GreenDelta

Whitepaper

Module D in Environmental Product Declarations (EPDs)

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Interface

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Content

Executive Summary

This whitepaper addresses the complexities of modeling Module D in Environmental Product Declarations (EPDs), particularly in the context of the EN 15804+A2 standard. Module D, which aims to account for net credits and environmental impacts from recyclable materials and energy recovery at the end of a product's life cycle, presents several challenges for modeling in the context of EPDs.

Key challenges include the variability in recycling processes, geographical discrepancies in material recovery, and the difficulty of obtaining reliable datasets. These challenges can lead to substantial differences in the reported environmental benefits and burdens, especially in cases where assumptions are required. Additionally, Module D can be a potential trap for greenwashing. It is relatively easy to claim that a significant portion of a given product is recycled when, in reality, it may end up in landfills. Moreover, the D stage is based on probable scenarios and not site-specific as A1-A3.

These challenges explain why EPD programme operators support the reporting of each life cycle module separately, and to not report EPDs with a single value.

Aim of this whitepaper is to provide guidance for practitioners on an adequate modeling of module D, in line with the EN15804+A2 standard.

A comparative analysis of existing EPDs for products like steel pipes, hot-rolled steel bars, and ready-mix concrete highlights the variability in Module D results compared to other life cycle stages (Modules A1-A3). In conclusion, while the principle of Module D is straightforward, accounting for the net environmental impacts of recycling and reuse—the complexities of implementation require careful attention to avoid inconsistencies and potential misrepresentation of environmental performance

1 Introduction

Environmental Product Declarations (EPDs), as regulated in ISO 14025[1] and EN 15804[2], are summaries of life cycle assessment (LCA) results. These LCAs need to follow product-group specific category rules (PCRs); published EPDs are verified by an independent verifier that is accredited by an EPD program operator. The idea is to align LCA models for EPDs for products in the same product group, and to ensure quality of published EPDs.

LCA models assess a life cycle from production to use to disposal. EN 15804 has a very detailed "segmentation" of the life cycle, where the stages are split into smaller parts (see Figure 1).

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[1] ISO. (2006). ISO 14025:2006 - Environmental labels and declarations — Type III environmental declarations — Principles and procedures. International Organization for Standardization. https://www.iso.org/standard/38131.html

[2] EN 15804:2012+A2:2019 + AC:2021 - Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products

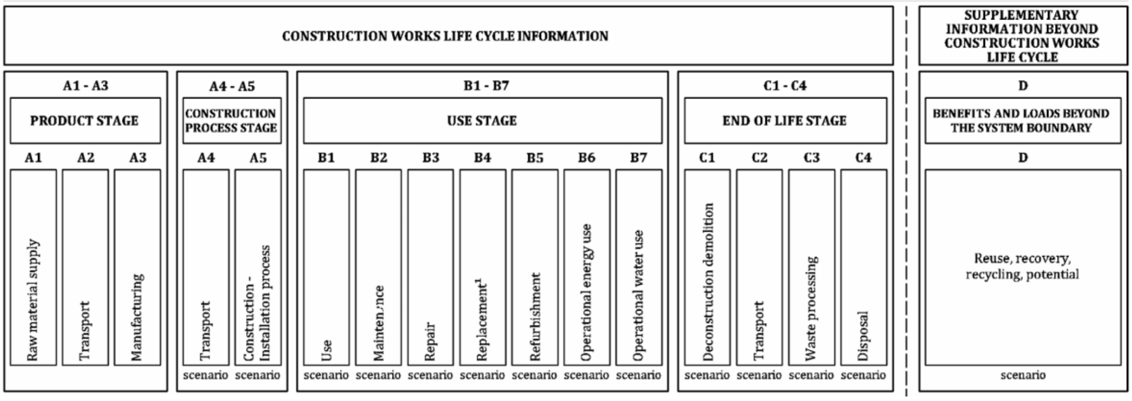

Figure 1 EN15804+A2 System boundaries, screenshot from the standard EN 15804:2012+A2:2021

Quite often, life cycles receive inputs from previous life cycles in the form of energy (such as heat from waste incineration) or materials (such as scrap) and produce outputs that are used in subsequent life cycles (including scrap or energy). For simplicity, we will refer to both types of inputs and outputs as “recyclates” in the following discussion. In EPDs according to EN 15804, the output of valuable materials or energy to subsequent life cycles—i.e., these recyclates—is addressed in Module D. Essentially, a system expansion modeling approach is applied in the life cycle, and net credits from this system expansion are allocated to Module D. Due to these credits, Module D has negative amounts for impacts that could seem to reduce the overall impacts reported for the EPD. Module D is here not part of the real life cycle, but an abstract term for collecting net credits from previous and coming life cycles as seen in Figure 2. In other words, the life cycle in reality, for the investigated product, consists of stages A1 to C, while the life cycle model, including credits, includes, according to the standard, the life cycle of the product plus module D. This distinguishes Module D from all other modules in the EPD life cycle and raises questions about the correct modeling of this module. The aim of this text is to provide guidance on modeling Module D in accordance with EN 15804+A2.

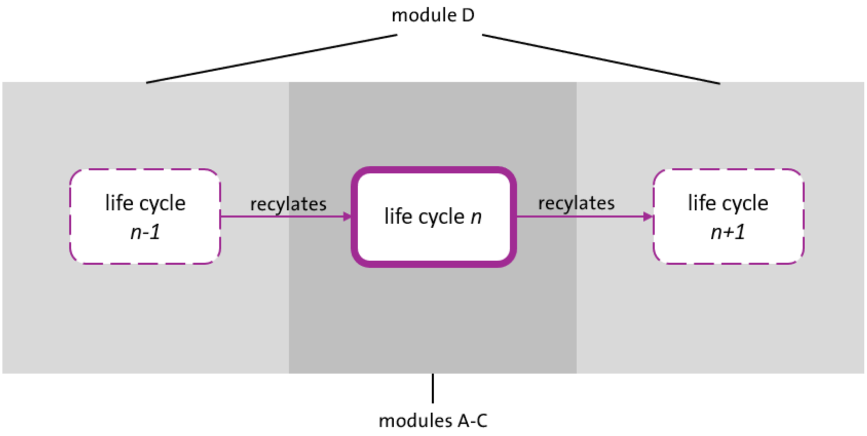

Figure 2 Modules A-C and module D in relation to a specific life cycle n of an investigated product. Module D addresses inputs and outputs of recyclates to previous and next life cycles

2 Challenges for modeling module D in EPDs

As mentioned, module D aims to collect credits and burdens for trans-life cycle valuable flows and energy. This is challenging in practice, for a variety of reasons:

1. Module D needs to consider the efficiency of recycling processes and the potential for material recovery, both typically not under control of the company producing the modeled product, and both widely dependent on the context, i.e. the location and the specific use of the project. This leads to assumptions, which potentially influence the result of the EPD a lot.
2. Module D is dependent on geographical context, as recycling, reuse, and energy recovery can differ significantly between regions. This makes it necessary to predict in which location the product will ultimately be disposed of, which is challenging. Further, datasets for modeling end of life in different regions worldwide are lacking, making it difficult to include this in the life cycle model.
3. Module D requires the calculation of net benefits or loads, which involves subtracting environmental burdens from the benefits gained through recycling or reuse from impacts linked to recyclates on the input side of the subsequent product life cycle. This calculation is not straightforward, and again often lacks sufficient datasets. The previous life cycle is typically not under control of the company producing the product, and thus again it is not easy to estimate the efforts related to the production of the recyclates from there.
4. Recyclates are initially often mixed in waste streams which need to be separated or cleaned; when modeling the recyclates, it is important to identify the point in the life cycle when they become useful recyclates, and to identify a process that produces an equivalent product, to be used in system expansion. Copper scrap, for example, cannot be replaced with electro-refined copper. This is always an issue in system expansion and LCA, but often more complicated for EPDs, as there is typically a sequence of cleaning and refining steps for the waste and recyclate stream.

In addition, Module D can be a potential trap for greenwashing. It is relatively easy to claim that a significant portion of a given product is recycled when, in reality, it may end up in landfills. Similarly, one might assume that incineration plants are highly efficient, and that heat recovery is possible, even though this may not be the case in the specific life cycle under study.

All these challenges make it worthwhile to provide guidance on modeling module D.

3 Observations on module D in existing EPDs

For a start, to get an overview of how module D is addressed now in EPDs, we compared several EPDs that were identical in declared/functional unit and calculated the variation of values in terms of standard deviation and coefficient of variance. Using the openLCA software, EPDs were imported via its Soda4LCA interface, and the results for modules A1-A3 and module D were extracted for the impact category GWP-total of EF3.0. EPDs were sourced from the International EPD System and EPD Italy. The products considered were:

1. 1 kg of steel pipe
2. 1 kg of hot-rolled steel bar
3. 1 m^3 of ready-mix concrete

The following Table 1 summarizes the standard deviation (σ), mean (μ), and coefficient of variation (CV) based on the GWP-total (kg CO_2 eq) of the EPDs imported for modules A1-A3 and module D.

Table 1 variation of module A1-A3 and module D values

Name of product	Declared unit	No. of EPDs evaluated	A1-A3 σ	A1-A3 μ	A1-A3 CV	D σ	D μ	D CV
Steel pipe	1 kg	7	466.78	2300.47	0.20	946.99	-1000.33	-0.95
Hot rolled steel bar	1 kg	9	173.02	676.92	0.26	586.13	-110.96	-5.28
Ready mix concrete	1 m^3	47	85.73	280.88	0.31	7.55	-10.77	-0.70

When considering the end-of-life scenario for a steel pipe, the material can either be recycled or disposed of as scrap. As shown in Table 1 and Figure 3, the variation in module D values is much higher than that of modules A1-A3, with the coefficient of variation (CV) being -0.95 and -0.2, respectively. This is also clear across other products, as demonstrated in Figure 4 and Figure 5, where module D always shows greater variability compared to modules A1-A3.

Although the variation is not as clearly depicted in Figure 5 for ready-mix concrete, the calculated CVs for modules A1-A3 and D, shown in Table 1, still support the claim that module D values are more variable. Figure 5 suggests, even, that the module D value for an EPD is greater than the total value module A1-A3, in absolute terms, which means that the entire EPD from A1 to D has a negative value for climate change. The respective EPD is S-P-08504[3] which indeed has about -500 kg CO2eq. per ton of steel.

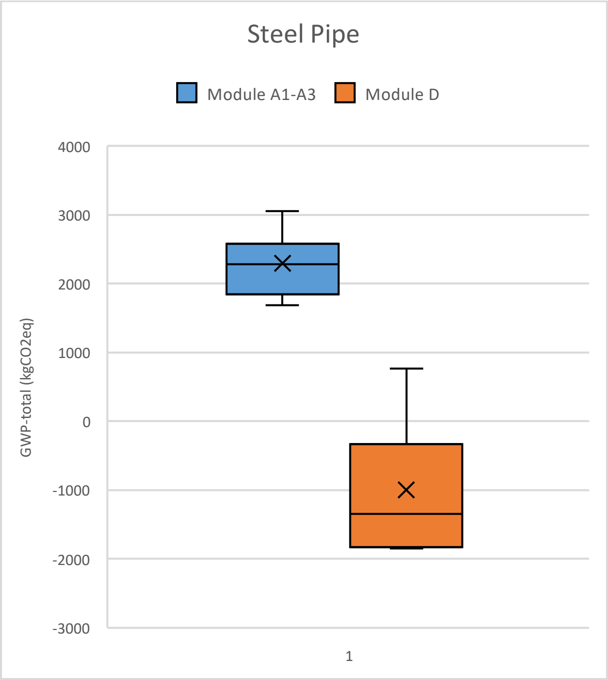

Figure 3 Module A1-A3 and Module D GWP-total values for Steel pipe EPDs

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[3] EPD: https://api.environdec.com/api/v1/EPDLibrary/Files/297b581d-06e8-4120-8185-08dbb657dbae/Data

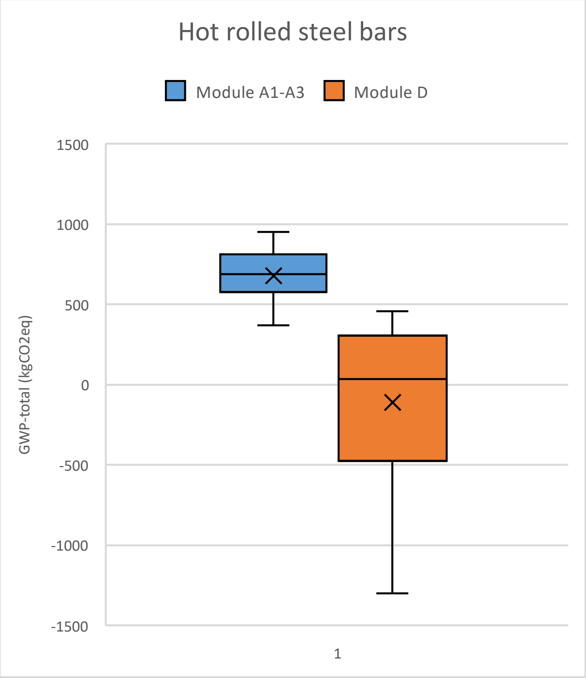

Figure 4 Module A1-A3 and Module D GWP-total values for hot-rolled steel bars EPDs

Looking at the readymix concrete in Figure 5, Module D is relatively small compared to other product categories. A potential reason for this may be significant differences in concrete datasets between ecoinvent and the Sphera database (GaBi), which arise from variations in the modeled cement production[4]—the main component of concrete. Differences between the ecoinvent and Sphera databases can include factors such as whether processes like wet milling are included or not, potential heat recovery from waste or not, and whether only primary fuels or both primary and secondary fuels are used. The cement production modelled in GaBi database is taken from Ökobaudat database which is created by the German federal institute for research on building (BBSR)[5] while the ecoinvent cement dataset claims to be European production average[6]. Since operators do not require the use of a specific database, users can choose whichever they prefer.

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[4] Saleh, S., Ciroth, A.: Zementdatensatzanalyse, commissioned by BBSR, 2022

[5] OEKOBAU.DAT (oekobaudat.de)

[6] cement production, alternative constituents 21-35% - Europe without Switzerland - cement, alternative constituents 21-35% | ecoQuery (ecoinvent.org)

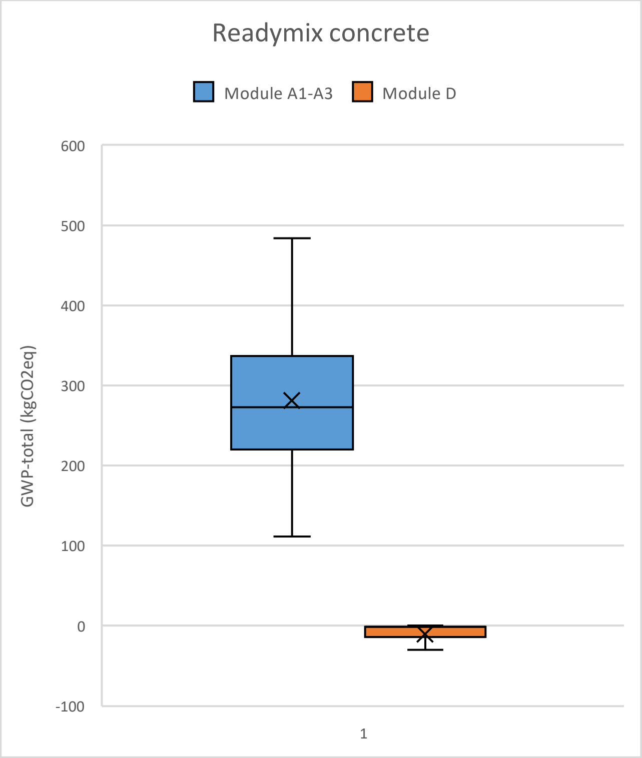

Figure 5 Module A1-A3 and Module D GWP-total values for readymix concrete EPDs

Negative values for climate change impact of conventional steel production are really surprising, and highlight the need for more guidance by PCRs, or for stricter verification criteria. The concrete example shows that there are also other aspects than module D that lead to a variation of EPDs for the same product group and PCR. All in all, thus, alignment of EPDs regarding module D seems highly needed, but will not make “everything” in EPDs aligned.

4 The EN15804 standard on module D

EN15804 is a European Norm that was last updated 2022, it addresses specifically EPDs in the construction sector and is used worldwide for EPDs. The norm contains specific rules for module D.

According to the EN 15804+A2 standard, Module D aims "at transparency for the environmental benefits or loads resulting from reusable products, recyclable materials, and/or useful energy carriers leaving a product system, e.g., as secondary materials or fuels." However, there is a major clause to this statement: "Any declared net benefits and loads from net flows (...) leaving the product system that have passed the end-of-waste state shall be included in Module D, except those which have been allocated as co-products."

Breaking down this clause, we find several important points:

1. Both net benefits and impacts are to be considered.
2. Only "net flows" shall be included.
3. Double counting is to be avoided by excluding allocated co-products from Module D.

The benefits and loads for a given product to be considered can include

- the export of secondary materials to replace virgin materials (D1),
- the export of secondary fuels to replace primary fuels (D2),

- the export of energy from waste incineration (only when the incineration facility efficiency is greater than 60%) (D3), and
- the export of energy because of landfilling (D4).

This is reflected in the following equation which is in the EN15804+A2 standard Annex:

$$e_{module\ D} = e_{module\ D1} + e_{module\ D2} + e_{module\ D3} + e_{module\ D4} \qquad \text{equation 1}$$

For each D_1 and D_2, or where the product exits ‘intact’ to be used in a subsequent product system, the formula looks as follows, as stated in Annex D in EN15804+A2 standard:

$$e_{module\ D1} = \sum_i (M_{MRout}|_i - M_{MRin}|_i) \times \left(E_{MR\ after\ EoW\ out}|_i - E_{VMSub\ out}|_i \times \frac{Q_{R\ out}}{Q_{Sub}}|_i\right) \qquad \text{equation 2}$$

$M_{MR\ in}$ = amount of input material to the product system that is recycled/recovered from a previous product system

$M_{MR\ out}$ = amount of material exiting the system that will be recovered (recycled and reused) in a subsequent system.

$E_{MR\ after\ EoW\ out}$ = specific emissions and resources consumed per unit of analysis arising from material recovery (recycling and reusing) processes of a subsequent system after the end-of waste state OR load behind processing after End-of-Waste until functional equivalence

$E_{VM\ Sub\ out}$ = specific emissions and resources consumed per unit of analysis arising from acquisition and pre-processing of the primary material, or average input material if primary material is not used, from the cradle to the point of functional equivalence where it would substitute secondary material that would be used in a subsequent system OR impacts behind producing the substituted material from cradle to the point of functional equivalence.

$Q_{R\ out}/Q_{sub}$= quality ratio between outgoing recovered material (recycled and reused) and the substituted material

While in case of D2, it focuses on substitution in terms of fuel/energy content.

In $e_{module\ D3}$ and $e_{module\ D4}$, the product end-of-waste process takes place within the system boundary and exits as exported energy (as heat and/or electricity). The equation for the case of D3, as stated in Annex D in EN15804+A2 standard,

$$e_{module\ D3} = -M_{INC\ out} \times (LHV \times X_{INC\ heat} \times E_{SE\ heat} + LHV \times X_{INC\ elec} \times E_{SE\ heat}) \qquad \text{equation 3}$$

$M_{INC\ out}$ = amount of waste that will be incinerated with efficiency of energy recovery lower than 60 % or that is used for energy recovery with energy efficiency greater than 60 % but which has not reached the end-of-waste state

LHV = lower heating of the material

$X_{INC\ heat/elec}$ = efficiency of the incineration process for heat/electricity

$E_{SE\ heat/elec}$ = specific emissions and resources consumed per unit of analysis that would have arisen from specific current average substituted energy source: heat/electricity

In the case of D4, landfilling, the same equation also applies with emissions and efficiency relative to the landfilling process. In the ‘practical advice’ section 6, there are practical examples on application of the equations above.

5 Product Category Rules on module D

Product category rules (PCR) provide guidance on how to perform an LCA for a certain product group and on the reporting of EPDs as well. Typically, program operators such as the International EPD System, IBU, BRE, and others develop their own PCRs. For construction-related materials, they adhere to the EN15804+A2 standard.

Module D is addressed in PCRs sometimes, typically providing more details. One example is PCR 2019:14, version 1.3.4[7] for construction products, which is part of the International EPD System, where a detailed figure explains how to model module D (Figure 6). This PCR, however, emphasizes an inconsistency in the EN15804+A2 standard concerning module D.

According to Note 4 in Section 7.2.4.4 of the EN15804+A2 standard, materials intended for waste incineration are excluded from the 'Materials for energy recovery' indicator. Motivation is that waste incineration plants have a lower energy efficiency rate than e.g. power stations when incinerating secondary fuels. However, in the same EN15804+A2 standard, Annex D states that in module C3, users should model the impacts of waste processing for energy recovery, i.e., producing secondary fuels, before reaching incineration. This means it shall exit the system in module C as 'energy recovery,' with the loads/benefits to be modeled in module D.

The PCR highlights this inconsistency between the EN15804+A2 standard body text and its annex, in note 2 in section 4.5.4 of the PCR, particularly in how the "Materials for energy recovery" are accounted for. In the PCR, and as seen in Figure 6 below, materials undergoing incineration with the incineration plant having an efficiency of more than 60% would be declared as 'materials for energy recovery'. The PCR thus follows the annex of EN15804+A2, but not its main body text, concerning this aspect.

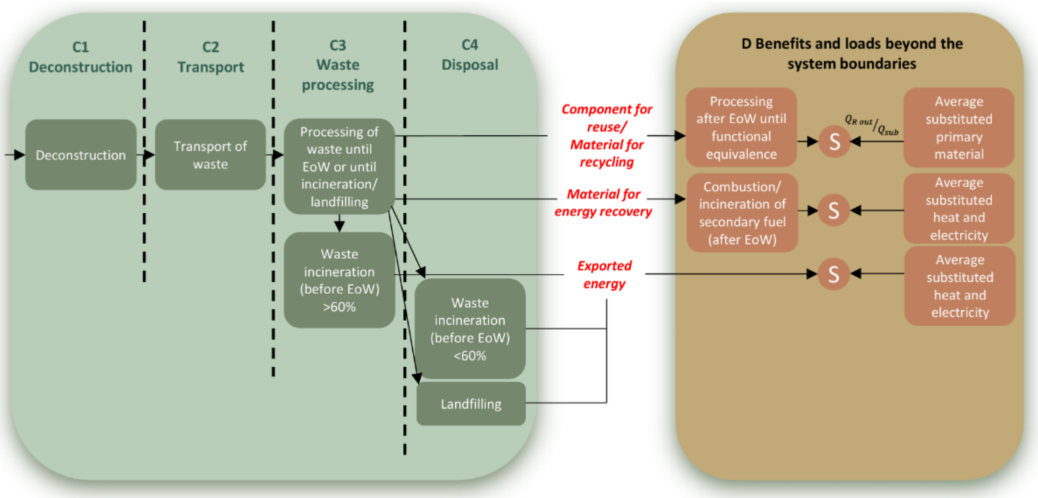

Figure 6 Illustration of the processes and flows of modules C and D from PCR2019:14 construction product

As a side note, the PCR itself also contains an inconsistency or rather a mix of terms. In Note 2 in section 4.5.4 the PCR is writing 'materials for recycling' when it should be 'material for energy recovery.

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[7] Environdec 2024. PCR 2019:14 VERSION 1.3.4 https://api.environdec.com/api/v1/EPDLibrary/Files/fe17e14b-3ff4-4ab3-07a6-08dc685f3598/Data

6 Practical advice

For practical use of module D in EPDs, there are four main aspects to be aware of:

- The determination of the final waste stage
- The determination of the quality ratio, both interrelated
- How to model and calculate the net flows
- And finally, how to address recyclates for packaging.

We will go through these in the following sections.

6.1 Determination of the final waste stage

If a waste flow is considered final waste, the process of treating it, i.e. having it as input, is the last process of the considered life cycle. An evident example is a landfill, where waste is stored, or incineration. The only remaining effort that takes place is then potential maintenance of the waste, e.g. the maintenance of the landfill site. Often, life cycle systems have a sequence of waste treatment processes, waste is collected, sorted, and may then be split into different fractions, some final waste, and some being valuables / recyclates, which may then be further treated. These treatments are, however, not responsibility of the considered life cycle, but of the "next" life cycle which takes up these recyclates. This means that if a waste stream is considered final waste too early in the waste treatment chain, the impacts calculated for the system will be too low; and if it is declared final waste too late, the calculated impacts will be too high. As the recyclates that are output of the system are contributing to module D, as discussed above, the final waste decision influences also module D and module C3, the waste treatment stage. It is good practice to first outline the step-by-step waste treatment process, as well as the production process that transforms the waste into a usable product for the market.

Several criteria determine whether a flow can be considered final waste. A waste is final waste if these criteria are met[8] :

1. The substance or object is commonly used for specific purposes.
2. A market or demand exists for such a substance or object.
3. The substance or object fulfils the technical requirements for specific purposes and meets the existing legislation and standards applicable to products.
4. Use of the substance or object will not lead to overall adverse environmental or human health impacts.

Take, for example, steel products that undergo partial recycling. As seen in Figure 7, in the C3 stage, which represents waste processing, the process involves collection, sorting, and pressing/shredding of the portion to be recycled. In module D, there is the component of 'load,' presented in equation 2 with the variable $E_{\text{MR after EoW out}}$. The emissions associated with this variable, in the case of steel, would represent the impact of melting, refining, and solidification, so that the material can properly perform the function of the substituted primary material. In many cases, the variable $E_{\text{MR after EoW out}}$ may be

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[8] Taken from https://www.epa.ie/our-services/licensing/waste/end-of-waste-art-28/

underestimated or even overlooked, leaving only the variable $E_{VM\ Sub\ out}$ to be modelled, which can result in an overestimation of benefits.

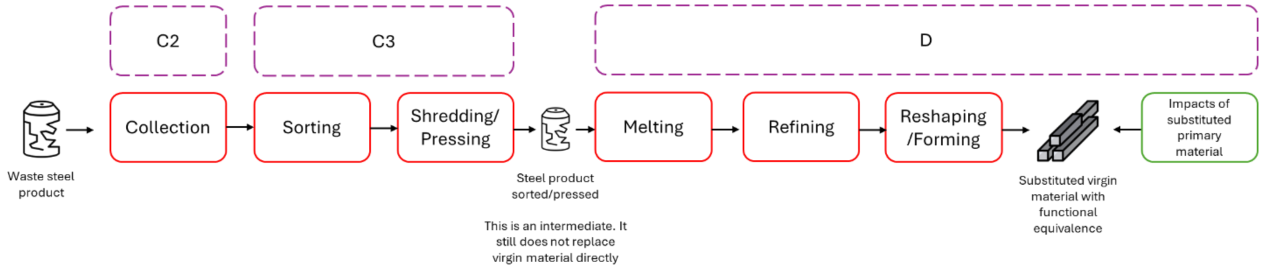

Figure 7 Example: step-by-step waste modelling of recycling steel module C and D

6.2 Determination of the quality ratio and the "correct" substitute

The quality ratio $Q_{R\ out}/Q_{sub}$ expresses a potential different quality of the recyclate and the substituting primary material. For example, a plastic recyclate may have has weaker technical properties[9], and thus for a given board made from plastic 10% more material is needed than if primary material was used. The substitution is then not 1:1 but 1:1.1 (primary to recyclate), the quality ratio would be 1.1.

According to the PCR 2019:14 version 1.3.4, the value can be based on the economic value (price of recyclate vs virgin material), the complementary PCR may recommend something specific. Typically, a correct determination is not easy as it requires an assumption and know-how about the use of the recyclate in a next life cycle.

Many cases set the quality ratio to 1, which is also mentioned e.g. in the environdec PCR 2019:14 version 1.3.4[10]. Setting the quality ratio to 1 is, however, the best case. Consequently, the benefits of Module D would be overstated, resulting in greenwashing.

Similar for final waste, setting the appropriate substitute flow that is used for obtaining the credits in module D is important, setting a too-precious substituted product may yield too high credits.

If we take copper as recyclate as an example, setting the substituted material as copper produced through 'electrorefining' does not fit to a recyclate output of copper scrap, with copper produced from electrorefining being considered 99.99% pure while scrap copper, depending on the source will still contain trace elements lowering its quality overall.

6.3 Modeling the net flows, loads and benefits

To elaborate on the modeling of the flows, we will use an illustrative example of a plastic product.

Given a product X, a plastic product, which has a declared unit of 10 kg, made entirely from virgin plastic material, and is subject to this scenario at end-of-life:

- Of the 10 kg of plastic product, 5 kg will be recycled, and 5 kg will be disposed of in a landfill. As illustrated in Figure 8, the C3 module captures the impact of producing the 5 kg of plastic that will be recycled, represented by the dataset from Ecoinvent. In the C4 module, the remaining 5 kg of HDPE is modeled for landfilling. Finally, in module D, the environmental load associated

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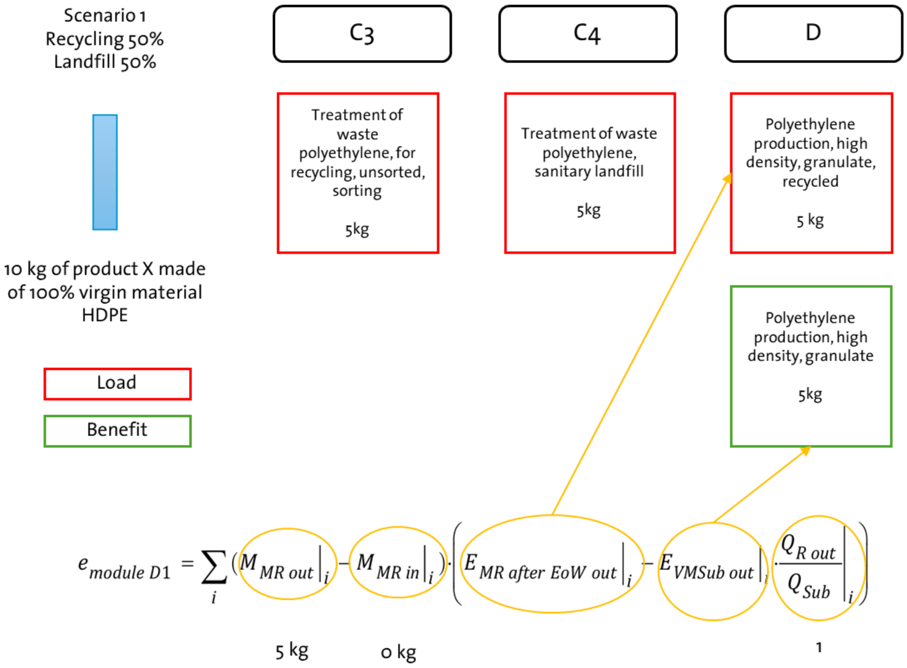
[9] Mazzoni, M., di Francesco, M., & L. P. Giudici (2022). Quality model for recycled plastics (QMRP): An indicator for holistic and consistent quality assessment of recycled plastics using product functionality and material properties. Journal of Cleaner Production, 339, 130646. https://doi.org/10.1016/j.jclepro.2022.130646

[10] Page 20: "In many cases the ratio Q_{ROut}/Q_{Sub} can be set to 1"

with recycling and the avoided impacts of producing virgin HDPE are modeled, as shown in Figure 8.

This process is also reflected in the equation displayed in Figure 8 from the EN15804+A2 standard. The variable $M_{MR\ out}$ displays how much mass is exiting the product system and will reenter a subsequent system. In this scenario, it is assumed only 5 kg will undergo recycling. The variable $M_{MR\ in}$ displays the mass of recycled content in the main product. In this case, it is assumed that 100% of the plastic product is made of virgin materials and hence it shall be 0 kg. In other words, the subtraction between $M_{MR\ out}$ and $M_{MR\ in}$ reflects the 'net flows' that was described earlier. The next two variables reflect the load (red box) and benefit (green box), and these are represented by the boxes seen under module D. Finally, the ratio of $Q_{R\ out}$ / Q_{Sub} represents the quality ratio between outgoing recovered material and substituted material. For simplicity in this demonstration, it is assumed to be 1. However, in practice, this factor should be investigated further as mentioned earlier in previous subsection.



$$e_{module\ D1} = \sum_i \left(M_{MR\ out}\Big|_i - M_{MR\ in}\Big|_i\right) \cdot \left(E_{MR\ after\ EoW\ out}\Big|_i - E_{VMSub\ out}\Big|_i \cdot \frac{Q_{R\ out}}{Q_{Sub}}\Big|_i\right)$$

Figure 8 Scenario 1: Recycling and landfilling modelling

- Scenario 2a: 10 kg will be incinerated with heat recovery i.e., exported energy (knowing that the waste incineration facility has an efficiency >60%). As seen in Figure 9, In this scenario, like scenario 1, the impacts behind processing the waste to obtain 10 kg worth of HDPE is modelled in C3. The load behind incineration will be modelled in C4 stage, and finally the exported energy which would be the subject of substituting heat and/or electricity will be modelled in D. As seen Figure 9, the amount of substituted heat plays a factor of both the lower heating value of the product and the incineration plant efficiency. This is also depicted in the equation displayed. It is important to note that regardless of whether secondary materials are used in the main product or not – the entire product mass shall be accounted for. As seen in Figure 9, the equation displayed, energy recovery can be substituted with heat generation or electricity generation. For simplicity in this demonstration, it is assumed to be only heat recovery. However, in practice, this factor should be investigated further.

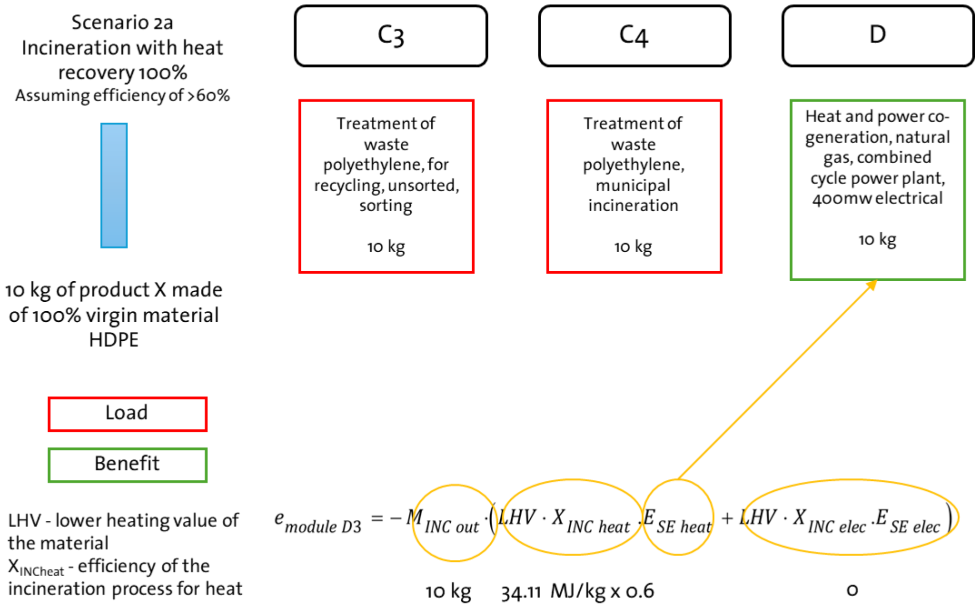


Figure 9 Scenario 2a: Export of energy because of waste incineration

- Scenario 2b: 10 kg of plastic product is going to be used in another product system as a secondary fuel. The difference from the previous scenario 2a is that the product exiting the system is intact and will be used to produce heat/electricity for another subsequent product system. In this case, instead of modelling the impact of incineration in C4, it will be shifted to the D stage reflecting the 'load' that is also shown in the equation as seen in Figure 10. Again, like scenario 1, the net flows are depicted in the variables of $M_{ER\ out}$ and $M_{ER\ in}$ where again the amount of material entering the product system that has reached the end-of-waste state before incineration in a previous system and entering the product system as secondary fuel has to be subtracted from the amount of material leaving the system as secondary fuel.

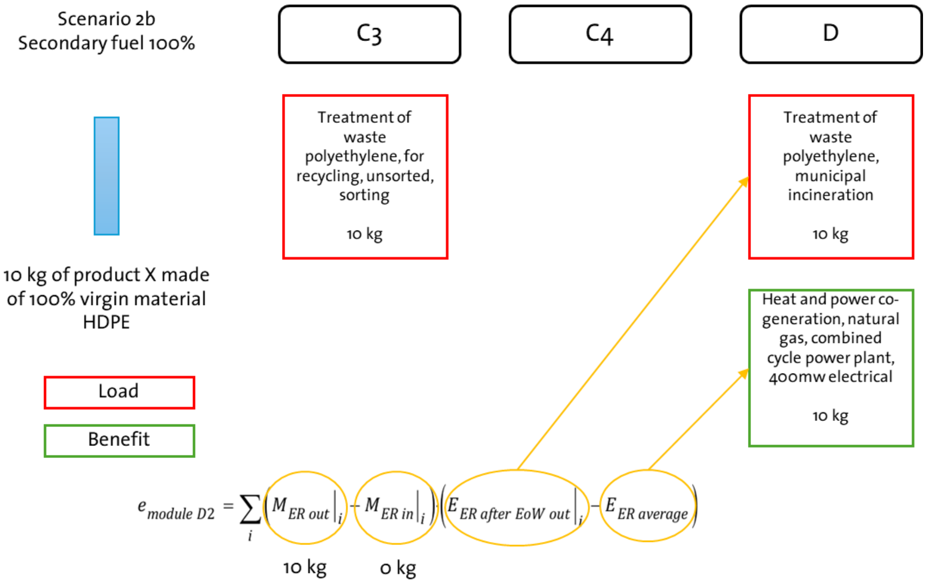


Figure 10 Scenario 2b: Export of energy as a result of waste incineration

- Scenario 3: 10 kg of plastic product which is 20% made up of recycled plastic (secondary material) and 80% made up of virgin material. 100% of the product is going to undergo recycling. In this case, the net flows shall be the deduction of the recycled mass (2kg) from the overall mass, leaving 8kg to be replacing the virgin material in a subsequent product system as shown in **Error! Reference source not found.**. The impacts associated with the 2 kg are not accounted for in module D again because they have entered this product system with no impact. Therefore, accounting for both its load and benefit would result in double counting. This explanation is supported by Figure 12 below, which demonstrates that the impacts for recyclates entering the system are always linked to their previous life cycle, not the current one. This highlights the importance of accounting only for "net flows," as mentioned in section 4.

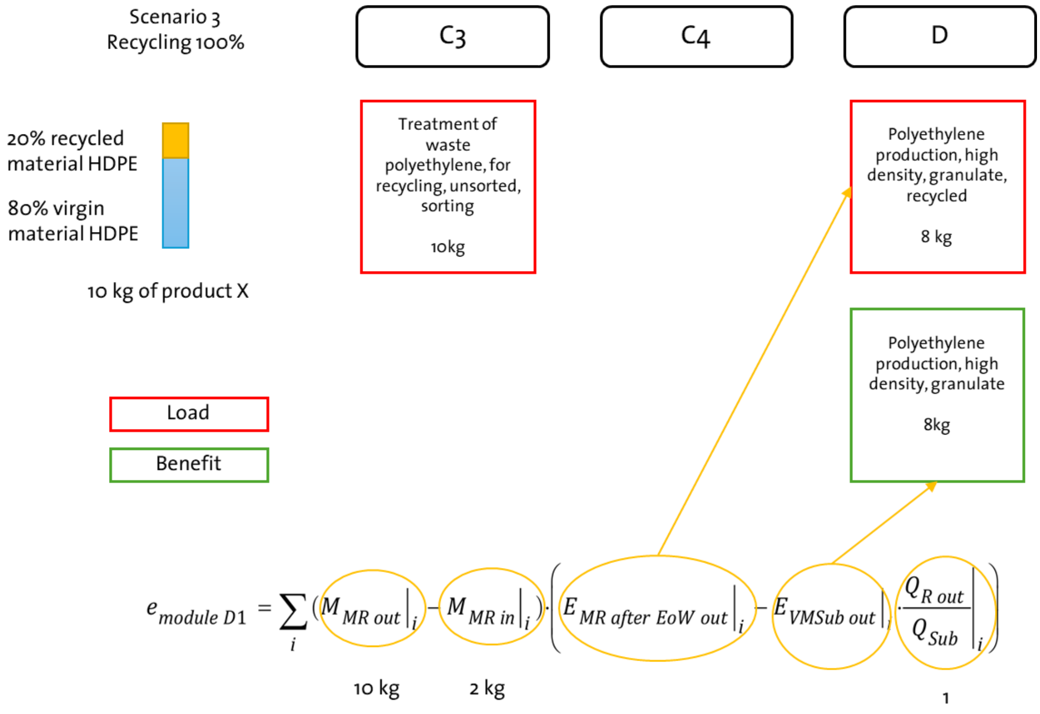


Figure 11 Scenario 3: Recycling of product made up of recycled content

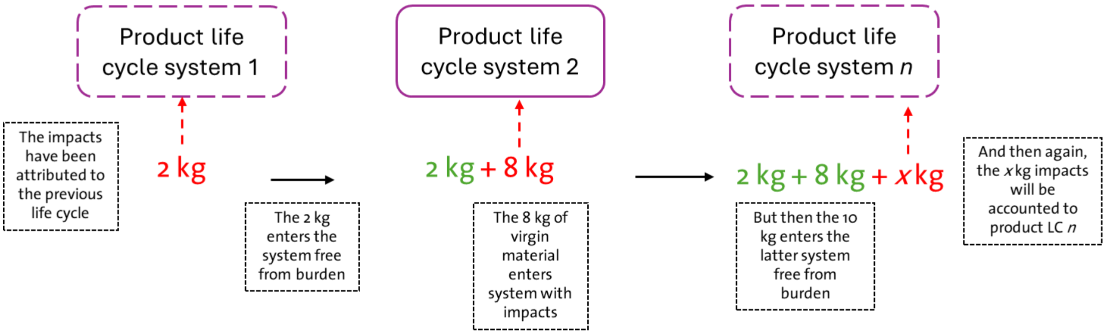


Figure 12 Accounting of recyclates from one product LC to another

- Scenario 4: A 10 kg plastic product that is 50% made up of recycled plastic (secondary material) and 50% made up of virgin material. This would yield a net flow of 0 kg exiting the system, according to Equation 1, and hence no benefits are expected.
- Scenario 5: A 10 kg plastic product made up of 60% recycled material and 40% virgin material. According to Equation 1, this would result in a -2 kg net flow, which would actually indicate a load rather than a benefit in this case.

6.4 Packaging recycling

Packaging of the investigated product needs special consideration. Many products are shipped from the manufacturer's gate (A3 stage) with their packaging to the installation/market (A5 stage). The A5 stage encompasses the impacts associated with waste processing from product packaging, according to the EN15804+A2 standard. However, there are cases where the packaging undergoes recycling or reuse—especially when the packaging is wood-based, such as wooden pallets or paper packaging. The environmental load associated with the recycling of the product's packaging will be reported in the A5 stage, as well as the benefits of recycling, such as the substitution of virgin materials.

So, following PCRs, benefits from recycling of product packaging must not be considered in module D, but in module A5, when the packaging is removed before installation.

7 Conclusion

While the specific rules for modeling can become intricate, the principal logic remains straightforward: Module D needs to consider net flows, i.e., the difference between input and output. Flows that have already been accounted for in an allocation within the system cannot be addressed again in Module D. Additionally, differences in quality between the recyclate and the substituted product must be reflected by a factor (Q_R/Q_{sub}). This factor is applicable in cases where the lower quality of recycled material can be compensated for by using a higher amount, such as in the mechanical recycling of plastic, where more recycled material is needed to match the strength of the virgin product.

Given that even the standard and broadly used PCR documents contain mistakes in addressing module D modeling requirements, it seems fair to ask whether maybe the rules for the EPDs are too intricate and complicated, and whether a more simplified and straightforward modeling would instead be beneficial.

Especially in module D modeling, decisions can change the overall result of the EPD a lot. It could make sense to require a documentation of the decisions made in the EPD, similar to a log file, so that readers are aware of final waste states, substitutes chosen, the selected quality ratio, and related aspects.

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