illustrated by examples and decision trees, explain how to adequately select the reference scenario. They also indicate the role of the regulation in the reference scenario selection process (existing or new demand).

Precisions brought by the RECORD Guide

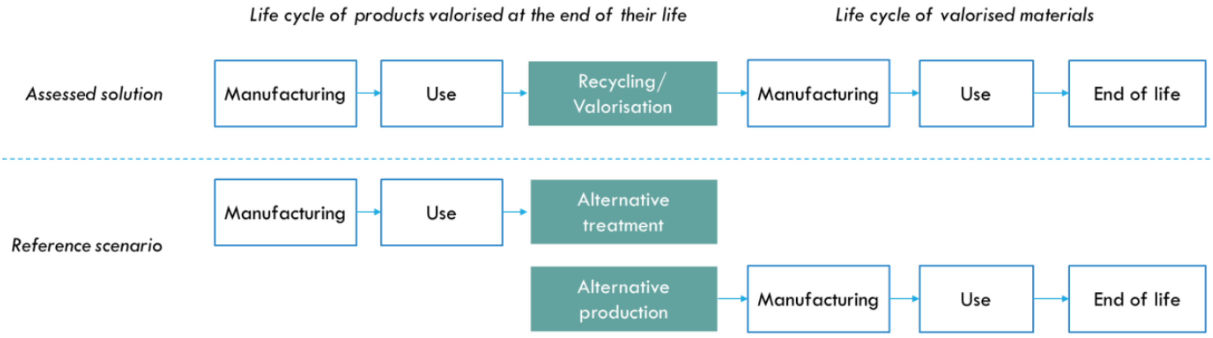
- To enhance AE's credibility and comparability among companies, RECORD proposes a list of **description requirements** to better formulate the assessed solution. It is adapted to energy recovery and the production of secondary materials.

- Recycling processes have several inputs/outputs, which makes them multi-functional. An allocation procedure explains which **multifunctional model** choose (system expansion, system reduction, substitution).

- Guidance to set the **system boundaries** (the processes and life cycle stages to include in the AE analysis), the temporality and the **functional unit** are provided, along with industry-specific examples. They ensure comparability between the assessed solution and the reference scenario.

- A list of both conceptual and applied alternatives to choose the most suitable **reference scenario** is provided in the report.

<u>Example of RECORD's guidance to help set system boundaries</u> (extract from the guide):



"In principle, all stages of the life cycle of waste treated by recycling/recovery processes and the life cycle of recovered materials/energy are considered. However, **steps that show identical emissions** between the evaluated solution and the reference scenario **can be omitted** from the analysis."[3]

"Processes for which data are not available may be excluded from the analysis if their contribution is estimated to be negligible according to the cut-off criteria. The **cut-off criteria**, taken from EN-15804 (CEN, 2012), are 1% of the consumption of renewable and non-renewable primary energy and 1% of the total mass input of a unit process. Total neglected input flows must be a maximum of 5% of mass and energy consumption. […] At a minimum, the boundaries of the system should include the collection, preparation and recycling of recovered end-of-life products. The **point of substitution** – i.e. the point in the production chain where recycled material can substitute virgin material – must be defined. Diagrams should be included to clarify the inclusion (and exclusion) of processes within the boundaries of the systems studied. Any exclusion from a process must be mentioned and justified."[4]

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3. Data

While the NZI highlights three different data-precision levels, according to their granularity and availability, it gives little to no guidance on how to deal with uncertainties.
The WBCSD lists the different acceptable data sources for the calculation of avoided emissions, which is illustrated by examples.

Precisions brought by the RECORD Guide

- To enhance the transparency and robustness of the study, RECORD indicates a list of both data **quality requirements**, and **quality assessment strategies**.
- The Guide also contains data already computed by RECORD, such as key emission factors and their associated **uncertainty levels**. They should be used to standardize the computation of the reference scenario emissions. Uncertainties (whether linked to the data source of the emission factor) are key indicators since they may impact AE claims' validity, notably in the case of overlapping ranges.
- The **data sources** are communicated for transparency purposes and will enable the reader to verify and/or modify these calculations, if necessary.
- There is also a focus on the quality of recovered materials, which generally have a lower quality (lifetime, recyclability) than primary ones. A specific **dataset of quality factors** for the recycling industry is provided.

Example of RECORD's guidance to enhance data representativeness by applying quality factors (extract from the guide):

"In the example of the production of recycled PET for use in the manufacture of cars, the difference in quality of recycled PET compared to primary PET should be described. In this case, it is possible that the recycled plastic has only a dark color, which limits the applicability of recycled PET only to certain parts of the vehicle. However, if a substitution rate of 1:1 can be achieved for these applications and no additional effects occur throughout the subsequent life cycle, no quality correction factors should be applied.
If […] other limiting aspects of quality are present, which would require, for example, the replacement of a part during the life of the vehicle, **substitutability […] should be reduced through a quality correction factor**."[5]

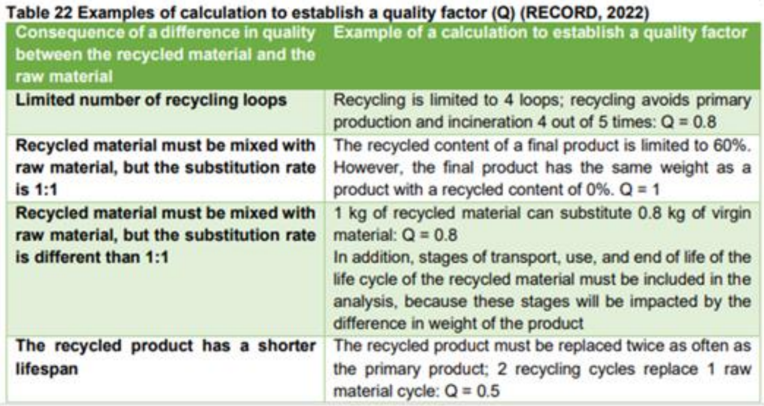

Table 22 Examples of calculation to establish a quality factor (Q) (RECORD, 2022)

Consequence of a difference in quality between the recycled material and the raw material	Example of a calculation to establish a quality factor
Limited number of recycling loops	Recycling is limited to 4 loops; recycling avoids primary production and incineration 4 out of 5 times: Q = 0.8
Recycled material must be mixed with raw material, but the substitution rate is 1:1	The recycled content of a final product is limited to 60%. However, the final product has the same weight as a product with a recycled content of 0%. Q = 1
Recycled material must be mixed with raw material, but the substitution rate is different than 1:1	1 kg of recycled material can substitute 0.8 kg of virgin material: Q = 0.8 In addition, stages of transport, use, and end of life of the life cycle of the recycled material must be included in the analysis, because these stages will be impacted by the difference in weight of the product
The recycled product has a shorter lifespan	The recycled product must be replaced twice as often as the primary product; 2 recycling cycles replace 1 raw material cycle: Q = 0.5

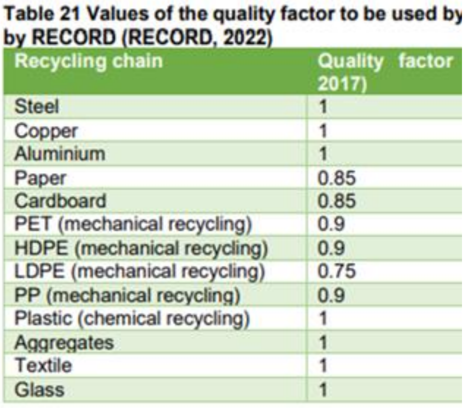

Table 21 Values of the quality factor to be used by by RECORD (RECORD, 2022)

Recycling chain	Quality factor 2017)
Steel	1
Copper	1
Aluminium	1
Paper	0.85
Cardboard	0.85
PET (mechanical recycling)	0.9
HDPE (mechanical recycling)	0.9
LDPE (mechanical recycling)	0.75
PP (mechanical recycling)	0.9
Plastic (chemical recycling)	1
Aggregates	1
Textile	1
Glass	1

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4. Avoided emissions assessment

Both the NZI and WBCSD clearly explain the formulas required to compute avoided emissions. Since emissions can be avoided over a long period of time, they also precise how to compute them over time, and how internal or external factors (performance loss, future decarbonization of the electric mix) can impact them. The AE aggregation at company level is also covered but doesn’t mention uncertainties.

Several companies can play a different role in avoiding the same emissions (ex: different players along the same value chain). It is the case for intermediary solutions, which, according to the NZI, must respect an AE allocation rule that advocates for consistency between Pillars A & B. This methodology also allows for AE additionality and double claiming: different actors along the same value chain can claim the same AE.

WBCSD states that AE should be allocated to the company within the value chain that is responsible for the decarbonization effect of the considered solution.

Precisions brought by the RECORD Guide

- Regarding computation of AE over time, the RECORD Guide provides an additional list of **time-sensitive effects** on the emissions and considers different **scenario evolutions** over time.

- It also **opposes the NZI’s allocation rule** by recommending not to allocate AE to individual actors. It rather advises each company to communicate about the contribution of the cumulative AE along the value chain, in the case of intermediary solutions. **It also differs from the WBCSD’s guidelines** as it allows all companies within the value chain to claim AE, although they didn’t enable the decarbonization effect.

  NB: RECORD’s guidelines regarding allocation apply to both recycling and energy recovery.

- The Guide also precises the NZI methodology by clearly explaining how to include **uncertainty** into the AE calculation, while providing industry-specific examples.

- It also contains guidelines on how to **aggregate AE at company level**, while including uncertainty.

Example of RECORD’s guidance for applying AE allocation rules (extract from the guide):

“The **dependence of the success of the recycling/recovery sector on the involvement of all actors** in the value chain is shown in Figure 6.

Therefore, the proper functioning of a recycling value chain requires the contribution and significant efforts of multiple actors, which could be overlooked via an allocation of avoided emissions to specific actors in the value chain. Thus, **this guide does not recommend attributing avoided emissions to individual actors**. Instead, each actor can communicate that "our participation in the recycling/recovery sector contributes to a cumulative reduction in the GHG emissions of the actors involved of X tonne of CO2 equivalent per year".”[6]

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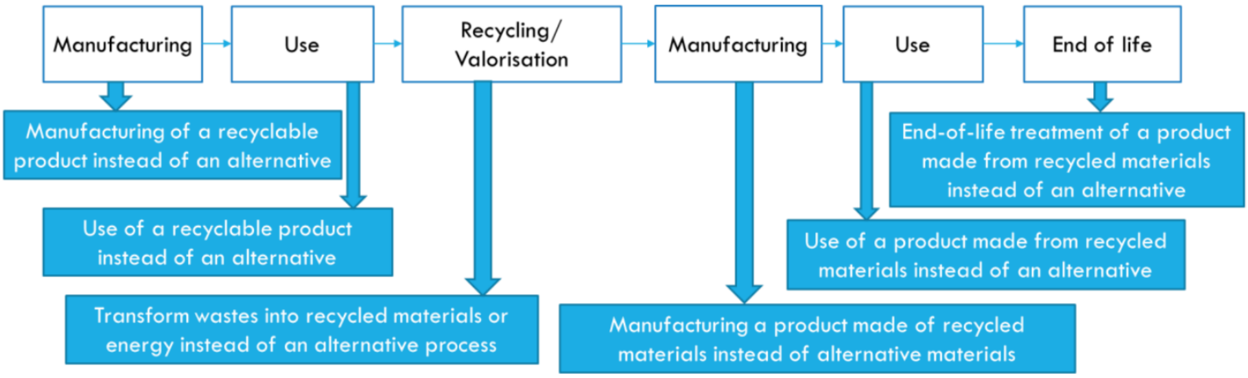


Figure 6 Presentation of the point of view of each actor in the value chain who could thus assess the avoided emissions it induces. The definition of the "alternative" scenario is specified in Step 3 (RECORD, 2022)

5. Communication

The NZI and WBCSD guides provide the general reporting rules and list the main indicators to disclose, as well as the dos & don'ts of AE claims' communication, by quoting examples of good and bad practices. It allows to avoid misunderstandings with the audience, while ensuring compliance.

They also have a focus on AE classification, explaining how to disclose the share of AE linked to emission reduction (EE_R in French, AE_R in English), and "lesser-increase" (EE_{MA} in French, AE_{LI} in English).

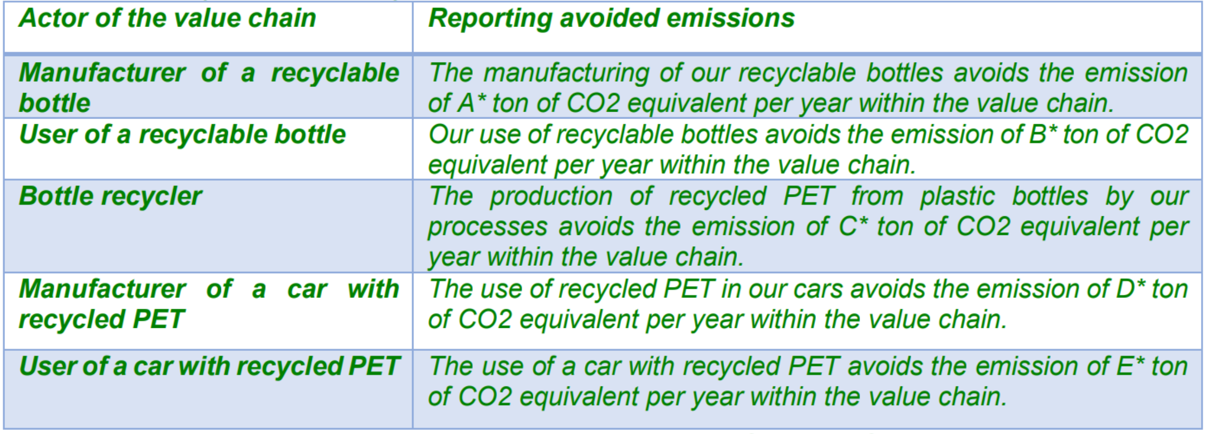
Precisions brought by the RECORD Guide

- It enhances the AE claims' communication dos & don'ts part, by providing industry-specific examples, as well as best practices including **additional information to provide along with the claims**, claim differences according to the methodology used and the place of the company within the value chain.
- There is a specific guidance, with examples, on how to **adapt the AE communication materials according to the audience**, whether they are LCA experts, non-experts or if the AE are communicated for corporate reporting.
- A specific guidance regarding the robustness of the results and the allowed associated claims is presented. It clearly explains what AE can be claimed in case of **overlapping uncertainty ranges** between the assessed solution and the reference scenario. This guideline applies to all uncertainties (of the data and the emission factor). As a result, data quality can be managed and monitored by measuring uncertainty.

Example of RECORD's guidance for different AE claims according to the place in the recycling value chain (extract from the guide):

"The use of recycled PET instead of market-average PET in the manufacturing of cars results in avoided GHG emissions attributed to the entire value chain, which includes consumers of plastic bottles as well as potential buyers of the company's cars.
The car manufacturer could report avoided GHG emissions as follows: "Our participation in the plastics recycling chain translates into a total of X tons of avoided GHG emissions attributed to the value chain". Other examples of communication phrases for all actors in the value chain are presented in Table 26."[7]

Table 26 Examples of reporting on avoided emissions from the perspective of different actors in the value chain (RECORD, 2022)



Actor of the value chain	*Reporting avoided emissions*
Manufacturer of a recyclable bottle	*The manufacturing of our recyclable bottles avoids the emission of A* ton of CO2 equivalent per year within the value chain.*
User of a recyclable bottle	*Our use of recyclable bottles avoids the emission of B* ton of CO2 equivalent per year within the value chain.*
Bottle recycler	*The production of recycled PET from plastic bottles by our processes avoids the emission of C* ton of CO2 equivalent per year within the value chain.*
Manufacturer of a car with recycled PET	*The use of recycled PET in our cars avoids the emission of D* ton of CO2 equivalent per year within the value chain.*
User of a car with recycled PET	*The use of a car with recycled PET avoids the emission of E* ton of CO2 equivalent per year within the value chain.*

**The quantity is relative to the annual production/consumption of the specific actor*

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6. Sector-specific information

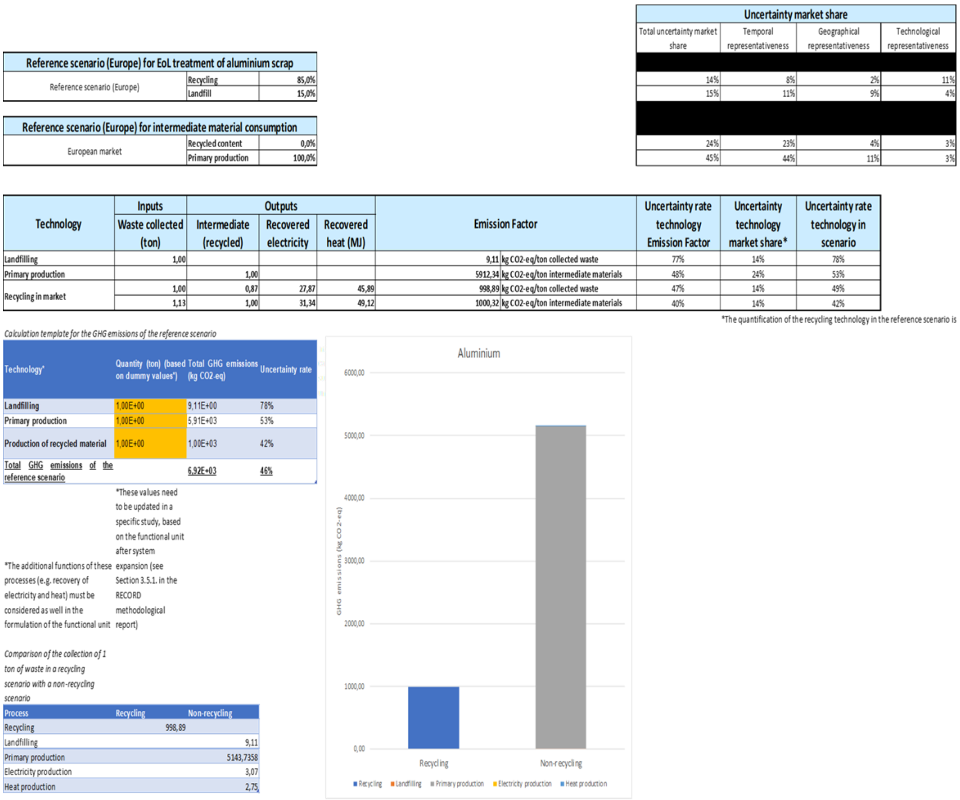
The NZI Guide offers a general methodology supposedly applicable to all sectors. To facilitate AE assessment by companies, it includes in the document guidelines related to specific solutions likely to generate AE, for three sectors: mobility, building and energy.

The WBCSD is built upon several existing methodological frameworks, including sectoral guidance from the chemical and recycling industries. However, the WBCSD guide doesn't provide sector-specific information, except for a few examples.

Precisions brought by the RECORD Guide

- **State of the art** summary regarding AE, comparing and synthetizing methodologies, while explaining how they apply to the waste treatment and recycling sector.
- **Methodological guide** for the evaluation and communication of avoided emissions, which contains detailed examples and use cases for the waste treatment and recycling industry
- **Industry-specific emission factors** (and validity period), providing key data for the reference scenario emissions' calculation process.
- Datasets, lists, classifications, processes, and **methodologies applicable to the waste treatment and recycling sector**.

Example of reference emission factors for the recycling sector, provided by RECORD (extract from the guide):
"As an annex to this report, Reference Emission Factors (REFs) (emission factors that can be used in a reference scenario) are developed that can be used in the evaluation of avoided emissions within the value chains listed."[8]



Reference scenario (Europe) for EoL treatment of aluminium scrap		
Reference scenario (Europe)	Recycling	85,0%
	Landfill	15,0%

Reference scenario (Europe) for intermediate material consumption		
European market	Recycled content	0,0%
	Primary production	100,0%

Uncertainty market share			
Total uncertainty market share	Temporal representativeness	Geographical representativeness	Technological representativeness
[redacted]	[redacted]	[redacted]	[redacted]
14%	8%	2%	11%
15%	11%	9%	4%
[redacted]	[redacted]	[redacted]	[redacted]
24%	23%	4%	3%
45%	44%	11%	3%

Technology	Inputs	Outputs			Emission Factor		Uncertainty rate technology Emission Factor	Uncertainty technology market share*	Uncertainty rate technology in scenario
	Waste collected (ton)	Intermediate (recycled)	Recovered electricity	Recovered heat (MJ)					
Landfilling	1,00				9,11	kg CO2-eq/ton collected waste	77%	14%	78%
Primary production		1,00			5912,34	kg CO2-eq/ton intermediate materials	48%	24%	53%
Recycling in market	1,00	0,87	27,87	45,89	998,89	kg CO2-eq/ton collected waste	47%	14%	49%
	1,13	1,00	31,34	49,12	1000,32	kg CO2-eq/ton intermediate materials	40%	14%	42%

*The quantification of the recycling technology in the reference scenario is

Calculation template for the GHG emissions of the reference scenario

Technology*	Quantity (ton) (based on dummy values*)	Total GHG emissions (kg CO2-eq)	Uncertainty rate
Landfilling	1,00E+00	9,11E+00	78%
Primary production	1,00E+00	5,91E+03	53%
Production of recycled material	1,00E+00	1,00E+03	42%
Total GHG emissions of the reference scenario		6,92E+03	46%

*The additional functions of these processes (e.g. recovery of electricity and heat) must be considered as well in the formulation of the functional unit

*These values need to be updated in a specific study, based on the functional unit after system expansion (see Section 3.5.1. in the RECORD methodological report)

Comparison of the collection of 1 ton of waste in a recycling scenario with a non-recycling scenario

Process	Recycling	Non-recycling
Recycling	998,89	
Landfilling		9,11
Primary production		5143,7358
Electricity production		3,07
Heat production		2,75

Extract from the aluminum emission factors provided in the Excel files (modified data, non-representative)

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Conclusion

RECORD's "*Guide to accounting for avoided GHG emissions in waste recovery and recycling*" is basically a sector-specific approach for computing AE. Based on already existing reference methodologies, it is a deep dive into the waste treatment and recycling industry, applied to AE.

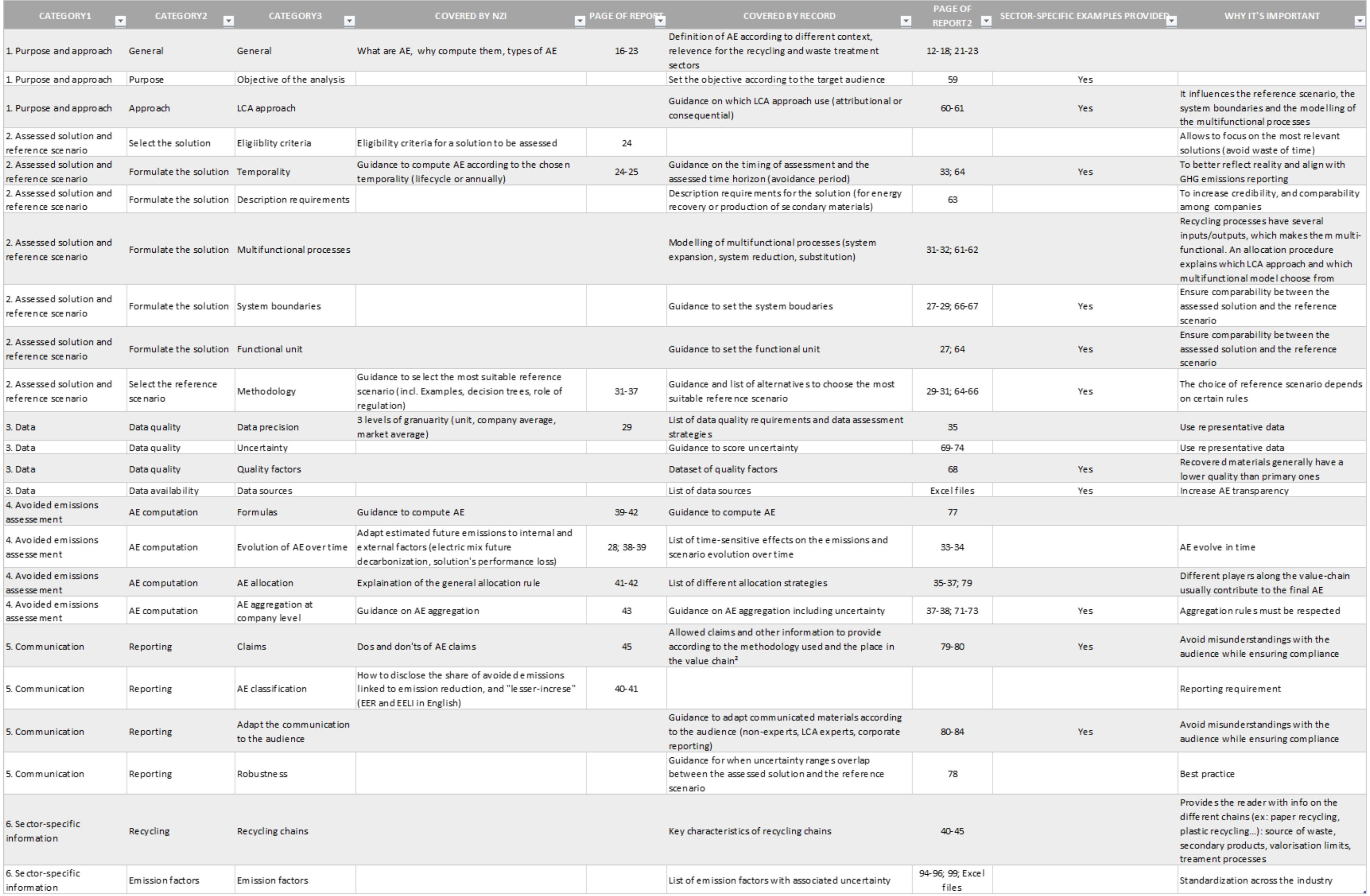
The Guide paves the way for aligning AE and reporting practices among all the actors of the value chain, which is fundamental to ensure comparability, and initiate coordinated GHG emissions reduction actions.

This edition is the first step of an ongoing process aiming to further precise the AE methodology in the waste treatment and recycling sector, and future improvements are expected.

Other sectors of the economy should inspire from RECORD's work to come up with dedicated guidelines applicable to their respective industries.

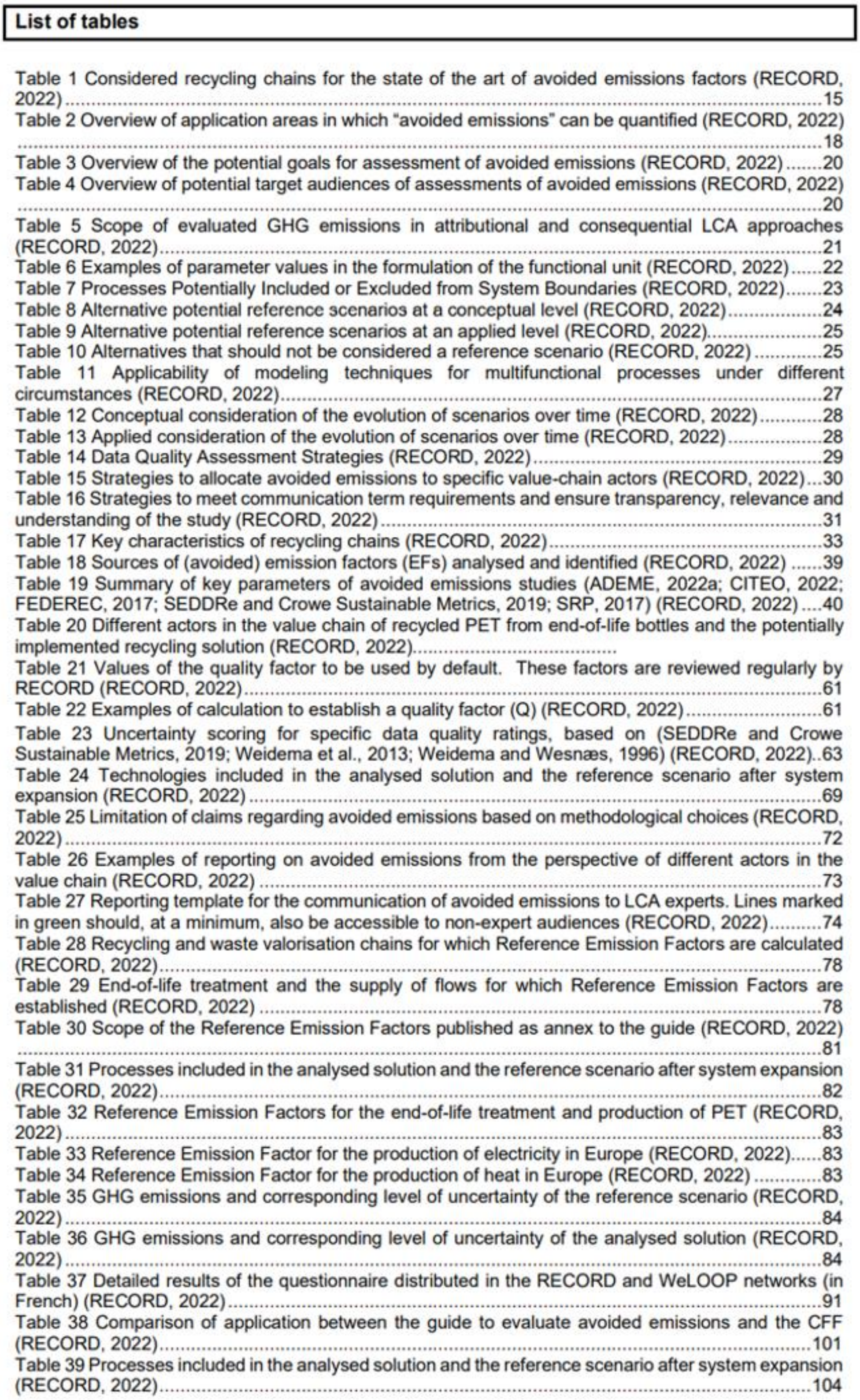
Annex

Annex 1: Comparison of the NZI methodology report with the RECORD Guide (ECOACT, 2022).



CATEGORY1	CATEGORY2	CATEGORY3	COVERED BY NZI	PAGE OF REPORT	COVERED BY RECORD	PAGE OF REPORT2	SECTOR-SPECIFIC EXAMPLES PROVIDED	WHY IT'S IMPORTANT
1. Purpose and approach	General	General	What are AE, why compute them, types of AE	16-23	Definition of AE according to different context, relevence for the recycling and waste treatment sectors	12-18; 21-23		
1. Purpose and approach	Purpose	Objective of the analysis			Set the objective according to the target audience	59	Yes	
1. Purpose and approach	Approach	LCA approach			Guidance on which LCA approach use (attributional or consequential)	60-61	Yes	It influences the reference scenario, the system boundaries and the modelling of the multifunctional processes
2. Assessed solution and reference scenario	Select the solution	Eligiiblity criteria	Eligibility criteria for a solution to be assessed	24				Allows to focus on the most relevant solutions (avoid waste of time)
2. Assessed solution and reference scenario	Formulate the solution	Temporality	Guidance to compute AE according to the chosen temporality (lifecycle or annually)	24-25	Guidance on the timing of assessment and the assessed time horizon (avoidance period)	33; 64	Yes	To better reflect reality and align with GHG emissions reporting
2. Assessed solution and reference scenario	Formulate the solution	Description requirements			Description requirements for the solution (for energy recovery or production of secondary materials)	63		To increase credibility, and comparability among companies
2. Assessed solution and reference scenario	Formulate the solution	Multifunctional processes			Modelling of multifunctional processes (system expansion, system reduction, substitution)	31-32; 61-62		Recycling processes have several inputs/outputs, which makes them multi-functional. An allocation procedure explains which LCA approach and which multifunctional model choose from
2. Assessed solution and reference scenario	Formulate the solution	System boundaries			Guidance to set the system boudaries	27-29; 66-67	Yes	Ensure comparability between the assessed solution and the reference scenario
2. Assessed solution and reference scenario	Formulate the solution	Functional unit			Guidance to set the functional unit	27; 64	Yes	Ensure comparability between the assessed solution and the reference scenario
2. Assessed solution and reference scenario	Select the reference scenario	Methodology	Guidance to select the most suitable reference scenario (incl. Examples, decision trees, role of regulation)	31-37	Guidance and list of alternatives to choose the most suitable reference scenario	29-31; 64-66	Yes	The choice of reference scenario depends on certain rules
3. Data	Data quality	Data precision	3 levels of granuarity (unit, company average, market average)	29	List of data quality requirements and data assessment strategies	35		Use representative data
3. Data	Data quality	Uncertainty			Guidance to score uncertainty	69-74		Use representative data
3. Data	Data quality	Quality factors			Dataset of quality factors	68	Yes	Recovered materials generally have a lower quality than primary ones
3. Data	Data availability	Data sources			List of data sources	Excel files	Yes	Increase AE transparency
4. Avoided emissions assessement	AE computation	Formulas	Guidance to compute AE	39-42	Guidance to compute AE	77		
4. Avoided emissions assessement	AE computation	Evolution of AE over time	Adapt estimated future emissions to internal and external factors (electric mix future decarbonization, solution's performance loss)	28; 38-39	List of time-sensitive effects on the emissions and scenario evolution over time	33-34		AE evolve in time
4. Avoided emissions assessement	AE computation	AE allocation	Explaination of the general allocation rule	41-42	List of different allocation strategies	35-37; 79		Different players along the value-chain usually contribute to the final AE
4. Avoided emissions assessement	AE computation	AE aggregation at company level	Guidance on AE aggregation	43	Guidance on AE aggregation including uncertainty	37-38; 71-73	Yes	Aggregation rules must be respected
5. Communication	Reporting	Claims	Dos and don'ts of AE claims	45	Allowed claims and other information to provide according to the methodology used and the place in the value chain[2]	79-80	Yes	Avoid misunderstandings with the audience while ensuring compliance
5. Communication	Reporting	AE classification	How to disclose the share of avoided emissions linked to emission reduction, and "lesser-increse" (EER and EELI in English)	40-41				Reporting requirement
5. Communication	Reporting	Adapt the communication to the audience			Guidance to adapt communicated materials according to the audience (non-experts, LCA experts, corporate reporting)	80-84	Yes	Avoid misunderstandings with the audience while ensuring compliance
5. Communication	Reporting	Robustness			Guidance for when uncertainty ranges overlap between the assessed solution and the reference scenario	78		Best practice
6. Sector-specific information	Recycling	Recycling chains			Key characteristics of recycling chains	40-45		Provides the reader with info on the different chains (ex: paper recycling, plastic recycling…): source of waste, secondary products, valorisation limits, treament processes
6. Sector-specific information	Emission factors	Emission factors			List of emission factors with associated uncertainty	94-96; 99; Excel files		Standardization across the industry

Annex 2: List of tables and figures available in the RECORD Guide (RECORD, 2022)



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