Allocation of Greenhouse Gas Emissions in Open-Loop Recycling

Case Study

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for

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The Challenge

The allocation of emissions for recycling when conducting a Life-Cycle Assessment (LCA) is clear in some cases but less obvious in others, such as open-loop recycling systems. In open-loop recycling, upstream products are recycled and serve as input material for the production of downstream products. Thus, upstream and downstream product systems are linked, but unknown, and it becomes unclear how to allocate emissions, energy and waste to each system.

Although the allocation methods used here are applicable to all environmental impact metrics, this case study focuses on greenhouse gas (GHG) emissions as they are relevant to ClearCarbon's work in climate change consulting. Overall, this case study demonstrates that the choice of allocation method in open-loop recycling situations creates different incentives for recycling and for using recycled materials.

The Approach

Allocating 100% of raw material inception impacts to virgin material processing creates an incentive to develop recyclable products. In contrast, a 100% allocation of impacts to recycled material processing generates an incentive to use recycled materials. ClearCarbon prefers a 50/50% allocation to virgin and recycled material processing, which creates an incentive to use recycled materials and produce recyclable products. The incentives and allocation methods are described in more detail in ClearCarbon's *Evaluating the Impact of Open-Loop Recycling in Life-Cycle Assessment: White Paper* and illustrated below in Figure 1.

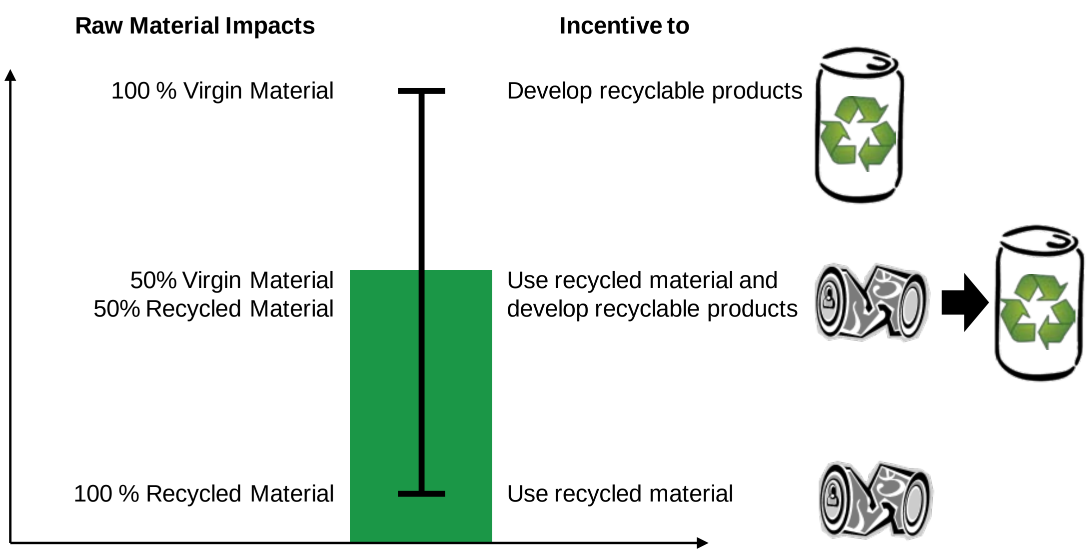

Figure 1: Different Allocation Methods Produce Different Incentives

To illustrate these concepts, this case study compares the outcomes of three recycling impact allocation methods for three materials — recycled polyethylene terephthalate (rPET), recycled aluminum, and recycled steel. Depending on how impacts are allocated in the raw material inception and end-of-life phases, different incentives are created. The resulting carbon dioxide equivalent (CO_2e) emissions for producing 1 kg of each of these three materials are presented in Table 1.

Table 1: CO2e Emissions for Recycled PET, Aluminum, and Steel by Allocation Method

	Raw material inception burden			End-of-life credit/burden		
	kg CO_2e/kg material					
	A	B	C	A	B	C
Material	**100% burden on virgin materials**	**50/50% burden on virgin and recycled**	**100% burden on recycled materials**	**100% credit for virgin materials, 100% burden on recycled**	**50/50% burden on recycled, credit for virgin materials**	**No material credit/burden; burden/credit from waste treatment**
Recycled PET	3.3	2.1	0.8	-0.3	-0.05	0.3
Recycled Aluminum	12.6	7.0	1.5	-5.0	-2.5	0.003
Recycled Steel	2.3	1.4	0.6	-1.1	-0.5	-0.004

Emissions from waste disposal at end-of-life assume standard U.S. municipal solid waste treatment practices.[1] Life-cycle inventory data for material production as well as waste treatment are from the US-Ecoinvent database.[2] Product manufacturing and use phase considerations are excluded from this analysis.

Allocating the raw material inception impacts to 100% virgin material inputs yields the highest emissions; allocating the impacts to 100% recycled material inputs yields the lowest emissions. As one might expect, using a 50/50% allocation method produces an average of the two. It is worth noting that materials have inherently different virgin and recycling processing impacts, which become more pronounced depending on the choice of raw material burden allocation.

Figure 2 shows the results of the raw material inception and end-of-life CO_2e emissions for rPET, recycled aluminum, and recycled steel by allocation method. The red bars represent emissions using a 50/50% allocation method for both raw material inception and end-of-life phases (columns labeled “B” in Table 1). The upper tail of the black “uncertainty bar” represents the emissions that result when attributing 100% of the raw material inception burden to virgin material processing and end-of-life, using a 100% credit for virgin materials and 100% burden on recycled material processing (columns labeled “A” in

Table 1). The lower tail represents emissions when assigning 100% of the raw material inception burden to recycled material processing and only burdens and credits from waste treatment are considered at end-of-life (columns labeled "C" in Table 1). In calculating end-of-life burdens and credits, standard U.S. recycling rates are assumed.[3] For a complete discussion of raw material burden and end-of-life credits calculations, see *Evaluating the Impact of Open-Loop Recycling in Life-Cycle Assessment: White Paper*).

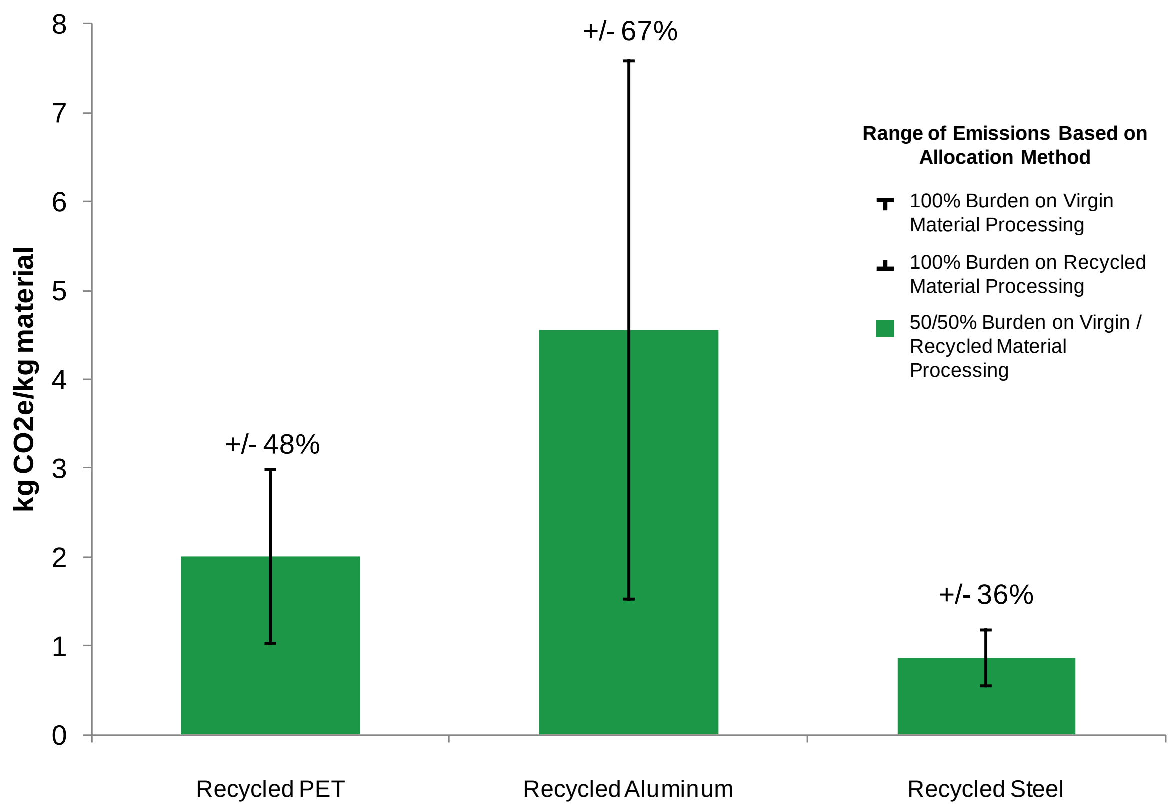

Figure 2: Allocation methods affect the emissions results for different materials

As Figure 2 shows:

- For rPET, life-cycle emissions can vary up to 48% higher than the 50/50% allocation method if the raw material inception is allocated to 100% virgin material processing, or 48% lower if allocated to 100% recycled material processing.
- For recycled aluminum, raw material inception and end-of-life emissions vary by 67% from the 50/50% allocation scenario when compared with either of the 100% allocation methods.
- For recycled steel, raw material inception and end-of-life emissions differ by 36% from the 50/50% allocation method when compared with the 100% allocation methods.

The impact of the allocation method depends on the energy intensity associated with virgin material processing and recycled material processing. The considerable difference between allocation method emissions for aluminum occurs because of the substantial difference in processing energy needed to extract virgin aluminum as compared to producing recycled aluminum. The relative impacts of the allocation method will vary, but the incentive created by the allocation method used will always be the same (i.e., 100% virgin material burden will always create the incentive to produce recyclable products).

Value Added

In choosing which open-loop recycling allocation method to apply in a product life-cycle, producers need to understand the impacts of allocation methods. If a product producer seeks to create an incentive around using a high portion of recycled material in a product, an allocation method where 100% of the raw material inception impact falls on recycled material processing could be applied in an LCA.

Conversely, if the objective is to produce a product that can be recycled at its end-of-life, then an allocation method where 100% of the raw material inception burden falls on virgin material processing may be applied.

A more conservative approach that **equally incentivizes both producers and users of recycled material is the 50/50% allocation method**. This allocation method is simple from a calculation standpoint, does not double-count credits or burdens, and is practical to apply when there is little knowledge about upstream and downstream products.

ClearCarbon uses in-house LCA expertise in coordination with our clients to:

- determine the most appropriate recycling allocation method that will accurately capture a product's life-cycle emissions;
- transparently document these assumptions; and
- present the implications of alternative methods.

By clearly presenting the influence allocation choices have on recycled and recyclable materials, ClearCarbon enables our clients to make well-informed carbon management decisions.

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[1] 80% of waste is sent to landfill and 20% is incinerated.

[2] The US-Ecoinvent Life-Cycle Inventory (LCI) database adapts the Ecoinvent 2.1 database to apply US electrical conditions for 3,952 unit processes contained in the Ecoinvent database by rerouting electricity production and distribution from European regions to electricity production and distribution. Recycled material production for rPET was modeled with Ecoinvent datasets based on industry-provided energy data. The IPCC 2007 GWP 100a v1.02 impact assessment methodology was applied to the US-Ecoinvent datasets.

[3] In calculating end-of-life burdens and credits, standard US recycling rates are assumed. Recycling rates taken from Container Recycling Institute "Wasting and Recycling Trends." Accessible from http://www. container-recycling.org/assets/pdfs/reports/2008-BMDA-conclusions.pdf. PET: 23.5%, Aluminum: 42.5%, Steel: 63.3%.