State of Oregon Department of Environmental Quality

Technical overview of the Waste Impact Calculator

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Summary

The Waste Impact Calculator (WIC) is an analytical framework for estimating the life cycle environmental impacts of solid waste materials, and for projecting the consequences of solid waste management decisions.

WIC is intended to be a practical and relatively accessible tool for sustainability and waste managers. Solid waste has traditionally been managed, measured, and understood in terms of sheer weight, but the newer perspective of sustainable materials management requires an understanding of the life cycle environmental impacts of waste materials. However, life cycle assessment is a highly specialized discipline, and most sustainability analysts and waste managers do not have the time or experience to practice it.

WIC is intended to bridge the two perspectives. It uses traditional solid waste data – as might be obtained through recycling surveys and waste sorts – as input; applies a simplified form of life cycle assessment; and outputs estimated life cycle impacts in some detail. WIC also allows the comparison of management scenarios, for example "increased recycling" or "reduced food waste." It requires some programming or database skills, but no experience with formal life cycle assessment.

This paper focuses on the mechanics of WIC's impact calculations, including the proper form of input data files and the type of operations necessary to produce meaningful results. Two complementary documents provide additional detail and illustration. *Impact modeling for the Waste Impact Calculator* has extensive details on impact calculations for individual materials, while *Example applications of the Waste Impact Calculator* shows how the framework may be used to create diverse types of output.

WIC was created by Oregon DEQ with Oregon users and applications in mind, but its concept, code and impact factor database are published freely; they may be altered and improved by other users.

Introduction

Context: the "problem" of solid waste

For decades municipal solid waste has been a focus of environmental concern, activism, and management. Solid waste is often used as a symbol or proxy for resource consumption, and waste management activities such as recycling are seen as ways to reduce environmental impacts such as greenhouse gas emissions and water use.[1]

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[1] e.g. Daniel Hoornweg, Perinaz Bhada-Tata, and Chris Kennedy, "Environment: Waste Production Must Peak This Century," *Nature News* 502, no. 7473 (October 31, 2013): 615, https://doi.org/10.1038/502615a; Abi Bradford, Sylvia Broude, and Alexander Truelove, "Trash in America: Moving from Destructive Consumption to a Zero-Waste System," accessed September 16, 2018, https://uspirgedfund.org/sites/pirg/files/reports/US%20-%20Trash%20in%20America%20-%20Final.pdf; Sustainable Materials Management Coalition, "Reducing the Environmental Impact of Materials Use," November 2016,

Nonetheless the life cycle impacts of the solid waste, and the consequences of solid waste management decisions, remain unclear. Local governments, and some private entities, record and study waste in terms of weight, not life cycle impacts. Meanwhile life cycle assessment[2] (LCA) has been applied to individual waste materials and processes[3], but rarely to civic waste streams composed of mixed materials.

The field needs tools that illuminate the life cycle impacts of the materials in solid waste, and can help inform practical waste management decisions. In particular, sustainability analysts and waste managers for local governments, corporations, and NGOs want to answer questions like "which waste materials represent the biggest impacts?"; "how will impacts change if we compost more?"; and "which is more effective, reducing waste generation or increasing recycling?"

One existing tool of this type is WARM from US EPA.[4] Version 14 of WARM is both popular and well-documented, but is not well suited to Oregon's purposes. WARM version 14 focuses on *differences* in impacts between management scenarios, rather than total life cycle impacts, and does not display impacts from the production phase of the materials life cycle in a straightforward fashion. It is also limited to two management scenarios and two impact categories, GHG emissions and energy use.

The Waste Impact Calculator

This paper introduces a new and different analytical framework that better suits Oregon's particular needs – and may be useful to others as well. The "Waste Impact Calculator" (WIC) from the Oregon Department of Environmental Quality (DEQ) creates a bridge between the weight and impact perspectives of waste, and allows users to calculate the impacts associated with a large variety of management scenarios.

As input, WIC uses standard solid waste data, where mixed waste streams are described in terms of tons of specific materials going to specific end-of-life fates. This is the type of data that typically results from municipal recycling surveys and "waste sorts." For example, a simple waste stream might be described with the following entries: "10 tons of food waste going to landfill, 6 tons of food waste going to composting, 5 tons of steel going to landfill, and 4 tons of steel going to recycling."

WIC applies a simplified form of life cycle assessment to such data, and outputs potential life cycle impacts in a useful amount of detail. WIC also allows the user to predict and compare the impacts linked to as-yet-untried management scenarios, for example "increased recycling" or "reduced food waste."

The most likely users of WIC are analysts who are familiar with the concept of life cycle impacts and sustainable material management (SMM)[5], but who are not full time practitioners of LCA – for example,

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https://www.michaeldbaker.com/MDB_WP_live_site/wp-content/uploads/2016/11/SMMC_Reducing_the_Impact_Final_508.pdf.

[2] "Life-Cycle Assessment," in *Wikipedia*, October 24, 2017, https://en.wikipedia.org/w/index.php?title=Life-cycle_assessment&oldid=806786959.

[3] David A. Turner, Ian D. Williams, and Simon Kemp, "Greenhouse Gas Emission Factors for Recycling of Source-Segregated Waste Materials," *Resources, Conservation and Recycling* 105, Part A (December 2015): 186–97, https://doi.org/10.1016/j.resconrec.2015.10.026.

[4] United States Environmental Protection Agency, "Waste Reduction Model (WARM)," accessed September 29, 2016, https://www.epa.gov/warm.

[5] Joseph Fiksel, "A Framework for Sustainable Materials Management," *JOM* 58, no. 8 (August 1, 2006): 15–22, https://doi.org/10.1007/s11837-006-0047-3; United States Environmental Protection Agency, "Sustainable Materials Management: The Road Ahead," June 2009, https://www.epa.gov/sites/production/files/2015-09/documents/vision2.pdf.

sustainability analysts and waste managers in local governments, corporations, and NGO's. Though WIC is designed with Oregon's needs in mind, its code and impact factor database are published freely and can be adapted and altered by others.

More framework than model

WIC is better described as a "framework" than a "model" because it has only three basic elements:

- a data file containing weight-based solid waste information;
- a data file containing impact factors, relating weight to impacts; and
- some sort of code or interface that connects the two data files and filters and sums results.

This is a flexible arrangement that allows a large variety of analyses to be performed. Waste impacts can be studied for any number of user-generated scenarios, using single materials or complex mixtures, for different end-of-life transport distances, etc.

The drawback of this flexibility is that it is possible for users to make mistakes, especially if they are coding entirely new analyses. New users should read this paper, and study the companion document *Example applications of the Waste Impact Calculator*, to see how the framework can be properly applied.

That document contains at least two examples using the R language: a simple report in R Markdown, which shows how to avoid the most likely pitfalls; and screenshots from an interactive web application written in R's "shiny" module. A web interface such as the latter example, once programmed, eliminates the need for (and hazards of) original coding and may be sufficient for some users.

However, these examples are just that – examples. Many other types of output could be created, and there is no requirement that R be utilized.

The authors of WIC (Martin J. Brown and Peter Canepa) welcome both improvements to their own code and completely different expressions of the framework. Find WIC on github at [address TBA].

The nature of solid waste and its implications for life cycle modeling

The waste stream and weight-based statistics

The subject of WIC is the ***solid waste stream***, the waste materials collected from homes, businesses, and other operations after their useful lifes, and sent to various end-of-life fates such as recycling, composting, landfilling, and combustion (aka "incineration").

All the stuff in solid waste takes part in the ***materials life cycle***.[6] Though waste managers may be most interested in environmental impacts at "end-of-life" phase of the life cycle, environmental impacts also occur when the stuff is produced, distributed, transported, and used.

Legal definitions of solid waste vary by jurisdiction, but it is important to note that government solid waste statistics do not represent the entirety of waste or material consumption. Worldwide, few if any waste statistics include mining and forestry waste, but almost all definitions include the more familiar "municipal" waste (from residential collections).[7] Jurisdictions vary most greatly in whether they include commercial waste (e.g. from stores and restaurants) and construction materials.

[6] United States Environmental Protection Agency, "The Road Ahead."
[7] Figure 3.1 in United Nations Environment Programme and International Solid Waste Association, *Global Waste Management Outlook*, 2015, https://wedocs.unep.org/handle/20.500.11822/19339.

Oregon's definition of solid waste, as applied in the calculation of waste statistics required by state law,[8] includes municipal waste, commercial waste, and some construction materials. These statistics exclude inert construction materials (e.g. concrete, dirt), and industrial and agricultural waste.

Governments and other entities typically summarize their waste streams with weight-based statistics. In Oregon, ***waste generation*** is the total tonnage collected, no matter where it is destined – for landfilling, recycling, composting, etc. The amount ***recovered*** is the tonnage recycled, composted, or (for a few specific materials) combusted with energy recovery. The amount ***disposed*** is the tonnage of everything else, which includes all of the waste landfilled and most of the wasted combusted. The ***recovery rate*** is a percentage: the tons recovered divided by the tons disposed.[9]

Other governments and entities calculate similar statistics with slightly different names and definitions. "Recycling rate" may refer to the percentage of generation which is recycled or composted (perhaps omitting combustion). "Diversion rate" may refer to the percentage of generation that is not landfilled.

The nature of "materials" in solid waste

Solid waste streams are nearly always *mixtures* of different substances, even when some sorting is applied by the generator or processor of the waste. They are rarely uniform in chemical makeup or physical form. For example, a household may separate its waste into "trash" and "recyclable" bins. Each of these bins in turn contains a mixture. The recycling bin might be sorted by a recycling operator into several portions, for example glass, paper, and plastic.

For some end-of-life applications such broad "materials" categories may be sufficient, but for others additional separation is necessary. A bin of unspecified mixed "plastic" may be shredded and used as packaging fill, but for recycling into new containers separation by chemical compound (PET, HDPE, etc) may be necessary. Even these relatively "pure" classifications may themselves be mixtures, whose components have different impact characteristics – for example currently blow-molded PET is more commonly recycled than thermoformed PET.

Thus the word ***material*** is a generic term whose breadth depends on context. WIC uses the word "material" to refer to any identifiable class of stuff, narrow or broad, for which it provides impact information. For example WIC has impact information for specific plastic compounds including PET and HDPE, and also a more generic material category called "Rigid Plastic Containers." If the user can input their waste stream in terms of specific plastic compounds, they will get more relevant impact outputs. If not, they can use the more generic category, which summarizes the impacts for an assumed mixture of specific compounds.

Weight-based waste studies

The way that governments study and quantify solid waste demonstrates the fluid definition of "material."

In Oregon and other jurisdictions, every truck-full of waste destined for disposal is weighed before its contents are landfilled or incinerated. The total of such measurements is the total tons disposed. However, the materials making up that waste are much less frequently characterized. It requires a study often described as a "waste sort," where samples of disposed waste are separated into distinct material categories and weighed. Waste sorts are highly laborious,[10] especially if high specificity of material

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[8] ORS 459A.010, "Policy," 459A.010 § (2015), 010, http://www.oregonlaws.org/ors/459A.010.
[9] ORS 459A.010, 010.
[10] e.g. CalRecycle, "2018 Facility-Based Characterization of Solid Waste in California," May 15, 2020, https://www2.calrecycle.ca.gov/Publications/Download/1458.

categories are desired, so they tend to be conducted infrequently. Oregon DEQ conducts one every five or six years, and uses more than 100 material categories[11] – though for the purpose of analysis and reporting, the 100+ categories are often lumped into a smaller number.

Recycling and other recovery is harder to study because the recycling market is complex. Materials are collected for recovery by a variety of parties – garbage haulers, scrap metal collectors, grease handlers, etc. After collection, they enter a marketplace where they are bought and sold in different states of separation and/or processing. They may change hands several times before they are finally used.

State and local governments have various ways of extracting information from this marketplace and summarizing it. In Oregon, law[12] requires participants in the recycling marketplace to report to DEQ,[13] which summarizes and de-duplicates the records. But regardless of the system, the end result is a list of tonnages for specific materials that are destined for recovery.

It is not always clear how materials collected for recovery are actually going to be used – an uncertainty which has important implications users of a system like WIC or WARM. Many materials may be "recovered" in multiple ways. Food waste may be composted aerobically or anaerobically digested. Glass can be melted and reformed into new containers, or crushed for use as roadbed. All of these count as "recovery" in Oregon, but each has different sets of associated impacts.

A system like WIC or WARM cannot rely on legal definitions of "recovery," "recycling," "disposal," etc. to calculate end-of-life impacts, because these words represent general conceptual ideas of how to handle waste materials, not specific technical processes. Users of WIC are required to assign each material tonnage in their solid waste stream a specific end-of-life ***disposition*** – that is, a specific technical process to be applied to the material. For example, composting must be specified to be aerobic or anaerobic.

Consequences for an LCA approach to solid waste

For sustainability analysts, studies of the solid waste stream have the power of a broad scope. Solid waste data represent large quantities of material measured at a civic or even national scale. Moreover, waste data is not theoretical – it represents materials that have *definitely* been manufactured and used, and must be handled at the end of life. Waste represents a wide swath of real consumption and real life cycle impacts.

However, this breadth necessarily comes with a lack of precision. Waste materials are mixtures, even after some effort at separation has been applied. The way waste streams are studied, and the specificity to which mixed materials are sorted and characterized, varies greatly from place to place. WIC's users will come to the framework with data of widely varying breadth and quality.

Critically, many users will not know their materials have been used. For example, a ton of steel collected for recycling might be composed of refrigerator parts (whose use-phase impacts were probably considerable) or juice cans (whose use-phase impacts were probably negligible).

WIC, like WARM, does not assign any impacts to the use phase of the life cycle. Its life-cycle approach to the waste stream uses a standard weight of material as a "declared unit," rather than a functional unit.

[11] Oregon Department of Environmental Quality, "Statewide 2016 Waste Composition Study: Excel Results Files Updated June 20, 2018 [Sheet P16TOT]," 2018, https://www.oregon.gov/deq/FilterDocs/A01-StatewideWCS16.xlsx.
[12] ORS 459A.010, Policy, 010.
[13] Oregon Department of Environmental Quality, "Individual Material Collection Report [2015 Oregon Material Recovery Survey]," 2015, http://www.deq.state.or.us/lq/pubs/forms/sw/PrivateRecyclerSurvey.pdf.

Project goals

The goals of the WIC project are to create a system that:

- Creates reasoned, credible estimates of the life cycle environmental impacts of solid waste streams;
- Allows analysts who are not experienced LCA practitioners to calculate such impacts;
- Calculates such impacts at all the levels of detail relevant to a state or local SMM program, for example statewide totals, subtotals linked to geographic areas, material classes, life cycle stages, years, and legal classification as either "disposed" or "recovered" material;
- Allows the user to project the impacts associated with new, untried ideas for waste management, such as "increased recycling" or "reduced food waste";
- Can efficiently answer the most common questions waste managers and sustainability officers have about management options and life cycle impacts. Most of these questions involve changing the amount of material recovered, changing recovery or disposal dispositions, reducing waste generation, and changing end-of-life transport distances;
- Is as transparent, open, and adaptable as practical, given the limits of its creators' time, resources, and programming skill; and
- Reports results in a large and flexible number of impact categories (GHG emissions, water use, ecotoxicity, etc), including (ideally) all the impact categories that represent planetary boundaries.[14]

Overview of impact calculations

Within a given impact category, WIC defines the total impact of a solid waste stream as the sum of impacts from all materials in the waste stream. For materials *i=1 to m…*

$$IMPACT_{total} = \sum_{i=1}^{i=m} IMPACT_i$$

The impact of a single material *i* is the sum of impacts from three life cycle stages:

$$IMPACT_i = PROD_i + EOLT_i + EOL_i$$

Where

- PROD = Production, which is used in the broad sense, and includes extraction of resources, manufacturing or other processing, distribution and transport to retail;
- EOLT = End-of-life transport, which contains only the transport between the collection point (e.g. a home or business) and the point when the collector loses control over the material. For disposed materials, this will be the landfill or incinerator. For recovered materials, this will be the first meaningful participant in the marketplace for recovered materials. Most often this will be a MRF (material recovery facility) for mixed recyclables, but other possibilities are steel businesses (for scrap metal collections) and composting and anaerobic digestion facilities.
- EOL = End-of-life treatment, such as landfilling, incineration, recycling, etc. The end-of-life treatment phase may include additional transportation, after the material has left the control of the collector. End-of-life treatment emissions may be positive, for example when organic material is disposed in a landfill and decays, or negative (that is, a reduction), for example, when steel is

[14] Johan Rockström et al., "Planetary Boundaries: Exploring the Safe Operating Space for Humanity," *Ecology and Society* 14, no. 2 (November 18, 2009), https://doi.org/10.5751/ES-03180-140232.

recycled and WIC assumes it prevents greater impacts from some other source, for example production of virgin steel. The companion document *Impact modeling for the Waste Impact Calculator* discusses assumptions of end-of-life dispositions in detail.

These stages have been selected and delimited based on practical considerations from the waste manager's perspective. As noted earlier, the *use* phase of the materials life cycle is ignored (set at zero), because the typical waste manager will know very little about the uses of the materials that make up waste, even when it has been separated into commodity categories such as "steel."

The production stage includes processes that can be lengthy and complex, while the end-of-life transport phase is simple and short. This division reflects the boundaries of influence of local government and corporate waste managers. For better or worse, these figures have little influence over the way materials are produced or distributed. Accordingly, all production-related impacts are lumped together and unchangeable by the user.

Waste managers do, however, have some influence over how much waste is generated, to which dispositions that waste will flow, and how far it will be initially transported. Accordingly, end-of-life treatments in WIC are specific, and the end-of-life transport phase describes the portion of transport that waste managers can control.

$PROD_i$, $EOLT_i$ and EOL_i are not measured directly. Rather, the solid waste stream is characterized by the masses of each material found in solid waste records and sampling programs. Those masses are converted to $PROD_i$, $EOLT_i$ and EOL_i using ***impact factors*** relating impacts to unit weights, for example "3.2 kg CO_2 equivalents of greenhouse gas emissions per short ton of waste."

Production-related impacts for each material ($PROD_i$) are straightforward to calculate, as the product of the total mass of waste generated for that material ($MASS_i$) and a production impact factor (PIF_i):

$$PROD_i = MASS_i \times PIF_i$$

End-of-life treatment impacts for each material (EOL_i) are more complex, because materials have multiple plausible dispositions at the end of their useful lives, each of which has distinct impact characteristics. For material *i* and its dispositions $j=1$ to *d*…

$$EOL_i = \sum_{j=1}^{j=d} MASS_{i,j} \times EIF_{i,j}$$

That is, to find the total end-of-life treatment impact for each material, the mass of each unique combination of material and disposition ($MASS_{i,j}$)must be multiplied by the matching impact factor ($EIF_{i,j}$), and those products summed.

End-of-life-transport impacts are calculated in a similar way, using an end-of-life-transport impact factor ($TIF_{i,j}$), but with the addition of a scaling factor that allows users to customize transport distances (in relation to a default distance supplied by WIC).

$$EOLT_i = \sum_{j=1}^{j=d} MASS_{i,j} \times TIF_{i,j} \times \frac{custom\ distance_{i,j}}{WIC\ default\ distance_{i,j}}$$

This calculation process can be applied for a waste stream of any size – from the waste produced by a single household or business to the waste produced by a state or industry. WIC anticipates that users will want to compare waste streams representing different places ("Dane county vs. Smith county"), materials ("Steel vs. wood"), and management scenarios ("Business as usual vs. increased composting") – so its data files are set up to allow processing of multiple streams, as described below.

Data tables and their processing

Overview

WIC executes the impact calculation scheme described earlier by merging two related data tables and processing the result. In general, in WIC, $masses \times impact\ factors = impacts$, but the details of processing matter.

- One data table, **massProfiles**, describes the waste stream(s) under consideration by listing the weights of materials that compose them, and relevant end-of-life transport distances. These records can be labelled with additional classification variables such as management scenario name, geographic place, year, etc. The *massProfiles* table must be created and provided by the user – with the exception of several preconfigured *massProfiles* published with WIC's interactive web application (illustrated in the companion document *Example applications of the Waste Impact Calculator*).
- Another data table, **impactFactors**, contains impact information for a wide assortment of material and end-of-life dispositions, as well as impact information for the end-of-life transport and production. This file is provided as part of WIC.
- *massProfiles* and *impactFactors* are merged based on material and disposition names, and end-of-life-treatment impacts are calculated by multiplying mass by impact factor. Additional records are created as necessary to represent impacts in the end-of-life-transport and production phases of the life cycle.
- The result is **impactsInDetail**, a data table containing tonnages and impacts of waste in maximum available detail.
- *impactsInDetail* is then filtered and summarized as relevant to produce desired results.

In practice, the code or database instructions that merge the files and produce usable output can be very simple. Most of the user's effort will go into creating a *massProfiles* table that is well suited to their purposes and passes checks for internal consistency.

Formats

WIC requires no particular file format for the *massProfiles* and *impactFactors* tables, though the WIC project prefers nonproprietary formats (see project goals). In its current practice, Oregon DEQ plans to publish *impactFactors*, and any pre-packaged *massProfiles* or *impactsInDetail*, as simple CSV text files. Oregon DEQ codes its own applications of the WIC framework in R, so it may also publish data in the RData format. In the future Oregon DEQ may move to a "self-describing" format such as JSON.

The key role of massProfiles

Creation of a credible, internally consistent *massProfiles* is essential, because (with the exception of interactive apps created for the WIC framework) this table is the only way the user provides input to the system. The material names, weights, disposition names, scenario names, etc. in *massProfiles* must completely and accurately describe the scenarios and waste streams the user wants to study. For example, when comparing an "increased recycling" scenario to a "baseline" scenario, the "increased recycling" scenario should show increased tonnages for recycling dispositions and decreased tonnages for disposal dispositions. It is up to the user to assure that *massProfiles* describes their management ideas accurately.

Structure and logic of massProfiles

Here is a simple *massProfiles* table, expressing wastestreams for 3 scenarios ("baseline," "eliminate_food_waste", and "recover_nearly_all"). For brevity only two materials are shown ("Electronics" and "FoodWaste").

wasteshed	material	disposition	umbDisp	scenario	tons	miles
City A	Electronics	landfilling	disposal	baseline	2.827717e+03	180
City A	Electronics	Recycling	recovery	baseline	2.367066e+03	180
City A	FoodWaste	anaerobicDigestion	recovery	baseline	0.000000e+00	180
City A	FoodWaste	combustion	disposal	baseline	1.861940e-02	180
City A	FoodWaste	combustion	recovery	baseline	1.451891e+03	180
City A	FoodWaste	composting	recovery	baseline	1.567926e+03	180
City A	FoodWaste	landfilling	disposal	baseline	4.630180e+04	180
City A	Electronics	landfilling	disposal	eliminate_food_waste	2.827717e+03	180
City A	Electronics	Recycling	Recovery	eliminate_food_waste	2.367066e+03	180
City A	FoodWaste	anaerobicDigestion	Recovery	eliminate_food_waste	0.000000e+00	180
City A	FoodWaste	combustion	Disposal	eliminate_food_waste	0.000000e+00	180
City A	FoodWaste	combustion	Recovery	eliminate_food_waste	0.000000e+00	180
City A	FoodWaste	composting	Recovery	eliminate_food_waste	0.000000e+00	180
City A	FoodWaste	landfilling	Disposal	eliminate_food_waste	0.000000e+00	180
City A	Electronics	landfilling	Disposal	recover_nearly_all	0.000000e+00	180
City A	Electronics	Recycling	Recovery	recover_nearly_all	5.194783e+03	180
City A	FoodWaste	anaerobicDigestion	Recovery	recover_nearly_all	4.932163e+04	180
City A	FoodWaste	combustion	Disposal	recover_nearly_all	0.000000e+00	180
City A	FoodWaste	combustion	Recovery	recover_nearly_all	0.000000e+00	180
City A	FoodWaste	composting	Recovery	recover_nearly_all	0.000000e+00	180
City A	FoodWaste	landfilling	Disposal	recover_nearly_all	0.000000e+00	180

In the *massProfiles* table, ***tons*** is the critical field. This is a mass of some waste material, in short tons. All the other fields serve to identify or qualify where the *tons* came from, which management scenario they represent, what life cycle stage they represent, etc.

wasteshed is meant to identify a geographic source of the tonnage data (e.g. tons from "City A", "City B"), but it could also be used to identify tons from other types of sources (e.g. tons from "Company A", "Company B"), or periods of time ("2020" vs. "2021").

material is the name of the material, e.g. "Aluminum." Remember, as discussed before, that material names may represent broader or narrower categories which often overlap. PET bottles, for example, are common in municipal waste. If the waste stream data has specific detailed entries for PET, that material name can be used, but if the bottles are mixed with other plastics a more generic material category like "Rigid Plastic Containers" might be more appropriate. Tons of materials should not be counted twice.

disposition describes what happens to the tons at the end-of-life. It is important to recall that *disposition* names refer to specific technical processes, not generic concepts of disposal or recycling. For example, the common word "composting" can actually refer to two different processes, anaerobic digestion (called "anaerobicDigestion" by WIC), or aerobic composting (called "composting" by WIC).

material and full *disposition* names are fully described in the companion document *Impact modeling for the Waste Impact Calculator*. Some disposition names may be shortened from their full length according to rules described below under "Introduction to the impactFactors table".

umbDisp is short for "umbrella disposition." This field allows the user to group dispositions into convenient umbrella categories. This field is not strictly necessary to identify what happens to *tons* at end-of-life (*disposition* indicates that), or to calculate environmental impacts. However, it is provided to satisfy a common reporting requirement within the field of solid waste: the difference between "recovery" (which might also be known as "recycling" or "diversion") and "disposal" (typically through landfilling or combustion). "recovery", "disposal", and "production" are currently the only valid values of *umbDisp*. The use of the "production" as an *umbDisp* will be explored later.

Governments differ in which *dispositions* they consider to be recycling or diversion, so the user sets *umbDisp* to reflect their local conditions. In Oregon, the *disposition* "combustion" is sometimes linked with "disposal" and sometimes linked with "recovery" because Oregon law considers combustion to be recovery in some situations (e.g. scrap wood with no other recycling market) but not in others.

miles is an optional field related to end-of-life transportation impacts. If *miles* are not entered, WIC will use the standard distances in its database. If entered, *miles* should contain the distance traveled for end-of-life dispositions like recycling, composting, or landfilling. Specifically:

- For disposal dispositions such as landfilling and combustion, and for composting dispositions such as composting and anaerobic digestion, *miles* should contain the number of miles between pickup of the material (often at a house or business) and treatment (i.e. landfill, composter, or incinerator).
- For recycling dispositions it should include the miles between pickup and the first participant in the recycling market (e.g. a MRF).
- As elaborated earlier, *miles* should reflect the portion of end-of-life transportation that waste managers can actually influence.

WIC will compare these custom distances to standard distances in its database and scale end-of-life transport impacts in a linear way.

Note: in many cases, end-of-life transport impacts for waste materials are small compared to impacts from other life cycle phases. Users may want to preview impact results using default mileages before committing extensive labor to determining exact transport distances.

scenario is the last variable which helps classify the weight recorded in *tons*. *scenario* is a name which identifies a solid waste management strategy which has been expressed by values of *tons* linked to various combinations of *wasteshed*, *material*, and *disposition*.

Here is an example of how *massProfile* information expresses the difference between the solid waste management scenarios, "baseline" and "eliminate_food_waste". Note how the weights and dispositions for electronics are the same between scenarios, but in the "eliminate_food_waste" scenario food waste has been reduced to zero tons.

wasteshed	material	Disposition	umbDisp	scenario	tons	miles
City A	Electronics	Landfilling	disposal	Baseline	2.827717e+03	180
City A	Electronics	Recycling	recovery	Baseline	2.367066e+03	180
City A	FoodWaste	anaerobicDigestion	recovery	Baseline	0.000000e+00	180
City A	FoodWaste	Combustion	disposal	Baseline	1.861940e-02	180
City A	FoodWaste	Combustion	recovery	Baseline	1.451891e+03	180
City A	FoodWaste	Composting	recovery	Baseline	1.567926e+03	180
City A	FoodWaste	Landfilling	disposal	Baseline	4.630180e+04	180
City A	Electronics	Landfilling	disposal	eliminate_food_waste	2.827717e+03	180
City A	Electronics	Recycling	recovery	eliminate_food_waste	2.367066e+03	180
City A	FoodWaste	anaerobicDigestion	recovery	eliminate_food_waste	0.000000e+00	180
City A	FoodWaste	Combustion	disposal	eliminate_food_waste	0.000000e+00	180
City A	FoodWaste	Combustion	recovery	eliminate_food_waste	0.000000e+00	180

City A	FoodWaste	Composting	recovery	eliminate_food_waste	0.000000e+00	180
City A	FoodWaste	Landfilling	disposal	eliminate_food_waste	0.000000e+00	180

Addition of production tonnages

As provided by the user, *massProfiles* includes only tons of materials handled at the end-of-life phase of the life cycle.

WIC must also create records for the tons of those materials when they go through two other life cycle stages: end-of-life transport and production. WIC makes a simple assumption: the number of tons produced, or transported to end-of-life treatment, is the same as the number handled (and measured) at end-of-life-treatment itself.

This assumption is a logical, practical way to apply a life cycle approach to real waste streams composed of diverse materials. For example, it stands to reason that all the tons that are handled at end of life must previously have been produced.

This assumption does not imply that WIC assumes material losses during production or end-of-life-transport are zero. They surely are not. Rather, in WIC, if there are material losses in any phase, the consequences of those losses should be reflected in the relevant impact factors – given that *tons* are measured at end-of-life-treatment.

The *tons* associated with production are added to *massProfiles* with a simple copy and substitution operation, as is illustrated in *Example applications of the Waste Impact Calculator*. After R has loaded *massProfiles* into its workspace, it copies all records in *massProfiles* into a temporary buffer, sets the fields *disposition* and *umbDisp* to dummy values of "production," and appends the buffer to *massProfiles*. The result is saved as a new data table, ***massProfilesPlus***. *massProfilesPlus* has exactly twice the total number of *tons* as *massProfiles*.

End-of-life transport tons are generated a different way, as will be illustrated later.

Introduction to the impactFactors table; miscellaneous adjustments to LCA output

The *impactFactors* table contains all of the impact information available in the published version of WIC. Each record contains one impact factor, describing impact per short ton of waste material, classified by impact category, physical impact units (e.g. "joules"), material name, life cycle phase, and disposition.

These records are the processed results of original life cycle assessment work by Oregon DEQ, work that is described in detail in the companion document *Impact modeling for the Waste Impact Calculator*. While this work contains certain assumptions that are specific to Oregon, *impactFactors* should be useful to many outside of Oregon – especially given that the life cycle impacts of waste tend to be dominated by impacts in the production phase, which should vary little across potential users.

The direct output of the LCA software is altered in several miscellaneous ways before it is saved in the *impactFactors* table.

<u>Some dispositions omitted</u>

Some end-of-life dispositions that appear in *Impact calculations for the Waste Impact Calculator* are not currently relevant to Oregon solid waste statistics. These currently include incineration without energy recovery ("incinerationNoER" in the *Impact calculations* document), recycling glass to fiberglass ("recyclingFiberglass"), reuse of anything ("reuse"), and reuse of a beverage container ("reuseContainer").

<u>Some dispositions renamed</u>

Other end-of-life dispositions appearing in the *Impact calculations* document are renamed to be more intuitive when the impactFactors table is created.

"recyclingGeneric" in the Impact calculations document is renamed to simply "recycling"; "recyclingToAggregate" is renamed to "useAsAggregate"; "recyclingToContainer" is renamed to "recycling"; and "incinerationER" is renamed to "combustion".

<u>Some transportation impacts moved to production or end-of-life phases</u>

The transportation-related impacts described in the *Impact calculations* document are slightly transformed when impactFactors is created. These transformations serve the purpose of making the "end-of-life transport" phase relevant to the portion of transportation that waste managers can actually influence.

In particular,

- The direct LCA output distinguishes between "production" impacts and "production transportation" impacts. However, WIC's typical user (a manager of solid waste) has little influence over production transportation distances, so when *impactFactors* is created, these are summed together to create a total production impact.
- The direct LCA output gives end-of-life-transportation impacts for the whole end-of-life transport chain from local pickup (e.g. at curbside) to final processing (e.g. landfill or user of recycled material). But this full distance is not always under the control of local waste managers. For disposal (landfilling and incineration) and composting (aerobic and anaerobic) local waste managers have a good idea of the final destination, so for these dispositions end-of-life transport factors are left unaltered. However, for recycling dispositions, recovered materials enter an active marketplace where they may change hands numerous times and travel thousands of miles before the material is actually used. The local waste manager only has power over the first part of this journey – before the material enters the recycling market. Therefore for recycling dispositions, the end-of-life-transport factor is split into two parts. The part of that factor that can be influenced by the local waste manager is approximated by the landfilling end-of-life-transport factor for that material (in Oregon, this represents truck transport of about 180 miles). The remaining portion of the end-of-life transport factor represents transport impacts that are beyond the influence of the local waste manager, so this portion is added to the end-of-life-treatment impact factor for that material and disposition.
- All the end-of-life transport factors, whether transformed as described above or not, may still be scaled by *miles* values input by the user.

Structure and logic of the impactFactors table

A selection of the *impactFactors* file, concerning just 2 materials and 2 impact categories, looks like this:

material	LCstage	disposition	impactCategory	impactUnits	impliedMiles	impactFactor
Electronics	endOfLife	landfilling	Energy demand	MJ	180	832.8763
Electronics	endOfLife	recycling	Energy demand	MJ	180	-13408.5010
Electronics	endOfLifeTransport	landfilling	Energy demand	MJ	180	603.3414
Electronics	endOfLifeTransport	recycling	Energy demand	MJ	180	603.3414
Electronics	production	production	Energy demand	MJ	180	468130.3713
FoodWaste	endOfLife	anaerobicDigestion	Energy demand	MJ	180	-5592.4907
FoodWaste	endOfLife	combustion	Energy demand	MJ	180	-574.1139

material	LCstage	disposition	impactCategory	impactUnits	impliedMiles	impactFactor
FoodWaste	endOfLife	composting	Energy demand	MJ	180	-543.1128
FoodWaste	endOfLife	landfilling	Energy demand	MJ	180	319.6540
FoodWaste	endOfLifeTransport	anaerobicDigestion	Energy demand	MJ	180	603.4704
FoodWaste	endOfLifeTransport	combustion	Energy demand	MJ	180	603.4704
FoodWaste	endOfLifeTransport	composting	Energy demand	MJ	180	603.4704
FoodWaste	endOfLifeTransport	landfilling	Energy demand	MJ	180	603.4704
FoodWaste	production	production	Energy demand	MJ	180	39043.8618
Electronics	endOfLife	landfilling	Water consumption	kg	180	216.3978
Electronics	endOfLife	recycling	Water consumption	kg	180	-8811.4635
Electronics	endOfLifeTransport	landfilling	Water consumption	kg	180	108.2953
Electronics	endOfLifeTransport	recycling	Water consumption	kg	180	108.2953
Electronics	production	production	Water consumption	kg	180	271442.1168
FoodWaste	endOfLife	anaerobicDigestion	Water consumption	kg	180	1230.1352
FoodWaste	endOfLife	combustion	Water consumption	kg	180	-175.0662
FoodWaste	endOfLife	composting	Water consumption	kg	180	158.5119
FoodWaste	endOfLife	landfilling	Water consumption	kg	180	-250.7538
FoodWaste	endOfLifeTransport	anaerobicDigestion	Water consumption	kg	180	108.3185
FoodWaste	endOfLifeTransport	combustion	Water consumption	kg	180	108.3185
FoodWaste	endOfLifeTransport	composting	Water consumption	kg	180	108.3185
FoodWaste	endOfLifeTransport	landfilling	Water consumption	kg	180	108.3185
FoodWaste	production	production	Water consumption	kg	180	132157.0933

impactFactor is the field with the most essential information. This number expresses an environmental impact per short ton of waste of a particular material in a particular life cycle stage. All the other variables in each record identify or qualify the impact factor somehow – e.g. name the material, label its units, etc.

material is the material name.

LCstage means life cycle stage. Entries here express the three life cycle stages used by WIC to characterize the materials life cycle: production, end-of-life transport, and end-of-life treatment itself.

disposition is defined the same as it is in massProfiles. Disposition names are somewhat but not entirely redundant of entries in *LCstage*. In particular, in the impactFactors table, every end-of-life disposition is associated with two LCstages: endOfLife, and endOfLifeTransport.

impactCategory is the descriptive name for the environmental impact being calculated, for example "Water use" or "Energy demand".

impactUnits is the technical units applicable to the *impactFactor*, for example "MJ" (mejajoules) for energy use. <u>KEY POINT: all impact units are PER SHORT TON of the solid waste *material*.</u> So if *impactUnits* are entered as "MJ", the real impact units are "MJ/short ton". However the "short ton" part is omitted here for convenience in later processing.

impactFactor is the datum that actually relates impact to mass. So if *impactFactor* is 100000, *material* is aluminum, *LCstage* is production, *disposition* is production, *impactCategory* is Energy Use, and *impactUnits* are MJ, that means it takes 100000 MJ of energy to produce 1 short ton of aluminum.

impliedMiles is relevant only to the endOfLifeTransport LCstage, and ignored elsewhere. This expresses the number of transport miles assumed to be involved in end-of-life transport for the material in question. Once impactFactors has been merged with massProfiles, impliedMiles will be compared to any custom mileages that have been entered in massProfiles by the user, so that end-of-life transport impacts can be scaled up or down.

Merging the two data frames and calculating impacts

WIC merges the *massProfilesPlus* and *impactFactors* data frames on the basis of their common fields: *material* and *disposition*. Spellings of entries in these fields must match exactly between the two tables, or errors will be generated.

The merging command (for example, left_join() from R's dplyr package) is configured to create one record every time the pair of fields match across the tables. No fields from either table are dropped.

This creates a new data table with these properties. Within each impactCategory:

- It has *two* records for every record from *massProfilesPlus* that represents an end-of-life tonnage. The tonnage in each record will be the same, but one of these two cases will have the *LCstage* "endOfLife", while the other's *LCstage* is "endOfLifeTransport". (That is, merging the two files creates records that represent the *tons* associated with end-of-life-transport.)
- It creates one record for every record from *massProfilesPlus* that represents production tonnage. The *LCstage* for these records will be "production".
- Every record has both *tons* (based on original entries in the *massProfiles* table) and *impactFactor* (from the *impactFactors* table).
- Records with the LCstage "endOfLifeTransport" also have any custom *miles* values entered.
- Impacts have been calculated by multiplication and added as a new column. Impact = tons * impactFactor, except when *LCstage* is "endOfLifeTransport," where impact=tons*impactFactor*(miles/impliedMiles).

The resulting data table, ***impactsInDetail***, has records representing tons handled in 3 life cycle stages (production, end-of-life-transport, and end-of-life treatment), associated with and identified by values of *scenario*, *wasteshed*, *material*, *LCstage*, *disposition*, and *impactCategory*. In addition, each line is labeled with the *umbDisp* from *massProfilesPlus*, so distinctions can be made between recovery and disposal impacts or tonnages if desired.

An *impactsInDetail* table drawn from the previous examples of *massProfiles* and *impactFactors* is shown below. Note that the number of records have increased considerably. Some records have been added to reflect tonnages handled in production, and others for end-of-life transport. And a complete set of such tonnages exists for each impact category.

impactsInDetail table (example)

wasteshed	material	disposition	umbDisp	scenario	Tons	miles	LCstage	impactCategory	impactUnits	impliedMiles	impactFactor	impact
City A	Electronics	landfilling	disposal	baseline	2.827717e+03	180	endOfLife	Energy demand	MJ	180	832.8763	2.355138e+06
City A	Electronics	recycling	recovery	baseline	2.367066e+03	180	endOfLife	Energy demand	MJ	180	-13408.5010	-3.173881e+07
City A	Electronics	landfilling	disposal	baseline	2.827717e+03	180	endOfLifeTransport	Energy demand	MJ	180	603.3414	1.706078e+06
City A	Electronics	recycling	recovery	baseline	2.367066e+03	180	endOfLifeTransport	Energy demand	MJ	180	603.3414	1.428149e+06
City A	Electronics	production	production	baseline	2.827717e+03	180	production	Energy demand	MJ	180	468130.3713	1.323740e+09
City A	Electronics	production	production	baseline	2.367066e+03	180	production	Energy demand	MJ	180	468130.3713	1.108095e+09
City A	FoodWaste	anaerobicDigestion	recovery	baseline	0.000000e+00	180	endOfLife	Energy demand	MJ	180	-5592.4907	0.000000e+00
City A	FoodWaste	combustion	disposal	baseline	1.861940e-02	180	endOfLife	Energy demand	MJ	180	-574.1139	-1.068965e+01
City A	FoodWaste	combustion	recovery	baseline	1.451891e+03	180	endOfLife	Energy demand	MJ	180	-574.1139	-8.335508e+05
City A	FoodWaste	composting	recovery	baseline	1.567926e+03	180	endOfLife	Energy demand	MJ	180	-543.1128	-8.515606e+05
City A	FoodWaste	landfilling	disposal	baseline	4.630180e+04	180	endOfLife	Energy demand	MJ	180	319.6540	1.480056e+07
City A	FoodWaste	anaerobicDigestion	recovery	baseline	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	0.000000e+00
City A	FoodWaste	combustion	disposal	baseline	1.861940e-02	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	1.123625e+01
City A	FoodWaste	combustion	recovery	baseline	1.451891e+03	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	8.761733e+05
City A	FoodWaste	composting	recovery	baseline	1.567926e+03	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	9.461970e+05
City A	FoodWaste	landfilling	disposal	baseline	4.630180e+04	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	2.794177e+07
City A	FoodWaste	production	production	baseline	0.000000e+00	180	production	Energy demand	MJ	180	39043.8618	0.000000e+00
City A	FoodWaste	production	production	baseline	1.861940e-02	180	production	Energy demand	MJ	180	39043.8618	7.269730e+02
City A	FoodWaste	production	production	baseline	1.451891e+03	180	production	Energy demand	MJ	180	39043.8618	5.668743e+07
City A	FoodWaste	production	production	baseline	1.567926e+03	180	production	Energy demand	MJ	180	39043.8618	6.121789e+07
City A	FoodWaste	production	production	baseline	4.630180e+04	180	production	Energy demand	MJ	180	39043.8618	1.807801e+09
City A	Electronics	landfilling	disposal	eliminate_food_waste	2.827717e+03	180	endOfLife	Energy demand	MJ	180	832.8763	2.355138e+06
City A	Electronics	recycling	recovery	eliminate_food_waste	2.367066e+03	180	endOfLife	Energy demand	MJ	180	-13408.5010	-3.173881e+07
City A	Electronics	landfilling	disposal	eliminate_food_waste	2.827717e+03	180	endOfLifeTransport	Energy demand	MJ	180	603.3414	1.706078e+06
City A	Electronics	recycling	recovery	eliminate_food_waste	2.367066e+03	180	endOfLifeTransport	Energy demand	MJ	180	603.3414	1.428149e+06
City A	Electronics	production	production	eliminate_food_waste	2.827717e+03	180	production	Energy demand	MJ	180	468130.3713	1.323740e+09
City A	Electronics	production	production	eliminate_food_waste	2.367066e+03	180	production	Energy demand	MJ	180	468130.3713	1.108095e+09
City A	FoodWaste	anaerobicDigestion	recovery	eliminate_food_waste	0.000000e+00	180	endOfLife	Energy demand	MJ	180	-5592.4907	0.000000e+00
City A	FoodWaste	combustion	disposal	eliminate_food_waste	0.000000e+00	180	endOfLife	Energy demand	MJ	180	-574.1139	0.000000e+00
City A	FoodWaste	combustion	recovery	eliminate_food_waste	0.000000e+00	180	endOfLife	Energy demand	MJ	180	-574.1139	0.000000e+00
City A	FoodWaste	composting	recovery	eliminate_food_waste	0.000000e+00	180	endOfLife	Energy demand	MJ	180	-543.1128	0.000000e+00
City A	FoodWaste	landfilling	disposal	eliminate_food_waste	0.000000e+00	180	endOfLife	Energy demand	MJ	180	319.6540	0.000000e+00
City A	FoodWaste	anaerobicDigestion	recovery	eliminate_food_waste	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	0.000000e+00
City A	FoodWaste	combustion	disposal	eliminate_food_waste	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	0.000000e+00
City A	FoodWaste	combustion	recovery	eliminate_food_waste	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	0.000000e+00
City A	FoodWaste	composting	recovery	eliminate_food_waste	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	0.000000e+00
City A	FoodWaste	landfilling	disposal	eliminate_food_waste	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	0.000000e+00
City A	FoodWaste	production	production	eliminate_food_waste	0.000000e+00	180	production	Energy demand	MJ	180	39043.8618	0.000000e+00
City A	FoodWaste	production	production	eliminate_food_waste	0.000000e+00	180	production	Energy demand	MJ	180	39043.8618	0.000000e+00
City A	FoodWaste	production	production	eliminate_food_waste	0.000000e+00	180	production	Energy demand	MJ	180	39043.8618	0.000000e+00
City A	FoodWaste	production	production	eliminate_food_waste	0.000000e+00	180	production	Energy demand	MJ	180	39043.8618	0.000000e+00
City A	FoodWaste	production	production	eliminate_food_waste	0.000000e+00	180	production	Energy demand	MJ	180	39043.8618	0.000000e+00
City A	Electronics	landfilling	disposal	recover_nearly_all	0.000000e+00	180	endOfLife	Energy demand	MJ	180	832.8763	0.000000e+00
City A	Electronics	recycling	recovery	recover_nearly_all	5.194783e+03	180	endOfLife	Energy demand	MJ	180	-13408.5010	-6.965425e+07
City A	Electronics	landfilling	disposal	recover_nearly_all	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.3414	0.000000e+00
City A	Electronics	recycling	recovery	recover_nearly_all	5.194783e+03	180	endOfLifeTransport	Energy demand	MJ	180	603.3414	3.134227e+06
City A	Electronics	production	production	recover_nearly_all	0.000000e+00	180	production	Energy demand	MJ	180	468130.3713	0.000000e+00
City A	Electronics	production	production	recover_nearly_all	5.194783e+03	180	production	Energy demand	MJ	180	468130.3713	2.431836e+09
City A	FoodWaste	anaerobicDigestion	recovery	recover_nearly_all	4.932163e+04	180	endOfLife	Energy demand	MJ	180	-5592.4907	-2.758308e+08
City A	FoodWaste	combustion	disposal	recover_nearly_all	0.000000e+00	180	endOfLife	Energy demand	MJ	180	-574.1139	0.000000e+00
City A	FoodWaste	combustion	recovery	recover_nearly_all	0.000000e+00	180	endOfLife	Energy demand	MJ	180	-574.1139	0.000000e+00
City A	FoodWaste	composting	recovery	recover_nearly_all	0.000000e+00	180	endOfLife	Energy demand	MJ	180	-543.1128	0.000000e+00
City A	FoodWaste	landfilling	disposal	recover_nearly_all	0.000000e+00	180	endOfLife	Energy demand	MJ	180	319.6540	0.000000e+00

wasteshed	material	disposition	umbDisp	scenario	Tons	miles	LCstage	impactCategory	impactUnits	impliedMiles	impactFactor	impact
City A	FoodWaste	anaerobicDigestion	recovery	recover_nearly_all	4.932163e+04	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	2.976415e+07
City A	FoodWaste	combustion	disposal	recover_nearly_all	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	0.000000e+00
City A	FoodWaste	combustion	recovery	recover_nearly_all	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	0.000000e+00
City A	FoodWaste	composting	recovery	recover_nearly_all	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	0.000000e+00
City A	FoodWaste	landfilling	disposal	recover_nearly_all	0.000000e+00	180	endOfLifeTransport	Energy demand	MJ	180	603.4704	0.000000e+00
City A	FoodWaste	production	production	recover_nearly_all	4.932163e+04	180	production	Energy demand	MJ	180	39043.8618	1.925707e+09
City A	FoodWaste	production	production	recover_nearly_all	0.000000e+00	180	production	Energy demand	MJ	180	39043.8618	0.000000e+00
City A	FoodWaste	production	production	recover_nearly_all	0.000000e+00	180	production	Energy demand	MJ	180	39043.8618	0.000000e+00
City A	FoodWaste	production	production	recover_nearly_all	0.000000e+00	180	production	Energy demand	MJ	180	39043.8618	0.000000e+00
City A	FoodWaste	production	production	recover_nearly_all	0.000000e+00	180	production	Energy demand	MJ	180	39043.8618	0.000000e+00
City A	Electronics	landfilling	disposal	baseline	2.827717e+03	180	endOfLife	Water consumption	kg	180	216.3978	6.119116e+05
City A	Electronics	recycling	recovery	baseline	2.367066e+03	180	endOfLife	Water consumption	kg	180	-8811.4635	-2.085732e+07
City A	Electronics	landfilling	disposal	baseline	2.827717e+03	180	endOfLifeTransport	Water consumption	kg	180	108.2953	3.062285e+05
City A	Electronics	recycling	recovery	baseline	2.367066e+03	180	endOfLifeTransport	Water consumption	kg	180	108.2953	2.563422e+05
City A	Electronics	production	production	baseline	2.827717e+03	180	production	Water consumption	kg	180	271442.1168	7.675614e+08
City A	Electronics	production	production	baseline	2.367066e+03	180	production	Water consumption	kg	180	271442.1168	6.425214e+08
City A	FoodWaste	anaerobicDigestion	recovery	baseline	0.000000e+00	180	endOfLife	Water consumption	kg	180	1230.1352	0.000000e+00
City A	FoodWaste	combustion	disposal	baseline	1.861940e-02	180	endOfLife	Water consumption	kg	180	-175.0662	-3.259627e+00
City A	FoodWaste	combustion	recovery	baseline	1.451891e+03	180	endOfLife	Water consumption	kg	180	-175.0662	-2.541771e+05
City A	FoodWaste	composting	recovery	baseline	1.567926e+03	180	endOfLife	Water consumption	kg	180	158.5119	2.485349e+05
City A	FoodWaste	landfilling	disposal	baseline	4.630180e+04	180	endOfLife	Water consumption	kg	180	-250.7538	-1.161035e+07
City A	FoodWaste	anaerobicDigestion	recovery	baseline	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.3185	0.000000e+00
City A	FoodWaste	combustion	disposal	baseline	1.861940e-02	180	endOfLifeTransport	Water consumption	kg	180	108.3185	2.016824e+00
City A	FoodWaste	combustion	recovery	baseline	1.451891e+03	180	endOfLifeTransport	Water consumption	kg	180	108.3185	1.572666e+05
City A	FoodWaste	composting	recovery	baseline	1.567926e+03	180	endOfLifeTransport	Water consumption	kg	180	108.3185	1.698354e+05
City A	FoodWaste	landfilling	disposal	baseline	4.630180e+04	180	endOfLifeTransport	Water consumption	kg	180	108.3185	5.015341e+06
City A	FoodWaste	production	production	baseline	0.000000e+00	180	production	Water consumption	kg	180	132157.0933	0.000000e+00
City A	FoodWaste	production	production	baseline	1.861940e-02	180	production	Water consumption	kg	180	132157.0933	2.460685e+03
City A	FoodWaste	production	production	baseline	1.451891e+03	180	production	Water consumption	kg	180	132157.0933	1.918777e+08
City A	FoodWaste	production	production	baseline	1.567926e+03	180	production	Water consumption	kg	180	132157.0933	2.072125e+08
City A	FoodWaste	production	production	baseline	4.630180e+04	180	production	Water consumption	kg	180	132157.0933	6.119111e+09
City A	Electronics	landfilling	disposal	eliminate_food_waste	2.827717e+03	180	endOfLife	Water consumption	kg	180	216.3978	6.119116e+05
City A	Electronics	recycling	recovery	eliminate_food_waste	2.367066e+03	180	endOfLife	Water consumption	kg	180	-8811.4635	-2.085732e+07
City A	Electronics	landfilling	disposal	eliminate_food_waste	2.827717e+03	180	endOfLifeTransport	Water consumption	kg	180	108.2953	3.062285e+05
City A	Electronics	recycling	recovery	eliminate_food_waste	2.367066e+03	180	endOfLifeTransport	Water consumption	kg	180	108.2953	2.563422e+05
City A	Electronics	production	production	eliminate_food_waste	2.827717e+03	180	production	Water consumption	kg	180	271442.1168	7.675614e+08
City A	Electronics	production	production	eliminate_food_waste	2.367066e+03	180	production	Water consumption	kg	180	271442.1168	6.425214e+08
City A	FoodWaste	anaerobicDigestion	recovery	eliminate_food_waste	0.000000e+00	180	endOfLife	Water consumption	kg	180	1230.1352	0.000000e+00
City A	FoodWaste	combustion	disposal	eliminate_food_waste	0.000000e+00	180	endOfLife	Water consumption	kg	180	-175.0662	0.000000e+00
City A	FoodWaste	combustion	recovery	eliminate_food_waste	0.000000e+00	180	endOfLife	Water consumption	kg	180	-175.0662	0.000000e+00
City A	FoodWaste	composting	recovery	eliminate_food_waste	0.000000e+00	180	endOfLife	Water consumption	kg	180	158.5119	0.000000e+00
City A	FoodWaste	landfilling	disposal	eliminate_food_waste	0.000000e+00	180	endOfLife	Water consumption	kg	180	-250.7538	0.000000e+00
City A	FoodWaste	anaerobicDigestion	recovery	eliminate_food_waste	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.3185	0.000000e+00
City A	FoodWaste	combustion	disposal	eliminate_food_waste	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.3185	0.000000e+00
City A	FoodWaste	combustion	recovery	eliminate_food_waste	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.3185	0.000000e+00
City A	FoodWaste	composting	recovery	eliminate_food_waste	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.3185	0.000000e+00
City A	FoodWaste	landfilling	disposal	eliminate_food_waste	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.3185	0.000000e+00
City A	FoodWaste	production	production	eliminate_food_waste	0.000000e+00	180	production	Water consumption	kg	180	132157.0933	0.000000e+00
City A	FoodWaste	production	production	eliminate_food_waste	0.000000e+00	180	production	Water consumption	kg	180	132157.0933	0.000000e+00
City A	FoodWaste	production	production	eliminate_food_waste	0.000000e+00	180	production	Water consumption	kg	180	132157.0933	0.000000e+00
City A	FoodWaste	production	production	eliminate_food_waste	0.000000e+00	180	production	Water consumption	kg	180	132157.0933	0.000000e+00
City A	FoodWaste	production	production	eliminate_food_waste	0.000000e+00	180	production	Water consumption	kg	180	132157.0933	0.000000e+00
City A	Electronics	landfilling	disposal	recover_nearly_all	0.000000e+00	180	endOfLife	Water consumption	kg	180	216.3978	0.000000e+00
City A	Electronics	recycling	recovery	recover_nearly_all	5.194783e+03	180	endOfLife	Water consumption	kg	180	-8811.4635	-4.577364e+07
City A	Electronics	landfilling	disposal	recover_nearly_all	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.2953	0.000000e+00

wasteshed	material	disposition	umbDisp	scenario	Tons	miles	LCstage	impactCategory	impactUnits	impliedMiles	impactFactor	impact
City A	Electronics	recycling	recovery	recover_nearly_all	5.194783e+03	180	endOfLifeTransport	Water consumption	kg	180	108.2953	5.625707e+05
City A	Electronics	production	production	recover_nearly_all	0.000000e+00	180	production	Water consumption	kg	180	271442.1168	0.000000e+00
City A	Electronics	production	production	recover_nearly_all	5.194783e+03	180	production	Water consumption	kg	180	271442.1168	1.410083e+09
City A	FoodWaste	anaerobicDigestion	recovery	recover_nearly_all	4.932163e+04	180	endOfLife	Water consumption	kg	180	1230.1352	6.067228e+07
City A	FoodWaste	combustion	disposal	recover_nearly_all	0.000000e+00	180	endOfLife	Water consumption	kg	180	-175.0662	0.000000e+00
City A	FoodWaste	combustion	recovery	recover_nearly_all	0.000000e+00	180	endOfLife	Water consumption	kg	180	-175.0662	0.000000e+00
City A	FoodWaste	composting	recovery	recover_nearly_all	0.000000e+00	180	endOfLife	Water consumption	kg	180	158.5119	0.000000e+00
City A	FoodWaste	landfilling	disposal	recover_nearly_all	0.000000e+00	180	endOfLife	Water consumption	kg	180	-250.7538	0.000000e+00
City A	FoodWaste	anaerobicDigestion	recovery	recover_nearly_all	4.932163e+04	180	endOfLifeTransport	Water consumption	kg	180	108.3185	5.342445e+06
City A	FoodWaste	combustion	disposal	recover_nearly_all	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.3185	0.000000e+00
City A	FoodWaste	combustion	recovery	recover_nearly_all	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.3185	0.000000e+00
City A	FoodWaste	composting	recovery	recover_nearly_all	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.3185	0.000000e+00
City A	FoodWaste	landfilling	disposal	recover_nearly_all	0.000000e+00	180	endOfLifeTransport	Water consumption	kg	180	108.3185	0.000000e+00
City A	FoodWaste	production	production	recover_nearly_all	4.932163e+04	180	production	Water consumption	kg	180	132157.0933	6.518204e+09
City A	FoodWaste	production	production	recover_nearly_all	0.000000e+00	180	production	Water consumption	kg	180	132157.0933	0.000000e+00
City A	FoodWaste	production	production	recover_nearly_all	0.000000e+00	180	production	Water consumption	kg	180	132157.0933	0.000000e+00
City A	FoodWaste	production	production	recover_nearly_all	0.000000e+00	180	production	Water consumption	kg	180	132157.0933	0.000000e+00
City A	FoodWaste	production	production	recover_nearly_all	0.000000e+00	180	production	Water consumption	kg	180	132157.0933	0.000000e+00

Overview of creating impact results

The *impactsInDetail* data table is large, but very convenient, because it can serve as a single data source for all future output from WIC. Most results of interest – for example, the total waste tonnages and total impacts linked to each scenario – are the output of simple filtering, grouping, and summation operations on the *tons* or *impacts* in *impactsInDetail*.

Before creating results, it is wise to do a few quality checks to assure that the data is internally consistent and reflects the user's intended waste management scenarios. For example:

- Within each scenario, the tonnages applied to each *LCstage* should be the same. That is, the WIC framework asserts that within each scenario, the same number of tons have been produced, moved to an end-of-life treatment, and received an end-of-life treatment. (See earlier discussion under "Addition of production tonnages.")
- Every record should have a value in every field, with the exception of the *miles* field, which may be missing when *LCstage* is not "endOfLifeTransport." Critically, every record should have an *impactFactor* and an *impact*. That is, no *impactFactors* or *impacts* should be missing, and any that are zero should be viewed with suspicion (because impact factors of exactly zero are unlikely, and may represent a computation error or missing data).

When simple checks of this type fail, it often because the *massProfiles* table provided by the user somehow does not match the *impactFactors* table – perhaps in the spelling of material names or dispositions.

When creating results from an internally consistent *impactsInDetail*, recall that there is much redundancy in this data table – there are one or more lines for every combination of scenario, wasteshed, material, LCstage, disposition, umbDisp, and impactCategory. Data must be filtered and grouped conscientiously for each piece of output produced.

- In particular, when *tons* are summed, they should be restricted to tons linked to the "endOfLife" *LCstage*. The *tons* that appear in other *LCstages* are redundant and only serve for the calculation of the impacts of those stages.
- Likewise, when *tons* are summed, records should be restricted to a single *impactCategory* (the tons have appeared only once; they are simply duplicated within *impactsInDetail* for convenience).
- It is expected that *impacts* will only be summed within the context of a single *impactCategory*. If the user has a desire to combine or normalize results from multiple impactCategories, it is their responsibility to create and defend a method of doing so.

The companion document *Example applications of the Waste Impact Calculator* suggests quality checks that should prevent the most likely pitfalls in data processing.

Alternative formats

DEQ can provide documents in an alternate format or in a language other than English upon request. Call DEQ at 800-452-4011 or email deqinfo@deq.state.or.us.