recycled

MATERIAL ATTRIBUTE:

RECYCLED CONTENT

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

State of Oregon
DEQ Department of Environmental Quality

November 2018

CITE AS

Mistry M, Allaway D, Canepa P, Rivin J. Material Attribute: RECYCLED CONTENT – How well does it predict the life cycle environmental impacts of packaging and food service ware? State of Oregon Department of Environmental Quality. Portland, Oregon. 2018.

FULL TECHNICAL REPORT CAN BE DOWNLOADED AT:

https://www.oregon.gov/deq/mm/production/Pages/Materials-Attributes.aspx

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ACKNOWLEDGMENTS:

The State of Oregon thanks the following organizations for participating in a project advisory group that advised on and informed this research effort: County of Alameda (CA), StopWaste.org, Washington Department of Ecology, Metro (Portland, OR), City of Seattle, Minnesota Pollution Control Agency, CalRecycle, Sustainable Packaging Coalition, Sustainable Purchasing Leadership Council, City of Eugene (OR), U.S. Green Building Council, City of Portland (OR), and the Northeast Waste Management Officials Association.

Summary Highlights – *Recycled Content*

Many businesses, governments and individuals are designing or purchasing packaging to contain *recycled content* as a means of reducing environmental impacts and conserving resources. This is based on a common understanding that making products from recycled materials results in lower environmental impacts, when compared to using virgin resources.

Research suggest a more nuanced relationship. DEQ reviewed literature from the last 18 years of environmental life cycle assessments that compared packaging containing higher levels of *recycled content* against alternatives that contain no or lower levels of *recycled content*. Nearly 800 comparisons involving *recycled content* packaging were found. Two overarching observations emerge from that literature review.

- The first is that increasing the *recycled content* of a package once the material is selected almost always reduces negative environmental impacts. For example, if one has decided to package a beverage in a PET bottle, increasing the *recycled content* of that bottle improves environmental outcomes. This holds true for a wide variety of packaging materials, including glass, steel, aluminum, paper, and a variety of plastic resins, and for a variety of different types of environmental impacts.

  That benefit of using *recycled content* is a primary motivation for recycling collection, which as a waste management strategy tends to conserve resources and reduce pollution when compared to alternative waste management options, such as landfilling. While it is the resulting displacement of virgin resources where most of the environmental benefits of recycling typically occur, it is the act of separating and collecting materials for recycling that makes the use of *recycled content* possible. For some materials (such as PET resin), insufficient collection is the primary bottleneck that is preventing industry from using more *recycled content*.

- The second finding is that *recycled content* by itself is not a good predictor of lower environmental outcomes when comparing functionally equivalent (substitutable) packaging made from different materials. Just because a package contains higher levels of *recycled content* (on a mass or percentage basis) does not indicate that it has lower negative impacts because materials have substantially different production burdens. For example, a glass bottle may contain a higher percentage of *recycled content* than a lightweight flexible pouch or plastic bottle. Based on *recycled content* one may be inclined to prefer the glass container, but because of its higher overall weight glass may use more virgin material overall, and because of how it is made, may result in higher impacts such as emissions and resource depletion.

The attribute of *recycled content* is generally helpful once a specific material has been chosen, and producers, purchasers and policy makers should consider efforts to increase the *recycled content* of packaging materials. However, *recycled content* should not be used as a generic indicator of environmental goodness, and should never be used as a gauge of the relative “greenness” of competing materials. Instead, packaging design should be optimized by prioritizing the use of materials and formats with the lowest life cycle impact profiles, and only then increasing *recycled content* as feasible and appropriate.

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.

Recycled content is the portion of materials used in a product that was diverted from the solid waste stream.

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 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.

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.

One such popular packaging attribute is *recycled content*[1]. It is commonly assumed that if a package is made with *recycled content* its environmental footprint will be smaller than if it was made from virgin material. After all, making items from recycled waste tends to require less energy than making items from virgin resources. It also reduces the impacts of acquiring raw materials. Using recycled feedstocks to make products also typically reduces pollution.

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 *recycled content* attribute, and describes the findings from the meta-analysis of available research from the past two decades to determine how well the attribute *recycled content* correlates with reduced environmental impacts for packaging.

[1] The portion of materials used in a product that have been diverted from the solid waste stream and is a secondary feedstock for production of new items.

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. 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.

Recycled content is a popular attribute in packaging design and selection for several reasons. First, it is commonly understood that making a material from recycled wastes (or more commonly, a mixture of recycled and virgin feedstocks) requires less energy and raw materials, and results in less pollution, than relying exclusively on virgin resources. Second, the use of *recycled content* by industry is what makes the act of recycling possible. Indeed, the use of *recycled content* is recycling in action, whereas collected materials are merely potential feedstocks for new materials that must still go through many steps before being actually recycled. Particularly as collection programs are suffering from a reduction in end markets for collected materials[2], greater emphasis is being placed on "recycling market development" – or finding ways to increase the use of collected wastes (*recycled content*) as feedstocks by industry. Increasing the use of *recycled content* is widely understood to support the economic viability of recycling collection programs by increasing end markets (and prices) for those collected materials.

[2] Many recovered materials from some parts of the U.S. and Europe were traditionally exported to China for further processing and ultimate use to make new products. China has since initiated strict contamination rules thereby limiting those exports. As such markets for secondary materials have shrunk.

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[3]. 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.

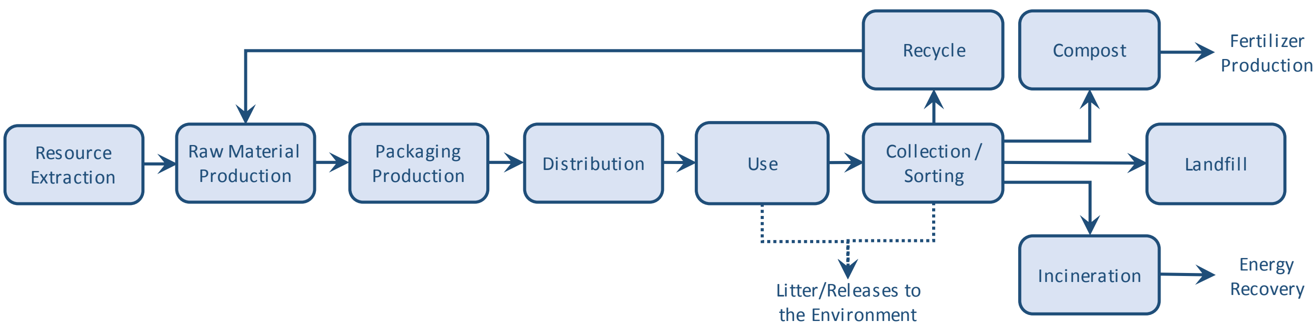

FIGURE 1 LIFE CYCLE OF SINGLE USE PACKAGING AND FOOD SERVICE WARE

[3] 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.

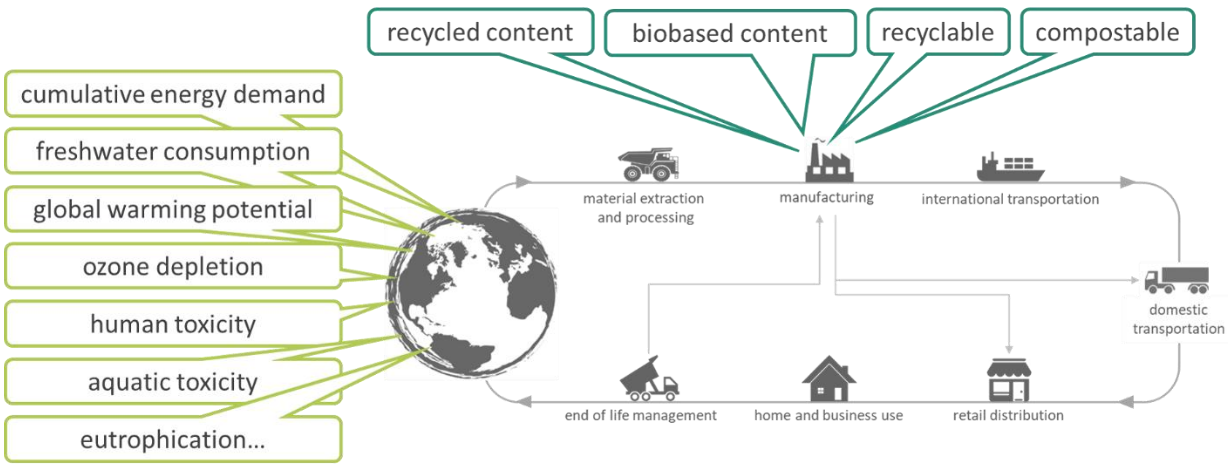

FIGURE 2 MATERIAL ATTRIBUTES AND LIFE CYCLE IMPACTS

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.*

Research approach

Packaging has been studied extensively by life cycle assessment. In fact, some of the first LCA studies 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 here.

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[4] 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.

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

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[5]. For example, our assessment compared a package with a given attribute (in this case, containing higher levels of *recycled content*) with a functionally-equivalent package that contained no or lower levels of *recycled content*. This basic approach gave us comparison ratios for all the attributes. It also allowed us to chart a range of five levels between “meaningfully lower life cycle impacts” and “meaningfully higher life cycle impacts” shown in Table 1.

The conclusions presented in this summary for *recycled content* packaging are drawn solely on the best case (meaningfully lower life cycle impacts) and the worst case (meaningfully higher life

[4] 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 way 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.

[5] 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.

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.

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 20 studies offering up nearly 800 comparisons for *recycled content*. Figure 3 shows the collective body of knowledge identified for the attribute *recycled content* for packaging (excluding food service ware). The chart shows three pieces of information (for detailed explanations see the technical report).

1. The materials represented in the literature.
2. The system boundaries, or the life cycle stages the researchers included.
3. The result categories[6] or impacts.

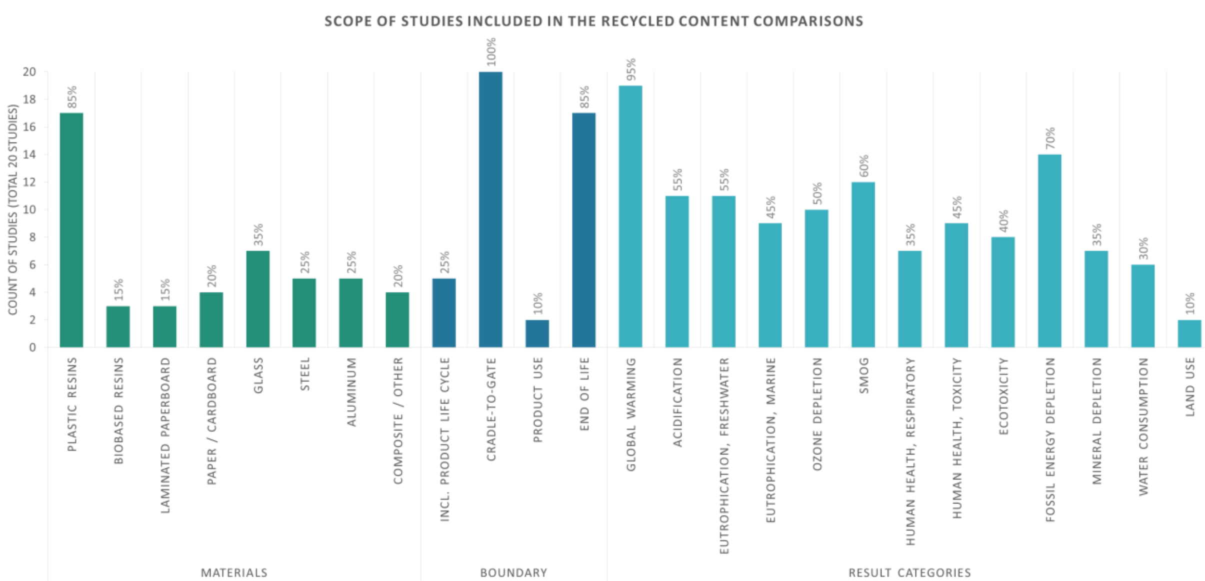

FIGURE 3 SCOPE OF RESEARCH FOR *RECYCLED CONTENT* IN PACKAGING (PERCENT VALUES REPRESENT FREQUENCY OF THE CATEGORY WITHIN STUDIES INCLUDED IN THE RESEARCH)

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

The full spectrum of materials typically used in packaging applications are represented in the literature, with plastics being the most studied material. Similarly, the literature included an assortment of results from different impact categories.

Packaging findings (excluding food service ware)

The use of *recycled content* is a common strategy used by packaging designers and purchasers to reduce environmental impacts of material choices in packaging. The research from the past two decades suggests that such a shorthand approach for inferring environmental benefits by using *recycled content* should be applied with specific caveats.

RECYCLED CONTENT IN PACKAGING – SAME MATERIALS

This literature review shows that producing packaging for a specific material with higher *recycled content* tends to be environmentally preferable to packages made from the same material but with less or no *recycled content* (i.e., virgin). Put another way, if you have decided on using a given material for packaging, increasing the *recycled content* of that given material will typically result in lower environmental impacts. Figure 4 offers an example of a beverage bottle made entirely with virgin polyethylene terephthalate (PET) and a similar bottle made with 30 percent *recycled content*. The bottle containing *recycled content* will have a lower environmental profile (green). In 20 percent of comparisons found in the literature, increasing *recycled content* of a specified material resulted in meaningful reductions in negative environmental impacts (see Figure 5a). In almost all other cases, the change in impacts was small and classified as "marginal" (see Table 1). But in almost all of those cases of marginal change, increasing *recycled content* still resulted in reductions in negative impacts. This trend holds true across most impact areas (Figure 5b), where lighter green bars indicate marginally lower life cycle impacts.

FIGURE 4 COMPARISON OF *RECYCLED CONTENT* FOR THE SAME MATERIAL

> *Once a material is selected, increasing recycled content results in reduced negative environmental impacts when compared against the same material with lower or no recycled content.*

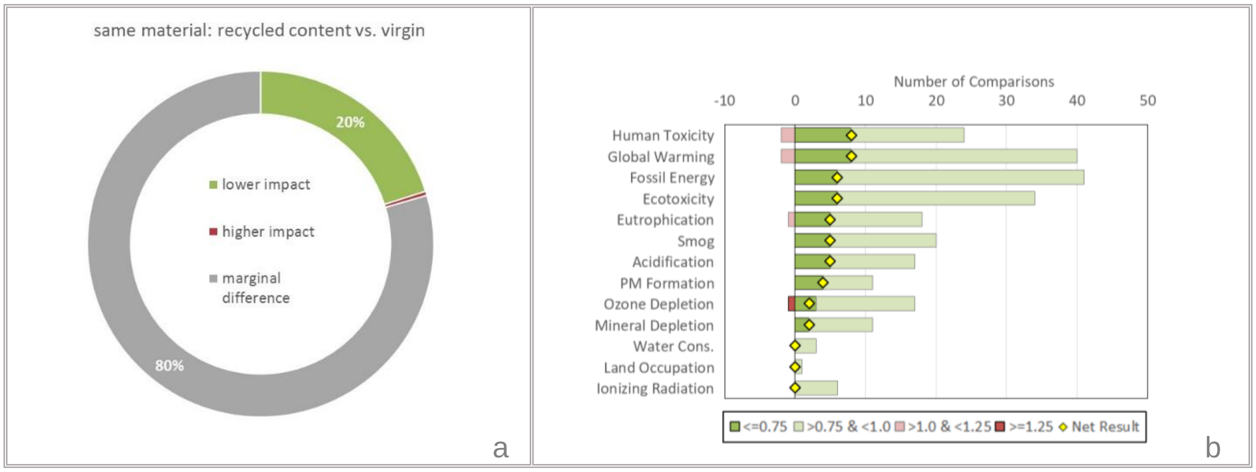

FIGURE 5 SUMMARY OF COMPARISONS FOR HIGHER *RECYCLED CONTENT* VERSUS LOWER (OR NO) *RECYCLED CONTENT* FOR THE SAME PACKAGING MATERIAL: (A) SUMMARY OF COMPARISONS ACROSS ALL IMPACT CATEGORIES, (B) SUMMARY OF COMPARISONS FOR EACH REPORTED IMPACT CATEGORY[7]

RECYCLED CONTENT IN PACKAGING – DIFFERENT MATERIALS

Choosing packaging made from different materials based on *recycled content* yields an entirely different outcome. While increasing *recycled content* for two packages made from the same material reduces that material's environmental impacts, comparing recycled content across different materials does not result in consistent environmental benefits. Figure 6 shows an example where a steel container with high amount of *recycled content* might be selected if the choice is made solely on the amount of *recycled content*. In reality, the functionally equivalent package with no *recycled content* generally has the lower environmental impacts.

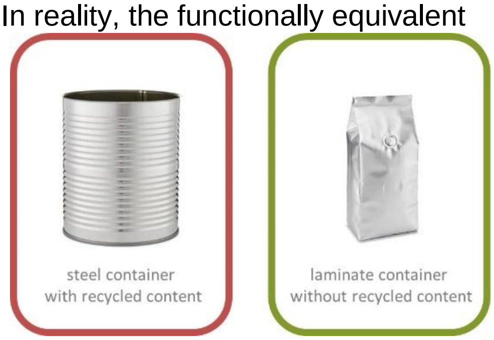

FIGURE 6 *RECYCLED CONTENT* ACROSS DIFFERENT MATERIALS

Figure 7a shows the trend considering over 530 comparisons between different materials containing different levels of recycled content. Sixty-one percent of the comparisons yielded worse environmental outcomes when *recycled content* was the sole selection criterion. Figure 7b shows mixed outcomes across different impact areas even after filtering for studies that expressly gave credit for using *recycled content*.

[7] Ratios reflect the result for the packaging with higher *recycled content* divided by the result for the packaging with lower or no *recycled content*. Thus ratios <1 indicate higher *recycled content* packaging performs better and are shown in the figure in green as the positive number of comparisons while ratios >1 indicates higher *recycled content* 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 differences. Light green and light red in Figure 5b represent counts of comparisons with ratios 0.75-0.99 and 1.01-1.25 respectively. These are classified as a "marginal difference" in Figure 5a.

Figure 7b represents a smaller subset of about 240 comparisons. This indicates that the *recycled content* attribute by itself is not a good determinant of environmental preference when comparing functionally equivalent but different materials against each other.

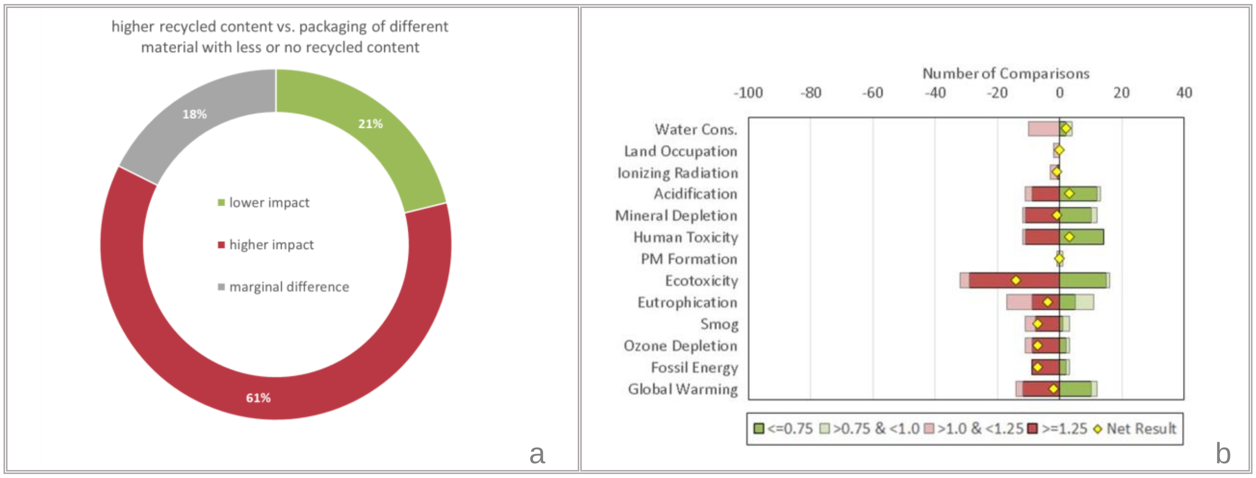

FIGURE 7 SUMMARY OF PACKAGING WITH HIGHER RECYCLED CONTENT TO PACKAGING OF DIFFERENT MATERIAL WITH LESS OR NO RECYCLED CONTENT (A) SUMMARY OF COMPARISONS ACROSS ALL IMPACT CATEGORIES, (B) SUMMARY OF COMPARISONS FOR EACH REPORTED IMPACT CATEGORY SELECTED FOR *RECYCLED CONTENT* USE (SEE FOOTNOTE 7)

Comparisons identified in the literature included various types of liquid food packaging systems used in the European market, including two laminate board cartons, a laminate pouch, a glass jar manufactured with 59 percent *recycled content*, a steel can, and a plastic container. Despite the *recycled content* in the glass jar, the glass packaging system had either the highest or second highest results for all the impact categories examined while the lightweight cartons performed the best.

When considering different materials, recycled content by itself is not a good determinant of reduced environmental outcome. The material type and the amount used are more important drivers of the environmental profile.

Several additional studies comparing heavier packaging (such as glass bottles, rigid plastic containers, steel cans and corrugated boxes) containing *recycled content* against lighter-weight, virgin packaging (such as laminate paperboard cartons, plastic laminate pouches and paper or film mailing bags), find that the lighter-weight packaging exhibits lower environmental burdens than the heavier packaging in all impact categories examined regardless of *recycled content*. This finding is driven predominantly by the additional impacts from material extraction, processing and manufacturing for heavier packaging materials rather than differences in transportation-related impacts associated with the packaging options.

Food service ware findings

The effect of *recycled content* on the life cycle impacts of food service ware has not been well examined. We were not able to identify any studies that provided impact results for the *recycled content* attribute in the format we needed to make meaningful comparisons. This may be partially due to perceptions about the safety and hygiene of using recycled materials for food contact. It is likely that the general patterns found for all packaging would hold true for food service ware.

Other considerations related to *recycled content* packaging and food service ware

Over the decades, recycling advocates have built up a worldview and framework regarding the environmental benefits of recycling that is now widely understood and accepted. This includes some common beliefs: that maximizing the use of post-consumer *recycled content* is necessary in order to maintain materials in perpetual closed loops, that closed loops are preferable to open loops, and that multiple looping of materials is preferable when compared to single looping. 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.[8]

Summary

Two high-level conclusions can be drawn from the literature review about *recycled content* as a predictor of environmental outcomes of packaging.

1. Increasing *recycled content* of any one packaging material almost always lowers environmental impacts.
2. When comparing different packaging materials against each other, *recycled content* is a poor indicator of reduced environmental impacts. The materials involved and the amounts used are stronger determinants of the overall environmental impacts of packaging.

The studies examined suggest that it is not possible to infer environmental preference for a package of one material type over another solely based on recycled content, with packaging material and weight being more relevant determining factors.

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

Discussion and Recommendations

Package Design

A commitment to use *recycled content* is a critical part of closing the material loop, and is a beneficial act that when applied properly can yield lower impact packaging and enhance brand identity. Packaging is often created based on common design criteria – cost, performance and brand-specific aesthetics (or customer preference). Sometimes regulatory criteria requiring *recycled content* may be part of the design process. Among packaging designers there is a common perception that *recycled content* yields lower environmental impacts and therefore it is understandable that this attribute is used as a design parameter. Since the first finding of this literature review and meta-analysis is that once a material is selected increasing the *recycled content* yields lower environmental impacts, the practice is relevant. However, more consideration is required when selecting across multiple material types. When designing product packaging, the following recommendations should be considered:

1. For a specific material, designing to meet performance criteria with the highest *recycled content* feasible can reduce environmental impacts.
2. Different materials have different life cycle impacts. When considering several functionally equivalent materials, start by selecting the material with the lowest life cycle impacts[9], then increase *recycled content* to optimize performance criteria.

Institutional and Corporate Purchasing

Material attributes are commonly used in procurement decisions as a guide for environmentally preferable purchasing. State and Federal statutes often set product procurement policy based on a preference for *recycled content*. Such decisions may need to be used with care and with a few basic caveats:

1. *Recycled content* should not be used as the determining factor for selecting packaging in general as it is not a good predictor of reduction of environmental impacts across different materials.
2. Once a material is selected, giving preference for higher *recycled content* for that material will likely yield a better environmental outcome, all other factors being equal.
3. Include specific environmental impacts, such as carbon footprint, as purchasing criteria and prioritize procurement to reduce those impacts.

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[9] 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/

Marketing

Although a principal function of packaging is to protect the product so it is safely delivered from the manufacturing facility to the customer, the reality is that 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. 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, there already exists a robust body of work that includes protocols[10], design guidelines[11], and tools[12] to implement informed design choices that can satisfy the demand for packaging with reduced environmental impacts. The following recommendations should be considered:

1. Make measurable, science-based environmental criteria (e.g., water consumption) part of the brand's marketing so the designer can work the criteria into the design optimization steps.
2. Shift from a prescriptive design requirement based on attributes (i.e., requiring *recycled content*) to a design guidance approach whereby packaging can be optimized for reduced environmental impacts.

Policy for end-of-life management

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 greatest potential to reduce environmental impacts, and generate clean and usable recycled materials that are in demand for product and package designs.

1. Prioritize feedstock quality (quality of materials sent to end markets) in the design and evaluation of material collection and processing systems. When recyclables sent to end markets are contaminated with other materials, it makes the use of *recycled content* by industry more expensive or even prohibitive, and undermines the economic viability of recycling. Collection programs can support the use of *recycled content* material by providing end-users (markets) with a clean flow of feedstocks.

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

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

[12] Various off-the-shelf Design for Environment (DfE) tools exist specifically for packaging design including but not limited to:

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/

2. Establish appropriate collection and processing systems based on the relative life cycle burdens of different materials. For example, tread carefully when considering adding materials to the recycling collection system, particularly if materials are commingled. Will the new materials disrupt existing sorting technologies and undermine the environmental benefits of existing recovery efforts?
3. Consider the full spectrum of end-of-life treatment options (recycling, incinerating with energy capture and landfilling) to reduce harmful environmental impacts.
4. Refrain from extreme policy measures that seek collection for recycling of all materials without an evaluation of net environmental impacts. Materials are different in their life cycle impacts and amenability to reprocessing, as well as market limitations.
5. Take a systems or life cycle perspective when considering market development activities to support recycling. A new package or product containing recycled materials may be viewed as desirable from a recycling market development perspective, for example, if it provides a domestic market for locally-collected materials. However, if the higher-order goal of recycling is to conserve resources and reduce pollution, then that new package or product needs to be compared against competing packages or products from that broader perspective. As shown in Figure 7, just because a packaging format contains recycled content does not guarantee that it has lower negative environmental impacts than competing materials in the marketplace. Since market development is intended to grow the market share of that new material, will that result in an overall reduction in negative environmental impacts, compared to the alternative materials? Asking that question – and making any investments contingent upon an affirmative answer – is necessary if recycling market development is to support the higher-order goals of recycling: not just recycling more, but conserving resources and reducing pollution.