recyclable

MATERIAL ATTRIBUTE:

RECYCLABLE

How well does it predict the life cycle environmental impacts of packaging and food service ware?

A summary report from a meta-analysis by:

State of Oregon Department of Environmental Quality

Franklin Associates, a Division of Eastern Research Group

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CONTACTS:

Minal Mistry, minal.mistry@state.or.us
David Allaway, allaway.david@deq.state.or.us

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Summary Highlights - *Recyclable*

Many businesses, governments and individuals are designing or purchasing packaging and food service ware to be *recyclable* as a means to reduce environmental impacts and conserve resources.[1] This is based on assumptions about the environmental benefits – and burdens – of *recyclable* packaging and food service ware when compared against alternatives.

Recycling – the act of recovering discarded materials and using them as secondary feedstock to be made into new products – is typically beneficial when compared against its alternatives (such as landfilling). However, *recyclability* introduces a much larger scope of issues, including the raw materials used to make *recyclable* feedstocks and the environmental impacts of those upstream processes. Just as not all materials are equally *recyclable*, different materials also have different overall environmental impacts. Do readily *recyclable* materials tend to also result in lower environmental impacts? And if not, does the benefit of actually recycling them obviate whatever higher impacts may be associated with their production?

DEQ reviewed literature from the last 18 years of environmental life cycle assessments that included *recyclable* packaging and food service ware. Over 960 comparisons involving *recyclable* packaging and over 460 comparisons for food service ware were found.

Comparisons of *recyclable* and non- (or less-) recyclable packaging (excluding food service ware), revealed no consistent correlation between the attribute of *recyclability* and reductions in life cycle environmental impacts. Often a *recyclable* packaging format will reduce some environmental impacts but increase others. In some cases, *recyclable* packaging consistently leads to higher impacts. So when choosing between packages made of different materials, *recyclability* is a poor predictor of environmental benefits and as such, should be avoided.

Food service ware showed a different pattern, with *recyclable* food service items (such as polypropylene drink cups) often showing lower environmental impacts than non-recyclable alternatives. This finding is limited by a small data set (only two studies) and ignores several practical limitations. *Recyclable* food service ware is often of low value to recyclers and may be contaminated with leftover food, which makes it unacceptable for recycling or more difficult to recycle. This limitation that was not reflected in the analytical results found in the literature.

As such, DEQ recommends against using *recyclable* as a primary design or procurement criteria for packaging or food service ware. Rather than using this attribute, producers should instead use life cycle assessment as part of a more holistic evaluation of environmental impacts. For businesses that want to advance the use of *recyclable* packaging, the focus needs to shift to using feedstocks that have lower environmental impacts.

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[1] Recognizing that recycling is a not a common avenue for food service ware, this research nonetheless reports findings from the literature review that examines recycling as an end of life treatment for select food service ware items, such as cups used for cold and hot drinks.

Background

Every day we encounter – and make decisions about – a wide variety of manmade materials. Packaging is a category of materials that is ubiquitous in our culture. We come in contact with packaging throughout our day. Most of the products we purchase are protected in packaging (such as thin films or containers) and often, the food we consume is also packaged.

Recyclable materials are those that have the potential to be recovered from the solid waste stream and turned into secondary feedstock to be made into a new product at the end of a prior product's useful life.

At times, we make individual purchasing choices based on characteristics of the packaging. It is common to use popular material attributes to make buying decisions, especially when we assume the attribute will lead to lower detrimental environmental impacts. Many governments similarly promote the use of these attributes. Businesses use them as well, often in response to public opinion or government mandates.

One such popular packaging attribute is *recyclable*[2]. It is commonly assumed that if a package is made to be *recyclable* its environmental footprint will be smaller than if it was made from a material that is not *recyclable*. Recycling packaging materials (such as paper, metal, glass and plastic) generally results in lower environmental impacts (compared to landfilling), so it may seem reasonable to assume that *recyclable* materials are similarly beneficial. But is this assumption valid?

It is widely believed that common packaging attributes such as being made from recycled or biobased content means the package has lower adverse environmental impacts relative to options without the same attribute. Similarly, packaging claiming to be recyclable or compostable is widely assumed to be environmentally preferable relative to non-recyclable or non-compostable alternatives. This research evaluates the validity of these assumptions and the ability of these four packaging attributes to predict better overall environmental outcomes.

Recyclable packaging may be made from a wide variety of different feedstocks, and with different industrial processes, than non-recyclable alternatives. Given differences in the physical characteristics of these materials, different amounts of materials may also be required. Harmful environmental impacts associated with sourcing feedstocks and upstream production practices may also be different. These upstream practices and impacts may be less visible to the public,

[2] *Recyclability* is the potential for a material to be recovered from the solid waste stream and turned into secondary feedstock to be made into a new product at the end of a prior product's useful life. Being *recyclable* is not the same as being recycled. Recycling is an end of life treatment route that produces useable secondary or recycled materials that can be used to make a new product.

but are no less relevant – and indeed, are often greater in overall impact – than the benefits of recycling and landfill avoidance.

The Oregon Department of Environmental Quality worked with Franklin Associates to evaluate how well popular environmental attributes for packaging and food service ware (FSW) predict environmental outcomes, and under what conditions. The four attributes examined are *recycled content, biobased* or *renewable material, recyclable* and *compostable*. This summary focuses on the *recyclable* attribute, and describes the findings from the meta-analysis of available research from the past two decades to determine how well the attribute *recyclable* correlates with reduced environmental impacts for packaging including food service ware.

Introduction

Packaging is often targeted in sustainable materials management strategies because it is generally disposed of after a single use and because of the large quantities of packaging entering the municipal solid waste (MSW) stream each year. According to the U.S. EPA's Advancing Sustainable Materials Management: 2015 Fact Sheet, Americans generated 78 million tons of packaging waste, comprising 30 percent of total MSW generation by weight. Even with a packaging recycling rate of 53 percent, packaging still represents 21 percent of the MSW sent to landfills or incinerated.

Public concern and policy often focuses on the impacts of packaging at the time of its disposal when it becomes waste. However, packaging affects the environment in many other ways. The production and transport of packaging consumes raw materials and energy which in turn generates pollution. In addition, the disposal of packaging in landfills or by incineration represents a loss of the resources they contain as well as further pollution. Packaging that is not correctly managed at end of life may end up in rivers or oceans, with negative impacts in freshwater and marine environments that are not yet fully understood, regardless of it being *recyclable*[3]. While packaging plays an important role in minimizing waste by preventing damage to products, improvements in packaging design and informed choices of packaging material have the potential to considerably lower environmental impacts of packaging.

When considering the benefits of *recyclable* packaging and FSW, it is important to represent accurately the portion of the material that is recycled. A few key factors play in to actual recovery rates of materials. The availability of collection services and drop off locations for *recyclable* material is the first consideration that determines the fraction of the material that may ultimately be diverted from landfilling or incineration. Once collected, materials are transported, sorted, cleaned, and reprocessed, and sold to manufacturers who use them to make new products. Some portion of the collected material can be lost in these steps, decreasing the fraction recycled. The benefits of *recyclable* packaging and FSW ultimately depend on the

[3] It is important to note that the link between *recyclable* packaging and marine litter is tenuous even though some organizations claim that making all packaging to be recyclable and then collecting it for recycling will reduce marine debris. The reality is complex, and related to how and where the recycling actually occurs, and also whether recycling collection reduces litter in the first place. In most parts of the United States the collection and processing of both landfill-bound waste and recyclables are well managed so that direct contribution to waterways is limited. However, if collected recyclables are exported to countries with underdeveloped infrastructure the story may be very different.

market for recycled material. The recovered material must actually be used by industry to make new products else the effort is in vain. The benefits depend not only on the material being used, but also how it is used, and more specifically, what other material (and with what other impacts) it is replacing.

The life cycle of packaging

The life cycle of packaging, as shown in Figure 1, includes raw material extraction, primary material production, packaging production, distribution, use, and end-of-life treatments consisting of recycling, reuse, composting or disposal. Litter refers to uncollected material releases to the environment produced from packaging, whether on land or water. The environmental impacts of many of these activities can be estimated using a quantitative method called Life Cycle Assessment or LCA[4].

Often comparative LCAs omit parts of the life cycle that are identical across comparisons. For example, when studying the impacts associated with different packaging options to package soft drinks, it isn't necessary to include the soft drink production steps (unless the soft drinks themselves are also being studied). For this reason, the environmental burdens related to the product contained in the package may or may not be included in LCAs examining packaging. This will affect the percent changes in impact metrics associated with packaging and food service ware scenarios. In most cases, the product itself contributes more to the overall life cycle impacts than the packaging.

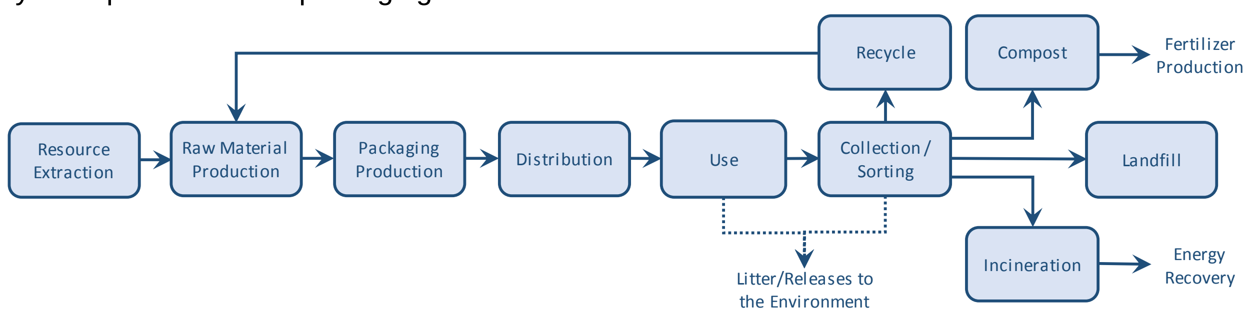

FIGURE 1 LIFE CYCLE OF SINGLE USE PACKAGING AND FOOD SERVICE WARE

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[4] Life cycle assessment or LCA is a systematic approach to estimating environmental burdens associated with drawing resources from the Earth, transforming them into usable technical materials, making items from them, distributing the items, using them and ultimately dealing with the remaining solid waste via different waste treatment and recycling activities. LCA is governed by several international standards that provide guidance about various aspects of accounting for the different processing and materials needed to make, use, and treat products at end of life. LCA is a foundational analytical approach to estimate environmental burdens of industrial systems and allows fair comparisons between different functionally equivalent systems. To learn more see: http://www.lcatextbook.com/.

How are attributes and life cycle impacts connected?

Material attributes are used as a simple way to communicate the characteristic of a material or product, and often also to convey some sort of environmental benefit. Material attributes are commonly used as design criteria and for product marketing and differentiation. While material attributes are related to the specific product or material, often marketing and purchasing decisions assume that these material attributes correlate with environmental goodness. Of course, the environment is affected by *all* activities related to the manufacturing, using and discarding of products. Some of these life cycle impacts can have local implications such as pollution in waterways or to soil, while others can affect wider areas or the whole planet such as greenhouse gas emissions. Figure 2 illustrates some common attributes and life cycle impacts.

The product categories and attributes included in the study were selected based on their role in many sustainable materials management strategies and the availability of sufficient LCA studies. Two product categories - packaging and food service ware - were evaluated against four attributes: *recycled content, biobased, recyclable* and *compostable.*

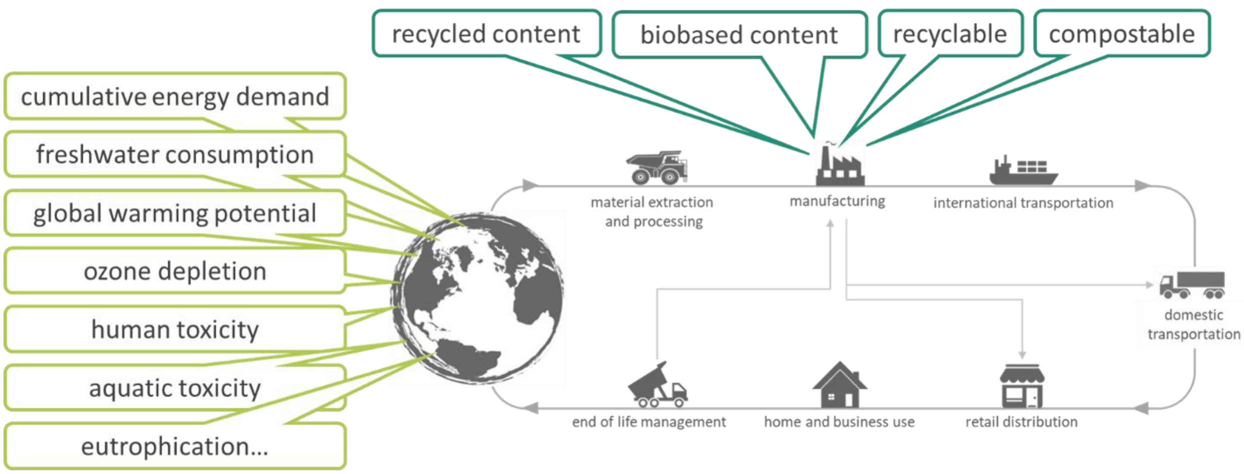

FIGURE 2 MATERIAL ATTRIBUTES AND LIFE CYCLE IMPACTS

Research approach

Packaging has been studied extensively by life cycle assessment. In fact, some of the first LCA studies performed focused on packaging, when almost 50 years ago companies like The Coca-Cola Company were evaluating the then novel material called plastic to deliver their products. Since then, many new formats and materials have been used for making packaging and food service ware, and many different scenarios have been independently studied by different researchers around the world. In this study we employed an approach called meta-analysis, whereby we collected existing peer-reviewed and published studies from 2000-2017, and gleaned comparisons relevant to the four attributes of interest.

While it is common practice to represent environmental outcomes in terms of climate change and greenhouse gas emissions, LCA is capable of simultaneously tabulating estimates of many other impact areas. These include indicators of human health and ecotoxicity, and effects on water systems such as eutrophication and acidification. Resource consumption measures such as water, energy and mineral consumption can also be included. This makes LCA a very effective tool to evaluate tradeoffs and hotspots – areas or steps in the life cycle of a system where disproportionately high environmental impacts occur. This broader perspective allows us to make informed choices for materials and design criteria to help optimize packaging and product systems. Some categories of impacts – such as marine debris[5] and human toxicological impacts associated with product use – are not currently evaluated well in LCA studies. Efforts are underway to better understand which marine debris related impacts could be evaluated well via LCA, including the data and methodological needs. Nevertheless, the inclusion of multiple other types of impact categories and consideration of all (or multiple) life cycle stages makes LCA a more holistic evaluation framework than other methods. In this research we documented all the impact or results categories represented in the literature to understand the overall picture in the past two decades of packaging analyses.

To maintain consistency, we evaluated the results within each study independently, generating intra-study comparisons based on the same background assumptions including the system boundary being assessed, energy mix and fuels used, end-of-life treatment, etc. This is critical to making apples to apples comparisons based on functional equivalency[6]. For example, our assessment compared a package with a given attribute (in this case *recyclable*) with a functionally-equivalent package that was not *recyclable*. This basic approach gave us comparison ratios for all the attributes. It also allowed us to chart a range of five levels between

Ratio = Impact result with attribute A ÷ Impact result without attribute A		
Category	Ratio	Interpretation
Meaningfully Lower Life Cycle Impact	<0.75	Suggests the attribute is potentially a good Indicator of environmental performance
Marginally Lower Life Cycle Impact	≥0.75 and <1.0	Inconclusive
No difference	1.0	No difference
Marginally Higher Life Cycle Impact	>1.0 and ≤1.25	Inconclusive
Meaningfully Higher Life Cycle Impact	>1.25	Attribute is potentially not a good indicator of environmental performance
The lower the ratio value, the lower the environmental impact of the material(s) being evaluated (*with* the attribute) compared to the equivalent material *without* the attribute.		

TABLE 1 MATERIAL ATTRIBUTE EVALUATION FRAMEWORK

[5] It is critical to acknowledge that while marine debris is spoken of as an "impact" in the common vernacular, it is not an impact category *per se.* This is because impacts of litter and pollution on the marine (or freshwater) environment can occur in a variety of ways including implications to the water chemistry, trophic variations in the water column, effects on filter feeders, herbivores and predators, bioaccumulation, changes to the benthic region, interaction of microorganism with micro plastics and more. Each of these impacts need specific methodological approaches to capture appropriate parameters, data requirements, validation and assessment. The marine debris issue will take time to untangle.

[6] Functional equivalence refers to the idea of comparing two or more things that serve as substitutes for each other to fulfill the function of interest. In LCA the functional unit establishes the basis for comparisons such that the assessment is apples to apples, or for like function.

“meaningfully lower life cycle impacts” and “meaningfully higher life cycle impacts” shown in Table 1.

The conclusions presented in this summary for *recyclable* packaging and food service ware are drawn solely on the best case (meaningfully lower life cycle impacts) and the worst case (meaningfully higher life cycle impacts) – the dark green and dark red data points only (Table 1). This simple framework allowed us to objectively answer the research questions below.

Among the four attributes, *recyclable* was perhaps the most difficult to fit into this evaluation framework. It is fairly common to imply environmental preferentiality by identifying a package as *recyclable,* but evaluating the actual environmental impacts and benefits is more complicated. Not all packages that are *recyclable* are fully recycled. Further, comparisons between *recyclable* and non-recyclable packaging is complicated by nuances in the definition of *recyclable.* The *recyclability* of a package imbues it with an aspirational characteristic of potentially being recycled following appropriate collection and sorting. However, *recyclable* packaging requires the existence of local infrastructure and access to collection services to make it feasible to collect and process post-consumer packaging from the municipal solid waste stream. Materials may be technically *recyclable* and yet have very limited or no practical recycling opportunities due to unfavorable economics. It is also possible that a packaging format is considered *recyclable* in one community but not in another due to the lack of adequate collection and sorting services, and processing capabilities.

In this summary, comparisons between *recyclable* and not *recyclable* packages actually consist of two different types of comparisons: 1) packages that are commonly recycled vs. ones that are never (or rarely) recycled (for example, cardboard boxes vs. plastic-paper mailing pouches); and 2) packages that are recycled at high rates vs. those that are recycled at lower rates (for example, aluminum cans vs. aseptic cartons). In this context *recyclable* vs. not *recyclable* is short-hand for “more readily *recyclable*” vs. “less readily or not *recyclable.*”

Two additional methodological issues are also worth mentioning, involving allocation and displacement. Within life cycle assessment, there are several different methods of accounting for the environmental impacts and benefits of recycling, and specifically, the avoided impacts when recycled materials substitute for virgin resources. Different accounting methods can differ in how they allocate those impacts and benefits between different products that share the same material (due to recycling). When a material is recycled (from one product or package into another), some studies assign all such benefit to the product or package that was recycled (the source), while others assign all of the benefit to the product or package that subsequently used the recycled material, and others share benefits between the two systems either 50/50 or based on material-specific economic considerations. The outcome is that not all studies that compare *recyclable* and non-recyclable materials evaluate the benefit of recycling *recyclable* materials consistently or in a manner that illustrates the full benefits of recycling. While the results from all relevant studies are included in DEQ’s technical report, this summary document only shows results from studies that assign the full benefits of recycling to *recyclable* packaging.[7] As such, by excluding results from studies that use any other allocation method (such as a standard that prefers *recycled content*), the findings below may represent overly-optimistic or favorable results

[7] The technical report by Franklin Associates refers to this as “0/100” or “avoided burden” allocation.

for *recyclable* packaging and food service ware. Additional details regarding allocation methods are included in the technical report.

In addition, it is often assumed – by both recycling professionals and life cycle analysts – that when something is recycled, something equal in quantity is displaced, or not produced. However, that is not always the case, particularly with growing consumption and expanding markets. The provision to industry of lower-cost recycled materials (provided by recycling collection programs) can increase overall supply, which can drive down commodity costs. This can lead to a net increase in total material use, so the provision of recycled materials do not always displace virgin feedstocks on a one-for-one basis.[8]

Research Questions

Since the material attributes *recycled content*, *biobased*, *recyclable* and *compostable* are commonly used to infer environmental preference, the main questions are:

1. How well do these material attributes predict positive environmental outcomes for packaging and food service ware?
2. Under what conditions are environmental impacts reduced?

Research outcomes

Packaging

The research uncovered 18 studies offering 960 comparisons for the attribute of *recyclability*. Figure 3 shows the collective body of knowledge identified for the attribute *recyclable* for packaging (excluding food service ware). The chart shows four pieces of information (for detailed explanations see the technical report).

1. The materials represented in the literature.
2. The scope variations represented in the studies that were included in the final review.
3. The system boundaries, or the life cycle stages the researchers included.
4. The result categories[9] or impacts.

[8] Roland Geyer, Brandon Kuczenski, Trevor Zink and Ashley Henderson, "Common Misconceptions about Recycling", Journal of Industrial Ecology, 2015.
[9] Note: Not all categories found in the studies represent impacts. Some such as mineral depletion are indicators and not impacts *per se*.

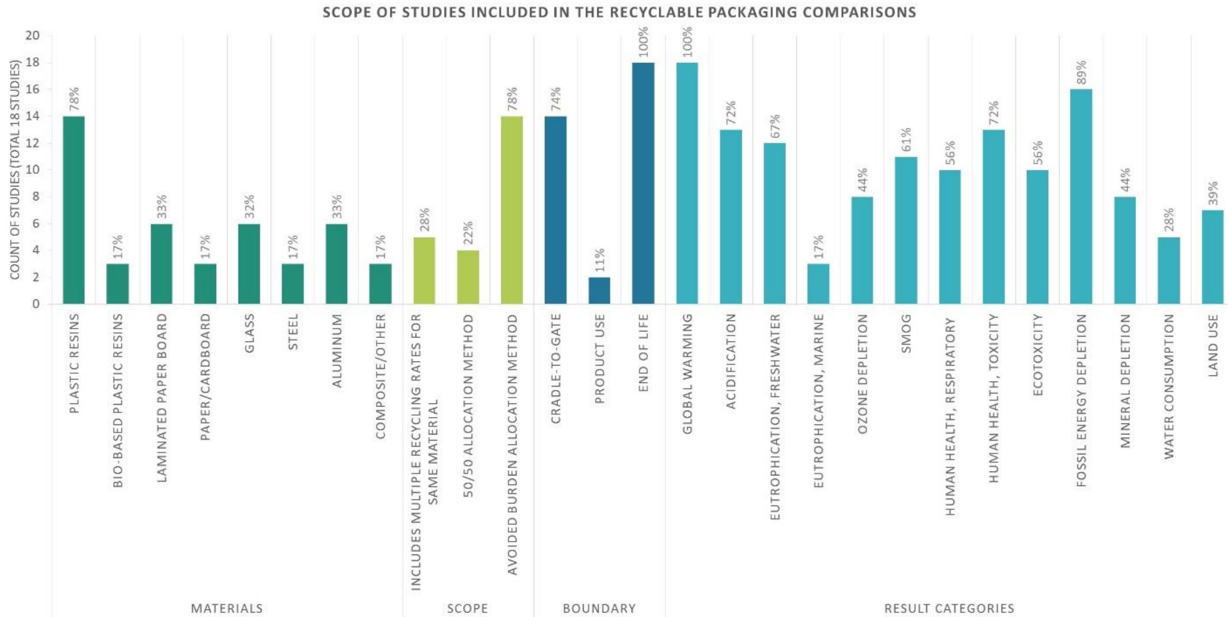

FIGURE 3 SCOPE OF RESEARCH FOR *RECYCLABLE* PACKAGING (PERCENT VALUES REPRESENT FREQUENCY OF THE CATEGORY WITHIN STUDIES INCLUDED IN THE RESEARCH)

The full spectrum of materials typically used in packaging applications was represented in the literature, with plastics being the most frequently studied category of materials. This is shown in Figure 3, which excludes food service ware. Similarly, the literature included an assortment of results from different impact categories.

Packaging findings (excluding food service ware)

RECYCLABILITY OF A PACKAGE IS A POOR INDICATOR OF ENVIRONMENTAL IMPACTS

Materials are not the same in terms of their life cycle impacts. Yet, it is commonly assumed that given the choice between a *recyclable* package and a non-recyclable package, the *recyclable* package is better for the environment. Figure 4 is an example of two different types of packaging, one *recyclable*, the other not. Popular wisdom might imply that the *recyclable* glass bottle has lower negative environmental impacts. However, research over the past two decades indicates that this simplified evaluation framework is unwise. *Recyclability* as a sole criterion for selecting packaging material is a poor predictor of environmental impacts. This is because material type, quantity, and packaging design significantly affect environmental burdens that cannot be fully recouped even if the packaging is recycled. Furthermore, not all products that are technically *recyclable* are actually recycled in practice.

FIGURE 4 DIFFERENT PACKAGING, ONE *RECYCLABLE*, THE OTHER NOT

The general trend from over 520 relevant comparisons revealed that the *recyclability* attribute is not a consistently reliable predictor of lower environmental impacts (Figure 5a). In some instances it results in lower impacts (green); in a slightly greater number of instances it results in higher negative impacts (red). When comparing *recyclable* packaging that is recycled against packaging of a different material that is recycled at a lower rate (i.e., limited by access to collection services or recycling services) or is not *recyclable* (i.e., limited by inherent material proprieties and/or recycling technology), the results are mixed (Figure 5b).[10]

Material type and weight appears to be more important than recyclability in determining life cycle environmental burdens of a package design.

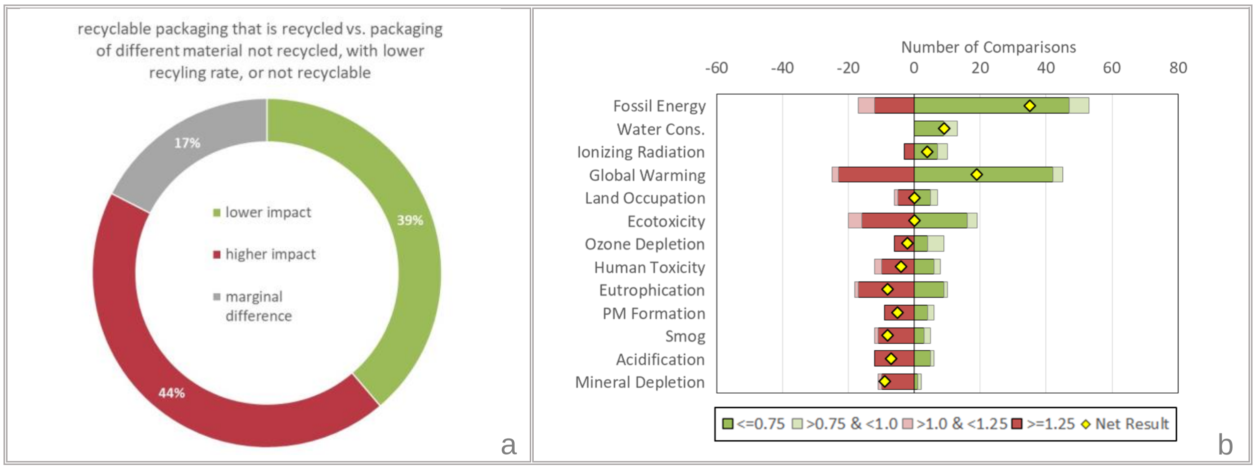

FIGURE 5 SUMMARY OF COMPARISONS FOR *RECYCLABLE* VERSUS NON-RECYCLABLE (ALSO MORE *RECYCLABLE* VERSUS LESS *RECYCLABLE*) PACKAGING MADE OF DIFFERENT MATERIALS: (A) SUMMARY OF COMPARISONS ACROSS ALL IMPACT CATEGORIES, (B) SUMMARY OF COMPARISONS FOR EACH REPORTED IMPACT CATEGORY[11]

An example of functionally equivalent packaging made from different materials are steel cans, which are recycled at a higher rate (more *recyclable*) and aseptic cartons, which are recycled at a lower rate (less *recyclable*). The steel cans always result in higher environmental impacts in this scenario due to the extraction and production burdens of making steel sheet and then cans. Other cases yield mixed results depending on the specific comparisons being made. These include comparisons between *recyclable* materials (steel, glass, aseptic carton, and HDPE packaging) and non-recyclable materials (laminate packaging). Some favorable comparisons for

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[10] Note: chart 5b represents only the studies that used the avoided burden or 0/100 method discussed previously.

[11] Ratios reflect the result for the *recyclable* packaging divided by the result for the functionally equivalent non-recyclable packaging. Thus ratios <1 indicate *recyclable* packaging performs better and are shown in the figure in green as the positive number of comparisons while ratios >1 indicates *recyclable* packaging performs worse and are shown in the figure in red as the negative number of comparisons. Dark green and dark red represent counts of comparisons with ratios <0.75 and >1.25 respectively and are considered meaningful.

recyclable packaging, when compared to non-recyclable alternatives, were between *recyclable* carton-based packaging and non-recyclable laminate pouches, where the carton packaging performed better for all impact categories considered. However, the comparisons between rigid *recyclable* steel, glass, and plastic containers vs. flexible laminate packaging tended to favor the lighter laminate materials despite the high recycling rates of glass and steel.

Food service ware findings

Materials, impact areas and research parameters found in the literature are reflected in Figure 6. The chart shows four pieces of information (for detailed explanations see the technical report).

1. The materials represented in the literature.
2. The scope variations represented in the studies that were included in the final review.
3. The system boundaries, or the life cycle stages the researchers included.
4. The result categories[12] or impacts.

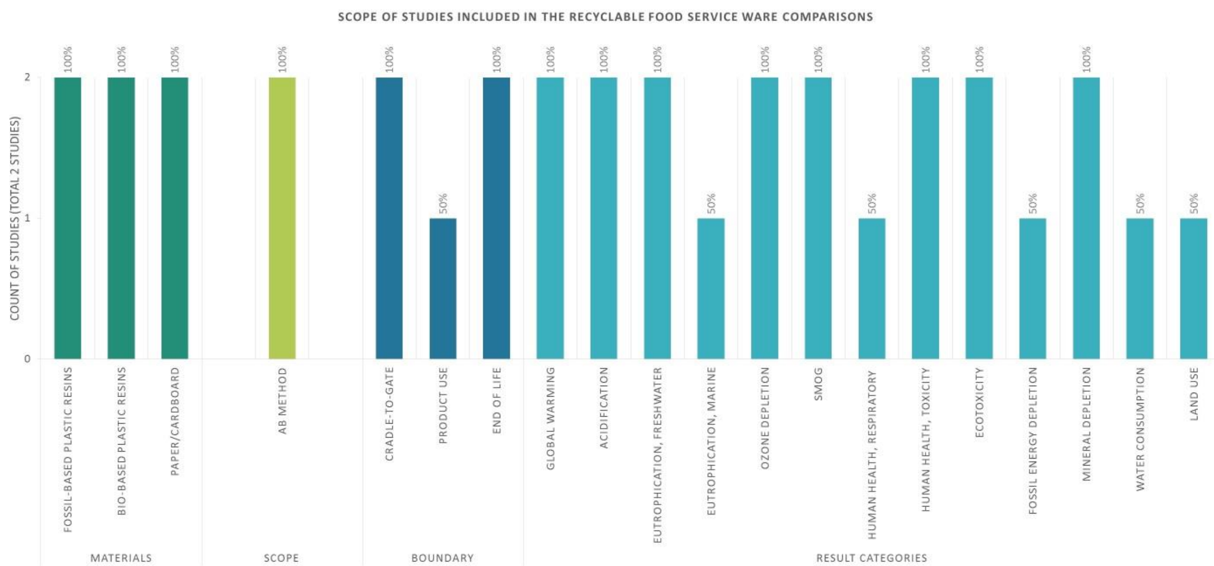

FIGURE 6 SCOPE OF RESEARCH FOR *RECYCLABLE* FOOD SERVICE WARE (PERCENT VALUES REPRESENT FREQUENCY OF THE CATEGORY WITHIN STUDIES INCLUDED IN THE RESEARCH)

Only two relevant studies were identified, providing over 460 comparisons for *recyclable* food service ware. Materials included in both studies were polystyrene, polypropylene, polylactic acid (PLA) and paper.

As with the results for *recyclable* packaging, the definition for *recyclable* FSW requires the existence of infrastructure to collect and reprocess post-consumer materials. Thus, it is possible that a packaging format which is *recyclable* in one jurisdiction may not be considered *recyclable* in another due to the lack of adequate collection services and/or processing facilities. This

[12] Note: Not all categories found in the studies represent impacts. Some such as mineral depletion are indicators and not impacts *per se*.

makes generalizing comparisons between *recyclable* and non-recyclable FSW challenging.[13] Therefore, and also due to the limited number of FSW materials included in the literature, this summary report limits discussion to comparisons between FSW that is *recyclable* and recycled at its end of life, and another FSW option that is also *recyclable*, but not recycled, or recycled at a lower rate. Additionally, the literature does not consider the impacts of food contamination on recycling *recyclable* food service ware. These impacts may include added energy or water required to wash food service ware, as well as higher levels of process loss (discards) in manufacturing processes.

RECYCLABLE FOOD SERVICE WARE ITEMS ARE PREFERABLE TO NON-RECYCLABLE ONES – IF THEY ARE ACTUALLY RECYCLED

Considering nearly 460 comparisons, *recyclable* food service ware that is recycled is preferable to different materials that are also *recyclable* but which are recycled at a lower rate (or not at all). Figure 7 shows that 56% of the comparisons yielded lower negative environmental impacts for more *recyclable* food service ware. It is important to consider that these comparisons are based on the potential for a material to be recycled. Often, used food service ware is contaminated with remnants of food rendering it unrecyclable. The literature results do not reflect the actual reality, and hence the findings must be considered in that context and are likely to be overly favorable.

Figure 7 shows comparisons between *recyclable* FSW recycled at the end of life with FSW of different materials that is not recycled or recycled at a lower rate at end of life. *Recyclable* FSW that is recycled or which has a higher recycling rate at end of life is frequently found to have lower impacts across all impact categories. *Recyclable* products compared include cups and dishes made of polystyrene and polypropylene.

Recyclable food service ware appears to be preferable to non-recyclable (or not recycled) food service ware.

[13] Recognizing that recycling is a not a common avenue for food contaminated food service ware, this research nonetheless reports findings from the literature review that examines recycling as an end of life treatment for food service ware. Some examples include cups used for cold and hot drinks.

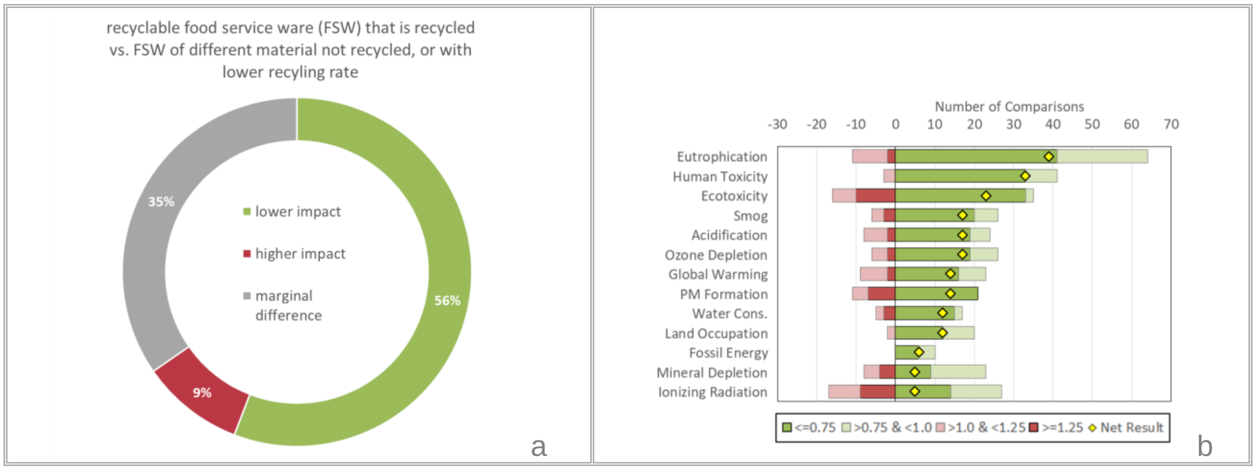

FIGURE 7 SUMMARY OF COMPARISONS FOR FSW PRODUCTS THAT ARE RECYCLED VS. DIFFERENT MATERIALS NOT RECYCLED OR RECYCLED AT A LOWER RATE: (A) SUMMARY OF COMPARISONS ACROSS ALL IMPACT CATEGORIES, (B) SUMMARY OF COMPARISONS FOR EACH REPORTED IMPACT CATEGORY (SEE FOOTNOTE 11)

Again, the studies included in Figure 7 do not explicitly mention food contamination when considering the recycling rates of the analyzed products. Since contamination from food can impact the rate at which some FSW items are accepted for recycling, these estimates should be considered a best-case scenario for recycling these items. It should also be noted that because of the low value (and volume) of some FSW and potential for contamination, few recycling processors and end-users currently are willing to accept FSW. The primary material (such as paper or polypropylene) may be *recyclable*, but most collection programs do not currently accept it in these formats.

The results for the comparisons for *recyclable* FSW products differ from the results for *recyclable* packaging, which showed mixed results overall (see Figure 5). This is primarily due to differences in the materials used for food service ware versus packaging. The unfavorable results for *recyclable* packaging were mainly comparisons of glass and metals with lighter materials such as plastics and aseptic cartons. Glass and metal are generally not used for disposable FSW products, and thus there is less variability in the production impacts and avoided burdens from recycling in the FSW comparisons.

Other considerations related to *recyclable* packaging and food service ware

It should be noted that *recyclability* has the potential to be environmentally beneficial in other aspects beyond the impact categories compared in this review. For example, in communities with a bottle deposit system on plastic bottles, a financial incentive exists to both separate covered containers for recycling as well as to pick up any such containers that may be littered, for example on beaches and roadsides. This may reduce the amount of plastics that end up in marine environments. However, for the most part, plastics recycling (at least in the U.S.) serves to divert plastic waste from landfills or incinerators, not from littering. In any event, marine debris impacts have not traditionally been measured by LCA studies and this is because impact assessment methodologies do not currently exist (though nascent efforts[14] are in progress). The same limitation applies to human toxicological impacts that may occur when food is in contact with food service ware. For those reasons, these emerging aspects are not included in the scope of this review. The marine environment, however, is impacted by other emissions measures tracked in this study. These include global climate change, acidification (an outcome of greenhouse gas emissions), and eutrophication (nutrient loading, particularly from agricultural runoff).

For recycling to provide environmental benefits, it needs to be performed responsibly across the entire supply chain. For example, requirements are needed to responsibly manage non-recyclable contaminants. Lacking those, bales of mixed plastics (including non-recyclable materials) should not be shipped to countries that lack the infrastructure to safely manage them.

Summary

Two important conclusions can be drawn from the global literature review on the *recyclability* of packaging and food service ware:

1. *Recyclability* by itself appears to be an unreliable predictor of lower impact packaging, therefore, attention to the life cycle impacts of the materials used is critical.
2. The literature on *recyclable* food service ware is limited in both number of studies and a general failure to characterize real-world scenarios. Specifically, the literature does not consider the impacts of food contamination on recycling *recyclable* food service ware. These impacts may include added energy or water required to wash food service ware, as well as higher levels of process loss (discards) in manufacturing processes. The finding of the literature – that *recyclable* food service ware appears to be preferable to non-recyclable food service ware – should be understood in that context.

Results of all comparisons between different materials across impact categories are mixed. This suggest that the type of packaging material may be more important in determining a package's environmental footprint than its recyclability.

[14] Medellin Declaration on Marine Litter in Life Cycle Assessment and Management - https://fslci.org/medellindeclaration/

Discussion and Recommendations

Package Design

There are significant movements to make packaging *recyclable* or *compostable*. Designing for *recyclability* fits into a common practice of Design for Recovery, sometimes referred to as DfR. *Recyclable* packaging is marketed as environmentally sound and many individual and institutional buying decisions are made based on this attribute. Many businesses, advocacy groups, and governments support this agenda, shaping goals and measures around the *recyclability* of packaging. Such goals are based on some simple premises that may sound reasonable. They include: 1) recycling *recyclable* packaging can offset most environmental impacts of virgin production; 2) new or additional resource extraction can be avoided if material loops are closed, and 3) marine debris could be reduced or curtailed if *recyclable* packaging is recycled.

While recyclability and recycling are important activities for materials management, recycling alone cannot entirely offset the impacts of production. When selecting packaging materials, the type of material may be more important in determining a package's environmental footprint than its recyclability.

Our research conclusions, based primarily on life cycle assessments over the past 18 years, shows that these premises are not appropriate for the goals of a) reducing environmental impacts, b) conserving resources, and c) preventing materials from entering the marine environment. This is because first, we know that materials are inherently different in terms of their life cycle environmental burdens. While *recyclability* and recycling are important, recycling alone cannot entirely offset the impacts of production, which are typically far greater than those of end-of-life management. Second, materials degrade over time in terms of quantity and quality. Their performance is diminished making the concept of infinite closed loops akin to a perpetual motion machine – breaking the laws of physics and ignoring entropy or the gradual decline of materials into disorder. Third, the issue of marine debris, and the flow of materials into waterways and oceans, is complex. The bulk of land-based marine plastics originates from Southeast Asia. While most Western nations have strong collection programs, they have historically exported some of their materials to Asia for processing, potentially contributing to the problem.

Several actions can be implemented via the packaging design process to address these issues:

1. Establish company-wide or portfolio-level sustainability measurement criteria for packaging.[15] The measurement criteria should be based on an assessment of impacts across the full life cycle of the packaging.

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[15] For guidance see: Global Protocol on Packaging Sustainability 2.0 https://www.theconsumergoodsforum.com/wp-content/uploads/2017/11/CGF-Global-Protocol-on-Packaging.pdf

2. Optimize packaging design by prioritizing the use of materials with the lowest life cycle impact profile[16], then consider the viable end-of-life fates to optimize recovery.[17]
3. Avoid setting or demanding extreme commitments or targets for *recyclability* (i.e., all packaging must be *recyclable* by a certain date). Rather consider life cycle burdens of different packaging format options. At this time the lowest inherent environmental burdens may be associated with non- or less-recyclable packaging formats simply because they use fewer materials.
4. Use *recyclable* terminology appropriately. *Recyclable* is a material attribute that describes the potential of being recycled and should be differentiated from the end-of-life action of collecting materials for recycling. Most materials are technically *recyclable*, yet the *recyclable* designation should be reserved for materials and packaging forms that are realistically recycled, otherwise they contribute to contamination.
5. If a base material has been chosen, and the designer is no longer considering competing materials, consider actions that will improve the *recyclability* of the package. For example, consider the recommendations of the Association of Plastic Recyclers' Design Guide for Plastics Recyclability[18]. Changes that involve increasing the use of material or changing associated materials (closures, wraps) to improve *recyclability* should be considered through the lens of both *recyclability* and life cycle impacts.
6. While not within the narrow realm of design, brand owners and material producers should also support – including the provision of financial support – waste collection, processing and handling systems, and public outreach, that advance both recycling, proper waste disposal, and other solutions to the problem of marine debris (such as reduction in packaging altogether, as well as effective waste collection and containment).

[16] Various off-the-shelf Design for Environment (DfE) tools exist specifically for packaging design:
1. EcoImpact (formerly Comparative Packaging Assessment or COMPASS) https://ecoimpact.trayak.com/WebLca/dist/#/landing
2. PIQET http://piqet.com/
3. PackageSmart: https://www.earthshiftglobal.com/software/packagesmart
4. GaBi Envision Packaging calculator: https://www.thinkstep.com/

[17] Such an approach can be loosely referred to as Design for Environment (DfE). In contrast to the aforementioned Design for Recovery (DfR), DfE attempts to optimize the entire life cycle of the product and package not just select stages such as end of life treatment such as recycling. Various software tools and design guidance exist for packaging to implement DfE.

[18] APR Design Guide: https://www.plasticsrecycling.org/apr-design-guide/apr-design-guide-home

Institutional and Corporate Purchasing

Material attributes are commonly used in procurement decisions as a guide for environmentally preferable purchasing. *Recyclable* packaging is often given preference based on statutes or recycling goals, with the assumption that if all packaging is *recyclable*, then recovery or disposal avoidance targets can be met via proper end-of-life management. But as described earlier, *recyclability* and environmental outcomes do not correlate well. Therefore, purchasing solely based on the *recyclability* of the package can lead to the unintended consequence of increasing environmental impacts. The following recommendations should be considered:

1. For packaging materials and FSW, *recyclability* should not be used as the determining factor for product selection as it is an unreliable predictor of reduced environmental impacts across different materials.
2. Instead, purchasers could include specific environmental impacts, such as carbon footprint, as purchasing criteria and prioritize procurement to reduce those impacts.
3. Ask vendors to provide information on the life cycle environmental impacts of their products, possibly through an environmental product declaration, and use those results to inform product selection. Although product environmental assessments are not commonly available (at present), they are becoming much more common, and the inquiry process may nudge more manufacturers into re-evaluating their product design and ultimately affect the market.
4. If *recyclability* is used as part of a selection process, understand what is actually collected and processed for recycling in your area. A *recyclable* item is only as good as the available collection services, processing technology and secondary markets.
5. Evaluate and consider reusable FSW options as appropriate based on environmental performance.
6. For product procurement that is shipped in variety of packaging, consider specifying a narrower set of packaging options to optimize reduction of impacts or collection.

Marketing

Although a principle function of packaging is to protect the product so that it is delivered from the manufacturing facility to the customer, packaging is also used as a marketing tool. Brand image is often tied to packaging formats, as is shelf appeal, or the ability of the package to grab the attention of the buyer on the retail shelf. Often design choices are driven by the desire of branding and marketing to satisfy the perceived customer demand. The opportunity to optimize a package for environmental outcome is often overlooked. However, the two desires need not be in conflict. Packaging design can be optimized for environmental outcomes and meet marketing desire to satisfy demand. In the packaging design realm, a robust body of work exists, such as protocols[19], design guidelines[20], and tools[21] to implement informed design

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[19] See the Global Protocol on Packaging Sustainability. https://www.theconsumergoodsforum.com/wp-content/uploads/2017/11/CGF-Global-Protocol-on-Packaging.pdf

[20] See Design Guidelines for Sustainable Packaging. https://sustainablepackaging.org/resources/design-guidelines-for-sustainable-packaging/

[21] Various off-the-shelf Design for Environment (DfE) tools exist specifically for packaging design:

1. EcoImpact (formerly Comparative Packaging Assessment or COMPASS) https://ecoimpact.trayak.com/WebLca/dist/#/landing
2. PIQET http://piqet.com/

choices that can satisfy the demand for packaging with reduced environmental impacts. The following recommendations should be considered:

1. Shift marketing claims of sustainability towards package optimization for life cycle impacts. For example: “This package optimized for lowest carbon footprint.”[22]
2. Do not make spurious or vague claims based on the attribute *recyclable* that are likely to cause a consumer to infer or misinterpret environmental superiority.
3. Avoid extreme proclamations and targets such as making all packaging *recyclable*.

Policy for end-of-life management

While recycling is often environmentally preferable, recycling and *recyclability* and not the same. *Recyclability* in general is not a reliable predictor of reduced environmental impacts of packaging. DEQ encourages policymakers, regulators and others interested in recycling to fully understand the environmental benefits – and limitations – of recycling. Over the past several decades, recycling advocates have built up a worldview and framework regarding the environmental benefits of recycling that is now widely understood and accepted. Unfortunately, key elements of and assumptions in this framework are not objectively true. DEQ recommends a review of a short 2015 article by Roland Geyer and others titled “Common Misconceptions about Recycling” for a cogent and concise exploration of these issues.[23]

A primary responsibility of policy measures for municipal solid waste management is to support the creation of usable secondary materials via recycling. A properly functioning recycling system should collect, sort and process material with the highest potential to reduce environmental impacts and to generate clean and usable recycled materials that are in demand for product and package designs. While the *recyclable* design criterion may set up packaging for end of life recovery, research clearly shows that it does not necessarily yield reduced environmental outcomes. In contrast, *recyclability* could be an asset for FSW if the products are recycled, but recycling may be limited by processing and contamination realities. In addition, making all products *recyclable* makes little practical sense unless all those recovered materials have functioning markets. Policy should:

1. Establish or use appropriate collection and processing systems based on the relative life cycle burdens of different materials. Collection policies should consider the role of producers in cooperation and collaboration for long term material stewardship.
2. Utilize the full spectrum of end-of-life treatment options (recycling, incinerating with energy capture and landfilling) to optimize environmental impacts.
3. Refrain from unrealistic policy measures such as total recycling of everything, all the time, regardless of net environmental consequences.

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3. PackageSmart: https://www.earthshiftglobal.com/software/packagesmart
4. GaBi Envision Packaging calculator: https://www.thinkstep.com/

[22] This example is a suggestion only. However, several credible material certifications exist that could be explored in this context. Examples include Green Seal, Cradle to Cradle, UL Environment etc.

[23] Roland Geyer, Brandon Kuczenski, Trevor Zink and Ashley Henderson, “Common Misconceptions about Recycling”, Journal of Industrial Ecology, 2015.

4. Establish goals that are expressed and measured in terms of environmental impacts (e.g., greenhouse gas emissions, toxicity, energy use) and consider full life cycle impacts, as opposed to tonnage-based landfill diversion or waste recovery goals. Traditional landfill diversion goals have several limitations. First, they treat prevention, reuse, recycling and composting as equals, although their environmental benefits are different. Second, they are insensitive to the upstream impacts of waste-focused policies (such as requiring materials to be *recyclable* without considering life cycle impacts). Third, they can inadvertently act to prioritize landfill avoidance above higher-order environmental goals, such as climate stability or ocean protection.
5. Ensure that recycling is performed responsibly across the entire supply chain, for example, not shipping bales of mixed plastics (containing non-recyclable plastics) to countries that lack infrastructure and requirements to responsibly manage non-recyclable contaminants.