SUPPORTING INFORMATION FOR:

Heller, M.C., S.E.M. Selke, and G.A. Keoleian. 2018. Mapping the Influence of Food Waste in Food Packaging Environmental Performance Assessments. *Journal of Industrial Ecology.*

Summary

This supporting information provides details of data sources and impact factors for packaging materials and transportation, results on energy demand distribution, and food waste rates utilized compared with empirically collected values. It also includes results from a sensitivity analysis and the methods and citation sources for Figure 2 in the main article.

Table S1. Data sources and impact factors for packaging material production and transformation.

process	Dataset origin	GHGE (kg CO_2eq/kg)	CED (MJ/kg)
General purpose polystyrene	USLCI	3.1	94.7
High density polyethylene resin (virgin)	USLCI	1.8	72.7
Recycled postconsumer HDPE pellet	USLCI	0.6	8.4
Low density polyethylene resin	USLCI	2.2	80.1
Linear low density polyethylene resin	USLCI	1.9	74.2
Polypropylene resin	USLCI	1.9	74.0
Polyvinyl chloride resin	USLCI	2.2	54.4
Ethylvinylacetate foil (proxy for Ethylene vinyl alcohol)	Ecoinvent 3	2.9	88.2
Ethylene vinyl acetate copolymer	Ecoinvent 3	2.2	76.5
Polyvinylidenechloride, granulate	Ecoinvent 3	5.1	80.3
Recycled postconsumer PET flake	USLCI	0.8	11.5
Polyethylene terephthalate resin (virgin)	USLCI*	2.7	71.1
Steel, low-alloyed, hot rolled	Ecoinvent 3	1.9	21.7
Corrugated board box	Ecoinvent 3	1.1	16.3
Kraft paper, bleached (used for all other paper beyond corrugated)	Ecoinvent 3	1.6	23.5
Rough green lumber, softwood, at sawmill (used for palletwood)	USLCI	0.1	1.3
Blow moulding	Ecoinvent 3	1.4	21.6
Calendaring, rigid sheets	Ecoinvent 3	0.4	6.9
Extrusion, plastic film	Ecoinvent 3	0.6	8.7
Injection moulding	Ecoinvent 3	1.3	22.2
Polymer foaming	Ecoinvent 3	0.9	10.8
Thermoforming, with calendering	Ecoinvent 3	0.9	14.7

*the "dummy" ethylene glycol manufacturing process included in the Ecoinvent 3 version of this process was replaced with "ethylene glycol, at plant" from the USLCI dataset.

Table S2: Data sources and impact factors for distribution transport processes.

process	Dataset origin	GHGE (kg CO_2eq/tkm)	CED (MJ/tkm)
1 tkm Transport, freight, lorry, unspecified	Ecoinvent 3	0.139	2.270
Refrigerated transport	Above, with modifications described in text	0.143	2.344

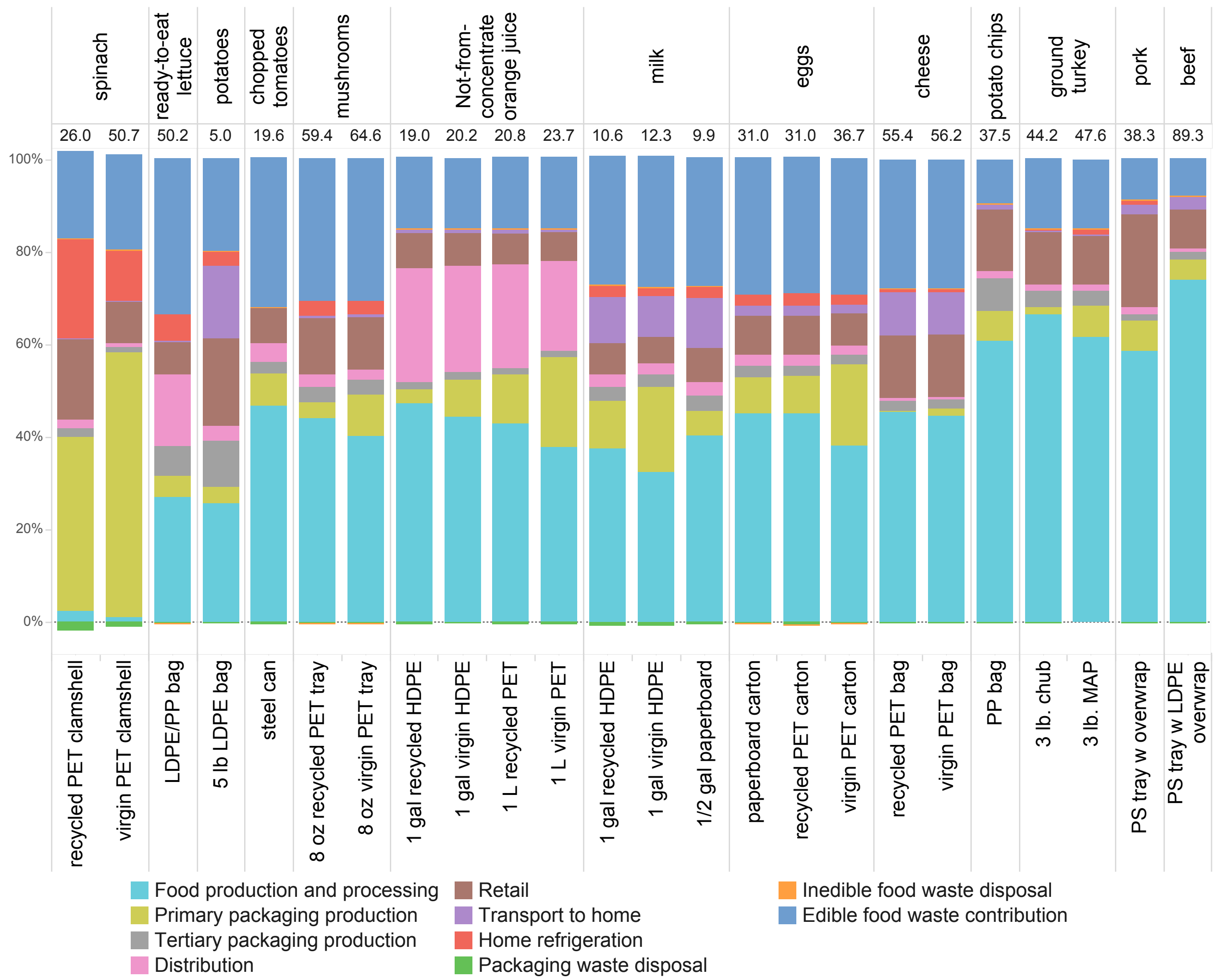

Figure S1. Distribution of non-renewable energy demand across life cycle stages for the food/package combinations in Table 1. Values above bars represent total energy demand in MJ (kg consumed)$^{-1}$. Note that "edible food waste contribution" includes emissions associated with edible retail- and consumer-level food waste accumulated throughout the life cycle: production, packaging, distribution, retail, refrigeration, and disposal.

Table S3. Food waste rates for food categories examined in study, comparing empirical values based on sales and waste data from a US retailer (averaging multiple products in each food category) and values available through USDA's Loss Adjusted Food Availability dataset.

Food category	**USDA LAFA waste rates**[a]		**Waste rate data from retail Partner**[b]	
	Retail	consumer	number of specific products (separate UPC IDs) averaged[c]	sales weighted average[d]
Spinach	14%	9%	3	0.87%
Lettuce	14%	24%	3	1.24%[e]
Tomatoes, chopped, canned	6%	28%	4	0.19%
Mushrooms	13%	21%	3	2.65%
Potatoes	7%	16%	5	0.42%
Potato chips	6%	4%	5	0.23%
Orange Juice	6%	10%	14	0.62%
Eggs	9%	23%	5	0.0005%
Cheese	11%	6%	8	3.42%
Milk	12%	20%	21	0.39%
Ground turkey	4%	12%[f]	2	2.64%
Pork	4%	5%[f]	6	3.86%
Beef	4%	4%[f]	9	2.80%

[a]from USDA Loss Adjusted Food Availability (LAFA) data, presented as food "loss" rates
[b]based on sales and "throwaway" tracking from an anonymous US retail chain, averaged over 2 years of sales at circa 200 storefronts.
[c]number of individual products of given food category included in estimates
[d]Average retail-level waste rate, weighted by the total sales of each product in the given category
[e]ready-to-eat romaine lettuce
[f]corrected for cooking losses (see methods in article)

Sensitivity Analysis

Table S4 offers the effect on total system GHGE and CED due to 20% perturbations in a full suite of modeling parameters for two cases: spinach in PET clamshell (a low FTP case) and ground turkey in MAP packaging (a high FTP case). Differing responses to positive and negative perturbations are due to parameters that enter into the model calculations as divisors. The parameter, "average retail price of product" influences the model through economic allocation of retail non-refrigeration energy use and retail-to-home transport.

Table S4. Sensitivity of total system GHGE and non-renewable CED for the 'spinach in PET clamshell' and 'ground turkey in MAP packaging' case to a ±20% change in model parameters.

	Spinach in PET clamshell				Ground turkey in MAP packaging			
Parameter change	+20%	-20%	+20%	-20%	+20%	-20%	+20%	-20%
Model parameter	Change in system GHGE		Change in system CED		Change in system GHGE		Change in system CED	
Agricultural production impact per kg	1.85%	-1.85%	0.65%	-0.65%	18%	-18%	13%	-13%
consumer-level food waste rate	8.44%	-7.43%	6.72%	-5.93%	3.10%	-2.90%	2.80%	-2.70%
retail-level food waste rate	2.09%	-2.02%	1.45%	-1.39%	0.80%	-0.78%	0.72%	-0.71%
weight of primary packaging	7.25%	-7.25%	8.92%	-8.92%	0.33%	-0.33%	1.60%	-1.60%
weight of tertiary packaging	0.24%	-0.24%	0.32%	-0.32%	0.35%	-0.35%	0.75%	-0.73%
transport distance to retail	0.28%	-0.28%	0.43%	-0.43%	0.13%	-0.13%	0.34%	-0.34%
total annual product sold nationally	-2.00%	3.01%	-1.04%	1.58%	-0.09%	0.14%	-0.05%	0.09%
total grocery sales, all products	-0.08%	-0.07%	-0.11%	-0.10%	-0.86%	1.30%	-2.00%	3.10%
average retail price of product	2.18%	-2.18%	3.21%	-3.21%	1.00%	-1.00%	2.40%	-2.40%
total display area (TDA) of retail refrigeration unit	-0.12%	0.18%	-0.06%	0.10%	-0.02%	0.03%	-0.02%	0.03%
product consumer facing area	2.42%	-2.42%	1.28%	-1.28%	0.13%	-0.13%	0.11%	-0.11%
days in home refrigerator	3.46%	-3.46%	5.03%	-5.03%	0.13%	-0.13%	0.30%	-0.30%
annual household refrigeration energy demand	3.46%	-3.46%	5.03%	-5.03%	0.13%	-0.13%	0.30%	-0.30%
home refrigerator volume	-2.88%	4.32%	-4.19%	6.29%	-0.11%	0.16%	-0.25%	0.37%
product volume	3.46%	-3.46%	5.03%	-5.03%	0.13%	-0.13%	0.30%	-0.30%
food composting rate	-0.10%	0.10%	0.01%	-0.01%	-0.02%	0.02%	0.00%	0.00%
PET recycling rate	-0.24%	0.24%	0.14%	-0.14%	-	-	-	-
PP recycling rate	-	-	-	-	0.00%	0.00%	0.00%	0.00%
corrugated cardboard recycling rate	-0.10%	0.19%	0.01%	-0.02%	-0.14%	0.28%	0.03%	-0.05%

Meta analysis contributing to Figure 2 (main article):

Figure 2 in the main article was developed out of a literature survey of the food LCA literature, drawing from a large variety of publicly available sources. A much larger collection of food GHGE data gathered from the literature was filtered to contain only scenarios that included packaging in the overall life cycle (excluding, e.g., studies for which the scope was only farm-gate). The citations listed below are those remaining after this filter, and are the sources for the data in Figure 2. The boundary conditions for these studies do not necessarily reflect the system boundaries for the current study (as presented in Figure 1) nor were any of the LCA data corrected or adjusted to reflect U.S. conditions.

All GHGE factors, reported per life cycle stage, were corrected to a functional unit (relative basis) of 1 kg consumed food. For animal-based foods, this correction was to 1 kg boneless, edible weight. The Food To Packaging (FTP) ratio data presented in Figure 2 was calculated as follows:

$$FTP = \frac{(agricultural\ production\ stage\ GHGE) + (processing\ stage\ GHGE)}{(packaging\ production\ stage\ GHGE)}$$

Note that waste disposal stages (either food waste or packaging waste) were not included in the FTP ratio.

It is important to recognize that the food LCA scenarios contained in this review represent a wide variety of food types, production methods and locations, and packaging configurations. Our intention in presenting the data in this manner is to communicate the potential range and variability of this parameter that may be relevant to considering food waste impacts in designing sustainable packaging solutions.

Citations in literature review

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