Handling Recycling in Life Cycle Assessment

Lise Laurin, CEO
lise@earthshiftglobal.com

Contents

Introduction

Handling the recycling of products in LCA is a special case of allocation. As shown in Figure 1, when a material is recycled, it has two or more lives. There are a number of different ways to consider how the burdens of these materials and the recycling process itself are divided. It is important to remember that there is no physical division between the two lives so there is no 'right' answer to the question. Different allocations offer different ways of looking at the same system and will provide different insights. It is important, however, to be consistent within an analysis.

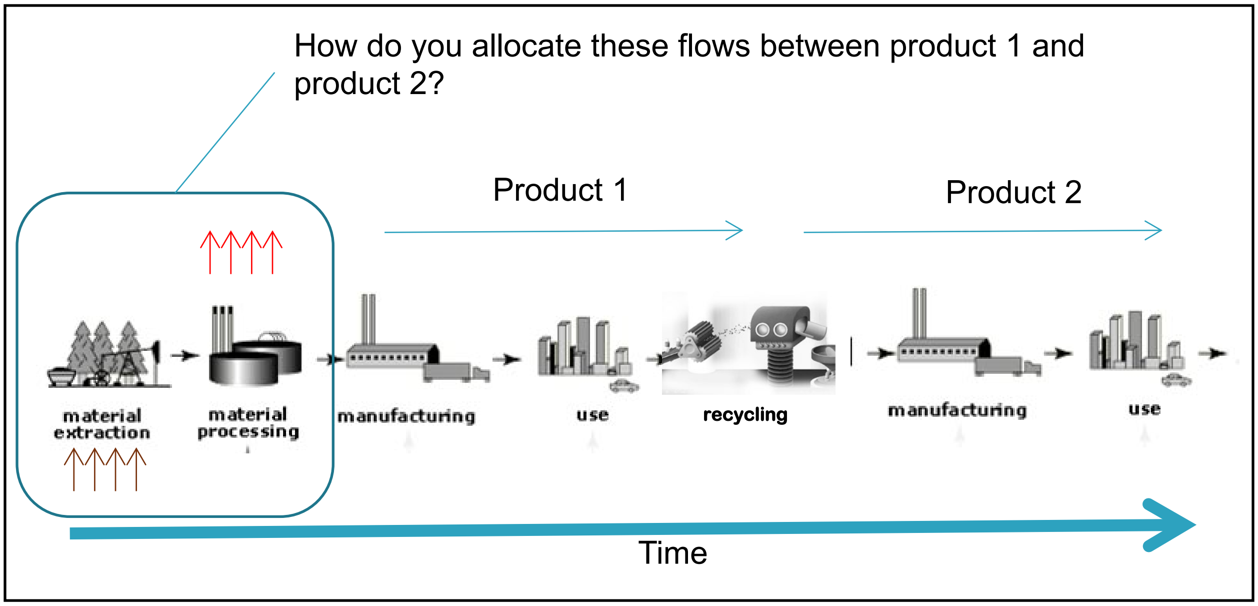

Figure 1: With recycling, two products are created at different times.

What do we need to consider?

Over the life span of the two products, there are a number of activities that might be allotted to one or more of the lives: raw material extraction and initial processing, collection, sorting and composting, reconditioning, packaging, transport, and activities that have been avoided through the reuse of the material. Different methods apportion those impacts differently to the first and second lives and may take into consideration further lives of the material. In addition to consistency between product systems, there must be consistency within a system: the same method should be used to apportion impacts at the beginning of a product life as well as at the end (e.g., incoming recycled material should be apportioned impacts through the same method as material leaving the system via the recycling bin.)

Before looking at each method in detail, it is important to start with a basic understanding of the two systems to be modeled as shown in Figure 2

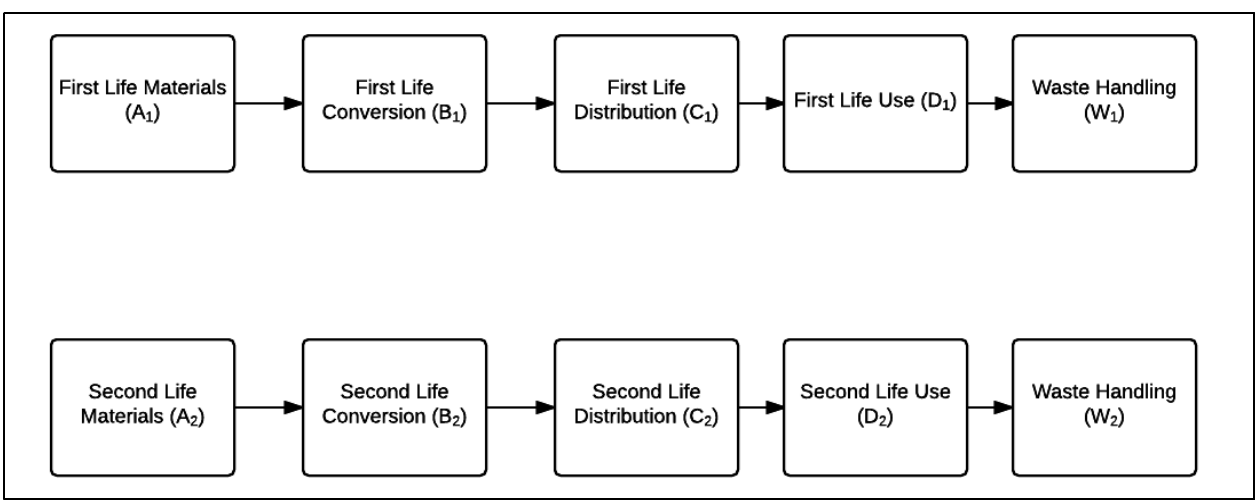

Figure 2: The processes needed to create a product which is put into the recycle bin at end of life (product 1) and the product created at time 2 (product 2) are designated by the subscript.

In both lives, there is a need for materials, conversion from materials into a product, distribution, use and then some kind of handling at end of life. These are denoted by the letters in parenthesis following the names (e.g., A_1, B_2, etc.). The subscript indicates which life the process belongs to. These indicators will be used in the equations for each LCA recycling method.

Closed Loop Allocation Procedure

ISO 14044 distinguishes two classes of recycled product: those that have the same properties as virgin material and those that have different properties (ISO 14044, 2006b). Specifically, section 4.3.4.3.3 of ISO 14044 states:

a) A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials.
b) An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties.

The closed loop procedure described in a) above also goes by these other names:

1. Open-loop with closed loop procedure (ISO 14049), (ISO/TR 14049:2000(E), 2000)
2. avoided burden approach,
3. end-of-life approach (supported by metals industry),
4. recyclability substitution approach (ILCD Handbook) (European Commission -Joint Research Centre -Institute for Environment and Sustainability, 2010),
5. closed-loop approximation (GHG Protocol) (Bhatia, et al., 2011)
6. 0/100 approach.

The Avoided Burden or Closed Loop approach is shown in Figure 3. If the product is landfilled, it must take the burden of Waste Handling (W_1). If it is recycled, it takes the burden of the refurbishment process (I) and gets credit for the amount passed on to the second life (A_2). The second life must take the burden of the virgin material which was displaced in the first life (A_2).

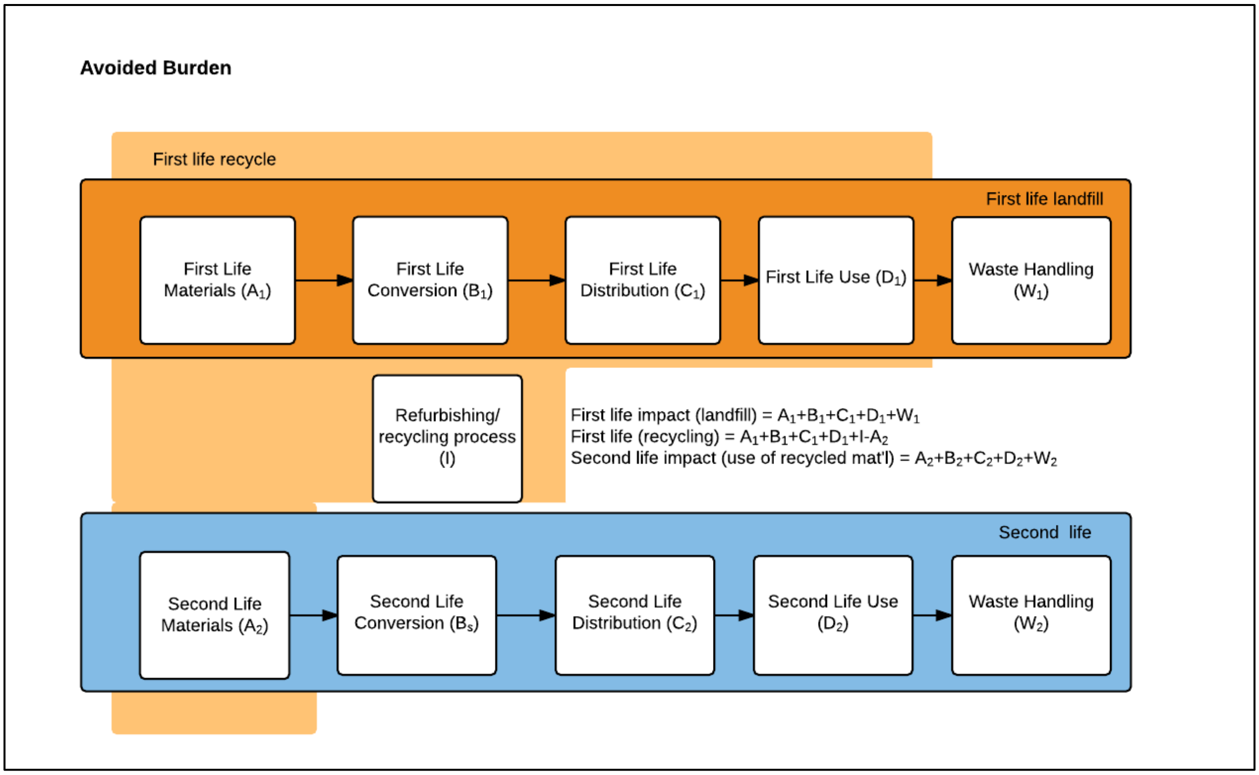

Figure 3: In the Avoided Burden or Closed Loop approach, the first life takes the burden of the recycling process but gets credit for the virgin material avoided by the second life.

The closed loop procedure encourages recycling at end of life but does little to encourage the reuse of recycled products.

Open Loop Approaches

Economic Allocation

In economic allocation (Howard, Edwards, & Anderson, 1999), the recycled material created from the first life becomes a coproduct. The impacts of cradle to gate (A_1+B_1) are allocated between Product 1 and Product 2 based on their sale price. If the price of Product 1 is $90 and the price of product 2 is $10, the second life would take (10/(90+1)) or 10% of the burden of A_1+B_1. This method can be applied whether or not the material changes properties and is useful when the recycled product is very different from the initial product. The drawback of this method is that scrap costs can be volatile and the market in which product 1 is sold at time 1 may be very different from the market when it is recycled. Thus, it is most useful for very short-lived products where the economics are well understood. Economic allocation further drives market forces.

Number-of-uses

The number-of-uses approach (ISO/TR 14049:2000(E), 2000) is a useful method when a product degrades over consecutive life cycles; it is supported by many in the paper industry (American Forest and Paper Association, 2006). Like the economic allocation method, the impacts of cradle to gate (A_1+B_1) are allocated between Product 1 and subsequent lives based on an allocation factor:

Allocation Factor for Primary product system = $(1-Z_1)+(Z_1/u)$

Allocation Factor for recycled product systems = Z_1 (u-1)/u

where :

u is the number of uses (lives)

Z_1 is the percent recycled after the first use.

The drawback to number-of-uses is that the modeler must know exactly how many times a product can be recycled and must know the percentage being recycled at Time 2.

The number-of-uses method benefits both recycling at end of life and use of recycled material.

Cut-off approach

One of the most used commonly used methods in LCA, the Cut-Off approach (Frischknecht, LCI modelling approaches applied on recycling of materials in view of environmental sustainability, risk perception and eco-efficiency, 2010) draws a simple boundary between Product 1 and Product 2 at the point when the user of Product 1 puts the product in the recycle bin (Figure 4).

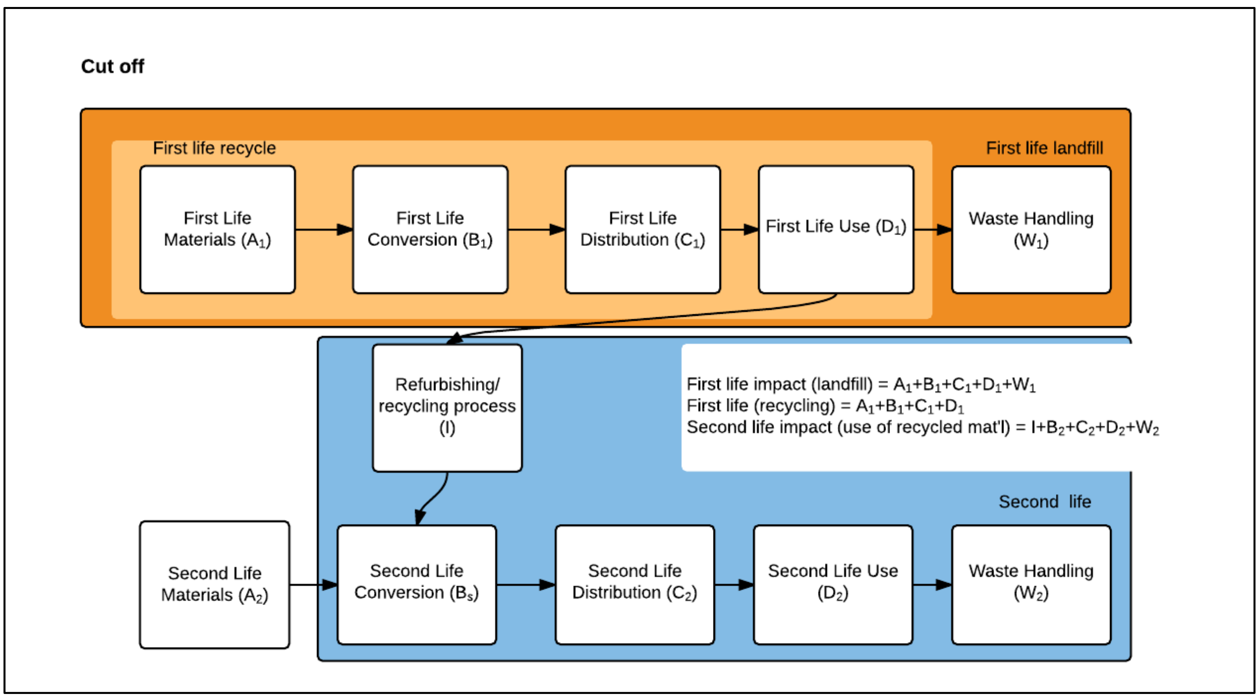

Figure 4: In the Cut-Off method, the first life takes burdens through disposal. The second life takes the material burden-free, with the exception of the refurbishing process.

This method is easier to apply than most other methods because it does not depend upon market conditions, number of uses, or other data. The primary beneficiary of this approach is the user of recycled material. While the life cycle of Product 1 does not have to take the burden of landfilling or incineration, it gains no benefit from the reuse of the material.

As Frischknecht discusses in his 2010 article, the closed-loop approaches are risk-seeking because they borrow environmental loans from future generations. The Cut-Off method, on the other hand, is risk-averse: environmental burdens are strictly linked to the product that causes them, irrespective of any potential future use.

50/50 Approach

The 50/50 approach (which can also be adjusted based on how much useful material is generated from a kilogram of material at end of life) allocates 50% of the burdens of (A_1+B_1) to each life (Ekvall, 2000). The equations for the impact look like this:

First-life impact (landfill): $A_1 + B_1 + C_1 + D_1 + W_1$

First life (recycling): $A_1 + B_1 + C_1 + D_1 + 0.5^* I – 0.5^* (A_1 + B_1)$

Second life (use of recycled material: $0.5 * I + 0.5 * (A_1 + B_1) + B_2 + C_2 + D_2 + W_2$

In the 50/50 approach, both lives benefit from the reuse of material. Setting the allocation at 50% can be thought of as arbitrary, but ascertaining exact values can be burdensome. This method is gaining traction with the steel industry where the amount of reused material is high and relatively well understood.

Market Model for System Expansion

The market model for system expansion, or the market-based approach, takes a consequential approach to end of life (Weidema, 2003). If a recycled material is fully utilized, meaning that all of the material which enters the recycling stream at end of life is reused, the consequence of using that material would be that another user would have to use virgin material. If a recycled material is underutilized, meaning that some of the material entering the recycling stream is either stockpiled, landfilled or incinerated, then use of that material avoids the end-of-life impacts. The diagram for the market-based approach is a bit different from that for the other methods and is shown in Figure 5.

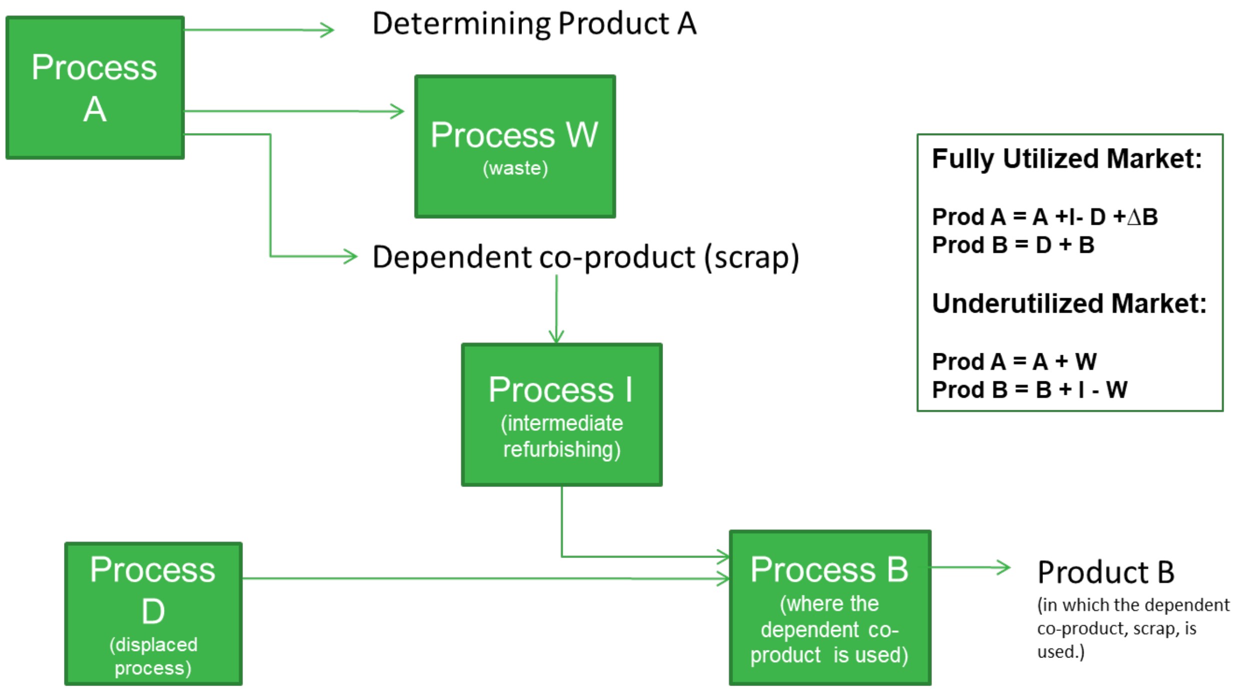

Figure 5 : In the market-based approach, the burdens are allocated differently depending upon the market for recycled product.

This method is similar to the closed-loop approach when recycled material is in demand. When there is little demand it is similar to Cut-Off, with the addition of burden for landfill or incineration for Product 1 and credit for that same end of life for Product 2.

The market-based approach requires a good understanding of market dynamics and the results will change as the market changes. *It is the only method for which different materials can be treated differently. It is also the only method which gives a credit for avoided landfill or incineration to the second life.* It is the method most often used in consequential studies.

Summary and Recommendations

When modeling either recycling at a product's end of life or the reuse of a material, the choice of method will change the product's impacts dramatically. It is important to keep a consistent perspective to prevent burdens (and benefits) from being double-counted: One cannot take a credit for something at end of life and at the same time avoid the burden of it at beginning of life.

When performing a comparative assertion, the use of the Market-Based approach under both conditions offers a comprehensive assessment of the differences between systems. Assuming a fully utilized market has the lowest impact for the first life and the highest impact for the second life. Assuming an underutilized market has the highest impact for the first life and lowest impact for the second life of any of the methods proposed to date. Thus, assessing scenarios under both conditions provides the full scope of impact.

The Market-Based approach also makes sense as a method for assessing a recycling process where the recycler has responsibility for collecting the waste material and redistributing useable product. Through its efforts, the recycler is reducing the amount of material going to landfill or incineration while reducing demands on virgin production.

Both the Market-Based approach and the Closed-Loop approach seem to apply to fully utilized markets, such as aluminum and steel. Because these materials are often compared with products in underutilized markets, the Market-Based approach offers a more consistent way of modeling.

In most other cases, the Cut-Off method is the preferred method for several reasons: results don't change with changes in market conditions, it is straightforward to apply, it does not result in "credits" which are difficult to explain and justify, and it encourages the reuse of material while not discouraging recycling at end of life.

As repeated in this document, it is important that the method used is consistent:

1. At both beginning and end of life
2. For all product systems being compared

When methods are applied inconsistently, burdens may be double-counted or applied inconsistently, resulting in unjustifiable conclusions.